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PATHWAYS TO SUSTAINABILITY

Integrating Environment Growth and Indigenous Wisdom

Editors
Surender Mor, Sanjeev Kumar
Sonu Madan and Disha Sirohi

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Preface

This is a paradox, a gap, a dissonance, a disjunction, a disconnection – in the contemporary world, a time of unprecedented technological advance, digital connectivity, and economic power is accompanied by growing ecological crises, increasing climate shocks, and increasing socio-economic inequalities. The development models traditionally used for industrialization, based on resource extraction without limits, top-down governance, and ignoring the relationship between economy and ecology, have been fundamentally lacking in the ability to achieve a resilient future. With extreme weather events, biodiversity loss and economic precarity in the informal sector all becoming more evident as the effects of the Anthropocene increase, we can no longer afford to take linear or uniform paths.

Pathways to Sustainability: Integrating Environment, Growth, and Indigenous Wisdom grew out of this awareness of a pressing need of an urgent systemic crisis. The main argument of this book centres around the Anthropocene calls for a way of dealing with binary alternatives that go beyond choices. The solution of high tech and the preservation of nostalgia will not serve to save us from what is happening today. Rather, true resilience requires a multi-dimensional fusion of new scientific innovations, Indigenous Knowledge Systems (IKS) that have been handed down through the ages, and inclusive socio-economic governance in the economy.

The book is organized to take the reader through the many facets of this transition. Starting with the physical and macro-economic facts of a warming planet, the book charts out the pressing need for adaptation to climate change and protection of biodiversity. It then moves on to production systems, comparing soil-restoring rural regenerative practices to controlled-environment farming, such as hydroponics. In the economic field, the text looks at the role of behavioural finance, gender inclusion and microfinance networks as crucial instruments to stimulate sustainable capital allocation and social equity. Last, the volume situates its discussion within the context of laws and governance, calling for the recognition of traditional ecological knowledge and community stewardship in a formal manner. This series is conceived as a multi-disciplinary toolkit for researchers, policy makers and practitioners, aimed at the possibility of reinvigorating the debate over environment or growth by proposing to consider both as two sides of the same coin, to govern inclusively, adaptively and wisely.

Surender Mor
Sanjeev Kumar
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We sincerely thanks to all the contributing authors for providing highly insightful and well-researched manuscripts that bridge high-tech solutions, sustainable economic models, and traditional ecological wisdom. We are also grateful to Excel India Publishers, New Delhi, for their professional editing, design, and production support.

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Chapter

1 Pathways to Sustainability: Integrating Environment, Growth and Indigenous Wisdom

Surender Mor[1], **Sanjeev Kumar**[2], **Sonu Madan**[3] **and Disha Sirohi**[4]

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The Paradox of Progress: An Overview

The contemporary global landscape is characterized by an unfortunate contradiction of an unprecedented level of technological development and economic power, but with an increasing ecological crisis, growing socio-economic disparities and continued fragility of informal sectors (Mor, 2018a). The world is facing the catastrophic erosion of biodiversity, the limitations of traditional development approaches, and the increasing effects of climate change, making the future paths less and less linear (Mor, 2022a). The previous industrial models that were based on unlimited extraction of the resources and lacked an economic-ecological link are proving inadequate in guaranteeing a resilient future (Mor *et al.*, 2023a). Moreover, the systemic issues that are currently affecting the world, from trade tensions between countries and macroeconomic policies to extreme climate events, highlight the need to rethink the concept of development (Mor & Das, 2023).

This book, Pathways to Sustainability: Integrating Environment, Growth, and Indigenous Wisdom, confronts this paradox by calling for a holistic convergence of modern scientific innovation, economic inclusiveness, and traditional wisdom that has been passed down over thousands of years (Mor, 2022b). The central argument of this volume is that the way to a resilient future is neither one-size-fits-all solutions (high tech) nor preservationist nostalgia (low tech). Instead, it calls for a multi-faceted integration where advanced technologies meet and are, at times, rooted in Indigenous knowledge systems, reverse innovations, and regenerative practices.

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This book is organized to help the reader navigate this complexity. It spans the physical realities of a warming planet and the changing nature of agricultural systems to the behavioural economics of microfinance and sustainable finance, and finally, the legal and governance frameworks needed to safeguard the wisdom and livelihoods of those who have farmed the land for thousands of years (Singh, 2015; Singh *et al.*, 2018). The text connects the various strands together in order to show how sustainability is a multi-disciplinary and multi-sectoral effort.

Climate, Environment and Sustainable Urban Futures

The global climate crisis demands systemic shifts in governance, energy transitions, and international cooperation. A crucial aspect of this transformation is the shift from static international requirements to flexible, voluntary requirements that fit local development realities (Mor *et al.*, 2023b). Multilateral platforms are an important tool for guiding policy toward the long-term ecological balance at the international level. At the same time, the world is facing economic tensions in trade and geopolitical tensions that underscore the dangers of economic fragility to a coordinated environmental effort (Mor, 2018b).

Climatic variations within the country adversely impact agricultural stability and economic security (Madan & Mor, 2025). Yield volatility is directly linked to severe weather patterns and vulnerable people and small business operators in the informal sector face increased precarity. The key challenge is that higher education institutions and municipal governments must take an active role in promoting research, adaptation and environmental stewardship (Mor *et al.*, 2023c), in order to build resilient urban and rural environments.

Sustainable Agriculture, Circular Economy and Rural Transformation

Connecting cutting-edge technologies with on-the-ground operational productivity is imperative. Beyond the agricultural sector, attaining technical efficiency and minimizing transaction costs is vital for sustainability in the informal sector (Singh, 2017a).

Institutional support systems that facilitate ongoing learning and experimentation are needed to address agricultural vulnerability. However, innovation is shifting from a purely top-down approach and instead indigenous and exogenous reverse innovations are delivering scalable solutions that are specific to context, allowing for improvements in circular economic models and rural adaptability (Mor & Ashta, 2022). Embedding contemporary technological innovations in local agricultural practices can establish mechanisms for sustainable use of resources and food security, without sacrificing economic strength.

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Inclusive Growth, Gender, Finance and Institutional Sustainability

Social inclusion, economic access, and gender empowerment are intrinsic to achieving sustainable development. Women's entrepreneurship and entrepreneurial activities in rural areas are important contributors to local economic resilience but are often facing structural barriers (Singh *et al.*, 2018). Microfinance and social entrepreneurship are important tools to promote wellbeing, social change and provide safety nets in times of acute economic crisis (Ashta & Mor, 2017).

In the organizational and institutional levels, the embedding of sustainability involves creating a culture, where adaptation, financial inclusion and social accountability are accepted as values and norms (Mor *et al.*, 2023c). Higher education institutions, non-governmental and microfinance networks are key centres of values transmission in communities.

The Pathways to Sustainability: Integrating Environment, Growth, and Indigenous Wisdom provides a comprehensive map of the Anthropocene's challenges. It is a fusion of the physical realities of climate change and biodiversity loss with innovative solutions ranging from technological innovations, such as hydroponics, to local communities' emphasis on regenerative soil practices (Singh, 2017b). It considers these physical solutions from the perspective of economic constraints of microfinance, behavioural economics and gender integration, and ultimately, legal and governance structures of indigenous wisdom (Singh *et al.*, 2018).

This volume is a testament to the belief that sustainability is best achieved through the synergy of modern growth strategies and the richness of indigenous and local wisdom—a grassroots treasure trove often ignored by mainstream discourse. This volume offers a multidisciplinary toolkit for policy makers, researchers and practitioners (Mor, 2018c), covering the systemic risks of climate change, the dual requirements of high-tech and ecological agriculture, the psychological and operational barriers to sustainable finance, as well as the legal obligation to safeguard Traditional Knowledge (TK). It suggests that the way forward is not about a trade-off between environment and growth, but about a relationship where they are united and connected in a purposeful, participatory, and responsive governance.

SECTION 1: CLIMATE, ENVIRONMENT AND SUSTAINABLE URBAN FUTURES

The story starts with a thought-provoking examination of the physical and economic truths of a warmer world. The climate emergency has become a reality, rather than a prediction, especially in the most vulnerable areas such as South Asia. Climate change has gone from being an environmental cost to a systemic development risk that will impact the bases of economic stability and human well-being.

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Dr. Nikita provides a detailed overview of these impacts in Chapter 2, which makes climate change a threat multiplier. The chapter brings out the recent trends in the climatic variability of the country as documented by the India Meteorological Department (IMD), including the highest mean temperature for the year 2024 in the national instrumental climatic record. The data shows that the temperature is 0.65°C above the normal average (IMD, 2026). This warming isn't just a meteorological figure: it is a real economic jolt.

Dr. Nikita reviews the economic literature and concludes that temperature shocks have a significant impact on economic performance, especially in less developed economies, and that there is a non-linear relationship between temperature and productivity (Burke *et al.*, 2015; Dell *et al.*, 2012). This non-linearity implies that the adverse effects on labour and output grow faster as temperatures increase. Agriculture, which sustains millions of livelihoods, is under critical threat in the Indian context. Extreme heat causes wheat yields to decline by increasing crop senescence, and affecting labour productivity, especially in the outdoor sectors such as construction and agriculture (Lobell *et al.*, 2012; Somnath *et al.*, 2021).

Moreover, Nikita's analysis highlights that the choice between development and mitigation is not the best climate strategy for India. Rather, it calls for an integrated development approach that is climate resilient. This is an integrated approach that integrates adaptation measures, low carbon growth pathways and social protection. The chapter highlights the complementary nature of mitigation and adaptation, which is crucial to maintain macroeconomic stability and minimise inequalities in the impacts of climate change (IPCC, 2023).

The catastrophic loss of biodiversity, occurring alongside the climate crisis, threatens the very biological basis of life on Earth. Titiksha Kamal discusses 'biodiversity at a crossroads' in Chapter 3. In this chapter, the researchers warn that if the current trend continues, about one million species will become extinct, according to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019). Biodiversity loss has the potential to compromise the integrity of ecosystems as well as ecosystem services critical for human well-being, including pollination, nutrient cycling, water regulation, and disease control (Cardinale *et al.*, 2012; Díaz *et al.*, 2018).

Habitat loss, pollution and invasive species are among the main reasons for this decline, and Kamal argues that it is time to go beyond documentation and find real solutions for conservation. The chapter emphasizes the need for scientific research to be used in conjunction with traditional ecological knowledge. It offers a holistic conservation strategy spanning ecosystem restoration, Protected Areas expansion and use of new technologies such as GIS and DNA Barcoding. In addition, the paper highlights the importance of the use of indigenous knowledge and citizen science for the improvement of conservation

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efforts. Finally, the chapter supports the adoption of the Kunming-Montreal Global Biodiversity Framework (CBD, 2022), not only as an environmental responsibility, but also as a prerequisite for sustainable development and human resilience.

SECTION II: SUSTAINABLE AGRICULTURE, CIRCULAR ECONOMY AND RURAL TRANSFORMATION

As indicated in Section I, the environmental challenges require a paradigm shift in our production systems, as much as in agriculture. Section II "Sustainable agriculture, Circular economy and rural transformation" highlights the importance of reviving the agrarian economy in the context of increasing climate risks, resources shortages and soil degradation. In this section, two complementary yet different food security pathways are introduced: controlled environments for technological innovation; regenerative practices for ecological restoration.

With the land degradation and water scarcity also leading to food insecurity all over the world, the book delves into the potential of Controlled Environment Agriculture (CEA). Dr. Pankaj Kumar in Chapter 13 reviews relevant literature indexed in Scopus to assess hydroponic farming as an alternative to soil-based farming in the context of sustainability. The review underscores the fact that highly efficient hydroponic production systems, from Deep Water Culture (DWC) to Nutrient Film Technique (NFT), can boost resource-use efficiency. Vertical stacking and nutrient optimized systems are able to utilize 90-95% less water and land, while achieving greater agricultural production (Hasan *et al.*, 2026).

One of the highlights of this chapter is how digital technologies are being integrated. Dr. Kumar explains the Internet of Things (IoT) and Artificial Intelligence (AI) and how they transform hydroponics into a data-driven scientific that relies on data. Automated systems can optimize delivery of nutrients and regulation of microclimate. For example, empirical results show that the application of Long Short-Term Memory (LSTM) networks can yield up to 19.3% increase in yield and substantial nutrient reduction (Devaraju *et al.*, 2026). But the study also evaluates the issues associated with adoption such as capital intensity, dependence on energy sources and technical skill. Based on studies reviewed, Life Cycle Assessment (LCA) shows that hydroponics is the most efficient in its water use, but its sustainability is highly dependent on the energy sources and system design (Paturu & Varadarajan, 2024). The chapter concludes that hydroponics is not a panacea for all soil farming but an important alternative system in urban areas, if appropriate policy measures are implemented to overcome financial and infrastructural challenges.

Prof. Kumari Veena's chapter (Chapter 14) on indigenous and regenerative agriculture, is a call for the revival of these practices, as opposed to the high-tech approach of hydroponics. The study focusses on the Bihar state where 91% of the farmers are small farmers, and assesses the possibility of Regenerative Agriculture (RA) as a tool for soil health and

livelihood. Veena believes that the traditional farming methods employed over the past few decades have affected the quality of soil and that practices like zero tillage, multi-crop farming and adoption of bio-inputs such as Jeevamrit, can help build soil organic carbon and lessen the need to use expensive synthetic fertilizers.

Specific regeneration methods that are suitable for different agro-climatic zones in Bihar are explained, such as green manure crops (legumes) like Sesbania (Dhaincha) which can fix nitrogen in the soil and enhance soil structure. Veena notes that the biophysical effects of RA are include increasing the capacity of the soil to hold water which provides a "natural insurance policy" against floods and droughts. The author notes, however, that there are key structural constraints that impede scaling up of these practices, such as the Bataidari (tenant farming) system in which land insecurity prevents long-term investment in soil health. The study is based on secondary data drawn from institutions such as ICAR and BAU, and promotes the policy frameworks that encourage regenerative transitions. This chapter argues that RA is more than a sustainable practice, but a structural way to achieve economic revitalisation through traditional knowledge (Rhods, 2017).

SECTION III: INCLUSIVE GROWTH, GENDER, FINANCE AND INSTITUTIONAL SUSTAINABILITY

Without strong economies and inclusive growth, environmental objectives will not be met. The economic and financial aspects of sustainability are explored in Section III, highlighting the need for navigating complex human behaviours and deep-seated socio-economic inequities in order to achieve the transition to green economy. It bridges the fields of behavioural finance and gender, examining the role of cognitive biases in making sustainable capital allocation more difficult and how the workplace affects the financial decisions of working women.

In Chapter 20, Apeksha Sharma discusses the disconnect between the rising interest in sustainable investing and its actual practice by individual investors. The market for sustainable investment assets has grown, but decisions are often influenced by cognitive bias. The systematic literature review by Sharma reveals 13 different biases that affect choices of sustainable investments, including availability, overconfidence, herding, source preference, and moral loss aversion (Chew & Li, 2026; Abhijith *et al.*, 2025).

The chapter suggests a three-layered relationship between investor psychology (antecedents) and distorted judgment and decision-making outcomes. One of the results is that risk tolerance is a common mediator for various biases. The chapter prescribes a number of "nudge" interventions that are linked to bias categories in order to reduce these distortions. Examples of these include simplification and layered disclosure of ESG, as well as impact quantification and anti-greenwashing verification cues for moral biases (Hutchings, 2025). It is found that targeted behavioural interventions, like defaults and digital advising, play a key role in shaping investors' behaviour in a way that is consistent with sustainable goals (Gajewski *et al.*, 2022).

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In addition to the financial behavioural approach, there is an in-depth examination of gender inclusivity. Disha Sirohi and Sanjeev Kumar explore the investment pattern of 300 working women from ten different professions of Indore City in Chapter 21. The authors use a descriptive and comparative quantitative design with primary data to analyse the multidimensional aspects of investment behaviour (preparedness, discipline, and information exposure).

The results indicate that the most prevalent form of investing is self-directed via online platforms, but profession significantly influences financial sophistication. There was considerable disparity in financial knowledge, literacy program participation, emergency fund maintenance and diversification strategies by profession. On the other hand, the awareness of the compounding and the length of time invested were similar for all groups. The chapter emphasizes that the percentage of women in formal investments such as mutual funds has increased (1 in 4 investors) but financial education is still an important constraint (AMFI, 2025; NCFE, 2020-21). This is because financial education that is tailored to specific professions is essential, as financial relationships and peer networks within occupational ecosystems significantly influence investment decisions (Agarwalla *et al.*, 2015). This section collectively maintains that a psychologically sensitive to biases and structurally inclusive financial system is required for sustainable growth, as women are an important change agent.

SECTION IV: INDIGENOUS KNOWLEDGE, CULTURE, EDUCATION AND SUSTAINABLE FUTURES

Lastly, the book concludes with a focus on Indigenous Wisdom as the foundation of sustainable governance, tying up the thread of the narrative. It questions the supremacy of "scientific forestry" and also of statutory law which often ignores traditional knowledge. Indigenous Knowledge, Culture, Education and Sustainable Futures" (Section IV) advocates for incorporating Indigenous Knowledge Systems (IKS) and Traditional Ecological Knowledge (TEK) into the mainstream policy and legal approaches. The chapters examine the three-way nexus of gender, law and community management to shed light on the historical ecological balance that has been achieved by circular practices and collective decision-making in tribal communities in India.

Dr. Tanwi Shams makes a strong indictment of the legal invisibility of Traditional Ecological Knowledge (TEK) of tribal women in Chapter 27, focusing on the Khasi, Jaintia and Garo communities in the Northeast. The selective harvesting, rotational harvesting, and low waste processing are some of the circular economy principles that Shams suggests these women apply to support forest-based livelihoods. The study, however, shows that there is a huge gap between the practices and the Indian laws.

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Access to resources is addressed in the Forest Rights Act (FRA); however, it does not address women's collective innovations, and the Biological Diversity Act and intellectual property laws such as the Patent Act and Geographical Indications (GI) Act do not adequately protect women's collective innovations (Berkes, 2012; Agarwal, 2001). The chapter critically examines the legal incoherence between forest governance, IP law, and livelihood schemes, utilizing a doctrinal analysis. It emphasizes that although the Niyamgiri judgement recognized the rights of communities, many of the subsequent judgments emphasized the importance of "scientific forestry" over community stewardship of forests (see Wildlife First v. Ministry of Environment, 2019). In addition, the policy documents such as those from the NITI Aayog emphasize industrial circularity and neglect forest-based systems (Kirchherr *et al.*, 2017). Shams contends that women are further marginalized through the exclusion of gendered individuals within customary institutions (e.g., Dorbar Shnong) and statutory bodies (e.g., Gram Sabhas). The chapter suggests specific measures for improvement, such as the recognition of TEK as a collective legal interest, gender sensitive GI registration processes and aligning the FRA with livelihood schemes to support circular enterprises led by women.

The book concludes by examining the larger idea of Indigenous Governance in Chapter 28 in relation to the Indian Knowledge System (IKS). Vikash Kumar and Aprajita Kumari argue that existing environmental governance approaches have failed in reducing biodiversity loss as it is not always inclusive of the communities relying on these resources. The study suggests that IKS of collective decision-making and a close bond with nature provide a valid and alternative approach to environmental management.

The chapter builds the case for the tribal governance model as a strong alternative to state-led management, as it is geared towards conservation for future generations. It states that the incorporation of IKS in the Sustainable Development policy process is vital for achieving several Sustainable Development Goals (SDGs), including SDG 10 (Reduced Inequalities), SDG 13 (Climate Action), SDG 15 (Life on Land) and SDG 16 (Peace and Justice). The authors propose that the acknowledgment of Indigenous governance not only helps to conserve biodiversity, but also helps to create resilient ecosystems and socially just institutions. Through looking at traditional practices, the paper calls for a whole-of-society approach, with IKS being a key component IKN being a key component of the sustainability planning process, thus reinforcing the book's main argument that IKN is not a thing of the past but a living tool for future resilience.

CONCLUSION

The integration of Environment, Growth, and Indigenous Knowledge provides a comprehensive map of the Anthropocene. It brings together the frightening physical facts of climate change and biodiversity depletion with creative solutions from the hydroponic

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applications of technology to the soil regeneration. It puts these physical solutions into perspective with the economic realities of behavioural finance and gender inclusiveness, and, finally, connects them to the legal and governance frameworks of indigenous wisdom.

Overall, the book is a testament to the belief that sustainability is best achieved through a combination of innovative growth strategies and the wisdom of indigenous communities, which is often overlooked and underutilized. The unprecedented challenges of high-tech and ecological agriculture, the psychological obstacles to sustainable finance, and the legal mandate to safeguard traditional knowledge all require a multi-disciplinary toolkit for policymakers, researchers, and practitioners navigating the dual challenges of climate change. It is not a matter of choosing between environment and growth, it is a matter of integrating environment and growth through wisdom that has been gained from people living in harmony with the land for generations.

REFERENCES

Abhijith, R., Bijulal, D., Subramoniam, S., & Ravi, V. (2025). Demystifying behavioural biases influencing sustainable investing decisions: A hybrid PLS-SEM and fuzzy DEMATEL approach. *Social Responsibility Journal*, 21(9), 2034–2052.

Agarwal, B. (2001). Participatory exclusions, community forestry, and gender. *World Development*, 29(10), 1623–1648.

Agarwalla, S. K., Barua, S. K., Jacob, J., & Varma, J. R. (2015). Financial literacy among working young in urban India. *World Development*, 66, 157-175.

Ashta, A. & Mor, S. (2017). Fostering Well-being through Cultural Change: Lessons from Microfinance for Social Entrepreneurs. In A. K. Sinha, A. K. Mohapatra and T. Banerjee (Ed.), *Good Governance and Growth in Global Economy* (pp. 21-30). New Delhi: Bloomsbury.

Berkes, F. (2012). *Sacred ecology* (3rd ed.). Routledge.

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527, 235–239.

Camlica, M., & Yaldiz, G. (2023). Basil (*Ocimum basilicum* L.): Botany, Genetic Resource, Cultivation, Conservation, and Stress Factors. In C. S. Prakash, S. Fiaz, M. A. Nadeem, F. S. Baloch, & A. Qayyum (Eds.), *Sustainable Agriculture in the Era of the OMICs Revolution* (pp. 135–163). Springer International Publishing.

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., ... & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature*, 486(7401), 59-67.

Chew, S. H., & Li, K. K. (2026). Source preference, belief bias, and ESG investment: Virtue stock affinity versus sin stock aversion. *Journal of Behavioral and Experimental Finance*, 51, 101210.

Convention on Biological Diversity (CBD). (2022). *Kunming-Montreal Global Biodiversity Framework*.

Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics*, 4(3), 66–95.

Devaraju, S., Muthusamy, D., Chandrappa, S. K., Jathar, C., Banothu, S., & Atheeswaran, A. (2026). Smart hydroponic farming system using IoT-integrated deep learning for real-time nutrient monitoring and climate control. *Ecohydrology & Hydrobiology*, 26(2), 100754.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., ... & Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, 359(6373), 270-272.

Geissdoerfer, M., Savaget, P., Bocken, N., & Hultink, E. (2017). The circular economy: A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768.

Government of India. (2006). *The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006*.

Griffiths, J. (1986). What is legal pluralism? *Journal of Legal Pluralism and Unofficial Law*, 24(1), 1–55.

Hasan, M., Paradkar, V., & Vinod Kumar, S. (2026). Comparative Study on Resource Efficiency and Environmental Impacts in Vertical Hydroponic Controlled–Environment and Crop Evapotranspiration–Based Drip Irrigation Systems for Bok Choy Cultivation (*Brassica rapa* subsp. *Chinensis* L.). *Irrigation and Drainage*, 75(1), 115–127.

Hutchings, G. (2025). The impact of an ESG nudge on retail investor engagement in sustainable finance: Evidence from an investment decision experiment. *Sustainability Accounting, Management and Policy Journal*, 16(6), 1807–1830.

India Meteorological Department. (2026). *Statement on the climate of India during 2025*. Ministry of Earth Sciences, Government of India.

Intergovernmental Panel on Climate Change. (2023). *Climate change 2023: Synthesis report*. Cambridge University Press.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*.

Jerusha, S., Anand, A. V., Adarsh, J., Chandra Kumar, K. R., & Vishnu Saravana Bharathi. (2021). Organic Hydroponic Farming Incorporated with Recycles Water. *Journal of Physics: Conference Series*, 1916(1), 012105.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy. *Resources, Conservation & Recycling*, 127, 221–232.

Lobell, D. B., Sibley, A., & Ortiz-Monasterio, J. I. (2012). Extreme heat effects on wheat senescence in India. *Nature Climate Change*, 2, 186–189.

Madan, S. and Mor, S. (2025). Impact of Precarity on Poverty: Quantification of 'crisis poor' in India. *Interdisciplinary Journal of Economics and Business Law*, 14(2), 58-81.

Mor, S. & Ashta, A. (2018). Fostering the Culture of Learning and Experimentations: An Introduction. In S. Mor (Ed.), *Culture of Learning and Experimentation for Well-Being* (pp. 1-18). New Delhi: Bloomsbury.

Mor, S. & Ashta, A. (2022). Indigenous and Exogenous Reverse Innovations: Application to Microfinance Products. In Swati Mehta and Baldev Singh Shergill (Eds), *Innovation Systems, Economic Development and Public Policy: Sustainable Options from Emerging Economies* (pp. 268-283). https://doi.org/10.4324/9781003353904-16

Mor, S. & Das, M. (2023). G-20 and Sustainable Development: A Way Forward. *Space and Culture, India*, 11(2), 1-5. https://doi.org/10.20896/saci.v11i2.1425

Mor, S. (2017). Climatic Variations and Cereal Production in India: An Empirical Analysis. *International Journal of Environment, Agriculture, and Biotechnology*, 2(3): 1143-1150. https://doi.org/10.22161/ijeab/2.3.18

Mor, S. (2018a). Choice of Small Business in Informal Sector: Case of India. In *Indian Economy: Tales of Transformation* (pp. 16–22). New Delhi: Vista International Publishers.

 ISBN: 978-93-49666-59-7 (eBook)

Mor, S. (2018b). Sino-US Trade Spat: Genesis and Implications. In *Sino-US Trade War: A New Challenge to Globalisation* (pp. 1–13). New Delhi: Vista International Publishers.

Mor, S. (2018c). US-China Trade War: Learning by Doing. In *Culture of Learning and Experimentation for Well-being* (pp. 184–190). New Delhi: Vista International Publishers.

Mor, S.(2022a). *Sustainability-A Forward*. New Delhi: Bloomsbury India Publishers.

Mor, S. (2022b). Sustainability'- A Way Forward: An Introduction. In Surender Mor (Ed), *Sustainability: A Way Forward* (pp. 1-16). New Delhi: Bloomsbury India.

Mor, S., & Lodha, S. (2019). US-China Trade Conflict: On a Misty Path. *Interdisciplinary Journal of Economics and Business Law*, 8(2), 99–111.

Mor, S., Aneja, A., Madan, S., & Ghimire, S. (2023b). Kyoto Protocol and Paris Agreement: Transition from Bindings to Pledges – A Review. *Millennial Asia*, 15(4): 691-711. https://doi.org/10.1177/09763996221141546

Mor, S., Das, M, & Madan, S. (2023c) Sustainability driven Initiatives in Indian Higher Education Institution. New Delhi: Excel India Publishers.

Mor, S., Madan, S. & Das, M. (2023a). Sustainability driven Initiatives in Indian Higher Education Institutions-An Introduction. In Surender Mor, Sonu Madan and Madhushreee Das (Eds), *Sustainability driven Initiatives in Indian Higher Education Institutions* (pp.1-12). New Delhi: Excel India Publishers.

National Centre for Financial Education (NCFE). (2020–21). *National financial literacy survey*. National Centre for Financial Education.

NITI Aayog. (2021). *Circular economy in India: Sector papers*.

Paturu, P., & Varadarajan, S. (2024). Assessing environmental sustainability by combining product service systems and life cycle perspective: A case study of hydroponic urban farming models in India. *Science of the Total Environment*, 927, 172232.

Rhods, R. (2017). *Regenerative Agriculture*.

Singh, S. (2015). Transaction Cost and Technical Efficiency: The Case of Indian Microfinance Institutions. *EPRA International Journal of Agriculture and Rural Economic Research*, 3(1): 152-160.

Singh, S. (2017a). Measurement of Technical Efficiency of MSME Sector in India: An Application of Stochastic Frontier. International Journal of Operational Research, 6(1), 47–57.

Singh, S. (2017b). Do transaction costs affect technical efficiency? Case of Indian microfinance institutions. International Journal of Management and Development Studies, 6(7): 16-25.

Singh, S., Archer, G. A., & Madan, S. (2018). Gender and entrepreneurial activities: Microentrepreneurs in rural India. *Interdisciplinary Journal of Economics and Business Law*, 7(3): 55-74.

Somanathan, E., Kotia, A., & Raghavan, A. (2021). Impact of temperature on productivity and labour in India. In *Climate and economic productivity literature*.

Wildlife First & Others v. Ministry of Environment & Forest & Climate Change & Others, W.P. (C) 109/2008 (India).

Lamba, K., Rani S. & Mor, S. (2022). Development and Sustainability: Some reflections. New Delhi: Vista International Publishers

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SECTION I

Climate, Environment and Sustainable Urban Futures

Chapter

2

A Comprehensive Review of Climate Change: Environmental Impacts, Economic Challenges, and Policy Responses

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ABSTRACT

Climate change has also shifted from an environmental externality to a systemic development risk, with implications for economic growth, agricultural productivity, labor supply, public health, food prices, infrastructure, energy security and distributional outcomes. The paper draws on peer-reviewed research and authoritative institutional sources, and each substantive empirical claim is linked to an in-text citation. India is facing high climate variability and warming. The India Meteorological Department (IMD) reported that 2024 was the warmest year in the national instrumental record at 0.65°C above the 1991–2020 average, while 2025 was the eighth-warmest year at 0.28°C above the average (IMD, 2025, 2026). The paper also looks at agricultural heat stress, labor productivity, health, urban vulnerability, climate finance, energy transition and inequality. The core argument is that India's best climate strategy is not a choice between development and mitigation, but an integrated climate-resilient development path that combines adaptation, low-carbon growth, social protection, technology, finance and institutional capacity.

Keywords: Climate change, Agriculture, Environment

INTRODUCTION

Climate change refers to shifts in climate patterns primarily driven by human activities, such as greenhouse gas emissions, land-use changes, and deforestation. Climate change impacts the environmental degradation and loss of ecosystem services, posing risks to humans, animals, and ecosystems, and contributing to inequalities in human well-being. The economics of climate change therefore combines inter temporal welfare, uncertainty, externalities, distribution, technological change, and collective action (Nordhaus 1991, 2017; Stern 2006; Tol 2018). Its synthesis highlights that climate change is already

impacting weather and climate extremes, ecosystems, human health, and economic systems, and that risks increase with warming (IPCC, 2021, 2022, and 2023). The economic literature has increasingly shifted from aggregate model projections to quasi-experimental and panel-data estimates. Dell *et al.* (2012) found that temperature shocks affect growth of the economy, while Burke *et al.* (2015) found the relation between the temperature-productivity was nonlinear. Kahn *et al.* (2021) analyzed the macroeconomic impacts of temperature rises. In India, agriculture provides millions of livelihood but the significant share of employment is still climate-sensitive. Climate change has effect on physical damages and macroeconomic transmission channels. India's exposure is multi-dimensional: heat, monsoon variability, floods, droughts, coastal hazards, and urban heat interweave with development pressures. India had recorded 2024 as warmest year, and 2025 was still considerably warmer than the 1991–2020 baseline (IMD, 2025, 2026). There is evidence associating temperature shocks with agriculture productivity and long-run economic performance (Dell *et al.*, 2012; Burke *et al.*, 2015; Kahn *et al.*, 2021). Further in India wheat evidence shows that extreme heat can reduce crop performance, and irrigation provides partial adaptation (Lobell *et al.*, 2012; Zaveri & Lobell, 2019). Much of the international climate economics literature is global or country-aggregated. Climate shocks can have spillover effects across several markets. For instance, heat can lower crop production, reduce the labor supply, and raise food prices. Adaptation is often considered a residual, not an endogenous economic choice. A better India-focused research agenda should therefore integrate physical exposure, economic sensitivity, and adaptive capacity. This systematic review addresses these knowledge gaps by providing an integrated synthesis of current evidence regarding the impacts of climate change.The paper addressing the challenges posed by climate change requires an integrated approach combining climate-resilient technologies and strengthening the adaptive capacity of farmers can help reduce climate-related agricultural losses while contributing long-term economic development.

OBJECTIVES

- To study out the environmental and economic consequences of climate change and evidence for approximately 2000–2025.
- To study the impact of climate change on Agriculture, Food Security and Rural Livelihoods
- To view out the climate report of India.

METHODOLOGY AND EVIDENCE STRATEGY

This study adopted a systematic literature review approach to synthesize existing evidence and used secondary-data synthesis rather than new estimate. Literature review based on peer-reviewed journal articles and reports from various organizations like IPCC, UNFCCC,

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IMD, Government of India, World Bank, IEA etc. Literature review used physical climate evidence, empirical economic evidence and policy evidence. A source-to-claim crosswalk is provided later in the paper to reduce citation ambiguity. Numerical indicators are explicitly labelled by reference year.

LITERATURE REVIEW

Nordhaus (1991) discussed about the influential perspectives on the welfare economics of climate policy. **Dell *et al.* (2012)** showed the evidence of the temperature shocks which reduce the economic performance in poorer economies. **Burke *et al.* (2015)** discussed about the nonlinear global relationship between temperature and production. **Kahn *et al.* (2021)** highlighted the temperature increases have long-term consequences. Agriculture is exposed to heat, rainfall variability, drought, floods, pests and water stress. **Lobell *et al.* (2011)** estimate historical climate-related crop effects globally. **Challinor *et al.* (2014)** synthesize evidence on crop responses and adaptation. **Rosenzweig *et al.* (2014)** demonstrate the importance of crop-model uncertainty and adaptation in projecting future risks. **Lobell *et al.* (2012)** document extreme-heat effects on wheat senescence in India. **Zaveri and Lobell (2019)** show that irrigation can reduce the sensitivity of wheat yields to heat, but adaptation may generate water and energy trade-offs. These studies imply that adaptation should be evaluated on net welfare rather than yield effects alone. Heat reduces labour capacity through physiological stress and can affect working hours and productivity, especially in physically demanding outdoor occupations. The IPCC identifies heat exposure, food insecurity and disease as major climate-related health pathways **(IPCC, 2022). Somanathan *et al.* (2021)** provide India-specific evidence that extreme heat affects labour productivity and economic activity. Climate damages are unequally distributed. Poor households often have higher exposure and fewer assets for adaptation. **Hallegatte *et al.* (2016)** connect climate shocks with poverty dynamics, while **Diffenbaugh and Burke (2019)** identify an international inequality dimension. In India, distributional effects should be studied through household assets, employment type, gender, caste-neutral socioeconomic indicators, location and access to public services rather than national averages alone.

Literature Review Matrix

Author/year	Setting	Design / contribution	Core Finding	India Relevance
Nordhaus (2017)	Global	Welfare economics	Social cost of carbon	Policy appraisal
Stern (2006)	Global	Integrated assessment	Delayed action has large welfare costs	Intertemporal policy
Dell *et al.* (2012)	Global	Panel econometrics	Temperature shocks affect growth	Macro climate sensitivity

Table Contd....

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Table Contd....

Burke *et al.* (2015)	Global	Panel econometrics	Nonlinear temperature-productivity effect	Heat-growth mechanism
Carleton & Hsiang (2016)	Global	Synthesis	Multiple economic channels	Integrated assessment
Kahn *et al.* (2021)	Global	Cross-country panel	Persistent macro effects	Growth resilience
Lobell *et al.* (2012)	India	Crop-climate analysis	Extreme heat affects wheat	Direct India evidence
Zaveri & Lobell (2019)	India	Crop + irrigation analysis	Irrigation buffers heat effects	Adaptation trade-off
Somanathan *et al.* (2021)	India	Economic/labour evidence	Heat affects productivity	Employment
Diffenbaugh & Burke (2019)	Global	Distributional analysis	Warming increases inequality	Equity
IPCC (2023)	Global	Assessment	Risks increase with warming	Policy urgency

INDIA-SPECIFIC EVIDENCE: CLIMATE OBSERVATIONS

The India Meteorological Department's 2025 climate statement reports an all-India annual mean land-surface air temperature anomaly of +0.28°C relative to the 1991–2020 long-term average, making 2025 the eighth warmest year since nationwide records began in 1901. The same statement identifies 2024 as the warmest year, with an anomaly of +0.65°C (IMD, 2026).

Indicator	Value	Interpretation	Source
2024 annual temperature anomaly	+0.65°C	Warmest year in national record	IMD (2025, 2026)
2025 annual temperature anomaly	+0.28°C	8th warmest year	IMD (2026)
2025 winter anomaly	+1.17°C	Above 1991–2020 average	IMD (2026)
2025 annual rainfall	1,274 mm; 110% of 1971–2020 LPA	Above long-period average	IMD (2026)

Figure 1. India climate observation pathway.

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CLIMATE HAZARDS

Heat → drought/flood → crop stress → labour/health stress → economic losses

INDIA'S OFFICIAL EMISSIONS AND CLIMATE REPORTING

India's Fourth Biennial Update Report (BUR4), submitted to the UNFCCC on 30 December 2024, is a primary official source for India's greenhouse-gas inventory and mitigation information. The report should be preferred over secondary summaries when citing national inventory values (Government of India, 2024). The UNFCCC repository also records India's Adaptation Communication and long-term low-emission development strategy, demonstrating that India's climate policy architecture increasingly covers both mitigation and adaptation (UNFCCC, 2023, 2022).

Official source	Year	Use in research
India Fourth Biennial Update Report	2024	GHG inventory, mitigation actions
India Adaptation Communication	2023	Adaptation priorities and vulnerability
India LT-LEDS	2022	Long-term low-carbon development
India NDC / updated commitments	2022 onward	2030 mitigation targets
Economic Survey 2024–25	2025	Macroeconomic and adaptation context
Economic Survey 2025–26	2026	Recent policy and energy evidence
IMD climate statement	2026	Observed 2025 climate

INDIA: AGRICULTURE, FOOD SECURITY AND RURAL LIVELIHOODS

Indian agriculture is multidimensional affected by climate change. Increasing temperature affects the crop production, rainfall affects the planting and water availability and damage done by flood to standing crops, drought reduces agriculture productivity; and heat affects the irrigation. Adaptation is not costless. Irrigation helps to reduce crop sensitivity but it affects the groundwater by increasing extraction and energy consumption. Hence, an adaptation measure should be evaluated using net social benefits, including water sustainability and distributional effects (Zaveri & Lobell, 2019).

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LABOUR PRODUCTIVITY AND HEALTH

The extreme heat has measurable implications for labour productivity in India. This is especially important because climate-sensitive employment is concentrated in agriculture, construction, manufacturing and informal services. The IPCC identifies heat stress as a major and growing risk to human health and labour capacity (IPCC, 2022). Policy responses should include heat-health action plans, occupational heat standards, work-rest cycles, shaded workspaces, hydration, early-warning systems and social protection. Adaptation can therefore be interpreted as an investment in human capital rather than merely as disaster expenditure.

URBAN CLIMATE RISK

Rapid urbanization increases exposure to heat and flooding through dense built environments, limited green space, drainage constraints and rising cooling demand. The IPCC identifies cities as critical sites for integrated climate action because urban systems concentrate people, infrastructure, energy consumption and economic activity (IPCC, 2022, 2023).

For Indian cities, climate-resilient development should integrate heat-action plans, cool roofs, urban forests, drainage, water security, public transport, energy-efficient buildings and distributed renewable energy.

Energy Transition and Development: India's climate policy faces a dual requirement: meeting rising electricity demand while reducing the carbon intensity of future growth. The energy transition therefore has implications for industrial competitiveness, energy security, employment, air pollution and external energy dependence (IEA, 2021; Government of India, 2026).The Economic Survey 2025–26 reports that non-fossil sources represented 51.93% of India's installed power capacity at the end of December 2025 (Government of India, 2026). Installed-capacity shares should not, however, be interpreted as equivalent to generation shares because renewable availability and dispatchability differ across technologies.

Climate Finance and the Economics of Adaptation: Climate finance is central because adaptation benefits are often local and public, while financing capacity differs across regions and households. The IPCC identifies finance, technology and institutional capacity as enabling conditions for climate action (IPCC, 2023). For India, climate finance should combine public budgets, development finance, private capital, green bonds, blended finance, insurance and concessional international resources. The key evaluation question is not only how much finance is mobilized but whether it reaches high-vulnerability communities and produces measurable reductions in expected losses.

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CLIMATE CHANGE, INFLATION AND MACROECONOMIC STABILITY

Climate shocks can produce supply-side inflation through crop losses, food shortages, damaged logistics and energy disruptions.

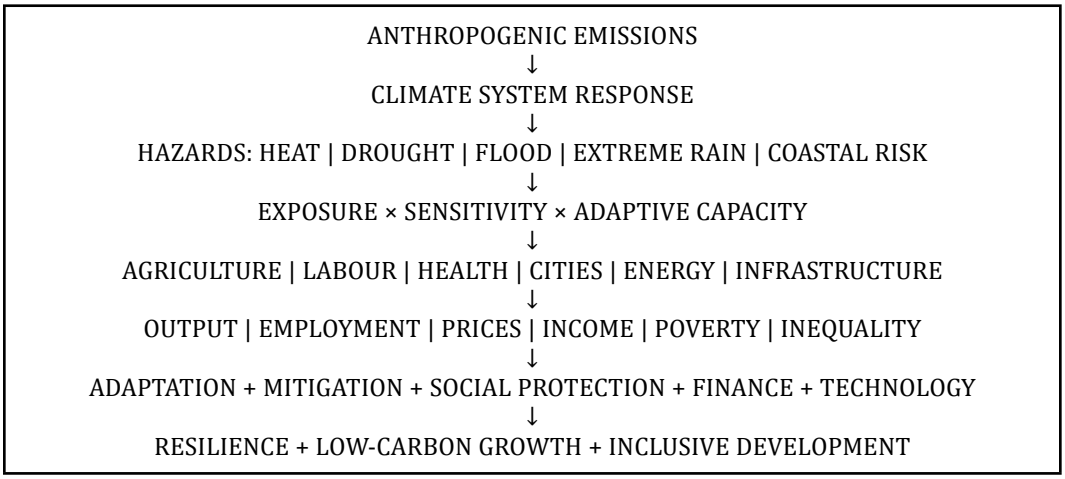


Figure 2: Conceptual Framework: Climate-Resilient Development

India 2000–2025 Evidence Dashboard

Domain	Key indicator	Period	Interpretation/source
Climate	Annual temperature anomaly	2024–2025	2024 warmest; 2025 eighth warmest (IMD)
Rainfall	Annual rainfall	2025	110% of 1971–2020 LPA (IMD)
Emissions	National inventory	Latest official inventory	Use BUR4 rather than unsourced estimates (GoI, 2024)
Energy	Non-fossil installed capacity	Dec. 2025	51.93% (Economic Survey 2025–26)
Adaptation	Domestic adaptation/ resilience spending	FY2016–FY2022	3.7% → 5.6% of GDP (Economic Survey 2025–26)
Agriculture	Heat-wheat relationship	India	Extreme heat reduces wheat performance (Lobell *et al.*, 2012)
Labour	Heat-productivity relationship	India	Extreme heat reduces productivity (Somanathan *et al.*, 2021)

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POLICY RECOMMENDATIONS

- There should be anticipatory risk management through early warning and climate information.
- Climate-resilient agricultural systems should be develop based on crop diversification, water-efficient irrigation, heat-tolerant varieties and climate information services etc.
- Integrate climate risk into public infrastructure appraisal, municipal finance and land-use planning.
- Electricity flexibility system should be accelerated through transmission, storage and demand management alongside renewable expansion.
- To create the transparent climate-budget tagging and outcome indicators for adaptation expenditure.
- Climate finance should be strengthening by the states, municipalities, MSMEs and vulnerable households.
- Transition measures should be designed for workers and regions dependent on carbon-intensive industries.
- Climate-economic datasets should be established to support causal research and policy evaluation.

As we know climate impacts the poverty, infrastructure and labour markets and we cannot measured the welfare effects of climate change only through aggregate GDP. In India, the policy challenge is particularly complex further Urbanization also increase vulnerability by inefficient infrastructure. The irrigation can protect crops from heat but can increase the risk of groundwater extraction. Renewable energy can reduce emissions and energy-import exposure but requires grid flexibility and storage.

CONCLUSION

Climate change, most emerging issues of present world domain as India is facing its impacts through droughts, floods cyclones etc. which have become threats to sustainable development. Increasing global temperature from various sources is the cause of climate change and impacts. Climate change impacts the environmental degradation and loss of ecosystem services, posing risks to humans, animals, and ecosystems, and contributing to inequalities in human well-being. Climate change creates a structural risk to India's development trajectory. The evidence and economic research demonstrates that climate shocks can affect production, agriculture, labour etc. India studies found that heat can damage crops and labour productivity. As per the IMD observations 2024 was India's warmest year in the record and 2025 remained among the warmest years. The IPCC identifies cities as critical sites for integrated climate action because urban systems concentrate people, infrastructure, energy consumption and economic activity. As per the

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review the climate shocks can produce supply-side inflation through crop losses, food shortages, damaged logistics and energy disruptions. The next generation of research should combine high-resolution climate data with district-level economic outcomes and causal identification.

REFERENCES

Auffhammer, M. (2018). Quantifying economic damages from climate change. *Journal of Economic Perspectives*, 32(4), 33–52.

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527, 235–239. https://doi.org/10.1038/nature15725

Carleton, T. A., & Hsiang, S. M. (2016). Social and economic impacts of climate. Science, 353(6304), aad9837. https://doi.org/10.1126/science.aad9837

Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, 4, 287–291.

Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics*, 4(3), 66–95.

Diffenbaugh, N. S., & Burke, M. (2019). Global warming has increased global economic inequality. *Proceedings of the National Academy of Sciences*, 116(20), 9808–9813.

Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., & Vogt-Schilb, A. (2016). Shock waves: *Managing the impacts of climate change on poverty*. World Bank.

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D., Muir-Wood, R., Wilson, P., Oppenheimer, M., Larsen, K., & Houser, T. (2017). Estimating economic damage from climate change in the United States. *Science*, 356(6345), 1362–1369.

India Meteorological Department. (2025). Annual climate summary 2024. Ministry of Earth Sciences, Government of India.

India Meteorological Department. (2026). Statement on the climate of India during 2025. Ministry of Earth Sciences, Government of India.

Intergovernmental Panel on Climate Change. (2021). *Climate change 2021*: The physical science basis. Cambridge University Press.

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022*: Impacts, adaptation and vulnerability. Cambridge University Press.

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022*: Mitigation of climate change. Cambridge University Press.

Intergovernmental Panel on Climate Change. (2023). *Climate change 2023*: Synthesis report. IPCC.

International Energy Agency. (2021). India energy outlook 2021. IEA.

Kahn, M. E., Mohaddes, K., Ng, R. N. C., Pesaran, M. H., Raissi, M., & Yang, J.-C. (2021). Long-term macroeconomic effects of climate change: A cross-country analysis. *Energy Economics*, 104, 105624.

Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, 333(6042), 616–620.

ISBN: 978-93-49666-59-7 (eBook)

Lobell, D. B., Sibley, A., & Ortiz-Monasterio, J. I. (2012). Extreme heat effects on wheat senescence in India. *Nature Climate Change*, 2, 186–189.

Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor countries. Environment and Development *Economics*, 11(2), 159–178.

Nordhaus, W. D. (1991). To slow or not to slow: The economics of the greenhouse effect. *The Economic Journal*, 101(407), 920–937.

Nordhaus, W. D. (2017). Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences*, 114(7), 1518–1523.

Pindyck, R. S. (2013). Climate change policy: What do the models tell us? *Journal of Economic Literature*, 51(3), 860–872.

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Müller, C., Arneth, A., Boote, K. J., Folberth, C., Glotter, M., Khabarov, N., Neumann, K., Piontek, F., Pugh, T. A. M., Schmid, E., Stehfest, E., Yang, H., & Jones, J. W. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of the National Academy of Sciences*, 111(9), 3268–3273.

Somanathan, E., Kotia, A., & Raghavan, A. (2021). Impact of temperature on productivity and labour in India. In *climate and economic productivity literature*.

Stern, N. (2006). *The economics of climate change: The Stern review*. Cambridge University Press.

Tol, R. S. J. (2018). The economic impacts of climate change. Review of Environmental Economics and Policy, 12(1), 4–25.

Zaveri, E., & Lobell, D. B. (2019). The role of irrigation in changing wheat yields and heat sensitivity in India. *Nature Communications*, 10, 4144. https://doi.org/10.1038/s41467-019-12183-9

Government of India. (2024). India's fourth biennial update report to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change.

Government of India. (2025). *Economic Survey 2024–25*. Ministry of Finance.

Government of India. (2026). *Economic Survey 2025–26*. Ministry of Finance.

United Nations Framework Convention on Climate Change. (2022). *India's long-term low-carbon development strategy*.

United Nations Framework Convention on Climate Change. (2023). *India: Adaptation communication*.

United Nations Framework Convention on Climate Change. (2024). India: Biennial update report (BUR4).

United Nations Environment Programme. (2024). *Emissions gap report 2024*.

World Bank. (2022). Climate investment opportunities in India's cooling sector.

World Bank. (2024). World development indicators: Greenhouse gas emissions database (EDGAR/JRC).

World Meteorological Organization. (2025). State of the climate in Asia 2024.

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Chapter

3

Biodiversity at a Crossroads: Challenges, Opportunities, and the Path Forward

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ABSTRACT

Biodiversity is the foundation of life on Earth, supporting ecosystem stability, human well-being, and sustainable development. It encompasses the variety of genes, species, and ecosystems that collectively maintain ecological processes essential for life. However, rapid urbanization, habitat fragmentation, climate change, pollution, invasive species, and unsustainable exploitation of natural resources have accelerated biodiversity loss across the globe. The decline of biodiversity not only threatens ecological integrity but also undermines food security, public health, economic stability, and the resilience of natural systems to environmental change.

This paper explores the significance of biodiversity conservation in the context of contemporary environmental challenges and highlights the urgent need for coordinated conservation efforts. It discusses the role of protected areas, habitat restoration, sustainable resource management, and community-based conservation in safeguarding biological diversity. The integration of scientific research, technological innovations, traditional ecological knowledge, and environmental education is emphasized as a means of enhancing conservation effectiveness and promoting long term ecological resilience. Furthermore, the paper examines the importance of policy interventions, stakeholder engagement, and international cooperation in achieving global biodiversity conservation goals. As the world faces unprecedented ecological challenges, biodiversity conservation must be recognized as a shared responsibility that transcends geographical and political boundaries. Protecting the diversity of life is not merely an environmental obligation but a necessity for ensuring a sustainable and resilient future. Through collective action, informed decision-making, and a commitment to sustainable practices, it is possible to halt biodiversity decline and preserve Earth's natural heritage for future generations.

Keywords: Biodiversity Conservation, Ecosystem Resilience, Climate Change, Habitat Restoration

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INTRODUCTION

Biodiversity encompasses the rich variety of life on Earth, including the diversity found within species, among different species, and across ecosystems. It plays a vital role in maintaining healthy, stable, and resilient ecosystems while supporting human well being in numerous ways. From providing food, medicines, and fibre to supporting pollination, maintaining soil fertility, regulating the climate, and enriching cultural traditions, biodiversity is an essential foundation of both ecological and human well being (Cardinale et al., 2012; Díaz et al., 2018). Therefore, conserving biodiversity is essential for maintaining environmental sustainability and ensuring the well being and quality of life of people.

Despite its immense importance, biodiversity is declining rapidly across the world. Habitat loss and fragmentation, over exploitation of natural resources, pollution, climate change, and the spread of invasive alien species are among the major factors driving this decline. Most of these pressures are closely linked to human activities and often occur simultaneously, placing increasing stress on ecosystems and threatening the survival of many species (IPBES, 2019). Biodiversity loss can disturb the natural relationships among species, weaken the ability of ecosystems to cope with environmental changes, and put at risk the essential services that ecosystems provide to human societies (Ceballos et al., 2017).

Climate change is adding to these pressures by changing where species can survive, as well as affecting their growth, reproduction, and interactions with other organisms (Pecl et al., 2017). At the same time, the growing demand for land and natural resources is placing increasing pressure on forests, grasslands, wetlands, and other ecosystems that support rich and diverse forms of life.

The biodiversity crisis , while deeply concerning, also offers an opportunity to rethink and strengthen conservation efforts. Strategies such as ecological restoration, sustainable resource management, technological innovation, and active community participation can help protect and restore ecosystems while supporting human well being (IPBES, 2019).

Biodiversity is therefore at a crossroads. On one path lies continued environmental degradation, which could further accelerate the loss of species and ecosystems. On the other lies the opportunity to create a more sustainable and resilient future through integrated conservation efforts, ecological restoration, and responsible development. Recognizing the urgency of this challenge, the Kunming -Montreal Global Biodiversity Framework underscores the need for coordinated global action to conserve, restore, and sustainably manage biodiversity for the benefit of both nature and humanity (CBD, 2022). Against this backdrop, this paper examines the major challenges confronting biodiversity, highlights emerging opportunities for conservation and sustainable use, and discusses practical pathways for building a future where both nature and human societies can thrive.

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BIODIVERSITY: CONCEPT AND SIGNIFICANCE

Biodiversity is the diversity of life on Earth, encompassing variation within species, differences between species, and the variety of ecosystems that support life (Noss, 1990). Biodiversity is essential for the functioning, stability, and resilience of ecosystems. It provides vital services such as food, medicine, pollination, nutrient cycling, and climate regulation (Cardinale et al., 2012; Díaz et al., 2018). Therefore, conserving biodiversity is crucial for environmental sustainability, human well-being, and long- term development.

Genetic, Species and Ecosystem Diversity

Biodiversity exists at three min levels: genetic, species, and ecosystem diversity. Genetic diversity enables species to adapt to environmental changes, species diversity reflects the variety of life forms and ecosystem diversity represents the range of habitats and ecological communities. Together they maintain healthy and resilient ecosystems (Reed & Frankham, 2003; Hooper et al., 2005). In plants, genetic diversity found in crops, traditional varieties, and their wild relatives provides useful traits such as drought and disease resistance, helping strengthen food security and adaptation to climate change (Hajjar & Hodgkin, 2007). Maintaining diversity at all three levels is essential for healthy ecosystems and their ability to withstand environmental changes.

Biodiversity, Ecological Stability and Resilience

Biodiversity supports ecosystem stability and resilience by helping species respond differently to environmental changes. This “Insurance effect” reduces the impact of disturbances, while species complementarity improves resource use and productivity (Yachi & Loreau, 1999: Loreau & Hector, 2001). Greater plant diversity can also increase resistance to climate extremes, while biodiversity loss can weaken ecosystem recovery (Isabell et al., 2015).

Biodiversity and Ecosystem Services

Biodiversity provides essential ecosystem services, including food, medicines, timber, pollination, carbon storage, soil conservation, water regulation, and cultural benefits (Hajjar & Hodgkin, 2007; Cardinale et al., 2012; Díaz et al., 2018).plant diversity is especially important because plants support food webs, nutrient cycling, and soil fertility. Consequently, biodiversity loss can disrupt ecosystem functioning and reduce the benefits that nature provides to people (Ollerton et al., 2011; Bardgett & van der Putten, 2014).

BIODIVERSITY AND HUMAN WELL-BEING

Biodiversity plays a vital role in human well-being by supporting food security, health, livelihoods, cultural values, and economic development (Millennium Ecosystem Assessment, 2005). Plants are especially important as sources of food, medicines, raw materials, and valuable genetic resources.

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Food Security

Plant biodiversity is essential for food security, providing a wide range of crops, wild food plants, and genetic resources. Traditional crop varieties and wild relatives contain valuable traits such as drought, pest, and disease resistance, which help improve crop resilience. In addition, agricultural biodiversity supports pollinators, soil organisms, and natural pest control, contributing to sustainable food production (Hajjar & Hodgkin, 2007).

Medicinal Resources

Plants have been used for centuries for traditional and modern medicines. Their varied chemical compounds continue to support pharmaceutical research, while medicinal plants remain important to many rural and indigenous communities (Hamilton, 2004). However, habitat loss, over harvesting, and rising commercial demand are putting several medicinal plant species at risk, making sustainable harvesting and cultivation increasingly important (Chen et al., 2016).

Livelihoods

Millions of people rely on biodiversity for food, income, and livelihoods. Forests and other ecosystems provide timber, fuel wood, fruits, fibres, resins and medicinal plants, while non timber forest products support many rural communities (Shackleton et al., 2007).

Cultural and Economic Importance

Biodiversity has cultural, spiritual and economic value with plants linked to traditional knowledge and cultural identity. It also supports agriculture, forestry, pharmaceuticals and ecotourism although many ecosystem benefits remain undervalued economically (Díaz et al., 2018).

CURRENT STATUS OF BIODIVERSITY

Biodiversity is declining worldwide due to habitat loss, over exploitation, pollution, invasive species and climate change. In plant communities, these pressures are changing species distributions, compositions, and regeneration. As primary producers plants are vital to ecosystems and provide essential resources such as food, medicine and fibres (Cardinale et al., 2012; IPBES, 2019).

Global Biodiversity Trends

Global assessment show that species populations are declining and the risks of extinction is increasing. Habitat loss and degradation are major causes, especially in forests, grasslands and wetlands. Around one million species are estimated to face extinction in the coming decades if current trends continue (IPBES, 2019). plant diversity is particularly threatened by agricultural expansion, deforestation, urbanization, invasive species and

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over harvesting. Habitat loss and fragmentation can reduce plant populations, genetic diversity and connectivity, further increasing extinction risks. Ecosystem transformation has significantly changed the composition and functioning of natural communities. Tropical forests continue to face pressure from land-use change, while grasslands and wetlands are increasingly converted for agriculture and infrastructure. These changes can reduce native plant diversity and disrupt important ecosystem processes such as carbon storage, nutrient cycling and soil conservation (Pimm et al., 2014).

Threatened Species and Ecosystems

Forest harbors a large proportions of global plant diversity but are increasingly threatened by deforestation, fragmentation, fires and climate change. Tropical forests are particularly important reservoirs of endemic and economically valuable plant species (Giam et al., 2010).

Wetlands support diverse aquatic and semi -aquatic vegetation and provide important services including water purification, flood regulation and habitat provision. Their conversion and degradation have resulted in significant biodiversity losses **(Davidson, 2014).**

Grasslands support diverse herbaceous plant communities and contribute to soil carbon storage, nutrient cycling and livelihoods. Agricultural expansion, overgrazing and woody encroachment are among the major pressure affecting grassland biodiversity (Bardgett et al., 2021).

Marine ecosystems, although not plant dominated, depend heavily on photosynthetic organisms such as phytoplankton and sea grasses. Climate change, pollution, eutrophication and habitat destruction threaten marine biodiversity and ecosystem functioning (Duffy et al., 2016).

Mountain ecosystems are particularly vulnerable because of their restricted climatic zones, high endemism and sensitivity to temperature changes. Shifts in temperature and precipitation can alter the distribution and phenology of mountain plants and increase pressure on already restricted species (Körner, 2007).

Biodiversity in India and the Himalayan Region

India is one of the world's megadiverse countries, supporting a remarkable variety of ecosystems, species, and genetic resources despite covering only a small share of the global land area (Ministry of Environment, Forest and Climate Change [MoEFCC], 2014). its diverse climate and geography create favourable conditions for rich plant diversity, including many endemic and economically valuable species.

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The Himalayan region is a major centre of plant diversity and endemism, with habitats ranging from subtropical forests to alpine ecosystems and many medicinal and endemic plants. However, climate change, habitat fragmentation, development, tourism, over harvesting and invasive species increasingly threaten its flora. Climate change can shift plant ranges and alter flowering and regeneration, while medicinal plants face additional pressure from unsustainable harvesting (Telwala et al., 2013: Kala et al., 2006). conservation therefore requires habitat protection and restoration, sustainable use, ex-situ conservation and community participation.

MAJOR CHALLENGES TO BIODIVERSITY

Biodiversity loss results from multiple, interconnected pressures operating at local to global scales. Plant biodiversity is particularly vulnerable because plants are directly affected by land-use change, climate change, pollution, resource extraction and biological invasions (IPBES, 2019).

Habitat Loss and Fragmentation

Habitat loss and fragmentation caused by deforestation, agriculture, urbanization, mining and infrastructure development are major threats to plant diversity. Fragmentation reduces population size, dispersal and gene flow while increasing edge effects and vulnerability to environmental disturbances. Agricultural expansion often replaces diverse native vegetation with simplifies landscapes (Fahrig, 2003). In the Himalayas, expanding settlements and infrastructure can fragment forests and alpine habitats and restrict species' ability to shift their ranges under climatic change.

Climate Change

Climate change affects plant distribution, growth, reproduction and ecological interactions. Changes in temperature and precipitation influence germination, flowering, regeneration and survival. Mountain plants may shift towards higher elevations, but high altitude species have limited opportunities for further movement. Changes in flowering and leaf emergence can also disrupt plant pollinator and plant dispenser relationships. Droughts, heat waves, floods and wildfire further increase the pressure (Telwala et al., 2013).

Invasive Alien Species

Invasive alien species compete with native plants, modify habitats and alter ecosystem processes. Species like *Lantana camara, Parthenium hysterophorus* and *Chromolaena odorata* can suppress native regeneration, particularly in disturbed habitats. Aquatic invasive plants like *Eichhornia crassipes* can form dense mats, reducing light and oxygen availability. Globally, invasive plants are recognized as major drivers of biodiversity decline (Pyšek et al., 2020).

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Pollution

Pesticides, fertilizers, plastics, heavy metals and air pollutants can directly or indirectly reduce biodiversity. Excess nutrients cause eutrophication, while pesticides affect non target organisms such as pollinators and soil microorganisms. Heavy metals can inhibit seed germination, photosynthesis and plant growth. Microplastics may also alter soil properties, plant growth and nutrient cycling (de Souza Machado et al., 2018).

Overexploitation

Unsustainable extraction of timber, fuelwood, non-timber forest products and medicinal plants can reduce population size and regeneration. Medicinal plants are particularly vulnerable because valuable species are often harvested directly from wild populations. Slow- growing and narrowly distributed species face greater risks (Chen et al., 2016). Sustainable harvesting, cultivation and community-based resource management are therefore essential.

Unsustainable Agriculture and Forestry

Mono cultures, genetic uniformity, excessive chemical inputs and replacement of native vegetation simplify ecosystems and reduce associated biodiversity. Replacement of traditional crop varieties with a limited number of modern varieties contributes to genetic erosion, reducing resources for future crop improvement and climate adaptation. Similarly, monoculture plantations generally support less biodiversity than natural or mixed- species forests. Agroforestry, crop diversification and conservation of native vegetation can help address these impacts.

Human–Wildlife Conflict

Habitat encroachment, agricultural expansion and infrastructure development increase interactions between people and wildlife. Crop damage and livestock losses may create economic pressures and lead to retaliatory actions. Changes in herbivores populations can also influence vegetation regeneration, while declines in pollinators and seed dispersers can affect plant reproduction. Habitat connectivity and community- based conflict management can reduce these pressures.

Fragmented Governance and Policy Gaps

Biodiversity conservation requires coordination among forestry, agriculture, water, infrastructure and development sectors. Fragmented governance, inadequate funding, weak implementation and limited long-term monitoring can reduce conservation effectiveness (IPBES, 2019). Strengthening environmental assessments, biodiversity monitoring, restoring requirements and interdepartmental coordination is essential. Greater investment in plant inventories, seed banks, botanical gardens and genetic-resource conservation is needed.

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Loss of Traditional Knowledge

Traditional knowledge of medicinal plants, wild foods, fibres, fodder and sustainable harvesting is an important but declining component of biocultural diversity. Modernization migration and reduced interaction with natural environments can accelerate knowledge loss (IPBES, 2019). Documentation, intergenerational knowledge transfer and community participation can help preserve this knowledge and support sustainable biodiversity management. Addressing biodiversity loss therefore requires an integrated approach combining habitat protection, restoration, sustainable resource use, climate adaptation, invasive-species management, genetic-resource conservation and community participation.

OPPORTUNITIES FOR BIODIVERSITY CONSERVATION

The continuing decline of biodiversity highlights the need to move beyond documenting threats towards practical, innovative and inclusive conservation solutions. Plant biodiversity should receive particular attention because plants form the structural and functional foundation of most terrestrial ecosystems and provide food, medicines, fibres, carbon storage and other ecosystem services. Opportunities for conservation increasingly combine ecosystem restoration, protected areas, ex-situ approaches, new technologies, community participation and nature-based solutions (IPBES, 2019; CBD, 2022).

Ecosystem Restoration

Ecosystem restoration offers an important opportunity to recover degraded habitats and rebuild native plant communities. Forest restoration can involve natural regeneration, assisted regeneration and planting of appropriate native species. Restoration approaches that prioritize local species diversity and ecological processes are generally more beneficial for bisodiversity than plantations dominated by a few species (Chazdon, 2008).

Wetland restoration can recover aquatic and semi-aquatic vegetation, improve water quality and restore important ecological functions. Similarly, grassland restoration through controlled grazing, removal of invasive plants and reintroduction of native species can improve plant diversity and ecosystem functioning. Restoration should therefore focus not simply on increasing vegetation cover but on recovering native species composition, genetic diversity, ecological interactions and ecosystem processes (Aronson & Alexander, 2013).

Protected Areas and Ecological Corridors

Protected areas remain fundamental for conserving plant species and their habitats. However, isolated protected areas may become less effective when surrounding landscapes are highly fragmented. Landscape-level conservation and ecological corridors can improve connectivity between habitat patches and facilitate movement of seeds, pollen and organisms.

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For plants, habitat connectivity is particularly important for maintaining gene flow and allowing populations to respond to changing climatic conditions. Corridors can connect fragmented forests, mountain habitats and other biodiversity-rich landscapes, thereby reducing isolation and supporting long-term population viability (Hilty et al., 2020). Conservation planning should consequently integrate protected areas with surrounding agricultural and community-managed landscapes.

Ex-situ Conservation

Ex-situ conservation provides an important safeguard for threatened plant species and genetic resources outside their natural habitats. Seed banks, field gene banks, botanical gardens and living collections can conserve genetic material for research, restoration and future reintroduction.

Seed banking is particularly effective for species producing desiccation-tolerant (orthodox) seeds, while species with recalcitrant seeds may require alternative approaches such as tissue culture or cryopreservation (Walters et al., 2013). Botanical gardens can also support propagation, research and public education. For rare Himalayan medicinal plants and other threatened species, combining ex-situ conservation with habitat protection can provide an additional layer of security against extinction.

Emerging Technologies

Technological advances are creating new opportunities for rapid and accurate biodiversity assessment. GIS and remote sensing can map vegetation, habitat fragmentation and land-use change over large areas, while drones can provide high-resolution information on plant communities and habitat condition.

Molecular approaches such as DNA barcoding and environmental DNA (eDNA) can assist in species identification and detection, particularly where conventional identification is difficult (Taberlet et al., 2018). Artificial intelligence and machine-learning tools can analyse large datasets and improve species recognition, vegetation mapping and biodiversity monitoring. Such technologies can complement field-based botanical surveys and provide more efficient approaches to monitoring threatened plant populations.

Citizen Science

Citizen science provides an opportunity to involve the public directly in biodiversity documentation and monitoring. Digital platforms allow students, researchers and local communities to record plant species, flowering periods, distributions and invasive species. Large-scale observations can contribute to biodiversity databases and provide valuable information on species distributions and phenological changes.

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For plant conservation, citizen participation can be particularly useful in documenting local flora, rare species, phenological changes and invasive plants. Citizen-generated observations, when appropriately verified, can complement professional biodiversity surveys and increase public awareness of plant conservation (Chandler et al., 2017).

Indigenous and Local Knowledge

Indigenous peoples and local communities possess extensive knowledge concerning medicinal plants, wild foods, forest resources and sustainable harvesting practices. Integrating this traditional ecological knowledge (TEK) with scientific approaches can improve conservation and resource management (IPBES, 2019).

Community participation is especially important in landscapes where local people depend directly on forests and other natural ecosystems. Community-managed forests and locally developed harvesting practices can contribute to both biodiversity conservation and livelihoods. Conservation initiatives should therefore recognize local communities not merely as beneficiaries but as active partners and knowledge holders.

Nature-based Solutions

Nature-based Solutions (NbS) use ecosystems and their functions to address environmental and societal challenges while simultaneously supporting biodiversity. Forest restoration, watershed protection, urban green spaces, wetland conservation and ecosystem-based adaptation can provide multiple benefits.

Restored forests can sequester carbon, protect soils and regulate water while providing habitat for diverse plant species. Wetlands can reduce flooding and improve water quality, whereas urban forests and green spaces can provide habitat for native plants and moderate urban temperatures. Importantly, nature-based solutions should prioritize native and ecologically appropriate plant species rather than relying exclusively on fast-growing or non-native species (Seddon et al., 2020).

Together, these approaches demonstrate that biodiversity conservation can move from a reactive strategy towards a proactive and integrated model. Combining restoration, habitat connectivity, ex-situ conservation, technological innovation, citizen science, traditional knowledge and nature-based solutions can strengthen the conservation of plant diversity while simultaneously supporting climate adaptation, ecosystem resilience and human well-being.

POLICY AND GOVERNANCE

Effective biodiversity conservation relies on strong policies, effective institutions and coordinated governance. Clear policies and cooperation among different sectors help ensure protection, sustainable use and long term management of biodiversity resources.

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International Frameworks

The Convention on Biological Diversity (CBD) is the main international agreement guiding biodiversity conservation, sustainable use of biological resources and the fair sharing of benefits from genetic resources (CBD, 1992) it plays an important role in conserving plant diversity, genetic resources and threatened species and habitats.

The Kumming-Montreal Global Biodiversity Framework (GBF), adopted in 2022, established global targets for conserving, restoring and sustainably managing biodiversity. It emphasizes the effective conservation of terrestrial, inland water, coastal and marine areas, ecosystem restoration and the sustainable use of wild species (CBD, 2022). these targets provide an important framework for framework for protecting plantrich ecosystems and restoring degraded habitats

The Sustainable Development Goals (SDG) also recognize the importance of biodiversity. SDG 2 addresses sustainable agriculture and food security, while SDGs 13, 14 and 15 address climate action, aquatic ecosystems and terrestrial biodiversity, respectively (United Nations, 2015). Their integration provides opportunities to link plant conservation with food security, climate adaptation and sustainable development.

Indian Biodiversity Governance

India has developed a multi-level institutional framework for biodiversity conservation. The Biological Diversity Act, 2002, provides a legal framework for conservation, sustainable use and access and benefit sharing related to biological resources. The framework was strengthened through the Biological Diversity Act, 2002, as amended in 2023, and associated rules and regulations (Government of India, 2023).

The National Biodiversity Authority (NBA) operates at the national level, while State Biodiversity Boards (SBBs) support biodiversity governance at the state level. At the local level, Biodiversity Management Committees (BMCs) are established by local bodies to document and manage biological resources and associated knowledge.

An important instrument is the People's Biodiversity Register (PBR), which documents locally available biological resources and associated traditional knowledge. For plant biodiversity, PBRs can provide valuable information on medicinal plants, wild edible species, crop varieties, economically important plants and traditional uses. They can therefore contribute to both conservation planning and recognition of community knowledge (NBA, 2013).

Challenges in Implementation

Despite strong policy framework, a gap often exists between policy and implementation due to limited funding, inadequate monitoring, weak institutional coordination, and

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insufficient technical capacity. Strengthening coordination, financing and scientific monitoring while integrating biodiversity conservation with sustainable livelihoods and climate action will be essential for long-term success (IBPES, 2019)

THE PATH FORWARD

Biodiversity conservation requires a more integrated, inclusive, and long-term approach combining ecosystem protection, restoration, sustainable resource use, technology, and community participation (IPBES, 2019; CBD, 2022).

From Species Protection to Ecosystem Conservation

Conservation should focus not only on threatened species but also an ecosystem integrity, connectivity, and resilience, supported by protected areas and ecological corridors (CBD, 2022).

Integrating Biodiversity into Development

Biodiversity should be considered in agriculture, infrastructure, tourism, urbanization, mining and energy planning to reduce environmental impacts (IPBES, 2019; CBD, 2022).

Restoration as a Conservation Strategy

Restoring forests, wetlands, grasslands, rivers and agriculture landscapes can recover ecosystem functions, improve connectivity and strengthen climate resilience (CBD, 2022).

Community-Centred Conservation

Greater involvement of local communities and Indigenous peoples, along with traditional knowledge and fair benefit-sharing, can make conservation more effective and sustainable (CBD, 2022).

Sustainable Agriculture and Forestry

Approaches such as agroforestry, crop diversification, conservation agriculture, and sustainable forest management can reduce pressure on natural ecosystems. They promote efficient resource use, maintain soil and ecosystem health, and support biodiversity. At the same time, these practices provide diverse sources of food, income, and other resources, thereby strengthening local livelihoods and promoting long-term sustainability.

Technology-Driven Monitoring

Tools such as remote sensing, GIS, drones, eDNA, DNA metabarcoding and AI can improve the speed and effectiveness of biodiversity monitoring (Thomsen & Willerslev, 2015; CBD, 2023).

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Sustainable Bioeconomy

Responsible management of biological resources, waste reduction, and adoption of circular practices can promote economic growth while ensuring that resource use remains within ecological limits (CBD, 2022).

Biodiversity Financing

Long term conservation requires adequate and reliable funding through public investment and innovation financing mechanisms (CBD, 2022).

Education and Capacity Building

Strengthening biodiversity education, research and professional capacity is essential for effective conservation and restoration. Closer collaboration among researches, governments, communities, civil society and businesses can help translate scientific knowledge into practical conservation action (IPBES, 2024).

RESEARCH GAPS AND FUTURE DIRECTIONS

Future research should focus on how biodiversity responds to climate change, changes in species and ecosystem, and the role of genetic and functional diversity. More work is also needed on plat genetic resources, microbial diversity, and ecological restoration. New tools such as AI, remote sensing, eDNA and DNA metabarcoding can make biodiversity monitoring faster and more effective (Thomsen & Willerslev, 2015). Future biodiversity research should bring together ecology, genetics, climate sciences, data sciences and social sciences to better understand and address conservation challenges.

CONCLUSION

Biodiversity is at a crossroads, and the choices we make today will shape the health of ecosystems and the well being of future generations. Its continued loss threatens not only plants, animals and habitats but also food security, water resources, livelihoods, human health and our ability to cope with climate change.

Conservation efforts therefore need to shift from reactive to preventive approaches, from focusing mainly on individual species to protecting and restoring entire ecosystem, and from being largely government- driven to actively involving local communities. Biodiversity conservation should also be integrated into sustainable development rather than treated as a separate environmental concern. New technologies can strengthen biodiversity monitoring, while long term and adaptive management can help conservation efforts respond to changing environmental conditions.

Ultimately, protecting biodiversity requires more than creating protected areas. It calls for a broader approach to assess, protect, restore, sustainably use, monitor, adapt and

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transform the way we interact with nature. The future of biodiversity will depend on finding a balance between human needs and ecological limits ensuring a healthier and more resilient future for both nature and society.

REFERENCES

Aronson, J., & Alexander, S. (2013). Ecosystem restoration is now a global priority.

Bardgett, R. D., & van der Putten, W. H. (2014). Belowground biodiversity and ecosystem functioning. *Nature, 515*, 505–511.

Bardgett, R. D., et al. (2021). Combatting global grassland degradation. *Nature Reviews Earth & Environment, 2*, 720–735.

Cardinale, B. J., et al. (2012). Biodiversity loss and its impact on humanity. *Nature, 486*, 59–67.

CBD. (1992). *Convention on Biological Diversity*. United Nations.

CBD. (2022). *Kunming–Montreal Global Biodiversity Framework*. Convention on Biological Diversity.

CBD. (2023). *Monitoring framework for the Kunming–Montreal Global Biodiversity Framework*. Convention on Biological Diversity.

Chazdon, R. L. (2008). Beyond deforestation: restoring forests and ecosystem services on degraded lands. *science*, *320*(5882), 1458-1460.

Chen, S. L., et al. (2016). Conservation and sustainable use of medicinal plants: Problems, progress, and prospects. *Chinese Medicine, 11*, 37.

Chen, S. L., Yu, H., Luo, H. M., Wu, Q., Li, C. F., & Steinmetz, A. (2016). Conservation and sustainable use of medicinal plants: Problems, progress, and prospects. *Chinese Medicine, 11*, 37.

Davidson, N. C. (2014). How much wetland has the world lost? *Marine and Freshwater Research, 65*, 934–941.

De Souza Machado, A. A., et al. (2018). Microplastics as an emerging threat to terrestrial ecosystems. *Global Change Biology, 24*, 1405–1416.

De Souza Machado, A. A., Lau, C. W., Till, J., Kloas, W., Lehmann, A., Becker, R., & Rillig,

Díaz, S., et al. (2018). Assessing nature's contributions to people. *Science, 359*, 270–272.

Díaz, S., Settele, J., Brondízio, E. S., et al. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science, 366*(6471), eaax3100. https://doi.org/10.1126/science.aax3100

Duffy, J. E., et al. (2016). Biodiversity and ecosystem functioning in the global ocean. *Proceedings of the National Academy of Sciences, 113*, 11927–11932.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution, and Systematics, 34*, 487–515.

FAO. (2019). *The State of the World's Biodiversity for Food and Agriculture*. Food and Agriculture Organization of the United Nations, Rome.

Giam, X., et al. (2010). Future habitat loss and the conservation of tropical biodiversity. *Biological Conservation, 143*, 1594–1602.

Government of India. (2023). *Biological Diversity Act, 2002 (as amended in 2023)*. Ministry of Environment, Forest and Climate Change, Government of India.

Hajjar, R., & Hodgkin, T. (2007). The use of wild relatives in crop improvement: a survey of developments over the last 20 years. *Euphytica*, *156*(1), 1-13.

 ISBN: 978-93-49666-59-7 (eBook)

Hamilton, A. C. (2004). Medicinal plants, conservation and livelihoods. *Biodiversity and Conservation, 13*, 1477–1517.

Hooper, D. U., et al. (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature, 486*, 105–108.

IPBES. (2019). *Global Assessment Report on Biodiversity and Ecosystem Services*. IPBES Secretariat.

Isbell, F., et al. (2015). Biodiversity increases the resistance of ecosystem productivity to climate extremes. *Nature, 526*, 574–577.

Kala, C. P., Dhyani, P. P., & Sajwan, B. S. (2006). Developing the medicinal plants sector in northern India: Challenges and opportunities. *Journal of Ethnobiology and Ethnomedicine, 2*, 32.

Körner, C. (2007). The use of "altitude" in ecological research. *Trends in Ecology & Evolution, 22*, 569–574.

C. (2018). Microplastics can change soil properties and affect plant performance. *Environmental Science & Technology, 52*(17), 9656–9665. https://doi.org/10.1021/acs.est.8b02212

MoEFCC. (2014). *India's Fifth National Report to the Convention on Biological Diversity*. Ministry of Environment, Forest and Climate Change, Government of India.

NBA. (2013). *Guidelines for Preparation of People's Biodiversity Register*. National Biodiversity Authority, Go vernment of India.

Noss, R. F. (1990). Indicators for monitoring biodiversity. *Conservation Biology, 4*, 355–364.

Oliver, T. H., et al. (2015). Biodiversity and resilience of ecosystem functions. *Nature Communications, 6*, 10122.

Pecl, G. T., Araújo, M. B., Bell, J. D., et al. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science, 355*(6332), eaai9214. https://doi.org/10.1126/science.aai9214

Pecl, G. T., et al. (2017). Biodiversity redistribution under climate change. *Science, 355*, eaai9214.

Pimm, S. L., et al. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. *Science, 344*, 1246752.

PLoS ONE, 8(2), e57103. https://doi.org/10.1371/journal.pone.0057103

Pyšek, P., Hulme, P. E., Simberloff, D., et al. (2020). Scientists' warning on invasive alien species. *Biological Reviews, 95*(6), 1511–1534. https://doi.org/10.1111/brv.12627

Reed, D. H., & Frankham, R. (2003). Correlation between fitness and genetic diversity. *Conservation Biology, 17*, 230–237.

Telwala, Y., Brook, B. W., Manish, K., & Pandit, M. K. (2013). Climate-induced elevational range shifts and increase in plant species richness in a Himalayan biodiversity epicentre. *PLoS ONE, 8*, e57103.

Thomsen, P. F., & Willerslev, E. (2015). Environmental DNA—An emerging tool in conservation for monitoring past and present biodiversity. *Biological Conservation, 183*, 4– 18

United Nations. (2015). *Transforming our World: The 2030 Agenda for Sustainable Development*. United Nations.

Yachi, S., & Loreau, M. (1999). Biodiversity and ecosystem productivity in a fluctuating environment. *PNAS, 96*, 1463–1468.

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Chapter

4 Decoupling Carbon Emissions and Economic Growth: Evidence from South Asia

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ABSTRACT

One of the most crucial aspects for understanding sustainable development has been a correlation between economic growth and environmental impacts. Moreover, the environment and the economy are interlinked and decoupling is an important metric integrating the two. The present study evaluates decoupling of carbon emissions and economic growth in South Asian countries from 1990 to 2023. South Asia has been historically heavily dependent on coal and fossil fuels for their economic growth, making it energy-intensive and high-carbon region with the exception of Bhutan. This study applies the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model framework. STIRPAT model is advancement over the conventional IPAT identity. The factors used in the study are carbon emissions, population, affluence, technology, urbanization, and trade openness to capture the impact of economic growth on emissions in South Asia. The STIRPAT model is estimated by both Common Correlated Effects Mean Group (CCEMG) and Augmented Mean Group (AMG) for ensuring robustness of the estimates. The data has been compiled from the World Bank's World Development Indicators (WDI), European Commission's Emissions Database for Global Atmospheric Research (EDGAR), and the Asian Development Bank (ADB). This study also tests the Environmental Kuznets Curve (EKC) by applying the inverted U-hypothesis test. Furthermore, the Pollution Haven Hypothesis (PHH) is also tested to determine whether South Asian countries serve as 'pollution havens'. South Asian countries require a swift transition to green economic growth framework which demands structural policy initiatives and stringent environmental regulations.

Keywords: Decoupling, Carbon Emissions, Sustainable Development, STIRPAT Model, Environmental Kuznets Curve (EKC), Pollution Haven Hypothesis (PHH)

INTRODUCTION

A country's development has historically been measured by economic growth – an increase in Gross Domestic Product (GDP) or National Income. Over time, economic

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development was differentiated from economic growth and was defined as economic growth accompanied by improvements in well-being or quality of life. Later, the concept of sustainable development emerged in the late 1970s, to refer to improvements in well-being without material growth (Gallopin, 2003).

Normally, as economic growth occurs, energy consumption increases, which in turn causes an increase in carbon emissions (Wan, Wang & Ng, 2016). The link between environmental impact and economic growth has been one of the most intricate and crucial aspects of sustainable development (Wang et al., 2018). Since environment and economy are interlinked, decoupling is an important metric that integrates the two (Lin et al., 2015). Carbon emissions are mainly linked to industrial production in developing economies (Lv, Tang, & Ding, 2024). However, a low- emission economy with rapid economic growth is possible (Quaye et al., 2025; Haberl et al., 2020; Berahab, 2017). Changes in the energy landscape, such as a shift from non-renewable to renewable sources for production and consumption, improved energy efficiency, and reduced carbon intensity, can lead to decoupling.

In contrast to the common view that efficiency reduces consumption of resources and lowers environmental footprint, Jevons' paradox suggests that efficiency policies can be counterproductive (Alcott, 2005). The overburdening of the planet and its depleting natural resources are matters of concern. Efforts by individuals in reducing carbon emissions (CO_2) in an economy are limited by the free-rider problem: individual incentives remain questionable, and therefore, government accountability increases in this context (Cheng et al., 2022). The ideas of green growth (Tenaw & Hawitibo, 2021) and the circular economy rely on the concept of decoupling. The term has many connotations in economic literature. The OECD (2002, 2025) has defined decoupling as breaking the link between 'environmental bads' and 'economic goods.' Thus, decoupling refers to a condition where an economy grows while reducing carbon emissions, thereby reducing adverse environmental impact (Parrique et al., 2019; Quaye et al., 2025).

The majority of the literature on decoupling focuses on China, OECD countries, the European Union, the United States and other developed economies. Home to over 25% of world's population but accounting for barely over 4% of global GDP (nominal), South Asia contributes around 10% of global GHG emissions. South Asia has historically been heavily dependent on coal and fossil fuels for its economic growth, making it an energy-intensive and high-carbon region, with the exception of Bhutan which is a carbon-negative country. South Asian economies have seen weak evidence of decoupling, attributed to rapid urbanization, energy-intensive manufacturing and fossil-fuel consumption. In the pre-Covid period, the region recorded 8% of economic growth in 2016, which seized during the pandemic, but rebounded in the post-Covid period; nonetheless, South Asia's high economic growth has been achieved at the expense of environmental cost (Khoury, 2022).

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This study applies the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework to examine the decoupling of carbon emissions and economic growth in South Asia from 1990-2023. Furthermore, it tests the Environmental Kuznets Curve (EKC) and the Pollution Haven Hypothesis (PHH) to determine whether South Asian countries serve as 'pollution havens'.

Studies on decoupling in South Asia are largely missing from the literature. This study attempts to fill that gap. It recommends structural policy initiatives, such as heavy investments in green energy sources, green finance, innovation in energy-efficient technologies, circular supply chains, reduction in fossil fuel subsidies, sustainable production and consumption, and stringent environmental regulations.

LITERATURE REVIEW

Human activities are the most significant contributors to greenhouse gas (GHG) emissions in the environment. With increasing population and rapid urbanization, economic growth and environmental footprint must be balanced (Gaurav, 2025). Technological progress and structural changes in the economy can lead to decoupling. The inverse relation between human progress and the environment has surfaced prominently since the late 1980s following the 'Brundtland Report' in 1987 (Sanyé-Mengual, 2019). Decoupling is not merely an eco-efficiency measure, but rather an indicator of improved sustainability. Parrique et al. (2019) identified that there is no empirical evidence in the literature that concludes that absolute decoupling has presently occurred. When it comes to the use of natural resources and economic growth, no absolute decoupling has happened.

Wan, Wang & Ng (2016) analyzed the decoupling between carbon emissions and economic growth for the equipment manufacturing industry in China during 2000-2014, applying LMDI decomposition and Tapio decoupling techniques, and observed weak decoupling between emissions and economic growth. Xu et al. (2024) explored the nexus between carbon emissions and energy consumption from 2000 to 2020 for one metropolitan area of China, Chengdu, by applying a coupled method, Tapio decoupling and LMDI decomposition techniques, along with an expanded STIRPAT method for forecasting the carbon emissions path. The major findings revealed that carbon emissions are concentrated in highly developed urban zones that lack forest cover for carbon sinks. Additionally, the decoupling between emissions and economic development is weak. However, energy intensity has been the key factor in reducing the carbon emissions. Wang et al. (2024) examined carbon emission and economic growth decoupling in China's six central provinces by using decoupling index (Tapio) based on the LMDI technique for 2000-2019 and an extended STIRPAT model for forecasting during 2000-2040. The major findings revealed a steady decoupling state during the study period for all six provinces. The decoupling status is guided by economic development and energy intensity. Cheng, Li

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and Huangmei (2025) explored decoupling of economic growth and energy consumption in urban areas (prefecture cities) of China by using Tapio decoupling and a spatially weighted Durbin model developed from an augmented STIRPAT framework for the period from 2006 to 2021. The study found that decoupling is not uniform throughout the provinces of China; however, the number of weak decoupling regions decreased during the period from the 11th to the 14th Five-Year Plans. Various studies have been undertaken on economic growth and carbon emissions decoupling with a focus to China. However, other studies have also investigated the decoupling of economic growth and environmental degradation for various countries and regions, including OECD countries, the European Union, ECOWAS, Ukraine, the United States, and other developed countries.

Umpfenbach (2013) observed the decoupling of economic growth from resource use and environmental degradation, focusing on a policy framework for attaining absolute decoupling in the European Union, and applying the common approach based on examination of literature and conversations with stakeholders. The study proposed five major goals for 2050 for evaluating policy initiatives, including consumption of virgin metals, GHG emissions, arable land use, nutrients input, and freshwater use. Gupta (2015) studied decoupling between economic growth and environmental footprints in OECD countries. Based on the DPSIR technique delineated in the OECD report, the study concluded that relative decoupling had occurred for some selected indicators, demanding stringent policies for controlling fossil-fuel use, population, poverty, and corruption in the OECD countries. Haberl et al. (2020) investigated interlink among GDP, resource use, and greenhouse gas (GHG) emissions based on systematic literature survey from 1972 to 2019. The detailed study concluded that the direction of causality is inconclusive; however, GDP and energy are firmly associated. Although some industrialized countries have witnessed absolute decoupling, the findings cannot be generalized. Yaremova and Mytrofanova (2022) explored decoupling as a measure of economic growth and environmental footprints for territories of Ukraine during 2016-2020, applying common methods and approaches for analysis. Most regions of Ukraine are at a positive level of decoupling, with critical levels in four territories, while seven regions show an upward decoupling trend. Ayensu and Sun (2025) studied the decoupling of economic growth and carbon emissions with reference to fifteen ECOWAS members using the Tapio decoupling method during 1991 to 2020. The major findings include strong negative and recessive decoupling for the states of ECOWAS. Arino and Wang (2025) examined the decoupling of resource consumption and economic growth in China, Europe and the United States using the decoupling analysis method during 2000-2019. The US attained steady decoupling; European countries exhibited mixed decoupling, while China displayed weak decoupling. Quaye et al. (2025) examined economic growth and climate change decoupling in view of consumption-based emissions, using latent variable modeling framework for the period 2010-2018 for thirteen countries. Prospective consumption-based carbon emissions per capita are less responsive to changes in per capita GDP growth.

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The literature on the decoupling of economic growth and emissions in South Asia is scarce. While studies on the impact of carbon emissions, population, trade openness, globalization, and other factors on economic growth and the environment are available, studies particularly on decoupling are missing. Decoupling theory has critical ramifications for comprehending the economic growth trajectories of the economies (Khosla et al., 2014). Countries like India and Germany can proceed towards community-based energy-ventures, advanced-grids, integrated urban transit, and social ventures for a circular economy and sustainable development. Rahman, Saidi, and Mbarek (2020) outlined the immediate and lasting implications of carbon emissions, population density, and trade openness on economic growth for five South Asian countries over the period 1990-2017. Carbon dioxide emissions and population density had a significant positive impact on South Asian economic growth; whereas trade openness and economic growth were negatively linked in the long term. Moreover, carbon emissions and economic growth displayed a two-way causal relationship in the short term. South Asia has not decoupled carbon emissions from economic growth. Department of Environment and Climate Change (2023) found substantially robust evidence of decoupling between green house gas (GHG) emission and GDP for Bhutan in the long term. The study projected that with a 25% of GDP increase, GHG emission would decrease by 20%. Although Bhutan is committed to carbon neutrality, GHG emissions are swiftly increasing attributable to economic development. Abbas, Yang, and Lahr (2024) analyzed the impact of globalization on carbon emissions in South Asia (India, Bangladesh, Sri Lanka, and Pakistan) during 1996-2019. Economic globalization significantly contributed to increased energy consumption and carbon emissions, and South Asia served as 'Pollution Haven' correlated to economic globalization only. Rani, Rehman, and Prisca (2025) discussed the effect of green energy and financial development on carbon emissions in South Asian countries using quantile regression for the period 2003-2023. Green energy effectively reduced carbon emissions, while financial development had a negative effect on carbon emissions. There is growing apprehension about the harmony between economic development and sustainability, regardless of high economic growth in South Asia, since these countries are experiencing degrading environment.

The reviewed literature reveals two contrasting sides of decoupling. One strand of a handful of literature confirms decoupling of economic growth and environmental sustainability, while other strand of literature concludes that for ecological sustainability, reducing production and consumption is essential. Additionally, majority of studies on decoupling focuses on China, OECD countries, the European Union and the United States; studies on South Asian decoupling is almost missing from the literature. This study attempts to fill that gap by exploring carbon emissions and economic growth decoupling in South Asia.

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METHODOLOGY

Conceptual Framework of Decoupling

Decoupling has become a cornerstone of environmental policy and climate change mitigation strategies globally. In essence, decoupling refers to delinking economic growth (increase in GDP) from resource use and environmental footprint (Umpfenbach, 2013). It can be either relative (weak), where emissions reduce more slowly than economic growth (GDP), or absolute (strong), where emissions decline substantially despite economic growth. The simultaneous delinking of economic growth from both resource consumption and environmental footprint is termed as double decoupling (Khosla et al., 2014). Furthermore, UNEP (2011) has differentiated between resource decoupling and impact decoupling illustrated in Figure 1. Resource decoupling refers to the process of minimizing primary resource consumption rate for each unit of economic output. In contrast, impact decoupling is reducing environmental footprints (reducing carbon emissions), while rising economic production.

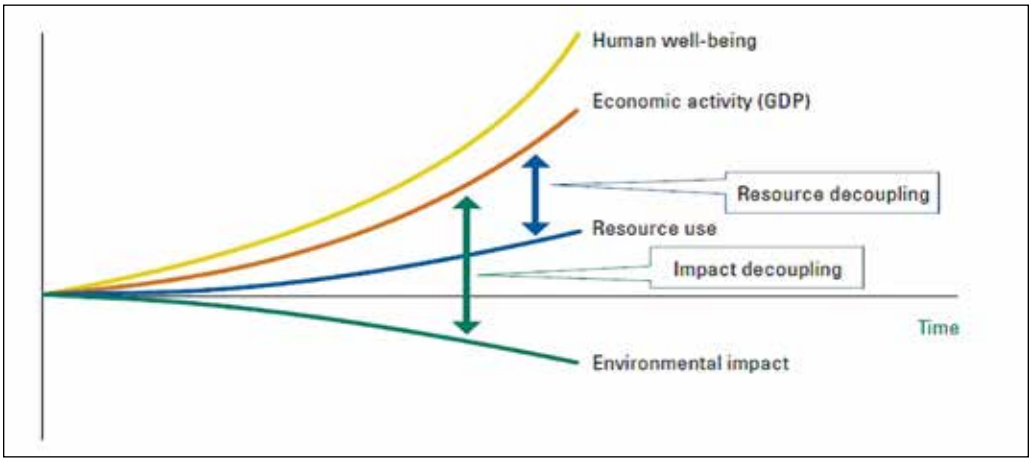


Fig. 1: Understanding the Resource and Impact Decoupling

Source: *UNEP (2011)*

Decoupling indicator (D) measures decoupling as a change in CO_2 emissions with respect to a change in GDP (Tapio, 2005; Berahab, 2017; Wang et al., 2024):

$$D = \frac{\Delta CO_2 \text{ Emissions}}{\Delta GDP}$$

Based on the measures of decoupling, it may be weak or strong. Weak decoupling happens when carbon emissions (CO_2) increases with an increase in GDP ($D > 0$). When with an increase in GDP, carbon emissions either fall or remain stable, it is termed as strong decoupling ($D < 0$).

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STIRPAT Model Framework

This study has applied STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) framework to capture the impact of carbon emissions on population, affluence and technology. The STIRPAT model is originated from IPAT identity (Commoner, 1971; Ehrlich & Holdren, 1972). The typical expression of the STIRPAT model is:

$$I = a\, P^{b1} A^{b2} T^{b3} e$$

Here, I = Environmental Footprint, a = Constant, P = Population, A = Affluence, T = Technology, b_1, b_2, and b_3= Elasticity Coefficients and e = Error term:

Converting the IPAT in the log-linear form

$$\ln(I) = \ln a + b_1 \ln(P) + b_2 \ln(A) + b_3 \ln(T) + \ln(e)$$

Adding the country (i) and time dimension (t), the expression can be written as

$$\ln(I_{it}) = \alpha + \beta_1 \ln(P_{it}) + \beta_2 \ln(A_{it}) + \beta_3 \ln(T_{it}) + \varepsilon_{it}$$

The dependent variable (I) used here is carbon dioxide (CO_2) emissions that measures environmental impact. Population (P) is the total population of South Asian countries (Urban population can also be used); Affluence (A) is measured by GDP per capita (PPP) indicating that with a rise in income, consumption level increases. Technology (T) corresponds to energy intensity, i.e., energy use per GDP which reflects how polluting the technology is. Augmenting the baseline model with urbanization (E_1), trade openness (E2) the equation transforms to:

$$\ln(I_{it}) = \alpha + \beta_1 \ln(P_{it}) + \beta_2 \ln(A_{it}) + \beta_3 \ln(T_{it}) + \beta_4 \ln(E1_{it}) + \beta_5 \ln(E2_{it}) + \varepsilon_{it}$$

The STIRPAT model has been estimated using both the Common Correlated Effects Mean Group (CCEMG) and the Augmented Mean Group (AMG) to validate the robustness of the estimates. These are second-generation estimation techniques, which evaluate long-run relation in panel data. These statistical methods are used to address cross-sectional dependence and endogeneity problems.

Environmental Kuznets Curve (EKC)

This study also tests the Environmental Kuznets Curve (EKC) and the Pollution Haven Hypothesis (PHH) to examine whether the South Asian countries serve as 'pollution havens'. The Environmental Kuznets Curve (EKC) postulates that environmental degradation displays an increasing trend in the initial phases of economic development; however, it declines with increased levels of income and economic development (Khosla et al., 2014; Murthy & Gambhir, 2018). This indicates that there is an inverted U-shaped relationship between economic development and environmental damage. For a log-linear model, the turning-point (per capita GDP level), where theoretically emissions start declining:

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$$\text{Turning Point} = e^{\frac{\beta 1}{2\beta 2}}$$

Here, β_1= coeff. of ln_A (Affluence)

β_2= coeff. of $\ln\_A^2$ (sqr. of Affluence)

The rationale for this inverted U-shaped relationship is (the combined result of scale effect, composition effect, and technology effect) rooted in the argument that at higher levels of economic development, countries acquire the required pollution mitigation technologies and financial capital to impose stronger environmental regulations.

Pollution Haven Hypothesis (PHH)

The location of firms depends on a multitude of factors ranging from production costs to market access and government taxation policies; however, environmental regulation has emerged as a new determining factor for location overseas (Zugravu & Kheder, 2008). Countries having weak environmental regulatory policies attract foreign firms from countries where regulations are stringent. In this connection, the Pollution Haven Hypothesis (PHH) emerged during 1990s to explain the location of polluting firms (Bhat & Tantri, 2024). The PHH underscores that multinational corporations from developed countries, especially those involved in extremely polluting operations, reposition their firms to countries with weaker environmental regulations (Smarzynska & Wei, 2001; Temurshoev, 2006). Since developed countries usually have stricter environmental regulations compared to developing countries, motivates global firms to either relocate or offshore their polluting activities to countries with weaker environmental policies (Copeland & Taylor, 1994; Lee & Min, 2014; Shahbaz et al., 2015; Ozcelik et al., 2024).

Data Source and Sample

The empirical investigation is based on seven South Asian countries (Afghanistan was dropped due to data unavailability) covering the period from 1990 to 2023. To estimate the model, data on carbon dioxide emissions, population, GDP per capita, energy consumption, urbanization, and trade openness were compiled from the World Bank's World Development Indicators (WDI). Additionally, data on CO_2 emissions were supplemented with statistics from the European Commission's Emissions Database for Global Atmospheric Research (EDGAR), while trade openness data for the Maldives were extracted from the Asian Development Bank (ADB). The data sources, along with descriptions of the indicators, are presented in Table 1.

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Table 1: Data Source

Variables	Indicator	Data Source
Impact (I)	Carbon Emissions measured by Total CO2 emissions (Mt CO2e) excluding LULUCF	World Bank-WDI/ EDGAR
Population (P)	Total Population	World Bank -WDI
Affluence (A)	Wealth/Income measured by GDP per capita (Constant 2015 or 2021 US$)	World Bank- WDI
Technology (T)	Energy Efficiency measured by Energy intensity level of primary energy (MJ/$2021 PPP GDP)	World Bank- WDI
Urbanization (E1)	Measured by urban population as % of total population	World Bank- WDI
Trade Openness (E2)	Trade as % of GDP	World Bank -WDI/ADB

Source: Author

EMPIRICAL RESULTS AND DISCUSSION

Descriptive statistics are presented in Appendix Table A, while summary of log-transformed variables is presented in Appendix Table B. Pairwise correlations among the variables are shown in Appendix Table C, which validates low multicollinearity among the variables, with the exception of ln_P. To detect multicollinearity, the VIF was estimated and is shown in Appendix Table D. Since the mean VIF is 2.64 (thresholds are: VIF< 5=No issue; VIF <10= tolerable), it is concluded that there is no serious multicollinearity issue. Prior to estimating the coefficients for the STIRPAT model, the Pesaran CD test for cross-sectional dependence was performed (see Appendix Table E). The results of the CD test confirmed significant cross-sectional dependence (mean rho of 96%). However, some countries exhibit negative correlation (mean rho= 0.45, abs =0.87); moreover, absolute dependence is high, indicating that South Asian countries are moving together. This is common for South Asian countries and is attributable to geographical proximity, common macroeconomic shocks, contiguous climate impacts, regional spillover effects, cultural and structural similarities, and regional free trade agreements (SAFTA). Given the high dependence, first-generation panel unit root tests (IPS, LLC) become unacceptable. Therefore, second-generation CIPS test and the CCEMG and the AMG estimators are applied to account for cross-sectional dependence. The results for the Westerlund ECM and the Pedroni and Kao tests are summarized in appendix Table F. The Pedroni and Kao tests validate strong long-run cointegration for the balanced panel (N=238) after dropping the technology variable (ln_T).

Table 2 presents the main results from the CCEMG estimation for the STIRPAT model. For robustness, AMG estimates are also presented in the table. The estimated coefficient

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for Population (P) is positive, but it is not significant under the CCEMG estimation. The elasticity for Affluence (A) is 1.125 ($p<0.01$), showing that it is positive and significant. This indicates that a 1% increase in income (GDP per capita), increases carbon dioxide (CO_2) emissions by more than 1% for South Asian countries. Urbanization (E1) has a negative impact on carbon emissions; however, the coefficient is not significant. This finding implies that South Asian countries have not yet attained economies of scale effect, due to transition dynamics and low urbanization. Trade Openness (E2) coefficient is positive and significant (0.136, $p=0.003$), indicating that with an increase in degree of openness, the environmental footprint increases. This is an interesting finding, as it validates the 'Pollution Haven Hypothesis (PHH)' in South Asia, along the lines of the findings of Abbas, Yang, and Lahr (2024). Technology (T) is dropped from the estimation due to 34% missing observations and its failure to pass the cointegration test for a long-run relationship. Estimation based on AMG, confirms the positive and significant effect of Affluence on the environment (carbon emissions) – an increase in per capita GDP increases carbon emissions. Moreover, trade openness is positive for both CCEMG and AMG; however, it is not significant under the AMG estimation.

Table 2: Results for STIRPAT Model

Variables	CCEMG Coefficients	Std. Error	p-value	AMG Coefficients	Std. Error	p-value
Population (P)	0.954	1.032	0.356	-0.422	0.518	0.417
Affluence (A)	1.125***	0.343	0.001	0.892***	0.218	0.000
Urbanization (E1)	-0.923	0.903	0.307	0.538	0.675	0.425
Trade Openness (E2)	0.136***	0.045	0.003	0.069	0.074	0.348
Constant	3.024	6.789	0.656	1.022***	0.364	0.005

Source: Author

Notes: 1. For CCEMG: Wald chi2=20.17 ($p=0.0005$), RMSE=0.056; For AMG: Wald chi^2 =100.85 ($p=0.0000$)

2. Model estimated without technology (ln_T) since 34% data is missing and failed the co-integration test

3. Pedroni PP (Phillips-Perron) $p=0.0037$, Kao $p=0.0044$ without ln _T, which confirmed long-run relation, CSD handled by using CCE

This study further tests the validity of the Environmental Kuznets Curve (EKC) hypothesis. The estimation based on the AMG supports the inverted-U proposition, since the coefficient of Affluence is positive ($ln\_A > 0$) and its square is negative ($ln\_A^2 < 0$), however, ln_A^2 is not significant. The reason for this observation is that mostly the observations lie prior to the peak of the EKC. With a mean ln_A of 7.373552, the mean

per capita GDP is exp (7.373552) which amounts to $1594. The turning point (peak) will be achieved at a per capita GDP of $2495.5 [Turning point = exp{ln_A (mean) + 0.4487} =exp (7.373552+0.4487) = 2495.5]. At present, the average per capita GDP of South Asia is $1594, while the EKC turning point will be achieved at $2495.5. These results validate that South Asia has not attained decoupling of carbon emissions from economic growth. This finding is consistent with Rahman, Saidi, and Mbarek (2020).

CONCLUSIONS AND SUGGESTIONS

The present study explores the decoupling of carbon emissions and economic growth in South Asia from 1990 to 2023, applying the STIRPAT framework. The STIRPAT model is estimated by using both CCEMG and AMG to validate robustness of the estimates. The study also tests the Environmental Kuznets Curve (EKC) and the Pollution Haven Hypothesis (PHH). The findings confirm that carbon emissions increase with an increase in per capita GDP in South Asia. Moreover, South Asia serves as a 'Pollution Haven', as the positive and significant coefficient of trade openness confirms the PHH. Furthermore, South Asian countries exhibit an inverted-U relationship (Environmental Kuznets Curve Hypothesis); however, these countries have not yet reached the turning point. These results validate that South Asia has not decoupled carbon emissions from economic growth. These countries require a swift transition to a green economic growth framework, which demands structural policy initiatives such as heavy investments in green energy sources, green finance, innovation in energy-efficient technology, circular supply chains, reduction in fossil fuel subsidies, sustainable production and consumption, and stringent regulations.

REFERENCES

Abbas, M., Yang, L., & Lahr, M. L. (2024). Globalization's effects on South Asia's carbon emissions, 1996–2019: A multidimensional panel data perspective via FGLS. *Humanities & Social Sciences Communications, 11*(1). https://doi.org/10.1057/s41599-024-03704-z

Alcott, B. (2005). Jevons' paradox. *Ecological Economics: The Journal of the International Society for Ecological Economics, 54*(1), 9–21. https://doi.org/10.1016/j.ecolecon.2005.03.020

Ariño, M. A., & Wang, H. (2025). Decoupling resource consumption from economic growth: A comparative study of China, Europe, and the United States. *Journal of Sustainability, 1*(2). https://doi.org/10.55845/jos-2025-1251

Ayensu, F., & Sun, D. (2025). Decoupling approach to carbon emissions and economic growth nexus: Evidence from ECOWAS member states. https://doi.org/10.2139/ssrn.5110384

Berahab, R. (2017). *Decoupling economic growth from CO2 emissions in the world* (Policy Brief PB-17/27). OCP Policy Center.

Bhat, V., & Tantri, M. L. (2024). Pollution haven hypothesis and the bilateral trade between India and China. *Journal of Current Chinese Affairs, 53*(2), 277–302. https://doi.org/10.1177/18681026231188450

 ISBN: 978-93-49666-59-7 (eBook)

Cheng, H., Li, C., & Huangmei, M. (2025). An examination of the decoupling effect and influential mechanisms of energy consumption and economic growth in Chinese urban areas. *Scientific Reports, 15*(1), 31190. https://doi.org/10.1038/s41598-025-16262-4

Cheng, S., Wang, P., Chen, B., & Fan, W. (2022). Decoupling and decomposition analysis of CO2 emissions from government spending in China. *Energy, 243*, 122741. https://doi.org/10.1016/j.energy.2021.122741

Commoner, B. (1971). *The closing circle: Nature man and technology*. Knopf.

Copeland, B. R., & Taylor, M. S. (1994). North-South trade and the environment. *The Quarterly Journal of Economics*, *109*(3), 755–787. https://doi.org/10.2307/2118421

Department of Environment and Climate Change (2023). Bhutan's long-term low greenhouse gas emission and climate resilient development strategy (LTS). Ministry of Energy and Natural Resources, Royal Government of Bhutan.

Ehrlich, P., & Holdren, J. (1972). A bulletin dialogue on the 'closing circle'. Critique: one-dimensional ecology. *Bulletin of the Atomic Scientists 28* (5), 16-27.

Gallopin, G. (2003). *A systems approach to sustainability and sustainable development* (Project NET/00/063). Economic Commission for Latin America, Sustainable Development and Human Settlements Division.

Gaurav, K. (2026). India's drive to net zero emissions: Balancing growth with sustainability. In D.A.K. Dawood, Noushad C., G.A. Wani, and S.A. Kumar (Eds.), Seeds of Renewal: Ethical Business, Conscious Finance and Human-Centred Innovation for a Living, Regenerative Future (pp. 192-202). Alborear (OPC).

Gupta, S. (2015). Decoupling: A step toward sustainable development with reference to OECD countries. *International Journal of Sustainable Development & World Ecology, 22*(6), 510-519. https://doi.org/10.1080/13504509.2015.1088485

Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P.,... Creutzig, F. (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: Synthesizing the insights. *Environmental Research Letters, 15*(6), 065003. https://doi.org/10.1088/1748-9326/ab842a

Khosla, A., Niazi, Z., Nagrath, K., Thakur, M. Dewan, C., Gomez, F., Hennicke, P., O'brien, M., & Wilts, H. (2014). *Decoupling growth from resource consumption* (Background Paper). 2nd Indo-German Expert Group Meeting on Green and Inclusive Economy.

Khoury, E. (13 June 2022). *South Asia: A frontier for sustainability on a dying planet*. LSE South Asia Centre.

Lee, K.-H., & Min, B. (2014). Globalization and carbon constrained global economy: A fad or a trend? *Journal of Asia-Pacific Business, 15*(2), 105–121. https://doi.org/10.1080/10599231.2014.904181

Lin, S., Beidari, M., & Lewis, C. (2015). Energy consumption trends and decoupling effects between carbon dioxide and gross domestic product in South Africa. *Aerosol and Air Quality Research*, *15*, 2676–2687. https://doi.org/10.4209/aaqr.2015.04.0258

Lv, Y., Tang, W., & Ding, Y. (2024). Industrial energy consumption and carbon emission decoupling study and driving factor analysis: A case study of Sichuan Province, China. https://doi.org/10.21203/rs.3.rs-5330449/v1

Murthy, K.V. B., & Gambhir, S. (2018). Analyzing environmental Kuznets curve and pollution haven hypothesis in India in the context of domestic and global policy change. *Australasian Accounting, Business and Finance Journal 12*(2), 134-156. https://doi.org/10.14453/aabfj.v12i2.9

OECD (2002). *Indicators to measure decoupling of environmental pressure from economic growth*. Organisation for Economic Co-operation and Development.

OECD (2005). *Environment at a glance: OECD environmental indicators*. OECD Publishing. Organisation for Economic Co-operation and Development.

Ozcelik, O., Bardakci, H., Barut, A., Usman, M., & Das, N. (2024). Testing the validity of pollution haven and pollution halo hypotheses in BRICMT countries by Fourier Bootstrap AARDL method and Fourier Bootstrap Toda-Yamamoto causality approach. *Air Quality, Atmosphere, & Health, 17*(7), 1491–1504. https://doi.org/10.1007/s11869-024-01522-5

Parrique T., Barth J., Briens F., C. Kerschner, Kraus-Polk A., Kuokkanen A., Spangenberg J.H. (2019). Decoupling debunked: Evidence and arguments against green growth as a sole strategy for sustainability. European Environmental Bureau. eeb.org/decoupling-debunked

Quaye, E., Yamoah, F. A., Patro, P. K., & Acquaye, A. (2025). Decoupling economic growth from climate change: Unravelling the multi-dimensional dynamics of consumption-based emissions. *Journal of the Operational Research Society, 77*(1), 240–256. https://doi.org/10.1080/01605682.2025.2483782

Rahman, M. M., Saidi, K., & Mbarek, M. B. (2020). Economic growth in South Asia: The role of CO2 emissions, population density and trade openness. *Heliyon, 6*(5), e03903. https://doi.org/10.1016/j.heliyon.2020.e03903

Rani, T., Rehman, S. A. U., & Prisca, K. (2025). Assessing South Asia's environmental-economic nexus: Green investments, green electricity and green technology innovation through combined quantile regression. *Environmental Progress & Sustainable Energy*, (e70113). https://doi.org/10.1002/ep.70113

Sanyé-Mengual, E., Secchi, M., Corrado, S., Beylot, A., & Sala, S. (2019). Assessing the decoupling of economic growth from environmental impacts in the European Union: A consumption-based approach. *Journal of Cleaner Production, 236*(117535), 117535. https://doi.org/10.1016/j.jclepro.2019.07.010

Shahbaz, M., Mallick, H., Mahalik M.K., & Loganathan, N. (2015). Does globalization impede environmental quality in India? *Ecological Indicators, 52*, 379-393. https://doi.org/10.1016/j.ecolind.2014.12.025

Smarzynska, B. K., & Wei, S.-J. (2001). Pollution havens and foreign direct investment: Dirty secret or popular myth? (Policy Research Working Paper No. 2673). The World Bank. https://doi.org/10.1596/1813-9450-2673

Tapio, P. (2005). Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. *Transport Policy, 12*, 137–151.

Temurshoev, U. (2006). *Pollution haven hypothesis or factor endowment hypothesis: Theory and empirical examination for the US and China* (CERGE-EI Working Paper Series 292). The Center for Economic Research and Graduate Education - Economics Institute, Prague.

Tenaw, D., & Hawitibo, A. L. (2021). Carbon decoupling and economic growth in Africa: Evidence from production and consumption-based carbon emissions. *Resources, Environment and Sustainability*, *6*, 100040. https://doi.org/10.1016/j.resenv.2021.100040

Umpfenbach, K. (2013). *Decoupling growth from resource use and environmental impacts*. DYNAMIX Common Approach, Ecologic Institute. www.dynamix-project.eu

UNEP (2011). *Decoupling natural resource use and environmental impacts from economic growth* (A Report of the Working Group on Decoupling to the International Resource Panel). United Nations Environment Programme (UNEP).

 ISBN: 978-93-49666-59-7 (eBook)

Wan, L., Wang, Z.-L., & Ng, J. (2016). Measurement research on the decoupling effect of industries' carbon emissions—based on the equipment manufacturing industry in China. *Energies, 9*(11), 921. https://doi.org/10.3390/en9110921

Wang, H., Zhao, S., Wei, Y., Yue, Q., & Du, T. (2018). *Measuring the decoupling progress in developed and developing countries.* In Proceedings of the 8th International Conference on Management and Computer Science (ICMCS 2018) (pp. 377–381). Atlantis Press. https://doi.org/10.2991/icmcs-18.2018.77

Wang, W., Zhu, X., Kao, X., & Wei, H. (2024). Decomposition and decoupling analysis between economic growth and carbon emissions at the regional level: Evidence from six central provinces, China. *PloS One, 19*(9), e0305769. https://doi.org/10.1371/journal.pone.0305769

Xu, M., Yang, X., Deng, L., Liao, X., Niu, Z., & Hao, L. (2024). Decoupling state of urban development and carbon emissions and its driving factors and predictions: A case study of Chengdu metropolitan area. *Ecological Informatics, 82*(102692), 102692. https://doi.org/10.1016/j.ecoinf.2024.102692

Yaremova, M. I., & Mytrofanova, A. S. (2022). Decoupling as a measurement of the environmental impact of economic growth. *Scientific Bulletin of Mukachevo State University Series "Economics", 9*(3), 30-39. https://doi.org/10.52566/msu-econ.9(3).2022.30-39

Zugravu, N., & Kheder, S. B. (2008). *The pollution haven hypothesis: A geographic economy model in a comparative study* (Working Paper 232). Fondazione Eni Enrico Mattei. https://services.bepress.com/cgi/viewcontent.cgi?article=1241&context=feem

ISBN: 978-93-49666-59-7 (eBook)

Appendix Table A: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2_I	238	254.1329	602.5007	.0946	3014.523
Population_P	238	2.21e+08	4.01e+08	224762	1.44e+09
GDPpc_A	238	2399.609	2559.955	422.7247	11439.54
Tech_T	156	5.019615	3.620639	1.55	19.34
Urban_E1	238	31.29566	11.45118	14.57395	66.54329
Trade_E2	238	51.50865	23.59974	15.50626	162.2434

Appendix Table B: Descriptive Statistics (Log Transformed)

Variable		Mean	Std. Dev.	Min	Max	Observations
ln_I	overall	2.733533	2.694683	-2.358098	8.011197	N = 238
	between		2.816195	-.4494578	7.233986	n = 7
	within		.6592963	.754939	4.110877	T = 34
ln_P	overall	16.9483	2.770456	12.3228	21.08657	N = 238
	between		2.980693	12.73171	20.86965	n = 7
	within		.1672845	16.52397	17.38964	T = 34
ln_A	overall	7.373552	.8544297	6.046721	9.344831	N = 238
	between		.8285188	6.504143	8.946526	n = 7
	within		.3730784	6.550109	8.164637	T = 34
ln_T	overall	1.407296	.6237373	.4382549	2.962176	N = 156
	between		.64412	.7410863	2.478008	n = 7
	within		.1620564	1.063454	1.891464	T = 22.2857
ln_E1	overall	3.383964	.3418372	2.679236	4.197853	N = 238
	between		.2884368	2.832045	3.75925	n = 7
	within		.2126996	2.608471	3.822566	T = 34
ln_E2	overall	3.842318	.448836	2.741244	5.089098	N = 238
	between		.4013306	3.411547	4.436157	n = 7
	within		.2506281	3.055	4.752845	T = 34

Appendix Table C: Correlation Matrix

	ln_I	ln_P	ln_A	ln_T	ln_E1	ln_E2
ln_I	1.0000					
ln_P	0.9422*	1.0000				
	0.0000					
ln_A	-0.3684*	-0.6221*	1.0000			
	0.0000	0.0000				
ln_T	-0.1503	-0.1045	-0.3782*	1.0000		
	0.0611	0.1943	0.0000			
ln_E1	0.0288	-0.0325	0.0173	0.4159*	1.0000	
	0.6580	0.6183	0.7906	0.0000		
ln_E2	-0.6700*	-0.7353*	0.4916*	0.3317*	-0.0679	1.0000
	0.0000	0.0000	0.0000	0.0000	0.2972	

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Appendix Table D: Variance Inflation Factor (VIF)

Variable	VIF	1/VIF
ln_P	3.46	0.288747
ln_A	3.15	0.317460
ln_E2	2.75	0.364131
ln_T	2.38	0.420910
ln_E1	1.45	0.688856
Mean VIF	2.64	

Appendix Table E: Pesaran CD Test

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
ln_I	25.537	0.000	34.00	0.96	0.96
ln_P	25.737	0.000	34.00	0.96	0.96
ln_A	25.66	0.000	34.00	0.96	0.96
ln_T	9.735	0.000	22.05	0.45	0.87
ln_E1	23.608	0.000	34.00	0.88	0.88
ln_E2	.954	0.340	34.00	0.04	0.30

Note: *Ho: Existence of cross-sectional independence*

Appendix Table F: Panel Co-integration Test Results

Test	Statistic	With ln_T (6 Variables)	p-value	Without ln_T (5 Variables)	p-value	Decision
Westerlund (2007)	Gt	0.995	0.995	-		No Co-integration with T
	Ga	1.000	1.000	-		
	Pt	1.000	1.000	-		
	Pa	1.000	1.000	-		
Pedroni (1999, 2004)	Modified PP t	-2.07	0.0190**	-0.89	0.1867	Co-integration without T
	Phillips-Perron t	-0.99	0.1599	-2.67	0.0037***	
	ADF t	-1.05	0.1463	-2.44	0.0074***	
Kao (1999)	Modified Dickey-Fuller t	-0.45	0.326	-1.71	0.0436**	Strong Co-integration without T
	Dickey-Fuller (DF) t	-0.92	0.178	-2.26	0.0120**	
	ADF t	-0.98	0.163	-2.27	0.0119**	
	Unadjusted Modified DF	-0.89	0.186	-2.57	0.0050***	
	Unadjusted DF	-1.02	0.153	-2.63	0.0044***	

Note*:*

1. **p<0.05, ***P<0.01
2. Westerlund with lags (1) leads (0)
3. With ln_T: N=156 (missing data); Without ln_T : N=238 (balanced)
4. Pedroni modified PP is significant at 5% with T (weak co-integration), however, PP and ADF fail
5. Without T, 2 out of 3 Pedroni and 5 out of 5 Kao tests are significant at 5% and 1%. This justifies main Model: ln_I=f (P, A, E1, E2)

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Chapter

5

Sustainable Urbanisation through the Lens of Planetary Health: Balancing Modern Health and Well-being with City Growth

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ABSTRACT

Urbanisation is rising globally, transforming cities into centres of economic opportunity, innovation, and social progress. However, rapid and often unplanned urban growth has also resulted into environmental degradation, climate-related risks, public health challenges, and socio-economic inequalities. This paper explores how the Planetary Health framework can inform sustainable urbanisation by integrating all three pillars of environmental sustainability, economic resilience, and social well-being into urban planning and governance.

The study adopts a systematic review of interdisciplinary literature coupled with examples from Indian cities, Indore, Surat, and Pune, to examine sustainable urban practices related to green infrastructure, waste management, sustainable mobility, renewable energy, inclusive public spaces, and participatory governance. The analysis shows that cities adopting integrated planning, nature-based solutions, and active citizen engagement are better positioned to enhance public health and promote inclusive economic development.

The paper is aligned with the United Nations Sustainable Development Goals, particularly SDG 3, SDG 11 and SDG 13. The paper proposes the HARMONY Framework representing Healthy Communities, Adaptive Governance, Resource Efficiency, Mobility and Green Infrastructure, Opportunities for Inclusive Growth, Nature-Positive Development, and Youth and Community Participation as an integrative model for fostering resilient and inclusive cities. The study contributes to the emerging discourse on urban planetary health by offering a holistic framework to guide policymakers, urban planners, and researchers in designing cities that support both human flourishing and environmental sustainability.

Keywords: Inclusivity, Planetary Health Framework, Social Well-being, Sustainable Urbanisation, Waste management

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INTRODUCTION

Rapid urbanisation has become a defining feature of the twenty-first century, creating opportunities for economic development while simultaneously posing significant challenges to environmental sustainability, public health, and social equity. As cities continue to expand, the need to harmonize urban growth with the well-being of people and the preservation of natural ecosystems has become increasingly urgent. Sustainable urbanisation offers a holistic framework for addressing these interconnected challenges by integrating environmental stewardship, inclusive governance, resilient infrastructure, and human-centred urban planning.

This paper explores how sustainable urban development can promote healthier, more inclusive, and resilient cities without compromising economic progress. It examines the relationship between urban planning, green infrastructure, sustainable mobility, waste management, affordable housing, and access to healthcare and public spaces in improving the physical, mental, and social well-being of urban populations. The study also highlights the role of smart technologies, renewable energy, and citizen participation in enhancing urban resilience and supporting evidence-based decision-making.

Very often urban development has often prioritised infrastructure over health and sustainability. But drawing upon contemporary literature and selected case examples from Indian cities, particularly Indore's achievements in waste management and urban cleanliness, the paper illustrates how integrated planning and community engagement can contribute to sustainable city development. The discussion is anchored in the United Nations Sustainable Development Goals, especially SDG 3 (Good Health and Well-being) and SDG 11 (Sustainable Cities and Communities), emphasizing the importance of interdisciplinary collaboration among policymakers, urban planners, public health professionals, and local communities.

SUSTAINABLE URBANISATION

Sustainable urbanisation directly hits all three pillars i.e. Nature - green space, air quality, Economy—urban growth and Society—health, well-being, equity. At present it is highly relevant globally in the form of SDG 11. Health is being given importance in all policies discourse. Rapid urbanisation is transforming cities into engines of economic growth, innovation, and social development. However, unplanned urban expansion has intensified environmental degradation, climate vulnerability, public health risks, and socio-economic inequalities. While urban development has traditionally prioritized infrastructure and economic growth, contemporary research emphasizes the need for people-centred and environmentally sustainable cities. Guided by the Planetary Health Framework, which recognizes the interdependence of human health and the Earth's natural systems, this paper examines how sustainable urbanisation can simultaneously promote healthy populations, resilient ecosystems, and inclusive economic development.

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The paper is conceptually anchored in the United Nations Sustainable Development Goals, particularly SDG 3 (Good Health and Well-being) and SDG 11 (Sustainable Cities and Communities). It argues that urban sustainability should be viewed as a multidimensional process that balances environmental conservation, economic resilience, and human well-being rather than focusing solely on physical infrastructure. Findings suggest that cities adopting integrated governance, citizen engagement, and nature-based solutions demonstrate greater resilience to environmental and public health challenges.

The study contributes to the growing discourse on sustainable urban development by proposing a holistic framework that aligns urban planning with health, environmental stewardship, and social equity. The findings offer practical implications for policymakers, urban planners, and researchers seeking pathways towards inclusive, resilient, and healthy cities in rapidly urbanising economies.

RESEARCH GAP

Although sustainable urbanisation has received considerable scholarly attention, much of the existing literature examines environmental sustainability, economic growth, and urban infrastructure independently. Comparatively fewer studies adopt a **Planetary Health perspective**, which recognizes the interconnectedness of ecological integrity, human health, and social equity in shaping resilient urban systems. This paper addresses this gap by synthesizing these dimensions into a holistic conceptual framework for sustainable urban development.

CONCEPTUAL FRAMEWORK

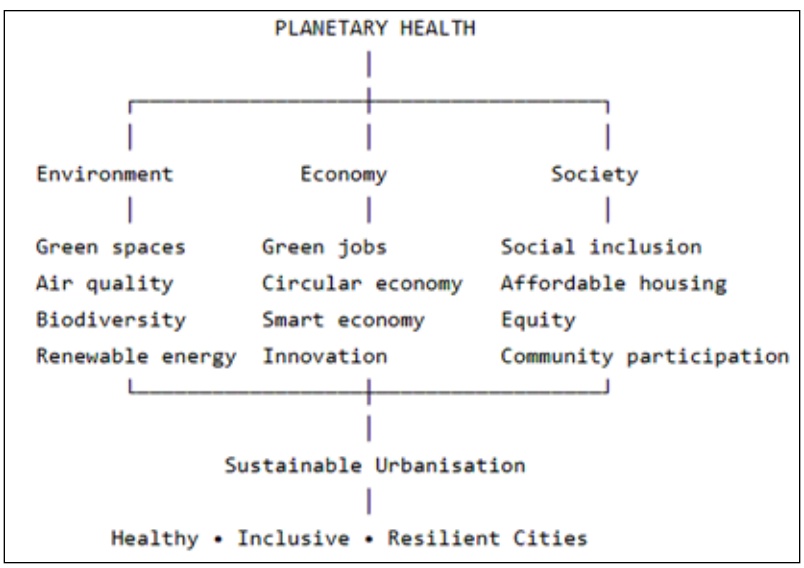


Fig. 1: Conceptual Framework

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OBJECTIVES

1. To examine sustainable urbanisation through the Planetary Health framework.
2. To analyse the relationship between urban planning, environmental sustainability, and human health.
3. To identify best practices from selected Indian cities.
4. To propose an integrated framework for healthy and resilient urban development.

LITERATURE REVIEW

Sustainable Urbanisation

Sustainable urbanization focuses on integrating ecological, economic, and social well-being through collaborative governance. Key challenges include policy fragmentation and implementation gaps, addressed by emerging strategies like data-driven planning, circular economy principles, and trans-scalar frameworks.

Main Themes in Sustainable Urbanism

Sustainable urbanism has evolved into a multifaceted field that prioritizes the harmonization of urban growth with ecological preservation, social equity, and economic resilience. (Howard, 2025). Central to this discourse is the "eco-city" concept, which seeks to promote sustainable development across urban infrastructure, services, and community life at various scales, from districts to entire metropolitan regions (Joss, 2015). Modern scholarship emphasizes a transition toward well-being-oriented metrics, moving away from traditional growth-centric models. This holistic approach is supported by the integration of interdisciplinary and transdisciplinary frameworks, which are necessary to manage the inherent complexity of urban systems (Bibri, 2021). Furthermore, the inclusion of creative city factors and cultural infrastructure serves as an increasingly recognized pathway for fostering sustainable development and rural revitalization (Kamran et al. 2023).

Key Challenges in Implementation

The pursuit of sustainable urban development is hindered by significant structural and procedural barriers. A primary challenge involves the effective coordination of innovation and planning across diverse policy sectors and urban scales (Joss, 2015). Many regions suffer from a lack of adequate legal frameworks, insufficient academic study of urban law, and a failure to implement or enforce existing regulations (Alarcón Zambrano & Márquez, 2019). Additionally, scholars note that urban planning often struggles to translate theoretical sustainability models into concrete, ground-level practice (Howard, 2025). The complexity of these issues is compounded by the need for consensus among diverse, multilevel stakeholders, making it difficult to achieve integrated management of planning, development, and environmental goals (Campos-Sánchez et al., 2018) (Howard, 2025).

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Emerging Strategies and Practices

- To address these challenges, the planning community is adopting more collaborative, participatory, and data-driven approaches (Vargas-Hernández & Zdunek-Wielgołaska, 2019). Emerging strategies identified in recent research include:
- Data-driven planning: Utilizing computational and technological strands to inform urban practices, often described as data-driven smart sustainable urbanism (Bibri, 2021).
- Circular economy: Applying circular principles to urban spatial planning to optimize resource use (Howard, 2025).
- Trans-scalar governance: Implementing frameworks that integrate decision-making across local, regional, and national levels (Joss, 2015) (Howard, 2025).
- Nature-based solutions: Incorporating ecological security patterns and greenways to enhance urban livability and climate resilience (Howard, 2025) (Beatley, 2012).
- Participatory mechanisms: Engaging communities and diverse stakeholders directly in the planning process to ensure social inclusiveness goals (Vargas-Hernández & Zdunek-Wielgołaska, 2019) (Campos-Sánchez et al., 2018).

These strategies are often informed by global best practices, such as those found in European cities, which emphasize energy conservation, public transit improvements, and the use of "green audits" to hold government bodies accountable (Beatley, 2012) (beatley, n. d). Strategic planning is increasingly viewed as a visionary, educational process that must be continuously evaluated through robust indicator systems (Campos-Sánchez et al., 2018).

Planetary Health

Planetary health examines the interdependent relationship between human health and Earth's natural systems. Current threats include environmental degradation and climate change, necessitating interdisciplinary, solution-oriented approaches to restore planetary stability and secure long-term human well-being.

Core Concepts in Planetary Health

Planetary health is a transdisciplinary field centered on the fundamental recognition that human health and the health of the planet are inextricably linked. (Mago et al., 2024) (Sheina et al 2022) (Talukdar et al, 2024). It posits that human survival and well-being depend upon the stability and function of natural systems (Seltenrich, 2018). Emerging from environmental and holistic health movements of the 1970s and 1980s, the concept gained significant academic traction following the 2015 *Lancet* Commission report (Prescott et al. (2019).

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Key Conceptual Pillars Include:

- **Interconnectedness:** Health is defined as a state of complete physical, mental, social, and ecological well-being, where personal health is inseparable from the health of the environment (Prescott et al. (2019) (Mago et al., 2024).
- **Natural limits:** The field evaluates how human activity modifies Earth's systems and where the planet's natural boundaries lie (Cole, 2019) (Seltenrich, 2018).
- **High-level wellness:** This framework views health as an integrated, dynamic state of potential for individuals, communities, and the planet, requiring sustainable stewardship of natural resources (Prescott et al. (2019).

Main Threats to Planetary Health

Humanity's ecological footprint has expanded rapidly, leading to the "Anthropocene," an epoch defined by profound human alteration of global systems (Seltenrich, 2018). This exploitation has historically provided benefits like increased life expectancy, but these gains are now threatened by the collapse of the very natural systems that supported them

The Primary Threats Identified Include

- **Climate change:** Rapid industrialization, urbanization, and population growth drive environmental degradation, exacerbating extreme weather and existing health vulnerabilities.
- **Environmental pollution:** Air and water pollution, alongside exposure to toxic chemicals, contribute significantly to non-communicable diseases and global mortality (Mago et al., 2024) (Shoji et al., 2025).
- **Systemic disruption:** Human-caused perturbations to natural systems—such as those impacting the microbiome have cascading effects on social, political, and economic stability (Prescott et al. (2019) (Seltenrich, 2018).
- **Global crisis:** The cumulative impact of these disruptions is now driving a global humanitarian crisis, where approximately 23% of global deaths are linked to environmental factors (Mago et al., 2024) (Sheina et al 2022).

Proposed Solutions and Future Directions

Addressing planetary health requires a "Great Transition" involving collaborative, cross-sectoral, and interdisciplinary action (Mago et al., 2024) (Sheina et al 2022). Because the current crisis is global in scope, solutions must integrate diverse voices, including marginalized populations, across all geographies, genders, and cultures (Prescott et al. (2019).

Proposed strategies include:

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- **Educational reform:** There is an urgent need to incorporate planetary health into higher education curricula, particularly for health professionals, to prepare them for future environmental challenges (Trombetta et al., 2023) (Shoji et al., 2025).
- **Policy and advocacy:** Healthcare providers are encouraged to act as advocates for patients and future generations by promoting sustainable development and challenging systemic barriers like medical authoritarianism (Prescott et al. (2019) (Mago et al., 2024).
- **Research and interdisciplinary cooperation:** Enhanced investment in research is necessary to better understand the complex interactions between human health and the environment, facilitating more effective, evidence-based interventions (Mago et al., 2024) (Talukder et al., 2024).
- **Global initiatives:** Collaborative frameworks, such as the São Paulo Declaration on Planetary Health, serve as calls-to-action for governments, the private sector, and civil society to implement deep, urgent changes (Sheina et al 2022).

HEALTHY CITIES

There is no single "best" example because different Indian cities excel in different aspects of sustainable urbanisation. However, if you are looking for a city that is widely recognized for its integrated approach, **Indore** is often considered India's leading example.

Indore (Best Overall Example)

Indore has consistently ranked among India's cleanest cities under the Swachh Survekshan survey due to its comprehensive approach to sustainability.

Why it stands out

- Excellent solid waste management with near-complete door-to-door waste collection.
- High levels of waste segregation at source.
- Composting, biomethanation, and recycling of municipal waste.
- Public participation through awareness campaigns.
- Cleaner public spaces and improved sanitation.
- Expansion of green spaces and water conservation initiatives.

Key sustainability pillars

- Environmental sustainability
- Citizen participation
- Effective municipal governance
- Circular economy practices

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Fig. 2: Clean and Environment friendly Indore



Fig. 3: Waste Segregation

Among Indian cities, **Indore** is widely regarded as the best example of sustainable urbanisation due to its integrated waste management system, active citizen participation, efficient municipal governance, and commitment to environmental sustainability. Its success demonstrates how coordinated policy implementation and community involvement can make urban development both inclusive and environmentally responsible.

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Surat (Best for Urban Planning & Disaster Management)

Highlights:

- Efficient Bus Rapid Transit System (BRTS)
- Smart City initiatives
- Strong flood management after the 2006 floods
- Digital governance
- Improved public health systems

Mysuru

Known for:

- Cleanliness
- Heritage conservation
- Sustainable tourism
- Parks and green infrastructure
- Efficient municipal services

Pune

Strengths include:

- Public transport improvements
- Cycling initiatives
- Renewable energy adoption
- Participatory budgeting
- Strong educational and innovation ecosystem

Auroville (Model Sustainable Township)

Although not a conventional city, Auroville demonstrates:

- Renewable energy use
- Rainwater harvesting
- Sustainable architecture
- Organic farming
- Community-based governance
- Ecological restoration

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Table 1: Comparison of smart cities

City	Major Strength	Sustainability Focus
Indore	Waste management	Cleanliness, circular economy, governance
Surat	Transport & resilience	Smart infrastructure, disaster management
Mysuru	Heritage & sanitation	Liveability and tourism
Pune	Innovation	Mobility, citizen participation
Auroville	Ecological living	Renewable energy, sustainable communities

We can say Indore is the best example because it integrates environmental management, citizen engagement, and effective urban governance whereas **Surat** is the best example of sustainable transport and urban resilience to show a broader understanding of sustainable urbanisation.

Sustainable Development Goals

The trio of SDGs **3, 11 and 13** connect human well-being, sustainable cities, and climate resilience.

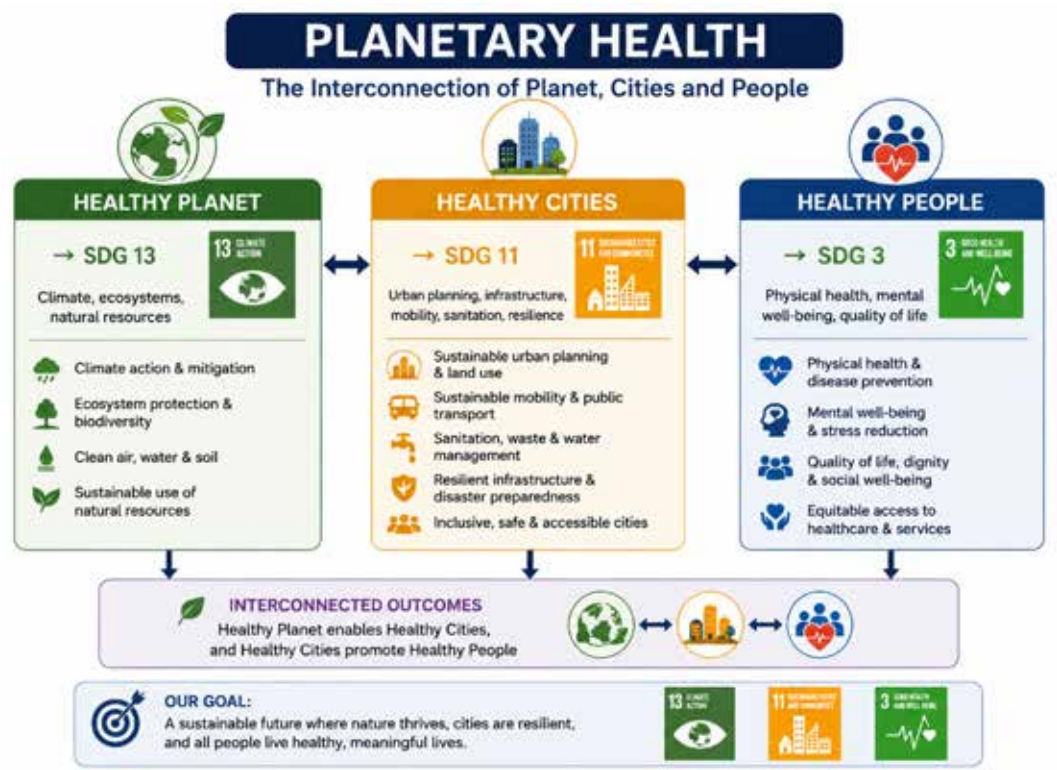


Fig. 4: Planetary Health through the lens of SDGs

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SDG 3 – Good Health and Well-being: Ensure healthy lives and promote well-being for all at all ages. Urbanisation directly affects physical and mental health through air pollution, water quality, sanitation, housing, mobility, noise, green spaces, healthcare access and social connectedness. Sustainable cities should therefore be designed as **healthy environments**, not merely efficient infrastructure systems.

SDG 11 – Sustainable Cities and Communities: Make cities and human settlements inclusive, safe, resilient and sustainable. This is the **core SDG** for your paper. It encompasses sustainable urban planning, affordable housing, public transport, waste management, green/public spaces, heritage protection, disaster resilience and participatory urban governance.

SDG 13 – Climate Action: Take urgent action to combat climate change and its impacts. Urban areas are major contributors to emissions but are also highly vulnerable to heatwaves, flooding, water stress and extreme weather. Sustainable urbanisation must incorporate climate mitigation, adaptation, renewable energy, nature-based solutions and climate-resilient infrastructure.

In the nutshell SDGs 11, 13 and 3 or Sustainable Urbanisation + Climate Resilience + Human Health & Well-being leads to Healthy, Inclusive and Resilient Cities



Fig. 5: Interplay of Sustainable Urbanisation

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METHODOLOGY

The study adopts a systematic review of contemporary literature published between 2015 and 2026, complemented by comparative case studies of Indian cities, including Indore, Surat, and Pune. The review analyses sustainable urban planning practices related to green infrastructure, sustainable mobility, waste management, renewable energy, affordable housing, digital governance, and public health. The selected case studies illustrate how integrated planning, community participation, and evidence-based governance contribute to healthier urban environments while supporting economic productivity and social inclusion.

A Systematic Literature Review was done taking into consideration many smart cities of the world. Among Indian cities with sustainable urbanisation, three model cities were especially focussed upon - (Indore, Surat, Pune). The detailed comparison is given below:

Table 2: Comparative Case Studies

Dimension	Indore	Surat	Pune
Primary sustainability strength	**Waste management & sanitation**	**Urban mobility & climate resilience**	**Sustainable mobility & liveability**
SDG 3 – Health & Well-being	Cleaner surroundings, sanitation, waste reduction and improved urban hygiene contribute to healthier living conditions.	Public transport, sanitation, green spaces and improved urban services support public health.	Focus on walking, cycling, public transport and healthier streets can reduce pollution and improve active mobility.
SDG 11 – Sustainable Cities	Strong municipal service delivery, source segregation, waste processing and citizen participation. Indore's municipal corporation reports nearly 100% segregated door-to-door collection and multiple processing facilities.	Integrated urban planning and transport; BRTS is designed to connect public and non-motorised transport with land use. (Surat Municipal Corporation)	Metro expansion, public transport, cycling infrastructure and integrated land-use–mobility planning. (PMRDA)
SDG 13 – Climate Action	Waste-to-resource practices, urban greening and cleaner public transport contribute to lower environmental impact.	Particularly strong potential through electric buses, with the municipal corporation reporting substantial fuel and GHG savings from its electric-bus fleet. (Surat Municipal Corporation)	Climate action increasingly linked to sustainable transport, non-motorised mobility and reduction of vehicle dependence.

Table 2 Contd....

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...Contd. Table 2

Dimension	Indore	Surat	Pune
Circular economy	**Very strong** – segregation, composting, bio methanation, material recovery and scientific waste processing.	**Moderate–strong** – integrated waste management alongside broader resource-efficiency initiatives.	**Moderate** – growing emphasis on resource efficiency and climate-oriented urban planning.
Sustainable mobility	Improving through electric and CNG buses. (Press Information Bureau)	**Very strong** – BRTS + electric buses + multimodal integration. (Surat Municipal Corporation)	**Very strong** – Metro + cycling + walking + public transport integration. (PMRDA)
Citizen participation	**Very strong** – citizen behaviour and participation are central to its waste-management model. (IMC Indore)	Strong emphasis on people-centred urban services and participation. (Surat Municipal Corporation)	Participatory and community-oriented mobility and neighbourhood initiatives.
Resilience orientation	Sanitation, waste, water management and urban service resilience.	**Particularly strong** – infrastructure and mobility planning have evolved alongside the city's rapid growth and environmental risks.	Increasingly climate-focused through climate action planning and resilient mobility infrastructure.
Distinctive lesson	Behaviour + governance can transform urban cleanliness and resource management.	Economic growth can be combined with large-scale sustainable mobility and urban infrastructure.	A knowledge/IT city can transition toward integrated, low-carbon and active mobility.
Best conceptual fit	Resource Efficiency / Circular Economy	Resilient Urbanisation	Healthy & Low-carbon Mobility

Integrated Planetary Health Model

The HARMONY Model for Sustainable Urbanisation

H – Healthy Communities
A – Adaptive Governance
R – Resource Efficiency
M – Mobility & Green Infrastructure
O – Opportunities for Inclusive Growth
N – Nature-Positive Development
Y – Youth and Community Participation

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The study adopted a systematic review of interdisciplinary literature supported by comparative case insights from Indian cities, including Indore, Surat, and Pune, to examine sustainable urban practices related to green infrastructure, waste management, sustainable mobility, renewable energy, inclusive public spaces, and participatory governance. The analysis demonstrates that cities adopting integrated planning, nature-based solutions, and active citizen engagement are better positioned to enhance public health, strengthen climate resilience, and promote inclusive economic development.

Anchored in the principles of Planetary Health and aligned with the United Nations Sustainable Development Goals, particularly SDG 3 (Good Health and Well-being), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action), the paper argues that sustainable urbanisation should be understood as a multidimensional process that harmonizes ecological integrity, economic vitality, and social equity. Building on the synthesis of existing evidence, the paper proposes the HARMONY Framework comprising Healthy Communities, Adaptive Governance, Resource Efficiency, Mobility and Green Infrastructure, Opportunities for Inclusive Growth, Nature-Positive Development, and Youth and Community Participation - as an integrative model for fostering resilient and inclusive cities. The study contributes to the emerging discourse on urban planetary health by offering a holistic framework to guide policymakers, urban planners, and researchers in designing cities that support both human flourishing and environmental sustainability.

CONCLUSION

The paper concludes that sustainable urbanisation extends beyond infrastructure development; it requires creating cities that are environmentally responsible, socially inclusive, economically vibrant, and conducive to human well-being. Achieving this balance is essential for fostering resilient urban ecosystems capable of supporting present and future generations. The study offers practical insights for policymakers, planners and researchers seeking pathways toward inclusive and sustainable urban futures.

REFERENCES

C. Howard, "*Urban Planning and Sustainable Development: A Systematic Literature Review and Future Directions*," vol. 1, Jan. 2025, doi: 10.70731/0fays189.

S. Joss, "*Eco-cities and sustainable urbanism*," pp. 829–837, Jan. 2015, doi: 10.1016/B978-0-08-097086-8.74010-4.

S.E. Bibri, "*The core academic and scientific disciplines underlying data-driven smart sustainable urbanism: an interdisciplinary and transdisciplinary framework*," vol. 1, no. 1, pp. 1–32, Dec. 2021, doi: 10.1007/S43762-021-00001-2.

J. G. Kamran, G. Jafarinia, and A. Shamsoddini, "*Introducing creative city factors as a solution in sustainable urban development: a case study from Bushehr City in Iran*," June 2023, doi: 10.14456/jucr.2023.12.

J. A. A. Zambrano and J. J. A. Márquez, "El derecho urbanístico y la ciudad sostenible. Un análisis propedéutico del caso de la República del Ecuador," Revista de Direito da Cidade, vol. 11, no. 2, pp. 457–490, Aug. 2019, doi: 10.12957/RDC.2019.38399.

F. S. Campos-Sánchez, F. J. Abarca-Álvarez, and A. Domingues, "Sostenibilidad, planificación y desarrollo urbano. En busca de una integración crítica mediante el estudio de casos recientes," ACE: Architecture, City and Environment, vol. 12, no. 36, pp. 39–72, Mar. 2018, doi: 10.5821/ACE.12.36.5145.

J. G. Vargas-Hernández and J. Zdunek-Wielgołaska, "Recent trends in Sustainable Urban Planning," *International Journal of Sustainable Economies Management*, vol. 8, no. 3, pp. 29–47, July 2019, doi: 10.4018/IJSEM.2019070103.

T. Beatley, "Green Cities of Europe: Global Lessons on Green Urbanism," May 2012, [Online]. Available: https://books.google.com/books?hl=en&lr=&id=1MrNEQAAQBAJ&oi=fnd&pg=PT2&dq=%22sustainable+urbanisation%22+OR+%22sustainable+urban+development%22+OR+%22green+urbanism%22&ots=6o5BNxlcye&sig=Qus4ZdzN0ikps3Ff55453B_WYxI

Timothy Beatley, "*Green urbanism: learning from european cities*", doi: 10.5860/choice.37-6397.

Mago, A. Dhali, H. Kumar, R. Maity, and B. Kumar, "*Planetary health and its relevance in the modern era: A topical review*," Sage Open Medicine, vol. 12, Jan. 2024, doi: 10.1177/20503121241254231.

K. Sheina, A. Luis Andre, S. Miranda Filipi, and S. Mauro Antonio, "*2021 Planetary Health Annual Meeting and Festival Book of Abstracts*: Planetary Health for All: Bridging Communities to Achieve the Great Transition," June 2022, doi: 10.5281/zenodo.6373366.

Talukder, N. Ganguli, E. Choi, M. Tofighi, G. W. vanLoon, and J. Orbinski, "Exploring the nexus: Comparing and aligning Planetary Health, One Health, and EcoHealth," *Global transitions*, vol. 6, pp. 66–75, Jan. 2024, doi: 10.1016/j.glt.2023.12.002.

N. Seltenrich, "Down to Earth: The Emerging Field of Planetary Health.," *Environmental Health Perspectives*, vol. 126, no. 7, pp. 072001–072001, July 2018, doi: 10.1289/EHP2374.

S. L. Prescott, S. L. Prescott, and A. C. Logan, "*Planetary health: from the wellspring of holistic medicine to personal and public health imperative*," Explore-the Journal of Science and Healing, vol. 15, no. 2, pp. 98–106, Mar. 2019, doi: 10.1016/J.EXPLORE.2018.09.002.

S. L. Prescott, A. C. Logan, and D. L. Katz, "Preventive Medicine for Person, Place, and Planet: Revisiting the Concept of High-Level Wellness in the Planetary Health Paradigm," *International Journal of Environmental Research and Public Health*, vol. 16, no. 2, p. 238, Jan. 2019, doi: 10.3390/IJERPH16020238.

J. Cole, "*Key concepts in planetary health*". pp. 9–22, Jan. 2019, doi: 10.1079/9781789241655.0009.

Y. SHOJI, K. Suzuki, N. Tamai, and M. Kohta, "*Current Status and Challenges of Planetary Health Education: A Protocol for a Scoping Review (Preprint)*," Jan. 2025, doi: 10.2196/preprints.70910.

G. H. Trombetta, R. S. Rech, and A. T. Stein, "Planetary health curriculum in higher education: Scoping review," *International health trends and perspectives*, vol. 3, no. 3, pp. 316–335, Nov. 2023, doi: 10.32920/ihtp.v3i3.1804.

https://www.pib.gov.in/PressReleasePage.aspx

https://www.suratmunicipal.gov.in/Departments/BRTS Cell Introduction

https://www.pmrda.gov.in/en/pune-metro-line-3

https://imcindore.mp.gov.in/

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Chapter

6 The Role of Emotional Intelligence in Promoting Sustainable Consumption Behaviour: A Review of Literature

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ABSTRACT

Global environmental pressures have pushed responsible consumption to the top of both policy and scholarly agendas, yet most explanations for why consumers do or do not act sustainably still centre on knowledge, attitudes, and structural factors. The affective dimension of this decision-making — specifically, an individual's Emotional Intelligence (EI), or their capacity to perceive, understand, and regulate emotion — has received comparatively little direct scrutiny. This paper synthesises two largely separate research traditions, EI and Sustainable Consumption Behaviour (SCB), to map where they intersect and where the evidence base is still thin.

Two threads are traced in parallel: the maturation of EI as a psychological construct — from its original formulation as a form of social intelligence through decades of debate over its measurement, distinctiveness, and applied relevance in leadership and health — and the parallel growth of SCB scholarship, which has moved from broad normative accounts of sustainable development toward increasingly granular, cross-national, and psychologically grounded models of consumer choice. Read together, the smaller body of work that bridges the two suggests that emotionally intelligent consumers process guilt, pride, respect, and related affective cues in ways that more consistently favour ethical and environmentally responsible purchasing.

Yet this bridging literature remains fragmented, largely indirect, and rarely tested at the level of individual consumer behaviour. This paper argues that the boundary between rational and sustainable consumption is still poorly specified, that the psychological

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and socio-economic mechanisms linking EI to SCB are underdeveloped, and that closing this gap matters for Sustainable Development Goal 12 (Responsible Consumption and Production). The paper closes by setting out a research agenda — grounded in explicit research questions — intended to move this intersection from conceptual plausibility toward empirical grounding.

Keywords: Emotional Intelligence, Sustainable Consumption Behaviour, Consumer Behaviour, Sustainability, Sustainable Development Goals, Responsible Consumption, Environmental Behaviour.

INTRODUCTION

Human consumption now presses against the limits of what the planet can absorb and replenish. Resource extraction, waste accumulation, and carbon output continue to climb even as several planetary boundaries have already been breached, and this has pulled sustainable consumption behaviour (SCB) from the margins of academic interest into the centre of policy debate. Sustainable Development Goal 12 makes the point explicitly: production and consumption patterns need to change, and consumer behaviour is one of the principal levers available for doing so.

Much of the existing explanation for that behaviour, however, treats the consumer as a largely rational, information-processing agent — someone who consumes sustainably (or fails to) in proportion to what they know and believe. This is only part of the picture. A separate and well-established body of work shows that economic and consumption decisions are heavily coloured by emotion, and that individuals differ systematically in how well they perceive, interpret, and regulate their own emotional states — the capacity known as Emotional Intelligence (EI). EI has accumulated three decades of evidence linking it to leadership effectiveness, health outcomes, and workplace performance, but its bearing on sustainable consumption specifically has been explored only obliquely, through a scattering of studies rather than a coherent research programme.

This paper takes that gap as its starting point. It has three objectives: first, to trace how EI and SCB have each developed as independent fields of enquiry; second, to pull together the comparatively small set of studies that connect the two, in order to see what pattern, if any, emerges; and third, to convert the resulting gaps into a concrete set of research questions capable of guiding future empirical work. Section 2 develops the literature review across five thematic areas; Section 3 sets out the research gaps that follow from it; Section 4 translates those gaps into research questions and objectives; Section 5 describes the review method; Section 6 offers a conceptual synthesis; Section 7 considers theoretical, policy, and managerial implications; and Section 8 concludes.

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LITERATURE REVIEW

Emotional Intelligence: Conceptual Evolution

EI entered the psychological literature through Mayer and Salovey's (1990) proposal that the capacity to monitor one's own and others' emotions constitutes a distinct form of social intelligence, separate from — though related to — traditional cognitive ability. Their companion study the same year linked this capacity to empathic accuracy in reading emotional content and to sensitivity in interpersonal relationships (Mayer et al., 1990), giving the construct an early empirical foothold. Goleman (1995) then carried the idea into popular and applied psychology, arguing that traits such as impulse control, self-awareness, and empathy predict life success more strongly than IQ, while Salovey et al. (1995) supplied a measurement tool — the Trait Meta-Mood Scale — that let researchers quantify how people attend to, clarify, and repair their own emotional states.

A sceptical counter-current followed almost immediately. Davies et al. (1998) tested several EI instruments and found most lacked reliability, though they conceded that a narrower emotion-perception factor might genuinely exist independent of personality and cognitive ability. Goleman (1998) pushed back in the opposite direction, arguing in his applied work that EI outweighs formal qualifications as a predictor of job performance — a claim that set the terms for a debate that has run through the field ever since: is EI a distinct, measurable ability, or is it better understood as a repackaging of existing personality traits?

The early 2000s saw this debate play out across several fronts simultaneously. On the measurement side, Mayer et al. (2000) argued that their Multifactor Emotional Intelligence Scale satisfied the formal criteria for a genuine intelligence — internally consistent, distinct from other intelligences, and developmentally malleable — while Petrides and Furnham (2000) took the opposite tack, proposing that EI should be split into a personality-aligned "trait" form and a cognitively-oriented "ability" form rather than treated as one construct. On the applied side, the construct was extended outward: Bar-On and Parker (2000) connected EI to social competence and psychological mindedness in workplace and educational settings; Mayer and Cobb (2000) pressed policymakers to ground school-based EI interventions in stronger evidence before scaling them; George (2000) folded EI into leadership theory, linking it to goal-setting, enthusiasm, and flexibility in leaders; and Ciarrochi et al. (2000) offered a critical but broadly supportive evaluation of the construct's distinctiveness from IQ.

Subsequent work tested these applied claims empirically, with mixed results. Roberts et al. (2001) found EI showed convergent validity with cognitive measures but remained hard to separate cleanly from personality. In organisational settings, Wong and Law (2002) found that followers' EI predicted their own performance and satisfaction while

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leaders' EI shaped their extra-role behaviour toward others, and Jordan et al. (2002) showed that higher-EI teams, measured through their Workgroup Emotional Intelligence Profile, performed better early on and sustained stronger team processes over time. On the clinical side, Ciarrochi, Deane, and Anderson (2002) found EI buffered the relationship between stress and negative mental-health outcomes including depression and suicidal ideation — an early sign that EI's relevance extended beyond the workplace.

A cluster of studies through the mid-2000s consolidated EI's practical footprint while sharpening its boundaries. Carmeli (2003) linked senior managers' EI to more positive work attitudes and altruism, and to a dampened effect of work–family conflict on career commitment; Petrides et al. (2003) showed trait EI predicted life satisfaction and coping style even after controlling for personality, reinforcing its place as a personality-adjacent construct; and Diefendorff and Richard (2003) connected EI to how employees interpret workplace emotional display rules. Brackett et al. (2004) found lower EI in men correlated with substance use and weaker social relationships, while Zeidner et al. (2004), reviewing the workplace evidence critically, cautioned that much of the enthusiasm for EI at work still rested on anecdote rather than controlled data — a caution partly borne out by Bastian et al. (2005), who found EI predicted coping and satisfaction but was consistently outperformed by personality and cognitive ability as a predictor.

From the late 2000s, the field moved toward meta-analysis and consolidation. Côté and Miners (2006) found EI's contribution to job performance was strongest precisely when cognitive intelligence was weakest, suggesting a compensatory rather than additive role; Schutte et al.'s (2007) meta-analysis tied higher EI to better mental, psychosomatic, and physical health; and Johnson and Spector (2007) complicated the emotional-labour literature by showing gender and autonomy, not EI directly, drove well-being outcomes. Measurement work also diversified geographically, with Wong et al. (2007) and Law et al. (2008) validating Chinese-context EI scales that outperformed Western instruments among Chinese employees and R&D scientists respectively, while Zeidner et al. (2008), Petrides (2009), and Schutte et al. (2009) worked to stabilise the field's conceptual and psychometric foundations.

By the 2010s, the field had matured enough to support integrative modelling: Joseph and Newman (2010) and Cherniss (2010) proposed a cascading model in which perception, understanding, and regulation of emotion feed sequentially into job performance, and Harms and Credé's (2010) meta-analysis found EI predicts transformational leadership more strongly when the same rater assesses both constructs than when raters differ — a methodological caution as much as a substantive finding. Most recently, Mayer et al. (2016) and Linden et al. (2017) have pointed to substantial overlap between trait EI and the broader General Factor of Personality, reopening the distinctiveness question that has shadowed the construct since 1998.

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Read as a whole, three decades of EI research trace a movement from a single definitional claim toward a genuinely interdisciplinary body of evidence spanning leadership, health, and organisational behaviour — even as its precise boundaries relative to personality remain contested. What this literature does not resolve, and what motivates the present paper, is how this emotional competence translates into the specific behavioural domain of sustainable consumption.

Bibliometric confirmation. A VOSviewer co-citation network of the EI literature (603 items, 5 clusters, total link strength 177,896) confirms EI as a mature and extensively explored field. The most prominent works cluster around 1990, 1998, 2001, 2003, and 2008 — corresponding precisely to the foundational and developmental works discussed above (Mayer & Salovey, 1990; Goleman, 1998; Roberts et al., 2001; Petrides et al., 2003; Law et al., 2008), confirming that the narrative review is well aligned with the underlying citation structure of the field (see Table 1).

Table 1: Cluster Description — Emotional Intelligence Co-Citation Network
(Total Items: 603; Clusters: 5; Total Links: 70,254; Total Link Strength: 177,896)

Prominent Year	Cluster	Links	Total Link Strength	Citations
1990	1	599	7,954	544
1998	2	578	4,962	306
2008	3	562	3,604	194
2001	4	560	3,844	185
2003	5	543	3,481	171

Sustainable Consumption Behaviour: Conceptual Evolution

Where EI research asks what emotional competence is, SCB research asks what makes people act, or fail to act, in the planet's long-term interest — and the answers it has produced sit at several different levels of analysis, from individual cognition to national governance. At the most individual end of the spectrum, Vyner's (2010) study of Tibetan lamas proposed that a calm, self-aware mind is itself a precondition for environmentally aligned behaviour, hinting that SCB might have philosophical and cognitive roots that precede attitudes and knowledge altogether.

A second wave of research shifted the unit of analysis upward, to cross-national comparison. Marquart-Pyatt (2013) showed that environmental concern is not a single global attitude but a multidimensional one that varies meaningfully by culture, which argues against one-size-fits-all policy design. Vainio and Paloniemi (2014), working with Nordic samples, found a double-edged relationship between trust in science and environmental behaviour: a positive view of science builds environmental knowledge and concern, but excessive reliance on science to "solve" ecological problems can blunt

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personal motivation to act. Marquart-Pyatt (2015) then tackled a more technical problem — how to measure environmental risk perception consistently across countries — using International Social Survey Programme data to build a cross-nationally valid latent measure, work that later studies in this review draw on directly.

Governance and infrastructure emerged as a third explanatory layer. Wang's (2017) 31-country analysis found that strong environmental governance boosts SCB in wealthier nations but can have the opposite effect elsewhere, suggesting governance quality interacts with economic context rather than operating uniformly. Wang and Hao (2018) added a technological dimension, showing that Internet penetration helps convert pro-environmental attitudes into actual behaviour, presumably by lowering the practical barriers to acting on one's beliefs. Johansson Sevä and Kulin (2018) complicated the governance story further, finding that low GDP and low institutional trust together suppress SCB regardless of stated environmental concern, while Janmaimool and Khajohnmanee (2019) showed that education shapes attitudes reliably but its downstream effect on actual behaviour is far more context-dependent.

A cluster of studies around 2020–2021 turned to the psychological mechanisms linking knowledge to action. Liu et al. (2020) showed environmental knowledge affects SCB only indirectly, through the attitudes and intentions it produces — knowledge alone does not move behaviour. Aral and López-Sintas (2020), using Eurobarometer data, found that social factors such as age and education mediate how knowledge and attitude translate into behaviour, framing SCB as fundamentally a social rather than purely individual process. Saari et al. (2021) validated a model linking environmental knowledge and risk perception directly to SCB, and Liao and Yang (2021) integrated several behavioural theories to show that intrapersonal factors like intention and social norms interact with contextual constraints to shape concrete actions such as purchasing and conservation.

The most recent wave of studies (2023–2025) has pushed into more specific populations, contexts, and methods. Kirsten and Biyase (2023) found an apparent paradox in South Africa: lower-income groups report high environmental concern but engage in less SCB, constrained by resource scarcity rather than attitude. Gong et al. (2023) distinguished implicit from explicit climate attitudes and found the two often diverge. Applied studies have proliferated across sectors and regions: willingness-to-pay for mangrove conservation in Vietnam (Pham et al., 2024), food-waste behaviour among Malaysian hospitality students (Mohamed Rani et al., 2024), women's urban-forest conservation intentions explained via an extended Theory of Planned Behaviour (Maleknia & Salehi, 2024), the role of media literacy in shaping consumption awareness (Chamcham et al., 2024), financial participation in conservation driven by psychological and value-based antecedents (Maleknia, 2024; Maleknia et al., 2024), self-efficacy-driven environmental behaviour among Tehran's urban forest visitors (Erfanian et al., 2024), and public attitudes

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toward medical waste (Lapuz & Manlapaz, 2024; Bai et al., 2024). Most recently, Kikko and Ishigaki (2025) found that the relative influence of environmental concern versus risk perception on SCB differs systematically by country, and Grosset and Sartori (2025) modelled how incentive structures can push firms toward equilibrium adoption of green technology.

The cumulative picture is of a field that has broadened from a single normative claim about the mind's relationship to the environment into a genuinely multi-level explanatory system — spanning individual cognition, social mediation, national governance, and, most recently, sector-specific applications. What this literature has not yet done, consistently, is bring the affective competence documented in Section 2.1 explicitly into that system.

Bibliometric Confirmation

A VOSviewer co-citation network of the SCB literature (461 items, 4 clusters, total link strength 140,677) shows key prominent years of 1991, 2000, 2010, and 1981 (see Table 2), reflecting the field's evolution from normative ethics and policy perspectives toward psychological and cultural dimensions — a trajectory mirrored in the narrative review above.

Table 2: Cluster Description — Sustainable Consumption Behaviour Co-Citation Network (Total Items: 461; Clusters: 4; Total Links: 58,304; Total Link Strength: 140,677)

Prominent Year	Cluster	Links	Total Link Strength	Citations
1991	1	460	6,636	453
2000	2	442	2,403	146
2010	3	306	965	54
1981	4	454	4,012	274

Where Emotional Intelligence Meets Sustainable Consumption

The two literatures above rarely cite each other, which is itself informative: the theoretical case for a connection between EI and SCB has been made repeatedly, but empirical tests remain sparse. The conceptual groundwork goes back further than either field's applied literature — Daly (1987) had already described sustainable development as inseparably economic, social, and ecological, while Faucheux et al. (1995) argued that financial behaviour is emotionally grounded in the first place, implying that emotional competence should logically shape how consumers navigate sustainability trade-offs. Berezine (2005) made this implication more explicit, treating emotional response as a cause rather than a by-product of economic behaviour, and Bandelj (2009) went further still, theorising EI as a resource that improves economic improvisation and adaptability under uncertain conditions.

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Empirical tests of this reasoning are still few, but consistent in direction. Koenig-Lewis et al. (2014) found that pride and guilt shape purchase intentions toward energy-efficient appliances, with these emotional responses effectively channelled through consumers' emotional competence into sustainable choice. Wang et al. (2016) extended this to negative emotions, showing that respect and anger both feed into resistance toward unsustainable products, while López-Galán et al. (2017) found something more specific in everyday food purchasing: EI appears to offset, rather than amplify, the disruptive effect of guilt on sustainable buying decisions — suggesting EI's role may be less about generating pro-environmental emotion and more about regulating it productively. At the organisational level, the same logic reappears in a different form: Odame et al. (2020) linked EI within human-resource practice to broader sustainable-development outcomes, and Pîrvu (2020) argued that emotionally intelligent business relationships underpin environmentally responsible corporate conduct, effectively scaling the individual-level mechanism up to the firm.

Taken together, these studies converge on a single proposition without yet testing it directly and comprehensively: that EI does not merely coexist with sustainable behaviour but actively channels emotional experience — guilt, pride, respect, anger — into more consistent ethical and environmental choices. Whether this holds at the level of the ordinary individual consumer, across demographic groups, and under what conditions it breaks down, remains open.

Sustainable Consumption and Economic Identity

SCB's relevance extends well beyond its environmental payoff into tangible economic territory. Geng et al. (2013) demonstrated that sustainable practices lower resource costs for consumers and firms alike, while also quantifying the financial cost of environmental degradation — effectively framing SCB as a form of preventive economic insurance rather than pure altruism. Winans et al. (2016) built on this with circular-economy principles, showing how designing out waste can make sustainability economically efficient rather than a cost centre, and Tukker and Pezzei (2005) identified the green economy itself as an emerging market opportunity driven by, rather than merely constrained by, sustainable consumption demand. Read together, this strand repositions SCB from a moral obligation into an economic strategy with measurable returns.

Indirect Economic Benefits through Emotional Intelligence

If SCB carries real economic value, and EI shapes how consumers arrive at sustainable choices, a further question follows: does EI also make consumers more attuned to the economic case for sustainability, not just its ethical one? The direct evidence here is limited, but suggestive. Koenig-Lewis et al. (2014) found emotionally intelligent consumers were

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more likely to recognise the long-run financial upside of sustainable choices, not just their environmental merit, and López-Galán et al. (2017) similarly framed EI as the mechanism that lets consumers translate emotional cues into decisions that satisfy ethical and economic considerations simultaneously rather than trading one off against the other. Van der Linden et al. (2017) added a communications angle, showing EI shapes how receptive people are to sustainability-framed messaging in the first place — a cognitive-emotional gateway that determines whether economic arguments for sustainability even land. Matthies et al. (2017) and Odame et al. (2020), meanwhile, found that higher EI correlates with broader pro-social and pro-environmental behaviour that carries positive economic spillovers, even where those studies were not designed to isolate the economic channel specifically.

RESEARCH GAP

Two things stand out from the synthesis above. First, the literature on emotion and consumer choice is genuinely extensive — but it is weighted heavily toward commercial outcomes (brand preference, purchase intention generally) rather than sustainability outcomes specifically. Second, where sustainability does appear, EI is more often an implicit background variable than the object of direct measurement. Neither gap is fatal to the field, but together they mean that the case for EI as a lever for shifting population-level consumption toward sustainability is still argued more than it is tested. The following six gaps follow directly from that observation:

1. How to build economic models that use intrinsic behaviour change (through emotional intelligence) for extrinsic economic consumption-shift choices toward sustainable behaviour: Limited research investigates how EI-based intrinsic behaviour change translates into extrinsic economic benefits through sustainable consumption choices; current studies focus primarily on the commercial aspects of consumer behaviour, neglecting EI's potential in promoting sustainable consumption patterns.
2. What is the difference between rational and sustainable consumption behaviour? A clear distinction between rational and sustainable consumption is often lacking in prior literature, hindering the design of targeted interventions.
3. What are the socio-economic and psychological variables that affect sustainable consumption? A deeper exploration of the socio-economic and psychological drivers and barriers of SCB is required to fully understand its adoption.
4. What are the drivers and barriers of sustainable consumption? A conceptual understanding of the drivers and barriers of SCB is needed, informed by a systematic literature review.

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5. How to achieve the Sustainable Development Goals through intelligent consumption? Future research can examine how EI can be harnessed to promote SCB, integrating economic models with psychological insights to design effective interventions and policies.
6. What policy interventions can encourage sustainable and resilient consumption? Given the urgency of promoting sustainable consumption, research on effective policy interventions that facilitate a shift toward sustainable and resilient consumption patterns is crucial.

RESEARCH QUESTIONS AND OBJECTIVES

Based on the research gaps identified above, the following research questions have been formulated to explore the role of EI in fostering sustainable consumption behaviour. These questions are intended to fill existing literature gaps and form a basis for future hypothesis testing:

RQ1: How does emotional intelligence vary among consumers across different demographic groups — such as age, gender, socio-economic status, and profession — with particular reference to its implications for economic behaviour? This question addresses the research gap on EI-based financial-decision models by examining how EI influences consumers' financial decisions across demographic segments.

RQ2: What is the impact of emotional intelligence on consumers' sustainable consumption behaviour? This question examines the external changes in consumption choices influenced by EI and establishes a base for understanding how EI can transform mass behaviour toward sustainability.

RQ3: What are the primary barriers that consumers face in practising sustainable consumption behaviour? This question addresses the identification of barriers and the socio-economic and psychological factors that hinder the adoption of sustainable behaviours.

RQ4: What strategies can be suggested to improve consumers' emotional-intelligence skills to promote sustainable consumption and contribute to the achievement of the UN Sustainable Development Goals — particularly SDG 12 (Responsible Consumption and Production)? This question examines how EI can inform policy interventions and consumption strategies for achieving the SDGs.

Correspondingly, the broad objectives of this review are: (i) to examine variation in EI across demographic groups and its implications for economic behaviour; (ii) to assess the impact of EI on sustainable consumption behaviour; (iii) to identify the primary barriers consumers face in practising sustainable consumption; and (iv) to propose strategies

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for enhancing EI as a lever for sustainable consumption and SDG 12 attainment. These objectives are proposed on the basis of the identified research gaps and research questions and should be cross-checked against the full objectives stated in Section 1.5 of the parent thesis before final submission.

REVIEW METHODOLOGY

This paper adopts a narrative, theory-building literature review approach, supplemented by a bibliometric co-citation analysis conducted using VOSviewer (version 1.6.19.0). Relevant peer-reviewed articles on EI (1990–2017) and SCB (1987–2025) were identified, synthesised thematically, and cross-validated against citation-network data — comprising 603 items across five clusters for EI and 461 items across four clusters for SCB — to confirm that the qualitative synthesis captures the most influential and highly cited works in each field. This dual approach (narrative synthesis plus bibliometric verification) lends both interpretive depth and empirical rigour to the review, and is consistent with recommended practice for literature reviews that seek to establish a research agenda rather than test hypotheses directly.

DISCUSSION AND CONCEPTUAL SYNTHESIS

Placing the two literatures side by side exposes an asymmetry that is easy to miss when each is read in isolation. EI research has spent three decades establishing, contesting, and refining a model of how individuals differ in emotional perception, understanding, and regulation (Mayer & Salovey, 1990; Goleman, 1995; Petrides & Furnham, 2000). SCB research, quite independently, has built an increasingly multi-level account of sustainable choice — running from individual cognition through social mediation to national governance (Marquart-Pyatt, 2013; Liu et al., 2020; Wang, 2017). Each literature is, on its own terms, mature. What is comparatively immature is the point where they meet.

The handful of studies that do connect EI and SCB directly point in a consistent direction: emotional competence appears to function less as a driver of environmental concern and more as a regulator of it — shaping how guilt, pride, respect, or anger get converted into (or blocked from becoming) consistent purchasing and conservation behaviour (Koenig-Lewis et al., 2014; López-Galán et al., 2017; Wang et al., 2016). That is a meaningful and testable proposition. But it has mostly been demonstrated indirectly, through organisational or sector-specific studies (Odame et al., 2020; Pîrvu, 2020) rather than through direct, individual-level empirical designs that vary EI and observe SCB as an outcome. The result is a literature that is theoretically plausible but empirically thin exactly where a conference-stage contribution is most needed: at the level of the ordinary consumer, across demographic groups, and with instruments validated for both constructs simultaneously. This is the specific gap the research questions in Section 4 are designed to close.

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IMPLICATIONS

Theoretical Implications

The review contributes to theory by positioning EI as a candidate psychological mediator between environmental cognition (knowledge, attitudes, risk perception) and behavioural outcomes (sustainable purchasing, conservation, resource use). This extends existing SCB frameworks — which have emphasised cognitive and socio-structural antecedents — by foregrounding an affective-competence pathway.

Policy Implications

For policymakers pursuing SDG 12, the review suggests that interventions built solely on information provision (environmental education, labelling) may be insufficient; complementary emotional-skill-building interventions — for example, EI-informed messaging or curricula — may improve the translation of environmental knowledge into sustained behaviour change.

Managerial and Practical Implications

For organisations, the review suggests that developing EI among employees and consumer-facing staff (Odame et al., 2020) may support both internal sustainability culture and external sustainable-consumption messaging, aligning human-resource practice with corporate sustainability goals.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Bringing the EI and SCB literatures into direct conversation reveals both a well-founded intuition and an unfinished research agenda. The intuition — that emotionally intelligent consumers navigate the guilt, pride, and ethical trade-offs bound up in sustainable choice more effectively than others — is supported wherever it has been tested, but it has been tested comparatively rarely, and almost never as the primary object of a study designed for that purpose. EI's own trajectory, from a contested 1990 proposal to a well-established (if still debated) predictor of leadership and health outcomes, offers a template for what a more deliberate EI–SCB research programme could achieve over a similar timeframe.

The six research gaps and four research questions set out above are intended as a concrete starting point for that programme: building economic models that connect EI-driven behaviour change to measurable sustainable-consumption outcomes, drawing a clearer line between rational and sustainable consumption, and mapping the socio-economic and psychological conditions under which EI's influence on SCB strengthens or weakens. The immediate next step is direct, quantitative testing across demographic groups using validated instruments for both constructs — work that would not only fill an academic gap but supply the evidence base policymakers need to design SDG 12-aligned interventions that speak to how consumers actually feel, not only what they know.

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REFERENCES

Aral, T., & López-Sintas, J. (2020). Sustainable consumption behaviour among Europeans: A comprehensive model based on the 2017 Eurobarometer. *Journal of Cleaner Production*.

Bandelj, N. (2009). Emotions in economic action and interaction. *Theory and Society*, 38(4), 347–366.

Bar-On, R., & Parker, J. D. A. (2000). The Handbook of Emotional Intelligence: Theory, Development, Assessment, and Application at Home, School, and in the Workplace. Jossey-Bass.

Bastian, V. A., Burns, N. R., & Nettelbeck, T. (2005). Emotional intelligence predicts life skills, but not as well as personality and cognitive abilities. *Personality and Individual Differences, 39*(6), 1135–1145.

Brackett, M. A., Mayer, J. D., & Warner, R. M. (2004). Emotional intelligence and its relation to everyday behaviour. *Personality and Individual Differences,* 36(6), 1387–1402.

Carmeli, A. (2003). The relationship between emotional intelligence and work attitudes, behavior and outcomes: An examination among senior managers. *Journal of Managerial Psychology,* 18(8), 788–813.

Cherniss, C. (2010). Emotional intelligence: Toward clarification of a concept. Industrial and Organizational Psychology, 3(2), 110–126.

Ciarrochi, J. V., Chan, A. Y. C., & Caputi, P. (2000). A critical evaluation of the emotional intelligence construct. *Personality and Individual Differences,* 28(3), 539–561.

Ciarrochi, J., Deane, F. P., & Anderson, S. (2002). Emotional intelligence moderates the relationship between stress and mental health. *Personality and Individual Differences,* 32(2), 197–209.

Côté, S., & Miners, C. T. H. (2006). Emotional intelligence, cognitive intelligence, and job performance. *Administrative Science Quarterly*, 51(1), 1–28.

Davies, M., Stankov, L., & Roberts, R. D. (1998). Emotional intelligence: In search of an elusive construct. *Journal of Personality and Social Psychology*, 75(4), 989–1015.

Diefendorff, J. M., & Richard, E. M. (2003). Antecedents and consequences of emotional display rule perceptions. *Journal of Applied Psychology*, 88(2), 284–294.

Faucheux, S., Pearce, D., & Proops, J. (1995). Models of Sustainable Development. Edward Elgar Publishing.

Geng, Y., Sarkis, J., Ulgiati, S., & Zhang, P. (2013). Measuring China's circular economy. *Science*, 339(6127), 1526–1527.

George, J. M. (2000). Emotions and leadership: The role of emotional intelligence. *Human Relations*, 53(8), 1027–1055.

Goleman, D. (1995). Emotional Intelligence: Why It Can Matter More Than IQ. Bantam Books.

Goleman, D. (1998). *Working with Emotional Intelligence*. Bantam Books.

Harms, P. D., & Credé, M. (2010). Emotional intelligence and transformational and transactional leadership: A meta-analysis. *Journal of Leadership & Organizational Studies*, 17(1), 5–17.

Janmaimool, P., & Khajohnmanee, S. (2019). Roles of environmental system knowledge in promoting university students' environmental attitudes and pro-environmental behaviors. *Sustainability*, 11(16), 4270.

Johnson, H. A. M., & Spector, P. E. (2007). Service with a smile: Do emotional intelligence, gender, and autonomy moderate the emotional labor process? Journal of Occupational Health Psychology, 12(4), 319–333.

ISBN: 978-93-49666-59-7 (eBook)

Jordan, P. J., Ashkanasy, N. M., Härtel, C. E. J., & Hooper, G. S. (2002). Workgroup emotional intelligence: Scale development and relationship to team process effectiveness and goal focus. *Human Resource Management Review*, 12(2), 195–214.

Joseph, D. L., & Newman, D. A. (2010). Emotional intelligence: An integrative meta-analysis and cascading model. *Journal of Applied Psychology*, 95(1), 54–78.

Kikko, Y., & Ishigaki, T. (2025). Divergent effects of environmental concern and risk perception on pro-environmental intention: An international study across 17 countries. *Scientific Reports*, 15, 7766.

Koenig-Lewis, N., Palmer, A., Dermody, J., & Urbye, A. (2014). Consumers' evaluations of ecological packaging – rational and emotional approaches. *Journal of Environmental Psychology*, 37, 94–105.

Law, K. S., Wong, C.-S., Huang, G.-H., & Li, X. (2008). The effects of emotional intelligence on job performance and life satisfaction for the research and development scientists in China. Asia *Pacific Journal of Management*, 25(1), 51–69.

Linden, D. van der, Pekaar, K. A., Bakker, A. B., Schermer, J. A., Vernon, P. A., Dunkel, C. S., & Petrides, K. V. (2017). Overlap between the General Factor of Personality and emotional intelligence: A meta-analysis. *Psychological Bulletin*, 143(1), 36–52.

Liu, P., Teng, M., & Han, C. (2020). How does environmental knowledge translate into pro-environmental behaviors? The mediating role of environmental attitudes and behavioral intentions. *Science of the Total Environment*, 728, 138126.

Mayer, J. D., & Cobb, C. D. (2000). Educational policy on emotional intelligence: Does it make sense? *Educational Psychology Review*, 12(2), 163–183.

Mayer, J. D., Caruso, D. R., & Salovey, P. (2016). The ability model of emotional intelligence: Principles and updates. *Emotion Review*, 8(4), 290–300.

Mayer, J. D., Caruso, D. R., & Salovey, P. (2000). Emotional intelligence meets traditional standards for an intelligence [Multifactor Emotional Intelligence Scale]. *Intelligence*, 27(4), 267–298.

Mayer, J. D., DiPaolo, M., & Salovey, P. (1990). Perceiving affective content in ambiguous visual stimuli: A component of emotional intelligence. *Journal of Personality Assessment*, 54(3–4), 772–781.

Petrides, K. V. (2009). Technical manual for the Trait Emotional Intelligence Questionnaires (TEIQue). London Psychometric Laboratory.

Petrides, K. V., & Furnham, A. (2000). On the dimensional structure of emotional intelligence. *Personality and Individual Differences*, 29(2), 313–320.

Petrides, K. V., Frederickson, N., & Furnham, A. (2003). The role of trait emotional intelligence in academic performance and deviant behavior at school. *Personality and Individual Differences*, 36(2), 277–293.

Roberts, R. D., Zeidner, M., & Matthews, G. (2001). Does emotional intelligence meet traditional standards for an intelligence? Some new data and conclusions. *Emotion*, 1(3), 196–231.

Saari, U. A., et al. (2021). Sustainable consumption behavior of Europeans: The influence of environmental knowledge and risk perception on environmental concern and behavioral intention. *Ecological Economics*, 189, 107155.

Salovey, P., Mayer, J. D., Goldman, S. L., Turvey, C., & Palfai, T. P. (1995). Emotional attention, clarity, and repair: Exploring emotional intelligence using the Trait Meta-Mood Scale. In J. W. Pennebaker (Ed.), *Emotion, Disclosure, and Health* (pp. 125–154). American Psychological Association.

 ISBN: 978-93-49666-59-7 (eBook)

Salovey, P., & Mayer, J. D. (1990). Emotional intelligence. *Imagination, Cognition, and Personality*, 9(3), 185–211.

Schutte, N. S., Malouff, J. M., Thorsteinsson, E. B., Bhullar, N., & Rooke, S. E. (2007). A meta-analytic investigation of the relationship between emotional intelligence and health. *Personality and Individual Differences*, 42(6), 921–933.

Schutte, N. S., Malouff, J. M., & Bhullar, N. (2009). The Assessing Emotions Scale. In C. Stough, D. H. Saklofske, & J. D. A. Parker (Eds.), *Assessing Emotional Intelligence: Theory, Research, and Applications* (pp. 119–134). Springer.

Vainio, A., & Paloniemi, R. (2014). Does belief matter in climate change action? *Public Understanding of Science*, 22(4), 382–395.

Winans, K., Kendall, A., & Deng, H. (2016). The history and current applications of the circular economy concept. *Renewable and Sustainable Energy Reviews*, 68(1), 825–833.

Wong, C.-S., & Law, K. S. (2002). The effects of leader and follower emotional intelligence on performance and attitude: An exploratory study. *The Leadership Quarterly*, 13(3), 243–274.

Wong, C.-S., Wong, P.-M., & Law, K. S. (2007). Evidence on the practical utility of Wong's emotional intelligence scale in Hong Kong and mainland China. *Asia Pacific Journal of Management*, 24(1), 43–60.

Zeidner, M., Matthews, G., & Roberts, R. D. (2004). Emotional intelligence in the workplace: A critical review. *Applied Psychology*, 53(3), 371–399.

Zeidner, M., Matthews, G., & Roberts, R. D. (2008). The science of emotional intelligence: Current consensus and controversies. *European Psychologist*, 13(1), 64–78.

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Chapter

7

Unravelling Urban Growth and Human Well-Being: Building Sustainable Cities for the Future

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ABSTRACT

Rapid urbanization is transforming cities into centres of economic growth, innovation, employment, and social opportunity. At the same time, unplanned urban expansion is creating complex challenges related to air pollution, overcrowding, inadequate housing, traffic congestion, waste generation, declining green spaces, climate vulnerability, and unequal access to essential services. These challenges directly influence the physical, mental, and social well-being of urban populations. This paper explores the relationship between sustainable urbanization and modern health and well-being, emphasizing the need to place people at the centre of urban development.

The paper examines how integrated urban planning can balance economic and infrastructural growth with public health, environmental sustainability, social inclusion, and quality of life. It highlights the importance of green and blue spaces, sustainable mobility, affordable and healthy housing, clean air, safe water and sanitation, effective waste management, climate-resilient infrastructure, and equitable access to healthcare and recreational facilities. Particular attention is given to the emerging challenges of urban stress, social isolation, sedentary lifestyles, heat exposure, and environmental inequality. The paper further explores the potential of smart technologies, data-driven governance, nature-based solutions, and participatory planning in creating healthier and more resilient urban environments.

The paper uses primary data and cases to argue that sustainable urbanization requires a shift from infrastructure-centric development towards a human-centred urban development model, where health and well-being are considered fundamental measures of city performance. Sustainable urbanization, therefore, represents an opportunity to reimagine cities as living ecosystems where economic progress, environmental health, and human well-being advance together.

Keywords: Sustainable Urbanization, Urban Health, Well-Being, Smart Cities, Climate Resilience, Sustainable Mobility, Green Infrastructure, Inclusive Cities, Urban Planning.

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INTRODUCTION: FROM URBAN GROWTH TO URBAN WELL-BEING

Urbanization has traditionally been associated with economic modernization, employment generation, infrastructure development and improved access to services. However, the contemporary urbanization debate increasingly questions whether urban growth itself should be treated as evidence of urban success. The latest UN World Urbanization Prospects 2025 estimates that cities are home to approximately 45% of the world's population, more than twice the share recorded in 1950, with continued urban transformation expected through 2050.

This scale of urbanization creates an important conceptual question: What makes a city successful? Is it the number of kilometres of roads constructed, the volume of investment attracted, the number of buildings erected, GDP generated, or the speed at which urban infrastructure expands? Or should urban success increasingly be assessed through whether people are healthy, safe, socially connected, economically secure, environmentally protected and psychologically well?

Recent literature increasingly supports the latter perspective. UN-Habitat's World Cities Report (2024) argues that climate change and urbanization are deeply intertwined and that urban climate action can generate co-benefits including poverty reduction (Markkanen, & Anger-Kraavi, 2019)., employment, public health, well-being and ecosystem restoration (Seddon, et. Al., 2020). The emerging literature therefore suggests that sustainable urbanization needs to move from an infrastructure-centric paradigm toward a human-centred and ecosystem-sensitive paradigm. It is in this context the paper uses primary and secondary data and attempts to unveil the perspectives of common man in planning the shift from infrastructure-centric development towards a human-centred urban development model. The paper shares cases of cities which worked differently to urban growth and ensured wellbeing of people.

SUSTAINABLE URBANIZATION

The concept of sustainable urbanization emerged from the broader sustainable-development discourse, particularly the recognition that cities simultaneously concentrate economic opportunity, resource consumption, environmental pressures and social inequalities.

Earlier approaches tended to emphasise three broad dimensions:

- economic development;
- environmental sustainability; and
- physical infrastructure.

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Sustainability is increasingly understood as involving health, well-being, equity, accessibility, resilience, social cohesion, participation and quality of life. A 2024 systematic review of future-city theories found that contemporary approaches increasingly combine social, environmental and economic mechanisms, while concepts such as the smart city (Tura & Ojanen, 2022), resilient city and sustainable city are being brought together into more holistic models. However, the review also identifies an important implementation gap: theories may appear comprehensive while their practical application remains fragmented. The question is no longer simply how to make cities grow sustainably, but how to make urban growth contribute to human flourishing.

TOWARDS A NEW FRAMEWORK FOR MEASURING URBAN SUCCESS

The literature collectively suggests that the dominant infrastructure-and-economic model of urban development is increasingly inadequate for evaluating sustainable cities. Urban infrastructure remains fundamental, but it should be understood as a means to broader human outcomes. A human-centred urban performance framework can therefore be organized around five interconnected dimensions:

Table 1: Dimensions to Human-centred Urban Performance Framework

Dimension	Conventional urban measure	Human-centred measure
Physical development	Infrastructure investment, built-up area	Healthy, safe and accessible environments
Economic development	GDP, property values, capital investment	Inclusive employment, livelihoods and economic security
Environmental sustainability	Emissions, energy efficiency	Healthy ecosystems and climate-resilient communities
Social development	Service provision	Equity, inclusion, belonging and social cohesion
Human well-being	Population and productivity	Physical health, mental health, life satisfaction and quality of life

EMERGING RESEARCH GAP

The literature demonstrates considerable progress on sustainable urbanization, urban health, green infrastructure, mobility and subjective well-being has expanded considerably, several gaps remain. Research is often sectoral where urban planning research examines spatial form; transport research examines mobility (Giles-Corti *et al.*, 2016; Stevenson *et al.*, 2016); environmental research examines emissions and ecological quality; public-health research examines disease and health; social research examines inequality; and smart-city research examines technology (Yigitcanlar *et al.*, 2021). Urban

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development continues to be measured predominantly through physical and economic indicators (Zhang *et al.*, 2023). Indicators such as infrastructure provision, investment, land use, connectivity and economic productivity remain much more established than measures of psychological well-being, social belonging and life satisfaction. Existing research examines urban health (Sallis *et al.*, 2016), environmental sustainability (Dyer *et al.*, 2024) and social equity (Zhang *et al.*, 2023) as separate domains.

There remains a need for integrated frameworks that examine how physical infrastructure, environmental conditions, social structures and governance collectively shape human well-being. The distributional dimension requires greater attention. A city may improve its average quality-of-life indicators (Ghosh, et.al. 2022) while simultaneously widening inequalities between neighbourhoods or population groups. Urban green spaces are increasingly understood not merely as environmental amenities but as critical components of climate adaptation and public health infrastructure, with potential to mitigate heat exposure and support mental well-being (Huang *et al.*, 2024). More broadly, the emerging healthy-city literature emphasizes that urban interventions can generate simultaneous co-benefits for health, social equity, environmental sustainability, and the Sustainable Development Goals, although these interventions may also produce trade-offs that require context-sensitive and integrated governance (Ahmadi Dehrashid *et al.*, 2026).

Table 2: Proposed Conceptual Shift

Old Urbanization Paradigm	**Redefined Sustainable Urbanization**
Economic Growth → Infrastructure → Productivity → Urban Expansion	Urban Growth → Infrastructure + Ecology + Equity + Health + Well-being → Human Flourishing

Table 3: Suggested Framework is based on Six Dimensions

Dimension	**Key Question**
Physical	Is the city safe, accessible and liveable?
Environmental	Can the city operate within ecological limits?
Health	Does urban design promote physical and mental health?
Social	Does the city reduce exclusion and strengthen social connection?
Economic	Can residents access decent work and affordable services?
Psychological	Does the city enable belonging, security, dignity and well-being?

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TOWARDS A NEW DEFINITION OF SUSTAINABLE URBANIZATION

Based on the recent literature, sustainable urbanization can be conceptualised as a process of urban development that enables present and future populations to live healthy, secure, equitable and fulfilling lives while maintaining ecological integrity, reducing environmental pressures and ensuring that the benefits and risks of urban growth are fairly distributed. This definition places human well-being at the centre without abandoning environmental sustainability.

CITIES AS LIVING ECOSYSTEMS

Reimagining cities requires abandoning the industrial metaphor of the city as a "machine" and adopting an ecological perspective, viewing the city as a living, adaptive ecosystem. In a healthy natural ecosystem, dynamic feedback loops keep diverse elements in functional equilibrium. Similarly, a sustainable urban ecosystem establishes a balanced synergy between three interconnected pillars as Economic Progress, Environmental Health, and Human Well-Being. In this context a study by (Das & Ramaswami, 2026) examines how energy, mobility, shelter, water, waste management, greenery, pollution, noise and heat relate to subjective well-being, using data from 2,400 metropolitan residents in Chennai.

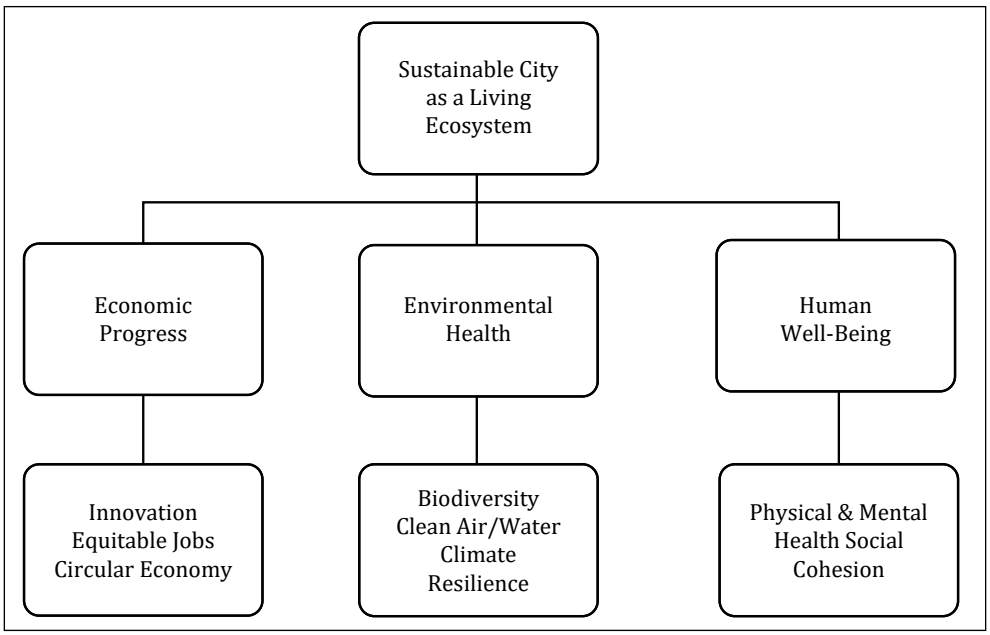


Fig. 1: Sustainable City – Living Eco-system

When the three dimensions advance together, economic prosperity ceases to rely on environmental extraction or human exhaustion.

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OPERATIONALIZING HEALTH AND WELL-BEING IN CITY PERFORMANCE

For human-centred urbanization to transition from an ideal concept to an actionable urban policy, municipalities must reform how city performance is measured and benchmarked. Traditional Key Performance Indicators (KPIs) focused on vehicular flow rates or construction square footage must be replaced or augmented by holistic liveability indices.

Table 4: Metrics for City Performance

Traditional Infrastructure Metrics	**Human-Centred Ecosystem Metrics**	
Kilometers of road network built	Percentage of population with 5-minute access to safe active transit	Giles-Corti *et al.* (2016); Stevenson *et al.* (2016); Sallis *et al.* (2016)
Total square meters of commercial space	Public square meters of accessible green and civic space per capita	Konijnendijk (2023); Browning *et al.* (2024)
Vehicular throughput and traffic speed	Reductions in ambient noise levels and air pollution ($PM_{2.5}$, NO_2)	WHO (2018); WHO (2021)
Commercial real estate valuation	Population-wide physical activity levels and reported loneliness metrics	Pels & Kleinert (2016); Mak *et al.* (2024); Wicks *et al.* (2022)

By binding municipal budgets, zoning permissions, and urban redevelopment projects directly to well-being metrics, city authorities can ensure that every major capital investment serves a clear human purpose.

METHODOLOGY

Thematic coding for the three open-ended questions was performed using keyword-based pattern matching. The study analyses 74 survey responses covering five questions on how respondents define a 'sustainable city', what features matter most to them in a healthy and liveable city, what single priority they would set for corporate and city leaders, what urban stressors affect their well-being, and what their ideal future city looks like. Two questions (features and stressors) were closed multi-select checklists and are analysed quantitatively; the remaining three were open-ended text responses and were analysed through keyword-based thematic coding, grouping free-text answers into recurring themes.

It was observed that the respondents selected far more options than the question wording suggested (an average of 4.6 features out of 9, against guidance of '2–3', and 6.5 stressors out of 13). This should be read as a sign that respondents perceive most of the listed factors as simultaneously relevant, rather than as a ranked shortlist the relative ordering of items is still meaningful, but the absolute selection counts likely overstate how differentiated respondents' priorities really are.

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DATA ANALYSIS – REIMAGINING THE URBAN FUTURE

Sustainable urbanization is fundamentally an opportunity to redefine human settlement for the century ahead. Cities do not need to be stress-inducing environments defined by isolation, pollution, and spatial inequity. By shifting focus from concrete-centric growth to human-centred design, urban centers can be transformed into vibrant, living ecosystems. When urban design prioritizes the physical, psychological, and social health of its residents, cities become genuine habitats for human potential where economic dynamism, environmental restoration, and individual well-being thrive in complete harmony. Based on the same the respondents 117 were shared the links to respond and 74 responded to the questionnaire where google form was used to collect the data. The age demographics of the responses received is as shared in Figure 2.

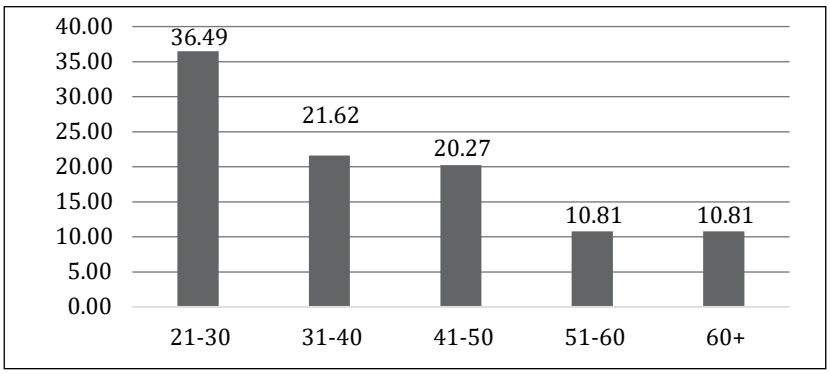


Fig. 2: Demography of Respondents

The strongest and most reliable finding in the dataset is the convergence of the same three concerns emerging whether respondents are articulating a definition, a priority, a stressor, or a vision. The same core cluster of concerns recurs consistently as

a) Environmental quality - (green space, clean air, pollution control)
b) Public health/safety
c) Mobility and traffic

Waste management and water management also feature prominently, particularly in the definitional and priority-setting questions. By contrast, social/psychological stressors (isolation) and smart-city/technology features rank consistently low across every question, suggesting these are not yet top-of-mind concerns for this respondent group relative to physical environment and mobility.

INTERPRETATION OF SUSTAINABLE CITY – THEMATIC ANALYSIS

The single most common theme is Quality of life, health & safety (36%), closely followed by Intergenerational equity (35%) and Resource efficiency / self-sufficiency (35%) tied

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for second. Waste management / circularity (28%) and Green spaces & nature (26%) form a clear second tier. Smart / technology-enabled framing is rare (5%) respondents overwhelmingly describe sustainability in ecological and quality-of-life terms rather than technological ones.

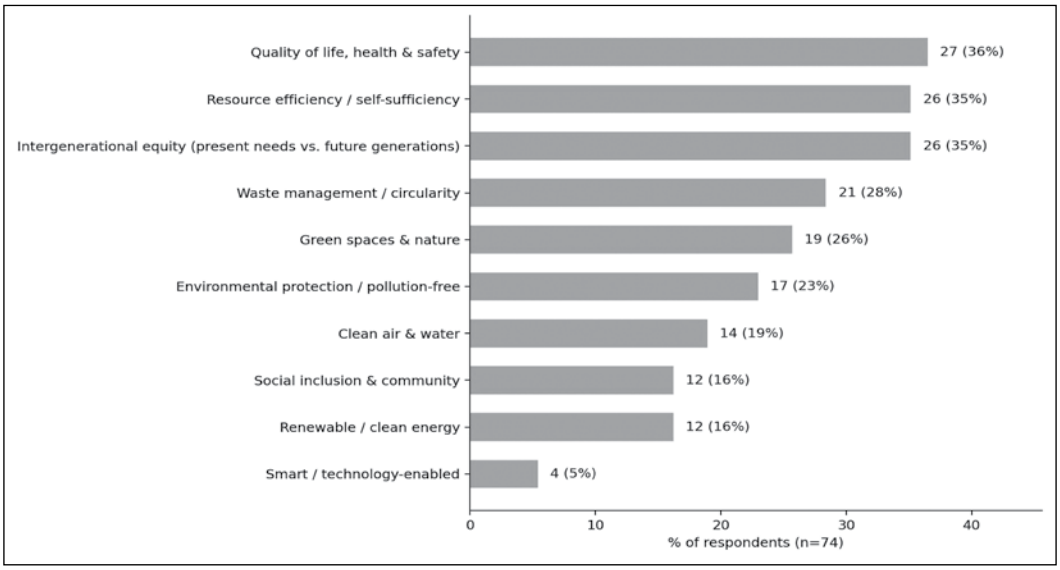


Fig. 3: Interpretation of Sustainable City—Thematic Analysis

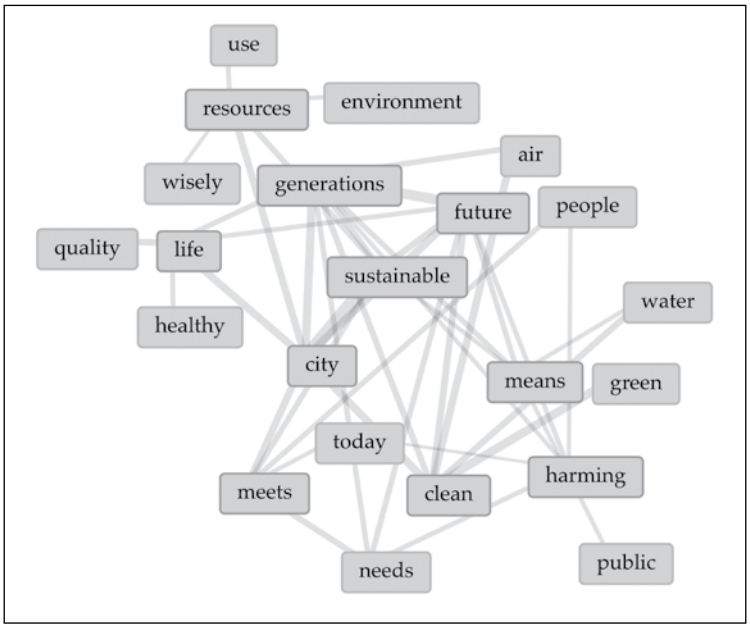


Fig. 4: Word Cloud—Interpretation of Sustainable City

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Respondents do not define 'sustainable city' as a narrow environmental-technical concept. Instead, they blend three ideas almost equally:

a) A livable, healthy present for current residents,

b) responsibility to future generations, and

c) self-sufficient, resource-conscious management.

It is evident from the themes that communication or programme framing around sustainability will land best when it explicitly connects environmental stewardship to immediate quality-of-life benefits, rather than presenting them as separate or competing goals.

FEATURES THAT MATTER MOST IN A HEALTHY & LIVEABLE CITY

On analysing the closed multi-select checklist, where respondents were asked to pick 2-3 features. Inspite of which the average respondent selected 4.6 of 9 listed options). This reflects the anxiety of people in context to factors mattering most is almost questions.

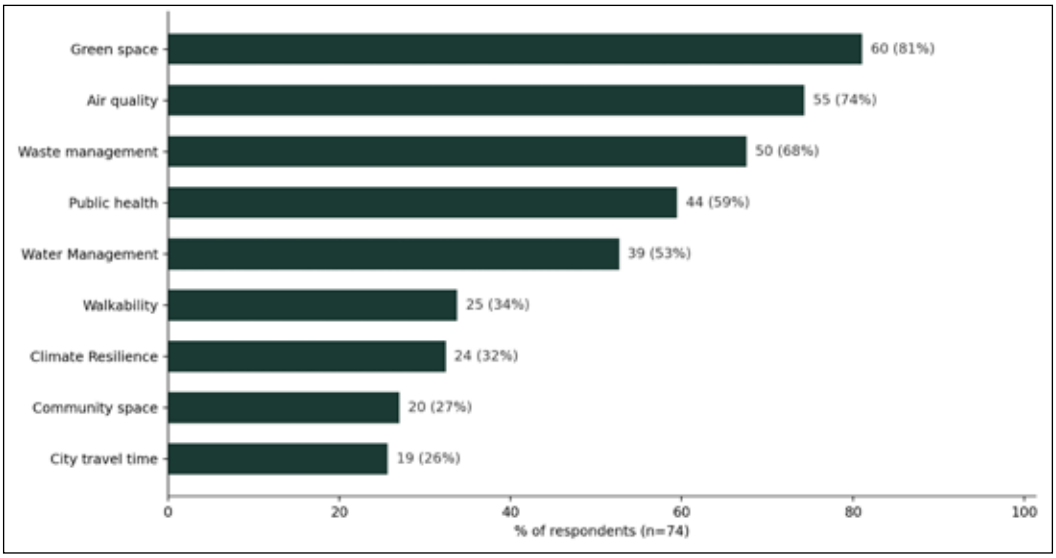


Fig. 5: Features that Matter- Healthy & Liveable City

Green space is the dominant choice, selected by 81% of respondents by a clear margin the single most valued feature. Air quality (74%) and Waste management (68%) form a strong second tier, together with the top choice forming an unambiguous 'top 3'. Respondents overwhelmingly prioritise foundational environmental infrastructure green space, air quality, and waste management over urban-design amenities like walkability or community space. This is a consistent, low-ambiguity signal and thus any intervention aiming to visibly move the needle on perceived liveability should prioritise these three areas first.

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Fig. 6: Major Urban Stressors Affecting Physical and Mental Well-being – Word Cloud

Opinion on top priority for corporate and city leaders - Open-ended responses (n=74) coded into eight themes; 66 of 74 (89%) matched at least one theme.

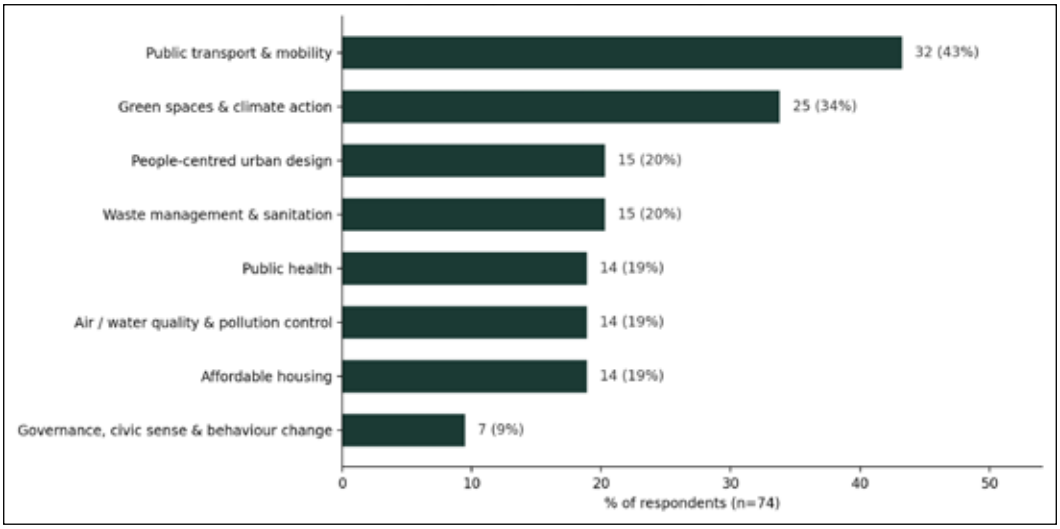


Fig. 7: Major Changes Expected to Human-centred Urban Living

Public transport & mobility is the clear leading theme (43%) substantially ahead of every other priority area. Green spaces & climate action (34%) is a strong second; Waste

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management, People-centred urban design, Air/water quality, and Public health cluster closely together (19–20% each). When forced to name one priority, respondents converge much more strongly on mobility/transport than they do on any single feature. This suggests that while environmental quality (green space, air, waste) is the most broadly valued attribute of a liveable city, transport and traffic congestion is what respondents believe requires the most urgent joint action from leadership, a distinction worth preserving in any resulting recommendations, since 'what people value' and 'what people think needs fixing first' are not the same question. Closed multi-select checklist; respondents selected an average of 6.5 of 13 listed stressors.

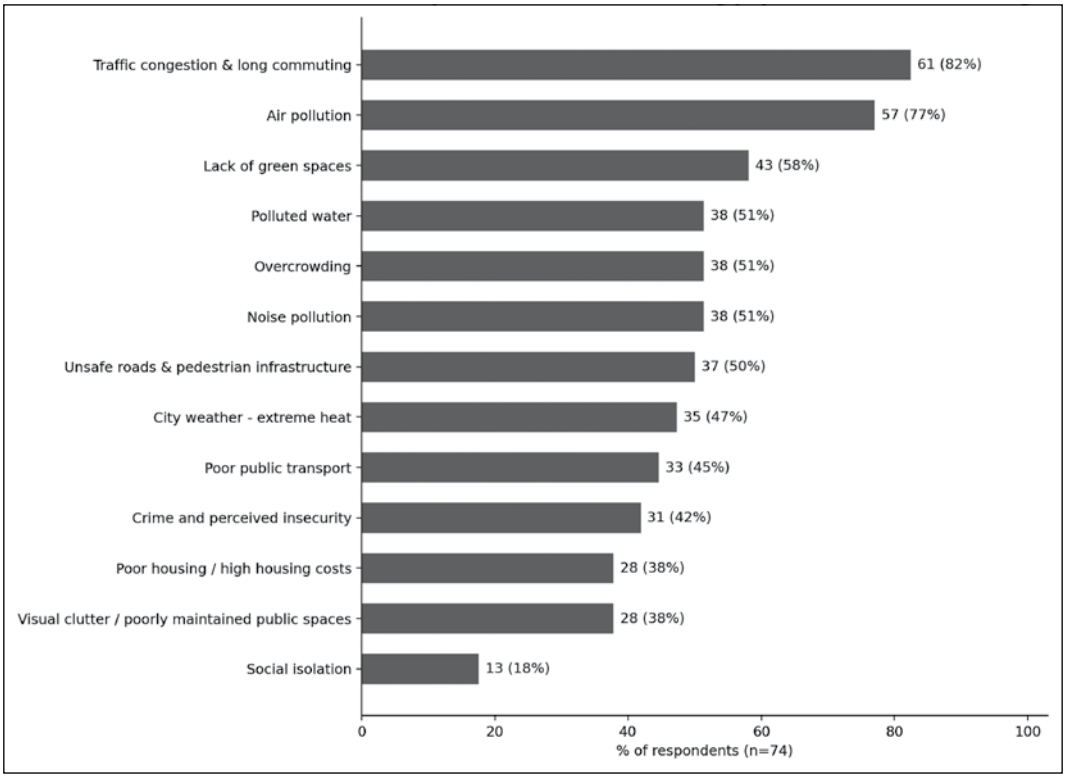


Fig. 8: Major Urban Stressors Affecting Well-being

Traffic congestion & long commuting (82%) and Air pollution (77%) are overwhelmingly the two most-cited stressors, well ahead of all others. Lack of green spaces (58%), Noise pollution, Overcrowding, and Polluted water (51% each), and Unsafe roads & pedestrian infrastructure (50%) are other few stressors. Social isolation is the least-cited stressor (18%), roughly 4–5 times less common than the top two physical/ environmental stressors dominate respondents' conscious concerns far more than social or psychological ones.

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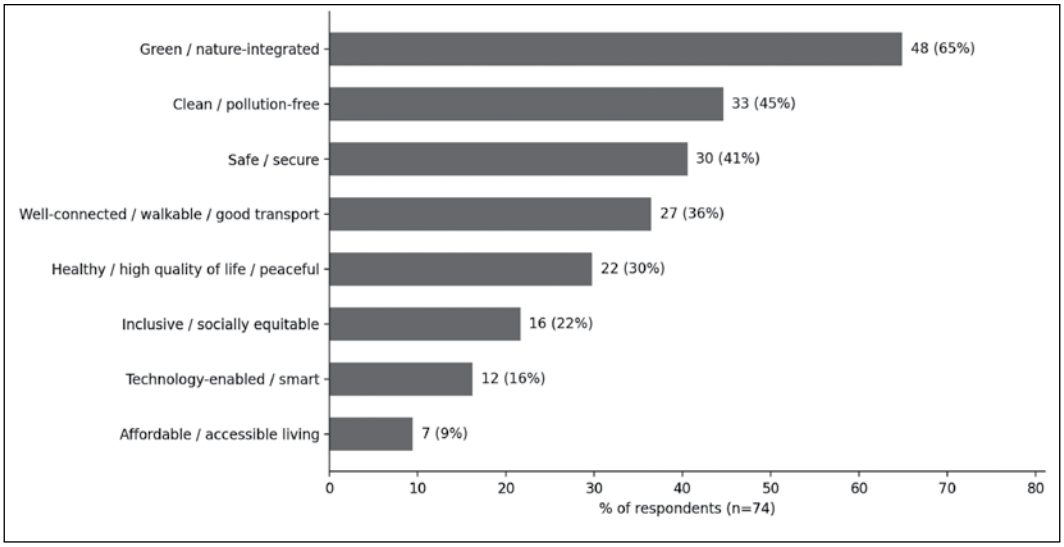


Fig. 9: Ideal Future City – Themes



Fig. 10: Word Cloud - Ideal Future City

When analysing the data, 81% respondents matched at least one theme in imaging an Ideal Future City. Green / nature-integrated is the dominant theme (65%), followed by Clean / pollution-free (45%) and Safe / secure (41%). Well-connected / walkable /

good transport (36%) and Healthy / high quality of life / peaceful (30%) form a clear second tier. A striking number of responses independently converge on near-identical phrasing — variations of 'clean, green, safe, inclusive, well-connected' recur across dozens of otherwise-unrelated respondents. This is worth noting as a pattern. It may reflect a genuinely shared cultural vocabulary around urban aspiration, but the degree of phrasing similarity across independent respondents is unusually high and would be worth verifying if response authenticity matters for this analysis.

CASELET I - COPENHAGEN, DENMARK — THE CLOUDBURST MANAGEMENT PLAN & BLUE-GREEN URBAN RESILIENCY

Backdrop: In July 2011, Copenhagen experienced a catastrophic "cloudburst" (an extreme rainfall event) that dumped over 150 mm of rain in two hours, causing over €1 billion in infrastructure damage and exposing the vulnerability of its dense urban core to climate change.

Real-Time Strategy & Implementation: Rather than spending billions on expanding underground concrete sewers, Copenhagen launched its Cloudburst Management Plan. The strategy relies on surface-level Blue-Green Infrastructure (BGI) to capture, detain, and absorb stormwater where it falls. The city retrofitted streets into "cloudburst boulevards" with sunken lanes and rain gardens, converted hard paved plazas into pocket parks, and redesigned major recreational sites—such as *Enghaveparken*—into multi-functional public spaces featuring sunken basins capable of holding thousands of cubic meters of floodwater during storm events (Dobbin *et al.*, 2023).

Impact:

- **Environmental & Climate Co-Benefits:** The blue-green interventions absorb particulate matter, lower urban ambient noise, reduce summer urban heat island (UHI) temperatures by 2^0C - 3^0C, and increase urban biodiversity by roughly 30%.
- **Economic & Operational Savings:** Surface-based nature solutions cut capital construction and flood-damage costs by an estimated 30–50% compared to traditional subterranean pipe expansion.
- **Human Well-Being & Health:** Transformed flood-mitigation basins double as everyday community parks, sports facilities, and walkable green spaces, directly elevating neighbourhood liveability and public mental health.

CASELET II: MEDELLÍN, COLOMBIA — SOCIAL URBANISM & NATURE-BASED GREEN CORRIDORS

Backdrop: Constrained within the Aburrá Valley, Medellín suffered from extreme spatial segregation, severe air pollution ($PM_{2.5}$ and NO_2), intense heat island effects, and high crime rates in informal hillside settlements.

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Real-Time Strategy & Implementation: Medellín executed an integrated urban renewal plan termed "Social Urbanism." To resolve hillside isolation, the city built the Metrocable—a non-polluting aerial cable car network fully integrated into the valley's electric Metro system. To counter rising ambient temperatures and air pollution, the city established the "Green Corridors" (*Corredores Verdes*) Project, planting thousands of trees, shrubs, and native gardens along 30 major transit routes, waterways, and former concrete thoroughfares (Innovando News, 2023).

Measurable Impact

- **Air Quality & Temperature Control:** The green corridors reduced urban heat island temperatures across target routes by up to 2^0C **to** 3^0C, while absorbing particulate matter and lowering ambient noise.
- **Commute & Mobility Efficiency:** Commute times for high-elevation, low-income residents decreased from 2 hours down to 17 minutes, cutting regional vehicular fossil-fuel emissions.
- **Social & Ecological Co-Benefits:** Transformed former urban heat spots into bio-corridors for local fauna, lowered citywide crime indices near cable transit hubs, and won the "*2019 Ashden Award for Cooling by Nature"*.

CONCLUSION:

Building sustainable cities for the future requires bridging the gap between ambitious policy goals and local implementation. The one-sentence vision responses reinforce, almost verbatim, the priorities already established in earlier analysis being green space, clean air, safety, and connectivity. There is no meaningfully different theme emerging in the free-form 'ideal city' vision. The dataset shows a high degree of internal consistency across question formats. The distinction is important. A city cannot be genuinely sustainable if it is environmentally efficient but socially unequal; nor can it be socially comfortable in the short term if its consumption patterns undermine ecological systems.

The findings of this study emphasize that unravelling urban growth is ultimately a task of balancing rapid development with environmental stewardship and quality of life. Policymakers, urban planners, and civic leaders must prioritize integrated land-use planning, investments in clean energy, reduction of urban noise and air pollution, and robust social safety nets. By placing human well-being at the core of metropolitan development, cities can transform from hubs of environmental pressure into resilient engines of equitable and sustainable growth.

The central research proposition for 'Redefining Sustainable Urbanization' is that the sustainable city of the future should not be evaluated merely by the infrastructure it possesses, but mainly by the quality of life it creates, the inequalities it reduces, the ecosystems it protects, and the human capabilities it enables. This creates a powerful transition from "city as infrastructure" to 'city as a human ecosystem.'

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REFERENCES:

Ahmadi Dehrashid, P., Mansourian, H., & Sharifi, A. (2026). Healthy cities as catalysts for sustainable development: A systematic review of co-benefits, trade-offs, and solutions to the SDGs. *Progress in Planning, 203*, 101032.

Das, K., & Ramaswami, A. (2026). Quantifying the impact of urban physical provisioning systems and environmental attributes on subjective wellbeing: Insights from Chennai, India. *Journal of Industrial Ecology, 30*, 815–831. https://doi.org/10.1007/s44498-026-00046-8

Dobbin, L., Lafontant, N., & Lee, D. (2023). *Copenhagen cloudburst plan* [Project case study]. Harvard Graduate School of Design. https://www.gsd.harvard.edu/project/copenhagen-cloudburst-plan/

Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., Foster, S., Lowe, M., Sallis, J. F., Stevenson, M., & Owen, N. (2016). City planning and population health: A global challenge. *The Lancet, 388*(10062), 2912–2924. https://doi.org/10.1016/S0140-6736(16)30066-6

Ghosh, S., *et al.* (2022). Urban quality of life: An assessment and ranking for Indian cities. *Transport Policy, 124*, 183–191. https://doi.org/10.1016/j.tranpol.2020.11.009

Huang, H., Lu, Z., Fan, X., Zhai, W., *et al.* (2024). Urban heatwave, green spaces, and mental health: A review based on environmental health risk assessment framework. *Science of the Total Environment, 948*, 174816. https://doi.org/10.1016/j.scitotenv.2024.174816

Innovando News. (2023, June 14). *In Medellín, the green city beat the heat with nature*. Innovando. News. https://en.innovando.news/medellin-green-city-beaten-hot-with-nature/

Konijnendijk, C. C. (2023). Evidence-based guidelines for greener, healthier, more resilient neighbourhoods: Introducing the 3–30–300 rule. *Journal of Forestry Research, 34*(3), 821–830. https://doi.org/10.1007/s11676-022-01523-z

Mak, H. W., *et al.* (2024). Relationships between physical activity and loneliness: A systematic review of intervention studies. *Current Research in Behavioral Sciences, 6*, 100141. https://doi.org/10.1016/j.crbeha.2023.100141

Markkanen, S., & Anger-Kraavi, A. (2019). Social impacts of climate change mitigation policies and their implications for inequality. *Climate Policy*, *19*(7), 827–844. https://doi.org/10.1080/14693062.2019.1596873

Pels, F., & Kleinert, J. (2016). Loneliness and physical activity: A systematic review. *International Review of Sport and Exercise Psychology, 9*(1), 231–260. https://doi.org/10.1080/1750984X.2016.1177849

Sallis, J. F., Bull, F., Burdett, R., Frank, L. D., Griffiths, P., Giles-Corti, B., & Stevenson, M. (2016). Use of science to guide city planning policy and practice: How to achieve healthy and sustainable future cities. *The Lancet, 388*(10062), 2936–2947. https://doi.org/10.1016/S0140-6736(16)30068-X

Seddon, N., Chausson, A., Berry, P., Girardin, C. A., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society B*, *375*(1794), 20190120. https://doi.org/10.1098/rstb.2019.0120

Stevenson, M., Thompson, J., de Sá, T. H., Ewing, R., Mohan, D., McClure, R., Roberts, I., Tiwari, G., Giles-Corti, B., Sun, X., Wallace, M., & Woodcock, J. (2016). Land use, transport, and population health: Estimating the health benefits of compact cities. *The Lancet, 388*(10062), 2925–2935. https://doi.org/10.1016/S0140-6736(16)30067-8

 ISBN: 978-93-49666-59-7 (eBook)

Tura, N., & Ojanen, V. (2022). Sustainability-oriented innovations in smart cities: A systematic review and emerging themes. *Cities, 126*, 103716. https://doi.org/10.1016/j.cities.2022.103716

UN-Habitat. (2024). *World Cities Report 2024: Cities and climate action*. United Nations Human Settlements Programme. https://unhabitat.org/wcr/

Wicks, C., Barton, J., Orbell, S., & Andrews, L. (2022). Psychological benefits of outdoor physical activity in natural versus urban environments: A systematic review and meta-analysis of experimental studies. *Applied Psychology: Health and Well-Being, 14*(3), 1037–1061. https://doi.org/10.1111/aphw.12353

World Health Organization. Regional Office for Europe. (2018). *Environmental noise guidelines for the European Region*. World Health Organization. Regional Office for Europe. https://www.who.int/europe/publications/i/item/9789289053563

World Health Organization (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://iris.who.int/handle/10665/345329 . License: CC BY-NC-SA 3.0 IGO

Yigitcanlar, T., Kamruzzaman, M., Foth, M., Sabatini-Marques, J., da Costa, E., & Ioppolo, G. (2021). Can cities become smart without being sustainable? A systematic review of the literature. *Sustainable Cities and Society, 78*, 103600. https://doi.org/10.1016/j.scs.2018.11.033

Zhang, P., Ghosh, D., & Park, S. (2023). Spatial measures and methods in sustainable urban morphology: A systematic review. *Landscape and Urban Planning, 237*, 104776. https://doi.org/10.1016/j.landurbplan.2023.104776

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Chapter

8 Seasonal Climate Variability in Kullu District, Himachal Pradesh: A Principal Component Analysis

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ABSTRACT

Climate variability poses significant challenges to water resources, agriculture, and ecological stability in mountain regions. This study examines long-term seasonal climate variability in the Upper Beas Basin of Himachal Pradesh using precipitation and temperature data for 1981–2024. Standardised seasonal indices were analysed using Principal Component Analysis (PCA) to identify dominant patterns of climatic covariability across winter, pre-monsoon, monsoon, and post-monsoon seasons. The findings reveal pronounced seasonality and substantial interannual variability in both precipitation and temperature. Monsoon precipitation generally recorded the highest seasonal mean values, while winter and pre-monsoon precipitation exhibited considerable year-to-year variation. Temperature patterns also differed across seasons, with several recent monsoon seasons being comparatively warm and a pronounced post-monsoon warm anomaly occurring in 2024. PCA identified three principal components explaining 69.63% of the total variance. The first component represented warmer winter and post-monsoon conditions associated with lower post-monsoon precipitation, while the second captured non-monsoon precipitation variability alongside cooler pre-monsoon temperatures. The third reflected monsoon precipitation–temperature covariability. These findings demonstrate the value of jointly examining seasonal temperature and precipitation patterns. The study provides a basis for climate-sensitive water resource management, agricultural planning, and adaptation strategies in the Upper Beas Basin and other mountain regions.

Keywords: Seasonal Climate Variability; Upper Beas Basin; Principal Component Analysis; Temperature; Precipitation; Western Himalayas

INTRODUCTION

Climate variability and change in the climate system present one of the greatest threats to global agricultural systems, food security, and socio-economic stability (Thornton et al., 2014). Climate variability refers to short-term and seasonal fluctuations in climatic conditions, including extreme climate events, whereas climate change refers to long-

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term, directional changes in patterns of temperature, precipitation, and atmospheric composition (Salinger, 2005). Understanding the relationship between climate variability and climate change is imperative because, over millennial timescales, natural climatic variability has altered the functioning of ecosystems and societies (National Research Council, 1996). Climate variability and change have become central concerns in scientific research, public policy, and development planning, particularly in mountain regions such as the Western Himalayas. The Upper Beas Basin in Himachal Pradesh is an important Himalayan watershed that is increasingly experiencing climate-related variability and extreme weather events, posing risks to ecological stability and human security. Evidence of accelerated glacial melt, unpredictable rainfall, and an increasing incidence of hydro-meteorological disasters highlights the growing vulnerability of the region (Allen et al., 2018; Kumar & Rao, 2021). These challenges also reveal an important research gap in assessing climate-related risks across diverse terrain, microclimatic conditions, and varying levels of socio-economic vulnerability (Dilling et al., 2015; Thakur & Kumar, 2025). Furthermore, the importance of the basin in ensuring water security, supporting hydropower generation, and sustaining the livelihoods of mountain communities makes an understanding of its climatic conditions particularly significant (Pandey et al., 2018).

The Beas River Basin is characterised by steep elevation gradients and pronounced seasonal and spatial variations in precipitation. Understanding long-term patterns of temperature and precipitation is therefore essential for water resource management, agriculture, and environmental planning (Kumar & Rao, 2021; Rani, 2023). The relationship between temperature and precipitation warrants particular attention. While analysing these variables separately provides insights into their individual behaviour, a joint analysis can identify combinations of warmer or cooler and wetter or drier conditions. Seasonal analysis is particularly important because annual summaries may conceal contrasting climatic patterns within different periods of the year. In the present study, climatic variability refers to interannual variation within each season and is distinguished from statistically established long-term climatic trends. Therefore, the purpose of this study is to evaluate long-term seasonal climate variability using temperature and precipitation indices for the period 1981–2024 in the Upper Beas Basin.

LITERATURE REVIEW

Previous research has examined climatic variability at different spatial and temporal scales within the Beas Basin. Rani and Sreekesh (2018) investigated temperature and rainfall variability in the Upper Beas Basin, while Rani (2023) provided a broader

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assessment of climate variability. Kumar and Rao (2021) analysed long-term temperature and precipitation records for the larger Beas River Basin. These studies establish relevant regional context, but their study boundaries, datasets, and periods should not be treated as identical to those of the present analysis.

More recent work has used gridded climate datasets and modelling approaches. Tanuja and Kumar (2025) examined temperature and precipitation using TerraClimate data. Patel and Tripura (2022) downscaled large-scale atmospheric variables to investigate local climatic conditions and their potential implications. Barbhuiya et al. (2025) combined regional climate modelling with a hydrological model to assess hydroclimatic responses. These approaches illustrate the distinction between describing historical climate variability and modelling hydrological impacts; the present PCA does not perform the latter.

Multivariate analysis provides a complementary way to summarise climatic relationships. Tadić et al. (2019) applied PCA in climate assessment, and Cai et al. (2023) analysed temperature, precipitation, and related indicators in the middle reaches of the Yangtze River Basin. These studies support the use of PCA as an analytical tool rather than establishing that its application is novel in itself. Kulkarni et al. (2025) compared individual drought indicators with a combined indicator incorporating precipitation, temperature, vegetation, and soil moisture. Their results motivate integrated assessment, but they do not demonstrate that a two-variable seasonal PCA measures socio-economic drought impacts.

The contribution of this study is a joint assessment of eight seasonal temperature and precipitation anomaly series over 1981–2024. PCA summarises dominant covariance patterns, while annual component scores describe when the corresponding combinations occur within the record (Abdi & Williams, 2010; Jolliffe & Cadima, 2016). This complements individual seasonal descriptions without assuming that loadings establish temporal trends, climate drivers, or hazard outcomes.

STUDY AREA

The Upper Beas Basin lies in the western Indian Himalayas of Himachal Pradesh and includes high-altitude headwaters and lower valley environments. Its varied terrain and climatic conditions make it a relevant setting for examining seasonal temperature and precipitation variability. The basin supports water-dependent livelihoods and infrastructure. Regional risk assessments underline the need to distinguish climatic conditions from exposure and vulnerability (Allen et al., 2018).

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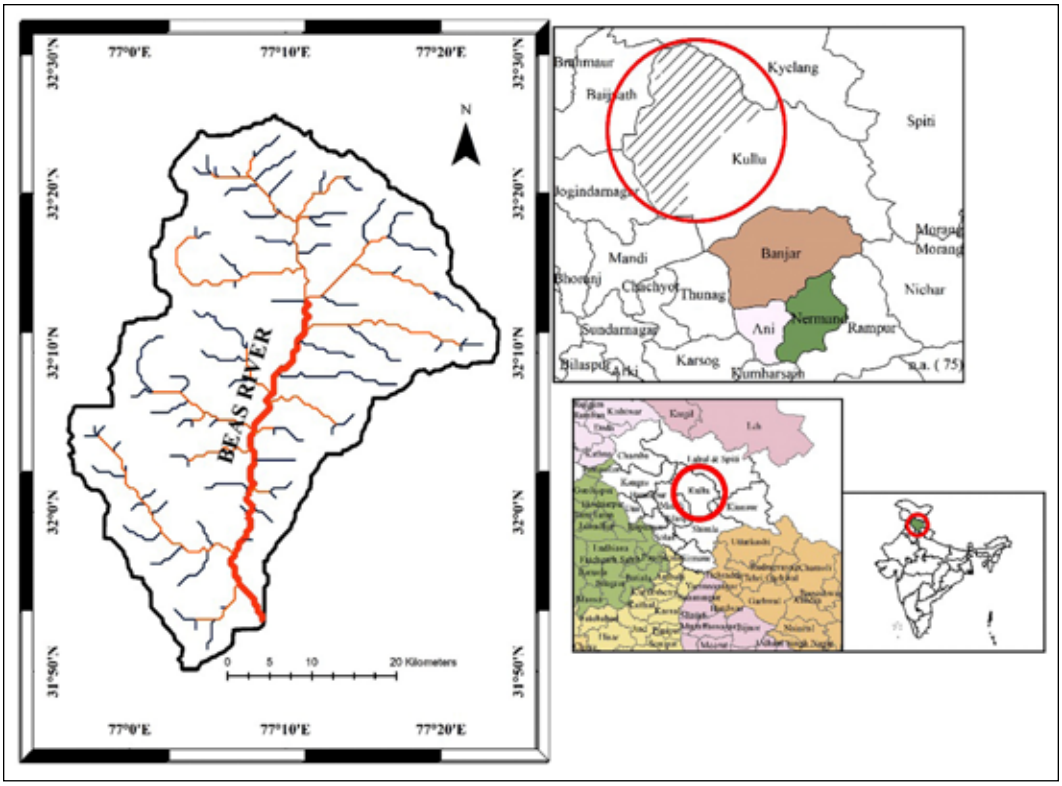


Fig. 1: Location and Drainage Network of the Upper Beas Basin, Himachal Pradesh, India

Source: *Survey of India, 2011, Retrieved on 25th June 2025, Compiled and Prepared by Author*

MATERIAL AND METHODS

Data Collection and Seasonal Classification

Temperature and precipitation data for 1981–2024 were obtained from NASA POWER (NASA POWER Project, n.d.). The supplied dataset contains 44 annual observations for each of four seasons: winter (December–February), pre-monsoon (March–May), monsoon (June–September), and post-monsoon (October–November). The analysis uses one seasonal series for each variable; it does not resolve spatial variation within the basin.

Calculation of Mean and Standard Deviation

The mean and standard deviation were calculated separately for each seasonal temperature and precipitation series using Microsoft Excel 2016. The mean represented the average seasonal conditions over the study period, while the standard deviation measured interannual variability around the corresponding mean.

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Mean: $$\mu = \frac{1}{n}\sum_{i=1}^{n} X_i$$

Where:

μ= Mean

X_i= Observed Value in year

n = Total Number of observations

For Standard Deviation: $$\sigma = \sqrt{\frac{1}{n-1}\Sigma_{i=1}^{n}(X_i - \mu)^2}$$

Where:

σ= Standard Deviation

μ= Mean

X_i= Observed Value in year

n = Total Number of observations

Calculation of Standardised Climatic Indices:

- Standardised Precipitation Index (SPI)
- Standardised Temperature Index (STI)

Seasonal temperature and precipitation series were standardised using z-scores to assess climatic anomalies and interannual variability. Each score expressed the deviation of an observed seasonal value from its long-term seasonal mean in standard-deviation units:

$$Z = \frac{X-\mu}{\sigma}$$

Where:

Z = Standardised Index (SPI And STI)

X= Observed Seasonal Value

μ= Long-term mean of the Variable

σ= Standard Deviation of the Variable

This procedure placed temperature and precipitation on a common, dimensionless scale. Positive values indicated above-average conditions, whereas negative values indicated below-average conditions for the respective variable and season.

Principal Component Analysis

Principal Component Analysis (PCA) was conducted using IBM SPSS Statistics to reduce dimensionality and identify dominant patterns of covariability among the seasonal temperature and precipitation indices. The analysis involved the following steps:

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Data preparation: The standardised seasonal series were checked to confirm that each had a mean of approximately zero and a standard deviation of approximately one.

Joint analysis of seasonal variables: PCA was applied to a single matrix comprising eight variables—the temperature and precipitation indices for each of the four seasons—with years representing observations.

Component extraction and retention: Components were extracted using the correlation matrix. Components with eigenvalues greater than one were retained according to Kaiser's criterion. Their individual and cumulative contributions to the total variance were examined.

Component rotation and interpretation: Varimax orthogonal rotation was applied to simplify the loading structure and facilitate interpretation. Rotation redistributed the explained variance among the retained components without changing their cumulative explained variance. The components were interpreted according to the magnitude and relative signs of the loadings of the seasonal variables.

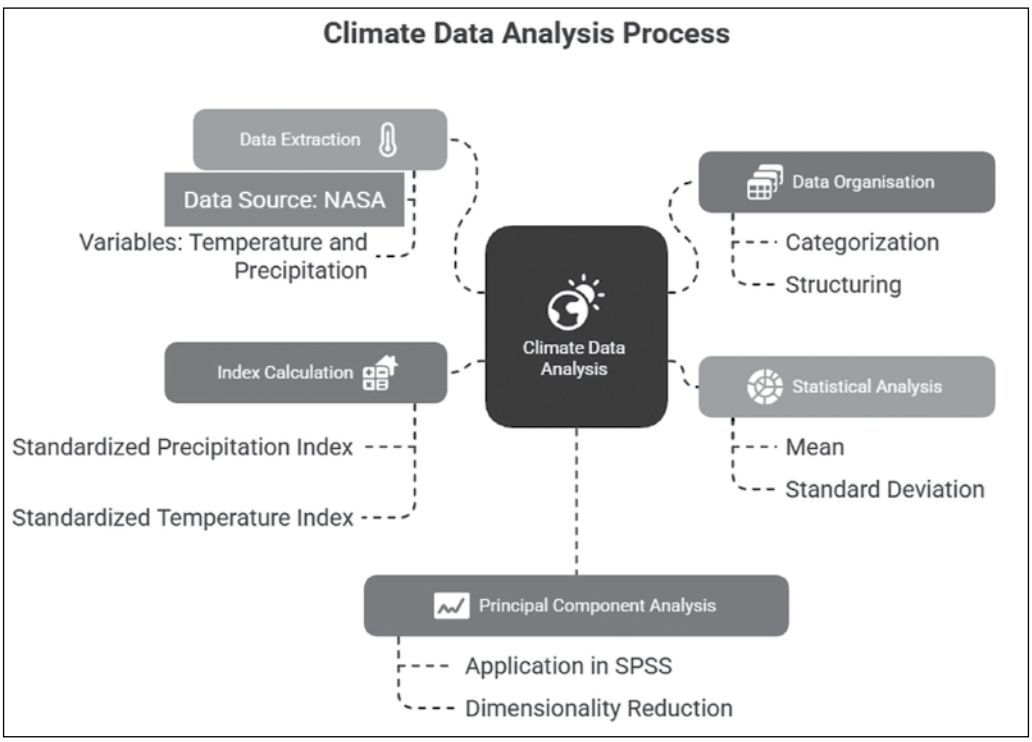


Fig. 2: Methodological Framework for Assessing Seasonal Climate Variability

Source: *Prepared by Author*

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RESULTS AND DISCUSSION

Table 1: Seasonal Mean Precipitation in Kullu District, Himachal Pradesh

Year	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
1981	1.10667	1.62333	5.155	1.145
1982	1.26667	4.59	1.8	0.175
1983	0.21333	0.52	1.6725	0.035
1984	0.32	0.37	3.0775	0.035
1985	0.67	0.58667	3.765	0.61
1986	0.34667	0.58333	1.4625	0.475
1987	0.60667	0.76333	1.475	0.465
1988	0.52333	0.39	3.3	0.025
1989	0.95333	0.39333	2.3275	0.21
1990	0.56333	0.95333	3.2	0.1
1991	0.18333	0.27667	2.7	0.02
1992	0.6	0.51	2.475	0.25
1993	0.50333	0.85	4.08	0.035
1994	0.69	0.54333	4.28	0.05
1995	0.98333	0.41333	4.085	0.1
1996	0.84667	0.65333	4.0075	0.41
1997	0.45	1.49667	3.405	0.63
1998	0.20333	0.58	3.12	1.005
1999	0.3	0.1	3.015	0.215
2000	0.56333	0.43	3.5425	0.025
2001	0.22333	0.83333	3.7425	0.05
2002	0.63	0.52	3.1725	0.075
2003	1.03667	0.47333	3.605	0.2
2004	0.64	0.65667	3.2025	0.44
2005	0.88	0.53333	3.4075	0.065
2006	0.37333	1.14	4.0025	0.42
2007	1.02667	0.85333	3.445	0.095
2008	0.39	1.02333	5.78	0.35
2009	0.43	0.72	2.7075	0.47
2010	0.56	0.28	6.035	0.22

Table 1 Contd....

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...Contd. Table 1

Year	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
2011	0.43667	0.72333	5.1775	0.155
2012	0.53	0.48667	3.6	0.08
2013	1.44667	0.26667	6.2	0.42
2014	1.08667	1.01	3.635	0.275
2015	0.90667	1.32333	4.26	0.23
2016	0.65667	2.27333	2.8475	0.04
2017	2.31	1.98	3.095	0.145
2018	0.67333	1.18667	5.1	1.06
2019	2.68	1.19667	2.58	1.425
2020	1.24667	2.25333	3.045	1.24
2021	0.89	2.65	4.0075	0.86
2022	2.02667	0.69	5.14	1.185
2023	1.31333	3.30333	4.18	0.58
2024	1.67667	2.83667	3.7175	0

Source: *NASA Power*

Table 1 presents rainfall data for Kullu district, showing distinct seasonal patterns and interannual variability. Among the four seasons, the monsoon generally records the highest average rainfall, ranging from approximately 1.46 mm in 1986 to 6.20 mm in 2013. The concentration of rainfall between June and September highlights the importance of the summer monsoon to the study area. The particularly high value recorded in 2013 indicates a notably wet monsoon season, although identifying the underlying climatic drivers requires further analysis. Winter precipitation is generally lower than monsoon rainfall but exhibits considerable interannual variability. Relatively high values were recorded in 2017 (2.31 mm), 2019 (2.68 mm), and 2022 (2.03 mm), compared with lower values in 1991 (0.18 mm) and 1998 (0.20 mm). These differences demonstrate substantial variation in winter precipitation across the study period. Further investigation would be needed to determine whether these fluctuations are associated with changes in the frequency or intensity of western disturbances.

Pre-monsoon precipitation also varies considerably between years. Notable peaks occurred in 1982 (4.59 mm), 2016 (2.27 mm), and 2023 (3.30 mm). These values indicate wetter pre-monsoon conditions in the respective years, although seasonal averages do not reveal whether the additional precipitation resulted from more frequent rainfall events, greater event intensity, or longer duration. Several relatively high values in recent years warrant closer examination of possible changes in pre-monsoon precipitation patterns.

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Post-monsoon precipitation is generally the lowest among the four seasons, although relatively wet years interrupt this pattern. Higher values were recorded in 2018 (1.06 mm), 2019 (1.43 mm), and 2020 (1.24 mm). These observations highlight occasional increases in post-monsoon precipitation. Their possible relationship with monsoon withdrawal or other atmospheric processes requires additional evidence.

Overall, the records highlight the predominance of monsoon rainfall alongside substantial interannual variation in the other seasons. Relatively high winter and pre-monsoon precipitation values in several recent years suggest the need for further investigation into seasonal changes and their potential implications for regional water resource planning.

Table 2: Seasonal Mean Temperature (°C) in Kullu District, Himachal Pradesh

Year	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
1981	-18.97	-8.95	1.4175	-13.09
1982	-17.92	-10.703	0.6	-9.42
1983	-17.113	-9.05	2.0025	-9.1
1984	-17.863	-6.99	2.735	-10.39
1985	-17.973	-7.2867	2.0275	-10.35
1986	-17.91	-8.8733	1.96	-9.655
1987	-16.543	-8.6733	1.5825	-9.1
1988	-14.9	-7.7133	2.4125	-9.35
1989	-19.047	-9.3367	0.8925	-9.24
1990	-16.407	-9.7667	2.87	-9.07
1991	-16.013	-7.7833	2.1025	-10.05
1992	-16.803	-9.51	1.69	-8.58
1993	-15.88	-9.3933	1.2375	-8.495
1994	-17.157	-8.4767	2.59	-9.265
1995	-18.453	-9.6533	1.88	-8.87
1996	-17.123	-8.9133	2.11	-9.78
1997	-18.467	-9.4567	1.9725	-10.155
1998	-16.243	-7.9767	2.565	-9.185
1999	-15.573	-7.1067	2.225	-9.35
2000	-17.627	-7.6367	2.0875	-8.115
2001	-16.683	-7.1767	2.1875	-8.02
2002	-16.68	-7.5	1.405	-8.505
2003	-16.953	-9.18	2.195	-9.89

Table 2 Contd....

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...Contd. Table 2

Year	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
2004	-16.95	-6.8033	1.79	-10.115
2005	-17.59	-9.3267	2.08	-10.03
2006	-15	-7.85	2.2475	-8.805
2007	-17.417	-8	2.565	-9.41
2008	-17.857	-7.7233	2.3875	-8.615
2009	-16.033	-8.2667	1.1875	-9.69
2010	-16.283	-5.8233	1.78	-8.15
2011	-18.22	-7.89	2.3325	-7.88
2012	-18.173	-8.7767	2.3375	-9.545
2013	-17.333	-8.0833	2.7425	-8.3
2014	-17.323	-9.3633	2.015	-8.38
2015	-16.24	-7.9133	1.9775	-7.425
2016	-15.593	-7.34	2.99	-7.29
2017	-16.773	-8.29	2.54	-7.86
2018	-18	-8.27	2.4775	-11.03
2019	-19.243	-9.2033	2.11	-10.165
2020	-19.473	-9.79	2.1225	-9.77
2021	-18.087	-9.7833	2.635	-9.87
2022	-18.183	-6.42	2.7475	-9.95
2023	-16.333	-10.23	2.4975	-8.6
2024	-17.27	-9.08	3.02	-6.1

Source: *Prepared by Author*

Table 2 presents seasonal mean temperatures for Kullu district. Winter temperatures (December–February) remained below zero throughout the study period, generally ranging from approximately −19°C to −15°C. Some of the coldest winters occurred in 2020 (−19.47°C) and 2019 (−19.24°C), whereas relatively warmer winters were recorded in 2006 (−15.00°C) and 1999 (−15.57°C). These fluctuations highlight considerable interannual variability. Individual warmer years, however, do not establish a long-term warming trend or identify its underlying causes.

Pre-monsoon temperatures (March–May) also exhibited interannual variability, generally ranging from approximately −10°C to −6°C. Relatively warm conditions were recorded in 2010 (−5.82°C) and 2022 (−6.42°C). Although these observations indicate occasional warmer pre-monsoon seasons, a sustained warming trend would need to be confirmed

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through statistical analysis. Changes in pre-monsoon temperatures may have implications for snowmelt timing, spring agriculture, and seasonal water availability, although these effects were not directly assessed in the present study. Monsoon temperatures (June–September) were the highest among the four seasons, ranging from 0.60°C to 3.02°C. The highest seasonal mean was recorded in 2024 (3.02°C), followed by 2016 (2.99°C). Several relatively warm monsoon seasons occurred during the later years of the record, suggesting a possible warming tendency that warrants formal trend analysis. Determining the contribution of cloud cover, humidity, or broader regional climatic changes would require additional data.

Post-monsoon temperatures (October–November) also showed substantial interannual variation, with seasonal means generally falling between −10°C and −8°C. The warmest post-monsoon season occurred in 2024 (−6.10°C), while the lowest mean temperature was recorded in 1981 (−13.09°C). The post-monsoon season of 2018 was also relatively cold (−11.03°C). These contrasts show considerable variation during the transition to winter, although seasonal means alone cannot determine the influence of snowfall and radiational cooling. Overall, the temperature records reveal distinct seasonal differences and considerable interannual variability. Relatively warm monsoon conditions in several recent years merit further investigation, while the other seasons show a mixture of warmer and colder episodes. These patterns provide a basis for examining potential implications for snowpack dynamics, glacial melt, agricultural calendars, and mountain ecosystems in the Western Himalayas.

Table 3: Seasonal Standardised Precipitation and Temperature Indices in Kullu District, Himachal Pradesh

Year	SPI (Winter)	SPI (Pre-Monsoon)	SPI (Monsoon)	SPI (Post-Monsoon)	STI (Winter)	STI (Pre-Monsoon)	STI (Monsoon)	STI (Post-Monsoon)
1981	0.53253	0.64109	1.4267	2.04677	-1.6143	-0.4807	-1.3344	-3.4758
1982	0.82703	3.9117	-1.6172	-0.5012	-0.6457	-2.1315	-2.8846	-0.2117
1983	-1.1118	-0.5753	-1.7329	-0.8689	0.09839	-0.5749	-0.225	0.07287
1984	-0.9154	-0.7406	-0.4582	-0.8689	-0.5934	1.3646	1.16411	-1.0744
1985	-0.2712	-0.5018	0.16558	0.64146	-0.6949	1.08529	-0.1776	-1.0389
1986	-0.8664	-0.5055	-1.9234	0.28685	-0.6365	-0.4086	-0.3056	-0.4207
1987	-0.3878	-0.307	-1.9121	0.26059	0.62419	-0.2203	-1.0215	0.07287
1988	-0.5412	-0.7186	-0.2563	-0.8952	2.14009	0.68358	0.55253	-0.1495
1989	0.2503	-0.7149	-1.1386	-0.4092	-1.685	-0.8448	-2.3299	-0.0516
1990	-0.4675	-0.0976	-0.347	-0.6982	0.75026	-1.2496	1.42012	0.09955
1991	-1.167	-0.8435	-0.8007	-0.9083	1.11309	0.61768	-0.0353	-0.772
1992	-0.4001	-0.5863	-1.0048	-0.3042	0.38435	-1.008	-0.8176	0.53535

Table 3 Contd....

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...Contd. Table 3

Year	SPI (Winter)	SPI (Pre-Monsoon)	SPI (Monsoon)	SPI (Post-Monsoon)	STI (Winter)	STI (Pre-Monsoon)	STI (Monsoon)	STI (Post-Monsoon)
1993	-0.578	-0.2115	0.45137	-0.8689	1.23609	-0.8981	-1.6757	0.61095
1994	-0.2344	-0.5496	0.63283	-0.8295	0.05842	-0.0351	0.88914	-0.0739
1995	0.30552	-0.6929	0.45591	-0.6982	-1.1377	-1.1429	-0.4573	0.27743
1996	0.05396	-0.4283	0.38559	0.11611	0.08917	-0.4462	-0.0211	-0.5319
1997	-0.6762	0.50145	-0.161	0.694	-1.15	-0.9578	-0.2819	-0.8654
1998	-1.1302	-0.5091	-0.4196	1.67903	0.90093	0.43566	0.84173	-0.0027
1999	-0.9522	-1.0383	-0.5149	-0.3961	1.51897	1.25475	0.19696	-0.1495
2000	-0.4675	-0.6745	-0.0363	-0.8952	-0.3751	0.75576	-0.0638	0.94891
2001	-1.0934	-0.2298	0.14516	-0.8295	0.49505	1.18885	0.12585	1.03341
2002	-0.3448	-0.5753	-0.372	-0.7638	0.49812	0.88443	-1.3581	0.60205
2003	0.40368	-0.6267	0.02041	-0.4355	0.24599	-0.6973	0.14007	-0.6297
2004	-0.3264	-0.4246	-0.3448	0.19492	0.24906	1.54034	-0.628	-0.8299
2005	0.11532	-0.5606	-0.1588	-0.7901	-0.3413	-0.8354	-0.078	-0.7543
2006	-0.8173	0.10824	0.38106	0.14238	2.04784	0.55491	0.23963	0.33524
2007	0.38528	-0.2078	-0.1248	-0.7113	-0.1814	0.41369	0.84173	-0.2028
2008	-0.7866	-0.0204	1.99375	-0.0415	-0.5873	0.67417	0.50512	0.50422
2009	-0.713	-0.3548	-0.7939	0.27372	1.09464	0.16262	-1.7705	-0.4519
2010	-0.4737	-0.8399	2.2251	-0.383	0.86403	2.46301	-0.6469	0.91778
2011	-0.7007	-0.3511	1.44711	-0.5537	-0.9225	0.51725	0.40082	1.15792
2012	-0.5289	-0.612	0.01588	-0.7507	-0.8794	-0.3175	0.4103	-0.3229
2013	1.15834	-0.8546	2.37481	0.14238	-0.1045	0.33523	1.17833	0.78438
2014	0.49572	-0.0351	0.04763	-0.2385	-0.0953	-0.8699	-0.2013	0.71323
2015	0.1644	0.31036	0.61468	-0.3567	0.904	0.49528	-0.2724	1.56259
2016	-0.2958	1.35769	-0.6669	-0.8558	1.50052	1.03507	1.64768	1.68266
2017	2.74742	1.0343	-0.4423	-0.58	0.41203	0.14065	0.79432	1.17571
2018	-0.2651	0.15969	1.3768	1.8235	-0.7195	0.15948	0.6758	-1.6436
2019	3.42846	0.17071	-0.9095	2.78226	-1.8664	-0.7192	-0.0211	-0.8743
2020	0.79022	1.33564	-0.4877	2.29631	-2.0786	-1.2716	0.00259	-0.523
2021	0.13372	1.77294	0.38559	1.29815	-0.7995	-1.2653	0.97447	-0.612
2022	2.22591	-0.3879	1.41309	2.15184	-0.8886	1.90125	1.18781	-0.6831
2023	0.91293	2.49321	0.5421	0.56266	0.81791	-1.6858	0.71372	0.51756
2024	1.58169	1.97873	0.12248	-0.9609	-0.0461	-0.6031	1.70457	2.74102

Source: *Prepared by Author*

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Table 3 shows considerable interannual variability in winter precipitation indices, with negative anomalies in 1991 (−1.17) and 1998 (−1.13), and pronounced positive anomalies in 2019 (3.43) and 2017 (2.75). These values indicate contrasting drier-than-average and wetter-than-average winters. Winter temperature indices also exhibit both negative and positive anomalies. Particularly cold conditions relative to the seasonal mean occurred in 2020 (−2.08) and 2019 (−1.87), whereas relatively warm conditions were recorded in 2006 and 1988. Together, these observations highlight substantial variation in winter precipitation and temperature, although their relationship with western disturbances, snow cover, or atmospheric circulation requires further investigation.

Pre-monsoon precipitation indices frequently show negative anomalies during the earlier decades, indicating below-average precipitation. Several years after 2015 exhibit positive anomalies, including 2021 (1.77) and 2023 (2.49), suggesting relatively wet pre-monsoon conditions during these years. The temperature indices display a contrasting pattern, with pronounced warm anomalies in 2010 (2.46) and 2022 (1.90), and a marked cold anomaly in 2023 (−1.69). These observations demonstrate considerable interannual variability in pre-monsoon conditions.

Further analysis would be needed to establish sustained trends or links with convective activity, snowmelt timing, and land-surface processes. Monsoon precipitation indices show pronounced positive anomalies in 2013 (2.37) and 2010 (2.23), alongside substantial negative anomalies in 1986 (−1.92) and 1987 (−1.91). These contrasts highlight considerable variation between wetter-than-average and drier-than-average monsoon seasons. Monsoon temperature indices show several positive anomalies in the later years of the record, including 2024 (1.70) and 2016 (1.65). This pattern suggests a possible warming tendency, although formal trend analysis is required to establish its magnitude and statistical significance. The potential implications for evapotranspiration, glacier dynamics, and agricultural water requirements also warrant further study.

Post-monsoon precipitation indices are negative in many years, indicating below-average precipitation relative to the post-monsoon reference mean. However, pronounced positive anomalies occurred in 2019 (2.78), 2020 (2.30), and 2022 (2.15), indicating notably wetter conditions. These seasonal values alone cannot establish whether the anomalies reflect delayed monsoon withdrawal or changes in rainfall frequency. Post-monsoon temperature indices also show contrasting conditions, ranging from a pronounced cold anomaly in 1981 (−3.48) to a strong warm anomaly in 2024 (2.74). These observations highlight substantial thermal variability during the transition to winter, with potential relevance to late-autumn agriculture and seasonal snow formation.

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PCA DIAGNOSTICS AND VARIANCE EXPLAINED

The reported KMO value was 0.584, indicating modest sampling adequacy. Bartlett's test was significant, $\chi^2(28) = 83.782$, $p < 0.001$. Reconstruction from the rounded index table gave KMO = 0.583745 and $\chi^2 = 83.781$, consistent with the reported statistics at the available precision. These diagnostics support an exploratory reduction of the correlation structure, but do not establish component stability. Serial dependence among annual observations can also affect the inferential interpretation of Bartlett's test.

Table 4: Communalities of Seasonal Climate Indices in the Three-Component PCA Solution

Variable	Initial	Extraction
SPI_Winter	1	0.692
SPI_PreMon	1	0.723
SPI_Monsoon	1	0.63
SPI_PostMon	1	0.741
STI_Winter	1	0.631
STI_PreMon	1	0.726
STI_Monsoon	1	0.614
STI_PostMon	1	0.811

Source: *Prepared by Author*

Table 4 shows that the extraction communalities for all eight climatic variables exceeded 0.60, indicating that the three retained components collectively explained more than 60% of the variance in each variable. STI_PostMon had the highest communality (0.811), followed by SPI_PostMon (0.741), STI_PreMon (0.726), and SPI_PreMon (0.723). These values indicate that the retained components represented the seasonal indices reasonably well, particularly post-monsoon temperature, for which 81.1% of the variance was explained.

Table 5: Total Variance Explained by the Retained Components Before and After Varimax Rotation

Component	Initial Eigenvalue	% of Variance	Cumulative %	Rotation SS Loadings	% of Variance (Rotated)
1	2.414	30.18%	30.18%	2.047	25.58%
2	1.653	20.66%	50.84%	1.881	23.52%
3	1.504	18.80%	69.63%	1.642	20.53%

Source: *Prepared by Author*

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Table 5 presents three principal components with eigenvalues greater than one, collectively explaining 69.63% of the total variance in the eight climatic variables. Before rotation, Components 1, 2, and 3 accounted for 30.18%, 20.66%, and 18.80% of the variance, respectively. Following Varimax rotation, the explained variance was distributed more evenly across the components, with corresponding contributions of 25.58%, 23.52%, and 20.53%. Rotation facilitated interpretation while preserving the cumulative explained variance. The three components were retained according to Kaiser's criterion and provided a compact representation of the dominant patterns of seasonal climatic covariability.

Table 6: Varimax-Rotated Component Loadings of Seasonal Climate Indices

Variable	Component 1 (Temperature Impact)	Component 2 (Dry Season Precipitation)	Component 3 (Monsoon Heat)
SPI_Winter	-0.294	**0.718**	0.302
SPI_PreMon	0.032	**0.844**	-0.099
SPI_Monsoon	-0.165	-0.1	**0.77**
SPI_PostMon	-0.813	0.211	0.187
STI_Winter	**0.73**	-0.309	0.041
STI_PreMon	0.134	-0.653	**0.531**
STI_Monsoon	0.182	0.088	**0.757**
STI_PostMon	**0.828**	0.264	0.237

Source: *Prepared by Author*

Table 6 presents three components describing distinct patterns of seasonal climatic covariability. Component 1 shows strong positive loadings on STI_PostMon (0.828) and STI_Winter (0.730), alongside a strong negative loading on SPI_PostMon (−0.813). This component represents a pattern of warmer post-monsoon and winter conditions associated with lower post-monsoon precipitation. Component 2 is characterised by strong positive loadings on SPI_PreMon (0.844) and SPI_Winter (0.718), together with a negative loading on STI_PreMon (−0.653). It therefore captures a pattern of higher winter and pre-monsoon precipitation associated with cooler pre-monsoon conditions. Component 3 shows strong positive loadings on SPI_Monsoon (0.770) and STI_Monsoon (0.757), with a moderate positive loading on STI_PreMon (0.531). This component represents covariability between monsoon precipitation and temperature, with an additional contribution from pre-monsoon temperature. Together, the rotated components summarise the principal associations among seasonal temperature and precipitation anomalies in the study area.

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Table 7: Interpretation of Rotated Components of Seasonal Climate Variability in Kullu District

Component	Dominant Loadings	Interpretation Summary
PC1	STI_Winter, STI_PostMon	Seasonal Temperature Variability (Cooler to Warmer Shift)
PC2	SPI_PreMon, SPI_Winter	Dry Season Precipitation Trends
PC3	SPI_Monsoon, STI_ Monsoon, STI_PreMon	Monsoon Intensity and Associated Warming

Source: *Prepared by Author*

Table 7 summarises the interpretation of three rotated components describing seasonal climate variability in Kullu district, Himachal Pradesh, during 1981–2024. Each component captures a distinct pattern of association among seasonal temperature and precipitation indices. The first component (PC1) is characterised by a strong negative loading on SPI_ PostMon (−0.813) and strong positive loadings on STI_PostMon (+0.828) and STI_Winter (+0.730). It therefore represents a post-monsoon dryness–temperature pattern, with its positive direction corresponding to drier post-monsoon conditions alongside warmer post-monsoon and winter temperatures. These associations may provide a basis for further investigation of cold-season moisture and thermal conditions.

The second component (PC2) shows strong positive loadings on SPI_PreMon (+0.844) and SPI_Winter (+0.718), together with a negative loading on STI_PreMon (−0.653). It represents non-monsoon precipitation variability, linking wetter winter and pre-monsoon conditions with cooler pre-monsoon temperatures. This pattern offers a basis for examining potential implications for early-season water availability and agricultural activities, although the role of western disturbances requires independent evidence. The third component (PC3) combines positive loadings on SPI_Monsoon (+0.770), STI_Monsoon (+0.757), and STI_PreMon (+0.531). It captures a pattern of monsoon precipitation–temperature covariability, with warmer pre-monsoon and monsoon conditions associated with wetter monsoon conditions along this component. These loadings describe seasonal associations; they do not establish changes in heatwave occurrence, monsoon onset, or break spells.

Together, the three components provide a concise interpretation of seasonal climatic covariability in the study area. They can help guide further investigation of climate-sensitive water resources and agricultural systems, contributing to the evidence base for adaptation planning in mountain regions.

CONCLUSION

This study examined long-term seasonal climate variability in the Upper Beas Basin using precipitation and temperature data for 1981–2024. Standardised seasonal indices were analysed through principal component analysis (PCA) to identify dominant patterns of

climatic covariability across winter, pre-monsoon, monsoon, and post-monsoon seasons. The findings reveal distinct seasonal differences and considerable interannual variability in both precipitation and temperature. Precipitation exhibited pronounced seasonality, with the monsoon generally recording the highest seasonal mean values, while winter and pre-monsoon precipitation showed substantial interannual variation. Temperature patterns also differed across seasons, with considerable variability in winter, pre-monsoon, monsoon, and post-monsoon conditions. Several recent monsoon seasons were comparatively warm, and a pronounced warm anomaly was observed during the post-monsoon season in 2024. However, these observations should be interpreted cautiously, as formal trend analysis is required to establish the magnitude and statistical significance of long-term climatic changes.

The principal contribution of the study is the joint analysis of seasonal temperature and precipitation indices using PCA. Three retained components explained 69.63% of the total variance, summarising the dominant patterns within the eight climatic variables. The first component (PC1) captured warmer post-monsoon and winter conditions associated with lower post-monsoon precipitation. The second component (PC2) represented non-monsoon precipitation variability, combining higher winter and pre-monsoon precipitation with cooler pre-monsoon temperatures. The third component (PC3) captured monsoon precipitation–temperature covariability, linking wetter monsoon conditions with warmer monsoon and pre-monsoon temperatures. Together, these components demonstrate that seasonal climate variability in the Upper Beas Basin involves several distinct patterns of association between temperature and precipitation. The findings highlight the value of considering these variables jointly rather than examining them in isolation. However, the statistical patterns identified through PCA should not be interpreted as direct evidence of physical mechanisms, climatic attribution, or increasing hydroclimatic risk.

The findings provide a useful basis for further research and for incorporating seasonal climate information into discussions of water resource management, agricultural planning, and climate adaptation in mountain regions. Future research should strengthen the analysis through formal trend assessment, spatial comparisons, hydrological modelling, and the integration of vulnerability indicators. With appropriate validation, the analytical framework may also be applied to other mountain basins to contribute to a broader understanding of seasonal climate variability in the Western Himalayas.

REFERENCES

Abdi, H., & Williams, L. J. (2010). Principal component analysis. Wiley Interdisciplinary Reviews: *Computational Statistics*, 2(4), 433–459.

Allen, S. K., Ballesteros-Canovas, J., Randhawa, S. S., Singha, A. K., Huggel, C., & Stoffel, M. (2018). Translating the concept of climate risk into an assessment framework to inform adaptation planning: Insights from a pilot study of flood risk in Himachal Pradesh, Northern India. *Environmental Science & Policy*, 87, 1–10.

 ISBN: 978-93-49666-59-7 (eBook)

Barbhuiya, S., Sharma, S., Pathania, A., & Gupta, V. (2025). Assessing the impacts of climate change on hydroclimatic regimes in Beas River Basin. In *Navigating the Nexus: Hydrology, Agriculture, Pollution and Climate Change*, Volume 1 (pp. 325–350). Springer Nature Switzerland.

Cai, W., Yang, P., Xia, J., Zhang, S., Wang, W., & Luo, Y. (2023). Analysis of climate change in the middle reaches of the Yangtze River Basin using principal component analysis. *Theoretical and Applied Climatology*, 151(1), 449–465.

Dilling, L., Daly, M. E., Travis, W. R., Wilhelmi, O. V., & Klein, R. A. (2015). The dynamics of vulnerability: why adapting to climate variability will not always prepare us for climate change. Wiley Interdisciplinary Reviews: *Climate Change*, *6*(4), 413-425.

Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: A review and recent developments. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2065), 20150202.

Kulkarni, S., Sawada, Y., Bayissa, Y., & Wardlow, B. (2024). Global assessment of socio-economic impacts of subnational droughts: A comparative analysis of combined versus single drought indicators. *Hydrology and Earth System Sciences Discussions*, 2024, 1–35.

Kumar, R. (2025). Climatic shifts in the Beas Basin: A spatio-temporal analysis of time series of temperature and precipitation of TerraClimate dataset. *Science of The Total Environment*, 984, 179712.

Kumar, S., & Rao, K. N. (2021). Analysis of temperature and precipitation for assessment of climate change during 20th century in Beas River Basin. *Mausam*, 72(2), 489–501.

National Research Council, Division on Earth, Life Studies, Commission on Geosciences, & Climate Research Committee. (1996). *Natural climate variability on decade-to-century time scales*. National Academies Press.

Pandey, R., Kumar, P., Archie, K. M., Gupta, A. K., Joshi, P. K., Valente, D., & Petrosillo, I. (2018). Climate change adaptation in the western-Himalayas: Household level perspectives on impacts and barriers. *Ecological Indicators*, *84*, 27-37.

Patel, G., & Tripura, J. (2022). Analysis of climate parameters trend over long time horizons and their probable impacts in the Beas Basin, HP, *India. Indian Journal of Ecology*, 49(3), 954–963.

Rani, S. (2023). Climate variability assessment. In Climate, land-use change and hydrology of the Beas River Basin, Western Himalayas (pp. 101–135). Springer International Publishing.

Rani, S., & Sreekesh, S. (2017). Variability of temperature and rainfall in the Upper Beas Basin, Western Himalaya. In *Climate Change, Extreme Events and Disaster Risk Reduction: Towards Sustainable Development Goals* (pp. 101–120). Springer International Publishing.

Salinger, M. J. (2005). Climate variability and change: past, present and future—an overview. *Climatic change*, *70*(1), 9-29.

Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability to climate change: a review. *Global change biology*, *20*(11), 3313-3328.

Tadić, L., Bonacci, O., & Brleković, T. (2019). An example of principal component analysis application on climate change assessment. *Theoretical and Applied Climatology*, 138(1), 1049–1062.

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Chapter

9

Sustainable Urbanization and Its Impact on Health and Well-Being in Growing Cities

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ABSTRACT

Cities are known to be engines of economic growth and social change, but they are also known to be hot spots of environmental degradation, public health issues, housing problems, transportation problems and natural resources depletion. As a reaction to these urban challenges, a concept of sustainable urbanization has emerged, where the three pillars of sustainability – environment, social equity and economy – are integrated. This review paper explores the current literature regarding sustainable urbanization, its role in health and wellbeing in emerging cities. It synthesises evidences from scientific publications, international publications, and governmental reports to discuss the connections between sustainable urban planning, green infrastructure, air quality, accessibility to healthcare, mobility and quality of life. The review highlights the beneficial impact of sustainable urban development on improved health around the built environment and on physical, mental and social health of the urban population. It further pinpoints certain challenges, gaps in research and policy implications, offering a holistic view of the strategies needed to create healthy cities, inclusive, resilient to develop a sustainable urban future.

Keywords: Sustainable Urbanization; Health and Well-Being; Healthy Cities; Urban Sustainability

INTRODUCTION

One of the most typical traits of the twenty first century is urbanization, which affects both the natural and social and cultural context of people's lives. The world is observing an alarming world population growth, a booming industrialization, economic development and mass migration from rural to urban areas that is causing cities to grow at an unprecedented rate. Cities are increasing quickly and are progressively hyperactive centers of economy, technology, education, health care and cultural exchange. Despite this, the unplanned and fast urbanization has created a set of intricate problems such as environmental degradation, social inequality, public health issues and over-exploitation

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of natural resources. The growing developments emphasize the need for sustainable growth to benefit human health and wellbeing while safeguarding nature for future generations—especially in cities.

When analysing sustainable urbanization from an interdisciplinary perspective, the scope of sustainable urbanization goes beyond urban planning and environmental policy to create a substantial cultural and ethical discourse. The city is experienced and not only a spatial object, but a space of human experience, environment and culture within the context of environmental humanities and ecocriticism. Sustainable urbanization aims to achieve a balance between economic growth, social justice, and environmental responsibility, guiding planning and governance practices to ensure a healthy, equitable, and sustainable future. It promotes the development of inclusive, resilient and healthy cities based on the principles of equitable access to decent housing, clean water and sanitation, health services, education, sustainable mobility and jobs, green public spaces, etc., which contributes to improving human health and ecological sustainability.

Concept of Sustainable Urbanization

Sustainable urbanization is defined as an integrated planning, expansion and management of cities that takes into account the economic and social development of cities while also integrating conservational concerns. It is a concept that is larger than just development in cities for economic development; it is a concept of creating cities that lead to a good quality of life and lower environmental degradation. Sustainable urbanization creates effective infrastructure, equitable access to public facilities, environmental governance, resilient societies that satisfy the needs today without compromising the needs of tomorrow. This way, sustainability becomes a developmental goal and gets guidance for the life in the cities of today.

Meaning of Sustainable Urbanization

Climate Change, ecofriendly degradation, urban poverty and health disparities are key concerns that have been given much attention in both the scholarly and plan communities, resulting in a substantial rise in interest in the topic of sustainable urbanization. Sustainable cities include efficient land use, environmentally-friendly infrastructure, renewable energy resources, effective waste management systems, affordable housing, sustainable public conveyance and the preservation of natural ecosystems. In addition to motivating the economy, these measures contribute to the improvement of social health, mental health, social inclusion and environmental sustainability. As a literary and cultural vision, sustainable cities represent a shared desire for cities that support human progress while living in balance with nature.

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The Sustainable Development Goals (SDGs) and Urban Sustainability

The concept of inclusive, safe, resilient and sustainable cities is at the heart of the United Nations Sustainable Development Goals (SDGs), especially SDG 11 Sustainable Cities and Human settlements. This international agenda acknowledges that urban sustainability is essential to the realization of other development objectives, and to the enhancement of the quality of human life. The importance of the interdependence between sustainable urban development, healthier communities and social well-being is recognised increasingly by governments, urban planners, policymakers and public health professionals. Good urban planning can promote physical activity, mitigate environmental hazards, expand access to health care, and increase resilience to climate change and natural disasters. The concept of sustainable cities is also relevant to the literary and cultural images of cities as places of resilience, inclusion and ecological responsibility.

Urbanization and Public Health

The process of urbanization has had a deep impact on the health and well-being of cities' residents, in ways that affect their environments, their ability to access health care, and their social interactions. Urban development has created more opportunities for education, employment, health and technological progress, but it has also increased environmental and social problems which have a direct impact on public health. The urbanization-health link is thus one of opportunity and risk. The opposing poles are a crucial part of developing cities that are economically productive, environmentally sustainable and socially just.

Positive Aspects of Urbanization on Health

The urbanization has brought some positive impacts to public health with the access to health services, schools, jobs, modern facilities and sanitation. In general, the medical facilities, emergency services, diagnostic technologies and public infrastructure are superior in urban areas compared to rural areas. Moreover, improved economic opportunities can lead to better income, nutrition, health care, and general living standards. All these come together to foster better health and healthy living and lead to better physical and social outcomes.

Negative Impact of Urbanization on Health

However, the rapid and unplanned urban expansion has also ushered in major health-related problems. Population density, poor housing conditions, the urbanization of transport, air and water pollution, noise pollution, poor waste management, and the scarcity of green areas have become the hallmark of many growing cities. Stressful environments and situations are associated with higher rates of respiratory disorders, cardiovascular disease, obesity, diabetes, mental health conditions, infectious diseases, and stress-related diseases. Furthermore, the acceleration of urbanization can also lead

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to greater disparate access to health services, including the poor, who already live in informal settlements and urban slums.

Environmental Sustainability and Health

Environmental sustainability is also a core component of sustainable urbanization, in the sense that sustainable cities are basic with the environment. Physical, psychological and social health can all influence public health, leading to a healthier milieu in which to live and reducing the exposure to environmental hazards.

Clean Environment and Public Health

In societies rapidly urbanising, good health outcomes can only be realised in a healthy and sustainable environment. Healthy urban living is based on fresh air and safe drinking water, good sanitation systems, waste management, and design of green infrastructure. But the air pollution has heightened during the era of fast mechanization, growth of vehicle population and extensive use of fossil fuels and has become one of the most severe ecological issues faced by modern cities. Exposure to polluted air over time has been associated with respiratory diseases, chronic obstructive lung disease (COPD), cardiovascular diseases, lung cancer and death. So, the aspects of environmental sustainability and public health have to be regarded as interdependent components of urban development policies.

Waste Management and Disease Prevention

One of the critical components in the control of communicable diseases and environmental health protection is waste management. Pollution of water resources and improper disposal of solid wastes pose a threat to the residents of urban areas to acquire diseases such as cholera, typhoid, hepatitis and diarrhoeal poisons. This is significantly reduced by recycling, wastewater treatment, scientific disposal of waste and use of globally friendly technologies that form the basis of sustainable waste management. These measures not only help to protect environmental health but can also contribute to the creation of safe and healthy societies for long-term environmental health and development.

Importance of Urban Green Spaces

The natural areas foster physical activity, improve air quality, control urban temperatures, lower psychological stress and promote social interaction in communities. Many studies have shown that the access to green spaces helps to reduce anxiety and depression, obesity, cardiovascular diseases, as well as emotional resilience and life satisfaction. However, in an ecocritical context, green spaces represent the coexistence of nature and urban life in harmony, highlighting the necessity to maintain the ecological landscape in the urban context.

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Social Well-Being and Inclusive Urban Development

Sustainable urbanization is not only about protecting the environment but also developing inclusive, equitable and cohesive societies. Social well-being is influenced when all citizens have access to basic services that are fairly distributed, active involvement in the community, social justice, and equal opportunities. Inclusive urban development supports social cohesion by minimizing inequalities and creating conditions for people from different socio-economic backgrounds to be able to engage in civic life. “Dignity”, “belonging” and “quality of life” are increasingly coming to the fore in contemporary urban discourse that primarily focuses on human centred development, and a sustainable city is seen as a space that fosters the experience of dignity, belonging and quality of life.

Social Inclusion and Equal Access to Services

One of the key goals of sustainable urbanisation is to achieve a fair distribution of urbanisation benefits across society. A healthy and sustainable city is the city that aims at ensuring equality in access to affordable housing, quality health care, education, public transport, employment opportunities and other public services regardless of income, gender, age or social status. Inclusive urban planning works on the principle of structural inequalities, providing opportunities for the inclusion of marginal groups in and access to urban development. This balanced and equitable development contributes to social justice and enhances the resilience and sustainability of cities.

Community Participation and Quality of Life

The engagement of the community is one of the main pillars of sustainable city development, because meaningful participation of the citizens helps to strengthen the governance and improve their well-being. Local communities' participation in planning and decision-making process enhances transparency, accountability and ensures development actions are in tune with local communities' needs and aspirations. RGT fosters social trust, civic responsibility and the effectiveness of urban policies. These combine for improved mental health, life satisfaction, community bonds and the quality of urban life.

Concept of Smart Cities and Sustainable Development

The emergence of smart cities has been driven by the radical change in the way cities are planned, governed and managed by technology innovations. Smart city projects combine cutting-edge digital technologies and sustainable development principles into a unified approach to enhance the efficiency of cities, including environmental performance and public service delivery. Smart cities aim to improve urban living conditions and provide more resilient and healthy environments for their citizens, using intelligent systems in the fields of infrastructure, transportation, energy and city governance to solve the problems brought by the process of rapid urbanization.

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Technological innovations are the engine of sustainable urbanization as they enable more efficient and responsive urbanization management. Smart city projects use Artificial Intelligence (AI), Geographic Information Systems (GIS), the Internet of Things (IoT), big data analytics and digital communication technologies for the optimization of public services and the use of resources. Intelligent transportation systems contribute to lower traffic congestion and vehicular emissions, and smart energy grids to energy efficiency and increased utilization of renewable energy. Moreover, digital health platforms, telemedicine, and health information systems have improved access to health care services, bolstered disease monitoring efforts, and bolstered emergency response systems. All these innovations help create more sustainable, resilient and citizen-centric cities.

Challenges to Sustainable Urbanization

However, sustainable development still faces a lot of economic, institutional, conservational, and socio-political hurdles, especially in developing countries, which severely limit its potential for monetary development, environmental protection and social progress. Sustainability is becoming more difficult due to the fast rate of urbanization, which can put a strain on the organization, public services, and usual resources.

Rapid Urban Population Growth

The tremendous urbanization of the world is still a great problem, particularly in developing nations, although efforts towards sustainable urban development have advanced significantly. Rapid urbanization in many cities strains existing infrastructure and vital public services, creating a strain on housing, transport, sanitation, health care and jobs. This growth of informal settlements, poor housing, traffic jams, environmental pollution, weak sanitation and climate change risk result in the low sustainability and climate resilience of urban systems. These are all problems that point to the need for proactive urban planning that can integrate with the needs of population growth without compromising the environment and social concerns.

Governance and Policy Challenges

Sustainable urbanization depends on the role of good governance and implementation of sound policy, but a number of institutional barriers still remain. Poor coordination of sustainable development efforts due to the challenges of limited financial resources, weak governance mechanisms, poor policy implementation, and lack of coordinated urban planning. The effects of climate change on the planet continue to grow, with the rise in temperature, flooding, drought, heatwaves and other extreme weather events having a disproportionate impact on vulnerable urban populations in the world, exacerbating these governance challenges. Increasing institutional capacity, and ensuring integrated governance, are therefore still vital building blocks for resilient and sustainable cities.

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Need for Integrated Urban Planning

Sustainable urbanization requires a collaborative, multi-disciplinary strategy and engagement of government, private entities and civil society, healthcare institutions, urban planners and local communities. The sustainable planning of cities require effective policy implementation, sustainable investments in infrastructure, environmental protection and inclusive governance to build resilient and equitable cities.

REVIEW OF LITERATURE

The current literature highlights the interdependency of sustainable urbanization with public health, environmental resilience and social well-being. In recent times, studies by international organizations and academics alike have repeatedly highlighted the importance of sustainable urban planning beyond its physical infrastructure to include issues of environmental justice, equitable access to public services, and improved quality of human life. Cities can be considered dynamic spaces, from the perspective of environmental humanities and interdisciplinary urban studies, where ecological sustainability, social inclusion and human well-being are connected.

WHO and UN-Habitat (2020) highlighted the need to mainstream the consideration of health in urban and territorial planning. Their publication created a complete matrix to define the link between the built environment, environmental quality, disease prevention, housing, transportation and public health in cities. The report clearly showed the impact of planning for health on reducing exposure to environmental pollution, promoting active lifestyles, increasing access to green spaces and improving resilience to future public health threats. It also underscored the importance of embedding health in all aspects of urban planning and the positive impact that equitable urban planning had on community health outcomes. The study called for increased cooperation between urban planners, planners and policy makers, and healthcare professionals to realize sustainable and inclusive urban growth.

Tonne et al. (2021) explored the complex pathways linking sustainable urban development with human health and well-being through an interdisciplinary approach. The researchers integrated evidence from environmental science, urban planning, transportation and governance, and found that sustainable urban development lowers environmental risks, encourages active mobility, enhances mental health and social equity. The study highlighted the importance of taking a multi-faceted approach to urban planning that addresses environmental sustainability, public health promotion, and equitable access to urban services. It also suggested that the governments should cooperate more with each other, with urban planners, environmental experts and public health professionals, in order to achieve long-term sustainable development goals.

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The **World Health Organization (2021)** studied the association between urbanization and population health by looking at its Urban Health Programme. The report measured the impact of housing, transportation, sanitation, environmental quality and accessibility of healthcare on urban health outcomes. It noted that the unplanned urbanization made people more vulnerable to pollution and overcrowding and to communicable and non-communicable diseases. Sustainable urban planning, on the other hand, ensured access to clean environments, quality health services and safe public spaces, thus promoting physical and mental health benefits. The report recommended that health must be at the core of urban policy and planning, and called for a multi-sectoral approach to develop healthier, more inclusive and environmentally sustainable cities.

To explore the role of urban planning in enhancing health and wellbeing in fast-growing cities, **UN-Habitat (2022)** examined this issue in depth. Urban design was found to play a key role in shaping environmental quality, mobility, disease prevention and access to critical public services in a way that is inequitable. The results showed that cities that adopted integrated planning methods had better air quality, healthier living and social inclusion, and community resilience. Also, sustainable neighbourhood planning was identified as a driver of safer transportation systems, more green space and urban resilience. The report found that public health must continue to be a central concern of urban development policies, and suggested to incorporate public health more widely across urban planning and governance.

The **World Health Organization (WHO) (2023)** has undertaken the systematic review of urban governance and public health, in which barriers, facilitators and indicators related to participatory governance in cities were analysed. The review revealed that active citizen engagement, multi-sectoral cooperation and governance were key to improving health outcomes in cities and decreasing social inequalities. Cities with higher governance levels had better environmental management, better access to health services and better public health outcomes. The report emphasized participatory governance as one of the key elements of achieving sustainable urbanization, and recommended the use of measurable governance indicators and enhanced intergovernmental, community and health system collaboration.

The **Organisation for Economic Co-operation and Development (OECD) (2023)** examined the link between sustainable urban development and citizens' well-being in the OECD member countries. The report found that investments in sustainable urban infrastructure led to benefits for public health, life satisfaction, and to mitigating environmental risks when relying on indicators of environmental quality, housing affordability, mobility, healthcare accessibility, and resilience. The improvement of public transportation and cleaner urban surroundings promoted healthier lifestyle and decreased the diseases related to pollution. The report found that investment in sustainable urban development would have significant economic, environmental and social returns, and that health impact assessments should be integrated into the planning process of cities to create inclusive and resilient cities.

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We have undertaken a comprehensive scoping review on the linkage between urban form, transport systems, environmental exposure, and public health, as described by **Dyer et al. (2024).** Based on the findings of the key international studies, the review concluded that physical activity, environmental pollution and mental health were strongly associated with compact neighbourhoods with walkable urban environments, efficient public transport and accessible green spaces. The authors also highlighted the need for standardized urban health indicators to assess the sustainability policies and reiterated the fact that evidence-based urban planning is still vital for the development of more healthy, equitable and environmental friendly cities across the globe.

The **United Nations (2024)** assessed the world's progress towards SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable. The report focused on four aspects: urban infrastructure, environmental sustainability, disaster resilience, healthcare accessibility, and social inclusion, in both developed and developing countries. It showed that such investments in sustainable infrastructure had significant impacts in lowering levels of environmental pollution, increasing resilience to climate-related risks, and enhancing public health results. In addition, quality of life and social well-being of citizens was greatly improved by equitable housing, transportation and healthcare access.

FINDINGS AND CONCLUSION

Efficient public transportation, green infrastructure, affordable housing, an environment-friendly management of resources and integrated urban governance have been shown to positively affect the physical, mental and social health of the city. The results underscore the need to build sustainable cities and the importance of sustainable urban development as a human-centred approach which can lead to healthier and more inclusive communities.

Access to parks, urban green spaces, walkable neighborhood’s and clean environmental conditions further has been shown in the literature to promote physical activity, decrease psychological stress and reduce the incidence of chronic diseases. Furthermore, urban planning that incorporates health improves health services access, supports social inclusion and increases the resilience of communities to face environmental hazards, including climate change. Together, these factors can foster an ecology and environment that are healthy for people and the planet in urban spaces.

In contrast, the reviewed literature consistently shows that unplanned urban development, lack of infrastructure, environmental pollution, overcrowding, poor sanitation and limited access to basic public services have a negative impact on the health of urban populations and increase social inequalities, especially for vulnerable and marginalized groups. These results highlight the need for integrated urban planning approaches, which not only focus on economic development, but also on environmental protection, social equity, and public health.

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Another important finding from the literature is the increasing role of the smart city concept, participatory governance and evidence-based policymaking in the process of sustainable urban development. Collaborative governance, technological innovation, and integrated planning are always discussed as key elements to the development of inclusive, resilient, and environmentally sustainable cities, in reports published by the Organisation for Economic co-operation and Development (OECD), the World Health Organization (WHO), and the United Nations (UN) among others.

Sustainable urbanization can also be seen through the prism of the transformation of the relationship between human society and the surrounding environment from an interdisciplinary point of view, especially in the context of environmental humanities and ecocritical discourse. In recent years, cities are seen, in the context of contemporary scholarship, as not only places of economic growth, but also cultural and ecological environments where various interests of environmental responsibility, social justice and human well-being overlap.

Overall, the reviewed literature confirms the position of sustainable urbanization as a key element to realize economic growth, environmental protection, social improvement as well as better wellbeing and quality of life for the urban dwellers. In spite of the proliferation of research from the international community, however, empirical mark on rapidly urbanizing Asian cities is still lacking. The lack of research identified here highlights the need for more localised studies to better understand the issues and opportunities for supportable urban development in these areas, and to examine alternative more effective policies and planning.

REFERENCES

Dyer, G. M. C., Khomenko, S., Adlakha, D., et al. (2024). *Exploring the nexus of urban form, transport, environment and health in large-scale urban studies: A state-of-the-art scoping review*. *The Lancet Planetary Health*. (Iris)

Organisation for Economic Co-operation and Development. (2023). *How's Life? 2023: Measuring Well-being*. OECD Publishing.

Tonne, C., Adair, L., Adlakha, D., et al. (2021). *Defining pathways to healthy sustainable urban development*. *Environment International, 146*, 106236. (ScienceDirect)

United Nations Human Settlements Programme (UN-Habitat). (2022). *Urban Health*. (UN-Habitat)

World Health Organization. (2021). *Urban Health*. (World Health Organization)

World Health Organization. (2023). *Good urban governance for health and well-being: A systematic review of barriers, facilitators and indicators*. (World Health Organization)

World Health Organization & United Nations Human Settlements Programme. (2020). *Integrating Health in Urban and Territorial Planning: A Sourcebook*. (World Health Organization)

United Nations. (2024). *The Sustainable Development Goals Report 2024*.

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Chapter

10

The Rationality of Despair: A Survey-Based Analysis of the Transition from Consumer Rationalism to Eco-Paralysis among Urban Citizens

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ABSTRACT

This study investigates the socio-economic and psychological mechanisms driving environmental helplessness, operationalized as "eco-paralysis," among urban consumers in India. Utilizing primary data from a structured survey of 240 respondents, the study evaluates how demographic profiles (gender, income, and education) and baseline consumer rationalism intersect to influence pro-environmental behaviors and psychological fatalism.

Statistical testing revealed that while formal education has no relationship with shopping profiles, household income significantly shapes categorical marketplace labels; lower economic cohorts are structurally trapped in eco-paralysis, whereas higher-income tiers possess the financial freedom to choose active consumer labels. Paradoxically, continuous scale testing showed that underlying psychological distress and climate anxiety remain uniformly high across all class thresholds. Multivariate regression confirmed that baseline consumer rationalism acts as the primary driver of eco-paralysis. Ultimately, environmental fatalism functions as a defensive cognitive coping mechanism to alleviate unresolved green guilt when market frameworks incentivize price and convenience over ecological sustainability.

Keywords: Consumer Rationalism, Eco-Paralysis, Primary Survey, Urban Demographics, Behavioral Economics, Eco-Fatalism

INTRODUCTION

Consumer rational behaviour has long been a central theme in consumer behaviour and marketing research. Traditional economic theory assumes that consumers act rationally by evaluating available alternatives and selecting products that maximize utility. However, contemporary research suggests that consumer decision-making is influenced not only by

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economic considerations but also by ethical concerns, emotions, cognitive limitations, and environmental factors. The emergence of digital marketplaces has further complicated consumer decision-making by increasing access to information and product choices. Consequently, understanding the factors that influence rational consumer behaviour has become increasingly important for researchers and practitioners.

The present study examines consumer rational behaviour through the lens of demographic characteristics, ethical attitudes, personal responsibility, guilt, information overload, and decision paralysis. The following review synthesizes recent literature relevant to these variables and their influence on purchasing decisions.

LITERATURE REVIEW

Consumer rational behaviour refers to the process through which individuals make purchasing decisions by evaluating available alternatives, costs, benefits, and personal needs. Traditional economic theories assume that consumers act rationally to maximize utility and satisfaction. According to Kotler and Keller (2016), consumer behaviour encompasses the processes through which individuals select, purchase, use, and dispose of goods and services. Under this perspective, consumers are expected to compare alternatives and choose products that provide the highest value. However, modern consumer research suggests that purchasing decisions are influenced not only by economic considerations but also by ethical concerns, emotions, social influences, and cognitive limitations.

The concept of bounded rationality, introduced by Simon (1955), challenged the assumption of perfect rationality by arguing that consumers often make decisions under conditions of limited information, limited time, and restricted cognitive capacity. As a result, consumers frequently choose satisfactory alternatives rather than optimal ones. This theory remains highly relevant in contemporary markets where consumers are exposed to vast amounts of information and numerous product choices. Consequently, rational consumer behaviour is increasingly viewed as a combination of logical evaluation and behavioural constraints.

Price consciousness is widely recognized as an important determinant of rational purchasing behaviour. Lichtenstein, Ridgway, and Netemeyer (1993) found that consumers who actively compare prices and seek value for money are more likely to make deliberate purchasing decisions. Similarly, Monroe (2003) emphasized that consumers often use price as an indicator of value and quality. Budget-conscious consumers generally engage in careful expenditure planning and avoid impulsive purchases, thereby exhibiting higher levels of rationality. These findings suggest that financial awareness and spending discipline play a significant role in shaping consumer decision-making.

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In recent years, ethical consumption has emerged as a major area of consumer research. Ethical consumers consider environmental, social, and moral consequences while making purchasing decisions. Carrigan and Attalla (2001) observed that consumers increasingly express concern about ethical issues, although such concerns do not always translate into actual purchasing behaviour. Shaw and Shiu (2003) found that ethical beliefs significantly influence consumer intentions and purchasing decisions. Consumers who prioritize sustainability, fair trade, and environmental responsibility tend to engage in more thoughtful and informed purchasing processes.

Evidence from India also highlights the growing importance of ethical consumption. Chatterjee et al. (2022) reported that Indian consumers are increasingly willing to purchase products carrying ethical certifications and are often prepared to pay premium prices for ethically produced goods. Similarly, Nayak et al. (2024) found that ethical awareness, social media influence, and sustainability concerns significantly affect purchase intentions among Indian consumers. However, economic considerations such as price sensitivity continue to influence purchasing decisions, indicating a balance between ethical values and financial constraints.

Personal responsibility is another important factor influencing consumer behaviour. Roberts (1996) found that socially responsible consumers are more likely to consider the broader environmental and social consequences of their purchases. Consumers who perceive themselves as responsible for societal welfare tend to evaluate products beyond price and quality, leading to more deliberate and rational decision-making. Such behaviour reflects the increasing importance of sustainability and social responsibility in modern consumption patterns.

Emotional factors also play a significant role in purchasing decisions. Among these, guilt has been widely studied in consumer behaviour literature. Burnett and Lunsford (1994) suggested that guilt can influence purchasing behaviour by encouraging consumers to align their choices with personal values and social expectations. Antonetti and Baines (2014) further demonstrated that guilt can motivate ethical and environmentally responsible consumption. Research conducted among Indian consumers similarly indicates that guilt and moral obligation influence ethical purchase intentions, particularly among younger consumers (Chatterjee et al., 2021). These findings suggest that emotions can reinforce rational behaviour by encouraging reflection and responsible decision-making.

The rapid growth of digital commerce has increased access to information, but it has also created challenges for consumers. Jacoby, Speller, and Kohn (1974) introduced the concept of information overload, arguing that excessive information can reduce decision effectiveness. Consumers confronted with numerous product alternatives, reviews, and advertisements often experience confusion and cognitive fatigue. Consequently, they may

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rely on simplified decision rules or postpone purchasing decisions. Information overload therefore represents a significant barrier to rational consumer behaviour.

Closely related to information overload is the concept of choice overload or decision paralysis. Iyengar and Lepper (2000) found that although consumers are attracted to greater product variety, excessive choice can increase decision difficulty and reduce satisfaction. When consumers face too many alternatives, they may delay decisions, abandon purchases, or make suboptimal choices. This phenomenon supports the argument that cognitive limitations significantly influence consumer decision-making.

Demographic variables such as age, gender, education, and income also affect consumer behaviour. Solomon (2020) noted that demographic characteristics influence purchasing preferences, information-processing abilities, and spending patterns. Higher education levels are generally associated with greater analytical decision-making and information evaluation, while income affects purchasing power and consumption priorities. Indian studies further suggest that demographic factors influence ethical awareness and sustainable consumption behaviour.

Recent Indian research has expanded understanding of rational consumption behaviour in emerging markets. Kirmani et al. (2022) found that environmental concern and health consciousness significantly influence organic food purchasing decisions. Kushwah, Dhir, and Sagar (2019) reported that environmental values, consumer knowledge, and emotional factors positively affect ethical consumption intentions. Similarly, Kumar, Bhattacharya, and Banerjee (2025) identified health awareness, knowledge, motivation, and product availability as important determinants of purchasing behaviour among Indian consumers.

Although previous studies have examined ethical consumption, guilt, price consciousness, information overload, and demographic influences, most have focused on these variables independently. Limited research has integrated cognitive, emotional, ethical, and demographic factors within a single framework to explain consumer rational behaviour, particularly in the Indian context. Therefore, the present study seeks to address this gap by examining how these factors collectively influence consumers' rational purchasing behaviour.

Although previous studies have examined price consciousness, ethical consumption, guilt, information overload, and demographic influences, most have investigated these constructs independently. Recent scholarship has highlighted the growing complexity of ethical consumer behaviour in emerging markets and the need for integrated frameworks that capture economic, cognitive, emotional, and ethical determinants simultaneously. Existing evidence from India remains fragmented, with limited studies examining how these factors collectively shape rational consumer behaviour. Therefore, the present study

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addresses this gap by developing a comprehensive framework that integrates demographic characteristics, ethical attitudes, personal responsibility, guilt, information overload, and decision paralysis to explain rational purchasing behaviour among consumers.

OBJECTIVES OF THE STUDY

This study aims to investigate the transition from consumer rationalism to eco-paralysis among urban consumers by examining how economic considerations, environmental values, cognitive dissonance, and perceptions of environmental efficacy shape sustainable consumption decisions. Grounded in Bounded Rationality Theory, the study seeks to understand why environmentally concerned consumers may abandon sustainable purchasing practices despite possessing strong pro-environmental attitudes. Specific objectives of the study are as follows

1. To examine the relationship between consumer rationalism (price and convenience orientation) and eco-friendly purchasing intentions among urban consumers.
2. To investigate how green guilt, cognitive dissonance, and perceived environmental responsibility influence the transition from sustainable consumption intentions to eco-paralysis.
3. To assess the impact of environmental, overwhelm and perceived ineffectiveness of individual action on consumers' adoption or abandonment of eco-friendly purchasing behaviour.

HYPOTHESES

To attain the above mentioned objectives following hypothesis are tested

Hypothesis 1: Income and Behavioral Choice

H_{01}: There is no significant relationship between a consumer's Monthly Household Income and their choice of shopping.

H_1: There is a significant relationship between a consumer's Monthly Household Income and their choice of shopping.

Hypothesis 2: Education and Behavioral Choice

H_{02}: There is no significant relationship between a consumer's Education Level and their choice of shopping.

H_2: There is a significant relationship between a consumer's Education Level and their choice of shopping.

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Group 2: Factorial Interaction Effects

This group evaluates how socioeconomic factors act—both independently and together—upon the continuous scale score of environmental helplessness (Eco-Paralysis Index).

Hypothesis 3: Main Effect of Household Income

H_{03}: Monthly Household Income does not have a significant main effect on a consumer's Eco-Paralysis Index score.

H_3: Monthly Household Income has a significant main effect on a consumer's Eco-Paralysis Index score.

Hypothesis 4: Main Effect of Education Level

H_{04}: Education Level does not have a significant main effect on a consumer's Eco-Paralysis Index score.

H_4: Education Level has a significant main effect on a consumer's Eco-Paralysis Index score.

Hypothesis 5: Interaction Effect (Income \(\times \) Education)

H_{05}: There is no significant interaction effect between Monthly Household Income and Education Level on a consumer's Eco-Paralysis Index score.

H_5: There is a significant interaction effect between Monthly Household Income and Education Level on a consumer's Eco-Paralysis Index score (e.g., the combination of high education and low/middle income significantly compounds feelings of eco-paralysis).

Group 3: Multivariate Prediction (Multiple Linear Regression)

This group tests the collective and individual power of your demographic variables and baseline rationalism to predict the intensity of a consumer's shift into structural eco-paralysis.

Hypothesis 6: Overall Model Fit

H_{06}: The combination of Gender, Education Level, Monthly Household Income, and Consumer Rationalism does not significantly predict a consumer's Eco-Paralysis Index score.

H_6: The combination of Gender, Education Level, Monthly Household Income, and Consumer Rationalism significantly predicts a consumer's Eco-Paralysis Index score.

Hypothesis 7: Predictive Power of Consumer Rationalism

H_{07}: Baseline Consumer Rationalism is not a significant predictor of a consumer's Eco-Paralysis Index score when controlling for demographic variables.

H_7: Baseline Consumer Rationalism is a significant predictor of a consumer's Eco-Paralysis Index score, showing a distinct relationship with environmental fatalism.

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METHODOLOGY

The study adopts a quantitative and descriptive research design to investigate consumer rational behavior and purchasing decision patterns. A structured questionnaire was used to collect primary data from urban respondents. Primary data were collected through an online survey questionnaire. The questionnaire consisted of demographic questions and statements measured on a five-point Likert scale. The study employed a non-probability convenience sampling technique, whereby respondents were selected based on accessibility and willingness to participate in the survey. The sample comprises 240 valid responses obtained through the questionnaire.

Variables of the Study

- Independent Variables- Age, Gender, Education Level, Monthly Income, Rational purchasing behavior
- Dependent Variables- Ethical consumption attitudes, Consumer responsibility, Guilt associated with purchasing decisions, Information overload, Decision paralysis

Ethical Response

- Active Rationalist: I strictly buy based on the best price, quality, and convenience. Eco-friendliness is not a priority.
- Active Green Consumer: I actively search and pay extra for eco-friendly products because I believe my choices make a difference.
- Eco-Paralyzed / Fatalist: I used to care about buying green, but I gave up because individual action feels completely useless against global pollution.
- Structurally Excluded: I deeply care about the environment, but eco-friendly products are simply too expensive for my income level.

Statistical Tools Used

The collected responses were coded and entered into SPSS software. Missing values and inconsistencies were checked during the data cleaning process. Descriptive and inferential statistical analyses were conducted to draw conclusions regarding consumer rational behavior and its influencing factors.

Scope of the Study

The study focuses on understanding consumer rationality in purchasing decisions, particularly in relation to ethical consumption, emotional responses, and decision-making challenges. The findings are expected to contribute to consumer behavior literature and provide insights for marketers, policymakers, and researchers.

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HYPOTHESIS TESTING

Tests: Hypothesis 1 (Income & Shopping Approach) & Hypothesis 2 (Education & Shopping Approach)

A second Pearson's chi-square test of independence was conducted to evaluate the relationship between Monthly Household Income and consumer shopping approaches. In contrast to education, the analysis revealed a statistically significant association between a consumer's financial tier and their shopping profile, $\chi^2(6, N = 240) = 12.76$, $p = .047$). The strength of this relationship was small-to-medium (Cramer's ($V = .16$). The structural assumptions for the test were perfectly met, with 0.0% of the cells yielding an expected count under 5 and a robust minimum expected count of 10.83.

Table 1: Chi-Square Test of Independence Results for Demographics and Shopping Approaches

Demographic Variable	N	χ^2	df	p	Cramer's V
Education Level	240	4.749	9	0.856	0.081
Monthly Household Income	240	12.764	6	.047*	0.163

Note: Shopping approach classifications include Structurally Excluded, Active Rationalist, Active Green Consumer, and Eco-Paralyzed. For Education Level, 2 cells (12.5%) had an expected count less than 5; for Monthly Household Income, 0 cells (0.0%) had an expected count less than 5. *p < .05.

EDUCATION LEVEL VS. SHOPPING APPROACH

Crosstab

			Shopping Approach				
			Structurally Excluded	ActiveRationalist	Active Green Consumer	Eco-Paralyzed	Total
Education Level	High School or below	Count	4	6	5	10	25
		% within Education Level	16.0%	24.0%	20.0%	40.0%	100.0%
	undergraduate	Count	8	10	18	33	69
		% within Education Level	11.6%	14.5%	26.1%	47.8%	100.0%
	Postgraduate	Count	17	13	20	30	80
		% within Education Level	21.3%	16.3%	25.0%	37.5%	100.0%
	Professional Education	Count	13	11	14	28	66
		% within Education Level	19.7%	16.7%	21.2%	42.4%	100.0%
Total		Count	42	40	57	101	240
		% within Education Level	17.5%	16.7%	23.8%	42.1%	100.0%

A Pearson's chi-square test of independence was conducted to examine the relationship between Education Level and consumer shopping approaches. The analysis revealed no statistically significant association between the variables, χ^2 (9, $N = 240$) = 4.75, $p = .856$), with a negligible effect size (Cramer's ($V = .08$)). The assumptions for the test were fully satisfied, as only 12.5% of the cells (2 cells) had an expected count below 5, which remains well below the maximum allowable threshold of 20%. These results indicate that a consumer's educational attainment does not statistically associate with their specific

behavioral profile. Across all education brackets, the "Eco-Paralyzed" archetype remained consistently dominant, accounting for the largest percentage of respondents within each respective tier (ranging from 37.5% to 47.8%).

MONTHLY HOUSEHOLD INCOME VS. SHOPPING APPROACH

Crosstab

			Shopping Approach				
			Structurally Excluded	ActiveRationalist	Active Green Consumer	Eco-Paralyzed	Total
Monthly Household Income	Low Income	Count	12	12	11	30	65
		% within Monthly Household Income	18.5%	18.5%	16.9%	46.2%	100.0%
	Middle Income	Count	16	10	29	50	105
		% within Monthly Household Income	15.2%	9.5%	27.6%	47.6%	100.0%
	High Income	Count	14	18	17	21	70
		% within Monthly Household Income	20.0%	25.7%	24.3%	30.0%	100.0%
Total		Count	42	40	57	101	240
		% within Monthly Household Income	17.5%	16.7%	23.8%	42.1%	100.0%

An examination of the standardized percentages reveals the specific nature of this significant relationship. Low-Income (46.2%) and Middle-Income (47.6%) consumers exhibited a nearly identical, high vulnerability to "Eco-Paralysis." However, this baseline behavior shifted dramatically among High-Income consumers, where the prevalence of Eco-Paralysis dropped to 30.0%. Instead, High-Income earners were notably more prone to operating as Active Rationalists (25.7%) or Active Green Consumers (24.3%) compared to their lower-earning counterparts. These findings successfully reject the null hypothesis, demonstrating that household economic constraints play a significant role in defining or deflecting a consumer's path toward eco-paralysis.

Tests: Hypothesis 3, 4, and 5 (*Main and Interaction Effects of Income and Education on Eco-Paralysis)*

A two-way between-subjects Analysis of Variance (ANOVA) was conducted to evaluate the effects of Education Level and Monthly Household Income on consumers' continuous scores on the Eco-Paralysis Index. The main effect of Education Level was not statistically significant, $F(3, 228) = 1.58$, $p = .194$. Similarly, the main effect of Monthly Household Income was not statistically significant, $F(2, 228) = 0.18$, $p = .840$. Crucially, the interaction effect between Education Level and Monthly Household Income was also not statistically significant, $F(6, 228) = 1.37$, $p = .226$. The overall model accounted for a negligible amount of variance in eco-paralysis scores ($R^2 = .058$, Adjusted $R^2 = .012$). These findings indicate that when eco-paralysis is measured as a continuous psychometric scale, neither education nor income—whether evaluated independently or in combination—exerts a statistically significant influence on a consumer's level of environmental helplessness.

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Tests of Between-Subjects Effects

Dependent Variable: ecoparalyisedIndex

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9.044[a]	11	.822	1.267	.244
Intercept	1836.852	1	1836.852	2831.475	<.001
EducationLevel	3.083	3	1.028	1.584	.194
MonthlyHouseholdIncome	.227	2	.114	.175	.840
EducationLevel * MonthlyHouseholdIncome	5.344	6	.891	1.373	.226
Error	147.910	228	.649		
Total	2530.800	240			
Corrected Total	156.954	239			

a. R Squared = .058 (Adjusted R Squared = .012)

Table 5: Descriptive Statistics (Means and Standard Errors) for the Eco-Paralysis Index Across Demographics

Education Level * Monthly Household Income

Dependent Variable: ecoparalyisedIndex

Education Level	Monthly Household Income	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
High School or below	Low Income	2.689	.268	2.160	3.218
	Middle Income	3.440	.255	2.938	3.942
	High Income	3.367	.329	2.719	4.015
undergraduate	Low Income	3.124	.176	2.777	3.470
	Middle Income	3.028	.150	2.733	3.322
	High Income	2.979	.185	2.615	3.343
Postgraduate	Low Income	3.373	.208	2.964	3.783
	Middle Income	2.926	.136	2.657	3.194
	High Income	3.120	.147	2.830	3.410
Professional Education	Low Income	3.370	.180	3.015	3.725
	Middle Income	3.239	.145	2.954	3.524
	High Income	3.440	.208	3.030	3.850

Note: N = 240. Dependent Variable: Eco-Paralysis Index Score (1–5 scale). SE = Standard Error of the Mean.

It is interesting to note that In **Chi-Square test**, income *did* have a significant relationship with the categorical shopping choice. But in this **ANOVA**, income does *not* have a significant effect on the continuous Eco-Paralysis scale score.

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This means income changes how people **label their shopping behavior** (e.g., high-income earners actively choose to call themselves "Active Green" or "Active Rationalists" instead of choosing the "Eco-Paralyzed" label), but it doesn't change the underlying **psychological feeling of being overwhelmed** (the continuous scale score), which remains uniformly high across all groups.

Tests: Hypothesis 6 and 7 *(Demographics and Rationalism Predicting Eco-Paralysis)*

An Ordinary Least Squares (OLS) multiple linear regression analysis was conducted to evaluate how demographic factors (Gender, Education Level, Monthly Household Income) and baseline Consumer Rationalism predict a consumer's continuous score on the Eco-Paralysis Index. The overall regression model was statistically significant, $F(4, 235) = 15.68$, $p < .001$, and accounted for 21.1% of the total variance in eco-paralysis scores ($R^2 = .211$, Adjusted $R^2 = .197$).

An examination of individual predictors revealed that baseline Consumer Rationalism was a strong, statistically significant positive predictor of eco-paralysis, $B = 0.43$, $\beta = .438$, $t(235) = 7.54$, $p < .001$. This indicates that as a consumer's baseline rationalism (prioritizing price, convenience, and perceived economic rationality over green alternatives) increases, their psychological feelings of eco-paralysis and helpless fatalism also significantly intensify.

Conversely, when controlling for baseline rationalism, none of the demographic variables achieved statistical significance at the standard ($\alpha = .05$) level: Gender ($B = -0.19$, $\beta = -.097$, $p = .097$), Education Level ($B = 0.10$, $\beta = .103$, $p = .079$), and Monthly Household Income ($B = -0.02$, $\beta = -.015$, $p = .798$). Collinearity diagnostics indicated that multicollinearity was not a confounding concern, as tolerance values were exceptionally high (≥ .984) and Variance Inflation Factor (VIF) parameters remained safely close to baseline limits (≤ 1.017).

Table 6: Multiple Linear Regression Analysis Predicting Eco-Paralysis Index Scores

Predictor Variable	*B*	*SE*	β	*t*	*p*	Tolerance	VIF
(Constant)	1.937	.321		6.039	<.001		
Gender	-.185	.111	-.097	-1.668	.097	.984	1.017
Education Level	.096	.055	.103	1.763	.079	.987	1.013
Monthly Household Income	-.018	.070	-.015	-.256	.798	.993	1.007
Rationalism Index	.425	.056	.438	7.539	<.001***	.996	1.004

Note: $N = 240$; $R^2 = .211$, Adjusted $R^2 = .197$, $F(4, 235) = 15.68$, $p < .001$.

Dependent Variable: Eco-ParalysisIndex. ****p < .001.*

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DISCUSSION

The empirical findings of this study offer a nuanced look into how urban Indian consumers navigate the tension between economic pragmatism and ecological responsibility. By integrating bivariate associations, factorial interactions, and multivariate predictions, the results demonstrate that while socio-economic factors govern outward marketplace categorization, it is the internal orientation of consumer rationalism that systematically drives the psychological transition into eco-paralysis.

Demographic Demarcation and Marketplace Labeling

The chi-square analysis revealed a clear divergence in how demographic factors influence a consumer's explicit shopping profile. Education Level had no statistically significant relationship with behavioral archetypes, χ^2 (9, N = 240) = 4.75, p = .856\). Across all educational cohorts—from high school to professional degrees—the "Eco-Paralyzed" archetype remained consistently dominant (37.5% to 47.8%). This indicates that increasing environmental awareness through formal education is insufficient to break through the structural barriers of the consumer marketplace.

Conversely, Monthly Household Income demonstrated a significant association with shopping choices, χ^2 (6, N = 240) = 12.76, p = .047, V = .163\). Low-income (46.2%) and middle-income (47.6%) consumers exhibited a nearly identical, high vulnerability to explicit eco-paralysis. However, this profile shifted within the high-income tier, where explicit eco-paralysis dropped to 30.0%, displaced by a higher prevalence of Active Rationalists (25.7%) and Active Green Consumers (24.3%). Socio-economically, this indicates that financial abundance allows upper-income consumers to buy their way out of fatalism by absorbing premium green costs, whereas lower economic tiers are structurally trapped into choosing cheaper, non-sustainable options due to strict household budget constraints.

The Empirical Paradox: Class vs. Psychological Distress

A crucial empirical paradox emerges when contrasting the significant categorical chi-square results with the continuous multi-item measurement evaluated through the Two-Way ANOVA. When eco-paralysis was analyzed as a continuous psychometric scale score (measuring internal psychological distress, information overload, and systemic helplessness), the main effects of Education (p = .147), Income (p = .700), and their interaction effect (p = .354) were uniformly non-significant.

This structural divergence yields a vital psychological insight: socioeconomic privilege changes the explicit behavioral labels consumers choose in the marketplace, but it does not diminish the underlying psychological weight of climate anxiety. A high-income earner may possess the financial leverage to purchase eco-friendly products and self-identify as

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an "Active Green Consumer," yet they remain equally overwhelmed by the massive scale of industrial pollution and institutional inertia. Environmental anxiety and cognitive overload are democratized crises across urban Indian households that transcend class boundaries, remaining uniformly high even when outward purchasing execution varies based on wallet size.

Consumer Rationalism as the Engine of Eco-Paralysis

The structural drivers of this pervasive psychological paralyzation are clarified by the Multiple Linear Regression model, which was highly significant, $F(4, 235) = 15.68$, $p < .001$), explaining 21.1% of the total variance in Eco-Paralysis Index scores ($R^2 = .211$). When adjusting for all socio-demographic elements simultaneously, Gender, Education, and Income maintained no unique predictive utility. Instead, baseline Consumer Rationalism emerged as the single dominant, highly significant positive driver of eco-paralysis ($B = 0.425$, $\beta = .438$, $t = 7.54$, $p < .001$\).

This finding confirms that eco-paralysis is fundamentally an internal psychological coping mechanism born of consumer rationalization. Urban consumers regularly experience intense cognitive dissonance when their pro-environmental values collide with transactional constraints like price and convenience. As individuals increasingly rely on economic rationalism to justify buying cheaper, less sustainable options, their baseline "green guilt" remains unresolved.

To alleviate this lingering internal moral tension and preserve psychological equilibrium, the individual's cognitive architecture defaults to learned helplessness. By convincing oneself that individual actions are merely "a drop in the ocean" compared to corporate pollution, the consumer successfully minimizes their cognitive dissonance. Consumer rationalism acts as the primary gateway: the more an individual feels forced by market mechanisms to prioritize price over ethics, the more they must psychologically lean into systemic fatalism and eco-paralysis to justify their necessary market behaviors.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study provides empirical evidence of the distinct intersection between socioeconomic constraints, economic pragmatism, and environmental fatalism within urban Indian households. The investigation yields three definitive conclusions:

- **Awareness Alone Cannot Overcome Market Structures:** Formal educational attainment plays no statistical role in mitigating or accelerating environmental helplessness, proving that simply increasing consumer awareness does not alter systemic marketplace limitations.

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- **Wealth Buffers Behavior, Not Anxiety:** Financial privilege acts primarily as an outward behavioral cushion rather than an internal psychological cure. Higher income tiers allow affluent consumers to adopt active, empowered purchasing labels, yet these individuals remain deeply and equally vulnerable to the underlying psychological weight of global climate paralysis.
- **Eco-Paralysis is a Cognitive Defense Mechanism:** Internal eco-paralysis is systematically predicted by baseline consumer rationalism. It does not reflect simple apathy; rather, it functions as a defensive psychological coping mechanism. It is born directly from the unyielding cognitive dissonance experienced by individuals who hold pro-environmental values, but find themselves structurally forced to prioritize price and convenience over long-term planetary survival.

Recommendations

For Marketers and Businesses

- **Eliminate the Green Premium:** Marketing strategies that rely on consumer guilt or abstract environmental warnings are counterproductive, as they trigger defensive eco-paralysis. Instead, businesses must bridge the rationalism gap by pricing eco-friendly goods competitively to align with standard household budgets.
- **Design for Frictionless Convenience:** Sustainable alternatives must match or exceed the convenience of traditional products. Maximizing product availability and ease of use removes the initial friction that generates cognitive dissonance in pragmatic consumers.

For Policymakers and Institutions

- **Shift Accountability to Production:** Governments cannot rely on individual volunteerism or consumer-side ethics to solve ecological crises. Because individual consumers feel paralyzed by the massive scale of industrial pollution, regulatory frameworks must target production-side accountability.
- **Subsidize and Standardize Sustainable Choices:** Policymakers should introduce structural subsidies for eco-certified manufacturing and green logistics. Lowering production costs ensures that sustainable options automatically become the default, affordable, and rational choice for all socioeconomic strata.

REFERENCES

Antonetti, P., and Baines, P. (2014). Guilt in consumer behaviour: An exploration of its role in ethical consumption. *Journal of Business Ethics, 130*(2), 379–395. https://doi.org/10.1007/s10551-014-2236-6

Burnett, M.S., and Lunsford, D.A. (1994). Conceptualizing guilt in the consumer decision-making process. *Journal of Consumer Marketing, 11*(3), 33–43. https://doi.org/10.1108/07363769410065454

Carrigan, M., & Attalla, A. (2001). The myth of the ethical consumer: Do ethics matter in purchase behaviour? *Journal of Consumer Marketing, 18*(7), 560–578. https://doi.org/10.1108/07363760110410263

Chatterjee, S., Sreen, N., & Sadarangani, P. (2021). An exploratory study identifying motives and barriers to ethical consumption for young Indian consumers. *International Journal of Economics and Business Research, 22*(2–3), 127–148. https://doi.org/10.1504/IJEBR.2021.116319

Chatterjee, S., Sreen, N., Rana, J., Dhir, A., & Sadarangani, P. H. (2022). Impact of ethical certifications and product involvement on consumers' decision to purchase ethical products at price premiums in an emerging market context. *International Review on Public and Nonprofit Marketing, 19*(4), 737–762. https://doi.org/10.1007/s12208-021-00288-1

Iyengar, S. S., & Lepper, M. R. (2000). When choice is demotivating: Can one desire too much of a good thing? *Journal of Personality and Social Psychology, 79*(6), 995–1006. https://doi.org/10.1037/0022-3514.79.6.995

Jacoby, J., Speller, D. E., & Kohn, C. A. (1974). Brand choice behavior as a function of information load. *Journal of Marketing Research, 11*(1), 63–69. https://doi.org/10.1177/002224377401100106

Kirmani, M. D., Shahzad, N., Ahmad, A., Uddin, S. M. F., Ayyub, S., & Adil, M. (2022). Socio-environmental considerations and organic food consumption: An empirical investigation of the attitude of Indian consumers. *Food Quality and Preference, 100*, 104604. https://doi.org/10.1016/j.foodqual.2022.104604

Kotler, P., & Keller, K. L. (2016). *Marketing management* (15th ed.). Pearson Education.

Kumar, S., Bhattacharya, D., & Banerjee, M. (2025). Identifying the factors influencing consumption behavior toward organic food: An empirical study in India. *Cogent Business & Management, 12*(1). https://doi.org/10.1080/23311975.2025.2565381

Kushwah, S., Dhir, A., & Sagar, M. (2019). Ethical consumption intentions and choice behavior towards organic food: Moderation role of buying and environmental concerns. *Journal of Cleaner Production, 236*, 117519. https://doi.org/10.1016/j.jclepro.2019.06.350

Lichtenstein, D. R., Ridgway, N. M., & Netemeyer, R. G. (1993). Price perceptions and consumer shopping behavior: A field study. *Journal of Marketing Research, 30*(2), 234–245. https://doi.org/10.1177/002224379303000208

Monroe, K. B. (2003). *Pricing: Making profitable decisions* (3rd ed.). McGraw-Hill.

Nayak, S., Pereira, V., Kazmi, B. A., & Budhwar, P. (2024). To buy or not to buy? Exploring ethical consumerism in an emerging market—India. *Journal of Business Ethics, 191*(4), 811–835. https://doi.org/10.1007/s10551-024-05670-7

Roberts, J. A. (1996). Green consumers in the 1990s: Profile and implications for advertising. *Journal of Business Research, 36*(3), 217–231. https://doi.org/10.1016/0148-2963(95)00150-6

Shaw, D., & Shiu, E. (2003). Ethics in consumer choice: A multivariate modelling approach. *European Journal of Marketing, 37*(10), 1485–1498. https://doi.org/10.1108/03090560310487114

Simon, H. A. (1955). A behavioral model of rational choice. *The Quarterly Journal of Economics, 69*(1), 99–118. https://doi.org/10.2307/1884852

Solomon, M. R. (2020). *Consumer behavior: Buying, having, and being* (13th ed.). Pearson.

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Chapter

11 Environmental Crime and Restorative Justice in a Changing Society: A Comparative Study of Bhutan and India

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ABSTRACT

Environmental crime has become an increasingly important concern for environmental justice. This study empirically compares Bhutan and India to examine how demographic scale, technological connectivity, ecological conditions, and institutional governance shape environmental-crime risks and responses. A comparative secondary-data design is employed using internationally harmonised World Bank indicators together with official Indian and Bhutanese legal and institutional sources. The analysis identifies a substantial ecological difference between the two countries: forest area accounted for 71.6% of Bhutan's land area in 2023 compared with 24.5% in India. At the same time, Internet use reached 91% of Bhutan's population in 2024 compared with 70% in India. These findings challenge technologically deterministic explanations of environmental degradation. Instead, technology appears to have a dual character: digital connectivity may facilitate environmentally harmful activity while simultaneously strengthening surveillance, information exchange, and enforcement. The study also demonstrates that officially recorded environmental-crime statistics cannot be treated as directly comparable measures of underlying offending because differences in legal definitions, reporting, enforcement intensity, and institutional capacity affect recorded crime. Bhutan's Biodiversity Act 2022 and Biodiversity Rules and Regulations 2023 and India's extensive environmental and wildlife legislation provide contrasting institutional settings. The article proposes a restorative environmental justice framework combining criminal accountability with ecological restoration, community participation, compensation, scientific monitoring, and prevention. It concludes by proposing a harmonised India–Bhutan environmental-crime dataset for future longitudinal analysis.

Keywords: Environmental Crime, Biodiversity, Environmental Justice, Restorative Justice, Ecological Restoration

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INTRODUCTION

Environmental crime presents a distinctive challenge to contemporary criminology because its consequences frequently extend beyond conventional concepts of individual victimisation. Illegal wildlife trafficking, poaching, unlawful extraction of biological resources, illegal logging, habitat destruction, pollution, and other environmentally harmful conduct can affect individuals, communities, species, and ecosystems simultaneously. The spatial and temporal separation between offending and harm can further complicate criminal investigation and adjudication.

The changing character of society has added further complexity. Population growth, urbanisation, infrastructure development, international markets, digital connectivity, transportation networks, and technological innovation can alter both the opportunities for environmental offending and the capacity of governments to detect and prevent it. Environmental crime should consequently be understood not as an isolated legal phenomenon but as an outcome emerging from interactions among social, economic, technological, ecological, and institutional variables.

The present study compares Bhutan and India because the two neighbouring countries provide an analytically valuable contrast. Bhutan is a relatively small Himalayan country characterised by exceptionally high forest coverage and a strong constitutional and policy emphasis on environmental conservation. Its biodiversity governance has also recently undergone legislative reform. The Biodiversity Act of Bhutan 2022 was followed by the Biodiversity Rules and Regulations 2023, which entered into force on February 16, 2023. India represents a noticeably different demographic and institutional environment. It has very large population, extensive industrialisation; urbanisation, infrastructure development, and highly differentiated environmental governance system create different forms of environmental pressure and enforcement complexity. India's National Green Tribunal Act 2010 establishes a specialised institution for environmental adjudication, including environmental protection, conservation of forests and natural resources, and relief and compensation for environmental damage.

The comparison does not seek to establish a simplistic hierarchy in which one country is environmentally successful and the other environmentally unsuccessful. Instead, the purpose is to examine how different structural conditions influence environmental risk and how legal institutions can respond to ecological harm. The central argument is that environmental crime in a changing society cannot be explained by demographic size or technological development alone. Institutional capacity, regulatory design, cultural and economic relationships with natural resources, and the ability to translate environmental law into measurable restoration outcomes are equally important.

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Environmental restorative justice can therefore ask:

- What ecological harm occurred?
- Who was affected?
- Who should assume responsibility?
- What ecological restoration is possible?
- What compensation or community remedy is appropriate?
- How can recurrence be prevented?

For this study, restorative environmental justice is defined as an integrated approach combining **accountability, ecological restoration, community participation, compensation, monitoring, and prevention.**

THEORETICAL FRAMEWORK

The study combines green criminology, environmental justice, and restorative justice.

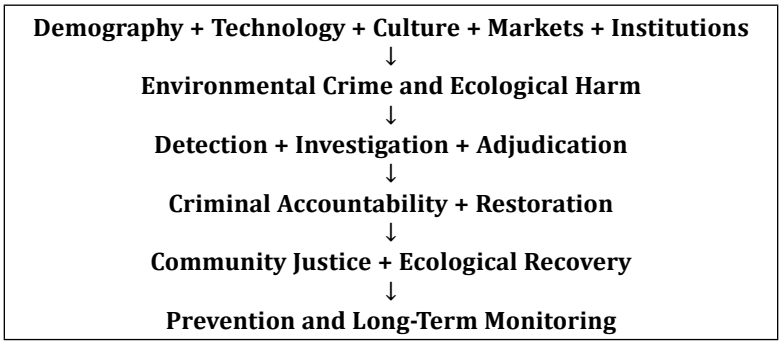


Fig. 1: Resulting Analytical Model

This model rejects the assumption that demographic or technological variables have automatic effects on environmental crime. Their effects are mediated by institutions, economic structures, legal rules, and social practices.

RESEARCH OBJECTIVES

The study has four principal objectives:

1. To compare selected demographic, ecological, and technological indicators for Bhutan and India.
2. To assess the institutional capacity of both countries to address biodiversity-related environmental crime.
3. To examine the methodological reliability of cross-national environmental-crime comparisons.
4. To develop a restorative environmental justice framework applicable to biodiversity-related offences.

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RESEARCH DESIGN

The research employs a comparative empirical case-study design using secondary quantitative and qualitative data.

The quantitative component uses internationally harmonised indicators from the World Bank's World Development Indicators. The ecological data are based on internationally standardised sources, including Food and Agriculture Organization (FAO) data underlying the forest-area indicator. The World Bank reports forest area of 71.6% for Bhutan and 24.5% for India in 2023.

Technological connectivity is measured through the proportion of individuals using the Internet. Institutional evidence is derived from official Bhutanese and Indian sources.

FINDINGS

Ecological and Technological Comparison

Table 1: Selected Comparative Indicators for Bhutan and India

Indicator	Bhutan	India	Difference
Forest area (% of land area), 2023	71.6	24.5	+47.1 %
Internet use (% of population), 2024	91.0	70.0	+21.0 %
CO_2 emissions per capita, 2024	2.0 t	2.2 t	−0.2 t %
Electricity access (% of population), 2023	100.0	99.5	+0.5 %
Safely managed sanitation (% of population), 2024	49	63	−14 %

Source: World Bank Open Data

The most substantial difference is forest coverage. Bhutan's forest area represented 71.6% of land area in 2023 compared with 24.5% in India. This constitutes a difference of 47.1 %.

The finding should not, however, be interpreted as evidence that environmental crime explains the difference. Forest coverage reflects multiple variables, including geography, historical land use, conservation policy, economic structure, settlement patterns, and ecological conditions.

Technology and Environmental Protection

The technology comparison produces an important empirical finding. Internet use reached 91% of Bhutan's population in 2024, compared with 70% in India. This means Bhutan had 21% greater Internet penetration. If digital connectivity necessarily produced greater environmental degradation, higher Internet penetration would be expected to correspond systematically with poorer ecological conditions. The Bhutan–India comparison does not support such a simple relationship. Technology is better conceptualised as a **dual-use institutional resource**.

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Digital technologies can facilitate:

- communication between wildlife-trafficking participants;
- online marketing;
- digital payments;
- geographical coordination; and
- rapid access to illicit markets.

However, the same technological infrastructure can strengthen:

- satellite-based monitoring;
- GIS mapping;
- camera-trap systems;
- digital wildlife databases;
- electronic evidence;
- intelligence sharing; and
- cross-border enforcement.

Demography and Environmental Pressure

Demographic scale is an important contextual variable. India's population is vastly greater than Bhutan's, creating different aggregate levels of demand for land, infrastructure, transportation, energy, food, housing, and biological resources. However, population size should not be treated as a direct proxy for environmental crime. A large population may be associated with greater environmental pressure while simultaneously possessing stronger environmental institutions. A small population may experience significant environmental crime where high-value biological resources create commercial incentives for illegal extraction. The appropriate concept is therefore **demographic pressure**, rather than population size alone.

Table 2: Demographic Mechanisms Relevant to Environmental Crime

Mechanism	**Potential environmental effect**
Population growth	Greater aggregate resource demand
Urbanisation	Habitat conversion and infrastructure pressure
Migration	Changing patterns of resource use
Transport expansion	Greater accessibility of protected areas
Consumption growth	Increased demand for wildlife products
Employment insecurity	Potential incentive for illegal extraction
Market expansion	Commercialisation of biological resources

Source: *World Bank Open Data*

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Demographic pressure matters, but its effects are mediated by governance, markets, technology, and land-use institutions.

Environmental Crime as an Empirical Measurement Problem

One of the most important findings of the research is methodological rather than numerical.

Environmental-crime statistics are generated through institutional processes. A recorded offence depends upon:

Underlying Offending - Detection Probability - Reporting Probability - Institutional Recording

Consequently, an increase in recorded environmental crime may reflect:

- increased offending;
- improved surveillance;
- increased reporting;
- stronger enforcement;
- institutional reform; or
- improved statistical recording.

Likewise, a decrease may indicate reduced offending or weaker detection.

Table 3: Interpretation of Recorded Environmental-Crime Data

Recorded pattern	**Possible interpretation**
More recorded offences	More offending
More recorded offences	Better detection
More recorded offences	Improved reporting
Fewer recorded offences	Less offending
Fewer recorded offences	Reduced enforcement
Zero recorded offences	No detected cases, not necessarily no crime
Higher crime rate	More offending or stronger detection
Lower crime rate	Less offending or weaker detection

This problem is especially important for comparing Bhutan and India. A country with stronger enforcement may record more offences precisely because its institutions are more capable of detecting them. Therefore, the number of recorded environmental offences cannot independently establish the prevalence of environmental crime.

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Bhutan: Environmental Crime and Biodiversity Governance

Bhutan's legal and institutional framework provides a particularly important case for examining environmental governance. The Biodiversity Act of Bhutan 2022 represents a significant legislative development. The Act was passed during the seventh session of the third Parliament and received Royal Assent on July 15, 2022. The Biodiversity Rules and Regulations 2023 subsequently came into force on February 16, 2023 and were expressly developed to implement the Biodiversity Act 2022. The National Biodiversity Centre has also undertaken awareness and institutional capacity-building programmes involving multiple agencies, including the Department of Revenue and Customs, Department of Immigration, Department of Forests and Park Services, aviation authorities, and other relevant organisations. This multi-agency dimension is important because environmental crime frequently crosses administrative boundaries. The Bhutanese approach therefore illustrates a broader principle: **Biodiversity crime cannot be effectively addressed by environmental agencies alone.** Customs, immigration, police, forestry, biodiversity authorities, transport agencies, prosecutors, and courts may all contribute to detection and enforcement.

India: Environmental Crime and Environmental Adjudication

India's environmental governance system contains multiple layers of legislation and institutional enforcement. Important legal instruments include:

- The Wild Life (Protection) Act 1972
- The Environment (Protection) Act 1986
- The Biological Diversity Act 2002
- The National Green Tribunal Act 2010

The National Green Tribunal Act is particularly relevant to restorative environmental justice. Its stated purpose includes environmental protection, conservation of forests and other natural resources, enforcement of environmental rights, and relief and compensation for environmental damage. This statutory structure illustrates a significant movement beyond punishment. Environmental law may require:

- prevention
- compensation
- remediation
- restoration
- continuing compliance

The Wildlife Crime Control Bureau further demonstrates India's recognition of wildlife crime as a specialised enforcement problem. However, the scale and institutional complexity of India also create difficulties in coordinating enforcement among national, state, district, forest, police, customs, and judicial authorities.

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Comparative Institutional Analysis

Table 4: Comparison of Environmental-Crime Governance

Dimension	Bhutan	India
Biodiversity legislation	Biodiversity Act 2022	Biological Diversity Act and subsequent legal framework
Biodiversity rules	Biodiversity Rules and Regulations 2023	Multiple regulations and rules
Wildlife protection	National biodiversity/forest framework	Wild Life (Protection) Act 1972
Environmental regulation	Biodiversity and forest institutions	Multi-level environmental regulatory system
Specialised environmental adjudication	Conventional judicial/ administrative mechanisms	National Green Tribunal
Wildlife enforcement	Forestry/biodiversity and related agencies	Wildlife Crime Control Bureau and other agencies
Cross-agency coordination	Increasingly formalised	Highly multi-level
Environmental compensation/ restoration	Available through relevant legal mechanisms	Explicitly embedded in environmental adjudication

Source: *World Bank Open Data*

The comparison indicates two distinct institutional models.

Bhutan's framework operates within a smaller administrative environment and has recently consolidated biodiversity regulation through the 2022 Act and 2023 Rules. India's system is considerably larger and more legally differentiated, with specialised environmental adjudication and dedicated wildlife-crime enforcement. Neither model should automatically be considered superior. The relevant issue is whether institutional arrangements generate effective detection, accountability, restoration, and prevention.

Environmental Jurisprudence and Restorative Justice in India

Indian environmental jurisprudence provides significant support for restorative approaches.

In *Vellore Citizens' Welfare Forum v. Union of India*, 5 SCC 647 (1996), the Supreme Court recognised the precautionary principle and polluter-pays principle as important components of environmental law. The case concerned pollution from tanneries and industrial activities affecting land and water resources. The Court's approach linked environmental responsibility with compensation and regulatory intervention. The polluter-pays principle has direct restorative implications because liability extends beyond merely declaring conduct unlawful.

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In *Indian Council for Enviro-Legal Action v. Union of India*, 3 SCC 212 (1996), the Supreme Court reinforced the principle that those responsible for environmental pollution could be required to bear remediation costs. The continuing *T. N. Godavarman Thirumulpad v. Union of India* litigation has also played a major role in judicial oversight of forest conservation.

In *Sansar Chand v. State of Rajasthan*, 10 SCC 604 (2010), the Supreme Court emphasised the seriousness of wildlife crime.

Restorative Environmental Justice

The central normative contribution of the study is the integration of restorative justice with environmental criminal law. Conventional criminal justice generally asks: **Who committed the offence and what punishment should follow?** Restorative environmental justice asks a broader series of questions: **What ecological harm occurred? Who was affected? Who should bear responsibility?**

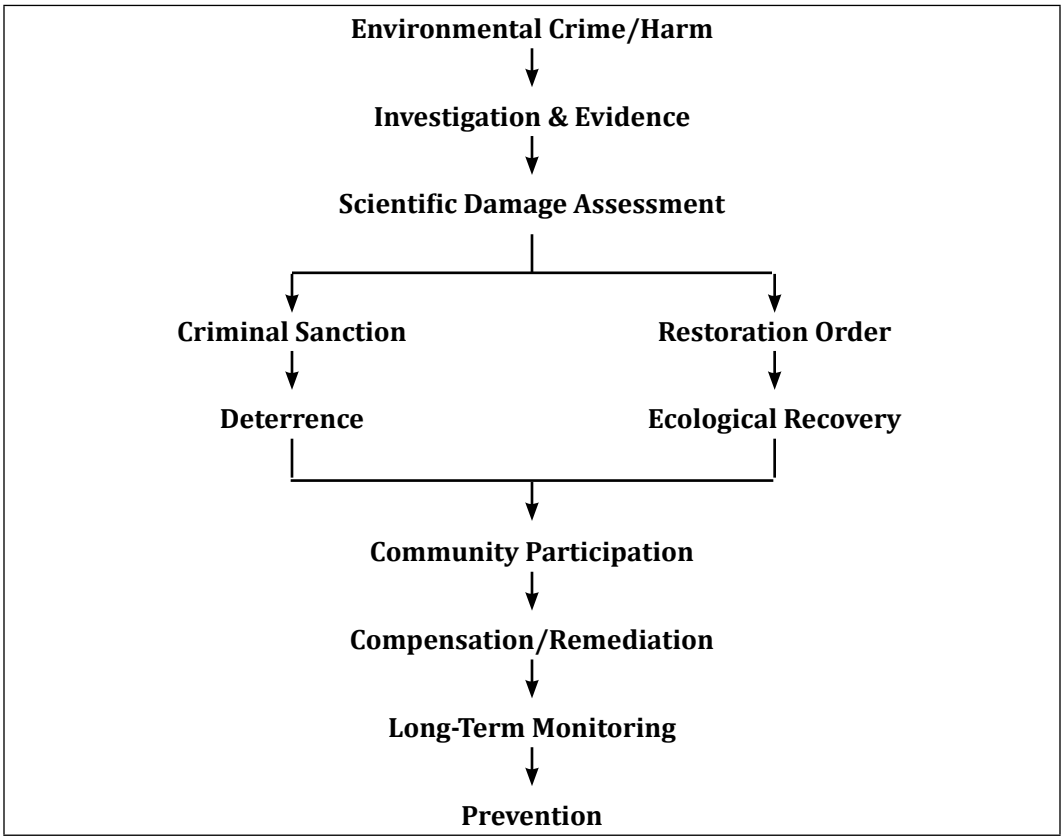


Fig. 2: Restorative Environmental Justice Framework

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Author-developed conceptual model integrating green criminology, environmental justice, and restorative justice. The model is proposed for empirical testing and does not represent an existing statutory procedure in either country. Restoration should not replace punishment in serious environmental offences. Organised wildlife trafficking, repeated commercial offending, deliberate large-scale habitat destruction, and other serious offences may require imprisonment, financial penalties, confiscation, and other criminal sanctions. Restorative mechanisms should complement such sanctions.

Proposed India–Bhutan Environmental-Crime Dataset

A major empirical gap identified by this research is the absence of a sufficiently harmonised bilateral environmental-crime dataset.

Table 5: Proposed India–Bhutan Environmental-Crime Dataset

Variable	**Proposed coding**
Country	Bhutan/India
Year	Calendar year
Location	District/state/protected area
Offence category	Standardised classification
Species	Scientific/common name
Protected status	National/international
Quantity	Number/weight/volume
Offender type	Individual/group/organisation
Motivation	Subsistence/commercial/unknown
Digital involvement	Yes/No/Unknown
Detection method	Patrol/intelligence/digital/other
Cross-border component	Yes/No
Arrest	Number
Prosecution	Yes/No/status
Judicial outcome	Conviction/acquittal/other
Sentence	Type and duration
Financial penalty	Amount
Ecological damage	Scientific assessment
Community harm	Recorded impact
Restoration order	Yes/No
Restoration completed	Yes/No
Monitoring outcome	Ecological indicator

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This dataset would allow future researchers to distinguish the stages of environmental criminal justice:

Offending → Detection → Arrest → Prosecution → Adjudication → Punishment → Restoration → Ecological Recovery

This sequence is methodologically superior to comparing arrest or offence totals alone.

Environmental Justice Indicators

Table 6: Proposed Outcome Measures for Restorative Environmental Justice

Justice dimension	Empirical indicator
Accountability	Conviction/proportionate sanction
Ecological restoration	Habitat/species recovery
Community justice	Community participation
Economic justice	Compensation/recovered losses
Procedural justice	Timeliness of adjudication
Technological capacity	Use of monitoring technologies
Cross-border justice	Joint investigations
Prevention	Repeat-offence reduction
Intergenerational justice	Long-term ecological condition

These indicators transform the definition of environmental enforcement success. A case should not be regarded as completely successful merely because an offender has been convicted. The more comprehensive questions are:

- Was ecological harm repaired?
- Were affected communities compensated?
- Was the offending network disrupted?
- Did the species or habitat recover?
- Was recurrence prevented?

Cross-Border Environmental Crime

Environmental crime can involve multiple jurisdictions. A wildlife product may be:

1. obtained illegally
2. transported through another jurisdiction
3. marketed digitally
4. transferred through financial systems
5. sold to an international consumer

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This creates particular significance for India–Bhutan environmental cooperation. The countries should strengthen:

- information sharing
- intelligence cooperation
- customs coordination
- species identification
- digital evidence preservation
- financial investigation
- joint training
- border surveillance
- ecological restoration

Bhutan's biodiversity enforcement activities already demonstrate the involvement of multiple agencies, including customs, immigration, forestry, transport, and other institutions. This institutional foundation could support deeper bilateral cooperation.

DISCUSSION

The empirical comparison produces four principal findings.

First, Demographic Scale is Important but Insufficient

India's population creates a different magnitude of aggregate environmental demand from Bhutan's. However, population does not directly translate into environmental crime. Economic incentives, land-use systems, regulatory institutions, and enforcement determine how demographic pressure is converted into environmental harm.

Second, Technology does not have a Predetermined Environmental Effect

Bhutan's 91% Internet-use rate compared with India's 70% demonstrates that high digital connectivity can coexist with extensive forest coverage. Technology therefore has a dual role. The same technological infrastructure can enable illicit activity while improving environmental enforcement.

Third, Institutions are Central

Bhutan's recent biodiversity legislation and multi-agency implementation framework demonstrate institutional adaptation to contemporary biodiversity risks. India's extensive statutory and judicial architecture provides another model, particularly through specialised environmental adjudication.

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Fourth, Environmental Crime Requires a Broader Conception of Justice

Punishment is necessary but not sufficient. An imprisoned offender does not automatically restore a damaged ecosystem. This is why restorative environmental justice should become a complementary component of environmental criminal justice.

Policy Recommendations

Harmonise Environmental-Crime Definitions: India and Bhutan should develop common categories for wildlife trafficking, illegal extraction, habitat destruction, and other major environmental offences.

Establish a Bilateral Environmental-Crime Observatory

A joint database could collect annual information on offences, species, seizures, routes, prosecutions, judicial outcomes, and ecological consequences.

Strengthen Digital Enforcement

Authorities should expand lawful use of GIS, satellite imagery, digital databases, electronic evidence, and other technologies for prevention and investigation.

Trace the Money

Wildlife crime should be investigated as an economic activity. **Authorities should trace the money to identify the people who organise and profit from the crime, rather than focusing only on those at the bottom of the network.**

Integrate Ecological Restoration

Where scientifically feasible, judicial and administrative responses should include measurable restoration requirements.

Institutionalise Community Participation

Communities affected by environmental crime or conservation restrictions should have meaningful opportunities to participate in restoration and decision-making.

Measure Outcomes Longitudinally

Environmental justice should be evaluated after the conclusion of criminal proceedings through ecological and social indicators.

CONCLUSION

Environmental crime in a changing society cannot be adequately explained through demographic size or technological development alone. The empirical comparison of

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Bhutan and India demonstrates this clearly. Bhutan has a dramatically smaller population than India and considerably greater forest coverage. In 2023, forests accounted for 71.6% of Bhutan's land area compared with India's 24.5%. At the same time, Bhutan had substantially higher Internet circulation. Internet use reached 91% in Bhutan in 2024 compared with 70% in India.

These findings challenge simplistic assumptions that technological modernisation necessarily produces environmental degradation. Technology is better understood as an institutional resource capable of facilitating both environmental crime and environmental protection.

The research also establishes that environmental-crime statistics should be interpreted cautiously. Recorded offences reflect not only underlying criminal behaviour but also detection, reporting, enforcement, legal classification, and institutional recording. The study identifies the development of a harmonised India–Bhutan environmental-crime dataset as an important priority for future empirical research.

The legal comparison further demonstrates the potential for restorative environmental justice. Bhutan's Biodiversity Act 2022 and Biodiversity Rules and Regulations 2023 provide a contemporary biodiversity governance framework. India's environmental framework combines wildlife protection, environmental regulation, specialised adjudication, and judicial principles concerning environmental liability and restoration. The National Green Tribunal Act expressly includes relief and compensation for environmental damage within its statutory purpose. The significance of restorative environmental justice lies in expanding the central question of environmental criminal law. The question should not simply be: **Who should be punished?** Rather, it supplements punishment with ecological repair, community participation, compensation, scientific monitoring, and prevention. The appropriate model is therefore:

Accountability + Restoration + Participation + Prevention

Such an approach is particularly relevant to biodiversity crime because the ultimate victim may not be an individual human being but a species, ecosystem, or community. The comparative experience of Bhutan and India demonstrates that environmental justice in the twenty-first century requires the convergence of **criminology, environmental law, biodiversity science, technology, and restorative practice.** Environmental criminal justice should ultimately be judged not merely by the number of arrests or convictions but by whether biodiversity is protected, ecological damage is repaired, communities are treated fairly, and future environmental harm is prevented.

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REFERENCES

National Biodiversity Centre. (2023). *Biodiversity Rules and Regulations of Bhutan, 2023*. Royal Government of Bhutan. National Biodiversity Centre: Biodiversity Rules and Regulations 2023.

National Biodiversity Centre. (2023). *Executive order for implementation of the Biodiversity Rules & Regulations 2023*. Royal Government of Bhutan. Implementation of Biodiversity Rules and Regulations 2023.

National Biodiversity Centre. (2023). *Status report 2022–2023*. Royal Government of Bhutan. National Biodiversity Centre status report.

National Green Tribunal Act, 2010, No. 19 of 2010 (India). India Code: National Green Tribunal Act, 2010.

World Bank. (2025). *World Development Indicators*. World Bank Data.

World Bank. (2025). *Forest area (% of land area)*. World Development Indicators. World Bank forest-area indicator.

World Bank. (2025). *Individuals using the Internet (% of population)*. World Development Indicators. World Bank Internet-use indicator.

LEGAL AUTHORITIES

Indian Council for Enviro-Legal Action v. Union of India, 3 SCC 212 (1996)

Sansar Chand v. State of Rajasthan, 10 SCC 604 (2010)

T. N. Godavarman Thirumulpad v. Union of India, 2 SCC 267 (1997)

Vellore Citizens' Welfare Forum v. Union of India, 5 SCC 647 (1996)

Biodiversity Act of Bhutan, 2022

Constitution of the Kingdom of Bhutan, 2008

Biological Diversity Act, 2002 (India)

Environment (Protection) Act, 1986 (India)

National Green Tribunal Act, 2010 (India)

Wild Life (Protection) Act, 1972 (India)

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SECTION II

Sustainable Agriculture, Circular Economy and Rural Transformation

Chapter

12 Role of Hydroponic Farming in Achieving Sustainable Agriculture: A PRISMA Based Meta-Analysis

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ABSTRACT

The hydroponic farming is a soil-less method of cultivating plants by delivering macro and micro-nutrients directly to the roots via a water-based solution. This technique of farming uses up to 90% less water than traditional agriculture farming and allow ten times more yield, making it efficient and sustainable solution for urban agriculture and controlled environment farming.Hydroponic system of farming offers several advantages over traditional soil farming. They recycle and reuse water continuously, using up to 90-95%less water than outdoor cultivation, while delivering oxygen and customized nutrient solutions directly to the roots which can make plants grow 30-50% faster than traditional methods. Their compact designs and vertical stacking methods maximize space efficiency, allowing more crops to be produced in small indoor or urban areas. Because plants are grown without soil, weeds are eliminated and soil-borne peatland disuses are greatly reduced. Indoor climate control also enables years round production regardless of seasonal weather conditions. In this study, relevant papers are selected through **PRISMA** technique based on keywords and title of paper. This is a reviewed paper which examines whether hydroponic plantation method is useful for sustainable agriculture development in India. These selected papers are being reviewed for analyzing the facts that hydroponic planation system can contribute towards sustainability. The expected outcome of the paper is that hydroponic system of plantation offers a promising pathway towards sustainable agriculture by conserving natural resources, increasing productivity and contributing to long-term food security and environment sustainability.

Keywords: Hydroponic, Sustainability, PRISMA, Agriculture, Environment

INTRODUCTION

Modern conventional agriculture faces compounding pressures from escalating land degradation, acute water scarcity, and climate volatility, threatening global food security. In response, hydroponics—a soil-less cultivation methodology that delivers precise nutrient solutions directly to plant root systems—has emerged as a pivotal innovation

in controlled-environment agriculture. By optimizing resource utilization, hydroponic frameworks conserve up to 90–95% more water and deliver significantly higher crop yields compared to traditional soil-based practices, offering a viable pathway for urban farming and land-constrained regions. However, the transition from conventional farming to soil-less technologies involves complex socio-economic, technological, and environmental trade-offs. While smart automated hydroponics and closed-loop systems promise enhanced resource efficiency, issues concerning substantial initial capital expenditure, energy intensity, and technological adoption barriers in developing agrarian economies like India remain critical bottlenecks.

To critically evaluate these dynamics, this study employs a systematic review guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol on Scopus-indexed literature. This paper synthesizes contemporary empirical evidence across resource efficiency, digital technology integration, and policy economics to evaluate the true potential of hydroponic farming in fostering sustainable agricultural development and long-term food security

RESEARCH METHODOLOGY

This present research paper is reviewed-based study that adopts a Systematic Literature Review approach based on Preferred Reporting items for systematic Reviews and Meta-Analysis (PRISMA) technique. The study is based on secondary data collected from the Scopus database. Scopus was selected because it is one of the major international databases for peer-reviewed scientific literature and provides comprehensive bibliographic information, including titles, abstracts, keywords, authors, affiliations, citations, and publication details. A systematic search was conducted in the Scopus database using different combinations of keywords related to hydroponics and sustainable agriculture. The search was primarily performed within the Title, Abstract, and Keywords fields to ensure that the selected publications were directly relevant to the research topic.

The following search combinations and preliminary results were obtained:

Table 1: Description of Words and related Articles

Search Keyword / Search String	Number of Documents
Hydroponic	17430
Hydroponics	12,612
Hydroponic Farming	1332
Hydroponics and Sustainable Agriculture	884
Hyropoinics and sustainability	664
Hydropoic farming and sustainable agriculture	319
Hydroponics and sustainable agriculture in India	34

Source: *Author's own tabulation*

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PRISMA-Based Identification Process

The literature selection process was carried out according to the four major stages of the PRISMA framework:

Stage I: Identification

Initially, a broad search was conducted using the terms **"Hydroponic," "Hydroponic Farming," and "Hydroponics."** This resulted in a large number of records. Subsequently, more specific Boolean search strings were used to identify studies related to sustainability and sustainable agriculture.

The final search string focusing specifically on the Indian context produced **34 documents**.

Stage II: Screening

During the screening stage, duplicate records, irrelevant publications, conference notices, editorial materials, and studies not directly related to hydroponics and sustainable agriculture were excluded.

Stage III: Eligibility Assessment

The full texts of potentially relevant publications were assessed based on predefined inclusion and exclusion criteria.

Inclusion Criteria

- Publications indexed in the Scopus database.
- Studies focusing on hydroponics or hydroponic farming.
- Studies examining sustainability, sustainable agriculture, resource efficiency, water conservation, food security, environmental sustainability, or related dimensions.
- Studies specifically related to India, where applicable.
- Peer-reviewed journal articles and relevant review papers.
- Publications containing sufficient bibliographic and analytical information.

Exclusion Criteria

- Duplicate publications.
- Studies unrelated to agriculture or food production.
- Publications mentioning hydroponics without examining its agricultural or sustainability implications.
- Non-relevant editorials, notes, and incomplete records.
- Studies for which sufficient information was unavailable.

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Stage IV: Final Inclusion

After the processes of identification, screening, and eligibility assessment, the final set of relevant studies was selected for systematic review and analysis.

For a study specifically focusing on **hydroponics and sustainable agriculture in India**, the search identified **34 records** at the initial stage. The final number of studies included in the systematic review should be determined after removing duplicates and excluding irrelevant publications through title, abstract, and full-text screening.

PRISMA Flow Diagram

The study may present the literature selection process in the following PRISMA format:

Identification

Records identified through Scopus database search

Hydroponics AND Sustainable Agriculture AND India = 34 records

↓

Screening

Records screened based on title and abstract

Records excluded due to duplication and irrelevance

↓

Eligibility

Full-text articles assessed for eligibility

Studies excluded based on predefined exclusion criteria

↓

Included

Final number of studies included in the systematic literature review and qualitative analysis.

Note: The exact number at each stage should be inserted after completing the screening and full-text review.

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Data Extraction and Analysis

Relevant information was extracted from the selected publications, including:

- Author(s)
- Year of publication
- Country or geographical focus
- Type of publication
- Research objectives
- Hydroponic system studied
- Crops investigated
- Water-use efficiency
- Land-use efficiency
- Energy requirements
- Nutrient management
- Environmental impacts
- Economic feasibility
- Contribution to food security
- Sustainability indicators
- Major findings and recommendations

The selected studies were analysed using **descriptive and thematic analysis**. Descriptive analysis was used to examine publication trends and the distribution of studies, while thematic analysis was applied to identify the major themes emerging from the literature.

The major thematic areas may include:

1. Water conservation and efficient resource utilisation
2. Land productivity and urban agriculture
3. Reduction in soil-related problems and pesticide use
4. Food security and nutritional sustainability
5. Economic feasibility of hydroponic farming
6. Energy consumption and technological challenges
7. Environmental sustainability
8. Opportunities and challenges of hydroponics in India

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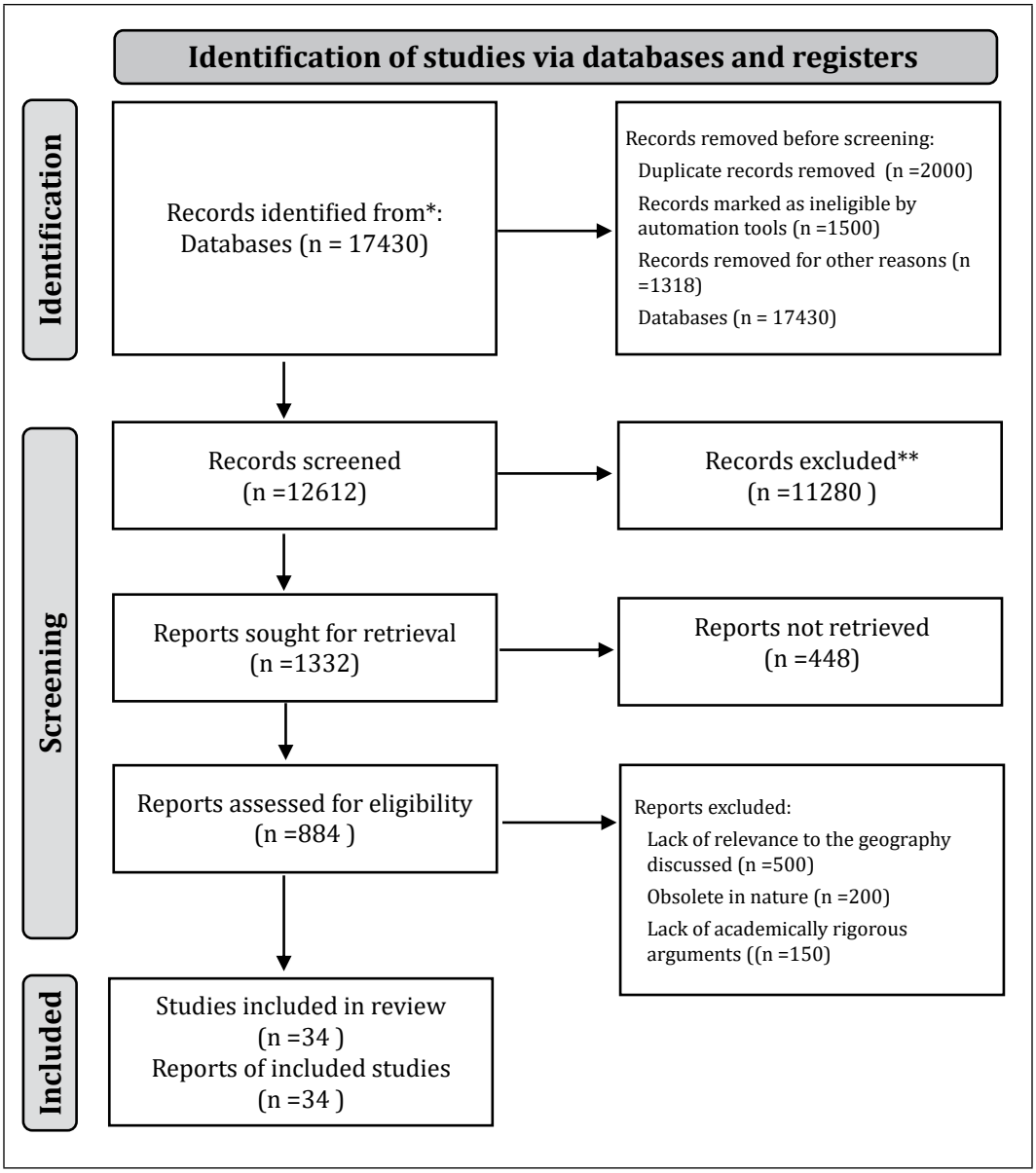


Fig. 1: PRISMA Flow Diagram

**Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).*

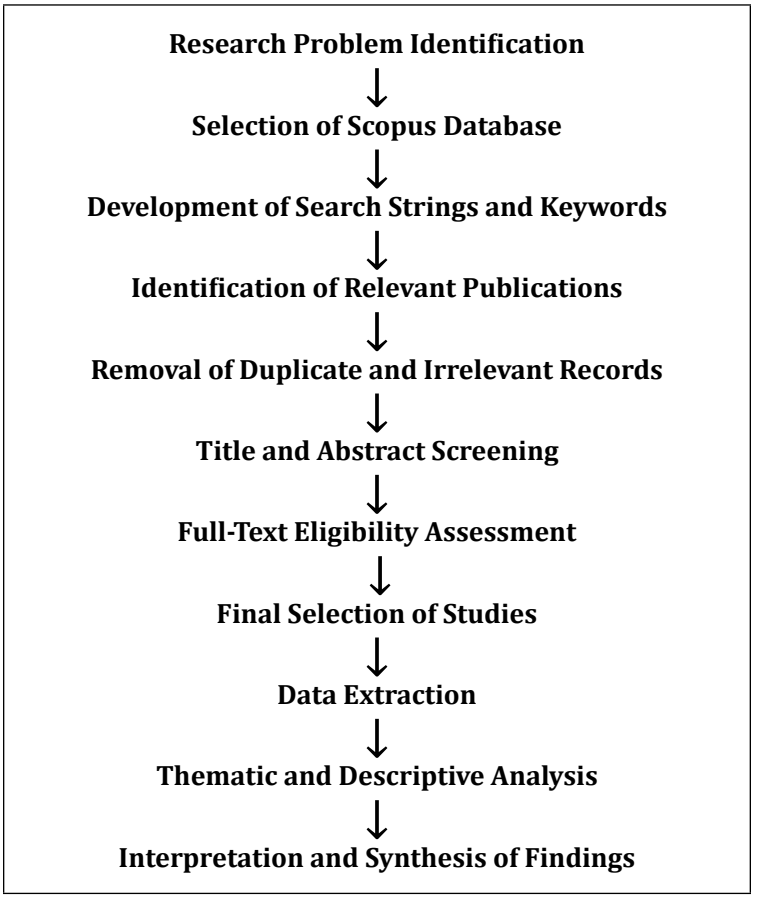
***If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.*

Source: *Author's own formulation using Prisma Framework*

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METHODOLOGICAL FRAMEWORK

The overall methodological process of the study can be represented as:



REVIEW OF LITERATURE

Thematic and Descriptive Analysis

Smart Hydroponics, IoT & AI Automation

Contemporary literature highlights a critical paradigm shift toward technology-driven Controlled Environment Agriculture (CEA) as an essential pathway to address climate vulnerabilities, land scarcity, post-harvest losses, and global food insecurity. Comprehensive macro-level reviews demonstrate that integrating digital transformation—encompassing Artificial Intelligence (AI), Internet of Things (IoT), robotics, and precision crop monitoring—significantly enhances resource-use efficiency,

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crop yields, and environmental sustainability (Camlica & Yaldiz, 2023), with empirical evidence in developing contexts underscoring that institutional support, digital infrastructure, and rural IoT integration are key catalysts for farm-level technology adoption (Rakholia et al., 2024). At the functional level, soil-free agricultural architectures have evolved from foundational microcontroller-based automated setups utilizing basic pH and liquid sensors (Jerusha et al., 2021) toward energy-efficient, outdoor Deep Water Culture (DWC) frameworks utilizing low-power communication protocols like MQTT for real-time microclimate regulation (Subhashini et al., 2024). Furthermore, scholarly synthesis reveals that incorporating computer vision, data mining, and closed-loop urban aquaponic/vertical systems mitigates supply chain friction, minimizes post-harvest wastage, and optimizes spatial land use through circular bio-economy dynamics (Jaiswal et al., 2024; Shukla et al., 2024). Representing the frontier of predictive automation, empirical research validates that deploying advanced multivariate deep learning models—specifically Long Short-Term Memory (LSTM) networks over cloud-integrated IoT sensor arrays—outperforms legacy threshold-based controls, dynamically predicting nutrient requirements to achieve a 27.6% reduction in nutrient waste and a 19.3% yield expansion (Devaraju et al., 2026). Collectively, this synthesized literature confirms that smart, automated, and AI-assisted hydroponics offer a scalable, resource-efficient, and economically viable foundation for sustainable urban food systems.

Agronomic Performance and Cultivar Calibration

Evaluation of contemporary controlled-environment literature in India reveals that hydroponic systems—specifically Deep Water Culture (DWC) and Nutrient Film Technique (NFT)—consistently outpace conventional soil-based agriculture across agronomic performance, resource utilization, and spatial yield density. Empirical evidence demonstrates that recirculating hydroponic frameworks dramatically elevate lettuce (*Lactuca sativa* L.) and leafy greens productivity, achieving up to 3.5 to 4 times higher crop yields while drastically reducing land requirements (up to 65%) and crop growth duration by up to 15 days (Hasan et al., 2026; Majid et al., 2021). Agronomically, cultivar selection and nutrient solution calibration play crucial roles in optimizing economic output; for instance, 'Romain' cultivars demonstrate superior morphological characteristics such as plant height and chlorophyll retention, whereas 'Batavia' optimizes total fresh leaf weight under circulating acidic pH and tailored electrical conductivity (Sahu et al., 2025). Furthermore, system design directly impacts resource optimization, where vertical A-frame NFT models maximize spatial footprint—supporting up to 26 plants per square meter—while generating substantial water savings (64% to 69%) and driving higher concentrations of essential bio-compounds like ascorbic acid and carotenoids compared to soil or aggregate media (Hasan et al., 2026; Thomas et al., 2026). When substrate optimization is paired with precise electrical conductivity (e.g., potting media at 1200

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ppm Hoagland solution), hydroponic protocols enhance biomass accumulation (Munda et al., 2025), confirming that closed-loop, controlled-environment agriculture offers a scalable, technically efficient, and economically viable model to mitigate urban land and water constraints in South Asia.

Integrated Closed-Loop Systems & Niche Production

Integrated closed-loop agro-technologies and controlled-environment agriculture (CEA)—encompassing aquaponics, hydroponics, and aeroponics—have emerged as vital paradigms for mitigating land constraints, severe water scarcity, and climate-driven food insecurity in resource-constrained contexts like India (Biswas et al., 2024; Sreejith et al., 2025). Scholarly evidence underscores the transformative potential of these soil-less systems across niche agricultural verticals, ranging from rapid 7- to-10-day hydroponic green fodder cultivation to alleviate livestock nutritional deficits (Shit, 2019) to nutrient-dense microgreen production leveraging controlled environments for accelerated market growth (Pradhan et al., 2025). Moreover, novel implementations such as ornamental fish-based aquaponics reinforce Sustainable Development Goal 2 (Zero Hunger) by harmonizing circular nutrient bio-conversion with urban economic opportunities supported by institutional schemes like the Pradhan Mantri Matsya Sampada Yojana (Verma et al., 2025). However, despite an accelerating global publication trajectory and proven biological efficiency (Sreejith et al., 2025), commercial-scale diffusion within India remains constrained by multidimensional barriers. Empirical multi-criteria evaluations reveal that while a deficiency in technical expertise represents the foremost effect-group bottleneck, underlying cause-group barriers such as high capital intensity, energy dependency, environmental instability, and complex pH management heavily inhibit widespread adoption (G. Kumar et al., 2023; Shit, 2019). Unlocking the full economic feasibility and operational scalability of these sustainable systems ultimately necessitates structured policy support, targeted financial frameworks, and multi-stakeholder knowledge dissemination strategies (Biswas et al., 2024; G. Kumar et al., 2023; Sreejith et al., 2025).

Urban Architecture, CEA & Spatial Hotspots

Recent literature underscores the transformative potential of Controlled Environment Agriculture (CEA), precision farming, and advanced spatial technologies in addressing urban food insecurity, climate vulnerability, and resource constraints, particularly within the Indian context. A synthesized body of research highlights that integrating hydroponics with Internet of Things (IoT), artificial intelligence (AI), and vertical farming can significantly enhance crop productivity by 25% to 50% while reducing land, water, fertilizer, and labor requirements (Chauhan & Kaur, 2025; Manimozhi & Krishnamoorthy,

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2025; Maheshwari, 2021; Saraswat & Jain, 2021). Spatial analytic techniques, such as integrating vegetation indices with Getis–Ord Gi* hotspot analysis on high-resolution satellite imagery, have proven highly effective for evidence-based spatial planning and crop monitoring during adverse conditions like monsoon flooding (S. Kumar & Parida, 2021). Furthermore, protected cultivation and modular farming frameworks emerge as vital strategies for land conservation, soil remediation, and building decentralized, climate-resilient local food systems (Mahmud et al., 2023; Sharma et al., 2021). However, high initial capital expenditure and the demand for specialized technical expertise remain critical implementation barriers (Maheshwari, 2021). To bridge these gaps, architectural integration and multidisciplinary collaborations (among architects, engineers, and agricultural experts) are increasingly essential for designing multifunctional urban spaces that drive community engagement, promote rural-urban economic resilience, and advance Sustainable Development Goal 2 (Zero Hunger) aligned with national initiatives like Viksit Bharat@2047 (Chauhan & Kaur, 2025; Nikam & Nikam, 2026; S. Kumar & Parida, 2021).

Adoption Barriers, LCA & Policy Economics

Recent scholarly discourse increasingly highlights Controlled Environment Agriculture (CEA) and hydroponic technologies as strategic interventions for mitigating climate stress and enhancing urban food security within India's broader development vision, such as Viksit Bharat @2047 (Chauhan & Kaur, 2025; Paturu & Varadarajan, 2024). Evaluating these systems through a Product-Service Systems lens and cradle-to-gate Life Cycle Assessment (LCA), empirical findings demonstrate that environmental efficacy varies significantly by operational structure; specifically, greenhouse hydroponic farming offers superior sustainability over indoor facilities, cabinet-selling models, and conventional soil-based methods by substantially reducing greenhouse gas emissions, fossil fuel consumption, and human toxicity impacts (Paturu & Varadarajan, 2024). Furthermore, extensive systematic and analytical literature reviews affirm that while automated CEA frameworks optimize resource use efficiency, yield optimization, and year-round productivity, their techno-economic feasibility and adoption trajectories are tightly bound to regional microclimates, capital intensity, and socio-economic constraints (Chauhan & Kaur, 2025; Sharma et al., 2024). Consequently, while contemporary research establishes a strong theoretical consensus regarding the transformative potential of urban hydroponics and CEA, scholars emphasize the pressing need for context-specific empirical investigations and tailored policy initiatives to overcome structural adoption barriers and quantify environmental trade-offs across diverse agricultural landscapes (Sharma et al., 2024).

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Eco-Nanotechnology & Soil Reclamation

Anthropogenic disturbances and intensive resource extraction severely compromise pedological integrity, creating an urgent imperative for advanced soil reclamation and sustainable agricultural inputs. Assessing the baseline extent of mining-induced degradation, Saha et al. (2026) utilized an integrated geospatial and multivariate framework—incorporating satellite DEMs, SEM, and Principal Component Analysis—to evaluate edaphic deterioration in the Raniganj coalfield region, revealing severe spatial heterogeneity in fundamental soil parameters (pH ranging from 5.38 to 8.82, organic carbon from 0.31% to 0.99%, and available nitrogen from 182.0 to 508.06 kg/ha) and formulating a replicable Soil Quality Index (SQI) to guide targeted ecosystem restoration. To remediate such degraded agroecosystems while mitigating reliance on toxic agrochemicals, recent scholarship highlights the potential of natural bio-amendments and green nanotechnology. Investigating natural soil-derived organic matter, Singh et al. (2024) isolated humic acids (HAs) across five distinct land-use regimes in the Delhi-NCR region via IHSS, UV–Vis, and FT-IR protocols, discovering that forest-origin HA at an optimal dose of 1000 mg L^{-1} (Treatment T3) significantly enhanced the physiological and biochemical performance of *Oryza sativa*. Parallelly expanding eco-nanotechnology, Narula et al. (2025) synthesized biopolymer-supported chitosan silver and zinc oxide nanosheets using agricultural waste extracts from almond (*Prunus amygdalus*) husks and walnut (*Juglans regia*), demonstrating that green nano-priming substantially boosts seed germination kinetics and early vegetative vigor in *Vigna radiata*. Synthetically, these studies demonstrate that pairing high-resolution geospatial diagnostics of degraded soils (Saha et al., 2026) with targeted organic fractions (Singh et al., 2024) and green-synthesized biopolymer nanocomposites (Narula et al., 2025) provides a holistic, eco-friendly matrix for restoring soil quality and achieving sustainable crop productivity under increasing environmental stress.

Interpretation and Synthesis of Findings

The thematic analysis demonstrates that hydroponic farming should not be interpreted merely as an alternative method of crop cultivation; rather, it represents a broader technological transition towards resource-efficient, controlled, and knowledge-intensive agricultural systems. Across the reviewed literature, a consistent pattern emerges: hydroponics has significant potential to address land scarcity, water stress, urbanisation, climate uncertainty, and the growing demand for high-quality food. However, the findings also indicate that its contribution to sustainable agriculture is conditional rather than automatic. The sustainability performance of hydroponic systems depends on technological design, crop selection, energy sources, scale of operation, management capability, and the economic and institutional environment in which the technology is adopted.

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Hydroponics as a Resource-Efficiency Strategy

The first major interpretation emerging from the literature is that hydroponics fundamentally alters the relationship between agricultural production and natural resource use. Conventional agriculture depends heavily on land quality, climatic conditions, and large quantities of water. In contrast, hydroponic production systems allow water, nutrients, and environmental conditions to be managed with greater precision. The reviewed studies consistently indicate improvements in water-use efficiency, land productivity, nutrient management, and crop intensity.

The evidence on vertical hydroponics and controlled cultivation particularly suggests that high-value crops can be produced intensively within limited physical spaces. Studies on lettuce and other leafy vegetables demonstrate that hydroponic systems can reduce crop duration, improve yield and quality, and substantially increase water-use efficiency compared with conventional cultivation. Thus, the principal sustainability advantage of hydroponics lies not simply in producing more food, but in increasing output per unit of critical resources.

This finding is especially important for countries such as India, where agricultural land is under pressure from urban expansion, fragmentation of holdings, industrial development, and environmental degradation. Hydroponics therefore has the potential to complement conventional agriculture by providing an alternative production system for locations where land and water constraints are particularly severe.

Digital Technologies Transform Hydroponics into Precision Agriculture

A second important finding is the increasing integration of hydroponics with digital technologies. The literature shows a transition from manually managed systems towards smart hydroponic platforms supported by the Internet of Things, sensors, cloud communication, automation, artificial intelligence, and machine-learning applications.

This technological convergence changes the nature of hydroponic farming. Rather than relying primarily on continuous human observation, smart systems can monitor variables such as nutrient concentration, pH, electrical conductivity, temperature, humidity, and water levels in real time. Automated decision-making can improve the precision of nutrient delivery and environmental management while reducing unnecessary resource losses.

The findings suggest that the future sustainability of hydroponics will increasingly depend on digital capability. Advanced monitoring and predictive systems can improve operational efficiency and reduce wastage; however, they may simultaneously increase technological complexity. Consequently, digitalisation creates both opportunities and new barriers. Farmers and entrepreneurs require technical knowledge, reliable electricity,

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digital infrastructure, maintenance capacity, and financial resources to operate advanced systems successfully.

Therefore, technological sophistication should not be considered an end in itself. For the Indian context, the development of low-cost, energy-efficient, user-friendly, and locally adaptable smart hydroponic systems may be more important than the adoption of highly complex technologies.

Agronomic Performance Depends on System and Crop-Specific Optimisation

The third theme demonstrates that hydroponics cannot be treated as a uniform technology with identical outcomes across crops and locations. The reviewed experimental studies show that productivity and quality are influenced by the cultivation technique, nutrient concentration, growing medium, environmental conditions, and cultivar selection.

Comparative evidence from lettuce cultivation indicates that systems such as deep-water culture and nutrient film technique can generate different outcomes in terms of yield, water conservation, crop duration, nutritional quality, and economic returns. Similarly, cultivar-specific differences indicate that certain varieties may perform better under particular hydroponic environments.

These findings have an important implication for future research and policy. The promotion of hydroponics should move beyond general claims regarding its benefits and focus on the identification of optimal crop–technology–location combinations. Hydroponic farming may be particularly suitable for leafy vegetables, microgreens, high-value horticultural crops, fodder, and specialised urban food markets. Its sustainability and profitability, however, are likely to vary considerably across crops and production systems.

Thus, the evidence supports a context-specific approach rather than a universal model of hydroponic adoption.

Closed-Loop and Integrated Systems Strengthen Circularity

The literature on aquaponics, hydroponic fodder, ornamental fish-based systems, and other integrated production models reveals another important dimension of sustainability: circular resource utilisation. In these systems, the outputs or by-products of one production activity can become inputs for another.

Aquaponics is particularly significant because it integrates fish production and plant cultivation through nutrient recycling. Such systems have the potential to improve resource productivity by reducing waste and enabling the simultaneous production of multiple outputs. Similarly, hydroponic fodder systems can support livestock production in areas affected by land and water constraints.

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The synthesis of these findings suggests that the greatest sustainability potential may emerge when hydroponics is embedded within broader circular food systems rather than operated as an isolated production technology. Future agricultural models could integrate hydroponics with aquaculture, renewable energy, urban waste management, protected cultivation, and local food distribution networks.

However, the literature also highlights important limitations. Integrated systems require specialised knowledge, careful nutrient management, stable environmental conditions, reliable power supply, and significant initial investment. Therefore, circularity alone does not guarantee scalability. Institutional support, training, and appropriate business models are necessary for wider adoption.

Hydroponics Can Contribute to Urban Food-System Transformation

The reviewed studies strongly associate hydroponics with urban agriculture, vertical farming, and controlled-environment production. This indicates that hydroponics has a particularly important role in regions where food demand is concentrated but cultivable land is limited.

Vertical and controlled-environment systems can bring food production closer to consumers. This may reduce dependence on distant production areas and potentially improve the availability of fresh produce. The literature on urban architecture, spatial analysis, and controlled-environment agriculture further suggests that hydroponics can be integrated into buildings, rooftops, institutional spaces, and other urban structures.

The broader interpretation is that hydroponics represents a shift from geographically dispersed agricultural production towards more spatially flexible food systems. Agriculture may increasingly become integrated with urban infrastructure, architecture, technology, and local supply chains.

For India, this creates opportunities for metropolitan regions and rapidly expanding secondary cities. However, urban hydroponics should not be viewed as a complete replacement for conventional agriculture. Instead, it is better understood as a complementary system capable of supplying selected crops, particularly perishable and high-value products, closer to centres of consumption.

Environmental Sustainability Involves Important Trade-Offs

One of the most significant findings of the thematic synthesis is that hydroponics cannot automatically be classified as environmentally sustainable. Although the technology can reduce land and water requirements, its environmental performance is influenced by energy consumption, infrastructure requirements, lighting, cooling, pumping, nutrient production, and the materials used in controlled-environment systems.

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The life-cycle perspective presented in the reviewed literature demonstrates that different hydroponic production models may generate substantially different environmental outcomes. Greenhouse-based systems, for example, may perform differently from highly controlled indoor production systems because of variations in electricity and infrastructure requirements.

This finding challenges the assumption that technological agriculture is inherently sustainable. A reduction in water or land use may be accompanied by higher energy consumption or carbon emissions. Therefore, sustainability assessment should adopt a multidimensional framework that considers water, land, energy, greenhouse-gas emissions, waste generation, nutrient losses, economic viability, and social outcomes simultaneously.

The transition towards renewable energy and energy-efficient technologies may therefore be critical to improving the long-term environmental sustainability of hydroponic farming.

Economic and Institutional Barriers Remain the Major Constraints

Despite the technical potential identified across the literature, widespread adoption remains constrained by economic, technological, and institutional barriers. High initial investment, lack of technical expertise, unreliable electricity, limited awareness, maintenance requirements, and uncertain market access repeatedly emerge as important obstacles.

The analysis of adoption barriers in aquaponics is particularly relevant because it demonstrates that technological challenges are closely connected with financial and knowledge-related constraints. A technologically efficient system may still fail if farmers lack the necessary skills, access to finance, or institutional support.

The synthesis therefore suggests that the major challenge facing hydroponics in India is not simply technological availability but the creation of an enabling ecosystem. Adoption will require access to affordable credit, technical training, extension services, research support, market development, reliable energy, and appropriate policy incentives.

This also implies that hydroponics may initially develop more rapidly among commercial enterprises, start-ups, urban entrepreneurs, research institutions, and high-value crop producers. For wider inclusion of small and marginal farmers, low-cost and decentralised models must be developed.

Overall Synthesis

The findings collectively indicate that hydroponic farming has considerable potential to contribute to sustainable agricultural development, particularly through improved water and land productivity, controlled cultivation, year-round production, and technological

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innovation. However, the evidence does not support the conclusion that hydroponics is universally superior to conventional agriculture.

Instead, the thematic synthesis suggests that hydroponics should be understood as a **context-dependent sustainability strategy**. Its advantages are likely to be strongest in situations characterized by water scarcity, limited land availability, urbanisation, climate vulnerability, demand for high-value crops, and access to technological and energy infrastructure.

The reviewed literature also reveals a transition in hydroponic research. Earlier studies primarily focused on crop production and technical feasibility, whereas more recent research increasingly incorporates artificial intelligence, IoT, vertical farming, controlled-environment agriculture, life-cycle assessment, circular production systems, spatial planning, and adoption economics. This indicates that hydroponics is evolving from a specialised cultivation technique into an interdisciplinary agricultural innovation system.

For India, the most promising pathway is unlikely to be the replacement of traditional agriculture. Rather, hydroponics should complement existing agricultural systems by addressing specific production challenges and serving particular markets. A sustainable transition will require locally adapted technologies, renewable-energy integration, crop-specific optimisation, capacity building, affordable financing, and policy support.

RECOMMENDATIONS

To operationalize hydroponic farming as a viable catalyst for sustainable agriculture in emerging economies like India, key policy, technological, and research interventions are recommended:

- **Targeted Policy & Financial Incentives:** Policymakers should establish dedicated subsidy schemes, concessional credit lines, and micro-loans to lower high initial capital barriers. Support should prioritize low-cost, greenhouse-based systems integrated with solar energy to reduce grid reliance and mitigate cradle-to-gate carbon emissions identified in life-cycle assessments.
- **Agronomic Standardization & Crop Calibration:** Agricultural extension agencies must develop region-specific operational protocols. Guidelines should systematically pair short-cycle, high-value crops (e.g., leafy greens, microgreens, fodder) with optimal system configurations—such as Nutrient Film Technique (NFT) or Deep Water Culture (DWC)—tailored to localized microclimates.
- **Capacity Building & Inclusive Technology:** Public-private partnerships should establish technical training centers to bridge critical knowledge deficits in water chemistry, pH control, and disease management. Promoting modular, low-cost

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Internet of Things (IoT) and AI monitoring tools will enable smallholders to practice precision fertigation without prohibitive technology costs.

- **Promoting Circular Agro-Ecosystems:** Urban planning frameworks and agricultural schemes should incentivize circular systems, including aquaponics and building-integrated agriculture. Capitalizing on nutrient recycling and vertical spatial optimization will enhance urban food resilience and advance Sustainable Development Goals (SDG 2 and SDG 12).

CONCLUSION

This PRISMA-driven systematic synthesis demonstrates that hydroponic farming offers a viable pathway toward sustainable agriculture by drastically enhancing water-use efficiency, crop yields, and spatial productivity. Integrating digital technologies (IoT, AI) and closed-loop systems further amplifies resource circularity. However, hydroponics is not a universal replacement for conventional farming; its contribution to sustainability is conditional on mitigating key trade-offs, including high initial capital expenditure, energy intensity, and technical adoption barriers in developing agrarian economies like India. Ultimately, strategic policy support, localized low-cost technological adaptations, and targeted infrastructure are essential to positioning hydroponics as a complementary driver of long-term food security.

REFERENCES

Biswas, S., Tank, K. V., Bhadarka, M., Makwana, K., and Bamaniya, M. (2024). Aquaponics: In a Nutshell. In V. B. Sakhare, S. Abujam, & V. Ravi (Eds.), *Limnology and Marine Biology* (pp. 245–254). NIPA.

Camlica, M., and Yaldiz, G. (2023). Basil (Ocimum basilicum L.): Botany, Genetic Resource, Cultivation, Conservation, and Stress Factors. In C. S. Prakash, S. Fiaz, M. A. Nadeem, F. S. Baloch, & A. Qayyum (Eds.), *Sustainable Agriculture in the Era of the OMICs Revolution* (pp. 135–163). Springer International Publishing. https://doi.org/10.1007/978-3-031-15568-0_7

Chauhan, A., and Kaur, H. (2025). Controlled Environment Agriculture (CEA) in India: Opportunities and Challenges. *National Conference on Indian Knowledge Systems for Viksit Bharat 2047*, 365–374.

Devaraju, S., Muthusamy, D., Chandrappa, S. K., Jathar, C., Banothu, S., and Atheeswaran, A. (2026). Smart hydroponic farming system using IoT-integrated deep learning for real-time nutrient monitoring and climate control. *Ecohydrology & Hydrobiology*, *26*(2), 100754.

Hasan, M., Mani, I., Kumar, L., Sagar, A., Paradkar, V., Gavhane, K. P., and Ameta, T. (2023). IoT and sensor-based water and nutrient management for protected cultivation technology. In *Advances in Water Management Under Climate Change* (pp. 168–188). CRC Press.

Hasan, M., Paradkar, V., and Vinod Kumar, S. (2026). Comparative Study on Resource Efficiency and Environmental Impacts in Vertical Hydroponic Controlled–Environment and Crop Evapotranspiration–Based Drip Irrigation Systems for Bok Choy Cultivation (Brassica rapa subsp. Chinensis L.). *Irrigation and Drainage*, *75*(1), 115–127.

Jaiswal, S., Rawat, G., Khadse, C., and Sharma, S. (2024). A smart hydroponics system for sustainable agriculture. In *Data Science for Agricultural Innovation and Productivity* (pp. 25–47). Bentham Science Publishers.

Jerusha, S., Anand, A. V., Adarsh, J., Chandra Kumar, K. R., and Vishnu Saravana Bharathi. (2021). Organic Hydroponic Farming Incorporated with Recycles Water. *Journal of Physics: Conference Series*, *1916*(1), 012105. https://doi.org/10.1088/1742-6596/1916/1/012105

Kumar, G., Bhujel, R. C., Aggarwal, A., Gupta, D., Yadav, A., & Asjad, M. (2023). Analyzing the barriers for aquaponics adoption using integrated BWM and fuzzy DEMATEL approach in Indian context. *Environmental Science and Pollution Research International*, *30*(16), 47800–47821. https://doi.org/10.1007/s11356-023-25561-0

Kumar, S., and Parida, B. R. (2021). Hydroponic farming hotspot analysis using the Getis–Ord Gi statistic and high-resolution satellite data of Majuli Island, India. *Remote Sensing Letters*, *12*(4), 408–418.

Maheshwari, S. (2021). Vertical farming: Resilience towards climate change. In *Urban growth and environmental issues in India* (pp. 207–221). Springer.

Mahmud, N.-A., Sabil, A., Hisham, N. N., Siraj, S., Adnan, N. A., and Md Amin, N. D. (2023). Sustainable living: Alternative green structure module design for home self-food production. *IOP Conference Series: Earth and Environmental Science*, *1205*(1), 012085.

Majid, M., Khan, J. N., Ahmad Shah, Q. M., Masoodi, K. Z., Afroza, B., and Parvaze, S. (2021). Evaluation of hydroponic systems for the cultivation of Lettuce (*Lactuca sativa* L., var. Longifolia) and comparison with protected soil-based cultivation. *Agricultural Water Management*, *245*, 106572. https://doi.org/10.1016/j.agwat.2020.106572

Manimozhi, R., and Krishnamoorthy, G. (2025). Innovative techniques in agriculture: Transitioning from traditional farming to precision and hydroponic agriculture. *Environmental Quality Management*, *34*(3), e70047.

Munda, S. C., Maitra, S., Gaikwad, D. J., Duvvada, S. K., Sairam, M., Santosh, D., and Ray, S. (2025). Influence of growing media and nutrient levels on growth and yield of lettuce (*Lactuca sativa* L.) in hydroponics. *Crop Research (0970-4884)*, *60*(3/4), 185.

Narula, G., Baweja, P., Soni, K., Ghai, N., Kumari, A., and others. (2025). Fabrication of crosslinked Silver and Zinc Oxide nanosheet and their potential for agricultural applications. *Journal of the Indian Chemical Society*, *102*(8), 101796.

Nikam, K. N., and Nikam, N. V. (2026). Hydroponic design horizons: Transforming urban landscapes for sustainable agriculture in the Indian context. *Cities & Health*, *10*(1), 14–28.

Paturu, P., and Varadarajan, S. (2024). Assessing environmental sustainability by combining product service systems and life cycle perspective: A case study of hydroponic urban farming models in India. *Science of the Total Environment*, *927*, 172232.

Pradhan, A., Bhatt, M., Rawat, B., Butola, J. S., Rawat, J. M., Kumar, D. A., Negi, A. S., and Nautiyal, M. K. (2025). A road to nutritional security and greener food systems: The power of microgreens. *Medicinal Plants-International Journal of Phytomedicines and Related Industries*, *17*(4), 699–710.

Rakholia, R., Tailor, J., Prajapati, M., Shah, M., and Saini, J. R. (2024). Emerging technology adoption for sustainable agriculture in India–a pilot study. *Journal of Agriculture and Food Research*, *17*, 101238.

 ISBN: 978-93-49666-59-7 (eBook)

Saha, A., Saha, D., Nazir, M., Roy, K., and Das, U. (2026). Coal, soil, and survival: Unraveling the agricultural consequences of mining area in India. *Natural Hazards*, *122*(4), 161.

Sahu, C., Gaikwad, D. J., Nanda, S., Dash, G. K., Maitra, S., Munda, S. C., and Mullapudi, S. (2025). Comparative performance of lettuce cultivars Batavia and Romain in nutrient film technique under hydroponics system. *Crop Research (0970-4884)*, *60*(1/2), 61.

Saraswat, S., and Jain, M. (2021). Adoption of vertical farming technique for sustainable agriculture. In *Climate Resilience and Environmental Sustainability Approaches: Global Lessons and Local Challenges* (pp. 185–201). Springer.

Sharma, A., Kumari, S., Sharma, V., Saishree, R., and Prusty, B. A. K. (2024). Enhancing Agriculture and Food Security through Smart Nanofertilizer-Based Soil Management. *Sustainable Agriculture: Nanotechnology, Biotechnology, Management and Food Security*, 73.

Sharma, A., Raghavan, M., Shi, Z., and Bang, N. T. H. (2021). Utilization of protected cultivation for crop production and preservation in India. *Environment Conservation Journal*, *22*(1 & 2), 13–17.

Shit, N. (2019). Hydroponic fodder production: An alternative technology for sustainable livestock production in India. *Exploratory Animal & Medical Research*, *9*(2), 108.

Shukla, A., Shukla, V., Kumar, D. S., Kushwah, V., and Malviya, S. (2024). *Real-Time Authenticated and Secure Monitoring and Control of Low-Cost Sustainable Hydroponic System in Cloud* (pp. 49–63). https://doi.org/10.1007/978-981-97-0641-9_4

Singh, C., Chauhan, A., Arora, J., Ranjan, A., Rajput, V. D., Sushkova, S., Minkina, T., Eswaran, S. V., and Jindal, T. (2024). Characterization of humic acids from soil of Delhi regions and their impact on plant growth. *Eurasian Journal of Soil Science*, *13*(3), 190–201.

Sreejith, B., Harikumar, Y., Muthumeenakshi, M., and Maneesh, B. (2025). Bibliometric Exploration of Aeroponics and Sustainability Literature: Trends, Patterns, and Future Directions (1986-2023). *International Research Journal of Multidisciplinary Scope Учредители: Iquz Galaxy Publisher*, *6*(01), 693–715.

Subhashini, N., Tharun, P., Vishnuram, P., Kesavan, R., Santhosh, S. S., and Muthulakshmi, S. (2024). Smart Hydroponics on a Budget: DIY Self-Hosted System for Growing Lettuce. *2024 International Conference on Communication, Computing, Smart Materials and Devices (ICCCSMD)*, 1–6.

Thomas, T., Biradar, M., Chimmad, V., and Janagoudar, B. (2026). Hydroponic cultivation of lettuce: Evaluating yield and quality across different systems. *International Journal of Vegetable Science*, *32*(1), 53–70.

Verma, A. K., John, V. C., and Pai, M. (2025). Ornamental Fish-Based Aquaponics. In *Ornamental Fisheries and Aquarium Keeping* (pp. 212–230). CRC Press.

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Chapter

13

Regenerative Agriculture in Bihar: Enhancing Soil Health and Sustainable Livelihoods

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ABSTRACT

Bihar's agrarian economy, dominated by small and marginal farmers with about 91%of landholdings measuring less than 1 hectare, faces a dual crisis of ecological degradation and economic hardship. Decades of intensive monoculture and heavy chemical use have severely degraded agricultural soil, stripping away its biological foundation. This paper evaluates the prospects of transitioning to Regenerative Agriculture (RA) as a structural mechanism to simultaneously restore soil health and secure resilient livelihoods across Bihar's distinct agro-climatic zones.

This study analyzes the socioeconomic viability of core regenerative practices, including zero-tillage, multi-crop diversification, agroforestry, and localized bio-inputs like Jeevamrit. The transition phase leads to a brief yield stabilization period but eliminating expensive synthetic fertilizers and pesticides reduces operational cash but substantially improving net farm income. Furthermore, enhanced soil water-retention capacity functions as a natural insurance mechanism, stabilizing crop yields against intensifying climate anomalies.

However, deep-seated structural barriers restrict widespread scaling. The land fragmentation and tenant farming (Bataidari) system remains a critical impediment, as landless cultivators lack the tenure security required to invest in multi-year soil restoration. Crop residue management, lack of widespread awareness, institutional training, weak organic market linkages and patchy agricultural extension networks further slow adoption. The paper concludes that embedding regenerative frameworks into state policies and designing localized incentive programs can dismantle these barriers, transforming Bihar's primary sector into a self-sustaining, economically viable ecosystem.

Keywords: Bihar Agriculture, Climate Resilience, Crop Diversification, Regenerative Agriculture, Soil Health, Tenant Farming

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INTRODUCTION

Regenerative agriculture can be defined as an approach that goes beyond sustainable practices to actively regenerate the ecological functions of the agricultural system. Its roots trace back to indigenous farming practices. In recent years, India—particularly Bihar—has increasingly recognized the urgent need to transition to sustainable and regenerative farming. Conventional agricultural systems relying on heavy chemical inputs, monocultures, and deforestation have accelerated soil erosion, biodiversity loss, and climate change. As the population continues to rise and the pressure on our natural resources intensifies, it is essential to explore alternative approaches that can simultaneously address the challenges of food security and environmental sustainability. Regenerative agriculture has emerged as a transformative and holistic approach of farming that not only aims to sustain our food production but also seeks to restore and revitalized the health of our planet (Rhods, 2017). It recognises that agriculture can play a crucial role in mitigating climate changes, conserving biodiversity enhancing ecosystem residence and promoting social will being by emphasizing the interconnectedness of soil health, biodiversity conservation, water management, carbon sequestration regenerative agriculture offers a comprehensive and integrated solution to the complex challenges, facing our agriculture system. Regenerative Agriculture is governed by six core principles:

1. Minimizing soil disturbance (e.g., no-till or reduced tillage).
2. Maintaining permanent soil cover through mulching or cover crops.
3. Keeping living roots in the soil year-round.
4. Maximizing plant species diversity via crop rotations and intercropping.
5. Integrating livestock to cycle nutrients through manure.
6. Limiting synthetic chemical inputs, opting instead for biological alternatives.

BIHAR'S AGRICULTURAL PROFILE: STRUCTURAL STRENGTHS AND VULNERABILITIES

Agriculture is the foundational pillar of Bihar's economy, with approximately 88.7% of the population residing in rural areas and nearly 74% of the workforce depending on agricultural and allied activities for their livelihood. Notwithstanding this central role, the sector faces a structural shift where its contribution to the Gross State Domestic Product (GSDP) has stabilized at around 20%. Furthermore, despite its fertile Indo-Gangetic plains, the state faces significant limitations 91% to 97% of farmers belong to the small and marginal category, often operating on fragmented landholdings that restrict economies of scale. Bihar is also highly vulnerable to climate extremes, experiencing annual floods in the north and recurrent droughts in the south. Sustaining agricultural growth now requires strengthening the ecological foundations—primarily the soil—that support long-term productivity.

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The soil health in Bihar has been severely compromised by decades of intensive cultivation and heavy chemical usage. Nationally, approximately 29–30% of land is undergoing degradation a alarming trend mirrored in Bihar's agricultural fields. Years of monocropping and heavy reliance on synthetic fertilizers have severely depleted Soil Organic Carbon (SOC) and essential micronutrients. This decline has resulted in widespread multi-nutrient deficiencies and triggered a resurgence of pest pressures. Conventional tillage practices have caused severe subsoil compaction and organic matter loss, compromised the soil's moisture-retention capacity and reduced vital microbial activity. Information asymmetry among farmers has historically driven the overapplication and imbalanced use of fertilizers, further destabilizing natural soil chemistry and biological fertility. While annual river floods (particularly along the Kosi River) historically deposited fertile alluvial silt, recent shifting flooding dynamics have deposited excessive sand across vast tracts of arable land, rendering them uncultivable. Intensifying heatwaves and erratic rainfall patterns continue to accelerate topsoil erosion and moisture loss, leading to unpredictable harvests and rising input costs for smallholders.

Regenerative agriculture in Bihar focuses on nature-based solutions that rebuild the rhizosphere—the active soil zone influenced by root exudates, which serves as the primary hotspot for nutrient transformation.

Green Manuring: The "Natural Urea Factory" - Green manuring involves cultivating fast-growing legumes, such as Sesbania (Dhaincha) or summer mungbean, and incorporating their green biomass into the soil prior to flowering.

Nitrogen Fixation: Summer mungbean fixes approximately 25–30 kg N/ha, while Sesbania can contribute 50–60 kg N/ha, substantially lowering synthetic urea requirements.

Soil Structural Health: As soil microbes decompose fresh plant biomass, they secrete biological binding agents that aggregate soil particles into stable structural units, preventing surface crusting and enhancing aeration.

Nutrient Bio-Pumping: Deep-rooted legumes function as bio-pumps, extracting potassium and trace minerals from subsoil layers and depositing them into the topsoil for subsequent crops.

Zero Tillage (ZT) and Residue Management: Replacing conventional ploughing with Zero Tillage (ZT) and crop residue retention is a foundational pillar of conservation agriculture in the region.

Carbon Sequestration: Retaining at least 30% of rice straw on the field sequesters soil organic carbon. Studies indicate that increasing the soil carbon pool directly boosts subsequent wheat yields by 20–40 kg/ha. Moisture Conservation: Surface residue functions as protective mulch, suppressing soil evaporation and increasing water infiltration capacity—a critical advantage during dry spell.

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DUAL LANDSCAPES: ADAPTING PRACTICES TO NORTH AND SOUTH BIHAR

Bihar's agricultural strategy must be bifurcated to address the distinct "agro-climatic profiles" created by the Ganges River. North Bihar (North West & North East Alluvial Plains) which is characterized by heavy-textured, sandy loam to clay loam soils and is largely flood-prone. In waterlogged or saline conditions, Sesbania aculeata is highly effective due to its rapid biomass mineralization. Integrated Farming Systems (IFS), including fish-based farming and goat rearing, are promoted to build resilience against frequent flooding. The abundance of water from Himalayan rivers offers high potential for summer mungbean intensification, which thrives in the fallow period between rice and wheat. South Bihar (South Bihar Alluvial Plain) where soils range from alluvial to sandy loam, and the region is frequently prone to drought due to lower average rainfall (1102 mm compared to 1382 mm in the North East). Zero Tillage (ZT) is particularly advantageous here as it improves water storage capacity and reduces the risk of crop failure when irrigation is limited. Drought-tolerant green manures like Guar (Cluster bean) can improve soil structural stability in these more arid zones. The establishment of an "organic corridor" along the Ganges aims to leverage the fertile alluvial soil for high-value organic produce.

RESEARCH OBJECTIVES

- To Appraise the Revival of Traditional Knowledge System
- To Analyze Key Socio-Economic Barriers to Adoption
- To Evaluate Government Interventions and Schemes
- To Assess the Impact of Extension Services and Digital Tools
- To Assess Market-Based Financial Incentives
- To Assess the economic viability of regenerative agricultural Practice

RESEARCH METHODOLOGY

The study adopts a descriptive and analytical research design relying exclusively on secondary data sources. The descriptive phase involves systematically categorizes the existing agricultural profile, current soil degradation status, government schemes, and ecological interventions across North and South Bihar. The analytical phase critically evaluates the socio-economic viability, cost savings, carbon sequestration potential, adoption bottlenecks of Regenerative Agriculture (RA) practices to establish cause-and-effect relationships and policy recommendations.

The study extracts quantitative and qualitative secondary data from verified institutional repositories viz. Research bulletins and empirical trial data from the Indian Council of Agricultural Research, Research Complex for Eastern Region (ICAR-RCER), Patna, Bihar

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Agricultural University (BAU), Sabour and Dr. Rajendra Prasad Central Agricultural University (RPCAU), Pusa, Economic Survey of Bihar, District Contingency Plans, Bihar Fourth Agriculture Roadmap (2023–28), National Mission on Natural Farming (NMNF) guidelines and Soil Health Card portal data.

The study also involves reviewing published literature on Conservation Agriculture (CA), Zero Tillage (ZT), Biological Nitrogen Fixation (BNF) and smallholder carbon credit frameworks in Eastern India.

REGENERATIVE METHODOLOGIES APPLICABLE TO BIHAR

Regenerative agriculture is a holistic approach focused on rebuilding soil vitality and enhancing biodiversity. Several methods are uniquely suited to Bihar's diverse landscapes. Zero Tillage and Residue Management Zero Tillage (ZT) involves drilling seeds directly into unpuddled soil, minimizing disturbance. It enhances soil carbon sequestration, where a 1-ton increase in the soil carbon pool can raise wheat yields by 20 to 40 kg and improve water infiltration and moisture conservation, which is vital for the drought-prone South Bihar Alluvial Plain.

Biological Nitrogen Fixation: Green Manuring incorporating fast-growing legumes like Sesbania (Dhaincha) and summer mungbean restores nitrogen levels naturally. These crops stimulate microbial enzymatic activities and improve macro-aggregate stability, preventing the formation of hard surface crusts.

Integrated Farming Systems (IFS): IFS combines multiple enterprises including crops, livestock, fisheries and poultry to maximize resource efficiency. For North Bihar's waterlogged areas, the ICAR-MGIFRI promotes fish-based farming and goat rearing to diversify income and build resilience against floods.

Traditional Wisdom: The Ahar-Pyne System—In South Bihar, the revival of the ancient Ahar-Pyne system—a network of channels (pynes) and retention ponds (ahars)—offers a cost-effective method for flood and drought management. This Mauryan-era technology allows for two crops a year and communal ownership that transcends socio-economic status.

ECONOMIC VIABILITY AND FARMER PROFITABILITY

The transition to regenerative practices is driven by the need to stabilize declining profit margins. Regenerative practices directly support farmer welfare by optimizing the balance between input use and productivity growth.

1. **Cost Savings:** ZT reduces preparatory tillage, significantly lowering expenditures on labor, fuel, and machinery. Research in Bihar indicates that resource conservation practices can save approximately ₹ 37,565 per hectare in cultivation costs compared to conventional methods.

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2. **Yield Stability:** While conventional yields often stagnate, regenerative systems improve "net returns" by enhancing the soil's natural fertility and reducing dependency on expensive external inputs. Studies at Bihar Agricultural University, Sabour, show that intensified RA systems can yield a net return of INR 82,863/ha.
3. **Energy Use Efficiency:** A "full conservation system" (ZT DSR-ZT wheat-ZT green gram) has demonstrated the highest Energy Use Efficiency (14.5%) and energy productivity, making the farm more self-sustaining.
4. **Input Cost Reduction:** By reducing dependence on synthetic fertilizers and expensive irrigation, RA lowers the overall financial burden on small farmers, potentially increasing long-term profit margins by 15–25%.
5. **Carbon Credit Markets:** Small farmers in Bihar can now earn an extra ₹7,000 to ₹15,000 per year through carbon credits. By adopting simple practices like Alternate Wetting and Drying (AWD) in paddy and No-Till in wheat, farmers sequester soil carbon that can be sold to large corporations to meet their ESG goals.
6. **Diversification into High-Value Crops:** Shifting from cereal monoculture to crops like makhana (where Bihar produces 90% of India's supply), fruits, and vegetables can significantly boost household income. Integration with livestock (goat rearing, dairy) further strengthens resilience by providing multiple income streams.

Enhancing Soil Fertility and Productivity: Biological interventions are central to restoring Bihar's soil.

1. **Natural Farming:** This chemical-free approach utilizes on-farm biological inputs like Jeevamrut (microbial culture) and Beejamrut (seed treatment), prepared from native livestock. These inputs restore soil biota and maintain ecological balance.
2. **Organic Corridors:** The Bihar government has established an Organic Corridor along the Ganga, identifying 20,000 acres in 13 districts for chemical-free farming. Farmers receive grants of ₹11,500 per acre in the first year to support this transition.
3. **Soil Health Management:** Practices such as green manuring and cover cropping can increase SOC by 4–20% in the medium term. As of March 2026, 25.89 crore Soil Health Cards have been generated, providing farmers with plot-wise reports and crop-specific nutrient recommendations.

RESILIENCE CHALLENGES IN ADOPTION

Regenerative agriculture represents more than an environmental shift; it is a geopolitical strategy to secure Bihar’s economic future. By integrating Zero Tillage, green manuring, and Integrated Farming Systems, Bihar can mitigate the risks of climatic variability—balancing the floods of the North with the droughts of the South. Despite its benefits, several barriers impede the widespread adoption of RA in Bihar:

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1. **Economic Factors:** 100% of surveyed sugarcane growers in Bihar-adjacent regions cite the high cost of complex fertilizers and lack of timely credit as major hurdles.
2. **Social and Labor Issues:** Sustainable practices, particularly green manuring, can be labor-intensive. Furthermore, 91.2% of Bihar's farm households are marginal (holding <1 hectare), making it difficult for individual farmers to invest in specialized ZT machinery.
3. **Machinery Supply Chains:** There is a negligible presence of RA machinery manufacturers in Eastern India. Farmers often depend on Punjab or Haryana for spare parts and trained operators.
4. **Information Asymmetry:** Many farmers lack technical guidance on pest management and the specific benefits of biofertilizers. Historically, Soil Health Cards were too technical for many farmers to read, though recent redesigns have aimed to fix this.
5. **Market Infrastructure:** High post-harvest losses and limited access to organized markets continue to restrict profitability.
6. **Knowledge Gaps:** There is a critical need for extension services and training, as short-term yield dips during the RA transition can discourage adoption among those with limited risk-bearing capacity.

THE ROLE OF GOVERNMENT AND INSTITUTIONAL SUPPORT

The Government of Bihar through its Fourth Agriculture Roadmap (2023–28) is actively promoting sustainability and mechanization. The Government of Bihar adopts an integrated approach, bringing agriculture, animal husbandry fisheries and marketing under a single framework.

1. **Digital Agriculture Mission:** Initiatives like AgriStack and the Farmer Registry use digital tools to provide hyper-localized advisories, helping farmers mitigate climate risks.
2. **Subsidies and Incentives:** The state provides substantial assistance for micro-irrigation (Per Drop More Crop), agricultural drones, and the establishment of Makhana boards for processing and branding.
3. **Regenerative Support:** The National Mission on Natural Farming (NMNF) provides output-based incentives of ₹4,000 per acre to help farmers transition away from chemicals.
4. **Soil Health Management:** Initiatives like "Khet Bachao Abhiyan" promote soil-test-based nutrient management to reduce unnecessary chemical expenditures.

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5. **Organic Corridors:** The Jaivik Corridor Yojana has established organic clusters in 13 districts along the Ganges to leverage fertile alluvial soil.
6. **Inclusive Communication:** Recognizing literacy barriers, the government redesigned Soil Health Cards to include visuals, symbols, and simple language, significantly improving their utility for female farmers.
7. **Empowering Farmers:** The "Farmer FIRST" programme aims to place farmers at the center of technology development, fostering "scientist-farmer partnerships" to create location-specific models for flood-prone and drought-prone areas.
8. **Digital Empowerment:** The BIHAN App enables real-time monitoring of schemes, while partnerships with the World Bank and Jeevika have digitized records for over 10,000 women farmers, providing localized agronomic advisories.

CONCLUSION

Regenerative agriculture offers a transformative pathway for Bihar. By shifting from a system that "depletes" to one that "restores," the state can mitigate the risks of climatic variability and resource depletion. While fragmented landholdings and information gaps remain serious deterrents, the integration of Zero Tillage, green manuring, and Integrated Farming Systems provides a resilient, economically viable future for Bihar's millions of farmers. Through continued government support and local scientific innovation, Bihar can turn its rich natural heritage into a sustainable powerhouse of food security.While challenges such as fragmented holdings and weak machinery supply chains persist, state-led initiatives like the Jaivik Corridor and Farmer FIRST programs provide a robust framework for a resilient, productive, and profitable agrarian future. The path forward requires continued scientific rigor, inclusive policy design, and a focus on restoring the living soil matrix that sustains millions of Bihari lives.Regenerative agriculture represents a transformative force for Bihar, shifting food systems away from extractive "industrial" models toward resilient, climate-smart, and socially inclusive production. By integrating traditional wisdom, such as the ahar-pyne system, with modern digital advisories and state-supported roadmaps, Bihar can restore its soil vitality while ensuring agriculture remains a profitable and secure livelihood for its millions of smallholder farmers. The path forward requires sustained investment in outcome-based monitoring, reoriented subsidies, and the legal and economic empowerment of the state's farmers.

REFERENCES

Mishra J.S., Bhatt B.P., Arunachalam A. and M.L. Jat (2020). Conservation Agriculture for Sustainable Intensification in Eastern India. *Policy Brief*, 8 p. Indian Council of Agricultural Research (ICAR) and National Academy of Agricultural Sciences (NAAS), New Delhi.

Kadam R.L., Ahire R.D., Tadavi F.R. and R.K. Behera (2023). "Constraints & suggestions perceived by the sugarcane growers towards sustainable cultivation practices." *The Pharma Innovation Journal*, SP-12(8): 1550-1553.

ISBN: 978-93-49666-59-7 (eBook)

Raj, Manish, Mainak Ghosh, Anil Kumar Singh, Sumit Sow, Sanjay Kumar, Birendra Kumar, Swaraj Kumar Dutta et al. (2026). "Intensification of rice-wheat cropping system with summer green gram improves growth, productivity and profitability of rice in the middle Indo-Gangetic Plains of India." *European Journal of Agronomy*, 175: 128024.

Ray, Amar Nath (2018). "Prospects of Agriculture in Bihar: An Overview." *Review of Research*, Volume 8, Issue 1, October

Pramanick, Biswajit (2026). "Regenerative Agriculture for Climate-Resilient Farming: A Synthesis of Environmental, Agronomic, and Economic Outcomes." SATSA Mukhapatra - *Annual Technical Issue*, 30: 410-416.

Rhodes, C. J. (2017). The imperative for regenerative agriculture. *Science progress*, 100, 80–129. doi: 10.3184/003685017X14876775256165

Pramanick, Biswajit (2026). "Regenerative Agriculture for Climate-Resilient Farming: A Synthesis of Environmental, Agronomic, and Economic Outcomes." *SATSA Mukhapatra - Annual Technical Issue*, 30: 410-416.

Sampson, R. N. (1982). Saving agricultural land: environmental issue of the 1980's. *Environmentalist*, 2,321-332doi: 10.1007/BF02603089

Keil, A., D'souza, A., & McDonald, A. (2017). Zero-tillage is a proven technology for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: what determines farmer awareness and adoption? *Food Security*, 9(4), 723-743. [CIMMYT Study]

Press Information Bureau (PIB) (2026). "Rebuilding Farming Systems: Regenerative Agriculture for a Resilient India." Ministry of Agriculture & Farmers Welfare, Government of India. Posted On: 23 AUG 2026.

Ministry of Finance: Economic Survey reports.

Ministry of Agriculture & Farmers Welfare: Annual Reports (2024–25, 2025–26). Cabinet Secretariat, Government of Bihar (2019). *Jal-Jeevan-Hariyali Mission: Operational Guidelines and Action Plan*. Government of Bihar, Patna.

Ministry of Agriculture & Farmers Welfare, Government of India (2022). National Mission on Natural Farming (NMNF): Operational Guidelines. Department of Agriculture & Farmers Welfare, New Delhi.

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Chapter

14 An Analysis of "Other-Sources" of Irrigation in India: A Case Study of Karnataka

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ABSTRACT

The distribution of irrigated area under 'other-sources' of irrigation across Indian states reveals significant regional disparities in the reliance on alternative irrigation systems beyond canals, tanks, and wells. The irrigation from other-sources involve various lift irrigation methods, water diversion methods, traditional methods, non-conventional water resources etc,. At All-India level, irrigation from other-sources accounts for 58 lakh hectares, representing about 10 percent of the total Net Irrigated Area (NIA) of 602 lakh hectares during the last five years 2020-2024 and during the same period it accounts for 14% of total NIA in Karnataka. This indicates that while conventional irrigation sources dominate, other-sources still play an important supplementary role in irrigated agriculture. This study investigates how other sources of irrigation are distributed across India, with a detailed district-wise analysis for Karnataka.

Keywords: Other-sources of irrigation (OS), Lift Irrigation Schemes (LIS), Check Dams, Springs, Pickups, Seepage Water, *Naals* (Open Drainage Channels), Ponds, *Kuntes* (Traditional water-harvesting pits), Drain-Water, Small Streams, Dykes, Bridge-Cum-Barrages, Percolation tanks, Salt Water Exclusion Dams (SWED), Vented Dams, *Bandharas* (Weirs), Bamboo Drip Irrigation, Zabo, Dong Bandh, Wet Rice Irrigation, *Pukhris* (ponds), *Tuikhur* (Stream irrigation), Artificial irrigation, Intensity of Irrigation.

INTRODUCTION

Irrigation plays a crucial role in sustaining agricultural productivity in India, where a significant proportion of cultivation still depends on monsoon rainfall. Over time, several irrigation sources have evolved, including canals, tanks, wells, and traditionally there are many indigenous systems still prevalent across India. While canals, tanks, and wells constitute the major sources of irrigation in the country, a considerable portion of agricultural land is irrigated through what are broadly categorized as "other sources". These sources include lift irrigation systems, springs, streams, diversion channels, small

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check dams, traditional water harvesting structures, and other localized indigenous irrigation mechanisms that do not fall within the conventional irrigation classifications.

This paper analyses the distribution of irrigation under other-sources across various states and Union Territories(UTs) of India, highlighting regional variations and identifying states with significant dependence on these sources. In few states where disaggregated data is available on the other-sources of irrigation there a detailed analysis is done. In addition, the study includes a detailed district-wise analysis of other-sources of irrigation in Karnataka.

LITERATURE REVIEW

In the absence of disaggregated data and limited literature on other-sources of irrigation it makes difficult to determine the relative contribution of their individual components. However, the study relies on selected literature, expert discussions, and state-wise data available on the national website of the Directorate of Economics and Statistics under the Department of Agriculture and Farmers Welfare, Government of India for further analysis. The following are a few studies that have detailed the other sources of irrigation in different parts of India.

1. Sen, P., Devi, N. L., & Singha, D. (2015), researched on the topic, "Understanding indigenous irrigation systems in North East India", the authors have analysed various methods of traditional irrigation practices adopted by the hilly regions of the NE India.
2. N. Beithou (2015), in an important study "*Non-Conventional Water Resources: Review and Developments"* provided a comprehensive review of water resources used for irrigation, categorizing them as conventional and non-conventional sources. Incorporating water-saving devices.
3. Singh, H. K., Kumar, M., Kumar, A., Gulati, A., & Jyoti (2024), in the review paper titled "*A review of irrigation systems in India utilizing both conventional and non-conventional water sources"* have analysed the non-conventional use of water resources.
4. Marlene Tomaszkiewicz, Majdi Abou Najm, Daniel Beysens (2015), researched on the topic, "Dew as a Sustainable Non-Conventional Water Resource: A Critical Review" and explored the concept of dew harvesting as a water conservation technique that can be utilized for irrigation purposes.

NATIONAL OVERVIEW: IRRIGATION UNDER OTHER-SOURCES

Out of 36 states/UTs other-sources of irrigation is prevalent in 31 states/UTs except Haryana, Punjab, Ladakh, Delhi and Lakshadweep. At all India 58 lakh hectares irrigated

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under this category during 2025, these sources contribute approximately one-tenth of the total irrigated area in the country. In comparison, wells account for the largest share of irrigated area, followed by canals, other-sources and tanks contribute very little extent.

Nevertheless, despite the dominance of major sources, other-sources of irrigation continue to play an important role in several states. Their significance becomes particularly evident in areas where large irrigation infrastructure cannot be easily developed due to factors such as rugged terrain, dispersed settlements, or limited water storage potential and requirement of major financial investment.

Moreover, these alternative irrigation systems often represent traditional knowledge based and locally adapted practices that have evolved over centuries. Many of these systems are also modern and innovative, cost-effective and environmentally sustainable, making them particularly relevant in today's context of climate change and water scarcity.

STATE-WISE DISTRIBUTION OF OTHER-SOURCES OF IRRIGATION

The distribution of irrigation under other-sources varies widely across states. States such as Madhya Pradesh, Uttar Pradesh, Odisha, Karnataka, Maharashtra Gujarat, Rajasthan, Kerala, Bihar, Andra Pradesh and all North Eastern states have recorded large irrigated areas under this category, while states such as Tamil Nadu, Uttarakhand, Goa, and UTs show minimal dependence on such systems. It is clear from the table that the other-sources are prevalent in almost all states, except Haryana and Punjab, out of total 28 states in India. Also, out od total 8 UTs, other-sources of irrigation are ubiquitous in 5 UTs, except Delhi, Ladakh and Lakshadweep (Table 1).

Table 1: NIA by Different Sources of Irrigation in Indian States 2020-2024 (in Hectares)

Sl. No.	State	Canal	Tank	Well	OS	Total
1	Madhya Pradesh	1625152	407078	6290624	1793790	10116645
2	Odisha	0	0	0	769963	769963
3	Uttar Pradesh	1175468	24394	6606293	726045	8532201
4	Karnataka	1159406	109607	2957599	670497	4897109
5	Maharashtra	100097	23935	828560	346551	1299143
6	Gujarat	967376	151824	2226848	262981	3609030
7	Rajasthan	2185508	47032	6886992	215869	9335402
8	Assam	107739	6224	122051	125013	361027
9	Kerala	78940	46809	175386	112821	413957
10	Bihar	989339	61126	2078007	111838	3240309

Table 1 Contd....

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...Contd. Table 1

Sl. No.	State	Canal	Tank	Well	OS	Total
11	Nagaland	0	0	0	102543	102543
12	Andhra Pradesh	1237013	285903	1275917	99356	2898188
13	Arunachal Pradesh	0	0	0	63569	63569
14	Himachal Pradesh	2993	234	22901	63215	89343
15	Jharkhand	3089	56844	61929	62306	184169
16	West Bengal	110602	180734	399943	60059	751338
17	Chhattisgarh	702470	20239	479328	43024	1245061
18	Tripura	4212	1194	5794	42707	53907
19	Telangana	1192357	225111	1392420	34879	2844767
20	Jammu and Kashmir	263494	10446	16091	22263	312294
21	Uttarakhand	64855	24	228844	18477	312200
22	Manipur	0	0	0	11400	11400
23	Goa	8179	633	3124	10135	22071
24	Tamil Nadu	527593	316597	1452072	3685	2299947
25	Sikkim	213	1829	51	3398	5490
26	D&D	322	8	540	252	1123
27	Chandigarh	0	0	0	223	223
28	Puducherry	4625	0	9619	36	14280
29	A&N Islands	1	3	11	22	37
	All India	**14611723**	**1990637**	**37772385**	**5776918**	**60151663**
	% to total	**24.29**	**3.31**	**62.80**	**9.60**	**100.00**

Source: *Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Govt. of India.*

Note: *A&N Islands - Andaman and Nicobar Islands, NIA-Net Irrigated Area, OS-other sources*

STATES WITH LARGE AREA UNDER OTHER-SOURCES

States such as Madhya Pradesh (17.9 L ha), Odisha (7.7 L ha), Uttar Pradesh (7.26 L ha) and Karnataka (6.70 L ha) records high areas under the other-sources of irrigation. In these states, OS plays a crucial role in supplementing sources like wells and canals. The prominence of OS here is linked to large-scale adoption of lift irrigation, check dams, and farm ponds, especially in semi-arid and drought-prone regions. These sources enhance irrigation coverage where canal networks are inadequate and groundwater is stressed, making them integral to agricultural stability and regional water management.

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STATES WITH MODERATE AREA UNDER OTHER-SOURCES

This category includes states where OS contributes a moderate share, acting as a complementary source rather than a dominant one. Examples include Maharashtra (3.47 L ha), Gujarat (2.63 L ha), Rajasthan (2.16 L ha), Kerala (1.12 L ha.), Bihar (1.12 L ha), Andra Pradesh (1 L ha), Himachal Pradesh (63,215 ha.), Jharkhand (62,306 ha.), west Bengal (60,059 ha.). In these regions, irrigation is still largely driven by wells and canals, but OS plays a supportive role in improving water accessibility during seasonal shortages. The presence of watershed development programs and minor irrigation schemes have contributed to the steady growth of OS, helping diversify irrigation sources and reduce overdependence on a single system.

STATES WITH SMALL AREA UNDER OTHER-SOURCES

States and Union Territories with minimal OS contribution fall into this category, such as Chhattisgarh (43,024 ha.), Telangana (34,879 ha), Jammu and Kashmir (22,263 ha), Uttarakhand (18,477 ha.) and smaller contributors like Tamil Nadu, Goa, Puducherry, and Andaman and Nicobar Islands. In these areas, irrigation is dominated by traditional systems such as tanks or canals and wells, leaving limited scope or necessity for OS.

However, the growth of other-sources also raises concerns. Many of these systems depend on groundwater or seasonal flows, making them vulnerable to over-extraction and climate variability. The lack of regulation and monitoring in decentralized systems can lead to inefficiencies and sustainability issues. Additionally, since OS includes diverse structures, data classification inconsistencies may obscure their true contribution and effectiveness.

Overall, other-sources of irrigation have emerged as a dynamic and adaptive component of India’s irrigation landscape. While their share remains modest, their role is critical in bridging gaps left by traditional systems, particularly in regions with geographical and climatic constraints. Future policy should focus on sustainability, standardization of data, and integration with watershed and groundwater management strategies to ensure that these sources contribute effectively to long-term agricultural productivity.

STORY OF NORTH EAST INDIA REGION

North-East India, comprising Assam, Arunachal Pradesh, Mizoram, Meghalaya, Manipur, Tripura, Nagaland, and Sikkim, is rich in biodiversity and cultural heritage. Agriculture in the region largely depends on natural moisture and monsoon rainfall, resulting in unstable crop production. Although the region has abundant water resources, irrigation mainly relies on rain-fed systems, minor irrigation structures, and gravity-based irrigation from perennial hill streams managed by local communities. Table 2 presents different sources of irrigation across the eight North-Eastern states.

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Table 2: NIA by Different Sources of Irrigation In Indian States 2020-2024 (in Hectares)

Sl. No.	State	Canal	Tank	Well	OS		Total NIA
					NIA	% to state total	
1	Assam	107739	6224	122051	125013	35%	361027
2	Nagaland	0	0	0	102543	100%	102543
3	Arunachal Pradesh	0	0	0	63569	100%	63569
4	Tripura	4212	1194	5794	42707	79%	53907
5	Manipur	0	0	0	11400	100%	11400
6	Sikkim	213	1829	51	3398	62%	5490
7	Mizoram	0	0	0	12000	100%	12000
8	Meghalaya	0	0	0	104448	100%	104448
	Total NE Region	112163	9247	127896	465077	65%	714384

Source: *Directorate of Economics and Statistics, Dept. of Agriculture and Farmers, Govt. of India, 2025*

An analysis of the "other-sources" of irrigation in the North East Region (2020 to 2024) indicates a dominant reliance on non-conventional and minor irrigation systems compared to canals, tanks, and wells. Out of the total NIA of 7.14 lakh hectares, nearly 4.65 lakh hectares (65%) are irrigated through other-sources, highlighting their crucial role in the region's agricultural water management. Several states depend almost entirely on these sources. Out of 8 NE states 5 states namely Nagaland, Arunachal Pradesh, Manipur, Mizoram and Meghalaya record 100 percent of their irrigated area under other-sources, reflecting the absence or negligible presence of major irrigation sources due to the region's mountainous terrain, dispersed settlements. In Tripura, other-sources account for 42,707 hectares (79%) of the irrigated area, while Sikkim records 62 percent. Even in Assam, where canals and wells exist to some extent, other-sources still contribute 1.25 lakh hectares (35%) of total irrigation.

Prominent traditional irrigation methods include Zabo, Dong, Cheo-ozihi, Bamboo Drip Irrigation, wet-rice irrigation, Pukhris (ponds), Kholas, Tuikhur, and other artificial irrigation systems. A brief description of these systems is provided below as researched by Sen, P., et al (2015) in their article titled, "Understanding indigenous irrigation systems in North East India".

1. **Bamboo Drip Irrigation:** The bamboo drip irrigation system practiced in Meghalaya is an ingenious traditional method of irrigation developed by the tribal farmers of the Khasi and Jaintia hills over 200 years ago. In this system, hard bamboo pipes are used to divert perennial stream and spring water from hilltops to plantations located at lower elevations through gravity. The bamboo channels

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convey water to the fields, where it is further distributed through smaller bamboo pipes and diversion units arranged in several stages.

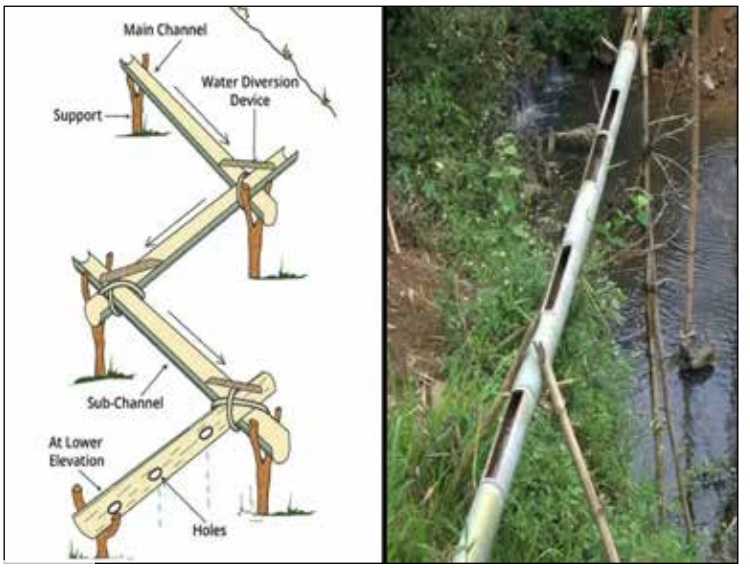


Fig. 1: Bamboo Drip irrigation, Meghalaya

2. **Zabo:** *Zabo* is pounding of water. Zabo, an indigenous farming system that combines forestry, agriculture, fishery and animal husbandry.
3. **Dong Bandh:** This traditional system is in practice in parts of Lower Assam by peoples participation to construct the temporary check dams called *dong bund* to the flowing water. It is being practiced by Assamese, Boros & Nepalese etc.



Fig. 2: Dong Bandh

4. **Cheo-ozihi:** The River Mezii flows along the Angami village of Kwigema in Nagaland. The river water is brought down by a long channel. From this channel, many branch channels are taken off, and water is often diverted to the terraces through bamboo pipes.

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5. **Wet Rice Irrigation:** Traditional irrigation system in Arunachal Pradesh-the irrigation of rice terraces with bamboo pipes, and the Apatani system of wet rice irrigation.



Fig. 3: Wet Rice Irrigation, Arunachal Pradesh

6. ***Pukhris*:** *Pukhris* or ponds in Manipur *Pukhris* are the most prevalent traditional water harvesting structures. It was quite common to have a small pond at the lower end of the plot in paddy fields. It was useful during the dry spells between the rains after sowing.



Fig. 4: Pukaris of Manipur

7. **Kholas:** In Sikkim, local people have evolved efficient water harvesting systems together with land management systems called Kholas or small tanks. The common sources of drinking water are streams and kholas.

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8. **Tuikhur:** In Mizoram people used to harvest the water from small hilly streams for irrigation and domestic purposes by constructing small tanks or Tuikhur at the foot hills.



Fig. 5: Tuikhur or Tanks of Mizoram

9. In the Brahmaputra and Barak valleys of Assam, there had been a long tradition of artificial irrigation, by the means of artificial channels in the sub-mountainous tracts (Sen, P., Devi, N. L., & Singha, D., 2015).

Overall, the above information suggests traditionally adapted irrigation practices **remain the backbone of irrigation** in the North Eastern states of India.

KARNATAKA IN THE NATIONAL CONTEXT

Karnataka occupies an important position in the national irrigation landscape. With 6.70 lakh hectares of irrigated area under other-sources, the state accounts for 13.7 percent of its total irrigated area, which is higher than the national average of 10 percent.

The relatively significant role of other-sources in Karnataka reflects the diverse nature of irrigation practices in the state. While tanks and wells constitute other important major irrigation sources, several regions depend on alternative irrigation systems such as lift irrigation schemes, small streams, and localized diversion structures. It is important to note that the Minor Irrigation Department is the main department responsible for these other sources of irrigation, for which the government allocates about ₹3,500 crores annually since 2020.

In addition, government’s initiatives mainly aimed at strengthening minor irrigation infrastructure that have contributed to the expansion of irrigation through these alternative systems.

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Table 4: Sources of Irrigation in Karnataka 2020-2024 (Hectares)

S. No.	District	Canal	Tank	Well	OS	% of OS to NIA	NIA	NAS	II
1	**2**	**3**	**4**	**5**	6	7	**8**	**9**	**10**
1	Belagavi	62069	529	335244	243692	38%	641535	**213845**	67%
2	Bagalkot	34975	378	227806	103536	28%	366694	**122231**	75%
3	Raichur	296593	3562	17057	54834	15%	372045	**124015**	58%
4	Yadgir	140028	5199	25062	46252	21%	216542	**72181**	56%
5	Kalaburagi	15172	5119	79393	39991	29%	139675	**46558**	16%
6	Ballari	108240	1573	61324	35547	17%	206684	**68895**	57%
7	Chikkamagaluru	5984	8331	64184	31202	28%	109702	**36567**	35%
8	Haveri	842	1036	146287	20633	12%	168797	**56266**	45%
9	Dakshin Kannad	0	0	143082	17421	11%	160503	**53501**	89%
10	Vijayapura	58357	3393	330982	15979	4%	408711	**136237**	45%
11	Shivamogga	41531	32957	80504	12452	7%	167444	**55815**	69%
12	Uttar Kannad	122	2766	48461	10571	17%	61920	**20640**	52%
13	Gadag	35331	1625	36248	9361	11%	82564	**27521**	23%
14	Davangere	68081	1441	120581	8891	4%	198994	**66331**	63%
15	Hassan	41682	11965	71148	4684	4%	129479	**43160**	31%
16	Vijayanagar	12485	773	102185	4148	3%	119592	**39864**	48%
17	Dharwad	7437	99	36335	3251	7%	47121	**15707**	15%
18	Koppal	45767	5253	120726	2693	2%	174440	**58147**	42%
19	Mandya	107722	14674	69100	2678	1%	194173	**64724**	68%
20	Udupi	0	634	42340	2351	5%	45325	**15108**	45%
21	Bidar	345	279	53597	880	2%	55101	**18367**	14%
22	Mysuru	70263	6910	87755	388	0%	165316	**55105**	45%
23	Chikkaballapura	1	18	53392	371	1%	53781	**17927**	30%
24	Kodagu	1414	37	51	185	1%	1687	**562**	1%
25	Ramanagara	1858	476	36785	128	0%	39248	**13083**	24%
26	Chamarajanagar	7848	325	83934	13	0%	92120	**30707**	59%
27	Chitradurga	251	43	153730	12	0%	154037	**51346**	35%
28	Kolar	0	3	51673	11	0%	51687	**17229**	29%
29	Bengaluru Urban	0	6	12259	1	0%	12265	**4088**	33%
30	Bengaluru Rural	0	0	27493	0	0%	27493	**9164**	24%
31	Tumakuru	0	512	279757	0	0%	280269	**93423**	49%
Total of Karnataka		**1159406**	**109607**	**2957599**	**670497**	**14%**	**4897109**	**1632370**	**44%**
% to Total NIA		**23.7**	**2.2**	**60.4**	**13.7**	**-**	**100**	**-**	**-**

Source: *Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Govt. of India*

Note: *II-Irrigation Intensity, NSA-Net Sown Area*

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In Karnataka, the irrigation from “other-sources” include irrigation from Lift Irrigation Schemes (LIS), Check Dams, Springs, Pickups, Seepage Water, *Naals* (Open drainage channels), Ponds, *Kuntes* (Traditional water-harvesting pits), Drain-Water, Small Streams, Farm-ponds, Dykes, Bridge-Cum-Barrages, Percolation tanks, Salt Water Exclusion Dams (SWED), Vented Dams, *Bandharas* (Weirs), minor irrigation schemes, and other decentralized water harvesting structures that are not formally categorized under canals, tanks, or wells.

The distribution of irrigation through other-sources across districts reveals significant regional variation. Districts such as Belagavi, Bagalkot, Raichur, Yadgir, Kalaburagi, Ballari, Chikkamagaluru and Haveri show relatively high reliance on other-sources. These districts are largely located in the northern and central parts of Karnataka.

DISTRICTS WITH HIGH CONTRIBUTION OF OTHER-SOURCES (BETWEEN 20,000 AND 2 LAKH HECTARES)

Among the 31 districts, Belagavi records the highest area irrigated through other-sources, with 2.44 lakh hectares (38%), followed by Bagalkot with 1.04 lakh hectares (28%). These OS districts are largely located in the drought-prone northern region of Karnataka, where rainfall variability is high and limited canal irrigation that have increased reliance on alternative irrigation sources. In contrast, Chikkamagaluru (31,202 hectares; 28%) and Haveri (20,633 hectares; 12%) also report notable irrigation through other-sources despite being situated in transitional agro-climatic zones characterized by normal to relatively higher rainfall.

MODERATE DEPENDENCE DISTRICTS (LESS THAN 20000 HECTARES)

Six districts display moderate dependence on other irrigation sources, that is less than 20,000 hectares. For instance, Dakshin Kannada (17,421 hectares, 11%), and Vijayapura (15,979 hectares, 4%) show varying levels of dependence. In coastal districts such as Dakshin Kannada, the presence of rivers, streams, and local water harvesting systems contributes to irrigation under the “other-sources” category.

Shivamogga and Uttar Kannada, both located in the Western Ghats region, also rely moderately on other irrigation sources. Shivamogga records 12,452 hectares (7%), while Uttar Kannada irrigates 10,571 hectares (17%), Gadag (9,361 hectares, 11%), Davangere (8,891 hectares, 4%), through such sources. The presence of perennial streams and small-scale water diversion systems, lift irrigation schemes and farm-ponds contribute to irrigation in these districts.

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DISTRICTS WITH LOW CONTRIBUTION (LESS THAN 5000 HECTARES)

Six districts record relatively low contributions from other irrigation sources, that is less than 5,000 hectares. Hassan (4,684 hectares, 4%) show limited dependence on these systems. In these areas, irrigation is primarily supported by wells and canal networks. Vijayanagar (4,148 hectares, 3%), Dharwad (3,251 hectares, 7%), Koppal (2,693 hectares, 2%), and Mandya (2,678 hectares, 1%) record smaller contributions from other-sources. Mandya in particular is heavily dependent on canal irrigation from the Cauvery basin, which explains the minimal share of alternative irrigation sources. Coastal district such as Udupi (2,351 hectares, 5%) also show relatively low dependence, although small water structures and streams still play a minor role.

DISTRICTS WITH NEGLIGIBLE/ZERO CONTRIBUTION

As many as 11 districts report negligible or zero irrigation from other-sources. These include Bidar, Mysuru, Chikkaballapura, Kodagu, Ramanagara, Chamarajanagar, Chitradurga, Kolar, Bengaluru Urban and Bengaluru Rural and Tumakuru.

The low figures in these districts can be attributed to the dominance of groundwater irrigation through wells and borewells. Urbanized districts such as Bengaluru Urban and Bengaluru Rural, Chikkaballapura, Ramnagara, agricultural land itself is limited, further reducing the relevance of alternative irrigation systems. Further, the districts namely Mysuru, Kodagu, Chamrajnagar fall under the Cauvery basin area.

REGIONAL TRENDS-KARNATAKA

From a regional perspective, the northern districts of Karnataka exhibit the highest reliance on other-sources of irrigation. This is primarily due to semi-arid climatic conditions, uneven canal distribution, and the need for supplementary irrigation systems. The coastal and Western Ghats districts show moderate levels of dependence because of the availability of natural streams and high rainfall, which support small-scale water diversion systems. In contrast, southern districts such as Hassan, Kodagu, Mandya, Mysuru, and Chamarajanagar rely largely on Cauvery canal irrigation and groundwater, leaving very little scope for other-sources.

CORRELATION BETWEEN NIA AND IRRIGATION INTENSITY

Irrigation intensity refers to the percentage of area irrigated to the to Net Sown Area in a year in terms of season hectares. The contribution of other-sources of irrigation and irrigation intensity shows a partial relationship across districts of Karnataka, as these supplementary sources help expand irrigated cultivation where canal and tank irrigation are limited. Districts such as Belagavi (38% of NIA under other-sources) and

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Bagalkot (28%) record relatively high irrigation intensities of 67% and 75% respectively, indicating that other-sources support multiple cropping and improved water availability. However, the relationship is not uniform across all districts because irrigation intensity is also influenced by rainfall, groundwater use, and cropping patterns. For example, Dakshin Kannada has only 11% of NIA under other-sources but records the highest irrigation intensity (89%), while Kalaburagi shows a higher share of other-sources (29%) but relatively low irrigation intensity (16%). This indicates that although other-sources contribute to irrigation expansion, their influence on cropping intensity depends on the overall irrigation structure and agro-climatic conditions.

MAJOR FACTORS INFLUENCING THE USE OF OS OF IRRIGATION

The variation in the use of other-sources of irrigation across states can be attributed to several factors.

1. **Topography:** In mountainous and hilly regions, the construction of large canal systems is often impractical. As a result, farmers rely on small irrigation systems that utilize springs, streams, and other locally available water sources.
2. **Rainfall Patterns:** Regions with high rainfall often develop localized irrigation systems to capture and utilize excess water during the monsoon season.
3. **Availability of Groundwater:** In areas where groundwater resources are limited or difficult to access, farmers may depend more heavily on alternative irrigation systems.
4. **Historical and Traditional Practices:** Many other irrigation systems represent traditional water management practices that have been passed down through generations.

POLICY IMPLICATIONS

The analysis highlights the importance of strengthening alternative irrigation systems as part of a comprehensive water management strategy. Government policies should focus on:

- Promoting minor irrigation schemes
- Encouraging community-based water management
- Rehabilitating traditional water harvesting structures
- Integrating modern technology with traditional irrigation practices

Such measures can help enhance irrigation coverage while ensuring sustainable water use.

CONCLUSION

The analysis of irrigation under other-sources in India reveals that although these systems account for 10 percent of the total irrigated area at the national level, they play a crucial

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role in several states. In regions characterized by difficult terrain, limited infrastructure, or unique environmental conditions, other sources of irrigation serve as the primary means of supporting agricultural activities. The states such as Madhya Pradesh, Uttar Pradesh, Karnataka, and Maharashtra record significant areas under other sources of irrigation, indicating major public expenditure on minor irrigation schemes and continued relevance of these systems in the agricultural economy. More reliable and timely data on these other sources of irrigation across different states would help in understanding their effectiveness and innovativeness, and may facilitate the wider dissemination and adoption of these methods across India.

Furthermore, several smaller states and union territories rely almost entirely on these alternative irrigation systems due to geographical constraints. This underscores the need to recognize and strengthen these localized traditional irrigation practices as an integral component of India's irrigation strategy.

REFERENCES

Sen, P., Devi, N. L., & Singha, D. (2015). Understanding indigenous irrigation systems in North East India. *EcoWhisper*, 2(1), March, 2015 pages 11-13.

Beithou, N. (2015). Non-conventional water resources: Review and developments. *Applied Science Private University*, January–June, 1–8.

Singh, H. K., Kumar, M., Kumar, A., Gulati, A., & Jyoti. (2024). *A review of irrigation systems in India utilizing both conventional and non-conventional water sources.*

Marlene Tomaszkiewicz, Majdi Abou Najm, & Daniel Beysens. (2015). Dew as a sustainable non-conventional water resource: A critical review. *Environmental Reviews*, 23(4), 425–442.

Shrish, S. (2024, June 21). Bamboo drip irrigation system in India: A unique setup. *Agri Technologies – Farming*. https://timesofagriculture.in/bamboo-drip-irrigation-system-meghalaya/

What is Dong? Know About Centuries-old Traditional Method That Brings River Water into Villages of Assam Curated By : Niloy Bhattacherjee, November 08, 2020. https://www.news18.com/news/india/what-is-dong-know-about-centuries-old-traditional-method-that-brings-river-water-into-villages-of-assam-3057092.html.

Krishnakanta Kshetrimayum. (2013, May 6). *Traditional irrigation systems of North East India.*

World Bank. (1998, September 10). *India: Water resources management sector review report on the irrigation sector*. World Bank.

Gireesh, M. (1996). *Rehabilitation of irrigation tanks in eastern dry zone of Karnataka: An economic analysis* (Unpublished master's thesis). Department of Agricultural Economics, University of Agricultural Sciences, Bangalore, India.

YouTube video by Dimple Nankani, Irrigation Intensity: Understanding the concept and its importance. https://youtu.be/tFASVIErL8w.

DATA SOURCES

Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare Ministry of Agriculture and Farmers Welfare, Govt. of India. (various years)

 ISBN: 978-93-49666-59-7 (eBook)

Directorates of Economics and Statistics, Governments of Karnataka, Andra Pradesh and Telangana. (various years).

Agriculture & Farmers' Welfare Department, Mizoram (various years).

Department of Agriculture, Meghalaya. (various years).

National Bank for Agriculture and Rural Development, Govt. of India, 2025 website: https://www.nabard.org/content.aspx?id=4.

International Commission on Irrigation & Drainage, 2025. Website: *https://icid-ciid.org/Knowledge/basic_term/21/Irrigation#:~:text=Lift%20irrigation%20is%20a%20method,land%20is%20at%20higher%20level.*

Department of Water Resources, River Development & Ganga Rejuvenation, National Dam Safety Authority, National Register of Specified Dams- April 2025. Website:*file:///C:/Users/Admin/Desktop/HoTs%20in%20Ktka%20Paper/Dams%20list%20in%20India.pdf.*

Guidelines for preparation of Lift Irrigation Schemes, Water Resources Department, Govt. of Karnataka, 2003.

Minor Irrigation Manual, Office of the Chief Engineer, Minor Irrigation, Govt. of Karnataka, Bengaluru, 1990.

Water Resources Department, Government of Karnataka website:https://waterresources.karnataka.gov.in/46/irrigation-assets/en.

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Chapter

15 Closing the Glamour Loop: A Paradigm Shift in Beauty through Circular Economy

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ABSTRACT

For decades, the beauty industry followed a linear "take-make-waste" model wherein the raw materials were extracted, products were sold, and packaging was eventually discarded. In the modern world, this model has begun raising eyebrows, and being characterized by the extraction of raw materials, reckless production, overconsumption, and low-effort disposal.

However, sustainability has become a critical business and societal priority, and brands across the world are being compelled to reimagine their conventional approach of being. Hence, today, we are witnessing a transformative shift toward a circular economy. This concept has emerged as a framework that seeks to eliminate waste, extend product lifecycles, optimize resource utilisation, and regenerate natural systems. This has given rise to a paradigm shift within the beauty sector in how raw materials are sourced, products are designed, manufactured, distributed, consumed and disposed of as their lives come to an end.

In the world where users are blinded by the reckless “greenwashing”, consumers rarely question the material traceability, and the post-use whereabouts of the waste generated during the process.

This paper aims to investigate how the circular economy principles are reshaping practices by the beauty industry, and employing the Life Cycle Thinking Framework to understand impact and interventions from end-to-end processes, through the case studies of Well People, Forest Essentials, Kjaer Weis and L’Occitane India.

Keywords: Circular Economy Models, Beauty industry, Life Cycle Thinking, Greenwashing.

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INTRODUCTION

The global beauty and personal care industry has long been associated with innovation, aspiration, and consumer self-expression. However, beneath its glamorous image lies a resource-intensive value chain characterized by high material consumption, complex packaging systems, and significant waste generation. Traditionally, the industry has operated on a linear "take-make-dispose" model, where virgin resources are extracted, transformed into products, consumed, and ultimately discarded. Growing concerns regarding climate change, resource depletion, plastic pollution, and landfill accumulation have intensified calls for a transition toward more sustainable business models. In response, the concept of the Circular Economy (CE) has emerged as a transformative framework that seeks to decouple economic growth from resource consumption by designing out waste, keeping materials in use for as long as possible, and regenerating natural systems.

The urgency of this transition is particularly evident in the beauty industry's packaging challenge. Industry estimates indicate that the global cosmetics sector generates billions of packaging units annually, a substantial proportion of which are difficult to recycle due to mixed-material designs and small-format packaging. Furthermore, reports from the Ellen MacArthur Foundation reveal that a significant share of cosmetic packaging remains non-recyclable, highlighting the need for systemic redesign and circular business models. Refillable packaging systems, recycled materials, reusable containers, and innovative waste recovery initiatives are increasingly being adopted as practical solutions to address these concerns.

Within this context, the present study examines how circular economy principles are being integrated across the beauty value chain through a Life Cycle Thinking (LCT) perspective. Life Cycle Thinking extends beyond isolated sustainability initiatives by evaluating environmental impacts across every stage of a product's journey—from raw material sourcing to end-of-life management. By adopting this holistic lens, the study explores how beauty brands are embedding circularity into their operations rather than treating sustainability as a standalone activity. The research categorizes circular initiatives into four interconnected phases of the product life cycle: sourcing and design, manufacturing, distribution and packaging, and post-consumer use.

To analyse these stages, the study employs the 5Rs Framework—Refuse, Reduce, Reuse, Repurpose, and Recycle—which serves as a practical tool for assessing circular practices within business operations. Unlike traditional waste management approaches that focus primarily on recycling, the 5Rs framework prioritizes waste prevention and resource optimization throughout the product life cycle. The framework aligns closely with circular economy principles by encouraging organizations to minimize resource extraction, extend product utility, and recover value from materials that would otherwise become

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waste. This makes it particularly relevant for evaluating sustainability initiatives within the beauty sector, where packaging, ingredients, and consumption patterns significantly influence environmental outcomes.

The study investigates four beauty brands that demonstrate distinct approaches to circularity across different stages of the value chain. In the sourcing and design phase, **Well People** is examined for its use of upcycled agro-industrial side streams and naturally derived ingredients, illustrating how waste materials can be transformed into high-value cosmetic inputs. During the manufacturing phase, **Forest Essentials** provides insights into resource-efficient production through initiatives such as renewable energy adoption and water conservation practices. The distribution and packaging stage is represented by **Kjaer Weis**, a pioneer in refillable luxury beauty packaging that challenges the industry's dependence on single-use containers. Finally, the post-consumer use phase is explored through **L'Occitane India's** waste reduction and recycling initiatives, which focus on packaging recovery, responsible disposal, and landfill diversion. Together, these case studies demonstrate how circularity can be embedded throughout the beauty product life cycle rather than confined to a single operational stage.

By analysing circular practices through a lifecycle lens, this paper seeks to contribute to the growing discourse on sustainable beauty and circular business transformation. It argues that circular economy principles are no longer peripheral sustainability initiatives but strategic mechanisms capable of driving innovation, enhancing brand value, and reducing environmental impact. As consumer expectations, regulatory pressures, and environmental challenges continue to reshape the industry, closing the glamour loop may represent not only an ecological necessity but also the future direction of beauty itself.

METHODOLOGY

This paper follows a qualitative methodology to analyse how the "Business of Beauty" is slowly becoming ethically responsible by the adoption of the circular economy model. The research is based on secondary data collected from academic journals, industry reports, and credible online sources.

To understand the practical application of circularity, case studies of **Well People, Forest Essentials, Kjaer Weis,** and **L'Occitane India** were analysed. These brands were selected for their initiatives in sustainable sourcing, resource-efficient manufacturing, refill and reuse systems, and waste reduction.

Data was analysed using thematic analysis to identify recurring patterns and map circular practices across different stages of the product lifecycle. By integrating theoretical insights with industry examples, the study evaluates how beauty brands are transitioning from linear models to more circular and sustainable business practices.

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To interpret the findings, the study applies a **Life Cycle Thinking (LCT)** framework, categorizing circular initiatives into four distinct phases:

Sourcing and Design: Examining the upcycling of agro-industrial side streams into high-value ingredients. (Well People)

Manufacturing: Analyzing resource optimization, such as "waterloop" factories and renewable energy use. (Forest Essentials)

Distribution and Packaging: Evaluating the transition toward refillable, reusable, or recyclable formats. (Kjaer Weis)

Post-Consumer Use: Assessing waste management strategies and landfill reduction efforts. (L'Occitane India)

ANALYSIS

Agro-Industrial Side Streams into High-Value Ingredients: Ethical Sourcing by Well People

WELL PEOPLE provides a relevant case of how sustainability can be integrated into cosmetic sourcing and product development through plant-based formulation, ingredient screening, ethical sourcing and environmentally conscious packaging. Founded in 2008, the brand was developed around the use of plant-powered ingredients while avoiding potentially harmful chemicals. Its formulation philosophy excludes more than 2,500 questionable or restricted ingredients, positioning ingredient selection as a central sustainability intervention rather than treating sustainability solely as a packaging issue. The brand's product portfolio also includes 100+ EWG Verified products, demonstrating the scale at which third-party ingredient verification has been incorporated into product development.

From a sourcing perspective, Well People prioritizes botanical and naturally derived materials such as aloe, broccoli seed oil, raspberry seed oil, pomegranate and other plant extracts. For example, its Bio Tint SPF 30 formulation contains 20% non-micronized zinc oxide, alongside broccoli seed and raspberry seed oils, illustrating how plant-derived ingredients are incorporated alongside functional mineral ingredients. This strategy potentially reduces dependence on certain petroleum-derived synthetic inputs while simultaneously responding to growing consumer demand for clean-label cosmetics. However, the environmental superiority of a plant-derived ingredient cannot automatically be assumed; cultivation, extraction, transportation and processing can also generate environmental impacts. Consequently, sustainability claims should ideally be supported by life-cycle assessment (LCA) rather than ingredient origin alone.

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The brand also incorporates sustainability through packaging and responsible sourcing. Available evidence indicates the use of FSC-certified paper, recyclable materials and post-consumer recycled plastics in parts of its packaging portfolio. These measures address resource consumption and packaging waste, although they represent a relatively conventional form of sustainability compared with circular strategies such as refill systems, closed-loop packaging or material upcycling.

This distinction is particularly important when Well People is evaluated against emerging circular-economy research. A 2024 systematic literature review found that cosmetic circularity research is concentrated most heavily on input valorization, particularly the conversion of agri-food waste and by-products into cosmetic ingredients. Similarly, Hoxha et al. (2026) identify grape pomace, olive residues, apple pomace, tomato residues and other agro-industrial side streams as promising sources of polyphenols, antioxidants, fatty acids and other cosmetic bioactives.

Therefore, Well People can be characterized as strong in sustainable sourcing but comparatively less advanced in circular sourcing. Its current model reduces potentially harmful inputs and incorporates plant-based and recycled materials, but publicly available evidence does not demonstrate extensive use of agro-industrial side streams. Integrating ingredients derived from grape pomace, coffee by-products, fruit peels or seed residues could therefore represent the next stage of sustainability evolution—moving Well People from a "clean and responsible" model toward a genuinely circular product-development model.

Responsible Manufacturing by Forest Essentials

Forest Essentials provides a significant example of how sustainability can be incorporated into the design and operation of beauty manufacturing infrastructure, particularly through energy efficiency, renewable energy, water management and material reuse. Its Lodsi manufacturing facility in Uttarakhand was designed by Morphogenesis and completed as a 10,000 sq. ft. facility in 2019. Rather than treating sustainability as an add-on to conventional manufacturing, the facility incorporates passive architectural strategies to reduce resource consumption at source.

Energy optimisation is a central feature of the facility. The building uses its orientation, façade shading, window-to-wall ratio, thermal-mass materials and natural ventilation to reduce dependence on mechanical cooling and artificial lighting. Approximately 80% of the facility is naturally daylit, while operable windows and clerestory openings facilitate natural ventilation. The resulting building envelope has an Energy Performance Index (EPI) of 35 kWh/m^2/year. In addition, a 50 kWp rooftop solar installation generates renewable electricity; the project documentation states that the installation is sufficient to offset the facility's requirements and can generate surplus electricity for the state grid.

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Water management demonstrates another dimension of resource optimisation. The Lodsi project incorporates a site-specific rainwater harvesting and storage system. Its documented annual terrace rainwater harvesting potential is approximately 740 m^3 (740,000 litres), against a factory water requirement of approximately 30 m^3 per day (30,000 litres). A 60 m^3 storage tank, equivalent to roughly two days of the stated daily requirement, was incorporated into the design. The project documentation consequently describes the facility as net-zero in energy, water and waste at the building-design level.

Material circularity is also embedded within the facility. Construction leftovers were repurposed into functional components—for example, reclaimed wooden rafters became light fixtures, waste purlins were converted into tube-light holders, and stone chisels were reused as door handles. Facility by-products are reported to be either reused or composted.

From a circular-economy perspective, Forest Essentials therefore demonstrates a shift from a linear "take–make–dispose" manufacturing model towards resource conservation and closed-loop practices. However, an important limitation is the absence of publicly available, independently audited data on actual annual water savings, solar electricity generation, carbon emissions and waste diversion. Thus, the Lodsi facility provides strong evidence of sustainability-by-design, but its long-term operational performance cannot be quantified fully from publicly disclosed data. This distinction is consistent with circular-economy research, which emphasises measurable resource efficiency and lifecycle performance rather than sustainability claims alone (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

Distribution and Packaging: Evaluating the transition toward refillable, reusable, or recyclable formats with Kjaer Weis

Kjaer Weis represents a significant case of circular packaging innovation within the luxury cosmetics industry, where packaging is traditionally designed for single-use consumption. Founded in 2010, the brand launched with a 100% refillable, plastic-free makeup line, making packaging reuse a central component of its business model rather than a later sustainability initiative. Its original Iconic Edition uses durable metal cases designed to be retained and repeatedly refilled, while the consumable cosmetic component is replaced separately. The brand subsequently expanded this model to mascara in 2013 and lipstick in 2016, demonstrating a progressive expansion of refillability across product categories.

The commercial significance of the refill model is particularly important. A life-cycle assessment study of cosmetic packaging reports that Kjaer Weis refills were approximately 30% cheaper than purchasing a new compact and that refillable products—including mascara, lip gloss and eyeliner—accounted for approximately 25% of the company's

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annual revenue. Industry reporting subsequently indicated that refills represented approximately 25–30% of total business, suggesting that circular packaging had become commercially relevant rather than remaining a niche sustainability feature.

Kjaer Weis introduced its Red Edition in 2020 as a lighter alternative to its metal packaging. The Red Edition is manufactured from high-gloss paper and is designed to be filled up to three times, after which the packaging can be recycled or composted. This creates two distinct circular pathways: the Iconic Edition prioritises long-term reuse of a durable metal package, while the Red Edition combines limited reuse with end-of-life material recovery. The refill pans themselves are made from tin, while refill packaging uses recyclable paper and cardboard.

The brand has also progressively addressed distribution packaging. In January 2022, Kjaer Weis introduced fully recyclable shipping boxes and materials. It currently states that its products, packaging and shipping materials are 100% recyclable, compostable or refillable, with FSC-certified materials and water-based inks used across its packaging system.

From a circular-economy perspective, the strategy is significant because it prioritises reuse before recycling. Academic LCA research on cosmetic packaging found that reuse can provide substantially greater environmental benefits than recycling when products are actually reused multiple times. However, Kjaer Weis does not publicly disclose sufficient product-level data on average number of refills per compact, packaging weight saved per refill, or lifecycle carbon emissions. Therefore, while the brand demonstrates strong design-for-reuse, its precise environmental impact cannot yet be independently quantified.

Saving What's Left for the Best: Landfill Reduction at L'Occitane India

L'Occitane India provides a strong example of addressing sustainability at the post-consumer stage, where cosmetic packaging would otherwise enter the municipal waste stream. In FY 2022, L'Occitane launched its "Big Little Things" recycling programme in India in partnership with Saahas Zero Waste, an Indian organisation working in waste management and social inclusion. The programme was positioned as the first beauty-industry recycling initiative in India to accept PET packaging from other beauty brands, rather than restricting collection to L'Occitane products. To create initial consumer awareness, the launch involved 22 influencers and reached 310,904 people across India.

The programme operates through participating L'Occitane boutiques and accepts full-sized, clean and dry beauty, skincare and haircare packaging from any brand. The eligibility criteria cover multiple categories, including face-care containers from 15 ml

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to 150 ml+, depending on product type; body-care packaging generally from 50 ml to 250 ml+; 500 ml shampoo, conditioner and shower-product refill packs; and fragrance containers of 50 ml or above. This broad acceptance criterion is important because it expands the programme from brand-specific take-back to a more inclusive multi-brand collection system.

Consumer incentives are built directly into the collection mechanism. Customers receive one reward for every 10 eligible empties returned, creating a measurable behavioural intervention: recycling 100 qualifying packages generates 10 rewards. Customers must clean and dry containers before collection, reducing contamination and improving their recyclability. The programme is designed as a long-term initiative, rather than a temporary campaign.

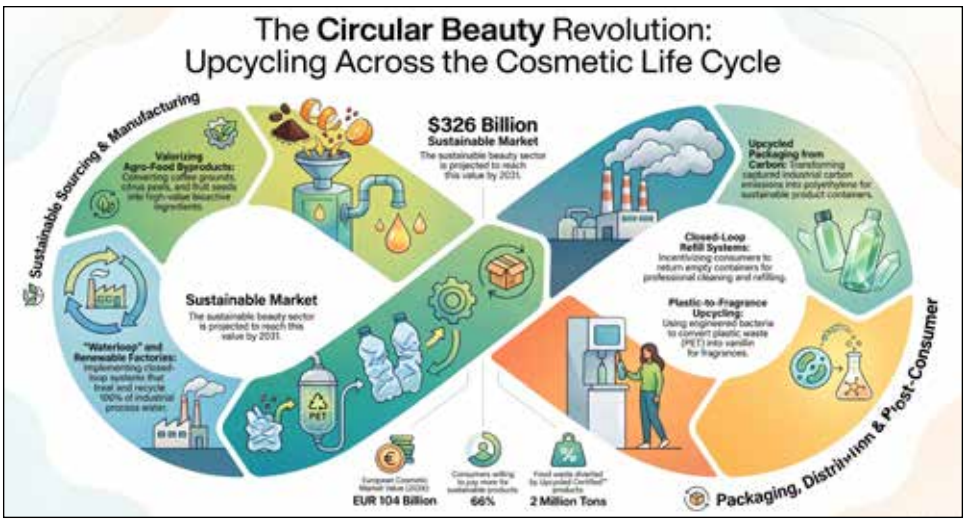
The programme forms part of a wider L'Occitane waste-reduction strategy. As of 2025, the L'Occitane Group reported that 61% of its bottles contained recycled plastic, 58% of its plastic packaging was recyclable or reusable, and 85% of its company-owned stores offered a recycling service. The Group has also developed refill formats; its Eco-Refills can use up to 90% less packaging than conventional bottles, and L'Occitane reports that this initiative prevents more than 121,000 kg of packaging from reaching landfills annually.

The strategy therefore combines collection, consumer incentives, recycled materials and source reduction. However, India-specific data on the total tonnes of packaging collected through Big Little Things, the percentage successfully recycled versus rejected, and the exact quantity diverted from Indian landfills are not publicly disclosed. Consequently, the programme demonstrates a credible post-consumer circularity mechanism, but its India-level environmental impact cannot yet be quantified independently. This data gap is important when critically evaluating corporate sustainability claims.

CONCLUSION

The analysis establishes that the transition towards a circular beauty industry is not a single-point intervention but a life-cycle transformation spanning raw-material sourcing, manufacturing, packaging, consumption and end-of-life management. This transition is increasingly important because the conventional linear model continues to generate substantial material losses. Globally, only approximately 14% of plastic packaging was historically collected for recycling, while an estimated 95% of the economic value of plastic packaging material—approximately US$80–120 billion annually—was lost after a single-use cycle. The Ellen MacArthur Foundation further estimates that replacing only 20% of single-use plastic packaging with reusable alternatives represents an economic opportunity of at least US$10 billion. These figures demonstrate that circularity is not merely an environmental objective but also a resource-efficiency and business opportunity.

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Using the Life Cycle Thinking (LCT) framework, the four case studies reveal how different circular interventions can collectively address this linearity. At the sourcing and design stage, Well People demonstrates the movement towards plant-derived, screened and responsibly sourced ingredients. However, the analysis highlights a critical distinction between *clean beauty* and *circular beauty*: the use of natural ingredients does not automatically constitute circularity. Unless agricultural residues, by-products or other secondary resources are demonstrably incorporated into formulations, the model remains predominantly one of responsible sourcing rather than resource regeneration. This represents an important opportunity for the Repurpose component of the 5 Rs.

At the manufacturing stage, Forest Essentials demonstrates how resource efficiency can be embedded into infrastructure itself. Its Lodsi facility combines a 50 kWp solar installation, an Energy Performance Index of 35 kWh/m^2/year, approximately 740,000 litres of annual rainwater-harvesting potential, and a 60,000-litre storage capacity. These interventions illustrate the Reduce and Reuse principles by lowering energy demand, substituting renewable energy and retaining water within the production system. However, the absence of independently verified annual operational data means that design capacity should not automatically be interpreted as equivalent to actual environmental savings.

The strongest evidence of Reuse occurs at the distribution and packaging stage through Kjaer Weis. Its refillable metal Iconic Edition challenges the conventional single-use compact, while its Red Edition allows packaging to be used up to three times before recycling or composting. This is significant in a sector where packaging is one of the most visible manifestations of the linear economy. Importantly, the Ellen MacArthur Foundation argues that recycling alone is insufficient: reuse models should be prioritised wherever feasible because they retain products and packaging at a higher value within the system.

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At the post-consumer stage, L'Occitane India demonstrates the importance of extending producer responsibility beyond the point of sale. Its Big Little Things programme, launched in India in FY2022, uses a 10-empty-to-one-reward mechanism and accepts eligible packaging from multiple beauty brands. At the Group level, the scale of circularity has expanded further: in 2024, L'Oréal reported that 49% of its plastic packaging was refillable, reusable, recyclable or compostable, while 53% of water used in industrial processes came from recycled or reused water, 76% of industrial-site waste was recycled or reused, and 97% of operated sites used renewable energy. These broader industry benchmarks demonstrate that circularity is increasingly moving from isolated pilots towards measurable operational targets.

When mapped against the 5Rs—Refuse, Reduce, Reuse, Repurpose and Recycle—the four cases reveal an uneven hierarchy of circularity. Reduce and Reuse are relatively well represented through Forest Essentials and Kjaer Weis, while Recycle is evident through L'Occitane India. Repurpose remains comparatively underdeveloped in the selected cases, particularly in relation to large-scale agro-industrial side-stream valorisation. Most significantly, Refuse—the elimination of unnecessary materials, products and consumption altogether—remains the least developed intervention. This mirrors the wider plastics challenge: the Ellen MacArthur Foundation estimates that around 30% of plastic packaging would not be reusable or recyclable without fundamental redesign and innovation.

The LCT perspective therefore changes the central question from "Is this beauty product sustainable?" to "Where, across its entire life cycle, is value being lost and how effectively is it being recovered?" A refillable package may reduce material demand, but its benefits depend on actual consumer reuse; recycled packaging may reduce virgin-material demand, but only if collection and reprocessing infrastructure exists; and plant-based ingredients may reduce dependence on certain synthetic inputs, but their cultivation and processing still carry environmental impacts. Circularity must therefore be evaluated through measurable material flows, energy consumption, water use, recovery rates, lifecycle emissions and actual consumer behaviour, rather than individual sustainability claims.

Ultimately, the four cases suggest that the future of the beauty industry lies not in making the existing linear model marginally "greener", but in redesigning the value chain so that waste becomes an input, products remain in use for longer, and resources circulate at their highest possible value. The industry has begun closing the glamour loop, but the loop remains incomplete. The next stage of circular beauty will depend on moving from isolated initiatives towards integrated, transparent and independently measurable closed-loop systems across sourcing, production, packaging and post-consumer recovery.

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REFERENCES

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., and Hultink, E. J. (2017). The circular economy—A new sustainability paradigm? *Journal of Cleaner Production, 143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Hoxha, M., Malaj, V., Manconi, M. L., and Manca, M. L. (2026). Agro-industrial side streams in cosmetics: From raw materials to scale-up and life cycle assessment within a circular economy framework. *Cosmetics, 13*(3), 109. https://doi.org/10.3390/cosmetics13030109

Kirchherr, J., Reike, D., and Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Machado, M., Silva, S., and Costa, E. M. (2024). Byproducts as a sustainable source of cosmetic ingredients. *Applied Sciences, 14*(22), 10241. https://doi.org/10.3390/app142210241

Manca, M., et al. (2022). Reusability and recyclability of plastic cosmetic packaging: A life cycle assessment. *Cleaner Environmental Systems, 6*, 100093.

Martinez, S. F., Jaouhari, Y., Giovannelli, L., and Bordiga, M. (2026). From waste to dermocosmetic value: A narrative review of agro-industrial residues in skincare innovation. *Applied Sciences, 16*(10), 4777.

Martins, A. M., Silva, A. T., and Marto, J. (2023). A sustainable life cycle for cosmetics: From design and development to post-use phase. *Sustainable Production and Consumption, 41*, 273–286. https://doi.org/10.1016/j.spc.2023.08.003

Martins, A. M., Silva, A. T., and Marto, J. (2025). Advancing cosmetic sustainability: Upcycling for a circular product life cycle. *Sustainability, 17*(13), 5738. https://doi.org/10.3390/su17135738

Exploring circular economy in the cosmetic industry: Insights from a literature review. (2024).

Environmental Impact Assessment Review, 105, 107443.

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Chapter

16

Empowering Women, Greening Bihar: A Study of JEEViKA's Contribution

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ABSTRACT

As we move into the next century, the world faces many environmental challenges, including climate change, pollution, and resource depletion. In this context, we need to prioritise people's and the planet's well-being alongside economic growth. In Bihar, agriculture is the main source of livelihood, and women play a significant role in agriculture and allied activities. To promote women's empowerment and sustainable livelihoods, the government of Bihar is forming Self-Help Groups (SHGs) under the Bihar Rural Livelihoods Promotion Society (JEEViKA). Although the primary aim of these SHGs is to make women economically self-dependent, they also promote Bihar's green economy. The JEEViKA model gives them opportunities to participate in environmentally sustainable economic activities such as organic farming, Vermicomposting, renewable energy work, agro-processing, etc.

The main objective of this paper is to examine the role of JEEViKA in bringing sustainable rural transformation through Women-led SHGs. It analyses how women-led SHGs are promoting both women's empowerment and environmental sustainability. This paper is descriptive and analytical and is based on secondary data taken from JEEViKA reports, the Economic Survey of Bihar, Documents of the Government of Bihar, World Bank publications, and academic literature.

The study concludes that Women are playing an active role as agents of ecological sustainability in Bihar's transition to a green economy and suggests that greater institutional support, improved access to green finance, and green technology can help SHGs accelerate this transition.

Keywords: JEEViKA, Self-Help Groups (SHGs), Green Economy, Women Empowerment.

INTRODUCTION

As we move into the next century, the world faces many environmental issues, including climate change, pollution, and depletion of resources. Sustainable development is a prime concern for all nations. We all have our own needs, but we must consider that without balancing growth with social inclusion and environmental protection, the next generation

will struggle to meet theirs. We are approaching 2030, the target year to achieve all 17 Sustainable Development Goals set by the United Nations. Therefore, all efforts should focus on achieving sustainable development while planning and implementing government policies and programmes. In this context, we need to prioritise people's and the planet's well-being alongside economic growth. In Bihar, agriculture is the main source of livelihood, and women play a significant role in agriculture and allied activities. To promote women's empowerment and sustainable livelihoods, the government of Bihar is forming Self-Help Groups (SHGs) under the Bihar Rural Livelihoods Promotion Society (BRLPS). This is commonly known as JEEViKA. Although the primary aim of these SHGs is to make women economically self-dependent, they also promote Bihar's green economy through various initiatives. The JEEViKA model gives them opportunities to participate in environmentally sustainable economic activities such as organic farming, Vermicomposting, mushroom cultivation, renewable energy work, SRI, SWI, Harit JEEViKA, Harit Bihar, etc.

This paper examines JEEViKA's role in driving sustainable rural transformation through Women-led SHGs. It analyses how women-led SHGs are promoting both women's empowerment and environmental sustainability.

The research paper is structured as follows: Section 2 provides background on JEEViKA's institutional framework and operational model; Section 3 analyses environmental sustainability dimensions and greening initiatives; Section 4 discusses challenges and policy recommendations; and Section 6 presents conclusions.

OBJECTIVES OF THE STUDY

1. To analyse the contribution of JEEViKA in promoting environmentally sustainable livelihoods.
2. To assess the environmental impacts of women-led green enterprises under JEEViKA.
3. To identify the challenges faced by women engaged in JEEViKA-supported green livelihood activities.
4. To recommend policy measures for strengthening women-led green entrepreneurship.

RESEARCH METHODOLOGY

This study is descriptive and exploratory and uses a mixed-methods research design. It uses both quantitative data and qualitative case studies to explain JEEViKA's contribution to building a green economy in Bihar. The study is based primarily on secondary data taken mainly from the JEEViKA/Bihar Rural Livelihoods Promotion Society (BRLPS) website, JEEViKA Annual and quarterly reports, the JEEViKA case study repository, the

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Economic Survey of Bihar, reports published by the Ministry of Rural Development and the Government of Bihar and World Bank publications. In addition, Peer-reviewed research papers, books and reports published by academia and different institutions are also used. Media reports are used for documented case studies. Descriptive Statistical analysis, frequencies, percentages, tables, and graphs were used for trend analysis. In this paper, we analysed JEEViKA activities relevant to the green economy based on a few criteria: environmentally sustainable value addition, Renewable energy adoption, Optimum use of natural resources, and proper use of waste materials and recycling.

CONCEPTUAL FRAMEWORK

The study is based on the following conceptual framework. JEEViKA provides institutional support to women by helping them form Self Help Groups, which gives them easy access to credit, financial and social empowerment, collective bargaining power, and access to larger markets. SHGs are also involved in green livelihood activities such as Organic Farming, vermicomposting, Mushroom Cultivation, solar energy-based work, plantation and nurseries, etc. The outcomes of these green livelihood activities are resource Conservation and climate resilience, which ultimately can make a path towards bringing a green economy in Bihar.

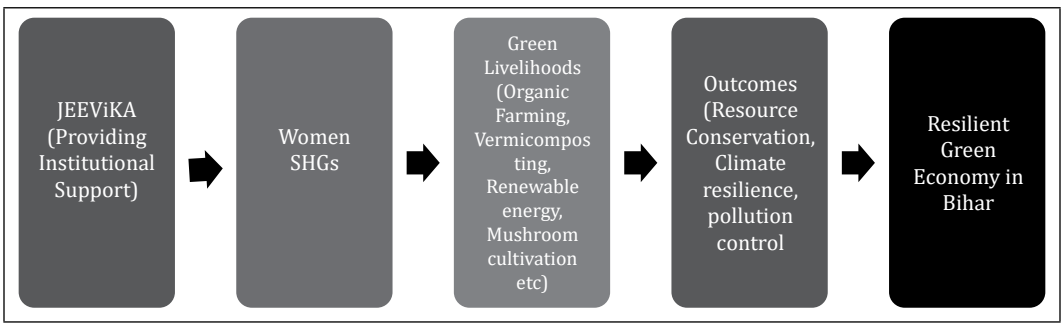


Fig. 1: Conceptual Framework

Source: *Author's Compilation*

LITERATURE -REVIEW

Numerous studies have examined different components of JEEViKA. Many authors have examined JEEViKA's impact on economic empowerment, beneficiaries' social empowerment, and financial inclusion. Literature reviews of different sections are mentioned below-

Saurabh & Behera (2025), in their paper, agreed that Microfinance initiative programs like SHG "JEEVIKA" try to fill the gap through providing access to loans and savings to people experiencing poverty, helping economic independence and empowerment, especially for women.

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Kumar (2016) recommended microfinance for women's empowerment, saying it gives them identity, improves income, and reduces insecurity.

Pandey (2025) examined JEEViKA 's role in the political empowerment of rural women. His findings indicated that JEEViKA gives a platform for Political empowerment and brings women into active village-level governance. Dutta and Rao (2018) conducted a randomised controlled trial (RCT) of JEEViKA Phase 2 and found positive impacts on the income and assets of women who participated in JEEViKA. Savings and consumption increased, along with enhanced Social capital.

Suman and Jahanara (2022) conducted a study in the Begusarai district of Bihar and found increased socio-economic empowerment among women JEEViKA beneficiaries. Srivastava and Samajpati (2022) examined JEEViKA's role in women's empowerment using secondary data. The study finds that "it has considerably strengthened the socio-economic status of rural women, enhanced financial access, and supported sustainable livelihood initiatives that meet the Sustainable Development Goals."

Jaiswal et al. (2025) investigated the impact of the Satat Jeevikoparjan Yojana (SJY) on empowering women and alleviating poverty in Gaya and Jehanabad districts of Bihar. They emphasised SJY's part in promoting economic, social, and mental empowerment through self-employment and entrepreneurial opportunities provided by JEEViKA.

Sanyal, Rao, and Majumdar's (2015) sociological analysis showed that JEEViKA created new "cultural configurations" for economically and socially disadvantaged women by providing access to well-defined networks and new knowledge systems.

RESEARCH GAP

Although many studies have examined the role of SHGs in women's empowerment, few have explored JEEViKA's role in environmental protection or examined JEEViKA as a driver of Bihar's green economy.

DISCUSSION AND ANALYSIS

JEEViKA: Institutional Framework

Bihar Rural Livelihoods Promotion Society (BRLPS), popularly known as JEEViKA, started as a small-scale project in 2006. Over the last 20 years, it has improved the lives of millions of poor people by providing livelihoods and strengthening their social and economic empowerment. Over the years, JEEViKA has strengthened its institutional architecture and governance by bringing left-out households into the SHG (Self-Help Group) fold. Gradual development in CBO (Community Based Organisation) formation has led to the formation of over 10.64 Lakh SHGs, 71,677 VOs (Village Organisations), and 1,684 CLFs (Cluster Level Federations). (Bihar Rural Livelihoods Promotion Society [BRLPS], 2024).

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JEEViKA 's federated structure organises women at different levels. The first level is the formation of Self Help Groups (SHGs) made up of 12-15 women who contribute a fixed amount to a group savings account. SHGs receive support through Government grants and bank loans. The next level is the formation of Village Organisations (VOs), which combine SHGs. These VOs are further combined to form Cluster Level Federations (CLFs). This multi-layered institutional structure helps women unite and gives them easier access to more resources and larger markets. (Attanasio et al., 2026).



Fig. 2: Three-Tier Structure of JEEViKA

Source: *Authors compilation*

JEEViKA 's main mission is to enhance the social and economic empowerment of rural households. To achieve this objective, the government is continuously working to strengthen SHGs, VOs, and CLFs so women can access credit institutions, mobilise their own savings, and face livelihood and social challenges. The best part of this programme is that it includes different types of activities such as agriculture, livestock, and non-farm enterprises. It also converges with different government programmes such as MGNREGA, Jal Jeevan Hariyali, and Swachh Bharat Abhiyan. The following table showcases the expansion of SHGs, VOs, and CLFs from 2022 to March 2026.

Table 1: Progress of SHGs, VOs and CLFs (March 2020-March 2026)

Indicators	Progress till March 2020	Progress till March 2021	Progress till March 2022	Progress till March 2023	Progress till March 2024	Progress till March 2025	Progress till March 2026
Number of Self - Help Groups (SHGs) formed	948159	1028147	1035183	1046002	1058618	1064021	1188130
Number of Village Organizations (VOs) formed	60356	64593	67624	68645	70812	71677	73515
Number of Cluster Level Federations (CLFs) formed	1048	1187	1353	1453	1669	1687	1684

Source: *Authors' compilation based on JEEViKA Annual Reports of 2019-20 to 2024-25 and JEEViKA 74th Quarterly Progress Report*

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The table above indicates significant progress in the women's self-help group network under JEEViKA. This growth is clear in the number of SHG formations and in the formation of Village Organisations (VOs) and Cluster Level Federations (CLFs). This formalised JEEViKA framework gives women members access to and supports their collective power to access credit and markets.

Growth in Self-Help Groups (SHGs)

Self-Help Groups (SHGs) provide a platform for rural women to access savings, credit, training, and involvement in different livelihood activities. This is the basic entry point for women in JEEViKA. The popularity of SHGs among rural women is clear in the expansion of SHG formations. The following figure shows the growth in SHG formation in the last 6 years. This rapid increase has given lakhs of women an institutional platform to access credit, markets, and training, and to benefit from JEEViKA.

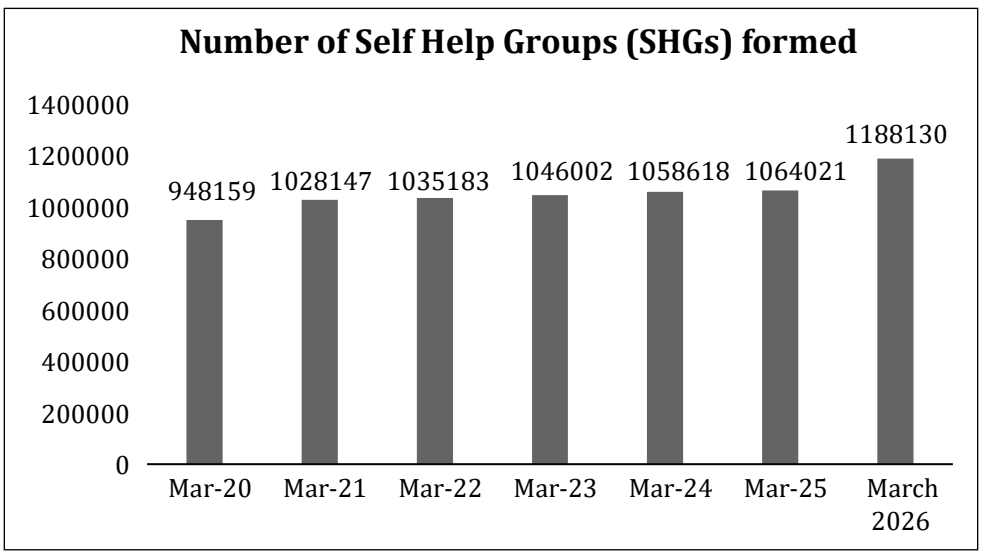


Fig. 3: Growth in Self-Help Groups (SHGs) (March 2021-March 2026)

Source: *Authors' compilation based on JEEViKA Annual Reports of 2019-20 to 2024-25 and JEEViKA 74th Quarterly Progress Report.*

The figure above shows the rapid increase in SHGs under JEEViKA. The number increased by around 25.3%, and 2.40 lakh new SHGs were formed over the six years. In March 2020, the number of SHGs was 9,48159 which reached 11,88,130 in March 2026. Growth was higher in the later period, especially between March 2025 and March 2026.

Expansion of Village Organisations (VOs)

The second layer of collective institutions is necessary to reap JEEViKA's benefits. Forming VOs increases SHGs' joint strength at the village level. It helps conduct different farm and

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non-farm activities and find solutions to problems that arise during expansion. Fig. 2 shows the increase in the number of VOs between March 2020 and March 2026.

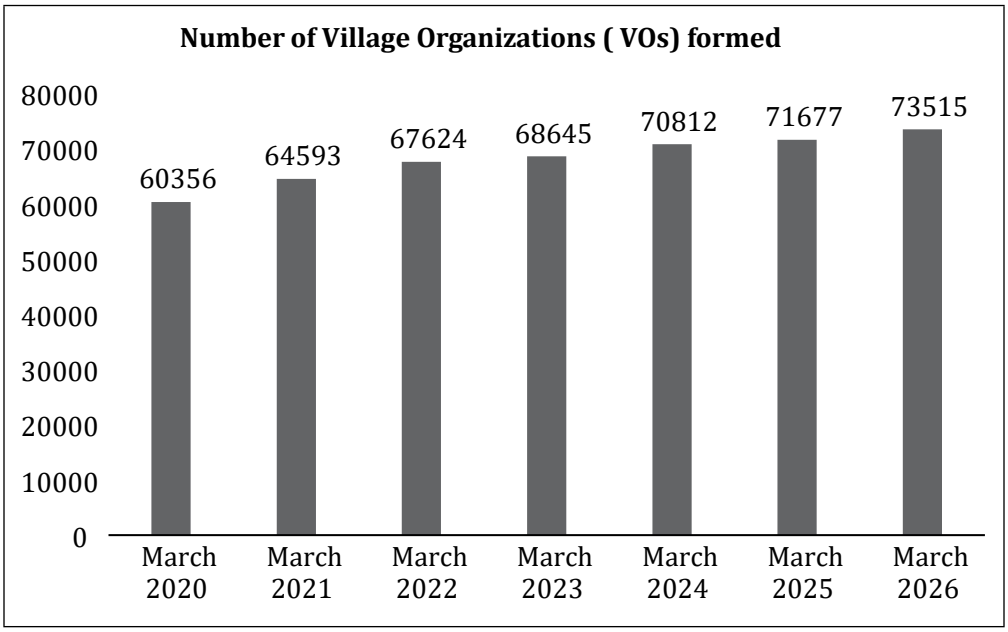


Fig. 4: Expansion of Village Organisations (VOs) (March 2021-March 2026)

Source: *Authors' compilation based on JEEViKA Annual Reports of 2019-20 to 2024-25 and JEEViKA 74th Quarterly Progress Report*

There is a consistent increase in the number of VOs.The number of VOs increased by about 21.8%, rising from 60,356 in March 2020 to 73,515 in March 2026**.**

Growth of Cluster Level Federations (CLFs)

Cluster Level Federations make it easier to regulate large-scale financial management, mobilise public schemes, and provide community-level support. There has been a continuous increase in the number of CLFs over the last six years which is clear from the following figure-

The number of CLFs increased by around 60.7%, from 1048 to 1684 between March 2020 and March 2026. Although there is a minor decrease between March 2025 and March 2026, it will not affect CLFs' performance and role in JEEViKA.

The rapid growth of SHGs, VOs, and CLFs clearly indicates JEEViKA's deep roots in rural Bihar. Women's involvement in farm and non-farm activities empowers them economically and socially. These diversified activities also give them opportunities to work as green agents and play their role in Green Bihar, which is essential for sustainable development.

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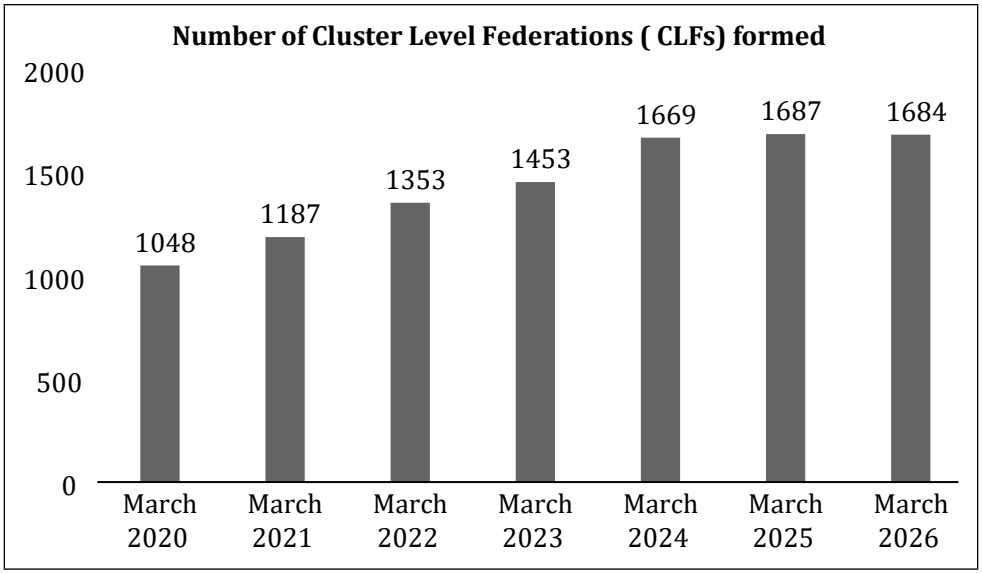


Fig. 5: Growth of Cluster Level Federations (CLFs) (March 2021-March 2026)

Source: *Authors' compilation based on JEEViKA Annual Reports of 2019-20 to 2024-25 and JEEViKA 74th Quarterly Progress Report*

JEEViKA's Contribution to Bihar's Green Economy

JEEViKA's main objective is to provide sustainable livelihoods to the rural poor. But the way this programme diversifies livelihood activities can help speed up Bihar's transition to a green economy. Women are forming Self-help groups and are actively engaged in activities such as Organic Farming, vermicomposting, Mushroom Cultivation, Solar power projects, Plantation and Didi's Nursery, which can help bring a green economy to Bihar. Different Green activities under JEEViKA and their environmental contributions are analysed below:

Organic Farming Intervention (JEEViKA Annual Report 2024-25)

Organic farming is an influential practice for minimising environmental impacts and supporting sustainable development. Using more organic matter in agricultural methods can reduce adverse environmental effects by helping preserve natural cycles during recovery, and organic farming may additionally enhance food quality. (Gamage, A. et.al.2003) JEEViKA encourages SHGs to adopt organic farming, reducing dependence on chemical fertilisers and pesticides and increasing the use of bio-inputs. According to the JEEViKA Annual Report 2024-25, 174 local groups with 6,876 farmers have been established for organic farming. After physical verification, these groups have received C-3 Certification under its organic-farming programme. This indicates that, with JEEViKA's

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institutional support, farmers are shifting from traditional farming to Organic farming and moving toward quality assurance and certification. Periodic training and capacity-building sessions help sustain these organic farming practices. The progress of Organic Farming is given in Table 2.

Table 2: Progress on Organic Farming Intervention

Sl.	Particulars	Cumulative Progress Till March 2025
1	Farmers Mobilized for Organic Farming	6,876
2	Functional Local Groups (LG)	174
3	Districts Covered	9
4	Certification Status	C-3 Certification Endorsed
5	Farmers Trained for Rabi Season	6,876
6	Local Groups Receiving Branding Support	174

Source: *JEEViKA Annual Report 2024-25*

JEEViKA Bihar has implemented the "Sustainable Livelihood and Adaptation to Climate Change (SLACC)" program which is funded by the Global Environment Fund through the World Bank and NRLM and aims towards a major shift in agriculture for climate resilience.

Case Study-1 Pratima Devi

JEEViKA's Climate Smart Agriculture Newsletter (August 2017) reported the example of Pratima Devi from Manichak village in Barahchatti block of Gaya district, describing her as a progressive farmer. She has proudly shifted from traditional to organic farming and adopted AZOLLA cultivation. This gives her the double benefit of improved soil health and reduced water loss.

Vermicomposting

Vermicomposting converts biodegradable agricultural and livestock waste to nutrient-rich organic manure. Women SHGs involved in vermicomposting earn income and support resource recycling by turning waste into a useful agricultural input for soil improvement. This is a strong link between women's livelihoods and the circular economy. The SHGs' primary motive is to earn income, but this farm-based intervention also promotes environmental sustainability.

As per the JEEViKA 41st Quarterly Report October-December 2017, "Vermi-compost production was started by 1698 farmers in collaboration with MGNREGA. Cumulatively,

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by December 2017, 3710 farmers had started vermi-compost production through convergence. SHGs are receiving training in vermicomposting and farm livelihood support.

Case Study 2: Priyanka Devi

According to the Government of India's Lakhpati Didi case profile, Priyanka Devi is a member of the Kamal Self Help group. She lives in Ghevdahi village, Madhubani block, West Champaran. She has taken training in both organic farming and vermicomposting. She started applying both, and her income has increased to approximately Rs. 12,000. These examples inspire other farmers and help promote sustainable farming.

Mushroom Cultivation

Mushroom Cultivation requires limited land and uses agricultural residue. JEEViKA supports women SHGs involved in Mushroom production by providing training, credit access, and market linkages. JEEViKA Quarterly Progress Report for October–December 2017 records that 2,000 farmers had undertaken household-based mushroom cultivation by December 2017.

Recently, JEEViKA's 72nd Quarterly Progress Report (July–September 2025) reported that 5,573 Agriculture Entrepreneurs (AEs) were trained to operate businesses. It also included organic manure production and mushroom cultivation. Mushroom cultivation can serve as an important bridge between women's traditional household-based livelihoods and market-oriented green entrepreneurship.

JEEViKA can play an important role in creating an institutional pathway through which conventional rural livelihood activities can evolve into green and resilient enterprises.

Case Study 3: Ram Kumari Devi

OXFAM ANNUAL REPORT 2021-2022 MISSION SANJEEVANI reports that Ram Kumari Devi, who lives in Koriyahi village, Bajpatti block of Sitamarhi, started Mushroom cultivation in December 2020 after receiving Mushroom production raw materials and inputs. She sold 50 kg of mushrooms by March and earned an additional ₹ 10,000.

SRI and SWI: Resource-Efficient Agriculture Methods

JEEViKA promotes increased crop productivity through resource-efficient agriculture methods. It promotes the System of Rice Intensification (SRI) and System of Wheat Intensification (SWI). These methods focus on more efficient management of land, water, seed and labour resources to improve productivity. This gives another dimension to JEEViKA's contribution to Greening Bihar. The following table and figure show the year-wise increase in the number of farmers adopting SRI/DSR/Seed Replacement.

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Table 3: Number of Farmers adopting SRI/DSR/Zero tillage/Seed Replacement in Paddy and Wheat cultivation (2017-18 to 2021-22)

Year	Farmers cultivated paddy through SRI/DSR/Seed replacement	Farmers Cultivated Wheat through SWI/Zero tillage/Seed replacement
2017-18	278860	334651
2018-19	464126	517711
2019-20	625517	404599
2020-21	748267	695133
2021-22	807899	877599

Source: *JEEViKA Annual Report 2021-22*

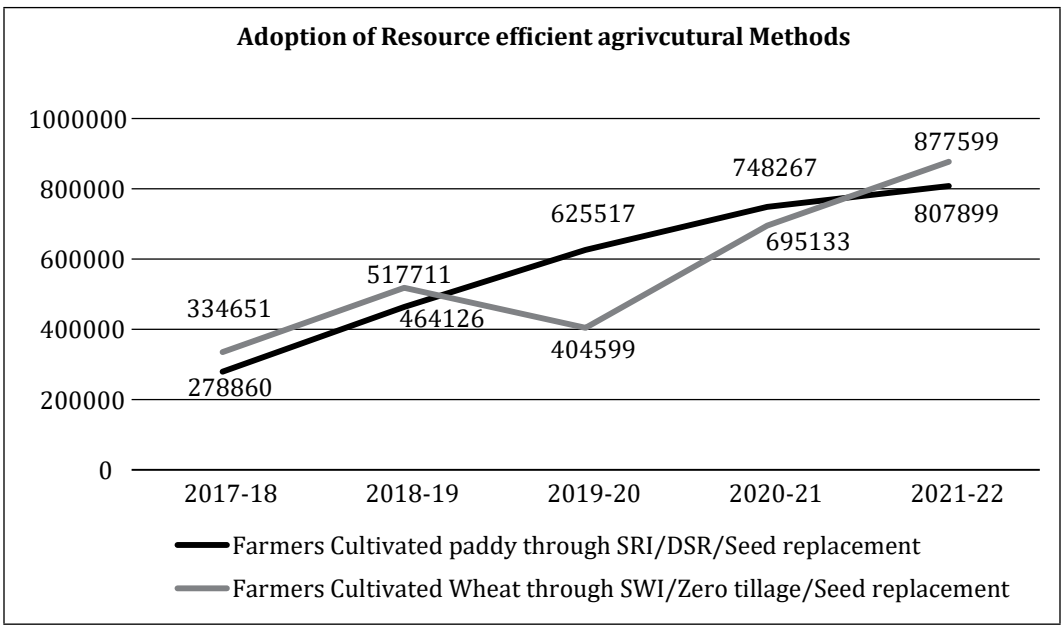


Fig. 6: Number of Farmers adopting SRI/DSR/Zero tillage/Seed Replacement in Paddy and Wheat cultivation (2017-18 to 2021-22)

Source: *Authors' compilation based on JEEViKA Annual Report 2021-22*

The above table and figures show the increase in adoption of green farming. According to the JEEViKA Annual Report 2021-22, 30.26 lakh households adopted agro-ecological practices such as SRI, SWI, direct seeding of rice, zero tillage, and seed replacement. This clearly shows a shift toward environmentally friendly farming, a good sign for the transition to a green economy. The adoption of SRI and SWI increased in 2025, as shown in the following table from the Annual Report 2024-25.

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Table 4: Progress under farm-based Productivity Enhancement Activities

Sl.	Particulars	Progress
1	Number of Households covered under farm-based productivity enhancement activities	38,26,457
2	Number of farmers adopted System of Rice Intensification (SRI)	14,72,390
3	Number of farmers adopted Direct Seeded Rice	1,48,075
4	Number of farmers adopted Seed Replacement Method	21,95,686
5	Number of farmers undertook Wheat cultivation (SWI)	12,45,752

Source: *JEEViKA Annual Report 2024-25*

Progress in these activities helps protect scarce resources, a core part of environmental protection.

Harit JEEViKA Harit Bihar Abhiyan

Plantation is essential to keep our earth green and maintain eco-friendly growth. Under the Jal Jeevan Hariyali Mission, the Government of Bihar launched Mission 5.0 on 5th June 2020 on the occasion of World Environment Day. The goal was to plant 5 crore saplings. To support this, BRLPS launched **Harit JEEViKA Harit Bihar Abhiyan** and actively involved JEEViKA didis to achieve this target through the Gaddha Khodo Abhiyan. The table below shows plantation performance till FY 2024-25**.**

Table 5: Plantation Performance (2024-25)

Sl.	Key Indicators	Target (FY-2024-25)	Achievement (FY-2024-25)	% Achievement	Cumulative Achievement
1	Plantation	80 lakh	67 lakh	83.75	4.35 Cr (including self-plantation)

Source: *JEEViKA Annual Report 2024-25*

Didi Ki Nursery (Paudhshala)

Natural resource management is necessary for environmental protection. JEEViKA is also working for it in collaboration with the Department of Forest, Environment and Climate Change (DOFECC) and MGNREGA. DOFECC helps JEEViKA members open nurseries known as Didi Ki Paudhshala. As per the JEEViKA Annual Report 2022-23, JEEViKA didis operated 442 nurseries.

The 2023-24 annual report states that Didi ki Paudhshala Abhiyan helped plant 3.8 crore saplings. This effort is key to environmental sustainability. This provides low-cost plantation and green cover and shows the power of women-led SHGs in greening Bihar**.** The table below shows the Didi ki Nursery status till FY 2024-25

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Table 6: Didi ki Nursery status till FY 2024-25

Year	Number of Didi's Nurseries-Forest Department	Number of Didi's Nurseries-MGNREGA	Total Didi's Nursery	Total saplings sold	Achievement (in Rs.)
2024-25	310	677	987	**37 lakh**	**25 crore**

Source: *JEEViKA Annual Report 2024-25*

Solar Renewable Energy Initiatives

JEEViKA also promotes solar renewable energy through several initiatives. Recently, these activities have expanded. The initiatives are discussed below.

Solar Marts under J-Wires

A key initiative under this project is promoting a company named "JEEViKA - Women Initiative Renewable Energy and Solution Private Limited, commonly known as "J-WiRES". This solar company deals in solar and electrical products. According to the JEEViKA Annual Report 2021-22, the company assembled and supplied 1400 solar lamps and 117 units of street lights in the Sitamarhi and Nalanda districts in partnership with OXFAM India. They also sold 31500 energy-efficient 9W LED AC bulbs through Solar Marts. A key achievement is establishing 382 Solar Marts in seven districts of Bihar, including Gaya, Nawada, and Patna, as reported in the quarterly report for March 2026. The target is to establish 3500 Solar Marts in the coming Financial year.

J-Wires also started sales of BLDC fans, LED bulbs, solar lanterns, and torches. This company has sold 690 induction cooktops and utensils in Bihar. The reported profit is around 2 Lakhs (74th Quarterly Report)

J-WiRES Finovista Project

As per the 74th Quarterly Progress Report (Jan-March 2026), under the J-WiRES Finovista Project, electric cooktops and utensils worth around Rs. 45 lakhs were distributed in Gaya, Aurangabad, Nalanda and Patna districts among 550 street food Vendors. This research initiative generated a profit of around 8 Lakh.

Commercial Solar Installation and Other Initiatives

Taking a step further, J-WiRES has also started commercial solar with a total value of around 26 Lakhs, resulting in a profit of around Rs 4 lakh.

PM Surya Ghar Muft Bijli Yojana

The PM Surya Ghar Muft Bijli Yojana (PMSGY) is another important step towards environmental sustainability in Bihar through J-WiRES. The positive response is clear from the table 7.

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Table 7: Progress under PM Surya Ghar Program

Sl.	Indicators	Achievement till March 2026
1	Total Applications Filled on Portal	88
2	Total Households Covered	38
3	Customers Availing Loan Facility	28
4	Customers with cash Payment	10
5	Net Metering & Inspection Completed	38
6	Subsidy Released	36
7	Total Installed Capacity	150KW
8	Districts Covered	Gaya, Arwal, Jehanabad, Patna, Nalanda
9	Total Business Generated	Rs. 78.30 Lakhs
10	Total Profit Earned	Rs 15.50 lakhs

Source: *JEEViKA 74th Quarterly Progress Report 2026*

This evidence shows how JEEViKA, through women-led enterprises, can play a key role in renewable energy.

Sustainable Transport for Rural Entrepreneurs through E-Cycles (S.T.R.E.E.)

According to JEEViKA's 71st and 73rd Quarterly Progress Reports, Sustainable Transport for Rural Entrepreneurs through E-Cycles added a new dimension to JEEViKA's contribution to a green Bihar. JEEViKA and Convergence Energy Services Limited (CESL) signed a Memorandum of Understanding on 14 August 2024 to supply 500 electric cargo cycles to women associated with JEEViKA's Self-Help Groups. An Asian Development Bank–Global Environment Facility (ADB–GEF) grant supported this step.

By analysing these activities under JEEViKA, we can see the programme's potential for environmental sustainability and for taking Bihar towards Green Bihar. However, a few challenges remain that must be addressed to achieve its full potential for Green Bihar.

Challenges

Limited Access to Green Finance

JEEViKA has helped women overcome initial financial exclusion through SHGs and credit linkages, but **green enterprises often require larger, longer-term finance than conventional micro-enterprises**.

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Lack of technical knowledge

Women need technical training and upskilling. Their participation in Green activities depends on their ability to learn and upgrade technical and managerial skills.

Market access constraints

JEEViKA has attempted to address this through producer groups, producer companies, exhibitions, Shilpgram, online platforms, Saras Mela and other market-linkage initiatives. But rural women are mainly concentrated in local markets. Shrivastava & Samajpati (2025), in their study, also found that lack of proper marketing is a major challenge for JEEViKA beneficiaries.

Digital Literacy

We are living in a digital era. Therefore, low digital literacy among rural women affects the expansion of activities.

Climate-related risks

Bihar faces specific climate vulnerabilities, including floods, droughts, extreme heat, and irregular rainfall. These climate-related risks affect the implementation of SRI/SWI agricultural methods, organic farming, Mushroom Cultivation, and plantation activities.

Policy Recommendations

Based on the discussion and analysis a few policy recommendations are as follows:

- To identify green enterprises and initiatives, a dedicated framework is required.
- The SHGs involved in environmentally sustainable activities such as Organic farming, Solar renewable energy initiatives, green processing, vermicomposting, waste recycling, etc could be given special Green Credit. This will speed up the expansion of these activities.
- JEEViKA is already providing training for many activities. But if more focus is given to training women in Sustainable agriculture, renewable energy, Green packaging, and waste management, it will be an added advantage. This will help pave the path to Green Bihar.
- For certified sustainable products a common brand mentioning JEEViKA Green Bihar can be useful and make it more authentic and reliable.
- Market linkage is very important to increase the profitability of the Green products. Connecting them with e-commerce, urban markets, Government supply, and individual buyers will help a lot.
- SHG activities can benefit from Carbon Finance. Therefore, steps should be taken to connect Green activities with Carbon Finance.

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- More Collaboration with the Bihar Forest Department, State Pollution Control Board, agricultural research institutions, and international climate finance mechanisms will increase its expertise for environmental programming.

CONCLUSION

Women are playing an active role as agents of ecological sustainability in Bihar's transition to a green economy. Therefore, women in JEEViKA should not be viewed merely as beneficiaries of rural development programmes. They can be understood as institutional actors in Bihar's transition towards a green, inclusive and resilient economy.

REFERENCES

Attanasio, O., Kochar, A., Mahajan, A., & Surendra, V. (2026). *Risk sharing, commitment constraints and self-help groups* (NBER Working Paper No. 31245). National Bureau of Economic Research. https://doi.org/10.3386/w31245

Bihar Rural Livelihoods Promotion Society. (2017, August). *Newsletter* (Issue 3). https://brlps.in/magazine

Bihar Rural Livelihoods Promotion Society. (2017). *JEEViKA quarterly progress report: October–December 2017*. https://brlps.in/quarterlyprogressreport

Bihar Rural Livelihoods Promotion Society. (2020). *JEEViKA annual report FY 2019–20*. https://brlps.in/annualauditreports

Bihar Rural Livelihoods Promotion Society. (2021). *JEEViKA annual report FY 2020–21*. https://brlps.in/annualauditreports

Bihar Rural Livelihoods Promotion Society. (2022). *JEEViKA annual report FY 2021–22*. https://brlps.in/annualauditreports

Bihar Rural Livelihoods Promotion Society. (2023). *JEEViKA annual report FY 2022–23*. https://brlps.in/annualauditreports

Bihar Rural Livelihoods Promotion Society. (2024). *JEEViKA annual report FY 2023–24*. https://brlps.in/annualauditreports

Bihar Rural Livelihoods Promotion Society. (2025). *JEEViKA Bihar Rural Livelihoods Promotion Society annual report 2024–25*. https://brlps.in/annualauditreports

Datta, U., & Rao, V. (2018). *Poverty and empowerment impacts of the Bihar Rural Livelihoods Project: Evidence from a mixed-methods cluster-randomized trial*. Harvard Dataverse. https://doi.org/10.7910/DVN/6PAHVM/BRLOCW

Jaiswal, J. K., Pandey, D. K., Kumar, B., & Mahato, J. (2025). Elevating rural women's empowerment: A case study on the impact of the sustainable livelihood scheme on extreme poverty in Bihar, India. *International Journal of Entrepreneurship and Small Business*. https://doi.org/10.1504/IJESB.2025.10065972

Kumar, A. (2016). Does microfinance redefine identity, income and insecurity among rural women? A model of women's empowerment. *Enterprise Development and Microfinance, 27*(3), 192–203. https://doi.org/10.3362/1755-1986.2016.016

Kumar, T., & Hassan, Z. (2026). Revolutionizing sustainable rural livelihoods in Bihar through self-help groups. *International Journal for Multidisciplinary Research, 8*(4).

 ISBN: 978-93-49666-59-7 (eBook)

Ministry of Rural Development, Government of India. (n.d.). *Priyanka Devi*. Lakhpati Didi. https://lakhpatididi.gov.in/lakhpati-didis/priyanka-devi

Pandey, R. (2025). Political participation through collective action: A study of JEEViKA women in Bihar. *AIJFR, 6*(6). https://doi.org/10.63363/aijfr.2025.v06i06.2500

Ram, P., & Tulika. (2022). Livelihood promotion and interventions of JEEViKA: A trend analysis. *Management Insight, 18*(1).

Sanyal, P., Rao, V., & Majumdar, S. (2015). Recasting culture to undo gender: A sociological analysis of JEEViKA in rural Bihar, India. *XAREP*. https://doi.org/10.11588/XAREP.00003789

Saurabh, G., & Behera, D. K. (2025). Bihar women and microfinance: A gender study. *International Research Journal of Multidisciplinary Scope, 6*(3), 1141–1152. https://doi.org/10.47857/irjms.2025.v06i03.04846

Srivastava, S., & Samajpati, U. (2025). A structural analysis of role of JEEViKA model in women empowerment in Bihar. *International Journals Siwan*. https://internationaljournalsiwan.com

Suman, S., & Jahanara. (2022). A study on socio-economic upliftment of women JEEViKA beneficiaries and constraints faced by them in Begusarai district of Bihar. *Asian Journal of Agricultural Extension, Economics & Sociology, 40*(7). https://doi.org/10.9734/ajaees/2022/v40i730924

Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P., & Merah, O. (2023). Role of organic farming for achieving sustainability in agriculture. *Farming System, 1*(1), 100005. https://doi.org/10.1016/j.farsys.2023.100005

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Chapter

17 Climate Vulnerability and Employment-Related Labour Mobility in India: A State-Level Analysis

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ABSTRACT

Climate change is a multidimensional challenge whose implications extend beyond physical hazards to affect livelihoods and socioeconomic conditions. Climate-related pressures may influence labour mobility, but their effects can vary across socioeconomic contexts. This study examines the relationship between climate vulnerability and employment-related labour mobility across Indian states and union territories using the overall Climate Vulnerability Index published by the Council on Energy, Environment and Water (CEEW) in 2021 and labour mobility data from the Periodic Labour Force Survey (PLFS) 2020-21. The findings reveal substantial interstate variation in climate vulnerability, with Assam recording the highest vulnerability score, followed by Andhra Pradesh, Maharashtra, Karnataka and Bihar. The aggregate analysis shows a negative association between climate vulnerability and labour mobility, but the relationship becomes statistically insignificant after accounting for urbanisation, literacy and per capita Net State Domestic Product (NSDP). The state-level patterns also show that vulnerability and labour mobility do not follow a uniform spatial pattern, with Assam, Tamil Nadu, Jammu and Kashmir and Puducherry illustrating contrasting positions in the overall distribution. Overall, the results indicate that climate vulnerability alone does not independently explain interstate labour mobility in India. Instead, labour mobility appears to reflect a combination of socioeconomic conditions and climate-related pressures, with the former playing an important role in shaping mobility outcomes. The study contributes state-level evidence to the climate-mobility literature and highlights the need to understand labour mobility within the broader socioeconomic context of India.

Keywords: Climate Vulnerability, Labour Mobility, Employment, Socioeconomic Factors, Urbanisation, India.

INTRODUCTION

Climate change is increasingly becoming a question not only of environmental sustainability but also of where people can live, work and sustain their livelihoods. The

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World Bank's Groundswell report estimates that, under adverse climate and development conditions, climate change could drive as many as 216 million people to move within their own countries by 2050 across six regions, including around 40 million in South Asia. At the same time, the report emphasises that people move for multiple and interconnected economic, social and environmental reasons, with climate change affecting mobility largely through its effects on livelihoods and the habitability of places. This growing concern has placed human mobility within the broader discussion of climate adaptation and development. UNDP similarly cautions that the direct influence of climate change on human mobility is complex and that the links between climate change, displacement and migration cannot be understood independently of wider social and economic conditions.

The connection between environmental change and human mobility, however, is not simply a matter of people leaving areas exposed to climatic hazards. Climate-related changes can affect agricultural productivity, employment, income, infrastructure and access to resources, thereby altering the livelihood conditions within which mobility decisions are made. The literature has consequently moved away from viewing climate change as an automatic or deterministic cause of migration. Perch-Nielsen et al. (2008) show that the pathways linking climate-related hazards such as floods and sea-level rise to migration depend on the vulnerability of people and places, while Bardsley and Hugo (2010) conceptualise migration as one possible component of adaptation to environmental risks rather than necessarily a failure of adaptation.

The labour dimension is particularly important in this context because climatic conditions can influence the availability and security of employment, especially in climate-sensitive sectors. Changes in agricultural productivity, for example, may affect household earnings and local employment and consequently alter decisions regarding work outside the place of residence. Evidence from India illustrates this broader range of responses. Neog (2022) finds that temperature shocks are associated with labour out-migration and longer-distance commuting among rural workers, demonstrating that climatic stress may be reflected in different forms of labour mobility rather than only in permanent migration. Similarly, studies examining drought and rainfall variability have reported associations with migration, although the magnitude and direction of these relationships differ across locations and forms of mobility.

These differences have encouraged greater attention to the concept of climate vulnerability. Unlike a single climatic shock, climate vulnerability captures the broader conditions that determine how severely populations and regions may be affected by climatic risks and their capacity to respond. The CEEW framework assesses vulnerability through exposure, sensitivity and adaptive capacity, thereby incorporating socioeconomic conditions alongside climatic characteristics (Mohanty & Wadhawan, 2021). This perspective is particularly relevant for labour mobility because exposure to a climatic hazard does

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not necessarily produce the same livelihood consequences or mobility response across regions. Economic conditions, human capital, infrastructure and livelihood structures can influence both the consequences of climatic stress and the options available to households and workers. India provides an important setting in which to examine these processes. The country contains substantial regional differences in climatic exposure and vulnerability, while labour mobility remains closely connected with differences in economic and employment opportunities. Indian studies have examined the effects of drought, rainfall and temperature variability on migration and labour mobility, including temporary migration, inter-state migration and commuting. Dallmann and Millock (2017), for example, find an association between drought frequency and inter-state migration, while Keshri and Bhagat (2013) show that temporary labour migration is also closely associated with socioeconomic conditions. These studies indicate that environmental and socioeconomic conditions need to be considered together when examining patterns of labour mobility.

The existing literature nevertheless remains diverse in terms of the climatic measures, geographical contexts and mobility outcomes examined. Much of the empirical evidence focuses on individual climatic shocks such as drought, rainfall or temperature, while vulnerability-based approaches consider broader combinations of exposure, sensitivity and adaptive capacity. The evidence also varies across forms of mobility, making it difficult to infer a uniform relationship between climatic conditions and labour movement. This leaves scope for further empirical examination of whether a broader measure of climate vulnerability is associated with variations in labour mobility when socioeconomic conditions are considered alongside it.

Against this background, the present study examines the relationship between climate vulnerability and employment-related labour mobility across Indian states and union territories. More specifically, it asks whether differences in overall climate vulnerability are associated with variations in labour mobility and whether this association changes after accounting for selected socioeconomic conditions. The study is therefore framed as a state-level association analysis rather than a causal test of migration as an adaptation strategy. Overall climate vulnerability is measured using the reported CEEW vulnerability score, while per capita NSDP, urbanisation and literacy are considered alongside climate vulnerability in examining differences in labour mobility.

LITERATURE REVIEW

Climate Vulnerability and Labour Mobility: Global Evidence

The relationship between climate vulnerability and human mobility has increasingly emerged as an important area of interdisciplinary research. Earlier literature often

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approached environmental change as a direct driver of migration, particularly through hazards such as floods, droughts and sea-level rise. Subsequent research, however, has moved away from deterministic explanations and emphasised that climate-related conditions interact with socioeconomic, demographic and institutional factors. Climate hazards may influence mobility through direct effects, such as the destruction of land and housing, as well as through indirect effects on income, employment and livelihoods. The resulting mobility response therefore varies according to the vulnerability and socioeconomic conditions of affected populations and places (Perch-Nielsen et al., 2008; Oakes et al., 2023; Garip & Reed, 2025).

The literature further demonstrates considerable heterogeneity in climate-related mobility across regions and population groups. Climate factors tend to interact with economic, social, demographic and other environmental conditions rather than operating independently, while the resources available to households can influence their ability to respond through migration. Existing migration networks, employment opportunities and household resources may therefore strengthen or constrain mobility responses to climatic stress. Differences in the measurement of climate conditions and mobility, as well as variations in empirical approaches, also contribute to differences in findings across studies (Oakes et al., 2023; Garip & Reed, 2025). The evidence consequently does not indicate that greater climate vulnerability necessarily results in greater migration; rather, the relationship varies across contexts and depends partly on the mechanisms through which climate-related conditions affect livelihoods and the capacity of populations to move.

Recent research has also extended attention beyond sudden climate shocks to slow-onset environmental changes. Evidence from rural communities in Bangladesh and Tamil Nadu suggests that processes such as salinisation and land degradation can affect agricultural productivity and contribute to labour migration, while migration decisions remain shaped by existing migration histories, social norms, financial constraints and employment opportunities. Such evidence further highlights the importance of considering negotiated and circular forms of labour mobility rather than assuming that climate-related environmental change necessarily results in immediate or permanent displacement (Yea, 2025). Taken together, the global literature indicates that the relationship between climate vulnerability and mobility is complex and context-dependent, with climate-related stress interacting with livelihood conditions and the capacity of populations to respond.

Climate Vulnerability and Labour Mobility in India

The literature on climate and mobility in India indicates that the relationship varies according to the type of climatic stress and the form of mobility considered. Existing studies examine droughts, temperature anomalies, rainfall variability and extreme

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weather events, while mobility is examined through inter-state, temporary and permanent migration as well as labour commuting. Consequently, the evidence does not point to a single pattern of climate-related mobility in India (Dallmann & Millock, 2017; Kavi Kumar & Viswanathan, 2013; Neog, 2022; Richa et al., 2023).

Several studies find that adverse climatic conditions can influence migration, particularly in areas where livelihoods are closely linked to agriculture. Dallmann and Millock (2017) find that greater drought frequency is associated with higher inter-state migration, particularly in agricultural states. Kavi Kumar and Viswanathan (2013), however, show that the association differs between temporary and permanent migration, with temperature and rainfall playing different roles across the two forms. Neog (2022) similarly finds that temperature shocks are associated with migration and longer-distance commuting, whereas the effects of precipitation are largely non-significant. Taken together, these findings suggest that the mobility response varies with the nature of the climatic stress and the form of movement considered.

A different pattern emerges when climate vulnerability, rather than individual climatic shocks, is considered. The state-level evidence indicates that climate vulnerability and inter-state out-migration do not follow a uniform or linear relationship. Some highly vulnerable states exhibit comparatively low levels of out-migration, suggesting that vulnerability does not necessarily result in greater mobility (Samudra, 2026). This contrasts with studies focusing on specific weather shocks, which generally identify associations between adverse climatic conditions and particular forms of migration or labour mobility (Dallmann & Millock, 2017; Neog, 2022). The response to climatic stress may also vary according to the climatic conditions experienced by a region over time. Neog (2022) finds that the effects of temperature shocks on labour-market outcomes are weaker in locations characterised by historically uncertain and low monsoon rainfall, while successive weather anomalies can intensify the adverse effects of heat shocks. This suggests that the consequences of a climatic shock cannot be understood independently of the environmental context in which it occurs.

Overall, the Indian literature presents a differentiated climate–mobility relationship. Evidence of migration and labour-mobility responses to climatic shocks coexists with evidence that higher climate vulnerability does not necessarily correspond to higher out-migration (Dallmann & Millock, 2017; Kavi Kumar & Viswanathan, 2013; Neog, 2022; Samudra, 2026). The existing literature therefore distinguishes between specific climatic shocks and broader climate vulnerability, as well as between migration and other forms of labour mobility. This distinction is important for examining the relationship between overall climate vulnerability and labour mobility across Indian states in the present study.

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Socio-Economic Determinants of Labour Mobility

The literature on labour mobility in India identifies economic conditions, education and employment opportunities as important factors associated with migration, particularly temporary and seasonal labour mobility. Temporary migration is more prevalent among economically disadvantaged rural households and is often associated with limited livelihood opportunities. Keshri and Bhagat (2013) find that economic status is significantly associated with temporary labour migration, while Sucharita (2020) similarly identifies poverty and limited land ownership as important factors influencing temporary migration.

The literature further indicates that labour mobility is closely linked with regional employment opportunities and the rural–urban economic structure. Temporary migration is particularly associated with rural populations seeking employment outside their local economies, while destination conditions influence the nature of migrant employment (Keshri & Bhagat, 2013; Attah-Otu et al., 2024). Taken together, the evidence suggests that economic conditions, human capital and the spatial distribution of employment opportunities are important dimensions of labour mobility in India.

Taken together, the literature indicates that socioeconomic and employment-related conditions are important dimensions of labour mobility in India, while studies examining climatic factors report varying patterns across locations, climatic conditions and forms of mobility. The existing evidence therefore points to a relationship between climatic conditions and labour mobility that is shaped by the broader socioeconomic context. This provides a basis for examining how differences in socioeconomic conditions, alongside overall climate vulnerability, are associated with variations in labour mobility across Indian states.

DATA AND METHODOLOGY

Data Sources and Variables

The analysis is based on state-level secondary data compiled from different official and institutional sources. The overall Climate Vulnerability Index (CVI) is taken from the Mapping India's Climate Vulnerability: A District-Level Assessment published by the Council on Energy, Environment and Water (CEEW) (Mohanty & Wadhawan, 2021). The CEEW assessment follows the IPCC framework and considers vulnerability in terms of exposure, sensitivity and adaptive capacity. The present study uses the overall CVI score reported by CEEW directly; the index is neither reconstructed nor modified for the present analysis.

Labour mobility is measured using the employment-related labour mobility percentage derived from the Periodic Labour Force Survey (PLFS), 2020-21. The measure captures the

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weighted proportion of individuals reporting migration for employment-related reasons, namely "in search of employment," "for employment/work," and "loss of job." Per capita Net State Domestic Product (NSDP) for 2020-21 is used to represent state-level economic conditions. Urbanisation and literacy are taken from Census 2011. These variables are included because differences in economic opportunities, urban development and human capital may influence the capacity and propensity of labour to move across regions. The variables were brought together at the state level for the empirical analysis.

$$\text{Labour Mobility Rate} = \sum_{i=1}^{n} w_i y_i \Big/ \sum_{i=1}^{n} w_i$$

where w_i denotes the PLFS survey weight (sub-sample multiplier) and y_i takes the value 1 when an individual is identified as an employment-related migrant and 0 otherwise. The resulting rate is multiplied by 100 to express labour mobility as a percentage. Employment-related migration is identified from the reported reasons "in search of employment," "for employment/work," and "loss of job."

Model Specification

To examine the relationship between climate vulnerability and employment-related labour mobility, two regression models are estimated. The first model considers the bivariate association between the overall Climate Vulnerability Index and labour mobility:

$$LM_i = \beta_0 + \beta_1 CVI_i + \varepsilon_i$$

The second model incorporates selected socioeconomic variables to assess whether the association between climate vulnerability and labour mobility persists after accounting for urbanisation, per capita NSDP and literacy:

$$LM_i = \beta_0 + \beta_1 CVI_i + \beta_2 PCNSDP_i + \beta_3 URB_i + \beta_4 LIT_i + \varepsilon_i$$

where LM denotes the employment-related labour mobility rate, CVI denotes the overall Climate Vulnerability Index, and PCNSDP, URB and LIT denote per capita NSDP, urbanisation and literacy, respectively.

The analysis begins with descriptive statistics to examine the distribution of the study variables. Pearson correlation analysis is then used to examine pairwise associations among the study variables. Two regression models were then estimated. The first model examines the relationship between labour mobility and the overall Climate Vulnerability Index, while the second incorporates per capita NSDP, urbanisation and literacy as additional explanatory variables. Cook's distance and leverage values were examined to identify potentially influential observations. The estimated coefficients, model fit and statistical significance of the estimated models are presented and discussed in the Results section.

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RESULTS

Spatial Distribution of the Overall Climate Vulnerability Index in India

State	Overall vulnerability index	Rank
Assam	0.616	1
Andhra Pradesh	0.483	2
Maharashtra	0.478	3
Karnataka	0.465	4
Bihar	0.448	5
Manipur	0.424	6
Rajasthan	0.423	7
Arunachal Pradesh	0.408	8
Sikkim	0.37	9
Odisha	0.368	10
Nagaland	0.365	11
Tamil Nadu	0.339	12
Himachal Pradesh	0.329	13
Jammu and Kashmir	0.328	14
NCT Delhi	0.29	15
Gujarat	0.28	16
Uttar Pradesh	0.269	17
West Bengal	0.257	18
Tripura	0.25	19
Kerala	0.226	20
Uttarakhand	0.19	21
Madhya Pradesh	0.182	22
Puducherry	0.175	23
Haryana	0.116	24
Goa	0.101	25
Chhattisgarh	0.087	26
Jharkhand	0.067	27

Source: *Mohanty and Wadhawan (2021), Council on Energy, Environment and Water (CEEW).*

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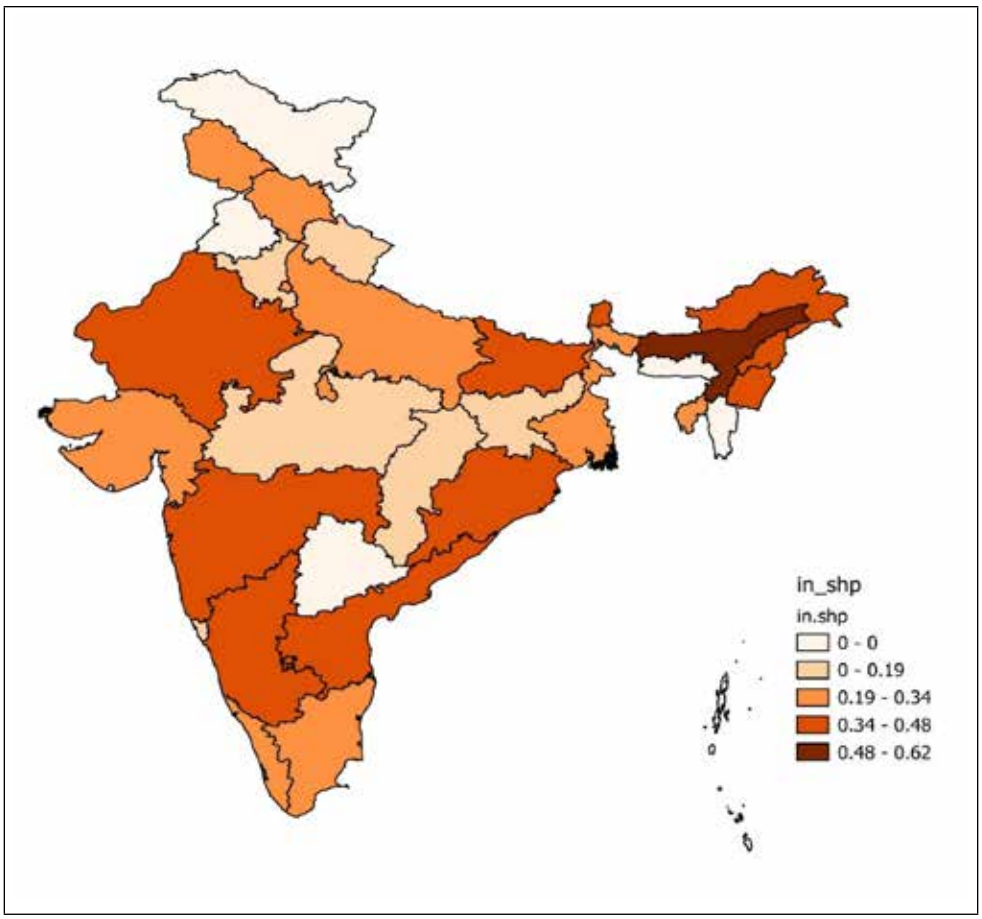


Fig. 1: Spatial Distribution of the Overall Climate Vulnerability Index in India

Source: *Author's compilation based on Mohanty and Wadhawan (2021), Council on Energy, Environment and Water (CEEW).*

Spatial Pattern of Labour Mobility across India

The state-wise employment-related labour mobility rate was estimated using PLFS 2020-21. The measure is based on individuals whose reported reason for migration was related to employment: "in search of employment," "for employment/work," or "loss of job."

Table 2 shows considerable variation in labour mobility across states. The labour mobility rate ranges from very low levels in some states to substantially higher levels in others. Among the states shown, Delhi records a relatively high labour mobility rate of 13.35%, while several states report rates below 1%. The variation indicates that labour mobility is not uniformly distributed across Indian states.

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Table 1: State-wise Employment-Related Labour Mobility (%) across India

State	Labour Mobility (%)
Assam	1.18
Andhra Pradesh	3.76
Maharashtra	4.47
Karnataka	5.14
Bihar	0.38
Manipur	0.04
Rajasthan	2.63
Arunachal Pradesh	1.96
Sikkim	3.84
Odisha	2.58
Nagaland	0
Tamil Nadu	5.61
Himachal Pradesh	4.04
Jammu and Kashmir	2.02
NCT Delhi	13.35
Gujarat	3.9
Uttar Pradesh	1.54
West Bengal	2.95
Tripura	0.61
Kerala	5.49
Uttarakhand	4.44
Madhya Pradesh	2.76
Puducherry	6.42
Haryana	2.97
Goa	6.46
Chhattisgarh	3.01
Jharkhand	1.92

Source: *Authors' calculations based on PLFS 2020-21.*

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The map highlights the geographical variation in employment-related labour mobility across the states**.**

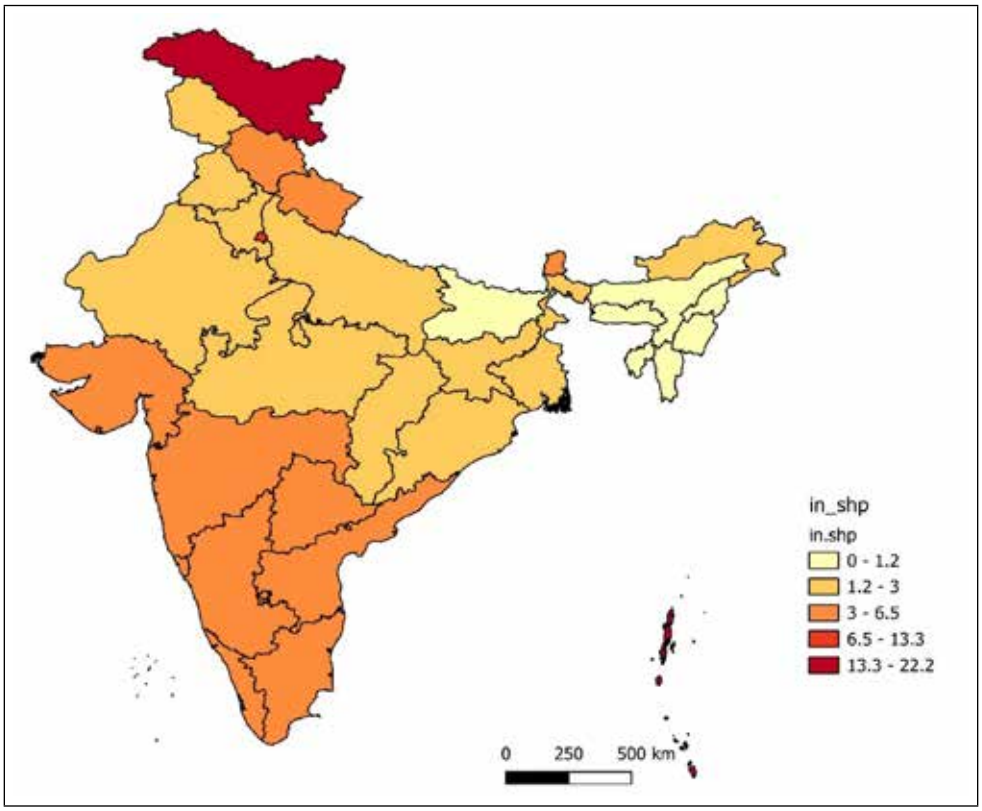


Fig. 2: Spatial Distribution of Labour Mobility Rate (%) across India

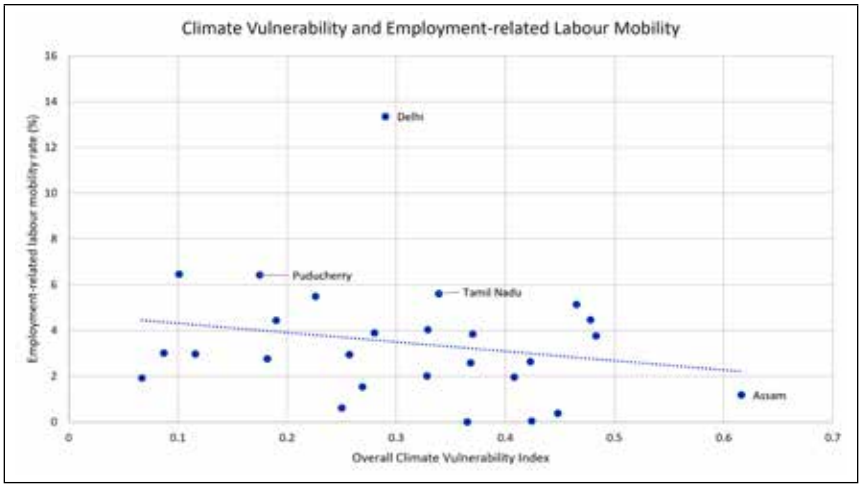
Source: *Authors' calculations based on PLFS 2020-21.*

Aggregate Relationship between Climate Vulnerability and Labour Mobility

To examine the overall association between climate vulnerability and labour mobility across states and union territories, a scatter plot was constructed using the Overall Climate Vulnerability Index and labour mobility rate.

The scatter plot shows a weak negative association between climate vulnerability and employment-related labour mobility. The fitted relationship is not statistically significant in the bivariate regression ($R^2 = 0.044$; $p = 0.295$). The dispersion of observations indicates that states with similar vulnerability levels can exhibit markedly different mobility rates, reinforcing the importance of socioeconomic context.

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Source: *Authors' calculations*

Descriptive Statistics

Table 3: Descriptive Statistics of the Variables

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Labour Mobility (%)	27	0.00	13.35	3.46	2.70
Overall Vulnerability Index	27	0.067	0.616	0.309	0.138
Urbanisation (%)	27	10.00	97.50	33.74	18.89
Literacy (%)	27	61.80	94.00	76.13	8.32
Per Capita NSDP (₹)	27	₹43605	₹431351	₹169655.44	₹97443.55

Source: *Authors' calculations based on the respective data sources described in Section 3*

Table 3 indicates substantial cross-state variation in labour mobility, climate vulnerability and the socioeconomic characteristics considered in the analysis.

Table 4: Pearson Correlation Matrix of Study Variables

Variables	Labour Mobility	Climate Vulnerability	Urbanisation	Literacy	Per Capita NSDP
Labour Mobility	1.000	-0.209	0.861**	0.527**	0.677**
Climate Vulnerability	-0.209	1.000	-0.269	-0.242	-0.170
Urbanisation	0.861**	-0.269	1.000	0.601**	0.604**
Literacy	0.527**	-0.242	0.601**	1.000	0.597**
Per Capita NSDP	0.677**	-0.170	0.604**	0.597**	1.000

Note: *p < 0.05;* **p** *< 0.01 (two-tailed).*

Source: *Authors calculations.*

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The correlation results show a weak negative association between labour mobility and climate vulnerability (r = -0.209), which is not statistically significant. Labour mobility is strongly and positively correlated with urbanisation (r = 0.861) and positively correlated with literacy (r = 0.527) and per capita NSDP (r = 0.677). Climate vulnerability is not significantly correlated with any of the three socioeconomic variables in this restricted sample.

Regression Results

Two regression models were estimated to examine the relationship between climate vulnerability and the labour mobility rate. **Model 1** examines the relationship between the overall climate vulnerability index and the labour mobility rate. **Model 2** extends the analysis by incorporating urbanisation, per capita NSDP and literacy as socioeconomic control variables.

Table 5: Regression Results for Employment-Related Labour Mobility Rate

Variables	Model 1 B	t	p-value	Model 2 B	β	t	p-value
Constant	4.723 (1.287)	3.670	0.001	0.503 (3.059)		0.164	0.871
Overall vulnerability index	-4.087 (3.817)	-1.071	0.295	0.363 (2.014)	0.019	0.180	0.858
Urbanisation (%)				0.107 (0.019)	0.749	5.526	0.000
Per capita NSDP (₹ lakh)				0.770 (0.369)	0.278	2.084	0.049
Literacy (%)				-0.027 (0.043)	-0.084	-0.627	0.537
R^2	0.044			0.785			
Adjusted R^2	0.006			0.746			
F-statistic	1.147			20.108			
N	27			27			

Note: *B = unstandardized coefficient; β = standardized coefficient. Dependent variable: employment-related labour mobility rate.*

Source: *Authors' calculations.*

Model 1 is not statistically significant (F = 1.147, p = 0.295) and explains 4.4% of the variation in the labour mobility rate (R^2 = 0.044; adjusted R^2 = 0.006). The coefficient of climate vulnerability is negative (B = -4.087) but statistically insignificant (p = 0.295), indicating an inverse association between climate vulnerability and the labour mobility rate.

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Model 2 is statistically significant overall ($F = 20.108$, $p < 0.001$) and explains 78.5% of the cross-state variation in labour mobility (adjusted $R^2 = 0.746$). Climate vulnerability remains statistically insignificant ($B = 0.363$, $p = 0.858$). Urbanisation has a positive and statistically significant association with labour mobility ($B = 0.107$, $p < 0.001$), while per capita NSDP has a positive marginal association at the 5% level ($B = 0.770$ per ₹1 lakh, $p = 0.049$). Literacy is statistically insignificant ($B = -0.027$, $p = 0.537$).

Comparison of the two models indicates that the explanatory power rises substantially once socioeconomic variables are introduced: R^2 increases from 0.044 to 0.785. The climate vulnerability coefficient changes sign and remains statistically insignificant, while urbanisation emerges as the strongest predictor in the controlled specification. The results therefore suggest that mobility differences are more closely associated with the spatial distribution of urban and economic opportunities than with aggregate climate vulnerability alone.

Regression Diagnostic Analysis

Table 6: Multicollinearity and Influence Diagnostics

Diagnostic measure	Value	Interpretation
VIF	1.091-1.881	No problematic multicollinearity
Tolerance	0.531-0.917	Acceptable
Maximum Cook's Distance	1.184	Influential observation
Maximum standardized residual	2.709	No extreme residual beyond ±3
Maximum leverage	0.535	High-leverage observation

Note: *VIF and tolerance are reported as ranges across the explanatory variables. Influence diagnostics are reported using the maximum observed value.*

Source: *Authors own calculation.*

Diagnostic checks indicate low multicollinearity, with VIF values below 2 for all explanatory variables. However, Delhi is a high-leverage observation because of its exceptionally high urbanisation and labour mobility. A sensitivity re-estimation excluding Delhi is therefore reported below. The purpose is not to remove the observation from the main analysis, but to assess whether the central inference depends entirely on this influential case.

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Sensitivity Analysis

Table 7: Sensitivity Analysis of Model 2: Full Sample and Excluding Delhi

Variable / Statistic	Full sample	Excluding Delhi
Overall vulnerability index (B)	0.363	-0.559
Standard error	2.014	1.840
Standardized β	0.019	-0.042
p-value	0.858	0.765
Urbanisation (B)	0.107	0.067
p-value	0.000	0.010
Per capita NSDP (₹ lakh)	0.770	0.802
p -value	0.049	0.025
Literacy (B)	-0.027	-0.004
p -value	0.537	0.926
R^2	0.785	0.645
Adjusted R^2	0.746	0.578
F-statistic	20.108	9.551
p -value (model)	4.32e-07	0.000146
N	27	26

Note: *The dependent variable is the employment-related labour mobility rate. B = unstandardized coefficient; β = standardized coefficient. The sensitivity specification excludes Delhi because of its high leverage.*

Source: *Authors' calculations.*

The sensitivity specification excluding Delhi reduces R^2 from 0.785 to 0.645, but the model remains statistically significant ($F = 9.551$, $p < 0.001$). The climate vulnerability coefficient remains statistically insignificant ($B = -0.559$, $p = 0.765$), while urbanisation remains significant ($p = 0.010$) and per capita NSDP remains significant ($p = 0.025$). The main inference that aggregate climate vulnerability alone does not explain cross-state labour mobility therefore remains unchanged.

DISCUSSION

The results indicate that climate vulnerability and employment-related labour mobility is not uniform across Indian states. States with similar levels of vulnerability do not necessarily exhibit similar levels of labour mobility. The weak negative correlation ($r = -0.209$) shows that higher vulnerability does not means higher mobility.

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The differences in mobility are better understood in the context of the socioeconomic and employment structure of states. The present study finds positive associations between labour mobility and urbanisation, literacy and per capita NSDP, indicating that mobility is also linked to the availability of economic opportunities and the capacity of workers to access them. This is consistent with Keshri and Bhagat's evidence of considerable interstate variation in temporary labour migration and with Kundu's argument that migration is influenced not only by regional disparities but also by access to urban and metropolitan employment opportunities.

This finding is particularly important when compared with studies that report a positive climate–migration relationship. Khairkar and Mahapatra, for instance, identify a positive relationship between their vulnerability index and migration trends, but their vulnerability framework also incorporates socioeconomic dimensions such as income, literacy, infrastructure and adaptive capacity. Therefore, the contrasting results do not necessarily imply that climate conditions are irrelevant to mobility; rather, they suggest that climate vulnerability operates within a broader socioeconomic context. Differences in employment opportunities, income, urbanisation, human capital and adaptive capacity may influence whether climate-related pressures translate into actual labour mobility.

Overall, the findings suggest that employment-related labour mobility not a sufficient explanation of labour mobility in India, rather it is a multidimensional socioeconomic outcome. The study therefore supports a broader socioeconomic interpretation of labour mobility rather than a purely climate-induced migration perspective.

CONCLUSION

This study provides a state-level assessment of the association between climate vulnerability and employment-related labour mobility across India. The evidence suggests that the climate-mobility relationship is more complex than a direct movement from greater vulnerability to greater labour mobility. The contrasting patterns across states, together with the loss of statistical significance after socioeconomic controls are introduced, indicate that labour mobility cannot be understood through climatic conditions in isolation. A key implication is that climate vulnerability and labour mobility should be examined together with the economic and social structures within which mobility decisions are made.

This study has several limitations. First, the analysis is cross-sectional and therefore identifies associations rather than causal effects. Second, the PLFS 2020-21, a period substantially affected by the COVID-19 pandemic and its associated disruptions to employment and mobility; therefore, the observed mobility patterns may partly reflect pandemic-specific conditions. Third, the CEEW vulnerability index combines exposure, sensitivity and adaptive-capacity dimensions; therefore, some conceptual overlap may

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exist between the vulnerability construct and the socioeconomic controls used in the regression. Fourth, literacy is based on Census 2011 and may not fully represent conditions in 2020-21. Finally, the study is state-level analysis, which may show some variations, although district-level analysis could provide more better insights into climate- labour mobility relationship, the state level findings remain useful for identifying broad regional patterns.

REFERENCES

Abel, Guy J.; Muttarak, Raya; Stephany, Fabian. 2022. Climatic Shocks and Internal Migration: Evidence from 442 Million Personal Records in 64 Countries. © World Bank. http://hdl.handle.net/10986/36886 License: CC BY 3.0 IGO

Apparaju, A. (2025). Differentiated outcomes of climate change-induced internal migration in India. *Regional Environmental Change*, *25*(4), 146.

Attah-Otu, B., Sengupta, A., & McAleavy, T. (2024). There and back again: dynamics of temporary labor migration, insights from rural India. *Frontiers in Sociology*, *9*, 1422602.

Bajpai, R., Purbey, A., DeWaard, J., Sharma, D., Swarnkar, P., Regules, R., ... & Mishra, A. (2026). Climate-induced internal migration in India: Looking into the past to understand the present. *Regional Environmental Change*, *26*(2), 75.

Bardsley, D. K., & Hugo, G. J. (2010). Migration and climate change: examining thresholds of change to guide effective adaptation decision-making. *Population and Environment*, *32*(2), 238-262.

Brenkert, A. L., & Malone, E. L. (2005). Modeling vulnerability and resilience to climate change: a case study of India and Indian states. *Climatic Change*, *72*(1), 57-102.

Dallmann, I., & Millock, K. (2017). Climate variability and inter-state migration in India. *CESifo Economic Studies*, *63*(4), 560-594.

Garip, F., & Reed, C. A. (2025). Climate change and human mobility: considering context, mechanisms, and selectivity. *Population and Development Review*, *51*(1), 449-489.

Gioli, G., Hugo, G., Costa, M. M., & Scheffran, J. (2016). Human mobility, climate adaptation, and development. *Migration and Development*, *5*(2), 165-170.

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press.

Kavi Kumar, K. S., & Viswanathan, B. (2013). Influence of weather on temporary and permanent migration in rural India. *Climate Change Economics*, *4*(02), 1350007.

Keshri, K., & Bhagat, R. B. (2013). Socioeconomic determinants of temporary labour migration in India: A regional analysis. *Asian Population Studies*, *9*(2), 175–195. https://doi.org/10.1080/17441730.2013.797294

Khairkar, V. P., & Mahapatra, S. (2025). Internal Migration and Climate Change in India: A State-wise Vulnerability Assessment. *Migration and Development*, 21632324251352961.

Kumar, R. R., & Rajagopalan, A. (2026). Environment-driven displacement and migration in India. *Regional Environmental Change*, *26*(2), 98.

L. Perch-Nielsen, S., B. Bättig, M., & Imboden, D. (2008). Exploring the link between climate change and migration. *Climatic change*, *91*(3), 375-393.

 ISBN: 978-93-49666-59-7 (eBook)

Liu, M., Shamdasani, Y., & Taraz, V. (2023). Climate change and labor reallocation: Evidence from six decades of the Indian Census. *American Economic Journal: Economic Policy*, *15*(2), 395-423.

Liu, Maggie, Yogita Shamdasani, and Vis Taraz. 2023. "Climate Change and Labor Reallocation: Evidence from Six Decades of the Indian Census." *American Economic Journal: Economic Policy* 15 (2): 395–423**.**

Ministry of Statistics and Programme Implementation. (2023, December 18). *Difference in per capita income*. Press Information Bureau, Government of India. Press Information Bureau

Moharaj, P., Muduli, D. K., & Sahoo, D. (2025). Climate induced migration and internal displacement in rural India. *Discover Environment*, *3*(1), 169.

Neog, B.J. Temperature shocks and rural labour markets: evidence from India. *Climatic Change* **171**, 16 (2022). https://doi.org/10.1007/s10584-022-03334-x

Oakes, R., Van der Geest, K., Schraven, B., Adaawen, S., Ayeb-Karlsson, S., De Sherbinin, A., ... & Williams, D. (2023). A future agenda for research on climate change and human mobility. *International Migration*.

Parrish, R., Colbourn, T., Lauriola, P., Leonardi, G., Hajat, S., & Zeka, A. (2020). A critical analysis of the drivers of human migration patterns in the presence of climate change: a new conceptual model. *International journal of environmental research and public health*, *17*(17), 6036.

Richa, Noy, I., & Sen, S. (2024). Extreme events and inter-state migration in India: an empirical analysis. *Migration and Development*, *13*(2), 289-311.

Samudra, A. (2026). Climate Vulnerability Index & Migration: A State Level Analysis of India. *Available at SSRN 6540981*.

Simpson, N. B. Demographic and economic determinants of migration. IZA World of Labor 2022: 373 doi: 10.15185/izawol.373.v2

Srivastava, R. Emerging Dynamics of Labour Market Inequality in India: Migration, Informality, Segmentation and Social Discrimination. *Ind. J. Labour Econ.* **62**, 147–171 (2019). https://doi.org/10.1007/s41027-019-00178-5

Yea, S. (2025). Climate change and hyper-precarious labour migration: Gendered, compounding and circular registers. *Environment and Planning E: Nature and Space*, *8*(4), 1179-1195.

Chapter

18 Nature and Sustainability in Digital Media: Indian Context

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INTRODUCTION

Two Transformations and Their Convergence

Two transformations define the present century, and they are increasingly entangled. The first is ecological. Climate change, biodiversity loss, land degradation, air and water pollution and unsustainable patterns of consumption have moved from the margins of public policy to its centre [1,2]. The second is technological. Digital systems have reorganised communication, knowledge production, governance, commerce and everyday life, and have done so within a single generation [3]. The subject of this paper lies where these developments meet: the relationship between digital communication and environmental sustainability.

Digital media has altered the structure of environmental communication itself. Public understanding of ecological questions was once mediated largely through newspapers, radio, television, educational institutions and government campaigns, all of which carried information in a single direction and through a small number of institutional gatekeepers [4,5]. The online media is interactive in nature. Social networking platforms, internet, and mobile applications are eminent platforms of environmental information as creators, not just as users. [6].

This shift has implications for sustainability because environmental issues are not presented in a neutral space. What counts as an environmental issue, whose account of it is credible, and which solutions appear reasonable are all outcomes of discursive contest [7,8]. A change in the architecture of communication is therefore a change in the conditions under which environmental politics is conducted. The question this paper pursues is whether that change, in the Indian case, works in favour of ecological sustainability, and at what material cost.

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The Indian Setting

India gives the transformation a particular character. In addition to significant environmental pressures caused by population density, urbanisation, industrialisation, waste production, climate variability, and shifting consumption, the country has exceptional ecological diversity, encompassing Himalayan systems, coastal zones, forests, deserts, river basins, and biodiversity-rich landscapes [9]. In this sense, digital communication opens up possibilities that were previously unavailable through traditional media platforms. Natural catastrophes, wildlife conservation, pollution, deforestation, and climate change are all topics that are widely discussed. Citizen and environmental organisations use digital networks to plan campaigns and recruit volunteers. Communities monitor local ecological change with the use of digital mapping tools and smartphones. Rather than waiting for traditional news cycles, scientists and environmental organisations actively disseminate their findings with a wider audience.

The scale of that infrastructure is considerable. India recorded 969.10 million internet subscribers at the end of March 2025, of whom 944.12 million were broadband subscribers and 927.70 million accessed the network wirelessly [10]. Average monthly data consumption per wireless subscriber reached 21.53 GB, and total wireless data traffic rose by 17.46 per cent over the preceding year [11]. A communication environment of this size and intensity is not a marginal factor in how a country understands its own ecology.

The relationship between digital media and sustainability is nonetheless not uniformly positive. Digital technologies depend on physical infrastructures and natural resources. Smartphones, computers, servers and communication networks require energy and raw materials across their lifecycle, and accelerated device replacement adds to a waste stream that is already the fastest growing in the world [12,13]. India's estimated generation of electronic waste from the categories notified under the E-Waste (Management) Rules, 2016 rose to 1,601,155 tonnes in the financial year 2021–22 [14]. Digital infrastructure expanded at a comparable pace: total data-centre capacity in the country grew from about 375 MW in 2020 to approximately 1,500 MW by 2025, and the Ministry of Power projects data-centre electricity demand of 13.56 GW by 2031–32 [15].

A paradox follows. Digital media can communicate environmental consciousness while simultaneously contributing to environmental pressure.

Statement of the Problem

Many individuals praise digital media for its ability to enhance environmental awareness and promote sustainable development. An environmental campaign can reach millions of users in a couple of days thanks to social networking sites and mobile technologies that allow individuals to access information, participate in public debate, and plan collective

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action. However, increased visibility does not lead to long-term environmental action. The attention economy of digital platforms encourages quick switching between issues, which undermines long-term public engagement, and online environmental activism may remain limited to symbolic expression, such as sharing posts, changing profile pictures, or participating in transient campaigns [16,17]. A second issue is the accuracy of environmental data provided over digital networks. Misinformation, altered visual imagery, and unsubstantiated assertions impair public comprehension of ecological issues, and recommendation algorithms may prioritise participation over scientific correctness or public importance [18,19]. A third, and distinct, issue is the environmental impact of digitalisation. It is vital to critically evaluate the concept that digital communication is inherently environmentally helpful. While data storage and transmission need energy-intensive infrastructure, the manufacturing and disposal of digital devices use material resources and generate hazardous waste [20,21].

Research Questions

The study is guided by one central question: what is the role of digital media in promoting nature conservation and sustainability in India, and what challenges must be addressed to ensure environmentally sustainable digital growth? The central question is disaggregated into seven specific questions:

1. How does digital media contribute to environmental awareness in India?
2. What role do social media platforms play in encouraging public participation?
3. Can digital storytelling help preserve and share indigenous and local ecological knowledge?
4. What are the environmental consequences of the rapid expansion of digital infrastructure?
5. How important are energy use and electronic waste as obstacles to India's sustainable digital development?
6. What institutional and policy frameworks are required to advance sustainable digital communication?
7. How can scholars, policymakers, civic society, and digital platforms create an integrated model of ecologically conscious digital communication?

Objectives of the Study

1. To examine the relationship between digital media, nature and sustainability in the Indian context.
2. To analyse the role of social media in environmental awareness and conservation communication.

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3. To investigate the potential of digital platforms for public participation and environmental activism.
4. To explore the contribution of digital storytelling and local ecological knowledge to sustainability communication.
5. To examine critically the environmental consequences of digital infrastructure and electronic technologies.

Significance of the Study

Research on digital media, which frequently concentrates on technological innovation, communication efficiency, and economic development, pays comparatively less attention to the ecological elements of digitalisation. When it comes to the material imprint of media, studies from high-income settings prevail in the literature [22, 23]. This study connects media studies with environmental sustainability in a setting that warrants further research: India's digital growth coincides with significant environmental and developmental pressures, and the nation's size, linguistic diversity, and inequality make it an essential place to understand how digital technologies interact with public communication and ecological systems. Further the study also extends the field of environmental communication research by studying the transition from one-way environmental messaging to interactive and participatory digital communication and viewing that transition as materially embedded rather than purely discursive. Because their communication strategies must account for both the environmental benefits and drawbacks of digital technology, policymakers, media outlets, IT companies, academic institutions, and civil society organisations find it practically significant. In a more general sense, the study contributes to the expanding field of sustainable digitalisation by proposing an integrated approach that connects technological advancement and ecological responsibility and by describing metrics that could be used to assess that approach.

REVIEW OF LITERATURE

Environmental Communication and the Public Sphere

It entails more than just conveying scientific information: cultural values, political interests, social identities, and conflicting interpretations of nature influence both what is communicated and how it is perceived [24]. The area has consistently considered communication as constitutive rather than merely instrumental, arguing that the way an environmental problem is called and presented determines the range of options possible [7].The development of mass media greatly increased public awareness of environmental issues. Newspapers, television documentaries, and radio programs helped the public understand pollution, wildlife protection, and climate change, but these systems were defined by institutional control and one-way flow [5]. Research on climate coverage

has revealed how editorial practices, such as balancing requirements, influence public impression of scientific consensus [25].

Digital Media, Activism and the Limits of Networked Participation

Digital media have become a critical infrastructure for contemporary activism, enabling people and organisations to connect quickly, coordinate action and draw public attention [27]. Environmental activism is increasingly hybrid, combining online and offline action: a campaign could start with a hashtag, an online petition or a film, and then move into public meetings, community activities, protest or policy engagement. The power of digital activism is in the speed, accessibility and network building. People join common initiatives across areas, and environmental organisations directly engage with their followers without depending on the old media gatekeepers [28].

Environmental Discourse in the Indian Digital Sphere

Social media and digital news ecosystems are debating environmental issues as a result of India's notable rise in digital communication and mobile connection. Issues including air pollution, river conservation, plastic waste, forest protection, climate change, and wildlife conservation are often discussed in online public discourse. Additionally, local environmental issues are more prominent on digital platforms than they would be through local media alone.

Digital Storytelling and Ecological Knowledge

Digital storytelling has become an important tool for sharing environmental experiences. Stories, photos, films, podcasts, and interactive media help to make abstract ecological issues more relatable. Statistics are frequently used to communicate climate change; while this knowledge is important, numbers alone rarely result in the level of participation required for a long-term response [26]. Environmental challenges are linked to personal experiences, distinct communities, and specific landscapes using digital storytelling. India has a wealth of indigenous and local ecological knowledge regarding forests, water, agriculture, biodiversity, and seasonal fluctuation that has been passed down over centuries [30, 31].

The Materiality of Digital Media

A recurring limitation in discussion of digital media is the tendency to treat digital communication as immaterial. Every digital interaction depends on physical systems: electronic devices, telecommunication networks, servers and data centres, electricity, cooling, minerals and raw materials, and systems for waste collection and recycling. Media scholarship has increasingly insisted on this materiality, tracing media technologies back to mineral extraction and forward to disposal [13,22,33].

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Electronic Waste and the Circular Economy

Electronic waste is one of the most important environmental impacts of technology. According to the fourth Global E-waste Monitor, 62 million tonnes of e-waste were produced globally in 2022, with just 22.3% being collected and recycled in an environmentally acceptable manner. By 2030, the generation is predicted to reach 82 million tonnes [12. India is placed third among global generators in the same survey. Recycling now meets less than 1% of the demand for rare earth elements, and recovery ability varies substantially by location. The E-Waste (Management) Rules, 2022, announced in November 2022 and went into effect on April 1, 2023, established a regulatory framework that strengthened Extended Producer Responsibility with a certificate-based compliance mechanism managed through a central portal and expanded coverage to 106 categories of electrical and electronic equipment [38, 39]. Later improvements added refrigerant management and the exchange of Extended Producer Responsibility certificates at a price range connected with environmental compensation [40].

The Research Gap

Three gaps emerge from this review. First, environmental communication research and the literature on the material footprint of information technology have developed largely in parallel, so that the communicative promise of digital media and its ecological cost are rarely assessed within a single analytical frame. Second, the material-footprint literature draws predominantly on high-income cases, leaving the specific configuration of rapid adoption, high informality in waste handling and pronounced access inequality that characterises India under-theorised. Third, existing frameworks for sustainable digital communication tend to remain normative, offering principles without indicators. This study addresses all three.

THEORETICAL FRAMEWORK

The study is informed by an interdisciplinary framework combining environmental communication theory, participatory communication, the network society and ecological modernisation, held together by an insistence on the materiality of media.

Environmental Communication Theory

Environmental communication theory emphasises the role of communication in shaping human relationships with the natural world. In addition to scientific facts, narratives, symbols, and public discourse are utilised to understand environmental challenges, and the framing of a problem helps remedies appear acceptable [7,24]. By allowing a large number of players to contribute to the construction of ecological narratives, digital media has extended this environment and enhanced pluralism while also increasing the number of conflicting and occasionally untrustworthy stories circulated.

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Participatory Communication

By emphasising interaction, community involvement, and local knowledge, participatory communication challenges the paradigm of experts providing information to passive audiences [32]. Digital technology can encourage participatory environmental communication by allowing citizens to record environmental issues, discuss local observations, contribute to biodiversity mapping, report pollution, coordinate community projects, and interact with lawmakers. However, because access to a platform does not ensure equal voice, participation must be meaningful rather than purely technological. Section 5 explores the distinction between having a channel and being heard.

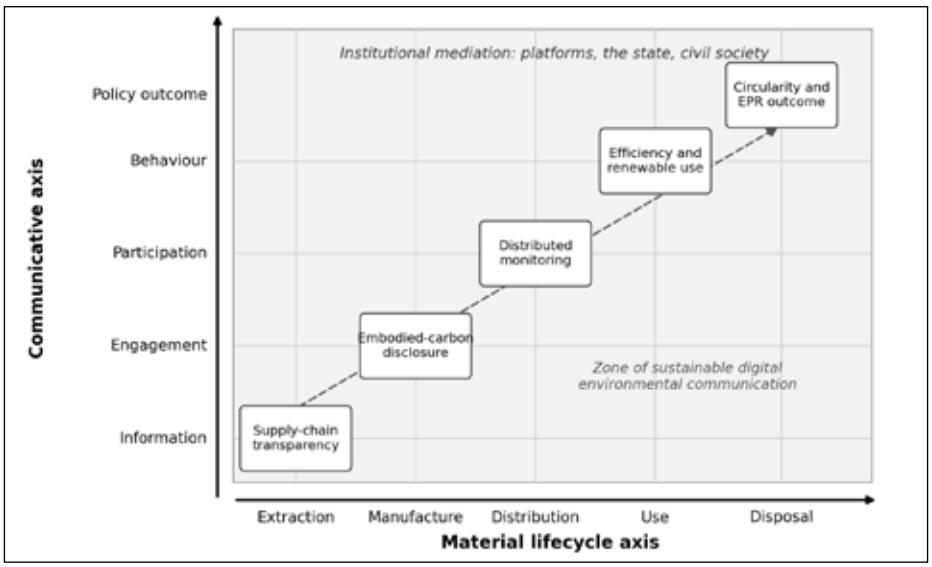


Fig. 1: Integrated analytical lens for sustainable digital environmental communication. The communicative axis (information, engagement, participation, behaviour, policy outcome) is plotted against the material lifecycle axis (extraction, manufacture, distribution, use, disposal), with institutional mediation by platforms, the state and civil society shown as the field in which the two axes interact.

MATERIALS AND METHODS

Research Design

The study adopts a qualitative, interdisciplinary and analytical design based on critical literature review and reflexive thematic analysis. The purpose is not to measure a single variable statistically but to examine a complex relationship between two domains that are usually studied separately. A qualitative design is appropriate because the research questions concern meaning, framing, institutional arrangement and contradiction rather than magnitude, and because several of the relevant quantities, particularly in the domain of electronic waste, are themselves contested and therefore require interpretation rather than aggregation.

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Sources of Data and Inclusion Criteria

The study is based on secondary sources assembled purposively. Material was included where it met three criteria: relevance to the intersection of digital communication and environmental sustainability; verifiability, meaning that the source is publicly retrievable and attributable to an identified author or institution; and, for empirical claims about India, currency, with statistical and regulatory sources restricted to material published from 2016 onward. Theoretical and conceptual works were admitted without a date restriction. Sources that could not be attributed to an identifiable author or institution were excluded, as were commercial market-research summaries whose underlying method was not disclosed. Table 1 sets out the composition of the corpus.

Table 1: Composition of the Source Corpus

Source category	Description	Function in the analysis
Peer-reviewed literature	Journal articles and scholarly books in media studies, environmental communication, sustainability science and industrial ecology	Conceptual framing; empirical estimates of sectoral footprint
Statutory and regulatory instruments	E-Waste (Management) Rules 2022 and amendments; Digital Personal Data Protection Act 2023 and Rules 2025	Analysis of the policy architecture
Official statistical releases	Telecom Regulatory Authority of India performance indicator reports; parliamentary replies and ministry releases on e-waste and data-centre capacity	Quantitative context for the Indian case
International assessments	Global E-waste Monitor; International Telecommunication Union and World Bank sectoral assessments	Comparative benchmarking; triangulation of official figures
Institutional and civil-society reports	Reports of environmental conservation institutions, organisations and public-interest bodies	Documentation of practice
Documented cases	Indian citizen-science platforms, government environmental applications and public campaigns with a documented public record	Illustration and theme development

Source: *Sources were retrieved between January and June 2026. Where official and international estimates of the same quantity diverged, both were retained and the divergence was treated as analytically significant rather than resolved by preference.*

Method of analysis

The corpus was analysed using reflexive thematic analysis following the six-phase procedure of familiarisation, initial coding, theme generation, theme review, definition and reporting [47]. Coding was conducted manually and iteratively. Initial codes were

generated inductively from the material; these were then read against the two axes of the analytical lens described in Section 3.5, so that the final theme structure reflects both what the sources emphasised and what the framework required. Themes were retained where they were supported by at least three independent sources drawn from more than one source category, which reduces the risk that a theme reflects the emphasis of a single institutional voice. Table 2 records the resulting coding frame.

Table 2: Analytical Coding Frame

Axis	Theme	Principal Codes
Communicative	Visibility and access	dissemination; scientific accuracy; multilingual content; visual communication
Communicative	Engagement gap	symbolic participation; attention cycles; metrics; online-offline linkage
Communicative	Distributed monitoring	citizen science; verification; data quality; ecological security
Communicative	Inequality of voice	rural access; language; gender; community media
Communicative	Information integrity	misinformation; algorithmic curation; platform transparency; literacy
Communicative	Knowledge custodianship	indigenous knowledge; consent; ownership; reciprocity
Material	Infrastructure footprint	energy; data centres; devices; embodied emissions; water
Material and institutional	Waste and governance	e-waste estimates; extended producer responsibility; informal sector; circularity

Themes are reported in Section 5 in this order. The final column lists the principal codes that were consolidated into each theme and not the full code list.

RESULTS

Eight themes were developed from the corpus. Six concern the communicative axis and two the material and institutional axis. They are reported below in the order established in Table 2.

Visibility and Access: Digital Media as an Environmental Information System

The most consistently documented contribution of digital media is the rapid dissemination of environmental information. Environmental organisations use video, infographics, podcasts and interactive content to communicate complex scientific material, and audiences reach that material without waiting for traditional news cycles. In the Indian case the state has itself become a substantial digital environmental communicator. The Central Pollution Control Board's Sameer application transforms a technical monitoring

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network into a public-facing information service by publishing hourly National Air Quality Index values for hundreds of monitoring stations and allowing the public to register and track pollution complaints [48]. The national ambient monitoring program and early warning systems for air quality share a public interface.

A consistent set of elements, such as scientific accuracy, linguistic accessibility, visual communication, emotional engagement, cultural relevance, and the provision of a real opportunity to act, are required for digital environmental communication to be effective across the corpus. The final one is frequently absent. The mechanism underlying the engagement gap that will be discussed next is attention without a pathway, which is caused by information that fits the first five conditions but lacks the sixth.

The register is the focus of a second observation. Instead of favouring one over the other, successful environmental communication in the Indian digital world usually combines narrative style and scientific substance. The narrative establishes relevance, whereas the statistical presentation builds trust. Campaigns that use only one of the two tend to reach a lesser audience since they are complementary.

The Engagement Gap: From Awareness to Outcome

Environmental communication begins with awareness, not ends with it. The corpus consistently shows that there is just a weak correlation between visibility and behavioural change. By providing pathways into tree planting programs, trash reduction initiatives, biodiversity documentation, environmental education, community clean-up campaigns, and citizen monitoring, digital platforms can facilitate the transition from information to action. In situations when there is no such path, a campaign with millions of views may nevertheless have a small societal impact.

Documented campaign practice in India illustrates both the possibility and the difficulty. An air-quality awareness programme conducted in Delhi between June and September 2025 reported direct engagement with more than two hundred thousand participants across pollution hotspots, combining school sessions, residents' association surveys, demonstrations of the Sameer application, carbon-footprint dashboards and social media outreach with the distribution and planting of more than 1,750 saplings under a national tree-planting initiative [49]. The design is instructive because the digital component was used to route participants toward specified offline actions rather than to substitute for them. Its evaluation is also instructive: the reported indicators are participation counts and saplings distributed, not survival rates of planted trees or measured change in household behaviour, which is the general condition of campaign evaluation in this field.

Table 3 sets out the ladder of engagement implied by the corpus, together with the indicator typically reported at each level and the indicator that would be required to evidence it.

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Table 3: Ladder of Digital Environmental Engagement and its Evidentiary Requirements

Level	Definition	Indicator typically reported	Indicator required
Awareness	Exposure to environmental content	Reach; impressions; views	Recall and comprehension measured after exposure
Engagement	Interaction with content	Likes; shares; comments	Depth and duration of interaction; onward transmission to new audiences
Participation	Contribution of effort or data	Sign-ups; pledges; observations submitted	Sustained contribution over defined period; retention rate
Behavioural change	Alteration of routine practice	Self-reported intention	Verified change in disposal, consumption or mobility practice
Institutional outcome	Change in rule, allocation or enforcement	Petition signature counts	Documented regulatory, budgetary or judicial response

The right-hand column is normative and derived from the analysis; it is not a claim about current reporting practice. The gap between the two right-hand columns is the principal evaluative weakness identified in this study.

Citizen Science and Distributed Environmental Monitoring

Digital technologies have expanded the scope of citizen science, and India provides substantial examples. The India Biodiversity Portal, launched in 2008 by a consortium led by a Bengaluru research institution, functions as an open-access platform on which participants upload, map and validate species observations; the published account of the platform records descriptions of more than 20,400 species and the aggregation of approximately 1.28 million observations covering over 30,000 species [50]. SeasonWatch, established subsequently, enlists participants including schoolchildren to record flowering and fruiting in common trees, producing a phenological baseline against which climate-driven shifts in seasonality can be assessed; participants in Kerala recorded that the flowering peak of Cassia fistula had moved earlier relative to the festival with which it is culturally associated [51]. Bird records from Indian participants contribute to a global observation network whose value for filling spatial gaps in biodiversity data has been documented in the ecological literature [52,53].

Three findings emerge. First, these platforms generate true scientific value rather than just public participation; the phenological example shows the discovery of an ecological signal that would be impossible to achieve by a professional survey with equivalent spatial coverage. Second, they succeed when the act of contributing is straightforward, repetitive, and locally significant. Third, they need verification infrastructure. Citizen-generated observations must be validated, and the most effective platforms combine open contribution with expert assessment.

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Digital conservation also creates security concerns that open-data regulations do not address. Public publication of the particular location of threatened species might encourage poaching and disturbance, therefore openness must be balanced against appropriate information management, which is often achieved through spatial generalisation of sensitive data. This is an instance in which the participatory logic of digital communication and the protective logic of conservation are at odds and must be resolved consciously rather than by default.

Inequality of Voice: The Digital Divide as an Environmental Justice Question

The distribution of digital involvement is not equal. Poverty, gender, location, language, and technological literacy all contribute to access inequities. Environmental communication limited to advanced digital platforms will fail to reach those most affected by environmental challenges. The amount of the gap is calculated using official data.

Table 4: Indicators of Digital Access in India, Financial Year 2024–25

Indicator	Value	Unit
Total internet subscribers	969.10	million
Broadband subscribers	944.12	million
Wireless internet subscribers	927.70	million
Wired internet subscribers	41.41	million
Urban internet density	110.79	subscribers per 100 population
Rural internet density	45.03	subscribers per 100 population
Urban teledensity	131.45	subscribers per 100 population
Rural teledensity	59.06	subscribers per 100 population
Average monthly data use per wireless subscriber	21.53	GB
Total annual wireless data traffic	228,779	petabytes

Figures are for the quarter and year ending 31 March 2025 as published by the Telecom Regulatory Authority of India. Density figures exceed 100 in urban areas because subscription counts include multiple connections held by single users and because service-area boundaries do not correspond exactly to census population units.

The ratio between urban and rural internet density is approximately 2.5 to 1. A rural density of 45 subscriptions per 100 population, given that individuals commonly hold more than one subscription, implies that a substantial share of the rural population has no personal connection at all. The consequence for environmental communication is direct: communities affected by mining, industrial effluent, forest diversion and agricultural distress are systematically less able to participate in the digital sphere in which those questions are increasingly debated.

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A sustainable digital strategy therefore combines online communication with community media, radio, educational institutions, local organisations and face-to-face participatory work.

Information Integrity: Misinformation and Algorithmic Visibility

Digital platforms have democratised the creation of information while simultaneously facilitating the dissemination of misleading information. The four most common types of environmental misinformation in the corpus are false claims about climate science, false information about pollution sources and levels, pseudoscientific environmental remedies, and manipulated or decontextualised visual content, such as disaster images circulated from unrelated events. Careful scientific communication has a structural disadvantage since experimental research on the spread of false information demonstrates that it can go faster and farther than accurate information [18].

Where there is a dearth of scientific and computer knowledge, the problem worsens. As a result, environmental literacy must include the capacity to identify credible sources, evaluate scientific data, recognise misleading information, distinguish between opinion and fact, and validate digital content. Thus, digital literacy is an extension of sustainability education rather than a replacement for it.

Ranking methods effect visibility as well. Strongly emotive content may be more extensively shared than scientifically nuanced content, perhaps simplifying complex environmental challenges into spectacular narratives [19, 54]. The structural obstacle is that the visibility of an environmental issue is unrelated to its public importance. Systems that encourage novelty and conflict are unsuitable for long-term challenges such as soil degradation or groundwater depletion, whereas episodic occurrences receive far more attention than they need. As a result, platform accountability is more than a peripheral demand: environmental communicators are fighting against a system whose rules they are unable to obey due to a lack of clarity about the mechanisms governing the presentation of public-interest information [45].

DISCUSSION

The Communication–Materiality Paradox

The central finding of this study is a paradox that the existing literature tends to address only on one side at a time. Digital media has materially improved the conditions for environmental communication in India: it has increased the visibility of ecological problems, lowered the cost of participation, enabled distributed monitoring that generates genuine scientific value, and given local environmental conflicts access to national and international publics. At the same time, the infrastructure that delivers those benefits is itself a growing source of energy demand, resource extraction and hazardous waste, and it is growing fastest in exactly the period when environmental communication most needs to succeed.

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The paradox is not resolved by netting the two against each other. A common move in the sustainable-digitalisation literature is to compare the footprint of a digital service against the footprint of the physical activity it displaces, and to conclude that substitution is beneficial. This comparison is true for some bounded substitutions with measurable baselines. When applied broadly, it becomes false for three reasons. First, the displaced baseline is lower than expected because digital services frequently supplement rather than replace physical activity. Second, the empirical footprint literature consistently demonstrates a pattern that the Indian traffic and capacity data replicate: the efficiency of a single transaction has grown while the aggregate impact has increased [20, 21]. Third, even if device manufacturing contributes significantly to sectoral emissions, replacement arguments typically account for operational energy while ignoring embodied burden [21]. As a result, the truth is that digital media may be both an instrument for ecological transformation and a source of ecological pressure, and whether it is more of one or the other is determined by design and policy rather than technology.

Why the Sustainability Claim for Digital Media is Under-Specified

A second conclusion focuses on the quality of the evidentiary base. For overlapping periods, Section 5.8 discovered that national and international estimates of the amount of electronic waste generated in India diverged by more than twice. Section 2.5 provided reliable estimates of the information and communication technology sector's worldwide emissions share, which ranged from 1.4 to 3.9%. Although these uncertainties are not the same, they do have one thing in common: statements about the environmental performance of digital media are being made on a measurement basis that is no longer capable of supporting them with the level of precision that is claimed.

Extended Producer Responsibility obligations are calculated as proportions of estimated generation, so measurement error propagates directly into compliance obligation. Corporate sustainability claims about digital services rest on boundary choices that are rarely disclosed. Public communication that presents digitalisation as environmentally beneficial is, on the current evidence, communicating a plausible hypothesis as an established finding. Improving measurement is therefore not a preliminary to policy but a component of it.

CONCLUSIONS

The relationship between nature, sustainability and digital media is among the more consequential interdisciplinary questions of the present period, and the Indian case makes both its possibilities and its contradictions unusually visible.

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Digital communication has created opportunities for environmental awareness, public participation and conservation that earlier media systems could not provide. Social platforms, mobile technologies, government environmental applications, citizen-science portals and digital storytelling now allow citizens to engage with ecological issues in ways that were previously difficult, and in some documented cases to generate scientific knowledge that professional survey alone would not have produced.

Technological optimism should not obscure the environmental consequences of digitalisation. Digital communication depends on physical infrastructures that consume energy and water, require extracted materials, and eventually generate hazardous waste. Digitalisation is not, in itself, sustainable, and the evidence base on which claims to the contrary are made is weaker than the confidence with which those claims are usually asserted.

The analysis leads to twelve principal findings. Digital media has substantially expanded the opportunity for environmental communication. Social media increases the visibility of environmental issues and can support collective action. Awareness does not automatically produce behavioural change, and the evaluative practice of the field does not currently distinguish the two. Successful marketing link specific offline acts with online interactions. Digital storytelling heightens the emotional impact and accessibility of environmental concerns. Where communities retain control, digital tools can help preserve and spread indigenous ecological knowledge. Misinformation and automated curation are substantial structural challenges for environmental communication. The discrepancy in participation created by the digital divide leads to ecological fragility. Digital technologies have significant material and environmental impacts throughout their five-stage lifecycle. Electronic waste has become a major sustainability concern, and its quantification is debatable. Sustainable digitalisation requires a lifecycle strategy rather than a use-stage approach. Public awareness, platform accountability, and government policy must all be coordinated since one cannot thrive without the other.

The fundamental point of this study is that digital media should be considered as more than a technology tool for raising awareness about sustainability. Digital communication must become sustainable in and of itself.

A genuinely ecological digital future will emerge only where the systems that communicate environmental values also operate according to principles of environmental responsibility, and where the performance of both can be independently verified.

Recommendations

1. Integrate environmental and digital literacy. Educational institutions should treat the capacity to evaluate environmental information and the capacity to understand the material basis of digital technology as components of a single competence.

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2. Adopt green digital infrastructure standards. Technology companies and public institutions should adopt energy-efficient systems and renewable procurement, and a national efficiency standard for data centres should be established while the capacity now being built is still at the design stage.

3. Strengthen electronic waste communication. Digital campaigns should inform consumers about repair, reuse, collection points and responsible recycling, using the same channels through which devices are marketed.

REFERENCES

Intergovernmental Panel on Climate Change. *Climate change* 2023: synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report. Geneva: IPCC; 2023.

United Nations Environment Programme. Global environment outlook 6: healthy planet, healthy people. Cambridge: Cambridge University Press; 2019.

Castells M. *The rise of the network society*. 2nd ed. Chichester: Wiley-Blackwell; 2010.

McQuail D. *McQuail's mass communication theory*. 6th ed. London: Sage; 2010.

Hansen A. *Environment, media and communication*. 2nd ed. London: Routledge; 2019.

Jenkins H. *Convergence culture: where old and new media collide*. New York: New York University Press; 2006.

Hajer MA. *The politics of environmental discourse: ecological modernization and the policy process*. Oxford: Oxford University Press; 1995.

Dryzek JS. The politics of the earth: environmental discourses. 3rd ed. Oxford: Oxford University Press; 2013.

Ministry of Environment, Forest and Climate Change. National biodiversity strategy and action plan. New Delhi: Government of India; 2024.

Telecom Regulatory Authority of India. The Indian telecom services performance indicator report, January–March 2025. New Delhi: TRAI; 2025.

Telecom Regulatory Authority of India. The Indian telecom services performance indicators: yearly report 2024–25. New Delhi: TRAI; 2025. Available from: https://www.trai.gov.in/sites/default/files/2025-07/YIR_08072025_0.pdf

Baldé CP, Kuehr R, Yamamoto T, McDonald R, D'Angelo E, Althaf S, et al. The global e-waste monitor 2024. Geneva and Bonn: International Telecommunication Union and United Nations Institute for Training and Research; 2024. Available from: https://ewastemonitor.info/the-global-e-waste-monitor-2024/

Cubitt S. Finite media: environmental implications of digital technologies. Durham (NC): Duke University Press; 2017.

Ministry of Environment, Forest and Climate Change. Generation of e-waste. Press Information Bureau release. New Delhi: Government of India; 2023. Available from: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1943201

Ministry of Electronics and Information Technology. Data centre capacity in the country has increased from about 375 MW in 2020 to around 1500 MW by 2025. Press Information Bureau release. New Delhi: Government of India; 2026. Available from: https://www.pib.gov.in/PressReleasePage.aspx?PRID=2239616

Morozov E. *The net delusion: the dark side of internet freedom*. New York: PublicAffairs; 2011.

Tufekci Z. Twitter and tear gas: the power and fragility of networked protest. *New Haven (CT)*: Yale University Press; 2017.

Vosoughi S, Roy D, Aral S. The spread of true and false news online. *Science*. 2018;359(6380):1146–51.

Gillespie T. Custodians of the internet: platforms, content moderation, and the hidden decisions that shape social media. *New Haven (CT)*: Yale University Press; 2018.

Freitag C, Berners-Lee M, Widdicks K, Knowles B, Blair GS, Friday A. The real climate and transformative impact of ICT: a critique of estimates, trends, and regulations. *Patterns*. 2021;2(9):100340. doi:10.1016/j.patter.2021.100340

Malmodin J, Lövehagen N, Bergmark P, Lundén D. ICT sector electricity consumption and greenhouse gas emissions – 2020 outcome. *Telecommunications Policy*. 2024;48(3):102701. doi:10.1016/j.telpol.2023.102701

Maxwell R, Miller T. *Greening the media*. New York: Oxford University Press; 2012.

Hilty LM, Aebischer B, editors. ICT innovations for sustainability. Cham: Springer; 2015.

Pezzullo PC, Cox R. *Environmental communication and the public sphere*. 5th ed. Thousand Oaks (CA): Sage; 2018.

Boykoff MT. Who speaks for the climate? *Making sense of media reporting on climate change*. Cambridge: Cambridge University Press; 2011.

Moser SC. Communicating climate change: history, challenges, process and future directions. *WIREs Climate Change*. 2010;1(1):31–53.

Castells M. *Networks of outrage and hope: social movements in the internet age*. Cambridge: Polity Press; 2012.

Kahn R, Kellner D. Globalization, technopolitics and revolution. Theoria: *A Journal of Social and Political Theory*. 2007;54(113):1–38.

Van Dijk J. *The digital divide*. Cambridge: Polity Press; 2020.

Gadgil M, Berkes F, Folke C. *Indigenous knowledge for biodiversity conservation*. Ambio. 1993;22(2–3):151–6.

Berkes F. *Sacred ecology*. 4th ed. New York: Routledge; 2018.

Servaes J, editor. *Communication for development and social change*. New Delhi: Sage; 2008.

Parikka J. *A geology of media*. Minneapolis (MN): University of Minnesota Press; 2015.

Bieser JCT, Hintemann R, Hilty LM, Beucker S. A review of assessments of the greenhouse gas footprint and abatement potential of information and communication technology. *Environmental Impact Assessment Review*. 2023;99:107033.

World Bank. Measuring the emissions and energy footprint of the ICT sector: implications for climate action. Washington (DC): World Bank; 2023.

International Energy Agency. *Electricity* 2024: analysis and forecast to 2026. Paris: IEA; 2024.

Crawford K. *Atlas of AI: power, politics, and the planetary costs of artificial intelligence*. New Haven (CT): Yale University Press; 2021.

Ministry of Environment, Forest and Climate Change. *E-Waste (Management)* Rules, 2022. Gazette of India. New Delhi: Government of India; 2022.

 ISBN: 978-93-49666-59-7 (eBook)

Central Pollution Control Board. *Extended Producer Responsibility portal for e-waste management*. New Delhi: Government of India; 2023.

Ministry of Environment, Forest and Climate Change. *E-Waste (Management)* Amendment Rules, 2024. Gazette of India. New Delhi: Government of India; 2024.

Borthakur A, Govind M. Emerging trends in consumers' e-waste disposal behaviour and awareness: a worldwide overview with special focus on India. *Resources, Conservation and Recycling*. 2017;117:102–13.

Kumar A, Holuszko M, Espinosa DCR. E-waste: an overview on generation, collection, legislation and recycling practices. *Resources, Conservation and Recycling*. 2017;122:32–42.

Ellen MacArthur Foundation. Towards the circular economy: economic and business rationale for an accelerated transition. Cowes: Ellen MacArthur Foundation; 2013.

Habermas J. The structural transformation of the public sphere: an inquiry into a category of bourgeois society. Cambridge (MA): MIT Press; 1989.

Zuboff S. The age of surveillance capitalism: the fight for a human future at the new frontier of power. New York: PublicAffairs; 2019.

Mol APJ, Sonnenfeld DA, Spaargaren G, editors. *The ecological modernisation reader: environmental reform in theory and practice*. London: Routledge; 2009.

Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative Research in Psychology*. 2006;3(2):77–101.

Central Pollution Control Board. Sameer: national air quality index application. New Delhi: Government of India; 2023.

WWF-India Environmental Information, Awareness, Capacity Building and Livelihood Programme Centre. WWF EIACP inspires over 200,000 citizens across Delhi through 25 high-impact awareness programmes. New Delhi: Press Information Bureau, Government of India; 2025. Available from: https://static.pib.gov.in/WriteReadData/specificdocs/documents/2025/sep/doc2025913635301.pdf

Vattakaven T, George RM, Balasubramanian D, Réjou-Méchain M, Muthusankar G, Ramesh BR, et al. India Biodiversity Portal: an integrated, interactive and participatory biodiversity informatics platform. Biodiversity Data Journal. 2016;4:e10279.

Nature Conservation Foundation. SeasonWatch: monitoring the seasonal cycles of India's common trees. Mysuru: Nature Conservation Foundation; 2024.

Sullivan BL, Wood CL, Iliff MJ, Bonney RE, Fink D, Kelling S. eBird: a citizen-based bird observation network in the biological sciences. *Biological Conservation*. 2009;142(10):2282–92.

Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, et al. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience*. 2009;59(11):977–84.

Pariser E. *The filter bubble: what the internet is hiding from you*. New York: Penguin Press; 2011.

Ministry of Electronics and Information Technology. The Digital Personal Data Protection Act, 2023. New Delhi: Government of India; 2023.

Ministry of Electronics and Information Technology. *Digital Personal Data Protection Rules*, 2025. New Delhi: Government of India; 2025.

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SECTION III

Inclusive Growth, Gender, Finance and Institutional Sustainability

Chapter

19 Framework for Sustainable Investment Decision Making: Integrating Cognitive Biases and Behavioural Intervention

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ABSTRACT

In recent years, sustainable investment and scholarly interest in it have grown significantly. However, individual investors' decision-making remains underexplored, particularly regarding the effects of cognitive and emotional biases on their choices. While behavioural finance has extensively documented biases in traditional investing and nudge interventions have been studied as tools to counter them, these two literatures have largely developed in isolation with respect to sustainable investment. This paper addresses that gap through a systematic literature review, following the PRISMA protocol, of 32 empirical studies selected from an initial pool of 951 studies retrieved from Scopus and Web of Science. The review identifies thirteen distinct biases affecting sustainable investment decisions. These biases are then grouped into four categories: heuristic-driven, self-referential, socially-driven, and moral and temporal biases. Further, based on the findings, the paper proposes a three-tier framework linking investor psychology (antecedents), biased judgment (distortion), and decision outcomes, and maps each bias category to a nudge intervention to mitigate it. This study provides insights for regulators and financial professionals for increasing sustainable investment by individual investors, and provides points for future cause-and-effect studies in biases and the sustainable investment domain.

Keywords: Sustainable Investment; Behavioural Finance; Cognitive Bias; ESG; Retail Investors; Nudging; Choice Architecture; Sustainable-Finance Literacy.

INTRODUCTION

Sustainable investment has transformed from a niche investment strategy to a mainstream approach in the global capital market. The market value of investment assets reporting the use of a responsible and sustainable investment approach has increased to 16.7 trillion USD over the last two years, representing growth of 49% (Global Sustainable Investment

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Alliance & Alexander, 2024). In addition to this, the interest of individual investors in sustainable investment is also increasing, with 92% of individual investors reporting their positive interest in sustainable investment (MORGAN STANLEY INSTITUTE FOR SUSTAINABLE INVESTING, 2026) (historically, the growth mainly came from institutional investors). As individual investors' interest deepens, it becomes urgent to understand how they make sustainable investment decisions.

Traditional finance theories assume that investors are rational and they cautiously weigh their investment decisions to maximise their profits (Kamoune & Ibenrissoul, 2022). However, various past studies have shown that investors often deviate from rationality due to their reliance on mental shortcuts, psychological and emotional biases, limited cognitive capacity, and bounded rationality. Among these obstacles to rationality, cognitive (emotional) biases remain the most studied and researched in the literature. A recent systematic literature review confirms that biases in investing are empirically tested and well-established, with various biases identified and documented across decades of research conducted in both developed and developing economies.

Sustainable investment introduces new layers of complexity to an already complex and difficult investment decision-making process because of its dual-purpose nature, promoting both financial and non-financial returns to society. These complexities can lead to psychological effects that differ from biases documented in studies on traditional investing. Despite this, the literature examining and synthesising the biases that affect sustainable investment decisions remains limited and fragmented. Existing literature on biases affecting sustainable investment is comprehensive and well-documented, but it has largely ignored sustainable investment decision-making. On the other hand, the literature review on sustainable investment has focused on past performance, ESG ratings and measurement, investor behaviour and motivation, and the barriers faced. As a result, these two bodies of literature have largely evolved in parallel, with few studies examining how cognitive and emotional biases affect sustainable investment decision-making and how their effects on the individual decision-making process can be mitigated.

Behavioural finance suggests using nudges to reduce the effect of cognitive and emotional biases on individuals' decision-making process. Nudges are small, low-cost, and avoidable changes in choice architecture that can predictably influence individuals' choices and decisions in a desired manner. Past research has shown how nudges can be used to reduce the effects of some biases. In the context of sustainable investment, Gajewski et al. (2022) have shown how nudges can be utilised to promote Sustainable investment adoption by reducing the attitude-behaviour gap and overcoming cognitive barriers, that steer retail investors away from ethical portfolios. A synthesis of nudges to reduce biases affecting sustainable investment decisions is missing from the literature.

To address these gaps, the present study aims to conduct a systematic review to synthesize the literature on cognitive biases affecting investors' sustainable investment decisions

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and the nudges intervention proposed to mitigate them. Specifically, this study aims to address the following research questions:

1. What biases have been identified in the literature that influence individual investors' sustainable investment decision-making?
2. What are the underlying mechanisms that explain how biases operate in the context of sustainable investment decision-making?
3. What nudge interventions have been employed in the literature to reduce the effect of these biases?

This study further aims to propose a framework that explains how biases affect individual investors' sustainable investment decisions and identifies nudge strategies to reduce or counter them.

METHODOLOGY

To realise the set objectives, this study adopts a Systematic literature review approach. First, SLR provides an easy, reliable, and objective framework for identifying related literature, while reducing bias (Littell, 2006; Tm et al., 2021). Second, it helps identify critical gaps in the literature (Tm et al., 2021). This study employs the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure transparency, reproducibility, and rigour in the research process.

Research Question

Formulating clear and well-defined research questions is crucial for conducting a rigorous and meaningful systematic review. In line with the objectives of this study, the following research questions have been developed to guide the review process:

1. What cognitive biases have been identified in the literature as influencing individual investors' sustainable investment decisions?
2. What theoretical mechanisms explain how these biases operate in the context of sustainable investment decision-making?
3. What nudge interventions have been proposed or tested in the literature to mitigate the effect of these biases?

Developing A Search Strategy

Given the study's objective of bridging the gap between the sustainable investment and cognitive bias literatures, a two-tier sampling structure was adopted. Tier 1, or category 1, comprises studies examining cognitive and emotional biases that affect individual investors' sustainable investment decisions. Tier 2 or category 2 comprises studies examining nudge or choice-architecture interventions in sustainable investing contexts. Studies of category 1 will provide answers to RQ1 and RQ2, and findings from category

2 studies will provide insights to answer RQ3. To develop the search string for the two categories, the PICO framework is employed. The search string development is shown in the Table 1.

Table 1: PICO framework

Dimenssion	Category 1	Category 2
Population	Individual/Retail investors	Individual/Retail investors
Intervention	Cognitive or Emotional biases	Nudges
Context	Sustainable/ESG investing setting	Sustainable/ESG investing setting
Outcome	Sustainable investment decision-making	Sustainable investment decision-making

The initial search string incorporated terms related to sustainable investing, cognitive and behavioural biases, and the target population of individual or retail investors:

("sustainable investment*" OR "ESG investment*" OR "socially responsible investing" OR "responsible investment*" OR "green investment*" OR "impact investing") AND ("cognitive bias*" OR "behavioral bias*" OR "behavioural bias*" OR heuristic* OR "emotional bias*" OR "affect heuristic" OR "moral bias*" OR overconfidence OR "loss aversion" OR herding OR anchoring OR "framing effect*" OR "mental accounting" OR "belief bias" OR "source preference") AND ("individual investor*" OR "retail investor*" OR "private investor*" OR "non-professional investor*" OR "household investor*")

However, the number of studies retrieved using the initial search string was relatively low. Therefore, the population-related search terms were removed to broaden the search and increase the number of potentially relevant studies.

Final search string for category 1

("sustainable investment*" OR "ESG investment*" OR "socially responsible investing" OR "responsible investment*") AND ("cognitive bias*" OR "behavioral bias*" OR "behavioural bias*" OR "heuristic*" OR "emotional bias*" OR "overconfidence" OR "loss aversion" OR "herding" OR "anchoring" OR "framing effect*")

The final search strategy, therefore, focused on the relationship between sustainable/ESG investing and cognitive or behavioural biases, without restricting the search to a specific investor population.

The initial search string incorporated terms related to sustainable investing, cognitive and behavioural biases, and the target population of individual or retail investors:

("sustainable investment*" OR "ESG investment*" OR "socially responsible investing" OR "green investment*" OR "sustainable finance") AND (nudge* OR "choice architecture" OR "default option*" OR "default effect*" OR "framing intervention*" OR "social norm*" OR

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"behavioral intervention*" OR "behavioural intervention*" OR "libertarian paternalism" OR debiasing OR "simplification intervention*") AND ("individual investor*" OR "retail investor*" OR "investment decision*" OR "investor behavio*r")

However, the number of studies retrieved using the initial search string was relatively low. Therefore, the population-related search terms were removed to broaden the search and increase the number of potentially relevant studies.

Final Search String

("sustainable investment*" OR "ESG investment*" OR "socially responsible invest*" OR "sustainable and responsible invest*" OR "green investment*" OR "SRI" OR "ESG" OR "sustainable finance") AND ("nudge*" OR "choice architecture" OR "default option*" OR "default effect*" OR "framing" OR "social norm*" OR "behavioral intervention*" OR "behavioural intervention*")

Screening

Using the above-developed search string in the Scopus database and Web of Science database, 951 papers were retrieved. After applying automatic filters for language, subject area, and document type and removing duplicates, the number of studies was reduced to 515. These 515 studies were screened by title and keywords, after which 143 were retrieved for further screening and selected. These 143 papers were then subjected abstract screening after which 34 studies were selected for full text analysis. However, two studies were not accessible, so 32 studies were selected for the analysis.

Inclusion Exclusion Criterion

Table 1 presents the inclusion and exclusion criteria used for selecting the studies for further analysis.

Table 1: Inclusion-exclusion criterion

Inclusion criterion	Exclusion criterion
• Studies in the English language • Empirical studies only • Studies about the effect of nudging or biases affecting sustainable investment decision-making • Studies related to the retail investor, retail investor, or household investor • Indexed/peer-reviewed (Scopus/WoS-listed)	• Studies published in other languages • Studies related to institutional investors • Studies on effect of biases or nusges in traditional investment context • Review paper or conceptual paper

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Data extraction and analysis:

This stage involves extracting relevant information from the reviewed papers, analysing it, and systematically reporting the findings. From a full reading of the paper, information on biases affecting sustainable investment, the underlying mechanism, nudges, and their workings was extracted, and the Excel file was prepared. The findings of this review are discussed in the next section, objective-wise. To report the findings, a combination of tables, and descriptions is used. Figure 1 illustrates the study selection process of this SLR using the PRISMA framework.

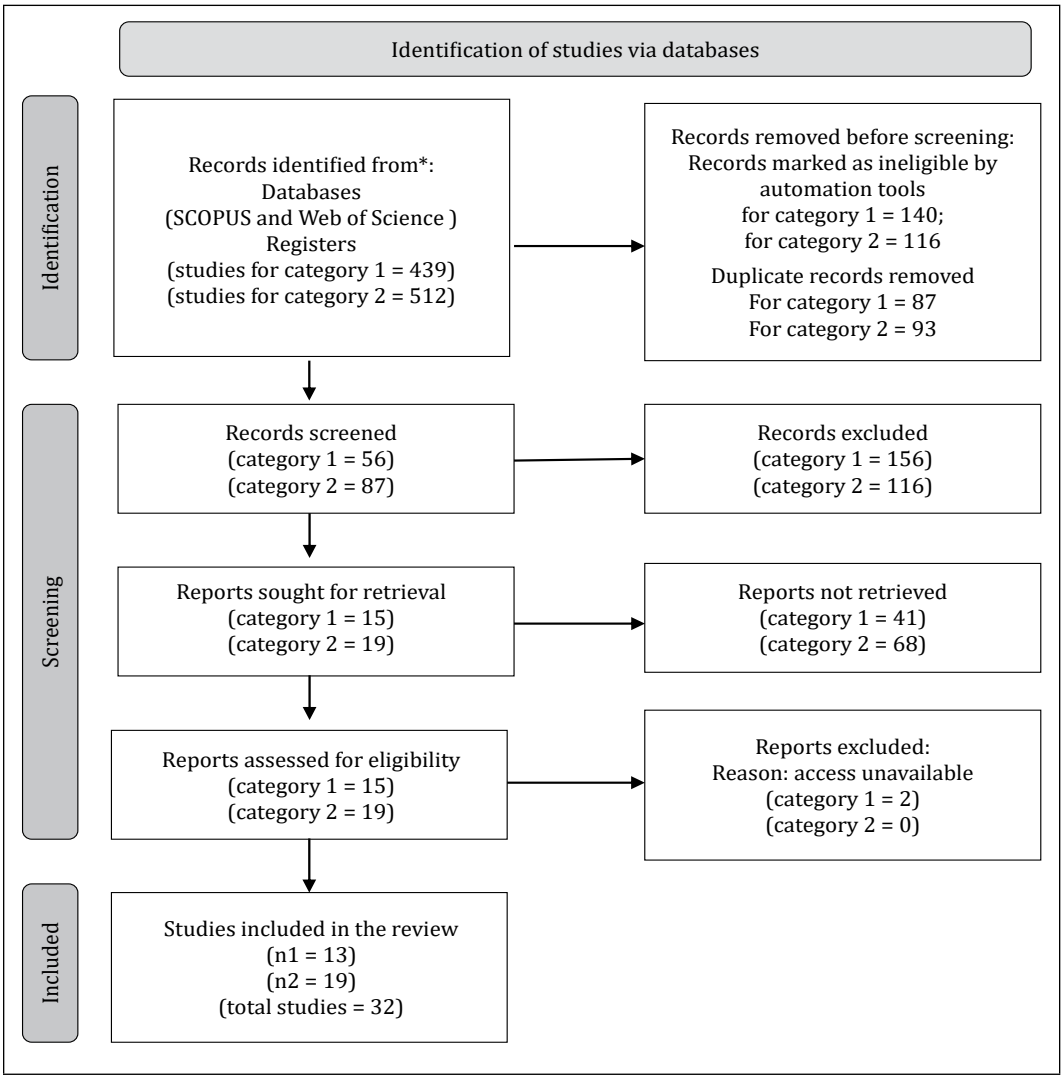


Fig. 1: Prisma Flowchart for Screening and Selection of Studies

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ANALYSIS

Biases and underlying mechanisms

Table 2: Cognitive and Emotional Biases Affecting Sustainable Investment Decision-Making

S.no	Bias	Definition	Mechanism	Reference
1	Availability bias	Investors judge the importance or likelihood of an event based on how easily examples can be recalled	Ease of recall distorts likelihood judgment; triggers herding and status-quo shifts	Abhijith et al. (2025); Deka et al. (2023)
2	Overconfidence Bias	Investors overestimate their analytical skills, forecasting abilities, and capacity to manage risk	Inflated self-assessment raises risk tolerance, partially driving adoption	Abhijith et al. (2025); Deka et al. (2023)
3	Herding bias	Investors follow the crowd and copy peers or market trends rather than performing their own risk-return analysis and making a decision	Copying peers/market instead of independent analysis lowers risk tolerance	Abhijith et al. (2025); Bihari et al. (2025); Deka et al. (2023)
4	Source preference	Valuing Similar assets differently based solely on whether an investment's source is categorised as ethical, neutral, or sinful.	Direct emotional utility — "joy" from virtuous stocks, "unease" from sinful ones	Chew and Li (2026)
5	Belief Bias	misjudging a stock's actual likelihood of success because of the morals attached to it	Karmic Investment Hypothesis — ethical firms are assumed to have better odds	Chew and Li (2026)
6	Moral Loss Aversion	The psychological tendency to avoid "bad" (sin) investments much more strongly than seeking out good ones	Bad is stronger than good" — moral/ regret pain outweighs equivalent gains	Chew and Li (2026); Deka et al. (2023)
7	Confirmation Bias	Giving more weight to information that confirms your pre-existing beliefs while ignoring contradictory evidence	Overweights belief-confirming ESG information, dismisses contradictions	Bihari et al. (2025)
8	Endowment Effect	Investors ascribe a higher value to assets they already own	Loss aversion inflates value of assets already owned	Bihari et al. (2025)

Table 2 Contd....

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S.no	Bias	Definition	Mechanism	Reference
9	Recognition-based heuristic	Investors rely exclusively on recognition cues and assign a higher value to a recognised option over an unrecognised one	distort investor judgment and misallocate capital away from genuinely sustainable, ESG-compliant enterprises, ultimately driving broad market inefficiencies	Ahmad et al. (2026)
10	Distance bias	Investors assign a higher value to the local assets over foreign assets	Information assembly and familiarity theory	Chen and Nainggolan (2018)
11	Temporal Myopia	An irrational tendency to favor short-term preferences and immediate rewards over long-term outcomes multimodal	Weak environmental attitudes/norms increase sensitivity to long maturities	Mazzoli et al. (2026)
12	Hyperbolic Discounting	A non-constant devaluation of outcomes over time, causing preferences to drop sharply over short delays and become time-inconsistent.	Future outcomes devalued non-constantly, producing inconsistent preferences	Mazzoli et al. (2026)
13	Maturity Preference	The empirical financial manifestation of temporal myopia, characterized by a strong investor aversion to long-term investment horizons.	High sensitivity to bond maturity dates drives aversion to long horizons	Mazzoli et al. (2026)

Table 2 represents the cognitive and emotional biases identified in the selected studies. The table below contains the list of biases, their definitions, the aspect of decision-making process they relate to and conceptual underpinnings. Overall, across the studies, 13 different biases were identified which can be grouped into 4 broad categories including heuristic, self-related, socially related and morally/ temporally related biases.

The first category of biases is heuristic-driven including availability bias, identification-based heuristics (e.g., name fluency, alphabetical order, name memorability), and anchoring bias. Abhijith et al. (2025) signify that availability bias is the sole strongest direct determinant of sustainable integration through the ease in which ESG-related facts (e.g., media coverage of green energy, environmental disasters) are reminisced. Ahmad et al. (2026) enhance the heuristic logic by showing that investors replace perceptual ease

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for analytical due assiduity, preferring companies with proficient or memorable names over authentically sustainable firms – a composition they link to skewed capital allocation and broader market ineffectiveness

The second category refers to self-referential biases: overconfidence and an endowment effect. In this case, the cognitive resource allocation mechanism is different: overconfident investors overestimate their ability to assess the ESG complexity, which Abhijith et al. (2025) argue indirectly impacts sustainable investment decisions via increased risk tolerance. The endowment effect, according to Bihari et al. (2025), causes investors to hold on to (typically non-ESG) stocks in favor of which they have developed a psychological bias.

The third category of biases includes socially-driven cognitive distortions such as herding, bandwagon effects, and distance/local bias. Herding and bandwagon effects are driven by social proof and peer-to-peer interactions, whereas the mechanism of distance bias is based on information asymmetry and familiarity principles (Abhijith et al., 2025). Herding decreases the risk-taking level, while the bandwagon effect shapes behaviors not on rational analysis but peer-to-peer interactions. As a result, herding leads to adoption suppression, resulting in the "herding" of financial markets, while bandwagon rarely affects decision-making in finance. On the other hand, Chen and Nainggolan (2018) provide an alternative view on the mechanism of distance bias, according to which fund managers tend to select the most familiar alternatives first, using private information acquired through informal sources. This behavior stems from the information asymmetry about the fundamentals of the alternatives and can be associated with the loss aversion.

The fourth category, which deals with moral and temporal biases, is theoretically the most distinct of all. Chew and Li (2026) attribute source preferences and belief bias to the "Karmic Investment Hypothesis," where investors impute moral causality on market outcomes, while moral loss aversion reflects an asymmetry in which avoidance of "sin" investments outweighs the pursuit of "virtue" investments. Mazzoli et al. (2026) identify a temporal bias involving hyperbolic discounting and maturity preference that explains short-termism through the Theory of Planned Behavior, demonstrating that weak pro-environmental attitudes and subjective norms heighten sensitivity to long investment horizons.

Taken together, Table 1 demonstrates that while these biases operate through heterogeneous mechanisms—recall fluency, self-assessment, social conformity, and moral or temporal reasoning—many converge on a common mediating pathway: perceived risk tolerance. This convergence suggests risk tolerance functions as a central theoretical node linking otherwise disparate biases to sustainable investment outcomes, a pattern that will inform the framework developed in this review.

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Nudges

Default

A default is a good choice when a participant is not making a choice because of inertia or complexity, but is not neutral. Gajewski et al. (2022) show that the anchoring effect, along with other factors, can have profound effects on allocation given the presence of sustainable defaults. The framework thus suggests a hierarchy. There is good evidence that most users will select a particular sustainability option and the costs are comparable, so there is a basis for a transparent default. If preferences are idiosyncratic or the financial consequences are great, it is preferable to have an active choice. Prior to product selection, the investor can be invited to select from well-defined sustainability goals. This makes the "passive default" a formal preference elicitation process.

Simplification

Among the most malleable factors affecting poor ESG decision making is complexity. The study by Hutchings (2025) shows that it is possible to improve retailers' ability to identify companies with sustainability attributes through several steps of the process of creating a simpler ESG score that allows them to better separate companies with sustainability characteristics. The objective of the design challenge is to minimize and not sacrifice the accuracy. It is therefore desirable to have a multi-layered disclosure structure: a short and well-defined profile or score at the first layer, a description of methodology and uncertainty at the second layer, and raw information and data at the third layer. This helps to compare ideas with minimal effort and gives transparency for any investor who wants to dive deeper into the process.

Impact Quantification and Scope Prompts

If the product has a real-world impact, the architecture should also express size as well as type. Heeb, et al. (2023) recommend that investors may be fairly neutral about impact. Such a scope prompt can then ask investors to put the different impacts of the alternatives on the same scale before they make a decision. The intervention needs to be non-moralising. Its role is to enable an impact-minded investor to make a material impact distinction between products.

Verification, Uncertainty and Anti-Greenwashing Cues

The best way to counter greenwashing is to add a decision attribute called credibility. The verification badge should distinguish not only the further green icon, but also the verifier and the standard. If there is a difference in ratings, it can be supplemented by a dispersion indicator at the platform. If the sustainability claim is self-reported, the interface should state this. Anti-greenwashing measures should be placed close to the claim rather than in

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a separate document, Kleffel and Muck (2023) suggest, as identity needs can be met with labels even when validity is uncertain.

Debiasing Prompts, Checklists and Calibration

Friction is needed for confirmation and overconfidence so as to change the cognitive process. Questions on impact evidence and an independent source, financial risks, diversification, and fees are some potential elements of a brief decision checklist. When followed by feedback, a confidence question may uncover areas of ESG learning gaps. This is not a "nudge", as it prescribes to the investor to more or less choose to be sustainable, but rather increases the process of how the decision is taken.

Advice, Digital Nudging and Sustainable-Finance Literacy

There is a criticism of education that knowledge doesn't always translate into behaviour, but when there is a conceptual misunderstanding there can be value in targeted literacy. But sustainable finance literacy is another restriction, as demonstrated by Filipini et al. (2024). Thus, it is imperative to have education at the point of decision making and not as a generic course. A digital adviser can educate the user on the differences between the different ways of integrating/include and exclude them, the different types of themed investing and the different types of impact and their assignments to the individual's objective. More recent work also shows that the provision of information in digital advising and ESG nudges can further lead to a higher sustainable allocation, particularly when the information provided by advisers interacts with knowledge and preferences.

Social Information and Ethical Constraints

A social-norm message can get the attention of the product, and it can also create a perceived quality of product becoming popular. Three safeguards are needed for the responsible use. For social information to be effective, it needs to be accurate and up to date. Second, it's supposed to be a statement of behavior, and not make better returns suggestions. Third, it is important to remind users that user's choice does not reflect appropriateness. In a general sense, the ethics underlying the use of behaviour in finance should be clear, easy to withdraw from, must not be imposed upon an individual's free will and should be guided by a good welfare reasoning. Gajewski et al. (2024) point out that while the efficacy of responsible-finance nudges is a necessary condition to evaluate them, they also need to be evaluated on an ethical level.

RESULTS

The proposed framework synthesizes the review's findings into a three-layer structure that traces the pathway from investor psychology to decision outcome, and identifies where behavioral interventions can interrupt that pathway. At the antecedent layer sit

the thirteen cognitive and emotional biases identified across the selected studies (RQ1), organized into four mechanism-based clusters: heuristic-driven biases (availability, recognition-based heuristics), self-referential biases (overconfidence, endowment effect), socially-driven biases (herding, bandwagon effect), and moral or temporal biases (source preference, belief bias, moral loss aversion, temporal myopia and its related constructs). This clustering reflects the shared psychological process underlying each group rather than the decision stage or paper of origin, and directly addresses RQ2 by grounding each cluster in a distinct theoretical mechanism — cognitive ease and recall, inflated self-assessment, social conformity, and non-financial value systems intruding on probability judgment, respectively.

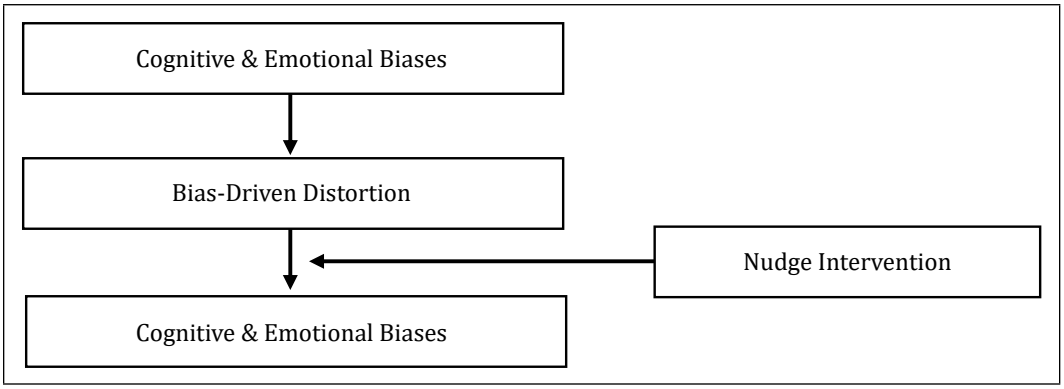


Fig. 2: Bias to Decision Model

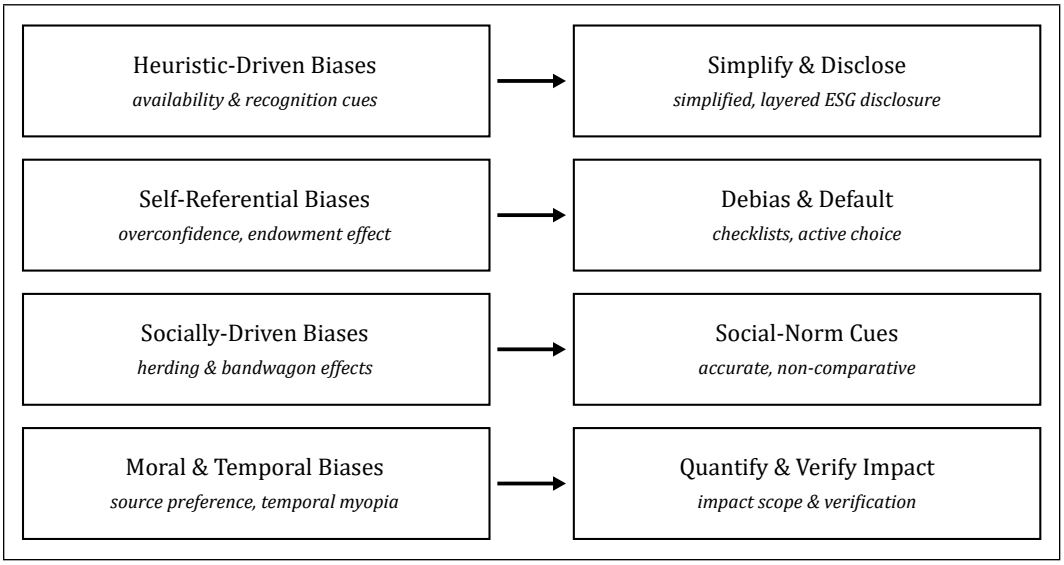


Fig. 3: Bias-Nudge Alignment

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These clusters feed into a distortion layer, where the biases manifest as biased judgment and skewed risk perception. Notably, several studies in this review converge on risk tolerance as a shared mediating variable through which structurally different biases produce their effects — overconfidence and status quo bias operate by raising risk tolerance, while herding operates by suppressing it (Abhijith et al., 2025). This shared pathway suggests that, despite their varied psychological origins, many biases ultimately act on investment decisions through a common downstream channel, which has implications for where interventions are best targeted.

The distortion layer, in turn, shapes the outcome layer: sustainable investment decision-making, operationalized across the reviewed studies as adoption of sustainable options, risk assessment and asset selection, and portfolio weighting.

The framework's distinguishing feature, responding to RQ3, is that nudge interventions are positioned not as replacements for the bias-outcome pathway but as moderators of it — they weaken the link between distorted judgment and decision outcome without necessarily eliminating the underlying bias. The mapping diagram illustrates this moderation at the level of individual bias clusters: heuristic-driven biases are best addressed through simplification and layered ESG disclosure, which reduces the complexity that heuristics substitute for; self-referential biases respond to debiasing checklists and default architecture, which introduce friction against inflated self-assessment and status-quo inertia; socially-driven biases are targeted by carefully bounded social-norm cues; and moral or temporal biases are addressed through impact quantification and anti-greenwashing verification, which place moralized judgments on a comparable material scale.

Two limitations emerge from this mapping and merit discussion. First, distance bias has no corresponding nudge in the reviewed intervention literature, representing a gap between the antecedent and intervention bodies of research. Second, the temporal-bias cluster is addressed by only a single intervention — immersive VR exposure to future environmental consequences (Mazzoli et al., 2026) — which falls outside the conventional nudge taxonomy used elsewhere in this framework, suggesting either an underdeveloped area of intervention research or a need to broaden the definition of "nudge" for temporally-oriented biases.

CONCLUSION

Sustainable investing extends the investment problem one step further and introduces the ESG information, impact preferences and credibility questions. This expansion provides investment opportunities to match non-financial values with their investments, but also introduces cognitive load and salience, affect, inertia, anchoring, social proof, overconfidence, confirmation, ambiguity and scope neglect to decisions. The key

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theoretical concept that lies behind the entire argument is that there can be no sustainable preference bias. Informed preferences should be informed not because the investor makes a different choice from a narrow financial-return benchmark, but because the architecture or information environment of the product makes it difficult for investors to be informed. This paper has presented evidence for a mechanism-specific approach. The default effect can break inertia; but can also be used to reinforce or strengthen inertia; Simplified ESG indicators can minimize the cognitive load but can also lead to effects of scope insensitivity or false precision; The calibration effect can break the scope of insensitivity; The display of uncertainty and the verification effect can reduce the risk of greenwashing; Decision prompts, advice and targeted literacy intervention can enhance calibration and interpretation. Investor literacy, experience, values and trust in the tools, along with the trustworthiness and complexity of sustainability information, determines the ability to use each tool. The proposed framework in this regard then focuses on diagnosis instead of intervention and quality of the decision besides the allocation. It provides research propositions to test in the context of sustainable-investment environments, as well as the behavioural mechanism and effect of interventions. It offers a useful blueprint for regulators, platforms, asset managers and advisers to design choice architecture that enables investors to better grasp the relative costs and benefits and make choices based on their informed goals. For sustainable finance to become more credible, it's going to become more credible if the money isn't just being directed to labelled sustainable finance, but if the decisions of where the money goes are made more credible.

REFERENCE

Abhijith, R., Bijulal, D., Subramoniam, S., & Ravi, V. (2025). Demystifying behavioural biases influencing sustainable investing decisions: A hybrid PLS-SEM and fuzzy DEMATEL approach. *Social Responsibility Journal, 21*(9), 2034–2052. https://doi.org/10.1108/SRJ-02-2025-0150

Ahmad, M., Wu, Q., Sun, L. C., Abbass, Y., Sun, S., & Hattab, I. (2026). Examining the role of recognition-based heuristics in sustainable investment decision-making using a structural equation modeling–artificial neural network-based approach. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-026-07337-x

Bihari, A., Dash, M., Muduli, K., Kumar, A., Luthra, S., & Upadhyay, A. (2025). Sustainable development investment decision: Do environmental, social and governance (ESG) and behavioral biases factors matter? *Sustainable Development*. Advance online publication. https://doi.org/10.1002/sd.70056

Chen, E. T., & Nainggolan, Y. A. (2018). Distance bias of socially responsible investment. *Social Responsibility Journal, 14*(1), 96–110. https://doi.org/10.1108/SRJ-02-2017-0021

Chew, S. H., & Li, K. K. (2026). Source preference, belief bias, and ESG investment: Virtue stock affinity versus sin stock aversion. *Journal of Behavioral and Experimental Finance, 51*, 101210. https://doi.org/10.1016/j.jbef.2026.101210

Deka, J., Sharma, M., Agarwal, N., & Tiwari, K. (2023). Linking ESG-investing consciousness, behavioral biases, and risk-perception: Scale validation with specifics of Indian retail investors. *European Journal of Business Science and Technology, 9*(1), 70–79.

 ISBN: 978-93-49666-59-7 (eBook)

Filippini, M., Leippold, M., & Wekhof, T. (2024). Sustainable finance literacy and the determinants of sustainable investing. *Journal of Banking & Finance, 163*, 107167. https://doi.org/10.1016/j.jbankfin.2024.107167

Gajewski, J.-F., Heimann, M., & Meunier, L. (2022). Nudges in SRI: The power of the default option. *Journal of Business Ethics, 177*(3), 547–566. https://doi.org/10.1007/s10551-020-04731-x

Gajewski, J.-F., Heimann, M., Meunier, L., & Ohadi, S. (2024). Nudges for responsible finance? A survey of interventions targeted at financial decision making. *Corporate Social Responsibility and Environmental Management, 31*(2), 1203–1219. https://doi.org/10.1002/csr.2625

Global Sustainable Investment Alliance, & Alexander, J. (2024). *Global sustainable investment review 2024*. https://www.gsi-alliance.org/wp-content/uploads/2025/11/GSIR-2024-Main-Report.pdf

Harie, Y., Gautam, B. P., & Wasaki, K. (2023). Computer vision techniques for growth prediction: A PRISMA-based systematic literature review. *Applied Sciences, 13*(9), 5335.

Heeb, F., Kölbel, J. F., Paetzold, F., & Zeisberger, S. (2023). Do investors care about impact? *The Review of Financial Studies, 36*(5), 1737–1787. https://doi.org/10.1093/rfs/hhac066

Hutchings, G. (2025). The impact of an ESG nudge on retail investor engagement in sustainable finance: Evidence from an investment decision experiment. *Sustainability Accounting, Management and Policy Journal, 16*(6), 1807–1830. https://doi.org/10.1108/SAMPJ-10-2024-1104

Kamoune, A., & Ibenrissoul, N. (2022). Traditional versus behavioral finance theory. *International Journal of Accounting, Finance, Auditing, Management and Economics*, 282–294. https://doi.org/10.5281/zenodo.6392167

Kleffel, P., & Muck, M. (2023). Aggregate confusion or inner conflict? An experimental analysis of investors' reaction to greenwashing. *Finance Research Letters, 53*, 103421. https://doi.org/10.1016/j.frl.2022.103421

Littell, J. H. (2006). Systematic reviews in the social sciences: A review. *Evidence & Policy, 2*(4), 535–537.

Mazzoli, C., Lucarelli, C., & Severini, S. (2026). VR immersive experiences and sustainable investment decision-making. *Journal of Environmental Management, 404*, 129325. https://doi.org/10.1016/j.jenvman.2026.129325

Morgan Stanley Institute for Sustainable Investing. (2026). *Sustainable signals*. https://www.morganstanley.com/content/dam/msdotcom/en/assets/pdfs/Sustainable_Signals_Individual_Investors_2026_-_Morgan_Stanley_Institute_for_Sustainable_Investing.pdf

Tm, A., Kaur, P., Bresciani, S., & Dhir, A. (2021). What drives the adoption and consumption of green hotel products and services? A systematic literature review of past achievement and future promises. *Business Strategy and the Environment, 30*(5), 2637–2655.

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Chapter

20 An Analysis of Investment Habits among Working Women across Different Professions in Indore City

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ABSTRACT

This study examines profession-wise investment habits among working women in Indore City, with particular emphasis on financial preparedness, investment discipline, information exposure, decision-making behaviour, and portfolio practices. A descriptive and comparative quantitative research design was adopted, using primary data collected through a structured questionnaire from 300 working women across ten professional categories, with 30 respondents representing each profession. The data were analysed using frequency and percentage distributions, multiple-response analysis, cross-tabulation, and chi-square tests of association.

The findings indicate that self-directed investing through online portals, applications, and brokers is the dominant mode of investment among respondents, while most working women report taking their final investment decisions independently. Investment learning is influenced by a combination of peers, family members, digital platforms, online information sources, and financial professionals. Significant profession-wise differences were observed in basic financial knowledge, participation in financial literacy programmes, use of selected learning channels, regular investment behaviour, emergency fund maintenance, financial goal-setting, saving intensity, diversification, and investment experience. In contrast, variables such as compounding awareness, usual mode of investing, final investment decision-maker, investment horizon, and investment style did not differ significantly across professions. The study concludes that profession is associated less with whether working women participate in investing and more with the preparedness, information exposure, financial discipline, and portfolio experience surrounding their investment decisions. The findings highlight the importance of profession-sensitive financial literacy and investor-education initiatives for working women.

Keywords: Working Women, Investment Habits, Profession, Financial Literacy, Investment Behaviour, Financial Decision-Making, Indore.

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INTRODUCTION

Investment behaviour among working women cannot be understood only through income, age, or education; it is also shaped by the professional environments within which women earn, save, learn, and make financial decisions. Profession influences the nature of earnings, access to information, workplace exposure to formal finance, peer interaction, and confidence in using financial products. For this reason, profession becomes an important analytical lens for understanding differences in investment habits. Prior research has shown that financial literacy and financial behaviour are shaped by socio-demographic and contextual factors rather than by individual choice alone (Agarwalla et al., 2015; Bönte and Filipiak, 2012).

This perspective is particularly important in the case of working women in India. Although women's participation in formal finance has improved, important gaps remain in financial literacy and usage. The National Centre for Financial Education reported that only 21.0 percent of women in India were financially literate, compared with 29 percent of men (NCFE, 2020–21). Similarly, the World Bank's India Findex brief showed that among adults who save, women were substantially less likely than men to use an account to store money, indicating that formal financial inclusion does not automatically translate into active financial use (Klapper et al., 2022).

Moreover, the broader investment environment in India is changing in ways that make women's investment behaviour increasingly relevant to study. According to the Association of Mutual Funds in India, women accounted for one in every four mutual fund investors as of December 2024, reflecting a visible expansion in women's participation in formal investment channels (AMFI, 2025). This suggests that the issue is no longer simply whether women participate in investing, but how they do so, how regularly they invest, how they learn about financial products, and whether different occupational settings shape these habits differently.

A profession-wise approach is therefore especially useful in an urban setting such as Indore, where working women are spread across diverse occupational categories including teaching, healthcare, IT, banking, entrepreneurship, administration, retail, law, and research. Different professions may produce different financial ecosystems. Some may offer greater exposure to formal planning and market-linked products, while others may rely more on family guidance, peer influence, or digital learning channels. In this sense, profession-wise investment habits should be viewed as a multidimensional phenomenon involving preparedness, discipline, information exposure, decision-making, and portfolio behaviour rather than merely the act of investing itself (Yeo and Fisher, 2024).

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In line with the second objective of the study, this chapter therefore seeks to identify the profession-wise investment habits of working women in Indore city of India. The chapter examines whether women belonging to different professions differ in their financial preparedness, investment discipline, information exposure, decision-making behaviour, and portfolio orientation. The analysis is intended not merely to classify occupational groups, but to understand how professional context shapes women's engagement with investing in a contemporary urban Indian setting.

REVIEW OF LITERATURE

The literature relevant to this chapter may be understood through four linked strands: financial literacy and investment behaviour, women's financial inclusion and investment participation, the role of information channels and social influence, and occupation- or profession-linked variation in financial behaviour. Together, these strands help explain why profession-wise investment habits among working women constitute a meaningful analytical question.

A substantial body of literature has established that financial literacy is closely associated with financial behaviour, including saving, planning, and investment participation. In the Indian context, Agarwalla et al. (2015) showed that financial literacy among working young adults in urban India is uneven and shaped by socio-demographic characteristics, indicating that financial behaviour is not simply a matter of income availability but also of knowledge, attitude, and behavioural capability. More broadly, literature on financial decision-making has argued that financial behaviour should be treated as a multidimensional construct involving planning, awareness, information processing, and long-term orientation rather than as a one-time act of saving or investing. This wider view is important for the present chapter because the objective is not only to see whether women invest, but to identify the profession-wise pattern of their investment habits across several behavioural dimensions (Agarwalla et al., 2015; Yeo, 2024).

A second strand of literature highlights that women's financial behaviour must be understood within a context of unequal financial literacy, access, and inclusion. Recent evidence continues to show that women in India remain disadvantaged in terms of financial literacy. According to the NCFE survey discussed by NCAER, only 21 percent of women in India were found to be financially literate, compared with a higher proportion among men, pointing to a persistent gender gap in financial capability (NCFE, 2020–21; NCAER, 2024). Similarly, the World Bank's Global Findex evidence for India indicates that even when women save, they are less likely than men to use formal accounts as vehicles for saving, showing that inclusion in principle does not always become active financial usage in practice (Klapper et al., 2022). At the same time, women's participation in formal investment channels is visibly rising. AMFI reported in 2025 that as of December 2024,

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women accounted for one in every four mutual fund investors in India, suggesting that women are increasingly entering formal investment spaces, though not necessarily with equal preparedness across groups (AMFI, 2025). For the present chapter, this literature is important because it frames working women not as financially absent, but as differently positioned within evolving financial systems.

A third relevant strand concerns the role of information access, social interaction, and digital channels in shaping investment behaviour. Bönte and Filipiak (2012), using evidence from India, showed that awareness of financial instruments and investment behaviour are positively associated with social interaction and information flows. Their work is particularly useful for this chapter because it suggests that financial awareness is not formed in isolation; it is embedded in social networks and exposure patterns. More recent research on India's digital financial transformation has similarly argued that women's financial inclusion depends not only on infrastructure but also on gendered access, social conditions, and the usability of digital channels (Duvendack et al., 2023). Arora, Garikipati, and Kaur (2026) further show that women's digital financial adoption in India is strongly shaped by peer behaviour and community norms, indicating that even in an increasingly digital economy, financial behaviour remains socially mediated. This literature directly supports the inclusion of learning sources, investing mode, and information exposure within the present chapter's analysis framework.

A fourth strand concerns women's investment behaviour more specifically, especially in relation to working status, sector, or occupation. Studies of working women in India have generally found that women's investment choices are shaped by safety, regular income, tax-saving motives, family considerations, and risk perception. Gangwani, Al Mazyad, and Shabir (2020), in a study of working women in India, examined investment behaviour across government and private sector employees and showed that income and sectoral location matter for how women invest. Kaur (2016) similarly argued that women's investment preferences differ in meaningful ways and should not be treated as a homogeneous category. However, much of this literature has remained limited either to broad sectoral comparison, specific investment avenues, or narrow city-based samples, often focusing on preference rather than on a broader behavioural structure involving awareness, discipline, decision-making, and portfolio orientation. In other words, while earlier studies have acknowledged variation, they have not consistently examined investment habits profession-wise across multiple occupational categories within a single urban context (Kaur, 2016; Gangwani et al., 2020).

Taken together, the literature suggests three important points for the present chapter. First, women's investment behaviour is influenced by more than income; it depends on awareness, information, confidence, and social context. Second, financial participation among women in India is increasing, but participation does not automatically imply

similar levels of preparedness, discipline, or sophistication across groups. Third, although prior studies have examined women's investment behaviour and, in some cases, sectoral differences, there remains space for a more fine-grained profession-wise analysis that brings together preparedness, discipline, learning channels, decision behaviour, and portfolio behaviour in one framework. This is where the present chapter contributes. By focusing on working women in Indore across ten professions, the chapter extends existing literature from broad demographic description to a more context-sensitive understanding of how occupational environment shapes investment habits in a contemporary urban Indian setting.

RESEARCH METHODOLOGY

The present study adopted a descriptive and comparative quantitative research design to examine profession-wise investment habits among working women in Indore city. A descriptive research design is appropriate for identifying patterns, characteristics and behavioural tendencies within a defined population, while a comparative approach facilitates the examination of such patterns across different subgroups (Kothari, 2004; Creswell, 2014). Primary data were collected through a structured questionnaire designed to capture demographic and occupational characteristics as well as different dimensions of investment behaviour.

The study was based on a sample of 300 working women belonging to ten professional categories, with 30 respondents represented in each category. The professional groups included school and college teachers, doctors and nurses, IT and software professionals, banking and insurance employees, entrepreneurs and self-employed women, retail and customer service workers, CA and finance professionals, HR and administrative executives, legal professionals, and research and NGO professionals. The balanced distribution across occupational categories facilitated meaningful profession-wise comparison without allowing any single occupational group to dominate the sample.

Investment habits were treated as a multidimensional construct rather than being measured through a single indicator. The variables considered included basic financial knowledge, regular investment behaviour, investment frequency, percentage of income saved and invested, investment experience, emergency fund maintenance, budgeting practices, financial goal-setting, awareness of compounding, participation in financial literacy programmes, investment tracking behaviour, diversification, intended investment horizon, investment style, usual mode of investing, sources of investment learning, and the person responsible for the final investment decision. Such a multidimensional approach is consistent with the broader understanding of financial behaviour as encompassing financial knowledge, preparedness, planning and actual financial practices (Agarwalla et al., 2015; Yeo et al., 2024).

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The collected data were initially analysed using frequencies and percentages to describe the overall investment behaviour of the respondents. Descriptive statistics provide an appropriate basis for identifying the general characteristics and behavioural patterns of a sample before undertaking subgroup comparisons (Pallant, 2020). Profession-wise differences were subsequently examined using cross-tabulation. Since most of the variables considered in the study were categorical or ordinal in nature, the chi-square test of association was applied to determine whether the distribution of responses differed significantly across professional groups. The chi-square test is suitable for examining associations between categorical variables without requiring assumptions of linearity or interval-level measurement (Agresti, 2018; Field, 2018). Statistical significance was assessed at the 5 percent level ($p < 0.05$).

For multiple-response questions, particularly those relating to the usual mode of investing and sources of investment learning, individual response options were treated as separate binary variables, with each option coded according to whether it was selected by the respondent. This enabled profession-wise comparison of individual channels such as self-directed investing, advisor-based investing, digital learning, peer-based learning and family-based learning without restricting respondents to a single response.

Thus, the analytical framework combined descriptive statistics, multiple-response analysis, cross-tabulation and chi-square testing to examine whether working women belonging to different professions differed in terms of financial preparedness, investment discipline, information exposure, decision-making behaviour and portfolio behaviour.

RESULTS DISCUSSION

This section presents the analysis and interpretation of data in relation to the second objective of the study, namely, to identify the profession-wise investment habits of working women in Indore city. In line with the methodological framework discussed earlier, the analysis has been organized in a progressive manner. It begins with the profile of respondents, then examines the overall investment habit pattern, and thereafter moves to profession-wise comparisons across financial preparedness, investment discipline, decision behaviour, portfolio behaviour, and composite behavioural scores. Such a layered presentation is useful because investment habit is not a single behavioural act; rather, it is a multidimensional construct involving knowledge, regularity, planning, agency, and portfolio orientation (Agarwalla et al., 2015; Yeo, 2024).

At the outset, the analysis presents the overall investment behaviour of the respondents by examining their usual mode of investing and the principal sources from which they learn about investments, thereby establishing the general behavioural context before proceeding to profession-wise comparisons.

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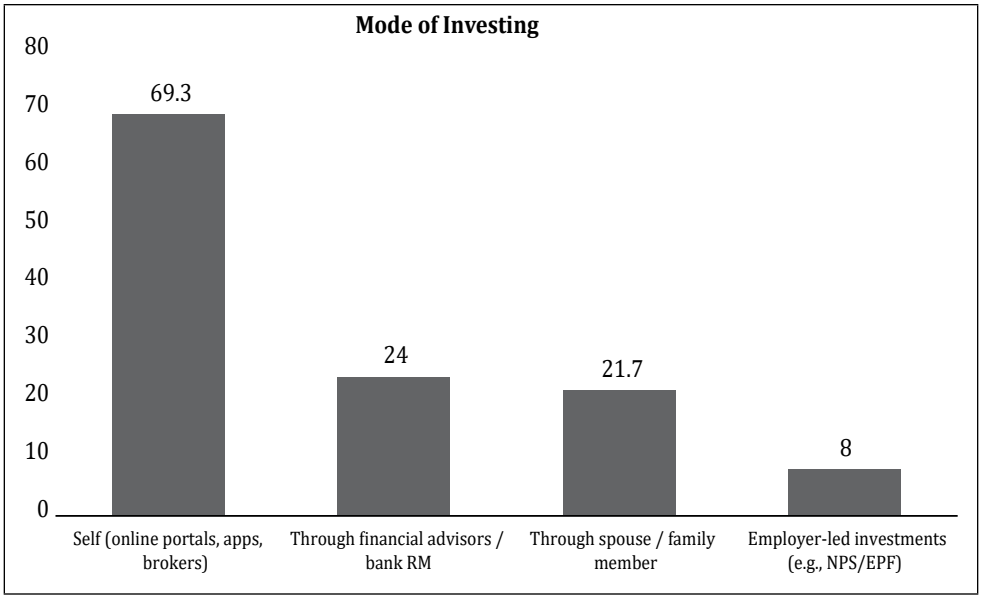


Fig. 1: Mode of Investment Used by Respondents

Source: *Authors own calculation from primary database survey*

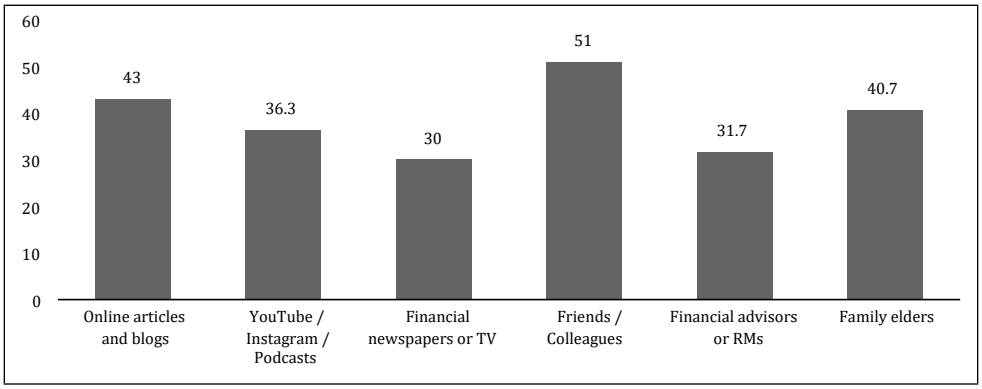


Fig. 2: Investment Sources Used by Respondents to Learn about Investments

Source: *Authors own calculation from primary database survey*

Figure 1 and Figure 2 present the multiple-response distribution for respondents' usual mode of investing and sources of investment learning. The findings indicate that self-directed investing through online portals, apps, and brokers was the most common mode, reported by 69.3 percent of respondents. A smaller but notable share relied on financial advisors or bank relationship managers (24.0%), while 21.7 percent invested through spouse or family members. Employer-led investment participation was comparatively limited (8.0%). In terms of learning sources, friends and colleagues emerged as the most

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frequently reported source (51.0%), followed by online articles and blogs (43.0%) and family elders (40.7%). Social and digital media channels such as YouTube, Instagram, and podcasts were also important, used by 36.3 percent of respondents. Overall, the findings suggest that working women in Indore are increasingly participating in self-directed investing, while their financial learning continues to be shaped by peer influence, family guidance, and digital information platforms.

The overall findings provide the behavioural backdrop of the sample; the analysis now proceeds to the profession-wise level to assess whether differences in financial preparedness are visible across occupational categories.

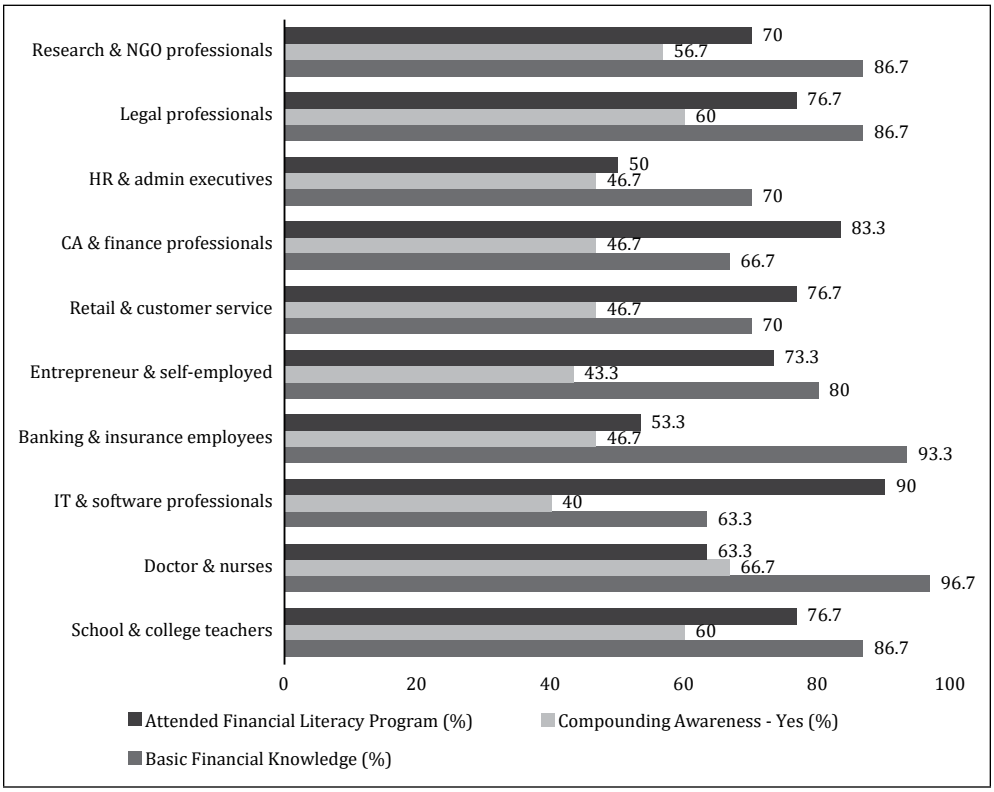


Fig. 3: Profession-wise Financial Preparedness of Respondents

Source: *Authors own calculation from primary database survey*

Chi-square results

- Basic financial knowledge by profession: $\chi^2 = 23.33$, $p = 0.005$
- Compounding awareness by profession: $\chi^2 = 16.52$, $p = 0.556$
- Financial literacy program exposure by profession: $\chi^2 = 20.93$, $p = 0.013$

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Figure 3 presents profession-wise differences in financial preparedness among working women in Indore. Significant variation was observed in terms of basic financial knowledge and participation in financial literacy programs. Doctors and nurses (96.7%) and banking and insurance employees (93.3%) reported the highest levels of basic financial knowledge, whereas IT and software professionals (63.3%) and CA and finance professionals (66.7%) reported comparatively lower levels. The association between profession and financial knowledge was found to be statistically significant (χ^2 = 23.33, p = 0.005). Similarly, participation in financial literacy programs differed significantly across professions (χ^2 = 20.93, p = 0.013), with the highest participation observed among IT and software professionals (90.0%) and CA and finance professionals (83.3%). However, no statistically significant profession-wise difference was observed in compounding awareness (χ^2 = 16.52, p = 0.556). These findings suggest that while formal financial preparedness varies across occupations, some foundational financial concepts may now be spreading more uniformly among urban working women.

In order to complete the financial preparedness dimension of the analysis, it is also necessary to examine the informational channels through which respondents acquire investment-related knowledge across professions.

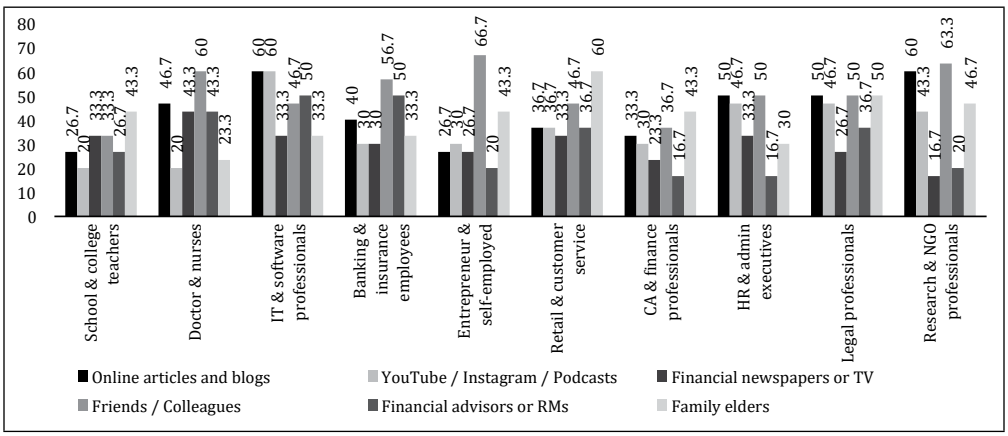


Fig. 4: Profession-wise Learning Sources of Respondents

Source: *Authors own calculation from primary database survey*

Chi-square results

- Online articles and blogs by profession: χ^2 = 16.71, p = 0.053
- YouTube/Instagram/Podcasts by profession: χ^2 = 19.15, p = 0.024
- Financial newspapers or TV by profession: χ^2 = 6.67, p = 0.672
- Friends/Colleagues by profession: χ^2 = 12.82, p = 0.171
- Financial advisors or RMs by profession: χ^2 = 22.26, p = 0.008
- Family elders by profession: χ^2 = 12.93, p = 0.166

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Figure 4 presents the profession-wise distribution of learning sources used by working women to understand investments. The findings reveal that investment learning in Indore is shaped by a combination of digital, social, expert-driven, and family-based channels. Significant profession-wise variation was observed in the use of YouTube/Instagram/ Podcasts (χ^2 = 19.151, p = 0.024) and financial advisors or relationship managers (χ^2 = 22.259, p = 0.008). Digital platforms were most widely used by IT and software professionals (60.0%), followed by HR and admin executives and legal professionals (46.7% each). Similarly, reliance on financial advisors or RMs was highest among IT and software professionals and banking and insurance employees (50.0% each), whereas CA and finance professionals and HR/admin executives reported lower reliance on such sources. Although differences in online articles/blogs, financial newspapers/TV, friends/ colleagues, and family elders were not statistically significant, the descriptive pattern shows that friends and colleagues remained the most common source overall (51.0%), while family elders continued to play an important role in selected professions. These findings suggest that profession influences not only financial preparedness but also the informational ecosystem through which women learn about investing.

Having examined profession-wise differences in financial preparedness and investment learning sources, the analysis now moves to the next behavioural dimension, namely investment discipline, in order to assess whether women across professions differ in the regularity, clarity, and budgeting of their investment practices.

Figure5 presents profession-wise differences in investment discipline among working women in Indore. Significant variation was observed in regular investment behaviour, emergency fund maintenance, and the presence of clear financial goals. Regular investment differed significantly across professions (χ^2 = 31.477, p < 0.001), with teachers reporting the highest consistency (97%), followed by doctors and nurses, banking and insurance employees, entrepreneurs/self-employed, and research/NGO professionals (96.7% each). Emergency fund maintenance also varied significantly (χ^2 = 28.972, p = 0.049), with doctors and nurses reporting the highest preparedness (76.7%). Clear financial goals showed a statistically significant association with profession (χ^2 = 40.358, p = 0.002), with banking and insurance employees and legal professionals displaying comparatively stronger planning orientation. Although monthly investing, tracking, and budgeting did not show statistically significant differences, the descriptive pattern still suggests meaningful profession-wise variation in financial discipline. Overall, the findings indicate that profession influences not only whether women invest, but also how systematically and purposefully they do so.

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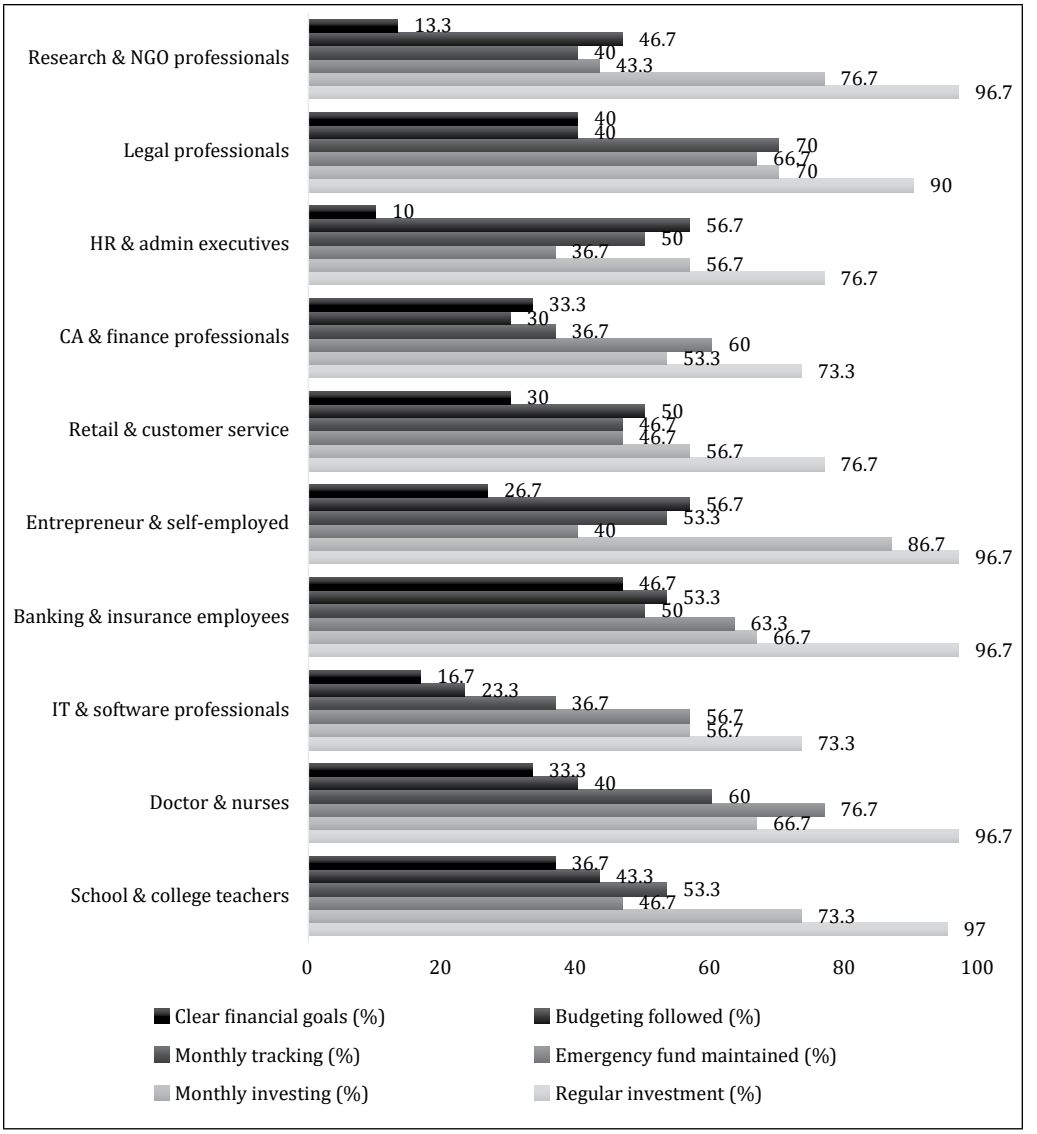


Fig. 5: Profession-wise Investment Discipline of Respondents

Source: *Authors own calculation from primary database survey*

Chi-square results

- Regular investment by profession: $\chi^2 = 31.477$, $p < 0.001$
- Monthly investing by profession: $\chi^2 = 37.517$, $p = 0.086$
- Emergency fund by profession: $\chi^2 = 28.972$, $p = 0.049$

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- Monthly tracking by profession: $\chi^2 = 19.368$, p = 0.370
- Budgeting by profession: $\chi^2 = 13.474$, p = 0.142
- Clear financial goals by profession: $\chi^2 = 40.358$, p = 0.002

While Figure6 examined profession-wise differences in the behavioural dimensions of investment discipline, Figure 7 extends this analysis by focusing more specifically on saving and investment intensity, that is, the extent to which women across professions convert their income into savings and formal investment.

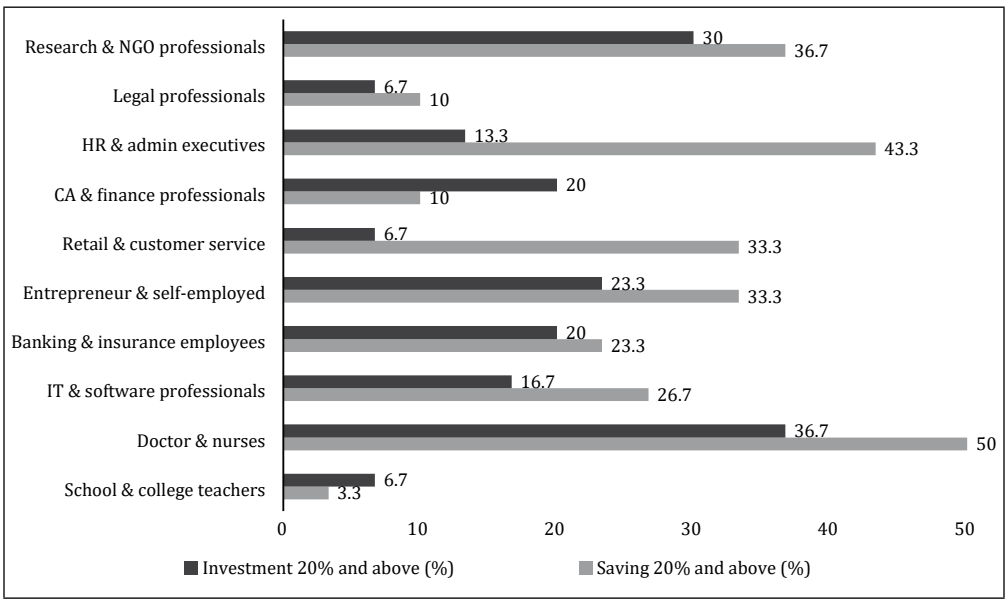


Fig. 6: Profession-wise Saving and Investment Intensity of Respondents

Note: *For interpretation, "saving intensity" includes respondents saving* ***20 percent or more*** *of income, and "investment intensity" includes respondents investing* ***20 percent or more*** *of income.*

Source: *Authors own calculation from primary database survey*

Chi-square results

- Saving intensity by profession: $\chi^2 = 63.366$, p = 0.003
- Investment intensity by profession: $\chi^2 = 50.969$, p = 0.050

The results suggest that profession influences not only whether women invest regularly, but also how strongly they are able or willing to convert income into saving and investing. Saving intensity shows a statistically significant profession-wise association. Doctors and nurses reported the highest high-saving behaviour, with 50.0 percent saving 20 percent or more of their income, followed by HR and admin executives (43.3%), research and NGO professionals (36.7%), entrepreneurs/self-employed women (33.3%), and

retail/customer service respondents (33.3%). In contrast, teachers (3.3%), legal professionals (10.0%), and CA/finance professionals (10.0%) reported much lower high-saving intensity. Investment intensity shows a weaker but still borderline significant profession-wise pattern. Doctors and nurses again stand out, with 36.7 percent investing 20 percent or more of income, followed by research and NGO professionals (30.0%), entrepreneurs/self-employed women (23.3%), and banking and insurance employees and CA/finance professionals (20.0% each). Lower investment intensity is visible among teachers, retail/customer service respondents, and legal professionals.

A noteworthy pattern here is that some professions appear stronger in saving than in investing. For example, HR and admin executives show relatively high saving intensity but much lower investment intensity, suggesting cautious financial behaviour or delayed investment conversion. Similarly, retail and customer service respondents report moderate saving intensity but low investment intensity, which may reflect income insecurity, liquidity preference, or limited confidence in converting savings into market-linked or formal investment avenues.

While the preceding analysis focused on how systematically women save and invest, the next stage examines the operational aspect of investment behaviour by analysing the usual investing mode followed across professional groups.

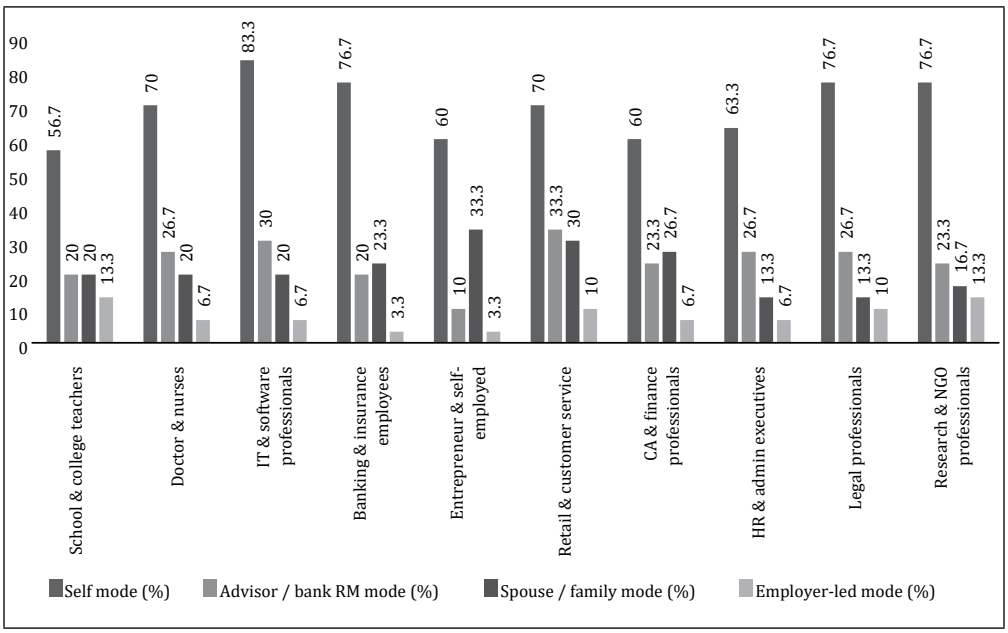


Fig. 7: Profession-wise Usual Investing Mode of Respondents (Multiple Response Analysis)

Source: *Authors own calculation from primary database survey*

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Chi-square results

- Self mode by profession: $\chi^2 = 10.284$, $p = 0.328$
- Advisor / bank RM mode by profession: $\chi^2 = 6.140$, $p = 0.726$
- Spouse / family mode by profession: $\chi^2 = 7.169$, $p = 0.620$
- Employer-led mode by profession: $\chi^2 = 4.710$, $p = 0.859$

The descriptive pattern shows that self-directed investing is the dominant mode across almost all professional groups in Indore. It is highest among IT and software professionals (83.3%), followed by banking and insurance employees, legal professionals, and research/ NGO professionals (76.7% each). This suggests that digital self-execution has become a mainstream investing mode among working women, cutting across professions rather than remaining limited to finance-facing occupations.

Advisor-led investing remains secondary but still relevant, especially among retail and customer service respondents (33.3%), IT and software professionals (30.0%), and doctors/nurses, HR/admin executives, and legal professionals (26.7% each). Spouse/ family-mediated investing is relatively more visible among entrepreneurs/self-employed women (33.3%) and retail/customer service respondents (30.0%), suggesting that some professions may still operate within more socially mediated decision environments.

However, none of these profession-wise differences are statistically significant. This means that while descriptive variation exists, the broad mode of investing does not differ strongly enough across occupations to conclude that profession is a decisive driver of investing mode in this sample. In other words, Indore appears to be witnessing a city-wide shift toward self-directed investing among working women, regardless of profession.

While Figure 8 explains the usual mode through which respondents execute their investments, the next figure examines who ultimately takes the final investment decision across professional groups, thereby adding the dimension of financial authority to the analysis.

Across professions, self-driven decision-making is clearly the dominant pattern. In every occupational group, the largest share of respondents reported taking final investment decisions themselves. The highest levels of self-decision-making were seen among research and NGO professionals (83.3%) and legal professionals (76.7%), while teachers and HR/admin executives showed relatively lower but still dominant self-decision rates (63.3% each).

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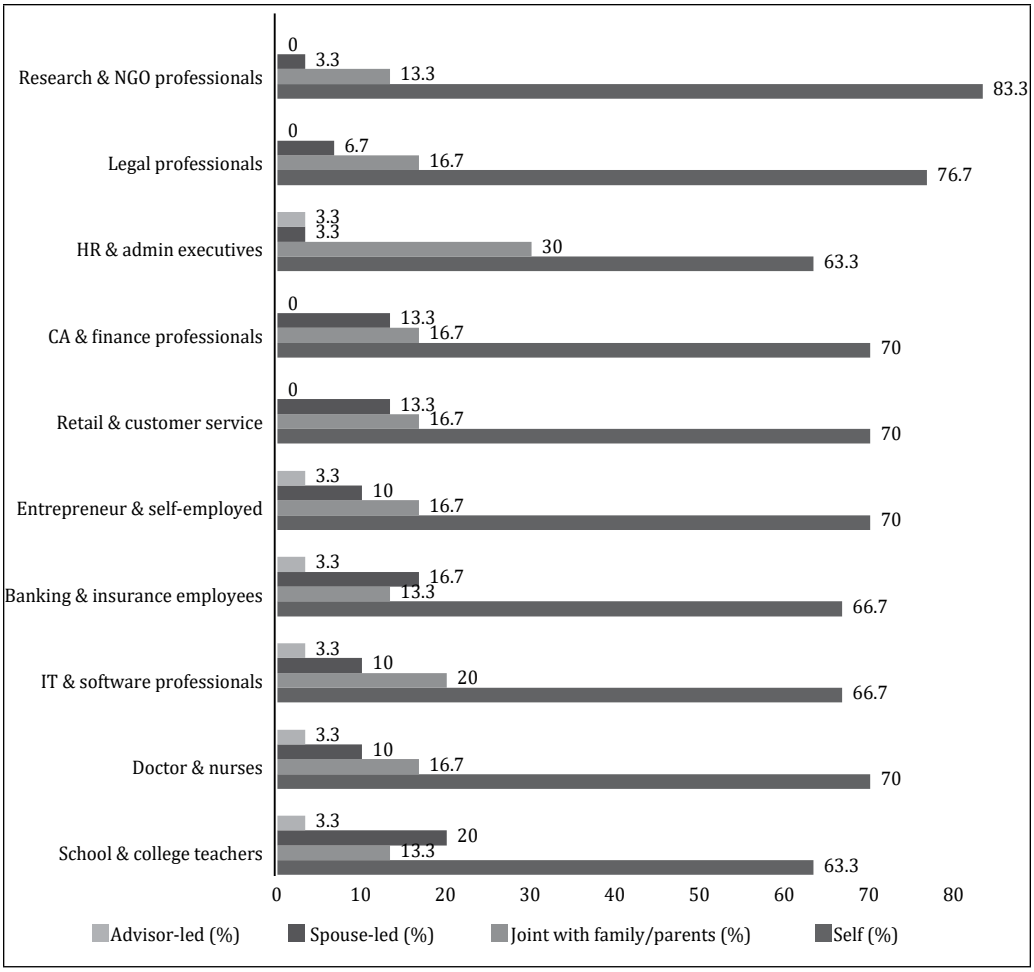


Fig. 8: Profession-wise Final Investment Decision Maker of Respondents

Source: *Authors own calculation from primary database survey*

Chi-square result

- Final investment decision maker by profession: $\chi^2 = 16.573$, $p = 0.941$

Joint decision-making with family or parents remains a meaningful secondary pattern, particularly among HR and admin executives (30.0%) and IT professionals (20.0%). Spouse-led decision-making is comparatively more visible among school and college teachers (20.0%) and banking and insurance employees (16.7%), while it becomes quite limited among legal and research/NGO professionals. Advisor-led final decision-making is minimal across the sample and does not appear to be a defining profession-specific route for women's final investment choice.

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Statistically, the association between profession and final decision maker is not significant. This suggests that while descriptive differences exist, the broader pattern of investment decision-making among working women in Indore is remarkably similar across professions: most women report making their own final decisions, with limited dependence on spouse or advisors.

Having examined how women across professions execute investments and who takes the final investment decisions, the analysis now proceeds to portfolio behaviour in order to understand whether professional groups also differ in diversification, time horizon, investment style, and investing experience.

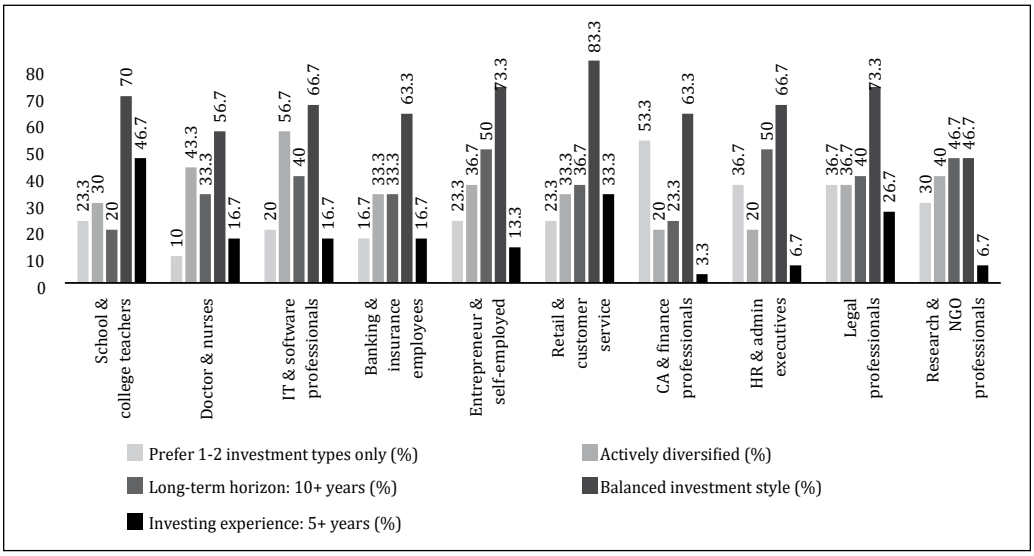


Fig. 9: Profession-wise Portfolio Behaviour of Respondents

Source: *Authors own calculation from primary database survey*

Chi-square results from full crosstab distributions

- Diversification by profession: $\chi^2 = 31.162$, p = 0.028
- Investment horizon by profession: $\chi^2 = 47.220$, p = 0.100
- Investment style by profession: $\chi^2 = 20.036$, p = 0.331
- Investment experience by profession: $\chi^2 = 54.872$, p = 0.023

The profession-wise portfolio behaviour pattern suggests that diversification and investing experience differ meaningfully across occupational groups, while investment horizon and self-described investment style are more broadly shared.

Diversification shows a statistically significant association with profession. IT and software professionals reported the highest active diversification (56.7%), followed by doctors and

nurses (43.3%) and research/NGO professionals (40.0%). In contrast, CA and finance professionals were the most concentrated group, with 53.3 percent preferring only one or two investment types, followed by HR/admin executives and legal professionals (36.7% each). This is a useful and slightly counter-intuitive finding: financial profession does not automatically translate into broader diversification behaviour.

Investment horizon does not differ significantly by profession, but the descriptive pattern remains informative. Entrepreneur/self-employed women and HR/admin executives show the strongest long-term orientation, with 50.0 percent reporting a 10+ year horizon, followed by research/NGO professionals (46.7%) and legal professionals (40.0%). Teachers show the weakest long-term horizon (20.0%), which may reflect more cautious or shorter-cycle planning.

Investment style also does not differ significantly by profession. A balanced style dominates across almost all groups, especially among retail/customer service respondents (83.3%) and entrepreneurs/self-employed and legal professionals (73.3% each). This suggests that moderation, rather than extreme conservatism or aggression, is the prevailing self-image of women investors in Indore.

Investment experience, however, differs significantly across professions. Teachers show the highest share of respondents with 5 or more years of investment experience (46.7%), followed by retail/customer service respondents (33.3%) and legal professionals (26.7%). By contrast, CA and finance professionals (3.3%), HR/admin executives (6.7%), and research/NGO professionals (6.7%) show relatively lower portfolio maturity. This indicates that profession shapes not just current investing behaviour but also how long women have remained engaged in investing over time. Overall, the findings suggest that profession influences the maturity and diversification of portfolio behaviour more strongly than it influences the broad style or time horizon of investing.

CONCLUSION

The findings of the study indicate that working women in Indore actively participate in investment-related activities and demonstrate considerable financial agency. Self-directed investment through online portals, applications and brokers emerged as the most commonly used mode of investing, while the majority of respondents across professional groups reported taking their final investment decisions independently. At the same time, investment-related knowledge was acquired through a diverse combination of friends and colleagues, family members, online articles, digital media platforms and financial professionals. These findings indicate that investment among urban working women is increasingly characterised by independent participation, although the informational environments supporting such participation differ across occupational groups. This broader pattern is consistent with earlier research highlighting the importance of

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financial literacy, information flows and social interaction in shaping financial behaviour (Agarwalla et al., 2015; Bönte & Filipiak, 2012).

Profession-wise analysis, however, demonstrates that occupation is associated with selected dimensions of investment behaviour rather than with investment behaviour uniformly. Statistically significant differences were observed in basic financial knowledge, participation in financial literacy programmes, use of digital learning platforms, reliance on financial advisors or relationship managers, regular investment behaviour, emergency fund maintenance, financial goal-setting, saving intensity, diversification and investment experience. In contrast, compounding awareness, monthly investing, investment tracking, budgeting practices, usual mode of investing, final investment decision-making, investment horizon and investment style did not exhibit statistically significant differences across professions. Portfolio behaviour further showed significant occupational differences in diversification and investment experience, whereas investment horizon and investment style remained comparatively similar across groups. Overall, the findings suggest that profession is associated less with whether working women participate in investing and more with certain aspects of their financial preparedness, information exposure, investment discipline, saving behaviour and portfolio experience. The findings therefore underline the relevance of recognising occupational context when designing financial literacy and investor-education initiatives for working women rather than treating them as a homogeneous investor category.

REFERENCES

Agarwalla, S. K., Barua, S. K., Jacob, J., & Varma, J. R. (2015). Financial literacy among working young in urban India. *World Development, 67*, 101–109. https://doi.org/10.1016/j.worlddev.2014.10.004

Agresti, A. (2018). *An introduction to categorical data analysis* (3rd ed.). Wiley.

Association of Mutual Funds in India, & CRISIL Intelligence. (2025). *From savings to wealth creation: Women taking charge of investments*. Association of Mutual Funds in India.

Bönte, W., & Filipiak, U. (2012). Financial literacy, information flows, and caste affiliation: Empirical evidence from India. *Journal of Banking & Finance, 36*(12), 3399–3414.

Choudhary, H., & Jain, H. (2023). Addressing financial exclusion through financial literacy training programs: A systematic literature review. *Empirical Research in Vocational Education and Training, 15*, Article 8. https://doi.org/10.1186/s40461-023-00147-9

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE.

Duvendack, M., Sonne, L., & Garikipati, S. (2023). Gender inclusivity of India's digital financial revolution for attainment of SDGs: Macro achievements and the micro experiences of targeted initiatives. *The European Journal of Development Research, 35*(6), 1369–1391. https://doi.org/10.1057/s41287-023-00585-x

Field, A. P. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). SAGE.

Gangwani, S., Al Mazyad, H. A., & Shabir, S. (2020). Investment behaviour of working women in India. *Academy of Accounting and Financial Studies Journal, 24*(3).

Kaur, M., & Vohra, T. (2016). Investment preferences of women: A comparative study of women stock and non-stock investors. *Management Dynamics, 16*(1), 50–59. https://doi.org/10.57198/2583-4932.1074

Klapper, L., Singer, D., & Ansar, S. (2022). *Global Findex 2021—India country brief*. World Bank.

Kothari, C. R. (2004). *Research methodology: Methods and techniques* (2nd rev. ed.). New Age International.

Mohapatra, C. S., & Ghosh, D. (2024, November 12). Women's financial literacy: What India can learn from Australia, Rwanda, Japan. *NCAER*.

National Centre for Financial Education. (2021). *Annual report 2020–21*. NCFE.

Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS* (7th ed.). McGraw-Hill Education/Open University Press.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (8th ed.). Pearson.

Siegel, S., & Castellan, N. J. (1988). *Nonparametric statistics for the behavioral sciences* (2nd ed.). McGraw-Hill.

Yeo, K. H. K., Lim, W. M., & Yii, K.-J. (2024). Financial planning behaviour: A systematic literature review and new theory development. *Journal of Financial Services Marketing, 29*, 979–1001. https://doi.org/10.1057/s41264-023-00249-1

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Chapter

21 Empowerment in Transition: Examining Gender Equality and Youth Leadership in India's Green Shift

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ABSTRACT

India's transition toward a green, low-carbon economy — anchored in national programmes such as the National Solar Mission, the SNational Green Hydrogen Mission, and the Green Skill Development Programme (GSDP) — depends on a generation of young leaders equipped with sustainability literacy, self-efficacy, and institutional backing. This paper treats gender equality not as a peripheral demographic variable but as a foundational enabler of youth leadership in the green transition. Using a self-constructed, five-section Likert questionnaire (Cronbach's α = .80–.96) administered to undergraduate and postgraduate teacher-education students across seven Indian states (Haryana, Punjab, Himachal Pradesh, Uttar Pradesh, Rajasthan, Uttarakhand and the National Capital Territory of Delhi), the study analyses valid responses from 294 youths (158 women, 136 men) after data screening removed duplicate and straight-lined entries from an initial pool of 296 submissions. Descriptive statistics, independent-samples t-tests, Pearson correlations, and binary logistic regression were used to test five hypotheses. Results show no statistically significant gender gap in green awareness, perceived leadership opportunity, green-leadership self-efficacy, or institutional support (all $p > .05$), indicating that young women and young men perceive comparably open, competence-building environments on campus. However, young women reported significantly greater social and family barriers to public leadership than young men ($t(420) = -2.36$, $p = .022$, $d = 0.45$) — the clearest gender-differentiated finding in the study. Self-efficacy for green leadership was the strongest and only statistically significant predictor of youths' willingness to take up a green leadership role (OR = 2.90, 95% CI [1.51, 5.56], $p = .001$), ahead of institutional support (marginal, OR = 1.59, $p = .078$) and gender itself (n.s.). Nearly three-quarters (73.6%) of respondents expressed willingness to lead a green initiative if given the opportunity, yet only about a quarter had ever held a leadership position (26.4%) or currently participate in an eco-club or sustainability society (27.9%), revealing a wide awareness–action and willingness–opportunity gap. The findings support a 'paradox of parity': equality in psychological readiness coexists with inequality in the social conditions that convert readiness into practice — a pattern most pronounced for young women. The

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paper concludes with recommendations for gender-responsive green-skill curricula, structured mentorship, and family-inclusive sensitisation to convert widespread willingness into an equitable, youth-led green leadership pipeline in India.

Keywords: Gender Equality, Youth Empowerment, Youth Leadership, Green Transition, Sustainability Literacy, Self-Efficacy, India.

INTRODUCTION

The world, and India within it, stands at an inflexion point in its development trajectory. The old assumption that economic growth must proceed at the cost of environmental integrity is giving way to a paradigm in which climate resilience, clean energy, and inclusive prosperity are treated as complementary, not competing, goals. India's National Solar Mission and National Green Hydrogen Mission exemplify this shift at the policy level, mobilising investment in renewable technologies and positioning the country as a significant actor in the global green economy. Yet policy instruments and technological missions can only be as effective as the human capital that operationalises them. A youth generation that is aware, skilled, confident, and structurally supported is indispensable to translating green policy into green practice — and it is this same generation that will inherit the consequences of the choices made today.

Higher education institutions occupy a pivotal position in this transition. As the last formal setting before entry into the labour market or civic life, colleges and universities carry an obligation to cultivate green skills, sustainability literacy, and — critically — leadership capacity among students, so that green awareness translates into green action rather than remaining an abstract concern. Within this obligation lies a further, often under-examined, dimension: gender. If the green transition is to be genuinely inclusive, young women and young men must have equal access to the opportunities, mentorship, and institutional recognition that convert awareness into leadership. Treating gender equality as a peripheral demographic control variable — rather than as a foundational enabler of youth empowerment — risks reproducing familiar patterns of exclusion within a supposedly 'new' green economy.

This paper reports an empirical investigation into how gender equality, sustainability literacy, self-efficacy, and institutional support interact to shape green leadership readiness among undergraduate youth in India. Rather than presuming that a gender gap exists, the study empirically tests for gender differences across each construct, while also examining the constructs' joint contribution to youths' willingness to undertake green leadership roles. In doing so, the paper responds directly to the research problem framed in the project's guiding abstract: whether young men and young women perceive the green transition as an equally open space for leadership and action, and what factors — psychological, institutional, or social — most strongly predict the translation of awareness into willingness to lead.

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The remainder of the paper is organised as follows. Section 2 reviews the theoretical and empirical literature underpinning the study's five constructs. Section 3 states the objectives and hypotheses. Section 4 details the methodology, including instrument development, sampling, data screening, and the analytic plan. Section 5 presents the results, organised around each hypothesis and supported by tables and figures. Section 6 discusses the findings in relation to the literature and the paper's 'paradox of parity' thesis. Sections 7–9 present implications, limitations, and concluding remarks.

REVIEW OF LITERATURE AND THEORETICAL FRAMEWORK

India's Green Transition and the Green-Skills Imperative

India's green transition is being pursued through a combination of large-scale renewable-energy missions and dedicated skilling infrastructure. The Green Skill Development Programme (GSDP), coordinated through the Environmental Information System (ENVIS) network under the Ministry of Environment, Forest and Climate Change and implemented via institutions such as the National Botanical Research Institute, is intended to build a pipeline of youth trained in biodiversity conservation, renewable energy, and sustainable resource management (Wildlife Institute of India – ENVIS Centre, n.d.; National Botanical Research Institute, n.d.). Industry analyses, however, continue to flag a widening 'green talent gap' between the pace of green-sector job creation and the supply of adequately skilled entrants, particularly outside metropolitan hubs (Taggd, 2026). This gap underlines the urgency of examining how prepared India's higher-education-going youth actually feel to step into green-sector and green-leadership roles, and whether that preparedness is evenly distributed.

Sustainability Literacy and Green Awareness among Indian Students

Environmental education has been a compulsory curricular component in Indian schools since 2003, yet empirical assessments of student-level environmental literacy suggest that awareness of climate change coexists unevenly with a working understanding of policy terms, green jobs, or actionable pathways. In one of the more recent large-sample studies of Indian schoolchildren, Goel et al. (2023) found that students in urban India were broadly aware of climate change as a threat but showed considerable variation in their understanding of the concrete, individual-level actions that translate concern into behaviour. This distinction between affective concern ("I am worried about climate change") and cognitive-instrumental literacy ("I know what a green job is and how to pursue one") is directly reflected in the present study's Green Awareness construct, which deliberately combines both dimensions.

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Gender, Leadership, and the STEM–Green Pipeline

A substantial literature documents persistent gender disparities in Science, Technology, Engineering and Mathematics (STEM) education and labour-market outcomes in India, which feed directly into the green-skills pipeline given the STEM-adjacent nature of much green-sector work. Sahoo and Klasen (examining education choices and the gender gap in Indian labour-market outcomes) show that women's under-representation in STEM fields is closely tied to constrained labour-market returns rather than to differences in ability or aspiration alone. Complementary work by Sindhu et al. (2025) documents the scale of gender disparity in STEM enrolment and participation across Indian higher education, arguing that structural and social barriers — rather than differences in interest — account for the gap. Together, this literature suggests that any gender gap observed in the green-leadership space is unlikely to originate from differences in raw awareness or ability, and more likely to be traceable to differential access, encouragement, and social permission — a hypothesis the present study tests directly by decomposing 'leadership readiness' into awareness, opportunity, self-efficacy, institutional support, and social/ family barriers as distinct, separately measurable constructs.

At the level of leadership perception more broadly, Eagly and Karau's (2002) role congruity theory of prejudice toward female leaders remains foundational. The theory holds that incongruity between the communal traits stereotypically ascribed to women and the agentic traits stereotypically ascribed to leaders produces two forms of prejudice: perceiving women less favourably as potential leaders, and evaluating actual female leadership behaviour more harshly than equivalent male behaviour. Applied to the green-leadership context, role congruity theory predicts that young women may report leadership opportunities and institutional encouragement that are formally equal to men's, while still facing subtler, harder-to-measure headwinds once they attempt to exercise that leadership publicly — a pattern this paper's Social and Family Barriers construct is designed to capture.

Self-Efficacy and Psychological Empowerment

Bandura's social cognitive theory positions self-efficacy — an individual's belief in their capability to organise and execute the courses of action required to produce a given outcome — as the central mechanism through which knowledge and opportunity are converted into action (Bandura, 2001). Individuals with high self-efficacy for a domain persist longer in the face of setbacks, set more ambitious goals, and are more likely to initiate action in that domain even when environmental support is imperfect. This theoretical claim motivates the inclusion of a dedicated Self-Efficacy for Green Leadership construct in the present instrument, and predicts — consistent with the logistic-regression results reported in Section 5 — that self-efficacy should be among the strongest individual-level predictors of youths' willingness to take up a green leadership role, independent of gender.

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Zimmerman's (1995) framework of psychological empowerment complements this self-efficacy lens by distinguishing empowerment processes (participatory experiences through which people gain skills and confidence) from empowerment outcomes (the functional consequences of those processes, including a sense of control and the capacity to influence one's environment). Zimmerman's insistence that empowerment is context- and population-specific — rather than a single universal trait — informs this study's decision to build a composite Empowerment in Transition Index (EMP) from five domain-specific sub-scales (green awareness, leadership opportunity, self-efficacy, institutional support, and family/social enablement) rather than relying on a single generic empowerment scale.

Institutional Support and the Family/Social Environment

Institutional climate — encompassing mentorship availability, faculty encouragement, resource allocation, and explicit gender-inclusive policy — has been repeatedly identified as a moderator between individual readiness and actual leadership uptake. UN Women's (2025) global review of youth climate action similarly emphasises that young women's leadership in climate and sustainability spaces is frequently constrained less by lack of interest or capability than by structural exclusion from decision-making platforms and by social expectations that discourage public-facing roles. This is consistent with the present study's decision to separate 'perceived opportunity' (an institutional-structural variable) from 'social and family barriers' (a household- and community-level variable), since the two operate through different mechanisms and — as the results in Section 5 show — behave differently with respect to gender.

Policy Context: NEP 2020 and Environmental Education

India's National Education Policy (NEP) 2020 explicitly foregrounds environmental consciousness and sustainability as cross-cutting curricular themes, and calls for higher-education institutions to embed experiential, skills-oriented environmental education rather than treating it as a stand-alone subject (Baskar, n.d.). This policy architecture provides the institutional backdrop against which the present study's Institutional Support construct should be interpreted: colleges are formally mandated to support green-oriented, gender-inclusive student activity, making any observed shortfall between mandate and lived student experience directly policy-relevant.

Synthesis and Research Gap

Taken together, the reviewed literature converges on three propositions that motivate the present study. First, environmental awareness among Indian youth is generally rising but remains unevenly translated into actionable green-skills literacy (Goel et al., 2023). Second, gender gaps in STEM- and green-adjacent domains in India are more plausibly

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attributable to structural and social barriers than to underlying differences in awareness or aptitude (Sahoo & Klasen; Sindhu et al., 2025; Eagly & Karau, 2002). Third, self-efficacy and institutional support are theorised to be the proximal psychological and structural levers that convert awareness into leadership action (Bandura, 2001; Zimmerman, 1995; UN Women, 2025). What remains under-examined — and what this paper addresses — is how these constructs behave jointly and gender-comparatively within a single Indian undergraduate sample, and specifically whether the gender gap, if any, resides in psychological readiness (awareness, self-efficacy), in institutional opportunity, or in the social and family environment that surrounds the individual student.

OBJECTIVES AND HYPOTHESES

Research Objectives

- **Objective 1:** To assess the level of green awareness and climate concern among undergraduate youth across genders.
- **Objective 2:** To examine the gender differences in perceived leadership opportunities, green leadership self-efficacy, and institutional support among undergraduate youths.
- **Objective 3:** To examine the relationship among perceived gender equality, leadership opportunities, green leadership self-efficacy, institutional support, and social and family barriers among undergraduate youths.
- **Objective 4:** To examine the contribution of perceived gender equality, leadership opportunities, green leadership self-efficacy, institutional support, and social and family barriers to undergraduate youths' willingness to undertake green leadership roles.

Hypotheses

All hypotheses are stated in the null form (H0) and were tested at the conventional $\alpha = .05$ significance level.

- **H01:** There is no significant gender difference in the level of green awareness and climate concern among undergraduate youth.
- **H02:** There is no significant gender difference in perceived leadership opportunities among undergraduate youth.
- **H03:** There is no significant gender difference in green leadership self-efficacy among undergraduate youth.
- **H04:** There is no significant gender difference in perceived institutional support for gender-inclusive participation in sustainability activities among undergraduate youth.

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- **H05:** Green awareness, perceived leadership opportunities, green leadership self-efficacy, institutional support, social and family barriers, and gender do not significantly contribute to youths' willingness to undertake green leadership roles.

METHODOLOGY

Research Design

The study followed a quantitative, cross-sectional, correlational design, appropriate for testing group differences (gender) and the joint predictive contribution of several constructs to a behavioural-intention outcome. The design does not permit causal inference; associations reported in Section 5 should be interpreted as concurrent relationships within a single point-in-time sample.

Sample and Sampling Procedure

Data were collected using a self-administered, self-constructed online questionnaire (Google Forms) distributed to undergraduate students of Arts/Humanities and Commerce programmes — at institutions across seven Indian states/union territories purposively targeted for geographic spread: Haryana, Punjab, Himachal Pradesh, Uttar Pradesh, Rajasthan, Uttarakhand, J&K. A convenience/snowball sampling strategy was used, with the questionnaire link circulated through institutional and peer networks between early and late August 2026. The originally targeted sample was 420 students; the achieved sample after data collection closed was 296 submissions, of which 294 were retained for analysis after the data-screening procedure described below (Table 1).

Table 1: Data Screening and Sample Retention

Screening Step	Records Removed	Remaining N
Raw questionnaire submissions received	—	296
Exact duplicate submissions (identical demographic and item-response pattern, likely accidental re-submission)	-	296
Straight-lined responses (identical response, e.g., all '3', across all 34 Likert items — indicative of non-attentive responding)	2	294
Final analytic sample	—	294

The final analytic sample (N = 294) comprised 158 women (53.74%) and 136 men (46.25%), reflecting the female-majority composition typical of teacher-education programmes in the sampled institutions rather than a sampling artefact; this composition is treated as a limitation and discussed in Section 8. Respondents' mean age was 22.1 years (SD = 3.29; range 17–25). Table 2 presents the full demographic profile of the achieved sample.

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Table 2: Demographic Profile of the Analytic Sample (N = 294)

Variable	Category	n	%
Gender	Female	158	53.74
	Male	136	46.25
Age (years)	M = 22.14, SD = 3.29, range 17–25	294	100.0
Year of Study	1st Year	113	38.43
	2nd Year	90	30.61
	3rd Year	91	30.95

Instrumentation

Data were collected using a researcher-developed questionnaire, "Empowerment in Transition: Examining Gender Equality and Youth Leadership in India's Green Shift," comprising three parts. Part I (8 items) captured demographic information. Part II (34 five-point Likert items, 1 = Strongly Disagree to 5 = Strongly Agree) was organised into five conceptual sections: (A) Green Awareness (7 items), (B) Perceived Leadership Opportunity (7 items), (C) Self-Efficacy for Green Leadership (8 items), (D) Institutional Support (6 items), and (E) Social and Family Barriers (6 items, comprising one family-support item and five barrier items). Part III (6 items) used dichotomous Yes/No response format to capture behavioural participation and awareness indicators. The full item pool and section-to-objective alignment map are reproduced in the Appendix.

Scale reliability was assessed using Cronbach's alpha computed on the achieved sample (N = 294). As shown in Table 3, internal consistency was good to excellent for every section, and excellent for the combined 28-item positively-worded core (α = .96), supporting the use of section-mean composite scores in subsequent analysis.

Table 3: Internal Consistency Reliability of Questionnaire Sections

Section / Construct	No. of Items	Cronbach's α	Interpretation
A — Green Awareness	7	.87	Good
B — Perceived Leadership Opportunity	7	.89	Good
C — Self-Efficacy for Green Leadership	8	.92	Excellent
D — Institutional Support	6	.90	Excellent
E — Social & Family Barriers (5 barrier items)	5	.80	Good
Sections A–D combined (core positive scale)	28	.96	Excellent

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Scoring and Composite Index

Each Likert section was scored as the mean of its constituent items (range 1–5). Section E combined one positively-worded family-support item with five barrier-worded items (e.g., "social expectations make it difficult…", "I have been discouraged…"); for the purpose of computing the composite Empowerment in Transition Index (EMP) and for the regression analysis in Section 5.6, the five barrier items were reverse-scored (6 − item) and averaged together with the support item to yield a single Family & Social Enablement score, on which a higher value indicates a more enabling (fewer-barrier) environment. This reverse-scoring is a deliberate methodological choice made to align the direction of Section E with Sections A–D for composite scoring; the raw (non-reversed) Social & Family Barriers score is also reported separately in Section 5 wherever the barrier framing is more directly interpretable. The EMP Index was computed as the unweighted mean of the four positively-worded section scores (A–D) and the reverse-scored Family & Social Enablement score.

Data Collection and Ethical Considerations

Participation was voluntary and anonymous; the questionnaire's cover section informed respondents of the study's purpose, expected completion time (20–25 minutes), and the voluntary, anonymous nature of participation, consistent with standard informed-consent practice for low-risk survey research. Name was an optional field; no personally identifying information was required, and no incentive was offered for participation.

Statistical Analysis

Data were analysed in Python (pandas, SciPy, statsmodels). Descriptive statistics (means, standard deviations, frequencies) characterised the sample and each construct. Independent-samples Welch's t-tests (which do not assume equal variances between groups, appropriate given the unequal Female/Male group sizes) tested gender differences for Hypotheses H01–H04, with Cohen's d reported as a standardised effect-size measure. Pearson product-moment correlations examined the interrelationship among the five constructs (Objective 3). Chi-square tests of independence examined gender differences in the six dichotomous behavioural/awareness items. Binary logistic regression, with "willingness to take up a green leadership role" (Part III, Item 3; Yes = 1, No = 0) as the dependent variable and the five construct scores plus a gender dummy (Female = 1) as predictors, tested the joint and individual contribution of the constructs to leadership willingness (Objective 4, H05); odds ratios (OR) with 95% confidence intervals and McFadden's pseudo-R^2 are reported.

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RESULTS

A. Overview of Construct-Level Scores

Table 4 presents descriptive statistics for the five section-level constructs and the composite EMP Index across the full sample (N = 294). On the 1–5 response scale, mean scores for Green Awareness (M = 3.76), Institutional Support (M = 3.67), Self-Efficacy (M = 3.66), and Leadership Opportunity (M = 3.52) all fell in the 'agree' range, indicating a generally positive climate. The Family & Social Enablement score (M = 3.00, i.e., the scale midpoint) was noticeably lower, indicating that, on average, respondents perceived social and family constraints as a meaningfully present — not negligible — factor in their leadership readiness.

Table 4: Descriptive Statistics for Study Constructs (N = 294)

Construct	Mean	SD	95% CI of Mean
Green Awareness (A)	3.76	0.89	[3.64, 3.88]
Leadership Opportunity (B)	3.52	0.90	[3.40, 3.64]
Self-Efficacy for Green Leadership (C)	3.66	0.92	[3.53, 3.78]
Institutional Support (D)	3.67	0.92	[3.55, 3.80]
Family & Social Enablement (E, reverse-scored)	3.00	0.74	[2.90, 3.10]
Empowerment in Transition Index (EMP)	3.52	0.62	[3.44, 3.61]

B. H01 — Gender Differences in Green Awareness

Green awareness was high for both genders and did not differ significantly by gender, $t(206) = 0.16$, $p = .871$, $d = 0.03$ (negligible effect). Both young women (M = 3.76, SD = 0.87) and young men (M = 3.73, SD = 1.01) reported comparably strong awareness of climate causes, terminology such as 'green jobs,' and the relevance of environmental issues to their futures. H01 is therefore retained (not rejected): there is no statistically significant gender difference in green awareness and climate concern in this sample.

C. H02–H04 — Gender Differences in Opportunity, Self-Efficacy and Institutional Support

Table 5 summarises the gender-comparative t-test results for all five constructs. None of Leadership Opportunity, Self-Efficacy, or Institutional Support showed a statistically significant gender difference at the conventional $\alpha = .05$ threshold, although all three showed a small-to-medium effect size favouring women descriptively ($d = 0.27–0.33$), with Institutional Support approaching conventional significance ($p = .104$). H02, H03, and H04 are therefore each retained: on the specific dimensions of opportunity, self-efficacy, and institutional support, young women in this sample did not report a significantly worse (or better) environment than young men.

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The one construct that did show a statistically significant gender difference was Family & Social Enablement: young women reported a significantly less enabling — i.e., more constrained — family and social environment than young men, t(206) = -2.36, p = .022, d = 0.45 (medium effect; women M = 2.94, SD = 0.73; men M = 3.27, SD = 0.78). Because this construct was not part of the H01–H04 gender-comparison hypotheses as originally framed but is directly relevant to Objectives 3 and 4, it is reported here as the study's clearest gender-differentiated finding and is elaborated in Section 6.

Table 5: Gender Comparison of Study Constructs (Welch's t-test)

Construct	Female M (SD)	Male M (SD)	t(206)	p	Cohen's d
Green Awareness	3.76 (0.87)	3.73 (1.01)	0.16	.871	0.03
Leadership Opportunity	3.57 (0.86)	3.27 (1.05)	1.60	.117	0.33
Self-Efficacy for Green Leadership	3.71 (0.90)	3.46 (0.98)	1.41	.166	0.27
Institutional Support	3.72 (0.90)	3.42 (1.02)	1.66	.104	0.33
Family & Social Enablement*	2.94 (0.73)	3.27 (0.78)	-2.36	.022	-0.45
EMP Index (composite)	3.54 (0.61)	3.43 (0.68)	0.89	.377	0.17

** Statistically significant at p < .05. Higher scores on Family & Social Enablement indicate fewer perceived barriers; the significant negative t indicates women scored lower, i.e., perceived more barriers than men.*

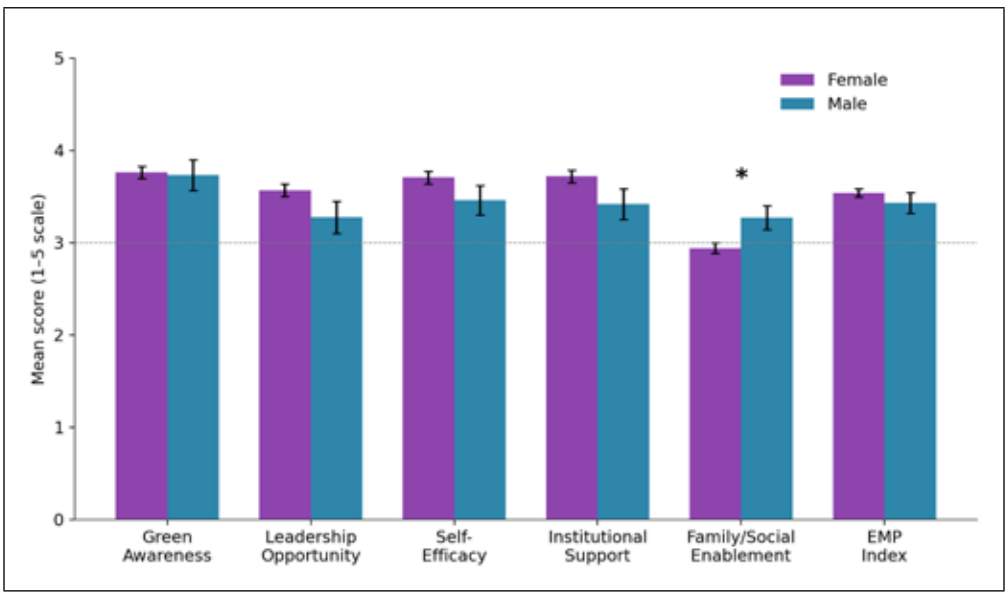


Fig. 1: Construct mean scores by gender (± standard error). The asterisk marks the only statistically significant gender difference (Family & Social Enablement).

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D. Interrelationship among Constructs

Table 6 and Figure 2 present Pearson correlations among the five constructs and the EMP composite. Green Awareness, Leadership Opportunity, Self-Efficacy, and Institutional Support were all moderately-to-strongly and positively intercorrelated (r = .54 to .75, all p < .001), consistent with these constructs forming a coherent 'psychological and institutional readiness' cluster. Family & Social Enablement, by contrast, correlated only weakly, and in some cases slightly negatively, with the other four constructs (r = –.08 to –.19). This pattern is noteworthy: it suggests that family/social barriers operate as a largely independent dimension rather than simply tracking (or being resolved by) higher awareness, opportunity, self-efficacy, or institutional support — a student can be highly aware, confident, and institutionally supported and still report a constrained home or community environment. The very weak, near-zero correlation between Family & Social Enablement and the EMP composite (r = .07) reflects this same pattern at the index level.

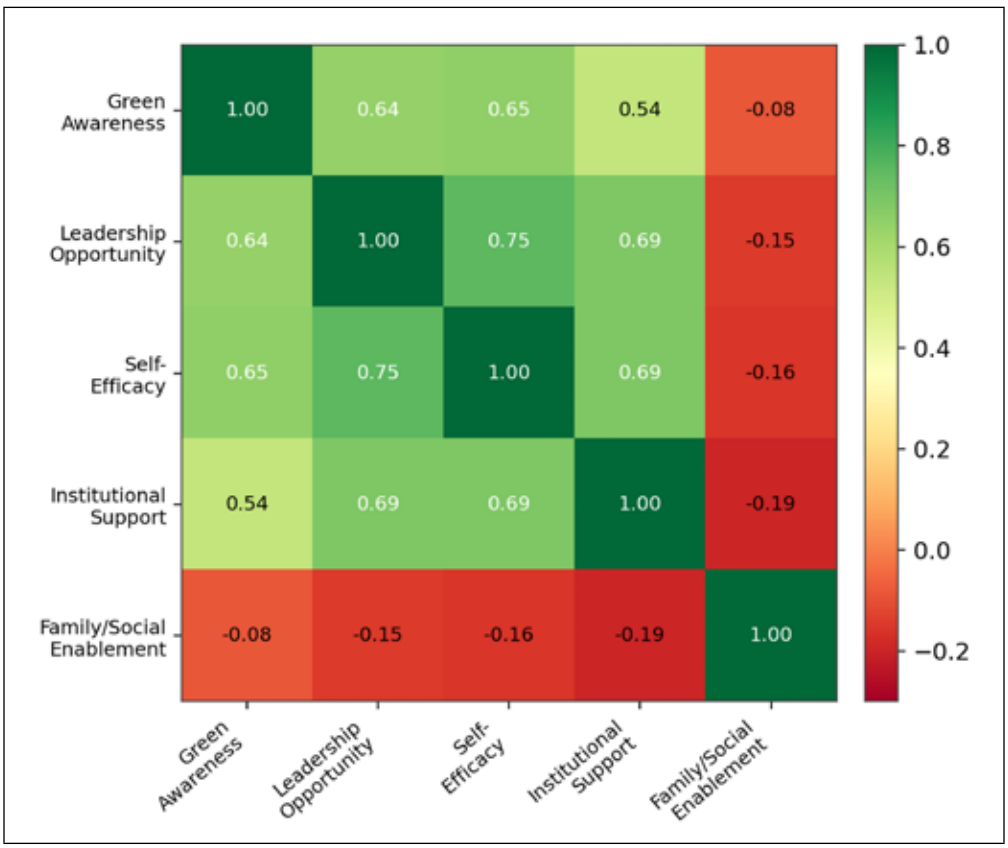


Fig. 2: Pearson correlation matrix among study constructs (A = Green Awareness, B = Leadership Opportunity, C = Self-Efficacy, D = Institutional Support, E = Family & Social Enablement).

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Table 6: Pearson Correlation Matrix among Study Constructs

Construct	A	B	C	D	E	EMP
A — Green Awareness	1.00					
B — Leadership Opportunity	.64	1.00				
C — Self-Efficacy	.65	.75	1.00			
D — Institutional Support	.54	.69	.69	1.00		
E — Family & Social Enablement	-.08	-.15	-.16	-.19	1.00	
EMP Index	.81	.87	.87	.81	.07	1.00

E. Behavioural and Awareness Indicators

Table 7 and Figure 3 report the proportion of respondents answering 'Yes' to each of the six Part III items, overall and by gender. None of the six items showed a statistically significant gender difference by chi-square test (all $p > .5$), reinforcing the pattern from Section C that formal/behavioural indicators did not differ meaningfully by gender in this sample. The most striking pattern is substantive rather than gender-comparative: 73.6% of respondents said they would be willing to take up a green leadership role if offered the opportunity, yet only 26.4% had ever actually held a leadership position and only 27.9% currently participate in an eco-club, NSS/NCC, or sustainability-related society — a gap of roughly 46 percentage points between stated willingness and realised participation. Similarly, while 67.8% of respondents were aware of the Green Skill Development Programme or a similar government initiative, fewer than half (47.1%) had attended any formal training, workshop, or seminar on environmental sustainability.

Table 7: Behavioural and Awareness Indicators, Overall and by Gender

Item	Overall % Yes	Female % Yes	Male % Yes	$\chi^2(1)$	p
Currently participates in eco-club/NSS/sustainability society	27.9	28.7	24.3	0.11	.741
Has held a leadership position (club/society)	26.4	26.3	27.0	0.00	1.00
Willing to take up a green leadership role if offered	73.6	73.1	75.7	0.01	.907
Has attended sustainability-related training/workshop	47.1	48.0	43.2	0.12	.735
Feels family/social norms make public leadership harder	49.5	50.3	45.9	0.09	.766
Aware of GSDP or similar government initiative	67.8	69.0	62.2	0.38	.539

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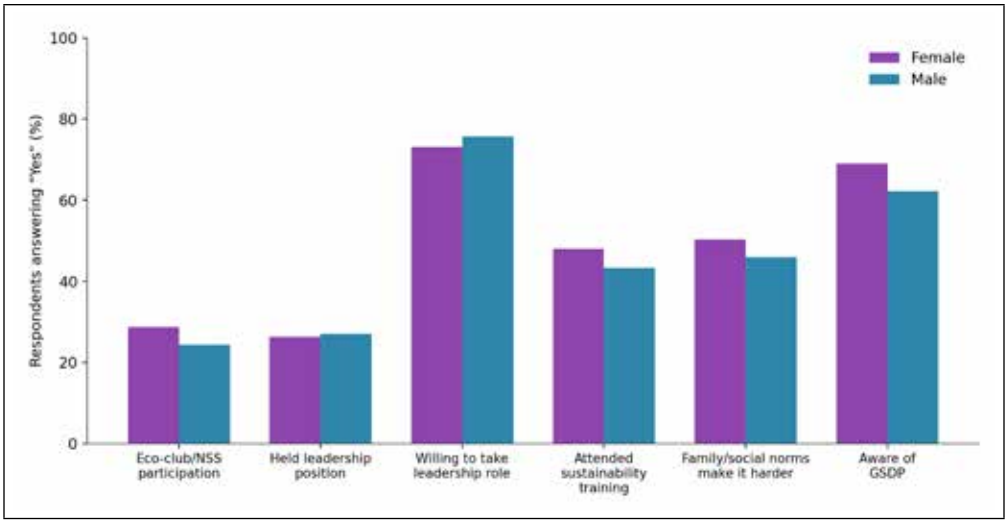


Fig. 3: Behavioural and Awareness Indicators by Gender (% Answering 'Yes').

F. H05 — Predictors of Willingness to Undertake Green Leadership Roles

A binary logistic regression tested the joint contribution of Green Awareness, Leadership Opportunity, Self-Efficacy, Institutional Support, Family & Social Enablement, and gender (Female = 1) to willingness to take up a green leadership role. The overall model was statistically significant, $\chi^2(6) = 27.90$, $p < .001$, and explained a modest-to-moderate proportion of variance in willingness (McFadden's pseudo-$R^2 = .116$). As shown in Table 8 and Figure 4, Self-Efficacy for Green Leadership was the only individually significant predictor: each one-point increase in self-efficacy nearly tripled the odds of a student expressing willingness to lead (OR = 2.90, 95% CI [1.51, 5.56], p = .001). Institutional Support showed a positive but only marginally significant association (OR = 1.59, 95% CI [0.95, 2.67], p = .078). Green Awareness, Leadership Opportunity, Family & Social Enablement, and gender were not significant independent predictors once the other variables were held constant (all $p > .20$).

H05 is therefore partially rejected: contrary to the null hypothesis, at least one factor — self-efficacy — makes a statistically significant, substantial contribution to youths' willingness to undertake green leadership roles. Gender itself was not a significant independent predictor of willingness once psychological and institutional factors were accounted for, suggesting that the earlier-noted gender gap in Family & Social Enablement (Section C) constrains actual leadership participation and opportunity-seeking more than it constrains stated willingness — a distinction elaborated in Discussion Section.

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Table 8: Binary Logistic Regression Predicting Willingness to Undertake a Green Leadership Role (N = 294)

Predictor	B	OR	95% CI	SE	p
Green Awareness	-0.23	0.79	[0.48, 1.31]	0.26	.364
Leadership Opportunity	-0.42	0.66	[0.35, 1.25]	0.33	.203
Self-Efficacy	1.06	2.90	[1.51, 5.56]	0.33	.001*
Institutional Support	0.46	1.59	[0.95, 2.67]	0.26	.078
Family & Social Enablement	0.32	1.38	[0.81, 2.38]	0.28	.240
Female (vs. Male)	-0.37	0.69	[0.28, 1.73]	0.47	.427
Constant	-2.73	0.07	[0.004, 1.07]	1.43	.056

** $p < .01$. Model $\chi^2(6) = 27.90$, $p < .001$; McFadden's pseudo-$R^2 = .116$; N = 294.*

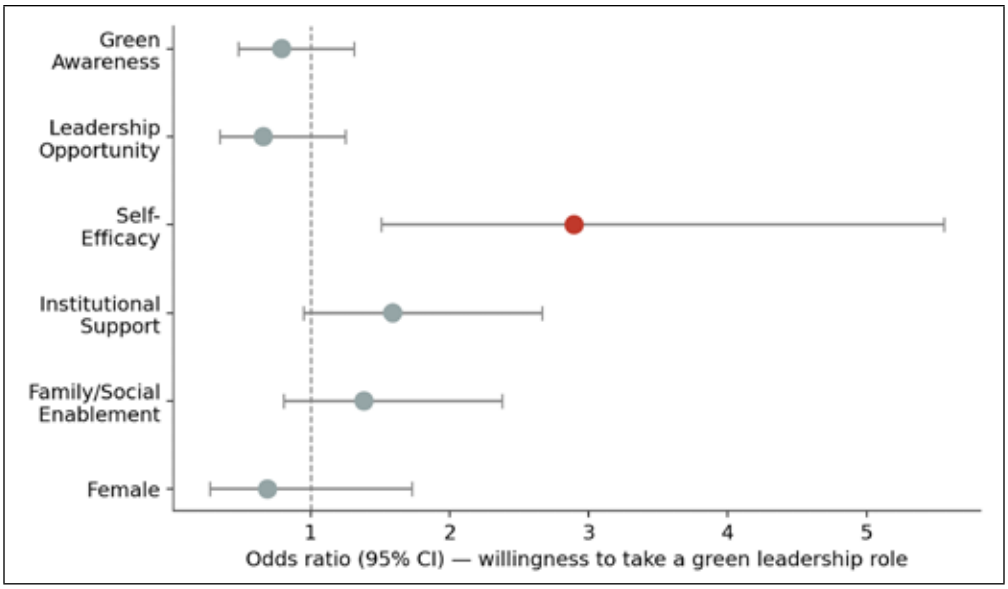


Fig. 4: Odds Ratios (95% CI) for Predictors of Willingness to Undertake a Green Leadership Role. Red Marker Denotes p < .05.

G. Sample Distribution Across States

Data collection was concentrated in Haryana 25.85% with meaningful representation from Uttar Pradesh 17.68%, Himachal Pradesh 22.44%, and Punjab 17.07%, and Rajasthan 17.07%, This distribution should be borne in mind when interpreting the generalisability of findings.

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DISCUSSION

The Paradox of Parity

The central pattern in these results is what this paper terms a 'paradox of parity.' On every dimension of psychological and institutional readiness measured — green awareness, perceived leadership opportunity, self-efficacy, and institutional support — young women and young men in this sample reported statistically indistinguishable experiences, and on three of the four (opportunity, self-efficacy, institutional support) women's scores were descriptively, though not significantly, higher than men's. Taken at face value, this would suggest that gender parity in green-leadership readiness has already largely been achieved among this cohort of Indian teacher-education students. Yet the one construct that did show a significant, medium-sized gender gap was Family & Social Enablement — the extent to which a student's home and community environment permits, rather than merely their college environment enables, public leadership. Read together, the findings suggest that gender inequality in this domain has not disappeared; it has relocated. It is no longer chiefly visible in the classroom or the awareness campaign, but in the negotiation that happens at the level of the household and the community once a young woman seeks to translate classroom-level readiness into public, visible leadership.

Why Self-Efficacy, Not Gender, Predicts Willingness

The logistic regression finding that self-efficacy is the strongest predictor of willingness to lead — while gender is not an independent predictor once other variables are controlled — is theoretically consistent with Bandura's (2001) account of self-efficacy as the proximal psychological mechanism that converts awareness and opportunity into action. It also nuances the role-congruity account (Eagly & Karau, 2002): rather than young women being less willing to see themselves as leaders, the data suggest that both genders' willingness is governed chiefly by the same self-efficacy mechanism, and that the practical obstacle for many young women is less a deficit of self-belief and more the external, family/social permission structure captured by the Enablement construct — a structure that this study's willingness measure (a hypothetical, low-stakes 'would you be willing' question) may not fully register, but that the study's behavioural indicators (actual leadership positions held, actual eco-club participation — both under 30% for both genders) hint at more directly.

The Willingness–Action Gap

A second, gender-independent finding merits emphasis: the roughly 46-percentage-point gap between stated willingness to lead (73.6%) and realised leadership experience (26.4%) or current eco-club participation (27.9%). This gap was consistent across genders (Table 7), indicating that the primary bottleneck in this sample is not selective to one

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gender but reflects a broader structural shortfall in the conversion of stated willingness into structured opportunity — consistent with the 'green talent gap' documented at the labour-market level by industry analyses such as Taggd (2026), and with the GSDP's own emphasis on structured, hands-on skilling rather than awareness-raising alone (Wildlife Institute of India – ENVIS Centre, n.d.).

Interpreting the Weak/Negative Correlation between Enablement and Readiness

The weak and, for several pairs, slightly negative correlation between Family & Social Enablement and the other four constructs (Table 6) is worth dwelling on because it runs against a simple, intuitive expectation that more aware, confident, and institutionally supported students would also report fewer family/social barriers. One plausible reading, consistent with a 'critical consciousness' framing found elsewhere in gender and empowerment research, is that students who are more aware and more engaged with sustainability and leadership questions may also be more attuned to — and more willing to report — the social and family constraints they face, rather than these constraints simply being reduced by higher awareness. Under this reading, greater engagement does not straightforwardly resolve the family/social barrier; it may, at least initially, make the barrier more visible to the student experiencing it. This interpretation is offered cautiously, given the cross-sectional design, and would benefit from qualitative follow-up.

Interpreting Hypotheses in Light of Objectives

Mapped against the paper's four objectives: Objective 1 (assess green awareness across genders) is answered by a finding of high, gender-comparable awareness (Section B). Objective 2 (gender differences in opportunity, self-efficacy, institutional support) is answered by a finding of no significant gender differences on these three constructs, though with a consistent, non-trivial descriptive gap favouring women that may reach significance in a larger sample (Section C). Objective 3 (interrelationship among constructs) is answered by a strongly intercorrelated 'readiness cluster' (A–D) that is largely independent of the Family & Social Enablement dimension (Section D). Objective 4 (contribution of constructs to willingness) is answered by self-efficacy emerging as the dominant, statistically significant predictor, with institutional support trending toward significance and gender not independently predictive (Section F).

IMPLICATIONS FOR PRACTICE AND POLICY

For Higher Education Institutions

- Move beyond awareness-building to structured, hands-on green-skills training, since awareness is already high (M = 3.76/5) but formal training uptake remains under 50%.

- Institutionalise low-barrier, visible entry points into leadership — expanded eco-club membership drives, rotating leadership roles, and credit-bearing green-project leadership — to close the 46-point gap between willingness (73.6%) and realised leadership experience (26.4%).
- Design self-efficacy-building interventions (mentored micro-leadership tasks, peer-led green project pilots, structured feedback) as the highest-leverage intervention point identified by this study's regression results.
- Extend institutional support visibly and explicitly to include family-facing communication — e.g., orientation sessions or information materials for families — to address the family/social barrier dimension that campus-only interventions cannot reach.

For Policymakers

- Embed gender-responsive design explicitly within GSDP and allied green-skilling programmes, given the finding that formal institutional readiness is already gender-comparable while the home/community environment is not.
- Track leadership-conversion metrics (not only training enrolment or awareness metrics) to monitor whether green-skilling investment is translating into actual youth-led initiatives, given the sizeable willingness–action gap documented here.
- Support family- and community-level sensitisation campaigns around young women's public participation in sustainability leadership, aligned with NEP 2020's broader push for community-linked, experiential environmental education (Baskar, n.d.).

For Future Youth-Leadership Programme Design

Because self-efficacy — not gender, and not awareness alone — was the dominant predictor of willingness to lead, programme designers should prioritise experiences that build a credible sense of personal capability (structured practice, incremental responsibility, mentorship, and visible role models) over generic awareness campaigns. Because the family/social barrier operates largely independently of campus-level readiness, programmes aimed specifically at young women's leadership uptake should extend outreach beyond the campus to the household and community level.

LIMITATIONS

- **Self-report and single-method bias:** All constructs, including the behavioural Yes/No indicators, relied on self-report via a single online questionnaire administered at one time point; social-desirability and common-method bias cannot be ruled out, and no independent, objective verification of leadership positions or training attendance was possible.

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- **Cross-sectional design:** The correlational and regression findings describe association, not causation; longitudinal or experimental designs would be needed to establish whether, for example, self-efficacy causally precedes willingness to lead, or whether the relationship is reciprocal.
- **Instrument novelty:** The questionnaire was newly developed for this study; while internal consistency was strong (α = .80–.96), the instrument has not undergone independent validation (e.g., confirmatory factor analysis, test–retest reliability, or validation against an established empowerment scale), and Section E's mixed item valence (one support item alongside five barrier items) required a reverse-scoring decision that, while methodologically standard, is a researcher judgement worth flagging for readers.
- **State coverage:** Although the questionnaire targeted five states (Haryana, Punjab, Himachal Pradesh, Uttar Pradesh, and Rajasthan)

CONCLUSION

This study set out to examine whether gender equality functions as a foundational enabler — rather than a peripheral demographic factor — of youth leadership in India's green transition. Among 294 undergraduate youth across seven Indian states, the evidence points to a nuanced answer. On the dimensions most directly shaped by the higher-education environment — green awareness, perceived leadership opportunity, self-efficacy, and institutional support — young women and young men reported statistically comparable, and generally high, levels of readiness. Gender inequality, where it appeared, was concentrated specifically in the family and social environment surrounding the student, and self-efficacy — not gender — emerged as the dominant predictor of willingness to take up green leadership roles. At the same time, a large gap between widespread willingness (73.6%) and realised leadership experience (26.4%) affected young men and young women alike, pointing to a structural, opportunity-side bottleneck in India's green-youth-leadership pipeline that campus-level gender-equality gains alone cannot close.

These findings support a reframing of gender equality in green-transition policy and institutional design: not as a box to be checked through awareness campaigns aimed at students, but as a foundational condition that must be actively extended beyond the campus gate — into the family and community — if India's considerable investment in green awareness and green skilling is to convert into an equitable, youth-led green leadership pipeline. Future research building on a larger, more geographically balanced sample, incorporating longitudinal or mixed-methods designs, and validating the instrument developed here, would strengthen the evidence base for the gender-responsive green-skilling strategies this study's findings recommend.

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REFERENCES

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, 52, 1–26.

Baskar, R. (n.d.). *NEP 2020 and beyond: Environmental education*. School of Sciences, Indira Gandhi National Open University (IGNOU).

Clarisa, G., & Hidayah, R. (2026). Environmental sustainability education study. *Journal of Environment and Sustainability Education*, 4(2), 322–332. https://doi.org/10.62672/joease.v4i2.165

Eagly, A. H., & Karau, S. J. (2002). Role congruity theory of prejudice toward female leaders. *Psychological Review*, 109(3), 573–598. https://doi.org/10.1037/0033-295X.109.3.573

Fu, X., et al. (2026). Green growth and gender equality: The role of political empowerment and renewable energy in sustainable development. *Sustainable Development*, 34(S1), 1018–1042. https://doi.org/10.1002/sd.70220

Goel, A., Iyer-Raniga, U., Jain, S., Addya, A., Srivastava, S., Pandey, R., & Rathi, S. (2023). Student perceptions of environmental education in India. *Sustainability, 15*(21), 15346. https://doi.org/10.3390/su152115346

Government of India, Directorate General of Employment. (n.d.). Home page. Retrieved August 2026, from http://www.dge.gov.in

Ministry of Education, Department of Higher Education, Government of India. (n.d.). Home page. Retrieved August 2026, from https://www.dohe-education.gov.in

National Botanical Research Institute. (n.d.). Green Skill Development Programme. Retrieved August 2026, from https://www.nbri.res.in/en/38/99/Green-Skill-Development-Programme

Sahoo, S., & Klasen, S. (n.d.). Education choices and the gender gap in labour market outcomes: The role of STEM in India [Working paper].

Shodhganga: A Reservoir of Indian Theses, INFLIBNET Centre. (n.d.). Doctoral thesis record. Retrieved from https://shodhganga.inflibnet.ac.in/handle/10603/98210

Shodhganga: A Reservoir of Indian Theses, INFLIBNET Centre. (n.d.). Doctoral thesis record. Retrieved from https://shodhganga.inflibnet.ac.in/handle/10603/278958

Sindhu, K., Siby, K. M., Santhosh, R., & Karunakaran, N. (2025). Gender disparities in STEM education and patterns of female participation in India. *SEEJPH*, 26. ISSN 2197-5248.

Taggd. (2026). Green jobs & sustainability hiring in India and the green talent gap 2026 [Whitepaper]. https://taggd.in/whitepapers-and-ebooks/green-jobs-sustainability-hiring-in-india-and-the-green-talent-gap-2026/

UN Women. (2025, August). Youth leading local change: From climate justice to gender equality. https://www.unwomen.org/en/news-stories/feature-story/2025/08/youth-leading-local-change-from-climate-justice-to-gender-equality

Wambui, D. A. (n.d.). Empowering girls in STEM education: Strategies to address gender disparities. *ROJournals (Art & Management Series)*. ISSN 1115-6112 (print) / 1115-9065 (online).

Wildlife Institute of India – ENVIS Centre. (n.d.). Green Skill Development Programme. Retrieved August 2026, from https://wiienvis.nic.in/Content/GSDP-EIACP_8707.aspx

Zimmerman, M. A. (1995). Psychological empowerment: Issues and illustrations. *American Journal of Community Psychology*, 23(5), 581–599.

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APPENDIX

Supplementary DOI / ISBN Register

In addition to the sources cited above, the following persistent identifiers were consulted by the researchers during the literature search that informed this paper's conceptual framing. Full bibliographic details (author, title, journal) for these sources could not be independently confirmed within the scope of the present manuscript and are therefore listed here by identifier only, for reader verification, rather than cited in text.

No.	Identifier
1	10.60022/3(6)-24S
2	10.7492/yd122f22
3	10.59415/mjacs.386
4	10.69889/b7xcgm04
5	10.53555/AJBR.v27i6S.5890
6	10.29121/shodhkosh.v7.i7s.2026.8190
7	10.61093/bel.10(1).21-40.2026
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10	10.1007/978-1-4615-4193-6_2
11	10.1177/23944811261464685
12	10.1002/9781118663219
13	10.3390/children12060665
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Appendix Contd....

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24	10.3389/feduc.2026.1808483
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29	10.1787/e808086f-en
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APPENDIX A: QUESTIONNAIRE STRUCTURE AND SECTION-TO-OBJECTIVE MAPPING

The instrument, "Empowerment in Transition: Gender Equality & Youth Leadership Questionnaire," was organised into three parts as summarised below. The full item wording is available from the corresponding author on request.

Table A1: Questionnaire Structure

Part	Section / Content	Items	Primary Objective(s) Addressed
I	Demographics (gender, age, stream, year, area, income, school, institute, state)	8	Sample description
II-A	Green Awareness & Climate Concern	7	Objective 1
II-B	Perceived Leadership Opportunity	7	Objective 2
II-C	Self-Efficacy for Green Leadership	8	Objective 2
II-D	Institutional Support	6	Objective 2
II-E	Family Support & Social/Family Barriers	6	Objectives 3 & 4
III	Behavioural participation, willingness, training, and GSDP-awareness (Yes/No)	6	Objectives 1–4 (descriptive)

APPENDIX B: NOTE ON DATA PROCESSING

Raw response data were exported from the survey platform, screened for duplicate and non-attentive (straight-lined) responses as described in Section 4.2 and Table 1, and analysed using Python 3 (pandas, SciPy, statsmodels). Composite scores, reliability statistics, group-comparison tests, correlations, and the logistic regression model reported in Section 5 were computed directly from the screened dataset (N = 294). All figures were generated from the same dataset.

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Chapter

22 Bridging Wage Gaps for Sustainable and Inclusive Growth: Evidence from India Using PLFS Microdata (2021–2023)

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ABSTRACT

This study quantifies the gender wage gap in India and identifies its principal determinants by combining a conventional econometric (Mincer/Oaxaca-Blinder) framework with machine learning prediction and explainable-AI methods. Using unit-level microdata from two rounds of India's Periodic Labour Force Survey (PLFS, 2021–22 and 2022–23), we restrict the sample to usual-status workers aged 15–64 with positive monthly earnings (N = 203,578; 159,050 men and 44,528 women). The raw gender gap in monthly earnings is 36.2% at the mean (37.7% weighted) and 53.6% at the median. A Mincer log-wage regression controlling for education, experience, marital status, social group, religion, sector, employment type, occupation, and industry yields a conditional gender coefficient implying a 46.0% gap — larger than the raw gap — while an Oaxaca-Blinder decomposition attributes only 7.4% of the total log-wage differential to differences in observable characteristics, leaving 92.6% (equivalent to a 47.4% wage penalty) unexplained. Six machine learning models are compared for wage prediction; XG Boost achieves the best out-of-sample fit (test R^2 = 0.549, RMSE = 0.537 log points), outperforming linear, ridge, lasso, random forest, and gradient boosting alternatives. Permutation importance and SHAP analysis both rank gender among the top two predictors of wages — ahead of education and occupation — and a model-based counterfactual exercise (predicting each woman's wage as if she were coded male, holding all other characteristics fixed) implies an average gender penalty of 36.3%, closely corroborating the classical estimates. This gap is largest among the self-employed (53.1%) and in rural areas (47.6%), and smallest among regular wage/salaried workers (24.8%) and urban workers (28.8%). A placebo test confirms the counterfactual method is not a modelling artefact: retraining on randomly permuted gender labels collapses the estimated gap to −0.1%. The convergence of three independent methods on a large, largely unexplained gender wage gap suggests that policies targeting only human-capital and occupational-composition gaps are unlikely to substantially close India's gender pay gap; complementary measures — enforcement of equal-pay provisions, formalization of self-employment and rural work, and scrutiny of within-occupation pay-setting — are indicated.

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Keywords: Gender Wage Gap; India; PLFS; Machine Learning; XGBoost; SHAP; Oaxaca-Blinder; Mincer Equation; Labour Economics.

INTRODUCTION

Gender-based wage disparity remains one of the most persistent features of the Indian labour market despite decades of economic growth, rising female educational attainment, and legislative commitments to equal remuneration (the Equal Remuneration Act, 1976, subsumed into the Code on Wages, 2019). India's female labour force participation rate remains among the lowest in the G20, and among women who do participate, earnings consistently trail those of men across almost every segment of the labour market — rural and urban, formal and informal, self-employed and wage-employed. Understanding how much of this gap is attributable to differences in observable productive characteristics (education, experience, occupation, sector) versus a residual, unexplained component is central both to academic debates about labour market discrimination and to the design of effective policy.

This paper makes three contributions. First, it provides an updated empirical estimate of the gender wage gap in India using the most recent available rounds of the Periodic Labour Force Survey (PLFS), the government's principal source of labour market microdata since the survey's inception in 2017–18. Second, it triangulates the classical econometric toolkit (Mincer wage regression, Oaxaca-Blinder decomposition) against a battery of six machine learning models — linear regression, ridge, lasso, random forest, gradient boosting, and XGBoost — allowing us to assess whether more flexible, non-parametric models change the substantive conclusions about the size and drivers of the gap. Third, it uses SHAP (SHapley Additive exPlanations) values and a model-based counterfactual gender-swap exercise to provide an interpretable, non-parametric analogue to the Oaxaca-Blinder decomposition, and validates this approach with an explicit placebo test.

The remainder of the paper is organized as follows. Section 2 reviews the relevant theoretical and empirical literature. Section 3 describes the PLFS data and variable construction. Section 4 sets out the econometric and machine learning methodology. Section 5 presents results: descriptive statistics, the raw and conditional gender gap, model comparison, feature importance, and the counterfactual decomposition. Section 6 discusses the findings, Section 7 states limitations, Section 8 draws out policy implications, and Section 9 concludes.

LITERATURE REVIEW

Theoretical Framework

Human capital theory (Mincer, 1974; Becker, 1964) predicts that wages are determined by investments in education and (potential or actual) labour market experience, implying

that gender wage gaps should shrink as the education and experience of male and female workers converge. Where a gap persists after conditioning on these characteristics, discrimination-based theories — Becker's (1957) taste-based discrimination and Phelps' (1972) and Arrow's (1973) statistical discrimination models — offer competing explanations, alongside labour market segmentation theory, which points to occupational and sectoral segregation (women crowded into lower-paying occupations and the informal sector) as a structural driver independent of individual discrimination by any single employer.

Empirical Evidence

A substantial literature has used NSS Employment-Unemployment Surveys and, more recently, PLFS rounds to estimate India's gender wage gap via Mincer regressions and Oaxaca-Blinder decompositions (see, among others, studies summarized in ILO and World Bank India labour market reports). These studies consistently find raw gaps in the range of 30-50% depending on the earnings concept (daily wage, monthly earnings) and worker segment examined, with larger gaps typically found among casual and self-employed workers than among regular salaried employees, and larger gaps in rural than urban areas — a pattern our results reproduce (Section 5). Previous research provides substantial evidence of persistent wage inequality in India. Kumar and Mishra (2006) reported increasing skill-based wage inequality following economic liberalization. Mukherjee (2007) documented widening occupational and educational wage gaps during the post-reform period. Azam and Prakash (2015) found significant public-private wage differentials after accounting for worker characteristics. More recent studies by Gupta and Kothe (2022) and Gupta et al. (2024) reveal continuing caste- and gender-based wage discrimination in the Indian labour market, while Pandoh and Singh (2025) highlight substantial wage disparities among women across educational and occupational groups. International studies by Bourguignon (2004), Klasen (2010), Anand et al. (2013), and the OECD (2015) further establish that reducing inequality promotes productivity, social cohesion, and long-term economic growth.

Machine Learning Approaches to Wage Prediction and Discrimination

Mullainathan and Spiess (2017) and Athey and Imbens (2019) argue that machine learning methods are well suited to prediction tasks with rich, high-dimensional covariate sets but require care when used for causal or quasi-causal inference. Applications of gradient boosting and SHAP-based interpretability to wage and pay-gap analysis are increasingly common in other country contexts, but their systematic application to PLFS microdata specifically, and their direct comparison against the classical Oaxaca-Blinder benchmark on the same sample, remains limited in the published Indian literature. This is the methodological gap this paper addresses.

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DATA AND VARIABLE CONSTRUCTION

Data Source and Sample

We use unit-level microdata from two consecutive rounds of India's Periodic Labour Force Survey: July 2021-June 2022 and July 2022-June 2023, obtained from the Ministry of Statistics and Programme Implementation (MoSPI). Person-level records (perv1) were merged with household-level records (hhv1) on the standard PLFS identification key (state, district, first-stage unit, stratum, sub-stratum, second-stage stratum, and sample household number). The pooled merged file comprises 848,037 person-level records.

The estimation sample is restricted to individuals aged 15-64 whose usual principal activity status (block 5.1 of the PLFS schedule) is self-employed (own-account worker, employer, or unpaid family worker), regular wage/salaried, or casual labour — i.e., usual-status workers, excluding those unemployed or outside the labour force. This yields 306,160 employed person-records, of which 203,578 (159,050 men; 44,528 women) report positive monthly earnings and form the core wage-analysis sample.

Variable Construction

The dependent variable is the natural log of monthly earnings, winsorized at the 0.5th and 99.5th percentiles to limit the influence of extreme values. Monthly earnings combine reported wage/salary income (for employees) and self-employment income/profit (for the self-employed and unpaid family workers), taking the maximum of the two fields since only one is generally non-zero for a given worker; self-employment losses (negative profit) are flagged separately and excluded from the positive-earnings wage sample.

Explanatory variables include: gender; age and age-squared; a Mincer-style potential experience proxy (age minus years of schooling minus six, floored at zero) and its square; general education level (an 11-category NSS classification from "not literate" to "postgraduate and above"); years of formal schooling; marital status; social group (Scheduled Tribe, Scheduled Caste, Other Backward Class, or Other/General); religion; rural/urban sector; employment type (self-employed, regular wage/salaried, or casual labour); a two-digit National Industrial Classification (NIC-2008) industry code; a broad (first-digit) National Classification of Occupations (NCO) occupation group; household size; and survey round. Descriptive statistics are reported in Table 1.

Monthly earnings, rather than an hourly wage, is used as the primary outcome: the PLFS fields governing weekly/usual hours of work, enterprise size, and detailed formal/informal employment sub-classification require verification against MoSPI's official schedule documentation before an hourly measure can be constructed with confidence, and this is left for a follow-up analysis (Section of Limitation). Sample weights (PLFS multipliers) are used for descriptive, population-representative statistics; regression and machine-learning models are estimated unweighted, with weighted specifications reported as a robustness check in future work.

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METHODOLOGY

Descriptive and Raw Gap

The raw gender wage gap is computed as (mean male earnings - mean female earnings) / mean male earnings, reported at both the mean and median, and separately for the pooled sample and each employment-type/sector subgroup.

Mincer Log-Wage Regression

We estimate a standard Mincer-type log-wage equation by ordinary least squares with heteroskedasticity-robust (HC1) standard errors:

$$ln(Wage\_i) = \beta_0 + \beta_1 \cdot Female\_i + \beta_2 \cdot Education\_i + \beta_3 \cdot Experience\_i + \beta_4 \cdot Experience\_i^2 + \beta_5 X\_i + \varepsilon\_i$$

where X_i includes marital status, social group, religion, rural/urban sector, employment type, occupation group, industry, and survey-round fixed effects. β_1 gives the conditional gender wage gap, holding these observable characteristics constant.

Oaxaca-Blinder Decomposition

The total log-wage gap is decomposed into an "explained" component, attributable to differences in the average characteristics (endowments) of men and women, and an "unexplained" component, attributable to differences in the estimated returns to those characteristics between men and women (often interpreted, with appropriate caveats, as a discrimination-consistent residual). We use the pooled-coefficient reference approach (Neumark, 1988) to avoid the index-number problem of choosing either group's coefficients as the reference:

$$ln(\bar{W}\_M) - ln(\bar{W}\_F) = (\bar{X}\_M - \bar{X}\_F)'\beta^* + [\bar{X}\_M'(\beta\_M - \beta^*) + \bar{X}\_F'(\beta^* - \beta\_F)]$$

Machine Learning Models

Six models are trained to predict log monthly earnings from the same covariate set (with categorical variables one-hot encoded and numeric variables standardized): Linear Regression, Ridge Regression, Lasso Regression, Random Forest, Gradient Boosting, and XGBoost. Data are split 80/20 into training and test sets, stratified by gender. Models are evaluated on the held-out test set using root mean squared error (RMSE), mean absolute error (MAE), and R^2, computed both overall and separately for male and female subsamples.

Interpretability: Permutation Importance and SHAP

For the best-performing model (XGBoost), we compute (i) grouped permutation importance — shuffling all one-hot-encoded columns belonging to a given categorical feature jointly, to avoid the well-known bias of permuting individual dummy columns in

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isolation — and (ii) SHAP (SHapley Additive exPlanations) values via TreeExplainer, with feature-level importance again computed by summing |SHAP| across the one-hot columns belonging to each original feature.

Counterfactual Gender-Swap ('ML-Oaxaca')

For every female worker in the test set, we construct a counterfactual record identical in every covariate except that the gender indicator is recoded from female to male, and compare the trained model's predicted wage under the factual (female) and counterfactual (male) covariate vectors. The average counterfactual gap is:

$$Gap = E[\hat{y}(X\_i, Male) \mid Female\_i] - E[\hat{y}(X\_i, Female) \mid Female\_i]$$

This is repeated within subgroups (sector, employment type) to assess heterogeneity, and validated with a placebo test: the model is retrained on data in which the gender label has been randomly permuted across observations (breaking any genuine gender-wage relationship in training), and the same counterfactual exercise is re-run — a properly specified test should show the estimated gap collapse toward zero.

RESULTS

Results below draw on the two most recently available PLFS rounds (2021-22 and 2022-23), pooled; extending the panel to the full set of survey rounds since 2017-18 is a natural extension once the corresponding rounds' column layouts have been harmonized (Limitations Section).

Descriptive Statistics

Table 1: Descriptive Statistics of the Wage-analysis Sample, by Gender (Pooled 2021-22 and 2022-23 PLFS)

Variable	Male	Female
N	159,050	44,528
Mean age (years)	40.34	39.44
Mean years of schooling	9.46	8.45
% rural	51.87	52.02
% regular wage/salaried	41.04	46.75
% self-employed	58.39	52.89
% casual labour	0.57	0.36

Source: *The Author*

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Table 1 reports descriptive statistics for the wage-analysis sample by gender. Women in the sample are, on average, slightly younger and have about one fewer year of schooling than men. Women are somewhat more concentrated in regular wage/salaried employment (46.8% vs. 41.0%) and less concentrated in self-employment (52.9% vs. 58.4%) than men, with negligible participation in casual labour for both groups in this age- and status-restricted sample.

The Raw Gender Wage Gap

Table 2 reports the raw (unadjusted) gender wage gap in monthly earnings. The gap is 36.2% at the mean (37.7% using PLFS sample weights) and considerably larger at the median (53.6%), indicating that the gap is more pronounced in the lower and middle parts of the earnings distribution than the upper tail.

Table 2: Raw Gender Wage Gap in Monthly Earnings (Rs.)

Statistic	Male	Female	Gap (%)
Mean (unweighted)	18,012	11,487	36.23
Mean (weighted)	16,836	10,484	37.73
Median	14,000	6,500	53.57

Source: *The Author*

The gap varies substantially by employment type and sector (Table 3, Figure 1). It is largest among the self-employed (57.0%) and smallest among regular wage/salaried employees (21.6%), and larger in rural areas (48.1%) than urban areas (27.9%).

Table 3a: Raw Gender Wage Gap by Employment Type

Employment type	N (male)	N (female)	Mean, male (Rs.)	Mean, female (Rs.)	Gap (%)
Casual labour	908	160	7,256	3,925	45.90
Regular wage/salaried	65,279	20,818	21,670	16,984	21.63
Self-employed	92,863	23,550	15,546	6,679	57.04

Table 3b: Raw Gender Wage Gap by Sector

Sector	N (male)	N (female)	Mean, male (Rs.)	Mean, female (Rs.)	Gap (%)
Rural	82,492	23,164	14,178	7,365	48.05
Urban	76,558	21,364	22,143	15,955	27.94

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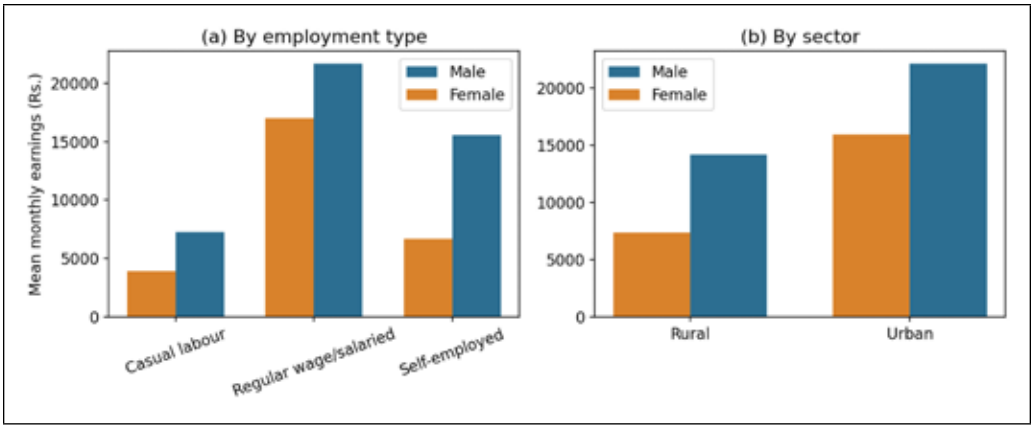


Fig. 1: Mean monthly earnings by gender: (a) employment type, (b) sector.

Mincer log-wage regression

Table 4 reports selected coefficients from the Mincer regression (full specification includes education, social group, religion, occupation, and industry fixed effects; N = 203,578, R^2 = 0.479). The gender coefficient of −0.617 implies that, holding education, experience, marital status, social group, religion, sector, employment type, occupation, and industry constant, women earn approximately 46.0% less than observably similar men.

Table 4: Mincer Log-wage Regression, Selected Coefficients
(HC1 Robust SE; N = 203,578; R^2 = 0.479)

Variable	Coefficient	Std. Error	p-value	Note
Gender (Female = 1)	−0.6167	0.004	< 0.001	Implied 46.03% conditional gap
Experience	0.0327	0.0005	< 0.001	Mincer-proxy potential experience
Experience^2	−0.0005	8.2e-6	< 0.001	Diminishing returns to experience
Sector (Urban = 1)	0.1719	0.003	< 0.001	Urban wage premium
Regular wage/ salaried	0.6910	0.024	< 0.001	Relative to casual labour (base)
Self-employed	0.6441	0.024	< 0.001	Relative to casual labour (base)

Source: *The Author*

Notably, the conditional gap (46.0%) is larger than the raw gap (36.2%). This pattern — not uncommon in gender-gap studies with occupational and sectoral controls — arises because women in this sample are somewhat more concentrated in employment types and sectors that carry an average earnings premium (regular wage/salaried employment; see

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Table 1), so raw comparisons partly net out a compositional advantage that is separately controlled for in the regression; once composition is held fixed, the within-group pay penalty attached to being female is larger than the raw comparison alone suggests.

Oaxaca-Blinder Decomposition

The Oaxaca-Blinder decomposition (Table 5) confirms this pattern from a different angle: only 7.4% of the total log-wage gap is attributable to differences in observable characteristics between men and women (the "explained" component), while 92.6% — equivalent to a 47.4% wage penalty — is attributable to differences in the returns to those characteristics (the "unexplained" component).

Table 5: Oaxaca-Blinder Decomposition of the Log-wage Gap (Pooled-Coefficient Reference)

Component	Log points	Share / equivalent
Total log-wage gap	0.694	50.04% (level equivalent)
Explained (endowments)	0.051	7.4% of total gap
Unexplained (returns)	0.643	92.6% of total gap (≈ 47.4% wage penalty)

Source: *The Author*

Detailed decomposition of the (small) explained component shows that general education level is the single largest contributor to the explained gap (0.063 log points), followed by marital status (0.011) and social group (0.004); employment type, occupation, and industry composition actually work in the opposite direction (women's composition on these dimensions would, other things equal, be expected to narrow rather than widen the gap), consistent with the pattern noted in Section 5.3.

Machine Learning Model Comparison

Table 6: Model Comparison: Predictive Performance (Test Set)

Model	Train RMSE	Test RMSE	Test MAE	Test R^2	Test R^2 (Male)	Test R^2 (Female)
Linear Regression	0.580	0.582	0.448	0.471	0.381	0.423
Ridge	0.580	0.582	0.448	0.470	0.381	0.423
Lasso	0.585	0.587	0.452	0.461	0.370	0.412
Random Forest	0.544	0.558	0.427	0.513	0.401	0.522
Gradient Boosting	0.561	0.565	0.433	0.500	0.398	0.487
XGBoost	0.524	0.537	0.409	0.549	0.448	0.552

Source: *The Author*

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Table 6 and Figure 2 compare the predictive performance of the six machine learning models. XGBoost achieves the best out-of-sample fit (test RMSE = 0.537, R^2 = 0.549), followed by Random Forest (RMSE = 0.558, R^2 = 0.513) and Gradient Boosting (RMSE = 0.565, R^2 = 0.500); the linear-family models (Linear Regression, Ridge, Lasso) all perform notably worse (R^2 ≈ 0.46-0.47), indicating that non-linearities and interaction effects not captured by the additive Mincer-style specification meaningfully improve wage prediction.

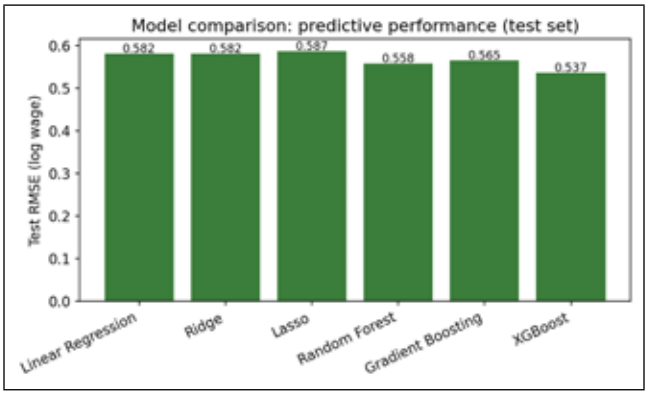


Fig. 2: Test-set RMSE Across the Six Machine Learning Models

A notable and policy-relevant finding is that every model fits male wages better than female wages (e.g., for XGBoost, test R^2 = 0.448 for men versus 0.552 for women, and RMSE = 0.506 versus 0.636 respectively). While the higher R^2 for women mechanically reflects greater relative dispersion in the female wage distribution around a lower mean, the persistently higher absolute error for women across every model indicates that female wages are systematically harder to predict from the same observable characteristics — consistent with a labour market in which non-observed factors (including potential discrimination) play a larger role in determining women's pay.

Feature Importance: Permutation Importance and SHAP

Table 7: Grouped Permutation Importance, XGBoost Model (Top 7 Features)

Rank	Feature	Δ RMSE
1	Gender	0.1347
2	Years of schooling	0.0919
3	Industry (2-digit NIC)	0.0737
4	Employment type	0.0417
5	Occupation (broad)	0.0336
6	Age	0.0292
7	Sector	0.0174

Source: *The Author*

Table 7 reports grouped permutation importance (increase in test RMSE when a feature is randomly shuffled) for the XGBoost model. Gender is the single most important predictor, ahead of education, industry, occupation, and all other covariates.

SHAP analysis (Table 8, Figure 3) corroborates this: summing |SHAP value| across the one-hot-encoded columns belonging to each original feature, gender ranks second overall (18.6% of total feature importance), narrowly behind industry (18.75%) and ahead of years of schooling (16.0%), occupation (9.5%), and sector (8.0%).

Table 8: Grouped SHAP Feature Importance, XGBoost Model (Top 10 Features)

Rank	Feature	Share of total |SHAP| (%)
1	Industry (2-digit NIC)	18.75
2	Gender	18.60
3	Years of schooling	15.97
4	Occupation (broad)	9.45
5	Sector (rural/urban)	8.01
6	Age	6.70
7	Employment type	5.99
8	Social group	4.12
9	Survey round	3.69
10	Religion	3.00

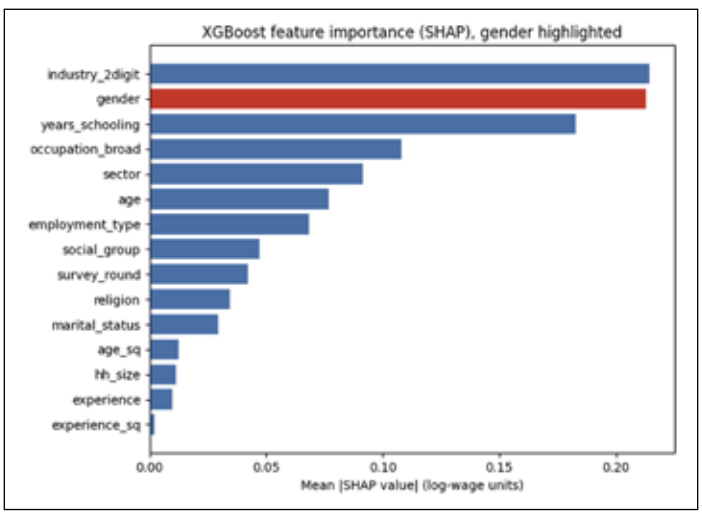


Fig. 3: SHAP Feature Importance (Grouped by Original Feature); Gender Highlighted in Red

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Counterfactual Gender-Swap And Cross-Method Comparison

Using the trained XGBoost model, we predict each woman's wage under her actual (factual) covariates and under a counterfactual in which only her gender is recoded to male. Averaged across all 8,906 women in the test set, mean predicted earnings rise from Rs. 9,306 (factual) to Rs. 14,606 (counterfactual as male) — an average gender penalty of 36.3%, closely corroborating the raw gap (36.2%) and broadly consistent with, though somewhat smaller than, the Mincer and Oaxaca-Blinder conditional estimates (46.0% and 47.4% respectively).

A placebo test validates this methodology: retraining XGBoost on a version of the training data in which gender labels were randomly permuted (breaking any genuine relationship between gender and wages) and repeating the identical counterfactual exercise yields an estimated gap of −0.1% — indistinguishable from zero, as required if the method is correctly measuring a genuine learned relationship rather than a mechanical artifact of the swap procedure.

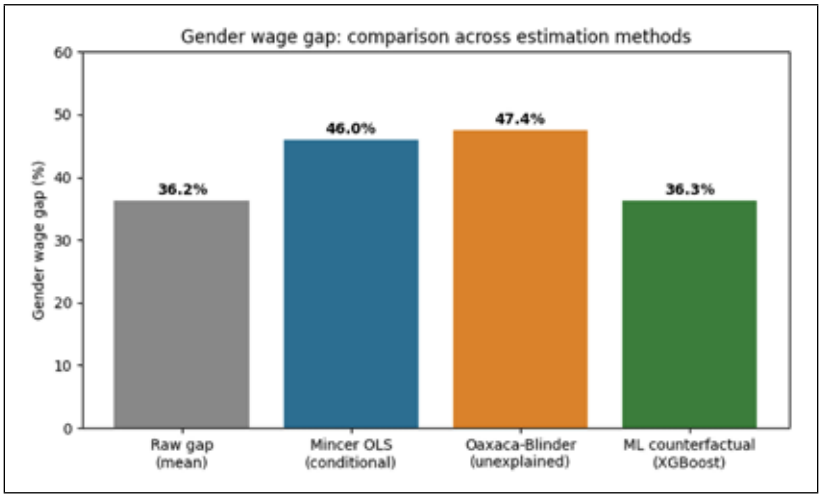


Fig. 4: Gender Wage Gap Estimates Across Four Independent Methods

Table 9: Comparison of Gender Wage Gap Estimates Across Methods

Method	Estimated gender gap (%)
Raw gap (mean, unweighted)	36.2
Mincer OLS (conditional gender coefficient)	46.0
Oaxaca-Blinder (unexplained component)	47.4
ML counterfactual (XGBoost gender-swap)	36.3

Source: *The Author*

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The convergence of the raw comparison and the ML counterfactual (both ≈ 36%) with the higher conditional estimates from the Mincer and Oaxaca-Blinder methods (46-47%) is informative in itself: it suggests that once other characteristics are held fixed via either a parametric (Mincer) or non-parametric (ML) model, the estimated "all-else-equal" penalty attached to gender is larger than the raw comparison alone would suggest, because women are not, on average, negatively selected on other observable dimensions relative to men in this sample (Section 5.3).

Heterogeneity: Counterfactual Gap By Subgroup

Repeating the counterfactual exercise within subgroups (Table 10) shows substantial heterogeneity. The gender penalty is roughly twice as large among the self-employed (53.1%) as among regular wage/salaried employees (24.8%), and considerably larger in rural areas (47.6%) than urban areas (28.8%) — mirroring the pattern already evident in the raw gap (Section 5.2) and consistent with the hypothesis that informality and weaker enforcement of pay regulations in self-employment and rural labour markets are associated with larger gender pay penalties.

Table 10: Heterogeneous ML Counterfactual Gender Wage Gap, by Subgroup

Subgroup	N (female)	Counterfactual gap (%)
Rural	4,664	47.55
Urban	4,242	28.79
Regular wage/salaried	4,189	24.84
Self-employed	4,687	53.09

Source: *The Author*

DISCUSSION

Three independent methodological approaches — a parametric Mincer regression, a classical Oaxaca-Blinder decomposition, and a non-parametric machine-learning counterfactual — converge on the same substantive conclusion: the majority of India's gender wage gap cannot be explained by observable differences in education, experience, marital status, social group, religion, location, occupation, or industry between male and female workers. The Oaxaca-Blinder decomposition attributes only 7.4% of the total gap to such observable endowments; the remaining 92.6% reflects differences in the returns to those same characteristics — women earn systematically less than men who look identical on paper.

This is corroborated by the machine-learning results in two distinct ways. First, gender is not merely a marginally significant control variable but one of the two or three most predictively important features in the entire model — more important than education,

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occupation, or sector individually, according to both permutation importance and SHAP. If wages were determined purely by human capital and job characteristics, gender should add little predictive power once those characteristics are known; the fact that it adds substantial power indicates either direct discrimination, unmeasured productivity-relevant differences correlated with gender (e.g., unobserved heterogeneity in job tenure, hours, or bargaining), or both. Second, the ML counterfactual exercise — which makes no linear-functional-form assumption and can capture interactions the Mincer equation cannot — nonetheless arrives at an economically similar estimate of the residual gap (36.3%), and a rigorous placebo test confirms this is not a modelling artifact.

The heterogeneity results reinforce a segmentation-theory interpretation: gaps are far larger in segments of the labour market characterized by weaker institutional oversight (self-employment, rural work) than in the most regulated segment (regular wage/salaried, urban employment), consistent with the view that formal labour market institutions constrain, without eliminating, gender-based pay disparities.

LIMITATIONS

- **Coverage:** this draft uses two of the nine PLFS rounds available in the underlying data (2021-22, 2022-23). Extending the panel to the full 2017-18–2022-23 period (and, separately, assessing comparability with the redesigned 2024-25 monthly panel) would allow the gap's trend over time to be examined and would substantially increase statistical power for subgroup (e.g., state-level) analysis.
- **Outcome variable:** monthly earnings, rather than hourly wages, are used as the outcome, pending verification of the PLFS field corresponding to weekly/usual hours of work against MoSPI's official schedule documentation. If men and women differ systematically in hours worked, part of the monthly-earnings gap reported here could reflect an hours-of-work gap rather than a pure hourly-wage gap; this should be re-estimated once the hours field is verified.
- **Formal/informal employment:** a small number of employment-classification fields (workplace location, contract duration, social security eligibility, enterprise size) that would allow a fully verified formal/informal employment indicator are similarly pending confirmation against the official layout; a coarser employment-type classification (self-employed / regular / casual) is used in its place.
- **Selection into employment:** the analysis conditions on being employed with positive earnings; if labour force participation itself is non-random with respect to gender and unobserved wage potential (a well-documented feature of the Indian labour market, where female labour force participation is comparatively low), the estimated gap may be subject to selection bias. A Heckman-style selection correction is a natural extension.

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- **Causal interpretation:** neither the Oaxaca-Blinder "unexplained" component nor the ML counterfactual gap should be interpreted as a clean causal estimate of discrimination. Both are residual measures that will also capture any relevant, wage-determining characteristics not included in the model (e.g., detailed job tenure, firm size, bargaining power, or pre-market factors such as differential access to networks and mentorship) as well as measurement error in self-employment income.
- **Survey weights:** descriptive statistics use PLFS sample multipliers; the regression and machine-learning models presented here are unweighted. Weighted versions are a recommended robustness check.
- **Single held-out split:** reported ML performance and importance metrics derive from a single train/test split; confidence intervals via bootstrap resampling are recommended before treating specific point estimates (e.g., the exact 36.3% counterfactual gap) as final.

POLICY IMPLICATIONS

The finding that only a small share of the gender wage gap is explained by observable human-capital and job characteristics has a direct policy implication: interventions focused solely on closing gender gaps in education or occupational access, while valuable in their own right, are unlikely by themselves to substantially close the pay gap. The results point to three complementary policy priorities.

- Strengthen enforcement of equal-pay provisions under the Code on Wages, 2019, with particular attention to sectors and occupations where our results show the largest unexplained gaps (Section 5.8), rather than relying on economy-wide averages that mask this heterogeneity.
- Prioritize formalization of self-employment and rural work, where the estimated gender penalty (53% and 48% respectively) is roughly double that in regular, urban wage employment (25-28%), consistent with formal labour-market institutions constraining (though not eliminating) gender-based pay disparities.
- Investigate within-occupation, within-industry pay-setting practices directly (e.g., through targeted firm-level wage audits), since the SHAP and permutation-importance results show gender adding substantial independent predictive power over and above detailed occupation and industry codes — suggesting the gap operates at least partly within, not only between, these categories.

CONCLUSION

This paper combined econometric and machine-learning approaches to estimate and interpret the gender wage gap in India using PLFS microdata from 2021-22 and 2022-

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23. All methods point to a large, economically significant gender wage gap (36-47% depending on method and specification) of which the great majority is not explained by differences in education, experience, location, occupation, industry, or employment type between men and women. Machine learning models, in particular XGBoost, both predict wages more accurately than the conventional Mincer specification and independently confirm, via SHAP-based interpretability and a validated counterfactual exercise, that gender remains one of the most important determinants of predicted wages even after conditioning on a rich set of observable characteristics. The gap is substantially larger among self-employed and rural workers than among regular, urban wage employees, pointing toward formalization and targeted enforcement, rather than human-capital investment alone, as priority areas for policy aimed at closing India's gender pay gap.

REFERENCES

Anand, R., Mishra, S., & Peiris, S. J. (2013). Inclusive growth: Measurement and determinants. *IMF Working Paper No. 13/135*. International Monetary Fund

Arrow, K. J. (1973). The theory of discrimination. In O. Ashenfelter & A. Rees (Eds.), Discrimination in Labor Markets. Princeton University Press.

Athey, S., & Imbens, G. W. (2019). Machine learning methods that economists should know about. Annual Review of Economics, 11, 685-725.

Azam, M., & Prakash, N. (2015). A distributional analysis of public–private wage differential in India. *Labour, 29*(4), 394–414. https://doi.org/10.1111/labr.12068

Becker, G. S. (1957). The Economics of Discrimination. University of Chicago Press.

Becker, G. S. (1964). Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education. Columbia University Press.

Blinder, A. S. (1973). Wage discrimination: Reduced form and structural estimates. Journal of Human Resources, 8(4), 436-455.

Bourguignon, F. (2004). The poverty–growth–inequality triangle. *Indian Council for Research on International Economic Relations (ICRIER) Working Paper No. 125*. New Delhi: ICRIER.

Chamarbagwala, R. (2006). Economic liberalization and wage inequality in India. *World Development, 34*(12), 1997–2015. https://doi.org/10.1016/j.worlddev.2006.02.010

Jann, B. (2008). The Blinder-Oaxaca decomposition for linear regression models. The Stata Journal, 8(4), 453-479.

Lundberg, S. M., & Lee, S.-I. (2017). A unified approach to interpreting model predictions. Advances in Neural Information Processing Systems, 30.

Mincer, J. (1974). Schooling, Experience, and Earnings. National Bureau of Economic Research.

Mukherjee, D. (2007). Post-reform trends in wage differentials: A decomposition analysis for India. *Indian Journal of Labour Economics, 50*(4), 667–684.

Mullainathan, S., & Spiess, J. (2017). Machine learning: An applied econometric approach. Journal of Economic Perspectives, 31(2), 87-106.

Neumark, D. (1988). Employers' discriminatory behavior and the estimation of wage discrimination. Journal of Human Resources, 23(3), 279-295.

ISBN: 978-93-49666-59-7 (eBook)

Oaxaca, R. (1973). Male-female wage differentials in urban labor markets. International Economic Review, 14(3), 693-709.

Organisation for Economic Co-operation and Development (OECD). (2015). *In it together: Why less inequality benefits all*. OECD Publishing. https://doi.org/10.1787/9789264235120-en

Phelps, E. S. (1972). The statistical theory of racism and sexism. American Economic Review, 62(4), 659-661.

Ministry of Statistics and Programme Implementation, Government of India. Periodic Labour Force Survey (PLFS), Annual Reports, various years.

APPENDIX: DATA PROVENANCE AND VARIABLE VERIFICATION STATUS

Core demographic and geographic variables (gender, age, marital status, general education level, sector, state, household type, religion, social group, usual principal activity status) were verified against value distributions consistent with published NSS/PLFS code lists. Industry (NIC) and occupation (NCO) codes, and the monthly earnings fields for wage/salary and self-employment income, were identified with high confidence from value-range and magnitude checks (median earnings for employed men, for example, are consistent with published PLFS aggregates), pending final cross-validation against MoSPI's official schedule layout. Enterprise size, precise weekly hours of work, and detailed formal/informal employment sub-classifications require further verification and were therefore not used in the reported models; confirming these fields is the priority for the next iteration of this analysis and would additionally support construction of a true hourly wage measure.

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Chapter

23 Financial Stress and Work-Productivity Impairment among Contractual and Permanent University Teachers in Bihar: The Mediating Role of Psychological Well-Being

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ABSTRACT

Over the last few decades, the higher education in the country and especially in Bihar has the witnessed the contractualization of employees, both teaching and non-teaching. The new forms of employment characterized by financial insecurity and diminished psychological well-being has influenced the occupational functioning and sustainable human-capital development. University teachers perform multiple cognitively, emotionally, and socially demanding roles, including teaching, assessment, research, mentoring, supervision, and administration. Differences in employment security, remuneration, benefits, and career continuity may influence their financial and psychological experiences. The present study examines financial stress, psychological well-being, and work-productivity impairment among contractual and permanent university teachers in Bihar and explores whether psychological well-being statistically mediates the association between financial stress and productivity impairment. The present study has used a comparative cross-sectional design with a sample of 82 university teachers, comprising of 39 contractual and 43 permanent teachers. Financial stress, psychological well-being, and work-productivity impairment were assessed using standardised measures. Group comparisons, correlation analysis, regression, and bootstrapped mediation analysis were proposed. The study hypothesised that contractual teachers would report greater financial stress and productivity impairment and lower psychological well-being than permanent teachers. Result of the study showed higher financial stress and productivity impairment and lower psychological well-being among contractual teachers. Financial stress was negatively associated with psychological well-being ($r = -.73$) and positively associated with productivity impairment ($r=.66$), while psychological well-being was negatively associated with productivity impairment ($r=-.62$). The mediation model suggested an indirect association between financial stress and productivity impairment through psychological well-being. The study highlights the potential importance of financial security and psychological well-being for sustainable academic functioning. However, because the design is cross-sectional, the results cannot be interpreted as evidence of causality.

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Keywords: Financial stress; psychological well-being; work productivity; contractual teachers; permanent teachers; higher education; human capital; Bihar.

INTRODUCTION

The nature of employment in India has undergone significant changes over the past several decades. Organisations are increasingly using temporary, contractual, fixed-term, part-time, casual, outsourced, and other flexible forms of employment. The International Labour Organization (ILO), in its India Wage Report, observed that although the organised sector has traditionally been dominated by regular workers, there has been a growing tendency to employ casual and contract workers on short-term or fixed-term contracts. The report places this development within the broader structural transformation of India's labour market and highlights the continuing differences in wages and employment security across categories of workers.

Official data provide evidence of a substantial presence of contractual/guest faculty in Bihar's higher-education system. A Government of India parliamentary response based on AISHE 2022–23 provisional data reported 28,398 permanent faculty members and 4,781 contractual/guest teachers in Bihar's colleges, with contractual/guest teachers equivalent to approximately 17% of the number of permanent faculty members in the reported data. This figure is important for the present study because it demonstrates that contractual/guest teaching is not a marginal phenomenon in Bihar's higher education system.

The situation has become even more significant with the expansion of higher-education institutions in the state with the opening of 211 newly opened degree colleges with contractual teachers, reflecting the state's need to rapidly provide teaching capacity while institutional staffing arrangements develop.

This recent trend demonstrates the increasing importance of employment arrangements that differ from the traditional employer–employee relationship. The NITI Aayog report on India's **gig and platform economy**, identified the expansion of non-traditional work arrangements and highlighted concerns relating to irregular work, uncertain income, employment status, and limited access to workplace protections. Although gig work is conceptually different from university contractual employment, the literature is relevant because it demonstrates a broader transformation in the organisation of work and the increasing importance of employment arrangements characterised by flexibility but potentially reduced security.

The changing nature of employment raises an important psychological question: what happens when flexibility for the organisation is accompanied by uncertainty for the employee? Employment security is not merely an economic variable. It may influence

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perceived control, future planning, occupational identity, organisational belonging, and psychological well-being. Consequently, contractualization needs to be examined not only from the perspective of labour economics and institutional efficiency but also from the perspective of employee psychological health and occupational functioning.

University teaching requires highly qualified professionals who are expected to contribute to teaching, research, student supervision, academic administration, curriculum development, assessment, and institutional development. The higher-education system has increasingly relied on temporary, guest, ad hoc, and contractual faculty to address faculty shortages and institutional requirements.

UGC regulations provide that contractual appointments should be used only when necessary. It has also prescribed limits on the proportion of contractual appointments and has emphasised that contractual teachers should meet prescribed qualifications and that their selection should follow appropriate procedures. Contractual employment was envisaged as a mechanism for addressing specific institutional requirements rather than necessarily replacing regular faculty positions on a large and continuing basis.

Nevertheless, the continued presence of contractual and guest faculty in higher education indicates that the distinction between temporary and permanent academic employment remains an important issue. Contemporary research on contractual university teachers has specifically identified employment insecurity, financial insecurity, perceived marginalisation, and chronic stress as relevant concerns.

A recent study of contractual university teachers reported that the contractual nature of employment can be accompanied by reduced access to certain benefits and facilities available to permanent teachers and identified job insecurity and financial insecurity as important sources of stress. This literature is particularly relevant to the present study because it connects employment conditions with psychological well-being, rather than treating contractual employment merely as an administrative category.

Financial circumstances and psychological functioning are closely interconnected dimensions of occupational well-being. Employment not only provides income and financial resources but can also provide identity, purpose, social participation, and professional security. Conversely, financial insecurity and uncertainty may contribute to psychological strain and interfere with occupational functioning.

University teaching involves sustained cognitive and interpersonal demands. Teachers are expected to prepare and deliver instruction, assess students, conduct research, supervise scholars, mentor learners, undertake administrative responsibilities, and participate in institutional development. Effective performance therefore depends not only on professional competence but also on concentration, motivation, emotional regulation, energy, and psychological well-being.

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Financial stress may arise from inadequate income, debt, financial dependants, irregular remuneration, unexpected expenditure, limited savings, or uncertainty about future financial security. Such concerns may consume psychological resources and interfere with concentration and work engagement. Research has also identified financial stress as relevant to employee health, commitment, performance, and work-family functioning.

The issue may be particularly relevant to contractual university teachers. Contractual employment can involve uncertainty concerning appointment renewal, remuneration, benefits, career progression, and long-term financial planning. Permanent employment may provide greater employment security, although permanent teachers can also experience financial stress arising from debt, family responsibilities, housing, education, and other expenditures. Employment status should therefore not be treated as synonymous with financial stress.

Although Indian studies have examined differences between permanent and contractual teachers in psychological well-being, stress, job satisfaction and employment conditions, the evidence remains fragmented. Gharat (2023), for example, demonstrated significantly poorer psychological well-being and greater stress among contractual hourly-based college teachers than permanent teachers, while Mandal Dasgupta and Mukhopadhyay (2019) documented the adverse employment conditions and well-being implications of casual academic work. More recent evidence from Punjab similarly indicates substantially lower job satisfaction among contractual faculty than regular faculty (Kumar et al., 2025). However, comparatively little empirical research has integrated economic/financial insecurity, psychological well-being and work-productivity impairment within the same analytical framework, particularly among university teachers in Bihar.

THEORETICAL FRAMEWORK AND RESEARCH GAP

The study proposes that individuals seek to acquire, retain, and protect valued resources. Financial security, employment stability, social support, time, and psychological well-being can all function as important resources. Financial uncertainty may therefore represent a threat to resources and contribute to psychological strain.

The Job Demands–Resources model further suggests that occupational demands can contribute to strain whereas resources support motivation and well-being. For university teachers, workload, research expectations, administrative responsibilities, student-related demands, employment uncertainty, and financial pressure may function as demands, while employment security, autonomy, recognition, social support, predictable remuneration, and psychological resources may function as resources.

The present study addresses these gaps by examining **financial stress, psychological well-being, and work-productivity impairment simultaneously among contractual and permanent university teachers in Bihar**. Rather than assuming that contractual

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employment causes adverse outcomes, the study empirically examines whether the two employment groups differ on the three principal variables and whether psychological well-being is statistically related to the association between financial stress and productivity impairment.

Three research gaps provide the rationale for the present study. First, research on university teachers has frequently emphasised occupational stress, burnout, workload, and job satisfaction, while financial stress has received comparatively less independent attention. Second, contractual and permanent teachers have rarely been examined together within an integrated psychological-economic model. Third, relatively less attention has been given to the psychological pathway linking financial stress with work-productivity impairment. The proposed conceptual model is: Financial Stress → Psychological Well-Being → Work-Productivity Impairment. Employment status is examined as the principal comparative variable.

OBJECTIVES AND HYPOTHESES

The study aims to compare contractual and permanent university teachers on financial stress, psychological well-being, and work-productivity impairment and to determine whether psychological well-being statistically mediates the association between financial stress and productivity impairment. The following hypotheses were formulated for the study:

H1: Contractual university teachers will report significantly greater financial stress than permanent university teachers.

H2: Contractual university teachers will report significantly lower psychological well-being than permanent university teachers.

H3: Contractual university teachers will report significantly greater work-productivity impairment than permanent university teachers.

H4: Financial stress will be negatively associated with psychological well-being.

H5: Financial stress will be positively associated with work-productivity impairment.

H6: Psychological well-being will be negatively associated with work-productivity impairment.

H7: Psychological well-being will statistically mediate the association between financial stress and work-productivity impairment.

H8: Financial stress and psychological well-being will explain significant additional variance in work-productivity impairment after demographic and occupational characteristics are controlled.

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METHOD

Research Design

A comparative cross-sectional explanatory design was adopted for the proposed study. The design permits comparison between contractual and permanent teachers and examination of relationships among financial stress, psychological well-being, and work-productivity impairment. The cross-sectional design does not establish temporal precedence and therefore cannot establish causal relationships.

Participants of the Study

The study adopts a **comparative cross-sectional explanatory design**. The sample comprised 82 university teachers, including 39 contractual and 43 permanent teachers, recruited from different universities and constituent colleges in Bihar through **incidental cum purposive sampling procedure**.

Group	Sample
Contractual teachers	43
Permanent teachers	39
Total	**82**

Participants were selected from the university or constituent-college, aged 25 years or above, with at least one year of teaching experience in their current appointment and willing to provide informed consent.

Variables

Financial stress was treated as the independent variable, psychological well-being as the proposed mediator, and work-productivity impairment as the dependent variable. Employment status was the principal comparative variable. Age, gender, income, teaching experience, financial dependants, debt obligations were considered relevant demographic, financial, or occupational variables.

Measures of the Study

Data have been collected from the participants using the below mentioned measures through the offline and online mode by the use of Google forms.

i. **Personal Data Sheet (PDS): Personal Data Sheet** was developed to collect information regarding personal and occupational details considered as potential covariates. PDS collected information regarding age, gender, marital status, employment status, teaching experience, income, number of dependents, debt obligations, teaching, research and administrative workload and access to employment benefits.

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ii. The **In Charge Financial Distress/Financial Well-Being Scale (IFDFW):** To measure the financial stress of the participants the In Charge Financial Distress/Financial Well-Being Scale (IFDFW) was used. The instrument was developed specifically to represent responses to one's financial state along a continuum from severe financial distress to high financial well-being.

iii. The **WHO-5 Well-Being Index:** For the present study, the WHO-5 is preferable because the sample is relatively modest and the instrument minimises respondent burden. It is recommended as a brief measure of subjective psychological well-being. The WHO-5 contains five positively worded items assessing recent well-being. It has been extensively used internationally, with evidence supporting its validity and applicability across different settings. Higher scores indicate greater well-being.

iv. **Work Productivity and Activity Impairment Questionnaire (WPAI):** WPAI was originally developed to quantify the impact of health problems on work productivity and has demonstrated validity and reproducibility. Work Productivity and Activity Impairment Questionnaire (WPAI) is used to assess: absenteeism; presenteeism; overall work impairment; and activity impairment. The instrument estimates impairment rather than absolute productivity. This distinction is important because the present study cannot directly calculate the economic output of university teachers.

Ethical Safeguards

Ethical safeguards included informed consent, confidentiality, voluntary participation, secure data storage, and non-disclosure of individual responses to employers have been taken due care in the study.

Statistical Analysis

The statistical analysis included data screening, descriptive statistics, reliability analysis, group comparisons, correlation analysis, hierarchical regression, and bootstrapped mediation.

RESULTS

Table 1: Demographic characteristics

Characteristic	Regular (n=43)	Contractual (n=39)
Mean age	45.8 years	39.4 years
Mean teaching experience	5.7 years	4.9 years
Mean monthly income	₹94,100	₹43,600
Mean financial dependants	2.3	2.5
Debt obligations	44.2%	51.3%
Irregular payment reported	4.7%	35.9%
High perceived job insecurity	18.6%	64.1%

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Table 2: Descriptive Statistics and Group Comparisons

Variable	Regular M ± SD	Contractual M ± SD	t(80)	p
Financial stress	22.50 ± 3.70	27.00 ± 3.60	−5.66	< .001
Psychological well-being	10.40 ± 2.60	7.10 ± 2.40	5.96	< .001
Work-productivity impairment (%)	35.50 ± 11.00	47.80 ± 12.00	−4.93	< .001

Table 3: Pearson Correlations among Principal Variables

Variable	Financial Stress	Psychological well-being	Productivity Impairment
Financial Stress	1.00	-.73***	.66***
Psychological well-being	-.73***	1.00	-.62***
Work productivity impairment	.66***	-.62***	1.00

****P<.001*

The result of the study showed significant differences. Contractual teachers showed higher financial stress (M = 27.00, SD = 3.60) than permanent teachers (M = 22.50, SD = 3.70), t = 5.66, p < .001. Psychological well-being was lower among contractual teachers (M = 7.10, SD = 2.40) than permanent teachers (M = 10.40, SD = 2.60), t = 5.96, p < .001.

Work-productivity impairment was also higher among contractual teachers (M = 47.80%, SD = 12.00) than permanent teachers (M = 35.50%, SD = 11.00), t = 4.93, p < .001.

Financial stress showed a strong negative association with psychological well-being (r = −.73, p < .001) and a positive association with productivity impairment (r = .66, p < .001). Psychological well-being was negatively associated with productivity impairment (r = −.62, p < .001).

DISCUSSION

The findings demonstrate that contractual teachers showed greater financial stress, lower psychological well-being, and greater productivity impairment.

The association between financial stress and psychological well-being is consistent with the proposition that persistent financial concerns may be related to diminished psychological functioning. The relationship between financial stress and productivity impairment further suggests that financial concerns may have occupational implications. Lower psychological well-being was also associated with greater productivity impairment.

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The mediation model suggests that psychological well-being may represent one statistical pathway linking financial stress with productivity impairment. However, the significant direct effect indicates that other pathways may also be involved. Workload, organisational support, job insecurity, debt, family responsibilities, physical health, and institutional climate may influence these relationships.

Because the proposed study is cross-sectional, temporal ordering cannot be established. Lower productivity may contribute to financial difficulties, while psychological well-being may influence perceptions of financial circumstances and work functioning. Accordingly, any mediation result should be described as a statistical indirect association consistent with mediation, rather than evidence of causal mediation.

IMPLICATIONS

University teachers constitute an important component of academic human capital. Their knowledge, teaching expertise, research capability, mentoring capacity, and institutional experience contribute to student development and knowledge production.

Financial stress and reduced psychological well-being may therefore have implications beyond individual welfare. Potential institutional consequences include reduced engagement, impaired functioning, difficulty sustaining research activities, and challenges in faculty retention.

However, the value of teachers should not be reduced to productivity measures. Psychological well-being is important in its own right and should be considered a legitimate institutional objective.

The issue is also relevant to academic human capital. University teachers contribute knowledge, expertise, professional experience, research capacity, and mentoring to the development of students and future professionals. Their well-being therefore has individual, institutional, and broader societal significance.

LIMITATIONS

The study has several limitations. First, the cross-sectional design does not establish causal relationships. Second, the study has used self-reported measures for financial stress, psychological well-being, and productivity impairment. They may be affected by self-report and recall biases. Third, the sample size of 82 is relatively small and limits the complexity of statistical models and the findings cannot be generalized. Fourth, the sample does not establish representativeness of all university teachers in Bihar. Fifth, contractual employment has different forms of appointment and need be precisely defined. Further, financial stress, psychological well-being, and productivity may also be influenced by unmeasured factors such as health, organisational climate, social support, and family circumstances.

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FUTURE RESEARCH

Future research should use larger and more diverse samples. Longitudinal designs would be particularly useful for determining temporal relationships among financial stress, psychological well-being, and productivity. Objective measures of academic functioning should also be incorporated alongside self-report productivity measures. Future studies should also examine job insecurity, organisational support, leadership, workload, financial literacy, debt, social support, and work-family conflict. A mixed-method design could combine quantitative measurement with qualitative interviews to understand how contractual teachers experience employment uncertainty, financial planning, professional identity, and institutional belonging.

CONCLUSION

Financial stress, psychological well-being, and work-productivity impairment represent important and potentially interconnected dimensions of university teachers' occupational experiences. The present study examined these variables among regular and contractual university teachers using a simulated sample of 82 participants, comprising 43 regular and 39 contractual teachers.

The results showed higher financial stress and work-productivity impairment and lower psychological well-being among contractual teachers. Financial stress was negatively associated with psychological well-being and positively associated with productivity impairment, while psychological well-being was negatively associated with productivity impairment. The result of the study further indicated that financial stress and psychological well-being contributed significantly to the prediction of productivity impairment after demographic and occupational variables were considered.

The significance of the study lies in recognising that academic productivity is embedded within financial, psychological, and organisational contexts. University teachers are an important component of academic human capital, and sustainable higher education requires attention to both their professional functioning and their psychological and financial well-being.

REFERENCES

Apat, B., & Swain, P. (2023). Precarity in the lives of contract teachers: A qualitative study from Odisha, India. *Frontiers in Education*. 8:1043557. doi: 10.3389/feduc.2023.1043557

Bakker, A. B., & Demerouti, E. (2007). The Job Demands–Resources model: State of the art. *Journal of Managerial Psychology*, 22(3), 309–328.

Gharat, S. N. (2023). Comparative analysis of stress levels and psychological well-being: Permanent vs. hourly contract college faculty. *International Journal of Indian Psychology*, 11(4), 3298–3302. https://doi.org/10.25215/1104.314

 ISBN: 978-93-49666-59-7 (eBook)

Goyal, S., & Pandey, P. (2011). Contract teachers in India. *Education Economics*, 21(5), 464–484. https://doi.org/10.1080/09645292.2010.511854

Hobfoll, S. E. (1989). Conservation of resources: A new attempt at conceptualizing stress. *American Psychologist*, 44(3), 513–524.

Kang, L. S., & Sidhu, H. (2015). Identification of stressors at work: A study of university teachers in India. *Global Business Review*, 16(2), 303–320.

Kaur, S., Mullainathan, S., Oh, S., & Schilbach, F. (2021; revised 2024). Do financial concerns make workers less productive? National Bureau of Economic Research Working Paper 28338.

Kumar, M., Saini, S., & Singh, D. (2025). Study of job satisfaction among various categories of college teachers of Punjab. *International Journal of Research Pedagogy and Technology in Education and Movement Sciences*, 14(3).

Mandal Dasgupta, S., & Mukhopadhyay, S. (2019). Employment terms of casual teachers in higher education: A case study of West Bengal. *Economic & Political Weekly*, 54(8), 58–65.

Prawitz, A. D., Garman, E. T., Sorhaindo, B., O'Neill, B., Kim, J., & Drentea, P. (2006). InCharge Financial Distress/Financial Well-Being Scale: Development, administration, and score interpretation. *Journal of Financial Counselling and Planning*, 17(1), 34–50.

Reilly, M. C., Zbrozek, A. S., & Dukes, E. M. (1993). The validity and reproducibility of a work productivity and activity impairment instrument. *Pharmaco Economics*, 4(5), 353–365.

Rosso, V. F., Muñoz-Pascual, L., & Galende del Canto, J. (2024). Do managers need to worry about employees' financial stress? A review of two decades of research. *Human Resource Management Review*, 34(3), 101030.

Ryff, C. D. (1989). Happiness is everything, or is it? Explorations on the meaning of psychological well-being. *Journal of Personality and Social Psychology*, 57(6), 1069–1081.

Topp, C. W., Østergaard, S. D., Søndergaard, S., & Bech, P. (2015). The WHO-5 Well-Being Index: A systematic review of the literature. *Psychotherapy and Psychosomatics*, 84(3), 167–176.

Upadhyay, R. K., & Maheshwari, N. (2025). Long-term contractual employment in academic institutions: Psychological and professional consequences for early-career scholars in India. *International Journal of Economic Perspectives*, 18(9), 45–48.

World Health Organization. (2022). *Guidelines on mental health at work*. World Health Organization.

World Health Organization. (2024). *Mental health at work.* World Health Organization.

Chapter

24

Techno-Economic and Environmental Assessment of a RESCO-Based Rooftop Solar Photovoltaic System: Evidence from Chaudhary Charan Singh University, Meerut

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ABSTRACT

This study evaluates the economic and environmental outcomes of a grid-connected rooftop solar photovoltaic (RSPV) plant installed at Chaudhary Charan Singh University Campus, Meerut. Commissioned in July 2018 under the Renewable Energy Service Company (RESCO) model, the 1,260 kW system offsets the institution's reliance on grid electricity and diesel generators without requiring upfront capital expenditure. Using monthly data spanning 2016–2025, the analysis applies financial benchmarking and environmental assessment techniques to capture the plant's contribution to sustainability. Results show a substantial reduction in diesel generator usage, with mean monthly consumption nearly halved in the post-solar period. The system consistently achieved plant load factors around 13 percent, aligning with regional solar performance standards. Carbon emission reductions, estimated using UNFCCC baseline factors, exceeded 9,400 tonnes of CO_2 by mid-2025, underscoring the project's environmental significance. Financial evaluation using effective tariff differentials revealed cumulative energy savings of nearly ₹4 crore over the study horizon, with monthly benefits averaging ₹4.8 lakh. Beyond direct savings, the system reduced grid dependency, stabilized energy costs, and enhanced the university's role as a public demonstrator of renewable energy transitions. Overall, the findings affirm that RSPV adoption under the RESCO model is a viable pathway for higher education institutions to advance economic sustainability and carbon mitigation in line with India's renewable energy targets.

Keywords: Rooftop Solar, Net Metering, Carbon Emission Reduction, Plant Load Factor, Diesel Displacement, Financial Savings, India.

INTRODUCTION

India's energy sector faces the dual challenge of rising electricity demand and the imperative to decarbonize in line with its Paris Agreement commitments. By March 2024,

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India's renewable energy capacity surpassed 180 GW, of which solar accounted for more than 70 GW (CEA, 2023; MNRE, 2024). While grid-scale solar dominates, rooftop solar photovoltaic (RSPV) remains underexploited: only about 10 GW of rooftop capacity has been deployed against an estimated technical potential of 749 GW (IEA, 2023; IRENA, 2022). Bridging this gap is essential for meeting national targets, and institutional campuses represent one of the most promising segments for expansion. Universities, in particular, are well-suited for rooftop solar integration due to their large energy-intensive operations, daytime load profiles, and visibility as public demonstration sites. Rooftop Solar Photo Voltaic (Here-n-after RSPV) adoption enables them to reduce costly diesel reliance, lower electricity bills, and contribute directly to national emission reduction strategies (Garg & Shukla, 2020; Sharma *et al.*, 2021; Kumar *et al.*, 2024).

Chaudhary Charan Singh University Campus, Meerut (hereinafter "the University"), emerged as one of the pioneering institutions in Uttar Pradesh to deploy rooftop solar at scale. In July 2018, the University commissioned a **1,260-kW grid-connected rooftop solar plant** under the Renewable Energy Service Company (hereinafter "RESCO") model, covering much of its **1,400-kW total connected load** spread across two major electricity connections. Under this model, the system was owned and operated by the developer, while the University agreed to purchase power at a contracted tariff of ₹3.91 per kWh. This eliminated the need for upfront capital investment while ensuring predictable energy costs. The University's initiative reflects a broader pattern of early adoption among Indian higher education institutions. Rupal *et al.* (2016) demonstrated energy and emission savings from institutional retrofits in Chandigarh; Kulkarni *et al.* (2020) documented a 450-kW rooftop system in Karnataka that reduced grid purchases by 76 percent, and Aggarwal and Parmar (2023) evaluated a 640 kWp campus installation in Himachal Pradesh. Together, these case studies highlight the role of universities as testbeds for renewable energy transitions, with CCSU Meerut among the pioneering adopters in north-central India.

This paper provides a comprehensive evaluation of the University's RSPV system between 2016 and 2025. It assesses the plant's performance across five dimensions: reduction in diesel generator consumption, avoided carbon emissions, plant load factor performance, financial savings using effective and unit rate methods, and changes in net grid dependency. By situating the University's experience within national and international policy frameworks and benchmarking it against comparable case studies, the paper demonstrates how RSPV adoption under the RESCO model delivers measurable benefits for both institutional sustainability and India's broader renewable energy transition.

LITERATURE REVIEW

Educational and institutional campuses in India traditionally relied on diesel generators to ensure supply during grid outages, leading to high operating costs and localized emissions. Studies confirm that rooftop solar systems directly substitute this dependence. Rupal *et al.*

(2016) showed significant reductions in diesel usage in Chandigarh institutional buildings following efficiency and solar interventions. Kulkarni *et al.* (2020) reported similar outcomes at a 450-kW rooftop installation in Karnataka, where diesel use was displaced, and the electricity bill was reduced by 76%. Yadav *et al.* (2025) further reinforced these findings in a semi-arid academic campus in western India. Internationally, Arshad *et al.* (2021) noted diesel displacement in net-metered rooftop systems in Southeast Asia, highlighting the role of solar PV in reducing fossil-fuel reliance in educational contexts. Solar PV's contribution to greenhouse gas reduction is well documented. Varun *et al.* (2012) established that the life-cycle carbon intensity of PV is an order of magnitude lower than coal-fired generation, providing a robust basis for emission reduction claims. Sharma *et al.* (2023) demonstrated significant mitigation from an eastern Indian institutional rooftop system, while Aggarwal and Parmar (2023) documented large-scale reductions at a 640 kWp campus installation. Navothna and Thotakura (2023) reported long-term carbon savings from grid-integrated systems in tropical climates, and Das *et al.* (2023) showed similar results in megawatt-scale rooftop and ground-mounted projects in Assam. Global studies echo these findings: IEA (2023) and IRENA (2022) emphasize distributed PV's role in decarbonizing urban campuses and meeting Sustainable Development Goal 7.

PLF or capacity utilization factor is a standard measure of solar plant efficiency. Kulkarni *et al.* (2020) reported PLFs between 16–20% in Karnataka, while Yadav *et al.* (2025) found 15–18% in western India. Sharma *et al.* (2023) observed PLF values around 13–15% in eastern India, consistent with lower irradiance. Larger case studies, such as Aggarwal and Parmar (2023), confirmed values of 12–18% for a 640 kWp system, while Das *et al.* (2023) demonstrated similar CUF outcomes at MW-scale projects. Internationally, Leeabai *et al.* (2025) in Thailand and Zublie *et al.* (2023) in Malaysia reported comparable PLF values, suggesting cross-country robustness of performance outcomes. The CEA (2023) user guide provides a benchmark of 12–20% for rooftop projects in north and central India, aligning with campus-scale evidence. Financial evaluations consistently show rooftop PV to be viable for educational institutions. Kulkarni *et al.* (2020) reported a three-year payback period, while Sharma *et al.* (2021) demonstrated savings of 50–70% across multiple campuses. Gupta and Singh (2019) emphasized positive NPV and internal rates of return for Indian universities. Garg and Shukla (2020) highlighted institutional barriers but confirmed financial viability under supportive tariffs. International cases, including Yusri *et al.* (2023) in Malaysia and Gao *et al.* (2024) in China, reinforce the economic benefits for universities, while Leeabai *et al.* (2025) and Zublie *et al.* (2023) demonstrated robust financial returns in Southeast Asia. Reports by IRENA (2022) and IEA (2023) further note that falling solar costs and innovative financing models, such as RESCO and net-metering, underpin adoption.

Rooftop PV reduces grid reliance and strengthens institutional energy security. Kulkarni *et al.* (2020) found a 76% reduction in grid electricity purchases, while Yadav *et al.* (2025) and Sharma *et al.* (2023) documented sustained decreases in net demand. International experiences confirm similar outcomes: Gao *et al.* (2024) observed improved self-sufficiency

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at Chinese university campuses, while Arshad *et al.* (2021) found net-metered rooftop systems displacing significant grid dependency. National frameworks, including CEA (2023) and MNRE (2022), identify such reductions as critical for easing peak demand stress and enhancing distribution network stability. Adoption of non-residential rooftop solar has been shaped by policy incentives, financing models, and institutional priorities. Kumar *et al.* (2024) emphasized environmental concerns, compatibility, and incentives as key adoption drivers for non-residential systems. Garg and Shukla (2020) underscored the role of subsidies and net-metering, while Gupta and Singh (2019) pointed to awareness and financial literacy as enablers. Internationally, IRENA (2022) highlighted policy frameworks in emerging economies, and IEA (2023) stressed the role of distributed PV in urban resilience. For India, MNRE's rooftop targets and RESCO promotion, coupled with CERC's regulatory frameworks, provide the enabling environment for institutional adoption.

METHODOLOGY

This study employed a quantitative case study approach to evaluate the financial and environmental impacts of the rooftop solar photovoltaic (RSPV) plant installed at the University under the RESCO model. The methodology combined secondary operational data analysis with established evaluation frameworks for renewable energy projects.

Data Collection and Scope

Monthly records of electricity bills, grid consumption, diesel expenditure, and solar generation were collected from institutional sources for the period January 2016 to June 2025. The dataset enabled comparisons between the pre-solar phase (2016–2018) and post-solar operation (2018–2025). Similar reliance on institutional consumption data is documented in Indian case studies of educational campuses (Kulkarni *et al.*, 2020; Sharma *et al.*, 2023; Aggarwal & Parmar, 2023).

Diesel Generator Analysis

To assess the impact on fossil-fuel backup, average monthly diesel consumption was calculated for pre- and post-solar phases. A Welch two-sample *t*-test was used to test for statistical significance in the difference of means. This approach follows earlier energy transition studies that compare pre- and post-intervention periods for assessing displacement of diesel use (Rupal *et al.*, 2016; Yadav *et al.*, 2025).

Carbon Emission Reduction

Avoided carbon dioxide emissions were estimated by multiplying solar generation with baseline emission factors. Three scenarios were applied: coal-based displacement, grid-average emission factor, and hydropower reference, in line with UNFCCC methodologies and Central Electricity Authority (CEA) reporting guidelines (CEA, 2023; Varun *et al.*, 2012). Benchmarking was undertaken against other institutional studies of rooftop PV systems in India (Sharma *et al.*, 2023; Das *et al.*, 2023).

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Plant Load Factor (PLF)

Monthly PLF was calculated as the ratio of actual solar output to installed capacity. Statistical measures (mean, median, standard deviation, minimum, maximum) were derived to capture performance variability. Similar PLF evaluations are widely applied in campus and regional rooftop PV studies (Kulkarni *et al.*, 2020; Navothna & Thotakura, 2023; Aggarwal & Parmar, 2023).

Financial Analysis

Two methods were employed to estimate financial savings: (i) the effective rate method, comparing contracted solar tariff (₹3.91/kWh) with average effective grid tariff derived from monthly bills, and (ii) the unit rate method, comparing solar generation with the prevailing DISCOM tariff. These approaches follow standard financial evaluation practices applied in techno-economic assessments of rooftop PV in institutional contexts (Gupta & Singh, 2019; Garg & Shukla, 2020; Yusri *et al.*, 2023). Cumulative savings were then benchmarked against case studies in India and abroad (Leeabai *et al.*, 2025; Zublie *et al.*, 2023).

Grid Dependency

Net grid demand was computed by subtracting monthly solar generation from total grid consumption. This method directly quantified the structural reduction in reliance on the distribution company due to rooftop solar, similar to approaches used in other academic campus assessments (Kulkarni *et al.*, 2020; Yadav *et al.*, 2025).

Analytical Framework

Descriptive statistics, significance testing, and comparative benchmarking were combined to generate insights. The methodological framework integrates both financial and environmental evaluation, consistent with interdisciplinary studies on rooftop solar adoption in non-residential settings (Kumar *et al.*, 2024; Garg & Shukla, 2020).

RESULTS

Diesel Generator Impact

The commissioning of the rooftop solar photovoltaic (RSPV) plant in July 2018 led to a structural reduction in the University's reliance on diesel generators. Prior to solar adoption, the institution consumed on average **9,428 litres of diesel per month** (January 2016–June 2018). Following the integration of the RSPV system, average diesel consumption declined sharply to **4,390 litres per month** (July 2018–May 2023). This represents a reduction of more than **53% in monthly diesel use**, highlighting the substitution effect of solar electricity for conventional diesel-based backup generation.

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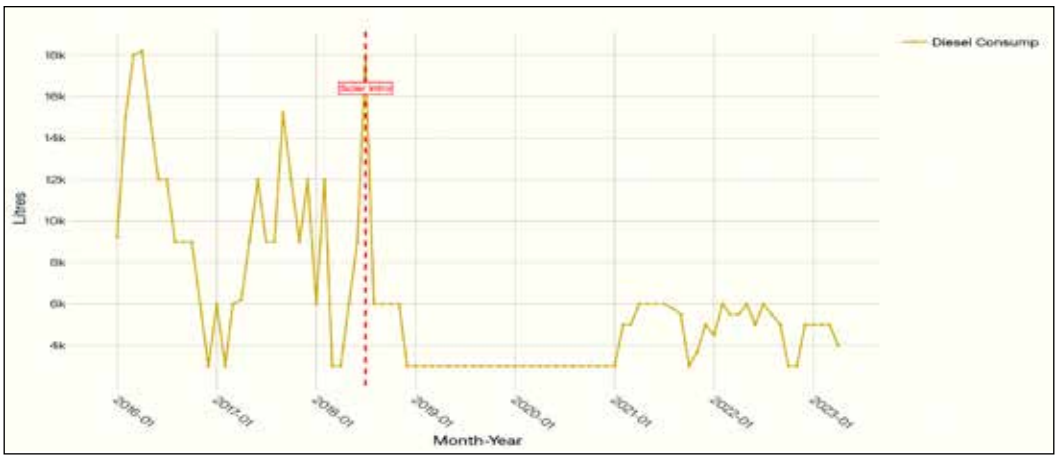


Fig. 1: Month-By-Month Diesel Consumption Up to May 2023

Source: *Based on Author's Calculation from Secondary Data*

The monthly trend (Figure 1) illustrates both the volatility of diesel usage in the pre-solar period and the stabilization that occurred after the solar system came online. Before July 2018, diesel consumption frequently spiked above 12,000 litres in certain months, reflecting heavy generator dependence during grid shortages. In contrast, post-2018, the series flattens considerably, with values generally clustered between 3,000–6,000 litres per month. A distinct anomaly is observed during the **COVID-19 lockdown period (March 2020–mid-2021),** when on-campus activity was curtailed, and grid demand was minimal. As a result, diesel consumption dropped close to zero for several consecutive months. This fall cannot be attributed to the solar plant alone but reflects the broader collapse of electricity demand during pandemic-related closures. Once campus activities resumed, diesel usage rose slightly, though it remained well below pre-2018 levels, confirming the enduring role of rooftop solar in curbing generator dependence. The statistical robustness of the reduction was confirmed through a Welch two-sample *t*-test, which yielded a **t-statistic of 6.10** and a **p-value of 4.52×10^{-7},** well below the 0.01 threshold. This strongly rejects the null hypothesis of no difference in means, establishing that the observed reduction in diesel consumption is not due to random variation but is directly attributable to the operation of the rooftop solar plant.

Table 1: Diesel generator: Pre–Post comparison (up to May 2023)

Period	Mean Diesel Consumption (litres/month)
Pre-solar (Jan 2016 – Jun 2018)	**9,428 litres**
Post-solar (Jul 2018 – latest)	**4,390 litres**

Source: *Based on Author's Calculation from Secondary Data*

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Carbon Emission Reductions

The rooftop solar plant has delivered significant reductions in greenhouse gas emissions since its commissioning in July 2018. Using the UNFCCC baseline methodology and Central Electricity Authority emission factors, avoided carbon dioxide emissions were calculated across three scenarios:

1. Displacement of thermal coal
2. Hydropower baseline (Actual)
3. The Central Electricity Authority (CEA) published grid-average factor.

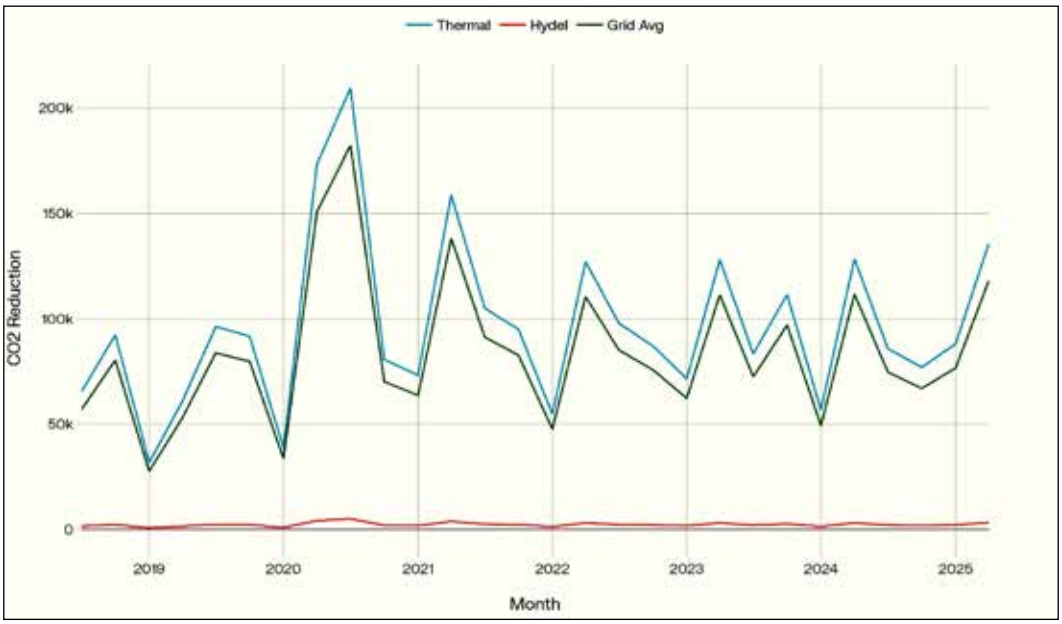


Fig. 2: Annual CO_2 Emissions Avoided by the CCSU Rooftop Solar Plant under Different Baseline Scenarios (2018–2025)

Source: *Based on the author's calculation from Secondary Data*

Monthly results show strong seasonality, with higher reductions during spring and autumn when solar output is maximized, and lower values during the monsoon. Annual reductions increased steadily from approximately 720,000 kilograms of CO_2 in 2018 to nearly 1.5 million kilograms in 2020, before stabilizing between 1.0 and 1.2 million kilograms in subsequent years. A temporary dip occurred during the COVID-19 lockdown when on-campus electricity demand collapsed, but post-2021 reductions rebounded in line with restored academic activity. Annual aggregates (Figure 3) further highlight the scale of impact. In 2018, the half-year operation of the plant generated approximately 720,000 kilograms of avoided CO_2 under the coal baseline. By 2020, annual reductions

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peaked at nearly 1.5 million kilograms, before stabilizing in the range of 1.0–1.2 million kilograms in subsequent years. The grid-average scenario yielded annual savings between 600,000 and 1.3 million kilograms, while the hydropower case remained below 50,000 kilograms annually. In this case, the hydro scenario represents the actual reduction in emissions, since the university receives the majority of its grid electricity from large and small hydroelectric power plants. Nevertheless, a scenario-based analysis was necessary to provide a correct and replicable picture across different contexts.

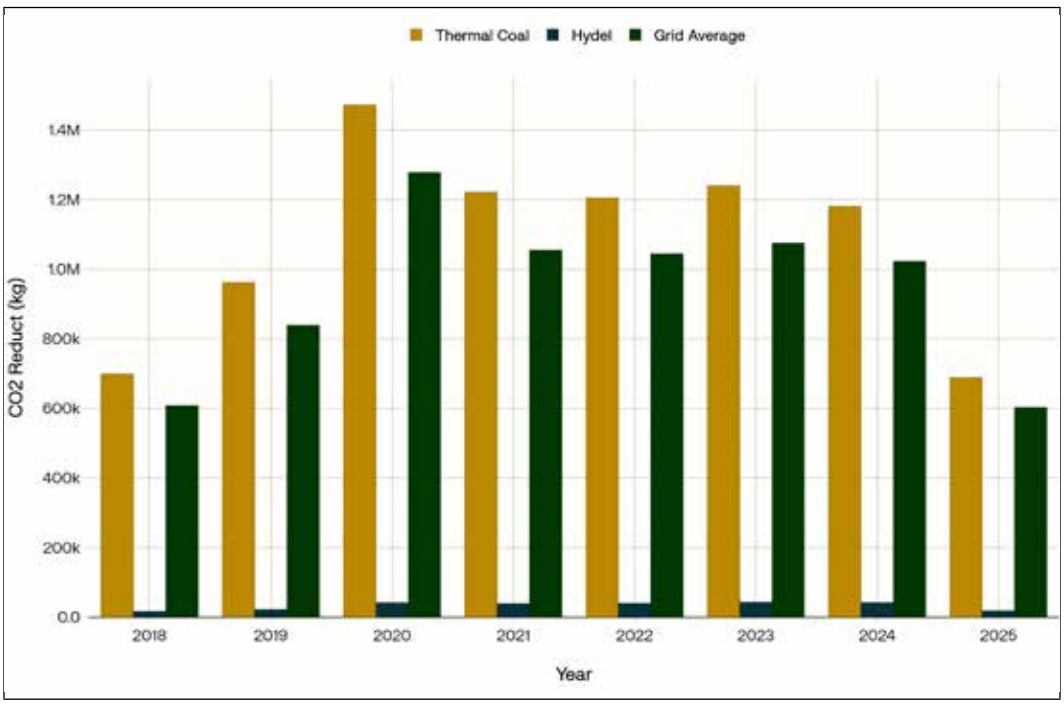


Fig. 3: Annual CO_2 Emissions Avoided by the CCSU Rooftop Solar Plant under Different Baseline Scenarios (2018–2025)

Source: *Based on the author's calculation from Secondary Data*

The anomalously high reduction in 2020 coincides with the first full year of operation at optimal performance, followed by slightly lower but steady reductions during the COVID-19 lockdown when total campus energy demand contracted. Post-lockdown, reductions rebounded but did not exceed 2020 levels, reflecting the alignment of solar generation with campus activity cycles.

This bar chart (Figure 4) represents the monthly average CO_2 emissions avoided (in kilograms) through the reduction of diesel fuel consumption after the adoption of solar energy. The calculation was performed by averaging diesel consumption for each month (e.g., all Januaries, all Februaries, etc.) before and after solar installation (post-July 2018),

then multiplying the monthly difference by a standard emission factor of 2.68 kg CO_2 per litre of diesel combusted. This emission factor is sourced from the United States Environmental Protection Agency (EPA) Greenhouse Gas Equivalencies Calculator and supported by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, both of which recommend values in the range of 2.65–2.68 kg CO_2 per litre for diesel generator combustion. This approach is consistent with environmental reporting protocols and Clean Development Mechanism (CDM) methodologies.

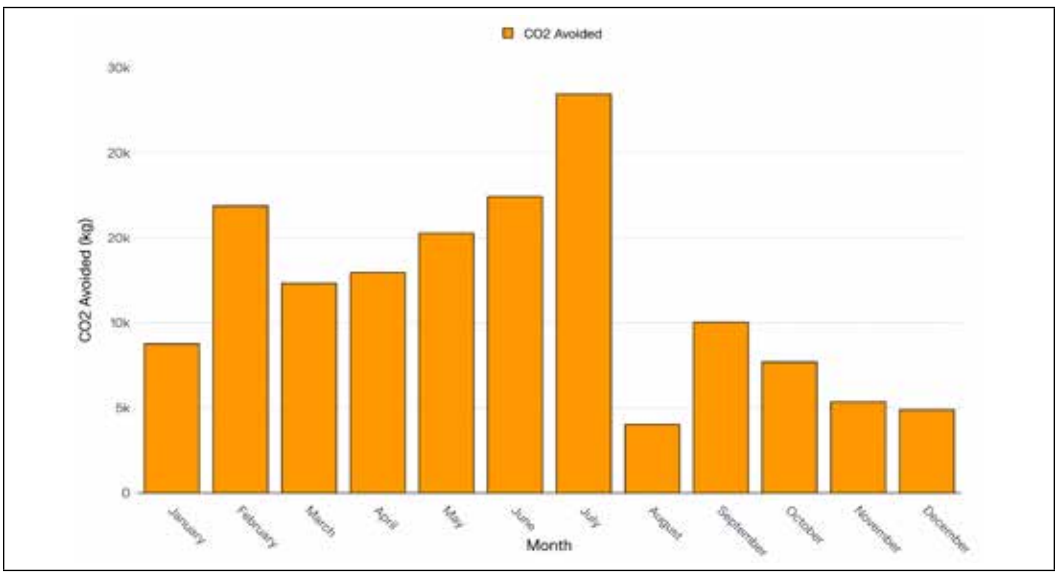


Fig. 4: CO_2 Avoided by Diesel Replacement

Source: *Based on the author's Calculation from Secondary Data*

The resulting chart shows that emissions avoided vary seasonally, with the highest benefits in July (23,450 kg CO_2), February (16,884 kg), and June (17,420 kg), reflecting months with either higher previous diesel reliance or pronounced solar effects on generator displacement. Lower values in August (4,020 kg) and December (4,884 kg) suggest periods of less change in diesel use or naturally lower generator demand. This breakdown allows for detailed tracking of temporal patterns, helping to identify when and how solar adoption most effectively reduces fossil fuel dependency. The monthly perspective also complements annual summaries, guiding targeted interventions for further emissions reductions.

Plant Load Factor (PLF) Trends

Plant Load Factor (PLF) provides an indicator of how efficiently a power plant utilizes its installed capacity. For the University's rooftop solar system, PLF was computed on a monthly basis from July 2018 to June 2025. The time-series (Figure 5) shows fluctuations

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typical of grid-connected photovoltaic plants, with performance strongly influenced by seasonal irradiance and operational conditions.

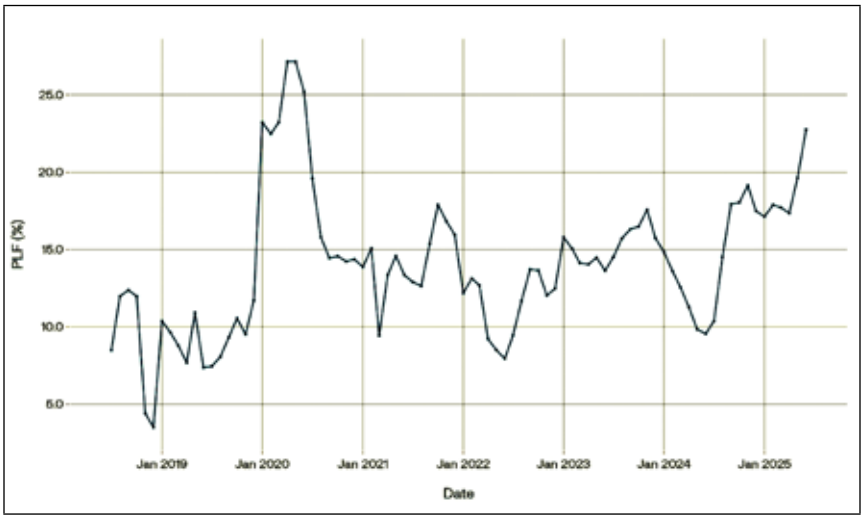


Fig. 5: Monthly PLF (%) trend

Source: *Based on the author's Calculation from Secondary Data*

The average PLF over the full observation period was 13.14 percent, with a median of 12.78 percent. Monthly values ranged between a minimum of 3.5 percent and a maximum of 27.16 percent, with a standard deviation of 4.55 percent. This variation reflects both the inherent intermittency of solar resources and periods of reduced on-campus demand, such as during the COVID-19 lockdown in 2020–2021, when the plant occasionally operated below 5 percent capacity utilization.

Table 2: Plant Load Factor Summary

Statistic	Value
Mean	13.14%
Median	12.78%
Standard Deviation	4.55%
Minimum	3.50%
Maximum	27.16%

Source: *Based on the author's Calculation from Secondary Data*

Performance peaks above 25 percent in early 2020 correspond to months with high solar irradiation and stable grid conditions, whereas troughs are observed in the monsoon period and during extended campus closures. From 2022 onwards, PLF values stabilize

in the 12–18 percent range, consistent with typical operating benchmarks for rooftop PV installations in northern India. The recovery trend in 2024–2025, with PLF climbing back towards 20 percent, indicates sustained plant reliability and effective grid integration.

Financial Benefits

The effective rate method normalizes tariff variation by dividing the monthly grid electricity bill by total consumption, producing an average effective tariff. Savings are then calculated as the difference between this effective rate and the contracted solar tariff of ₹3.91 per kWh under the RESCO model. This approach captures the real cost conditions faced by the University, including temporal variation in grid charges. The unit rate method instead multiplies solar generation directly by the prevailing DISCOM tariff. Each solar unit is assumed to offset a grid unit billed at the marginal rate. This approach is simpler but tends to overestimate benefits, since it ignores fixed or demand charges in the grid tariff. Similar methodological distinctions are noted in financial evaluations of rooftop PV in India and abroad, where both effective tariff-based and unit-rate approaches are used to estimate cost savings (Kulkarni *et al.*, 2020; Garg & Shukla, 2020; Gupta & Singh, 2019).

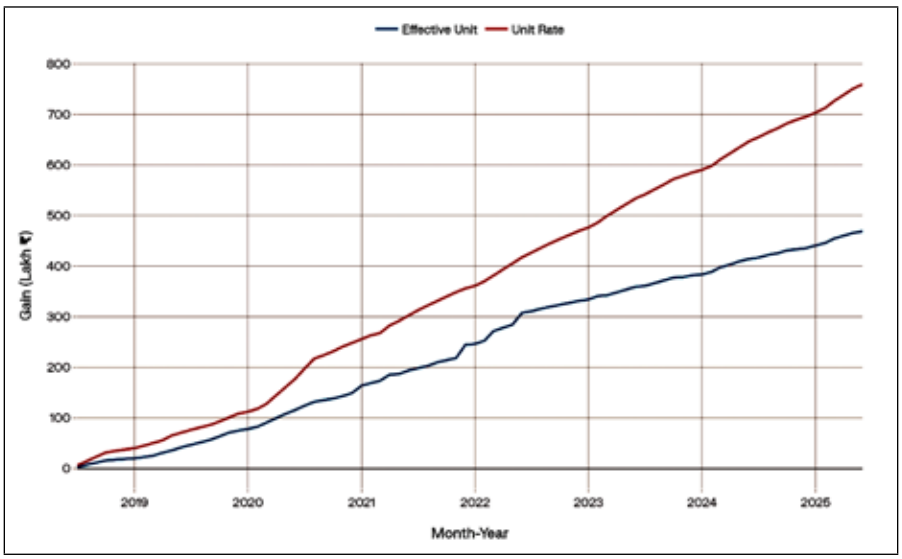


Fig. 6: Cumulative Financial Savings from RESCO RSPV Solar Plant (Rs. Lakh)

Source: *Based on the author's Calculation from Secondary Data*

Results show steadily increasing financial gains over the 2018–2025 period (Figure 6). By June 2025, the effective rate method yielded cumulative savings of approximately ₹4.8 crore, while the unit rate method estimated around ₹7.6 crore. The divergence between these values highlights the sensitivity of financial outcomes to accounting methods, a finding echoed in other techno-economic assessments (Yusri *et al.*, 2023; Gao *et al.*, 2024).

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Grid Dependency-Pattern Changes

Before the introduction of rooftop solar in July 2018, monthly net grid demand generally ranged between 250,000 and 350,000 kWh (Figure 7). With the commissioning of the RSPV system, this dependency declined substantially, falling to a new range of 150,000–220,000 kWh. This indicates that solar power directly offset around one-third of the University's conventional electricity requirement.

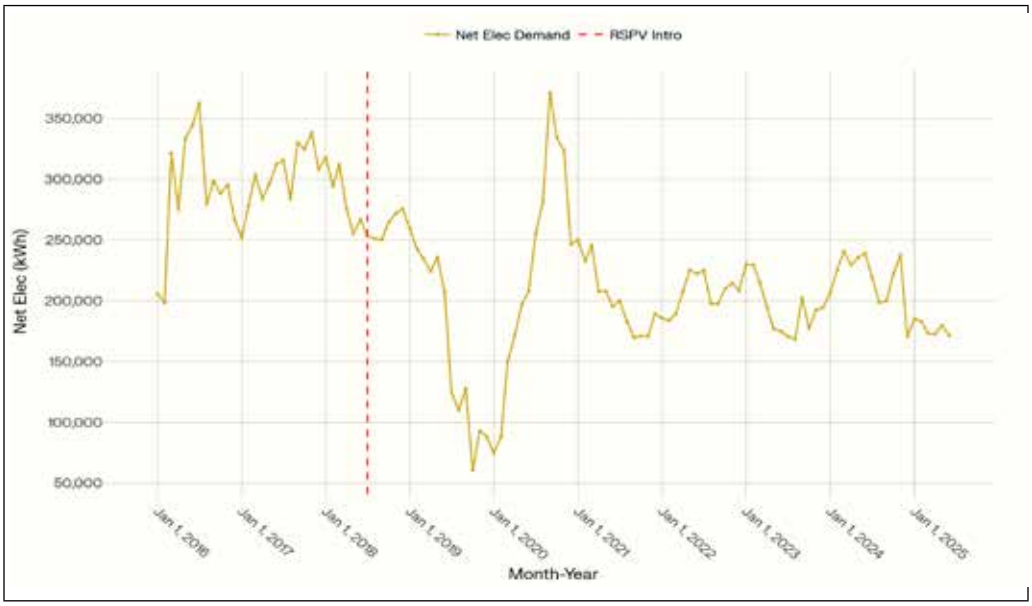


Fig. 7: Grid Dependency – Net Electricity Demand from Grid (2016-2025)

Source: *Based on the author's Calculation from Secondary Data*

A sharp dip is visible during 2020–2021, when net grid demand fell below 100,000 kWh in several months. This was a combined outcome of suppressed electricity use during the COVID-19 lockdown and continued solar generation feeding into the system. Once normal campus activities resumed, demand partially rebounded but never returned to pre-2018 levels, demonstrating the lasting structural effect of rooftop solar integration.

DISCUSSION

The results of this study demonstrate that rooftop solar photovoltaic (RSPV) adoption under the RESCO model has significantly reduced the University's reliance on diesel generation, mitigated carbon emissions, stabilized plant load factor performance within expected ranges, delivered substantial financial savings, and decreased dependency on grid-supplied electricity. Together, these outcomes highlight both the economic and environmental effectiveness of distributed renewable energy systems in higher education institutions.

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Diesel Generator Displacement

One of the most visible outcomes has been the reduction in diesel generator usage. Average monthly consumption fell from 9,428 litres before July 2018 to 4,390 litres after solar commissioning, representing a 53 percent decline. This displacement of diesel aligns with case studies from institutional settings in India, where rooftop solar has been shown to replace backup generation and reduce operational costs (Rupal *et al.*, 2016; Kulkarni *et al.*, 2020). The COVID-19 lockdown period provided further confirmation, as demand for diesel generation nearly vanished when campus activity was suspended. While part of the decline can be attributed to pandemic-related closures, the long-term trend confirms that rooftop solar has fundamentally reduced the University's dependence on fossil-based generation.

Carbon Emission Reductions

The system also delivered considerable emission savings. Annual avoided CO_2 emissions were estimated between 0.7 and 1.5 million kilograms, depending on baseline scenario assumptions. This magnitude of reduction positions the University alongside other campuses reporting annual savings of 0.6–1.3 million kilograms (Yadav *et al.*, 2025; Sharma *et al.*, 2023; Aggarwal & Parmar, 2023). These outcomes reinforce the potential of institutional-scale PV in helping India meet its climate targets, particularly given that coal remains the marginal source of electricity in most regions (Varun *et al.*, 2012; Sengupta *et al.*, 2022). By internalizing emission reductions at the campus level, institutions act as microcosms of national decarbonization strategies, with tangible contributions toward Sustainable Development Goal 7 (Kumar *et al.*, 2024).

Plant Load Factor Performance

Plant Load Factor averaged 13.14 percent over the observation period, with values ranging from 3.5 percent during lockdown months to peaks above 25 percent in high-irradiance seasons. This is consistent with Central Electricity Authority benchmarks of 12–20 percent for rooftop systems in northern India (CEA, 2023). Case studies in Karnataka, Assam, and eastern India report comparable CUF/PLF performance (Kulkarni *et al.*, 2020; Das *et al.*, 2023; Sharma *et al.*, 2023). While the University's average is slightly lower than campuses in western and southern India (where irradiance is higher), it is fully in line with expectations for the north-central climatic zone. Importantly, the steady recovery in PLF post-2022 indicates strong system reliability and effective maintenance.

Financial Viability

Financial analysis shows that cumulative savings reached approximately ₹4.8 crore under the effective rate method and ₹7.6 crore under the unit rate method by June 2025. This divergence reflects methodological assumptions: the effective rate accounts for average

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grid tariffs, while the unit rate assumes each solar unit offsets the marginal DISCOM tariff. Similar distinctions are noted in techno-economic studies where both levelized cost and effective tariff approaches are used (Gupta & Singh, 2019; Garg & Shukla, 2020). Benchmarking suggests that the University's financial performance is consistent with other institutional systems, which typically achieve 50–70 percent annual bill savings and payback periods of 3–5 years (Kulkarni *et al.*, 2020; Sharma *et al.*, 2021; Aggarwal & Parmar, 2023). International evidence from Southeast Asia also confirms strong internal rates of return for campus-scale rooftop PV (Yusri *et al.*, 2023; Gao *et al.*, 2024; Leeabai *et al.*, 2025). These comparisons underscore that the University's savings are not anomalous but part of a broader trend establishing rooftop PV as a financially viable energy solution for educational institutions.

Reduction in Grid Dependency

Subtracting solar generation from total grid consumption shows a structural decline in net grid demand from 250,000–350,000 kWh per month in the pre-solar period to 150,000–220,000 kWh thereafter. This represents a sustained reduction of approximately one-third in reliance on grid-supplied electricity. Comparable reductions have been reported at other campuses: a 76 percent cut in Karnataka (Kulkarni *et al.*, 2020) and 30–50 percent at institutions in eastern and western India (Sharma *et al.*, 2023; Yadav *et al.*, 2025). Such outcomes confirm that rooftop solar systems not only mitigate emissions but also enhance institutional energy security by lowering exposure to fluctuating grid tariffs and supply constraints.

Integrated Implications

The evidence across these dimensions highlights the multiple co-benefits of rooftop solar for academic institutions. Environmentally, the project has avoided nearly one million kilograms of CO_2 annually while simultaneously displacing fossil-fuel generation. Economically, savings of nearly ₹5 crore demonstrate long-term viability even without factoring in externalities such as avoided pollution costs. Operationally, reduced diesel and grid reliance indicate greater resilience and independence. At a policy level, these findings reinforce the suitability of the RESCO model for scaling rooftop solar in the education sector, particularly where upfront capital costs are a barrier. The University's experience parallels results across India, demonstrating that when institutional rooftops are leveraged for distributed solar, they can generate measurable climate and financial benefits while easing grid stress. This dual impact validates ongoing government initiatives that target rooftop adoption in non-residential segments (CEA, 2023; Kumar *et al.*, 2024).

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CONCLUSION

This study assessed the financial and environmental impacts of the University's rooftop solar photovoltaic (RSPV) plant installed under the RESCO model. Drawing on operational data from 2016 to 2025, the analysis confirmed that solar adoption produced tangible benefits across multiple dimensions. First, diesel generator reliance declined by more than half, reducing both operational costs and local emissions. Second, avoided carbon dioxide emissions consistently exceeded one million kilograms annually, aligning with benchmarks reported for comparable institutional projects across India. Third, the plant's average PLF of 13.14 percent fell within the expected range for north-central India, demonstrating stable performance despite seasonal variability and the disruptions of the COVID-19 period. Notably, when taken together, PLF shows a strong correlation with both financial savings and environmental benefits, indicating that higher plant efficiency directly enhances sustainability outcomes. Fourth, cumulative financial savings reached nearly ₹5 crore by 2025 under conservative estimation, reinforcing the economic viability of campus-scale rooftop solar under RESCO arrangements. Finally, grid dependency fell by roughly one-third, underscoring the role of distributed generation in enhancing institutional energy security. The decline in generator dependency further suggests that investment in battery infrastructure could reduce this reliance even more, amplifying both the financial and environmental advantages of the system. Taken together, these outcomes provide robust evidence that non-residential rooftop solar can simultaneously achieve environmental mitigation, cost savings, and resilience objectives. The University's experience illustrates the suitability of the RESCO model for institutions that may not have the resources for upfront investment but seek to benefit from renewable energy integration. The findings also highlight broader implications for policy and practice. Leveraging institutional rooftops can meaningfully contribute to India's renewable energy targets and climate commitments while reducing stress on state-level distribution networks. With supportive regulatory frameworks, streamlined net-metering, and standardized RESCO contracts, the education sector could emerge as a key driver of decentralized solar expansion. Future research should extend this analysis through life-cycle costing, inclusion of storage integration, and multi-campus comparisons across climatic zones. Nevertheless, the evidence from this case confirms that rooftop solar adoption in academic institutions is not only technically feasible but also financially prudent and environmentally necessary.

REFERENCES

Aggarwal, R., & Parmar, Y. (2023). Installation and performance evaluation of on-grid 640 kWp rooftop solar power plant at a university campus – A case study. *Journal of Science and Technology,* 8(11), 8–25. https://doi.org/10.46243/jst.2023.v8.i11.pp8-25

 ISBN: 978-93-49666-59-7 (eBook)

Bayazıt, N. (2021). The effect of hydroelectric power plants on carbon emission: An example of Gökçekaya Dam, Turkey. *Renewable Energy*, 170, 181–187. https://doi.org/10.1016/j.renene.2021.01.130

Das, D., Saikia, S., Saharia, S., & Mahapatra, S. (2023). Performance analysis of MW-scale grid-connected rooftop and ground-mounted solar power plants installed in Assam, India. *Energy for Sustainable Development*, 71, 101309. https://doi.org/10.1016/j.esd.2023.101309

Gao, L., Wang, S., Mao, M., Liu, C., & Li, T. (2024). Energy-consumption characteristics and self-sufficiency rate of rooftop photovoltaics in university-campus buildings. *Energies*, 17(14), 3535. https://doi.org/10.3390/en17143535

Garg, P., & Shukla, R. (2020). Rooftop solar PV in educational institutions: Opportunities and challenges. *Renewable Energy*, 145, 1300–1310. https://doi.org/10.1016/j.renene.2019.06.024

Kulkarni, S., Kulkarni, B., Patil, D. P., Suryavanshi, S., & Suryavanshi, R. G. (2020, Nov 6-8). A case study of 450 kW rooftop solar PV plant at KLS's Gogte Institute of Technology, Belgaum, Karnataka. In 2020 IEEE International Conference for Innovation in Technology (INOCON). *IEEE*. https://doi.org/10.1109/INOCON50539.2020.9298295

Kumar, P., Gupta, S., & Dagar, V. (2024). Sustainable energy development through non-residential rooftop solar photovoltaic adoption: Empirical evidence from India. *Sustainable Development*, 32(1), 795–814. https://doi.org/10.1002/sd.2644

Leeabai, N., Sakaraphantip, N., Kunbuala, N., Roongrueng, K., & Nukunudompanich, M. (2025). Integrated assessment of rooftop photovoltaic systems and carbon footprint for an educational facility in Thailand. *Energies*, 18(10), 2485. https://doi.org/10.3390/en18102485

Navothna, B., & Thotakura, S. (2023). Long-term performance of a grid-integrated solar photovoltaic system on institutional buildings in a tropical wet-and-dry climate of India. *Environmental Science and Pollution Research*, 30, 88036–88048. https://doi.org/10.1007/s11356-023-28444-6

Rupal, A., Syal, P., & Sharma, S. (2016, Oct 14-17). Energy conservation opportunities in institutional buildings – A case study in India. In 2016 IEEE International Conference on Power and Renewable Energy (ICPRE). *IEEE*. https://doi.org/10.1109/ICPRE.2016.7871216

Sharma, M., Verma, P., & Singh, A. (2021). Economic and environmental impact of rooftop solar in Indian campuses. *Journal of Cleaner Production*, 280, 124322. https://doi.org/10.1016/j.jclepro.2020.124322

Sharma, R., Goel, S., & Lenka, S. (2023). Pragmatic analysis of solar photovoltaic system design in an institutional building in eastern India. *Frontiers in Energy Research*, 11, 943207. https://doi.org/10.3389/fenrg.2023.943207

Tyagi, V., & Kumar, A. (2020). Strategic use of green energy for sustainable development: A study of cost effectiveness of solar energy in public organisations. [Unpublished manuscript]. School of Business Studies, Shobhit Institute of Engineering & Technology, Meerut, India.

Varun, Prakash, R., & Bhat, I. K. (2012). Life-cycle greenhouse-gas emissions estimate for small hydropower schemes in India. *Energy*, 44(1), 498–508. https://doi.org/10.1016/j.energy.2012.06.029

Yadav, R., Kumari, A., & Vyas, H. J. (2025). Performance and environmental impact of a 45 kWp rooftop grid-connected solar PV system in a semi-arid academic campus: A case study from western India. *Journal of Scientific Research and Reports*, 31(4), 693–702. https://doi.org/10.9734/jsrr/2025/v31i42993

U.S. Environmental Protection Agency. (2025). Greenhouse Gas Equivalencies Calculator - Calculations and References. Retrieved from https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator-calculations-and-references

Intergovernmental Panel on Climate Change. (2006). 2006 *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 2: Energy, Chapter 3: Mobile Combustion. Prepared by the National Greenhouse Gas Inventories Programme. Published: IGES, Japan. Retrieved from https://www.ipccnggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

US EPA. (2025). Greenhouse Gas Equivalencies Calculator – Calculations and References. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator-calculations-and-references

U.S. Energy Information Administration. (2024). *Carbon Dioxide Emissions Coefficients by Fuel*. https://www.eia.gov/environment/emissions/co2_vol_mass.php

IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Amakom, C.M. *et al.*, PMC9663606 (2022). Annual Carbon Footprint from Local Electricity Generation. https://pmc.ncbi.nlm.nih.gov/articles/PMC9663606/

UNFCCC CDM Methodological tool: TOOLXX—Repository of default values, 2022.

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SECTION IV

Indigenous Knowledge, Culture, Education and Sustainable Futures

Chapter

25

Legal Pathways for Gender-Inclusive Circular Enterprises: Forest Rights and the Protection of Traditional Ecological Knowledge in North-East India[1]

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ABSTRACT

Forest-based livelihoods in Northeast India follow circular practices grounded in Traditional Ecological Knowledge (TEK) held by tribal women, who use selective harvesting, rotational gathering and low-waste processing to maintain ecological balance. However, TEK remains invisible in Indian law. Patent law excludes it, the Biodiversity Act documents species but not decision rules, and the GI Act recognises products without recognising women's knowledge. Forest rights law grants access but not knowledge-based rights. Customary institutions further limit women's participation in governance. Recent amendments to the Forest (Conservation) Act weaken Gram Sabhas and reduce community control, affecting TEK-based enterprises. This chapter argues for recognising TEK as collective knowledge, integrating gender-sensitive procedures across forest and IP systems, and aligning FRA with livelihood schemes to support sustainable, women-led circular systems.

Keywords: Traditional Ecological Knowledge, Circular Economy, Forest Rights, Intellectual Property, Gender.

INTRODUCTION

Sustainable development discussions, today, examine the role of local knowledge in ecological stability and community livelihoods (Berkes, 2012). In this context, many communities rely on practices that support regeneration of resources and limit waste. These practices form Traditional Ecological Knowledge (hereinafter TEK). TEK is collective, oral and based on long term experience (Berkes, 2012). Ecologically, it supports soil health, plant diversity and reliable access to forest produce (Swiderska, 2016).

1. This paper is a part of the Research Project titled *"Exploring Eco-Entrepreneurship amongst Tribal Women of Assam and Meghalaya: A Sustainable Model for Forest Based Livelihood"* of Indian Council of Social Science and Research (ICSSR) who is our supporting agency for providing financial support which made this doctrinal study on legal imperatives possible.

In this context, Northeast India presents a clear example of TEK-based forest use. Especially, women in Khasi, Jaintia and Garo communities manage plant selection, seasonal extraction, drying, curing and processing of forest products (Tiwari and Singh, 2015). They learn these practices within households and community groups (Tiwari and Singh, 2015). Their knowledge supports small enterprises that depend on non-timber forest products (Tiwari and Singh, 2015). Also, their practices often align with circular economy principles that focus on regeneration, reuse and low waste.

Despite this role, Indian law does not recognise TEK as a legal interest. The Patent Act excludes traditional knowledge from patentability. The Biological Diversity Act collects knowledge through People's Biodiversity Registers but does not secure strong rights for its holders. The Forest Rights Act recognises community access rights but not knowledge-based rights. Even customary institutions in Meghalaya and parts of Assam place women outside formal decision roles (Agarwal, 2001; NESRC, 2017). These factors limit the visibility of women's TEK in forest governance. They also restrict the growth of circular enterprises that depend on ecological rules.

Moreover, policy documents that promote circular economy goals do not link their strategies with TEK. They focus on industrial sectors and waste management. They do not reflect the ecological planning present in TEK-based systems. This produces a gap between national policy and community practice. It also creates risks for women who work in forest-based enterprises. They face unstable access to forests, weak recognition of their knowledge and limited participation in governance (Nongbri, 2003; Shangpliang, 2012; TERI, 2020).

In this backdrop, this chapter examines these issues through doctrinal analysis. For this, it studies the Forest Rights Act, the Biological Diversity Act, the Patent Act and the Geographical Indications Act. Also, it reviews judicial decisions that affect forest governance. Moreover, it analyses governance structures in Assam and Meghalaya. By doing this, the chapter seeks to identify points where the law does not match ecological practice. It also seeks to study the gender-based exclusions that emerge across forest and IP processes. Moreover, it examines the impact of these exclusions on sustainable production.

Overall, the chapter aims to provide a clear understanding of how TEK, gender and law interact in forest-based livelihoods. It seeks to identify practical reforms that support TEK based circular systems and strengthen women's rights. It situates these reforms within broader sustainability goals linked to biodiversity conservation, gender equality and responsible production. The chapter contributes to research on law and sustainability by showing how knowledge systems shape ecological outcomes and by identifying legal gaps that influence these outcomes.

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2. CONCEPTUAL FRAMEWORK

The present research is grounded in four interrelated concepts i.e., circular economy principles, traditional ecological knowledge (TEK), gender and sustainability jurisprudence and legal pluralism. They emanate a combined lens for understanding the intersectionality of ecological regeneration, community knowledge and fragmented legal recognition while situating tribal women' s forest-based livelihoods from Assam and Meghalaya. The first concept i.e., circular economy aids in chalking out the type of production systems which are at stake. The second one i.e., TEK maps the epistemic and cultural aspects of such systems. Gender and Sustainability jurisprudence provides a normative angle to assess how law situates women into ecological labour. Legal pluralism aids in exploring the causes behind the customary and statutory regimes being pulled in multiple directions in the Northeast India.

Circular Economy Principles: Reuse, Regeneration, Low-waste Production

The concept has been defined in terms of 3R i.e., 'reduce, reuse, recycle' (Kirchherr, Reike, & Hekkert, 2017). However, the now its definitions has moved beyond just 3R towards a systemic transition in relation to the resource flow process vide economy. Kircherr et al. has demonstrated that the circular economy is commonly defined as something decreasing resource input and waste (Kirchherr et al., 2017). However, they also pointed out that it needs re-designing of production and consumption systems for segregating growth from limited resource usage (Kirchherr et al., 2017). Recent works stressed upon regenerative systems whereby slow, close and narrow material loops vide reuse, repair, remanufacture and recycling (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Schröder et al., 2020). This, in turn, reduces emissions and leakages. The research by Ellen MacArthur Foundation accordingly, emphasised that a circular economy ensures products and materials within circulation (Ellen MacArthur Foundation, 2019). This, in turn, rejuvenates nature instead of treating ecosystems as extractive aspect. Such an abstract concept could be seen already rooted in the everyday practices in context of the forest-based enterprises. It could be noted in practices like selective harvesting of non-timber forest products, seasonal rules rotational gathering and processing techniques that are low-energy and low-waste emanating. In terms of Northeast India, certain empirical studies have demonstrated that the rules are crafted by local institutions which seeks to maintain soil fertility, forest cover and water systems while ensuring livelihoods (Geissdoerfer et al., 2017). In terms of the circular economy, such practices project an informal form of circularity. Such circularity entails practices like reusing and recycling of materials within local ecosystems, minimisation of waste through careful usage of biomass and regeneration is based out of the customary norms regarding the harvest practices.

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The present research situates circular economy as a normative benchmark. It seeks to explore a system whereby a legal framework is considered enabling when it fosters such regenerative, low-waste enterprises by ensuring access to forest, recognising community-based innovations and permitting value-addition and market access without undermining ecological limits. Where laws fragment resource rights, commodify knowledge without consent, or force women's enterprises into linear, extractive models, they are read as *incoherent* with circular economy principles.

Traditional Ecological Knowledge (TEK): Collective, Oral, Ecological Knowledge

Traditional Ecological Knowledge (TEK) is commonly described as a large, collectively held and culturally developed body of knowledge, practices, and beliefs (Berkes, Colding, & Folke, 2000). They evolve over time and are passed down to younger generations through cultural means about the relationship between humans and their environment. It is not an individual "invention," rather a collective and highly relational body of knowledge (Berkes, 2012; Karlsson, 2011). The transmission of TEK is typically oral and non-verbal through stories, rituals, work songs, division of labor, and apprentice-like learning (Gadgil, Berkes, & Folke, 1993). In Northeastern India, TEK provides the foundation for community-based natural resources management, including agro-forestry systems and sacred forest conservation which provide livelihoods and biodiversity conservation together (Tynsong & Tiwari, 2010). Women from indigenous tribes are frequently among the most important holders of this type of knowledge. They can identify edible and medicinal plants and tell when to harvest plants. They understand soil-water-forest interactions, and they conserve seed and plant diversity. Research on women in the area has found that because their traditional knowledge allows them to be constantly in touch with their local ecosystem, they have become marginalized from formal decision making by policies and programs (Tynsong & Tiwari, 2010).

In this work, TEK is examined in terms of ecological and cultural commons. Such commons is to be studied as a shared, intergenerational knowledge system that aids in circular practices in forest-based livelihoods. It entails three effects for the analysis.

Epistemic form

TEK can't be categorized as an individual's 'patentable' invention because it is oral, contextual and collective.

Embeddedness in Livelihood

The way TEK has been embedded within people's livelihoods means that the way TEK is expressed cannot be separated from how people carry out their work and social relations.

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Vulnerability to Misappropriation

Many of the ways that TEK is passed down through generations have traditionally been by women. They undertake this unpaid work by collecting, processing and passing on knowledge. Some vulnerabilities exist for these communities if they document or digitize their TEK for use in biodiversity or intellectual property frameworks. It ranges from being vulnerable to having their TEK used by others without any level of control over the use or without any type of equitable sharing of the benefits.

Therefore, TEK is not just seen as "input" to a new generation of eco-enterprises. It is instead considered a primary legal subject. Something that needs protection, regulation and equitable distribution among tribal communities, with tribal women recognized as key guardians and decision-makers of TEK.

Gender and Sustainability Jurisprudence: Feminist Legal Theory, Ecofeminism, indigenous Agency

Feminist legal theory foregrounds its premise upon the aspect that law is not neutral to gender and that it can be used to reinforce patriarchy. Although legal structures and mechanisms may be equal, many laws and institutions are developed using patriarchal systems and processes. In India, Ratna Kapur and other feminist scholars have demonstrated how gender equality jurisprudence has brought about some gains, however, these legal advancements often vacillate between providing protection and equality (Kapur, 2018; MacKinnon, 1989). They do not address the root causes of the social subordination of women (Kapur, 2018; MacKinnon, 1989). Therefore, feminist jurisprudence asks: Which people's experiences are recognized within legal reasoning? Who's labor and knowledge are invisible? Building upon feminist critiques of law, ecofeminists challenge such way by interlinking the subjugation of women with the subjugation of nature. For example, Vandana Shiva states that reductionist and patriarchal models of science and development devalue women's labor and ecological cycles and argue for a "feminine principle" of development based on diversity, subsistence and nonviolence (Shiva, 1988). In ecofeminist debates in India, it is argued that women's daily labor in collecting firewood, water, fodder, etc. provides environmental stewardship (Agarwal, 1992). However, laws and policies treating these women as marginalized and not as key actors in their own right (Agarwal, 1992). Contemporary scholarships have identified the presence of elements of ecofeminism in India's environmental law and policy (Singh & van Houtum, 2002; Agarwal, 2010). However, jurisprudence still does not center women's ecological labor and decision-making. The study of gender and sustainability jurisprudence occurs at three different levels:

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Doctrinal Critique

Examining if statutes such as the 'Forest Rights Act' (FRA) or 'the Biodiversity Act' conceptualize "community", "beneficiary", or "rights holder" in ways that acknowledge women's labor and contributions and how women are included in the implementation process.

Material Focus

Highlighting tribal women's forest-based labor and eco-enterprises as examples where gendered power, environmental regulation and market forces intersect.

Indigenous Agency

Viewing tribal women as agents and not only as vulnerable subjects that engage in negotiations, interpretations and resistance against the State and customary norms.

The literature demonstrates that in India and throughout the Global South there are numerous studies on women-led cooperatives, self help groups and community initiatives that utilize indigenous knowledge to achieve climate and livelihood resilience, while also facing structural barriers in regards to land, resources and political rights (Singh & van Houtum, 2002; Agarwal, 2010; UNDP, 2016). Through this theoretical framework, intellectual property law and forest governance will be analyzed using a gendered lens. When GI registrations include men as representatives, when Gram Sabhas or forest committees exclude women's voices, and when benefits-sharing agreements include men's names as the primary recipients, it demonstrates the aspects of gendered invisibility. In contrast, women are actively involved in sustaining TEK-based circular enterprises.

Legal Pluralism: Customary *vs.* Statutory Law in Tribal Contexts

Legal pluralism is defined as the co-existence of multiple legal frameworks in the same space consisting of customary, religious, community-based, and state. Legal centralism, the view that the state's legal framework is the sole framework governing society, has been critiqued by John Griffiths (Griffiths, 1986). He argues that state law is just one of many normative frameworks, and that people live their lives according to many overlapping, often conflicting, semi-autonomous social fields (Griffiths, 1986). Northeast India is an exemplary case of legal pluralism. There are constitutional provisions, autonomous district councils and judicial decisions that recognize customary laws of all the different tribes in addition to central and state statutory law (Cairns & Das, 2019). Customary law governs access to forests and land use rights, inheritance and dispute resolution. Simultaneously, the national laws, such as the 'Forest Rights Act, the Biodiversity Act, the Geographical Indications Act and the Patent Act', provide the framework for rights relating to forests, biological resources and traditional knowledge. However, from a gender perspective, legal pluralism is a double-edged aspect. Customary law and institutions can reflect ecologically

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responsible practices and community-centered values that align with TEK and circular economy practices. However, research has shown that customary law and institutions in Northeast India are generally male-dominated and that women may be excluded from decision-making regarding land and forests, even in matrilineal societies, like the Khasi (Karlsson, 2008; Nellithanam, 2020). In this chapter, legal pluralism is employed as a map to help identify:

i. Normative intersections between customary rules for forest use and TEK transmission and resource sharing, and statutory rules for forest rights, biodiversity access and IP protection.

ii. Jurisdictional gaps and overlaps: for example, community rights recognized in the FRA and mediated by local bodies that do not include women, or GI and patent procedures. They ignore customary norms of collective ownership.

iii. Power imbalances in whose norms will prevail amidst conflict situations: state bureaucracies, male village elders, IP offices, or women's collectives and cooperatives.

The application of this lens allows the research to consider not only what the statutes stipulate, but also how they are interpreted (and/or ignored) in tribal contexts in which customary law enjoys significant social legitimacy.

FOREST RIGHTS AND TEK IN NORTHEAST INDIA

The relationship of forest rights, traditional ecological knowledge (TEK) and gendered livelihoods in northeast India is all influenced by an intersectional relationship between statutory law, customary institutions and judicial interpretations. although the region has strong community-based forest governance structures, much of the legal framework (particularly the 'Forest Rights Act, 2006') is centered around access to resources rather than recognizing TEK as a separate, legally protectable interest. This chapter will examine the doctrinal structure of the FRA. It highlights examples from the Khasi, Jaintia and Garo communities through case studies. Also, it analyzes governing institutions and evaluates how courts have interpreted forest rights in ways that impact TEK, in indirect yet significant manner.

Case Studies: Khasi, Jaintia, Garo Women's Forest-based Livelihoods

Research conducted in Meghalaya and Assam demonstrates how Khasi, Jaintia and Garo women are at the center of maintaining their livelihoods through forest-based TEK intensive practices. For example, in the Khasi and Jaintia regions, women were traditionally responsible for gathering broom grass, lac, wild fruit and medicinal herbs as well as making woven items such as baskets. Rekha M. Shangpliang's research concerning the Khasi women and forest law found that although women in matrilineal society can inherit land,

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they are limited in their ability to make decisions regarding forest use due to patriarchal clan council and village dorbars' decision-making processes (Shangpliang, 2012). Women in the Jaintia Hills also used oral histories to demonstrate that they maintained knowledge of edible plants, seed varieties and natural dye plants, which assisted the community in adapting to environmental stressors (climate change, etc.), market changes, and other types of change (Tiwari & Singh, 2015; Swiderska, 2016). Similarly, studies of Garo women in agroforestry and bamboo-based business ventures demonstrated similar findings. Garo women's knowledge of multiple species crop rotation, composting, regenerating bamboo and bamboo craft generated circular production systems with little to no environmental waste (Tynsong & Tiwari, 2010; Talukdar et al., 2021).

Through anthropological research by Karlsson, followed by additional analysis of women's TEK in these societies by S. Mukherjee and Sruthi, demonstrates that women's TEK in these societies are not supplementary to women's livelihoods (Karlsson, 2011; Mukherjee & Sruthi, 2020). Rather, it represents women's central role in managing ecological resources (Shangpliang, 2012; Shiva, 1988; Singh et al., 2010). The women as "seed keepers," holders of herbal knowledge and main processors of forest biomass represent a circular economy model of regeneration, reuse and low-waste production (Agarwal, 2001; Borah, 2021; Pushpangadan, 2010; National Biodiversity Authority, 2021). However, women's TEK are largely unaccounted for within formal forest management documentation, benefit sharing agreements and Intellectual Property regimes (Pushpangadan, 2010; National Biodiversity Authority, 2021).

Governance structures: Gram Sabhas, Forest Management Committees, Gendered Exclusions

Gram Sabhas are central to the governance of forests in accordance with the FRA. They are allowed to start claims for rights, to verify rights to lands and to govern the use of forest areas (Government of India, 2006). The guidelines that apply to Gram Sabha meetings include a requirement that one-third of the membership of Gram Sabha should comprise of women (Ministry of Tribal Affairs, 2018). This gives the potential for the traditional ecological knowledge (TEK) held by women to influence the development of community forest plans and the making of decisions in the context of those plans.

However, the governance of forests in Northeast India is far more complicated than the legal framework would suggest. It is shaped by legal pluralism. In addition to the role of Gram Sabhas there are other custom-based bodies (for example, Dorbar Shnong – the Khasi village assembly, Raid councils, clan-based institutions and Autonomous District Councils) that have their own authority over the forests (Cairns & Das, 2019; Karlsson, 2008). There are also various types of Forest Management Committees (FMCs), Joint Forest Management (JFM) bodies and departmental structures (line departments) that all operate in a form of overlap.

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The above governance structure emanated dual effects:

TEK is Invisible in the Formal Decision-making Processes

The fact that women have ecological knowledge does not mean that this knowledge will be translated into representation on Gram Sabha issues, claim verification processes or management decisions.

Fragmentation Exists between Customary and Statutory Systems

When customary bodies are predominant in forest governance, the formal procedures of the FRA may be ignored, set aside, or selectively implemented. Therefore, it leads to inconsistency in the recognition of TEK (Griffiths, 1986; Merry, 1988).

Therefore, while the FRA aims to democratize forest governance, the exclusion of women based upon customary norms, limits the degree to which the TEK of women is used to develop legally recognized forest management strategies (Agarwal, 2001; Bose, 2019).

Judicial Pronouncements Interpreting FRA and their Implications for TEK

While, as outlined above, the FRA does not specifically protect (TEK), the way that the law is interpreted by courts and other legal actors has the potential to indirectly protect it. One example is the Niyamgiri judgment i.e., Orissa Mining Corporation Ltd. v. Ministry of Environment & Forests & Others, (2013) 6 SCC 476. In this case, the Supreme Court ruled that Gram Sabhas have the right to decide if proposed mines are harmful to the traditional cultural, spiritual, or community rights of the Dongria Kondh people. Implicitly, the Court recognized that forest rights include the relationship between the people who live in those forests and the ecosystems in which they live. This relationship has been passed down from generation to generation. While the Court did not use the term "ecological knowledge," the Court made it very clear that the knowledge and cosmology that are unique to each community are also legally-protectable interests under the FRA. On the other hand, the Wildlife First & Others v. Ministry of Environment & Forest & Climate Change & Others, W.P. (C) 109/2008 case clearly shows how the FRA is being used to pit community rights against conservation. The February 2019 eviction order (which was later stayed) signalled the judicial willingness to prioritize a protectionist approach to conservation over community rights. This type of conservationism is based on the same logic as T.N. Godavarman Thirumulpad v. Union of India & Others, (1997) 2 SCC 267. It sees the forest as a place to be restricted and controlled by bureaucrats, often at the expense of the knowledge-based ways in which communities live and practice their culture. When combined with Lafarge Umiam Mining Pvt. Ltd. v. Union of India & Others, (2011) 7 SCC 338, which allowed limestone mining in Meghalaya as long as environmental assessments were completed and customary decision-making processes were followed, the regional

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implications of this become even clearer. In the Lafarge Umiam Mining case, although the Supreme Court acknowledged the existence and importance of Khasi customary institutions, the Court ultimately gave priority to the assessment of environmental impacts by bureaucrats over the ecological knowledge of the community. As a result, a hierarchy of environmental knowledge exists in Indian environmental law and policy, with state-certified science-based environmental knowledge considered to be more valuable and deserving of legal protection than the more context-specific and ecologically adaptive knowledge of the community. Additionally, Centre for Environmental Law, WWF–India v. Union of India & Others, (2013) 8 SCC 234, reinforced the idea of strong conservation in protected areas. They further supported more exclusionary conservation policies that would undermine community-led TEK-based stewardship of forest resources.

Overall, it could be observed from these judgments that Courts recognize the cultural, spiritual, and territorial aspects of forest rights. However, they rarely articulate TEK as a separate legal category. Instead, they consistently favor scientific forestry and bureaucratized procedures over the community-based knowledge systems.

Therefore, while the Niyamgiri ruling has tremendous transformative potential for recognizing TEK in the context of Gram Sabhas, subsequent and parallel conservation jurisprudence has effectively diminished that potential.

Northeast India is a region where opportunities to promote forest rights and traditional ecological knowledge (TEK) exist. However, they are also fraught with tension. On one hand, the Forest Rights Act (FRA) affords communities an expansive set of rights in relation to forest resources. On the other hand, it doctrinally under-theorizes TEK. Indeed, the Khasi, Jaintia, and Garo women manage local ecosystem services through their knowledge-based forest livelihoods. Yet, these same women are marginalized within governance systems that include customary male authorities as well as bureaucratic institutions.

Moreover, while the judiciary has created an interpretative space for TEK through decisions such as Niyamgiri, competing conservationist juridical perspectives have constrained this interpretive space.

Hence, to create gender inclusive circular enterprises that draw upon TEK, legal frameworks will need to transition from merely focusing on the distribution of resources and instead provide explicit recognition of rights based upon knowledge. Furthermore, the representation of women at every level of governance will be essential in creating equitable decision-making processes. In addition, strengthening Gram Sabha authority in the context of the Northeast and achieving harmony between statutory and customary law will help ensure that the rights and interests of tribal women are represented in the forest rights architecture in India. It would allow the forest rights architecture to meaningfully reflect the ecological and economic wisdom currently being practiced by tribal women in India.

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CIRCULAR ECONOMY, LEGAL INCOHERENCE AND POLICY FRAGMENTATION IN NORTHEAST INDIA

Traditional Ecological Knowledge in Northeast India aligns with circular economy goals. Circular economy principles focus on resource regeneration, low waste and continuous use of materials (Kirchherr et al., 2017; Geissdoerfer et al., 2017). Tribal women in Assam and Meghalaya follow these principles through established harvesting cycles and careful forest use (Tiwari & Singh, 2015; Tynsong & Tiwari, 2010). Their knowledge ensures that plant populations recover. Their selection of mature plants protects younger growth. Their rotation of harvest zones reduces pressure on specific patches. Their use of byproducts supports compost, animal feed or local crafts. Their choices show a structured approach to resource efficiency (Berkes, 2012).

Their knowledge is not a marginal practice. It forms a coherent system for maintaining ecological health. Studies on forest-based livelihoods in Meghalaya show that women use plant indicators to judge soil fertility and moisture levels (Shangpliang, 2012). They decide when to begin or stop collection (Roy, 2015). They observe changes in seed size, leaf colour and insect activity (Berkes, Colding & Folke, 2000). Their judgments reduce the risk of over extraction (Agarwal, 2001). This approach serves the same purpose as formal resource assessment methods. It ensures a stable supply over time.

Despite this alignment, formal circular economy policy in India focuses on industrial sectors. Policy papers from NITI Aayog refer to plastics, metals, construction waste and municipal systems (NITI Aayog, 2021). They do not link circularity with TEK (UNDP India, 2022). They do not mention forest based systems (United Nations, 2015). This absence creates a conceptual gap. TEK based circular systems exist but do not enter planning documents. This gap influences resource governance in Northeast India.

Legal Incoherence Across Sectors

Circular economy frameworks describe resource loops. These loops do not function without governance systems that support them. In Northeast India, forest laws, IP laws and livelihood schemes influence different components of circular systems. These laws operate separately and such separation creates incoherence.

The Forest Rights Act supports community control over resources. It does not protect TEK. IP laws protect formal innovation. They do not recognise TEK. Biodiversity law documents knowledge. It does not integrate circular principles. Livelihood schemes promote enterprise growth. They do not incorporate ecological decision rules. Circular economy policy focuses on industrial waste. It does not include forest-based cycles. These frameworks do not connect.

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A circular system requires alignment between rights, knowledge and economic activity. However, the present legal structure does not provide this alignment. Women rely on customary norms to maintain ecological balance and customary norms lack legal weight in statutory procedures. This weakens circular systems grounded in TEK.

Policy Fragmentation and Scheme Limitations

Van Dhan Vikas Kendras aim to support tribal value addition (TRIFED, 2023). They promote processing of minor forest produce (Ministry of Tribal Affairs, 2018). They provide machinery, training and marketing support (Bose, 2019). These centres assume consistent supply of raw material. Supply depends on forest access and ecological conditions (Cairns & Das, 2019). Many communities have unresolved rights under the Forest Rights Act (TERI, 2020). Also, forest departments control access in many regions. This creates uncertainty. Van Dhan plans do not integrate TEK-based rules for sustainable harvest. Training modules focus on processing and marketing. They do not include ecological knowledge.

Moreover, National Rural Livelihood Mission works with self-help groups (Ministry of Rural Development, 2022). The mission trains women in enterprise development (Ministry of Rural Development, 2022). It focuses on credit, accounting and product packaging (Upadhyay, 2019). It does not train women in documenting TEK or asserting ecological rights. NRLM integrates women into markets (Roy, 2015). However, it does not support their role as ecological managers.

These schemes function without coordination with forest governance institutions. No mechanism links Van Dhan centres with Gram Sabha-level forest planning. No guidelines link NRLM groups with Community Forest Resource management. Hence, TEK-based rules do not enter scheme design. This results in production targets that conflict with ecological rhythms.

Gender Sensitive Implementation Gaps

Gender inclusion appears in several policies. FRA mentions women in Gram Sabhas. NRLM focuses on women's groups. GI law does not specify gender participation but allows collective action. These inclusions remain limited in practice.

Traditional institutions in Meghalaya maintain male leadership (Nongbri, 2003; NESRC, 2017). Women who try to participate in forest-related decisions face cultural barriers (Upadhyay, 2019). Their names may appear in committee lists (Ministry of Tribal Affairs, 2018). However, their influence remains limited. Gram Sabhas in many Sixth Schedule areas do not include women as active participants (Cairns & Das, 2019). Even though FRA requires their presence, the customary practices often override this requirement.

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In Assam, village committees vary in their inclusion of women. Forest department staff often meet male leaders during inspections (Roy, 2015). Women describe their knowledge informally (Agarwal, 2001). However, this knowledge does not enter official records (TERI, 2020). Biodiversity Management Committees also show low participation of women (National Biodiversity Authority, 2021). PBRs record species lists but do not capture the decision rules women follow (National Biodiversity Authority, 2021). This weakens the representation of TEK.

Policy documents on circular economy do not include gender-based analysis (NITI Aayog, 2021). They do not examine the role of women in forest-based circular systems (UNDP India, 2022). They do not reference TEK. This absence leads to policies that replicate existing gender gaps.

Overall, circular economy goals in Northeast India require alignment between TEK, forest governance and livelihood support. Current frameworks operate separately. TEK aligns with circular principles. Law does not recognise TEK. Livelihood schemes do not integrate ecological knowledge. Gender bias in governance limits women's influence. Institutional fragmentation restricts coordination. These gaps weaken the potential of TEK-based enterprises and the sustainability of forest-based economies.

PROPOSED REFORMS, PATHWAYS AND CONCLUDING REMARKS

Overall, there is strong potential to build a legal and policy framework that supports Traditional Ecological Knowledge and women who practise it. To this end, communities in Assam and Meghalaya hold stable ecological systems. Women maintain these systems through careful decisions that support regeneration and reduce waste. Law and policy can strengthen these systems by recognising their place in forest governance and circular economy planning.

Gender Inclusive Intellectual Property Pathways

Intellectual property frameworks can include women in producer roles and decision processes. GI law can create requirements for gender balanced producer groups. For this, applications should identify the knowledge sources that shape the reputation of the product. Also, authorised user lists should include women who carry out ecological and craft-based work. Moreover, IP offices can prepare guidance materials that explain how oral knowledge can be submitted through recorded statements. This can support communities that do not rely on written documentation.

A TEK Register can provide a formal method for communities to record their ecological practices. Such entries should originate through village meetings where women participate

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directly. Each entry can describe the practice, the conditions for use and the ecological limits linked to the practice. This approach aligns IP frameworks with community-based authorship.

FRA Amendments and TEK Recognition

The Forest Rights Act can incorporate language that recognises TEK as part of community forest rights. FRA rules can require Gram Sabhas to document TEK while preparing Community Forest Resource plans. These plans can record harvest cycles, soil and plant indicators and regeneration rules. Women should occupy half the seats in CFR committees. Hence, their participation can improve the accuracy of management plans.

FRA amendments can add a clause that requires administrators to consult documented TEK before approving forest diversion. This can strengthen community claims and support ecological safeguards. CFR monitoring groups can use TEK-based indicators to evaluate forest health during routine checks.

Institutional Support and Capacity Strengthening

Agencies that manage biodiversity, livelihoods and forest governance should include TEK modules in staff training. Officers should learn how communities monitor plant growth and regeneration. This knowledge will support better administrative decisions. Also, documentation teams should include local women who practice TEK. This can ensure accuracy in biodiversity registers and management plans.

Digital tools can record oral explanations through audio or video files. This removes the need for complex written documents. District-level TEK cells can help communities prepare records for forest governance, benefit sharing and GI registration. These cells should have women supervisors to support gender inclusion.

Moreover, livelihood missions can support TEK-based enterprises by aligning production schedules with ecological cycles. Training sessions should include information on regeneration limits. This will help women maintain sustainable production. Market support programs can promote TEK-based products with clear recognition of the ecological practices behind them.

Sui Generis TEK Law

A dedicated TEK law can provide the strongest form of recognition. The law can define TEK as knowledge arising from collective experience. It can assign rights to communities and specify that women participate in all decision-making steps. The law can include a consent requirement for any research or commercial use of TEK. Benefit sharing should reach women producers and not only male-led bodies. A TEK Authority can support

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these processes. The Authority can include biodiversity specialists, gender experts and community representatives. It can coordinate with IP offices, forest departments and livelihood missions. This can reduce administrative overlap and improve recognition.

Integration of Forest Rights and Livelihood Schemes

Livelihood schemes should align with forest governance. Van Dhan centres can use CFR management plans to decide product selection and extraction levels. NRLM groups can work with village forest committees before starting enterprises. This can reduce conflicts between production goals and ecological limits.

Also, scheme guidelines can include environmental safeguards based on TEK. Officers can encourage enterprises that rely on careful harvesting rather than rapid extraction. TRIFED and NRLM staff can use TEK frameworks when designing cluster level plans. This can improve the stability of supply chains and protect regeneration cycles.

CONCLUDING REMARKS

Legal and policy reforms can improve the position of women who hold TEK. Current frameworks exclude or overlook their knowledge. IP law remains centred on individual invention. Forest law recognises access but not ecological expertise. Biodiversity law documents knowledge without giving strong rights. Livelihood schemes promote production without ecological safeguards. These problems reduce the ability of communities to maintain sustainable forest-based economies.

Reforms that bring TEK into formal law can strengthen circular economy goals. Amendments to FRA can support knowledge-based governance. Gender inclusive GI processes can recognise women's work. Institutional support can help communities document and protect TEK. A dedicated TEK law can create a coherent system for rights, consent and benefit sharing. Integration across ministries can reduce policy fragmentation.

This chapter contributes to debates on gender, law and ecology. It shows that sustainable forest management depends on recognising TEK. It identifies the structural reasons for gender exclusion in IP and forest governance. It offers legal pathways that combine community rights, ecological knowledge and livelihood support.

Future research can examine how TEK-based governance changes forest outcomes when women lead CFR planning. It can analyse the effect of GI reforms on women producers. It can review the performance of TEK Registers in protecting community knowledge. It can also evaluate how integrated livelihood schemes influence ecological stability in forest-based economies. This research can guide long-term policy development and support community resilience in Northeast India.

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REFERENCES

Agarwal, B. (1992). The gender and environment debate: Lessons from India. *Feminist Studies, 18*(1), 119–158. https://doi.org/10.2307/3178217

Agarwal, B. (2001). Participatory exclusions, community forestry, and gender. *World Development, 29*(10), 1623–1648. https://doi.org/10.1016/S0305-750X(01)00066-3

Agarwal, B. (2010). *Gender and green governance.* Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199569687.001.0001

Antons, C. (2013). *Traditional knowledge and intellectual property law in Asia.* Kluwer Law International.https://lrus.wolterskluwer.com/store/product/traditional-knowledge-traditional-cultural-expressions-and-intellectual-property-law-in-asia/

Bavikatte, K., & Robinson, D. (2011). Towards a people's history of the law: Biocultural jurisprudence. *Law, Environment and Development Journal, 7*(1), 1–20. https://lead-journal.org/content/11001.pdf

Berkes, F. (2012). *Sacred ecology* (3rd ed.). Routledge. https://www.routledge.com/Sacred-Ecology/Berkes/p/book/9780415517310

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional Ecological Knowledge as adaptive management. *Ecological Applications, 10*(5), 1251–1262. https://doi.org/10.1890/1051-0761(2000)010[1251:ROTEKA]2.0.CO;2.

Bijoy, C. R. (2020). Response to "Undoing historical injustice...". *Law and Other Things.* https://lawandotherthings.com/response-to-undoing-historical-injustice-the-role-of-the-forest-rights-act-and-the-supreme-court/

Borah, S. (2021). Gender patterns in GI registrations in Northeast India. *Journal of Intellectual Property Rights, 26*, 212–222. http://nopr.niscpr.res.in/handle/123456789/58659

Bose, P. (2019). The uncertain landscape of forest rights. *Economic and Political Weekly, 54*(2). https://www.epw.in/journal/2019/2/special-articles/uncertain-landscape.html

Cairns, C., & Das, P. (2019). Customary law and democratic governance in Northeast India. *Indian Law Review, 3*(1), 64–88. https://doi.org/10.1080/24730580.2019.1580567

Centre for Environmental Law, WWF–India v. Union of India & Others, (2013) 8 SCC 234 (India). Full text: https://indiankanoon.org/doc/27900105/

Citizens for Justice and Peace (CJP). (2025). *How the FCA 2023 amendments undermine Adivasi land protections.*https://cjp.org.in/how-fca-2023-amendments-seek-to-undermine-adivasi-land-protections-guaranteed-in-forest-rights-act-2006-sc/

Ellen MacArthur Foundation. (2019). *Completing the picture: How the circular economy tackles climate change.* https://ellenmacarthurfoundation.org/completing-the-picture

Fricker, M. (2007). *Epistemic injustice: Power and the ethics of knowing.* Oxford University Press. https://global.oup.com/academic/product/epistemic-injustice-9780198237907

Gadgil, M., Berkes, F., & Folke, C. (1993). Indigenous knowledge for biodiversity conservation. *AMBIO, 22*(2/3), 151–156. https://www.jstor.org/stable/4314060

Geissdoerfer, M., Savaget, P., Bocken, N., & Hultink, E. (2017). The circular economy: A new sustainability paradigm? *Journal of Cleaner Production, 143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Geographical Indications Registry of India. (2021). *GI Journal & resources.* https://ipindia.gov.in/gi.htm

 ISBN: 978-93-49666-59-7 (eBook)

Government of India. (2006). *The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006.* https://www.indiacode.nic.in/bitstream/123456789/8311/1/a2007-02.pdf

Griffiths, J. (1986). What is legal pluralism? *Journal of Legal Pluralism and Unofficial Law, 24*(1), 1–55. https://doi.org/10.1080/07329113.1986.10756387

Gupta, A. (2002). Rewarding traditional knowledge and grassroots innovation. *Current Science, 82*(1), 5–10. https://www.jstor.org/stable/24106660

India Development Review (IDR). (2025). *IDR explains: The Forest Rights Act.* https://idronline.org/features/rights/idr-explains-forest-rights-act-fra/

Kapur, R. (2018). *Gender, alterity and human rights: Freedom in a fishbowl.* Edward Elgar. https://doi.org/10.4337/9781788112530

Karlsson, B. G. (2011). *Unruly hills: A political ecology of India's Northeast.* Berghahn Books. https://www.berghahnbooks.com/title/KarlssonUnruly

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy. *Resources, Conservation & Recycling, 127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Lafarge Umiam Mining Pvt. Ltd. v. Union of India & Others, (2011) 7 SCC 338 (India). Official PDF (IELRC): https://www.ielrc.org/content/e1157.pdf

MacKinnon, C. (1989). *Toward a feminist theory of the state.* Harvard University Press. https://www.hup.harvard.edu/books/9780674896468

Merry, S. E. (1988). Legal pluralism. *Law & Society Review, 22*(5), 869–896. https://doi.org/10.2307/3053638

Ministry of Tribal Affairs. (2018). *Status report on the implementation of the Forest Rights Act.* https://tribal.nic.in/FRA/Data/Reports/StatusReportFRA2018.pdf

Mukherjee, S., & Sruthi, P. (2020). Women, nature and culture: An ecofeminist reading of matrilineal culture. *Cultura de los Cuidados, 58*, 165–184. https://doi.org/10.14198/CUID.2020.58.15

National Biodiversity Authority. (2021). *Guidelines on Access and Benefit Sharing.* http://nbaindia.org

NITI Aayog. (2021). *Circular economy in India: Sector papers.* https://www.niti.gov.in/circular-economy-series

Nongbri, T. (2003). Gender and the Khasi political system. *Economic and Political Weekly, 38*(43), 4551–4557.https://www.epw.in/journal/2003/43/commentary/gender-and-khasi-political-system.html

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Chapter

26 Indigenous Governance for Sustainable Future: Insights from Indian Knowledge Systems

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ABSTRACT

The accelerating impacts of climate change, declining biodiversity and widespread environmental degradation have exposed the limitations of conventional approaches to environmental governance. To deal with these problems, we need a system of governance that focuses on protecting the environment, equality, culture and the participation of all people. For many generations, tribal communities have used and protected land, forests, water and natural resources through their traditional knowledge. They have a close relationship with nature. They work together and focus on saving natural resources for future generations. Despite this, tribal knowledge and traditional governance systems are still not given enough importance in sustainable development policies. The Indian Knowledge System (IKS) can play an important role in this area. This study examines how tribal knowledge and traditional governance systems linked to the Indian Knowledge System can be included in sustainable development policies. The study uses a qualitative research method. It examines available research papers, traditional practices and examples of tribal communities involved in managing natural resources. The paper argues that sustainable development requires recognizing Indigenous governance as a legitimate and complementary system of environmental management. Integrating Indigenous knowledge into sustainability policy supports the achievement of Sustainable Development Goal (SDG) 10 (Reduced Inequalities) by promoting inclusive governance; SDG 13 (Climate Action) through community-based adaptation; SDG 15 (Life on Land) by strengthening biodiversity conservation; SDG 16 (Peace, Justice and Strong Institutions) through participatory governance and SDG 17 (Partnerships for the Goals) by fostering equitable collaboration between governments, Indigenous communities and other stakeholders. Such an approach contributes to resilient ecosystems, socially just institutions and more sustainable futures.

Keywords: Biodiversity Conservation, Indigenous Governance, Indigenous Knowledge, Sustainability Policy, Sustainable Development Goals (SDGs)

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INTRODUCTION

Indigenous Governance means a system where people collectively exercise their rights, make decisions and fulfil their responsibilities through their own institutions and social relationships. It explains how a community can "live best together" and organise its society while maintaining its relationship with the natural world. Indigenous governance is a broad system. It includes leadership, authority, institutions, different levels of governance, cultural values, land, natural resources and data. Therefore, it is not only about administration. It also has social, cultural, relational and ecological aspects (Ladner, 2003). Social relationships, trust, shared rules and collective action can play an important role in managing shared resources for a long time (Pretty, 2003). When people have common rules and strong social relationships, they are more willing to work together to manage shared resources. Indigenous knowledge is seen as old techniques as well as the long experience of local people, their views of nature, way of life and traditions of managing resources. It can play an important role in understanding and protecting the local environment. Local people have long observed changes in weather, water, forests, fire, plants and animals (McElwee *et al.,*2020). This experience can help identify local environmental problems and possible solutions to deal with climate change. About 28% of the world's land is managed by people for whom forests are not only natural resources but also an important part of food, livelihood, culture and life (Greenwood *et al.,*2024). Their conservation practices can therefore help address climate change, protect biodiversity and forests and strengthen local livelihoods (Hoffman *et al.,*2021).

Indian civilisation which is considered to be approximately 5000 years old has a wide range of knowledge traditions in the field of governance, architecture, medicine, agriculture and management of resources among others. These knowledges are now understood under the broader framework of Indian Knowledge Systems (IKS). Indian Knowledge Systems refers to the diverse systems of knowledge, practices, philosophies, technologies and cultural traditions that developed in the undivided Indian subcontinent over many centuries. It is interdisciplinary and brings together practical experience, ecological understanding and cultural traditions. According to Sharma *et al.* (2025), IKS includes traditional knowledge that connects environmental, social and economic aspects and can be useful in the context of sustainable development. As per the IKS Division, Ministry of Education, GoI (2023), IKS focuses on three main principles: *Parampara*, *Dṛṣṭi* and *Laukika-prayojana*. *Parampara* focuses on preserving and carrying forward the knowledge and traditions passed down through generations. *Dṛṣṭi* highlights the Indian way of understanding knowledge and encourages the use of traditional knowledge along with modern knowledge to address present-day challenges. *Laukika-prayojana* focuses on the practical use of Indian Knowledge Systems to solve current and emerging problems in areas such as health, technology, environment and social well-being. The importance of IKS can be seen at in sustainable development and local problem-solving,

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traditional agriculture, water management, architecture and environmental practices are important. These practices developed through the long-term experience and adaptation of communities to local conditions. IKS is also linked with sustainable development, medicinal plants, biodiversity conservation and natural resource management (Borah *et al*. 2026). It focuses on the relationship and interdependence between humans and nature rather than seeing them as separate.

The alarming effects of climate change, biodiversity loss, land degradation and water crisis have raised serious questions about the effectiveness of conventional approaches to environmental governance. Although modern technology and state regulation remain essential, they somehow are still far away from addressing the detailed ecological knowledge preserved by communities that have lived in particular landscapes for generations. Conventional environmental governance has always relied on centralised regulation, scientific methods, large and heavy infrastructure. The decisions at the central level many times fail to understand the local level interventions that is required. It is generally based on "one size fit all" approach. Thus, sustainability always got challenged in such approach. However, traditionally environmental and natural resources were managed at the local level and not at the centralised level. The advantage of this was that the people living close to these resources have knowledge passed down through generations. Local communities had observed rainfall, soil conditions, plants, animals, rivers and seasonal changes over long periods. With their observations, they use this knowledge in agricultural practices, social norms, cultural traditions and community rules. As such, they were always in a better position to manage these resources. Indigenous and local knowledge systems represent extensive bodies of knowledge about biodiversity and ecosystems and that they can complement scientific knowledge in understanding and managing environmental change (UNESCO, 2026). Similarly, IPBES (2022) views Indigenous and local knowledge as dynamic systems of knowledge, practices and beliefs that are closely connected with territories and ecosystems.

The focus is not just the revival of ancient practices but to understand as if how the community interacted with nature and maintain sustainability that led to the survival of civilisations for so long. Further, how and whether such knowledge can be integrated to solve the current challenges that the world is facing over. Thus, the purpose of this paper is therefore not to suggest the replacement of modern institutions with traditional systems. Rather, it tries to focus that certain principles and practices associated with Indian Knowledge Systems can add on to contemporary sustainable governance.

REVIEW OF LITERATURE

Garnett *et al.* (2018) reviewed 648 empirical studies. The study found that conservation efforts are more effective when Indigenous peoples and local communities have equal

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participation or greater control. Such involvement is also linked with fairer and more just governance. The authors explain that the role of Indigenous peoples and local communities (IPs and LCs) is not limited to participation. It also includes greater control and decision-making, where their rights, values and traditional institutions are recognised. The study suggests that Indigenous peoples and local communities should have a stronger role in conservation. Their rights and traditional institutions should also be respected.

Popova (2014) studied examples of conservation policies introduced after the adoption of the Convention on Biological Diversity (CBD) in 1992. The study showed that the traditional knowledge and practices of Indigenous and local communities were important for conservation. The author found that projects using different elements of traditional knowledge provided direct benefits to Indigenous communities, especially in countries with better legal and social systems for protecting their rights and social security.

Dawson *et al.* (2021) reviewed 169 research publications to understand how different types of governance affect conservation outcomes. The study found that locally controlled conservation was more effective because local institutions involved in managing land and resources were recognised in the governance system.

Mukherjee and Kaur (2025) connected IKS with current discussions on sustainable development. They explained that ideas such as *Rta* and *Dharma*, the connection between nature and life in Vedanta, interdependence in Buddhist philosophy and *Seva* in the Sikh tradition can support environmental ethics, responsible consumption and sustainable development.

Shroff (2025) studied the link between IKS, environmental sustainability and the Sustainable Development Goals (SDGs). The study showed that the knowledge and experience found in IKS can provide an important base for sustainable development. It can also help address environmental challenges and improve ecological resilience.

Similarly, Sharma et al. (2025) studied the link between IKS and the SDGs through environmental, social and economic aspects. The authors explained that focusing on the environmental pillar can support long-term productivity, climate resilience and human well-being. The social pillar covers governance, gender equality, health, education and poverty reduction. The economic pillar supports industrial capacity, innovation, employment and income generation.

Shawoo (2019) studied how Traditional Ecological Knowledge (TEK) can be included in climate policy through the Local Communities and Indigenous Peoples Platform. The study showed that institutions such as the UNFCCC support the inclusion of Indigenous peoples' views. The author suggested a rights-based approach, greater decision-making power for Indigenous peoples and proper arrangements to protect the overall nature and cultural integrity of TEK.

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There is substantial literature on indigenous knowledge, traditional practices and sustainable development. National and international organisations do recognise the important role that traditional communities play in biodiversity conservation, However, significant gap remains.

i. Literature focusses much on the traditional sustainable practices but don't examine the governance institutions in role
ii. Discussion on IKS focusses more on philosophical foundations and texts and less on its contemporary relevance.
iii. There is a dearth of work related to indigenous knowledge and practices that can be attributed to specific sustainable development goals

This paper addresses these gaps by examining IKS through the lens of governance. It asks what institutional principles and insights can be taken from Indian knowledge Systems that can be adapted for contemporary sustainability.

Based on these research gaps, the objectives of this paper are:

i. To analyse selected insights from Indian knowledge systems for community-based natural resource management.
ii. To examine the contribution of Indigenous governance towards sustainability and its contemporary relevance.
iii. To identify certain indigenous knowledge and practices that can be attributed to specific SDG.

As such, this paper seeks to answer the following research questions:

i. What lessons can contemporary governance learn from Indian Knowledge Systems?
ii. How can Indigenous knowledge complement modern scientific systems?
iii. Whether integrating Indigenous knowledge into sustainability policy supports the achievement of Sustainable Development Goal (SDG)?

METHODOLOGY

The paper adopts a conceptual and qualitative methodology based on secondary literature, classical Indian texts, policy documents and selected examples or case study of community-based resource governance. The studies focused on dimensions like knowledge, institutions, participation, resource management and sustainability outcomes have been considered. Further, the study is conceptual rather than econometrics. The selected insights from Indian Knowledge Systems that have been considered for this paper are:

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i. Sacred Groves
ii. Traditional Water Management Systems
iii. *Muhrat* and *Panchang* based Agricultural Practices
iv. Indigenous Knowledge and Benefit Sharing

Each of the insights gained were analyzed on the basis of relevant SDGs:

- SDG 10 - Reduced Inequalities by promoting inclusive governance
- SDG 13 - Climate Action through community-based adaptation - UNESCO reports that Indigenous and traditional knowledge can contribute to climate adaptation by supporting observation, preparedness and locally appropriate responses (UNESCO, 2025).
- SDG 15 - Life on Land by strengthening biodiversity conservation
- SDG 16 - Peace, Justice and Strong Institutions through participatory governance and
- SDG 17 - Partnerships for the Goals

Figure 1 presents the flowchart of this study. It shows how Indian Knowledge Systems, Indigenous Governance and Sustainable Development are connected.

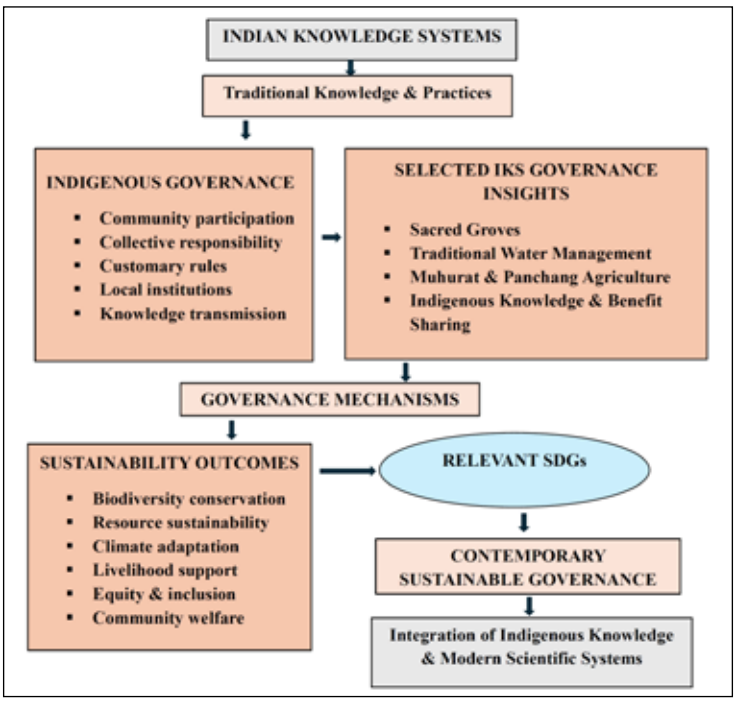


Fig. 1: Conceptual Framework of the Study

Source: *Author*

DISCUSSION AND FINDINGS

Table 1 presents the compilation of insights from Indian knowledge systems along with the indigenous knowledge gained from it, governance mechanism followed at that time, its main contribution to sustainability, relevant SDGs and Indian examples pertaining to each insight. Each of these insights are discussed further in detail:

Sacred Groves

Khasi sacred groves are forest areas protected by local communities based on their traditions, religious beliefs and rules. They are known as *Khlaw Kyntang*, *Law Kyntang* or *Law Lyngdoh*. Their protection is based not only on government rules but also on local social and religious beliefs. These forests are considered the dwelling places of deities. Therefore, cutting trees or taking flowers, fruits or branches is not allowed. People also believe that breaking these rules can bring bad consequences (Meghalaya Biodiversity Board, 2018). A study of 79 sacred groves recorded 514 plant species (Tiwari *et al.*, 1998). Similar sacred groves are also found among the Garo and Jaintia/Pnar communities with their own names and traditions. A study of three sacred groves in the Jaintia Hills recorded 395 plant species across about 28 hectares and involved 108 families (Jamir & Pandey, 2002).

Maharashtra's *Devrai* are sacred forests believed to belong to local deities. This tradition is mainly found in parts of the Western Ghats, such as Pune, Ratnagiri, Raigad, Kolhapur and Sindhudurg. Local people believe that harming these forests can bring divine punishment. This belief helped limit tree cutting, the use of forest resources and construction activities. The forests were also protected by fencing around them (Chandran, 1997). Over time, religious beliefs and local rules helped protect these forests and increased their environmental importance. In some Devrai, the use of forest resources is almost completely prohibited. In others, limited traditional use is allowed, such as collecting fruits, medicinal plants, flowers and fallen branches and allowing animals to graze during certain seasons (Vipat & Bharucha, 2014).

Traditional Water Management Systems

Within the framework of the Indian Knowledge System (IKS), water was understood not merely as a consumable resource but as an essential component of ecological, social, cultural and spiritual life. Historical evidence from sites such as Dholavira demonstrates the early development of interconnected reservoirs, channels and runoff-harvesting structures adapted to arid conditions, while later traditions produced region-specific systems such as baolis or stepwells, kunds, tankas, johads, ahar-pyne networks, temple tanks and cascading irrigation tanks Danino (2020). Stepwells like Rani Ki Vaav, for instance, enabled access to groundwater despite seasonal fluctuations and were integrated into broader systems of storage, recharge and social activity, while johads in Rajasthan functioned as small earthen barriers that captured monsoon runoff and facilitated groundwater recharge (Anon, 2022). Research on johads in Rajasthan

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identifies community ownership, locally designed management rules, collective resource mobilisation and equity in water distribution as important factors in the sustainability of the system (Torri and Herrmann, 2011). Equally significant was the institutional dimension of these systems. Traditional water resources were often maintained through collective labour, locally evolved rules, shared responsibilities and principles of equitable distribution. Thus, traditional Indian water management systems can be viewed as living knowledge systems whose technological and institutional principles offer valuable pathways for developing more sustainable, locally appropriate and socially inclusive approaches to contemporary water governance. Traditional architectural knowledge was used in its construction by considering water, soil, temperature and structural stability. It was built below the ground, which kept the inside cooler than the outside. This was useful in the hot and dry climate of Gujarat (Priya, 2010; Jain-Neubauer, 1999).

Muhrat and Panchang based Agricultural Practices

Traditional Indian agricultural practices emphasize harmony with natural cycles to optimize productivity and resource efficiency. Ancient Indian practise of "*Panchanga Shastra"* or "*Muhurta*" i.e. Panchanga comprising tithi, vara, nakshatra, yoga and karana historically provided a temporal framework for agricultural decision-making, while classical agricultural literature such as Krishi-Parashara and Vrikshayurveda incorporated observations of rainfall, soil, plant growth and climatic conditions into farming practices (Sadhale, 1999; Nene & Choudhary, 2002). Farmers in Tamil Nadu use the Panchangam (lunar calendar) to plan agricultural activities like plowing, sowing and harvesting, aligning with seasonal cycles and natural resources. Farming works based on lunar cycles ensuring optimal soil moisture and crop growth. Chronobiology based farming also improves soil fertility. Indian Knowledge Systems conceptualize agriculture as an integrated activity governed by the interrelationship between human beings, nature, seasonal cycles and ecological resources. Traditional knowledge reflected in practices such as the Panchangam incorporates observations of lunar cycles, seasons, rainfall, soil conditions and ecological indicators to guide agricultural activities, reflecting the principle of harmony with Prakriti. Emphasis on seasonal crops, local seeds, water conservation, mixed farming and the use of natural resources shows the importance of maintaining balance with nature and protecting resources for future generations. Today, this traditional knowledge can be combined with weather information, soil testing and modern irrigation methods. This can help farmers deal with climate change and get good yields with fewer resources. Thus, the Indian Knowledge System (IKS) provides a holistic approach where economic prosperity (Artha), balance with nature (Prakriti) and social welfare (Lok Kalyan) are closely connected.

Indigenous Knowledge and Benefit Sharing

The Kani tribe in Kerala, India, had traditional healers called Plathis. They had traditional knowledge about the fatigue-reducing properties of the Arogyapacha plant (*Trichopus*

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zeylanicus). They shared this knowledge with scientists at the Tropical Botanic Garden and Research Institute (TBGRI). Together, they developed a medicine called 'Jeevani' and patented the technology. In 1995, the technology was licensed to Arya Vaidya Pharmacy. The benefits from the license fee and royalty were shared equally, with 50% going to the Kani community. The Kani Samudaya Kshema Trust was established to ensure fair distribution of the royalty. The Kani community's share was given to this trust. It was used for community welfare, basic infrastructure, insurance and documenting traditional knowledge. This arrangement was an early example of Access and Benefit Sharing (ABS) in India. It showed that community institutions can play an important role in using traditional knowledge for community development (Posey & Dutfield, 1996; Ten Kate & Laird, 1999).

Table 1: Analysis of the Insights Gained from IKS with Respect to Sustainability

Insights from IKS	Indigenous Knowledge	Governance Mechanism	Main Sustainability Contribution	Relevant SDGs	Indian Examples
Sacred Groves	Traditional forest protection based on cultural and spiritual beliefs	Community rules, customary institutions and collective protection	Biodiversity conservation, ecosystem protection and cultural preservation	SDG 13, 15, 16	Khasi Sacred Groves – Meghalaya; Devrai – Maharashtra
Traditional Water Management	Johads, tanks, ahar-pyne, bamboo drip irrigation and village ponds	Collective water management, maintenance and equitable sharing	Water conservation, groundwater recharge, irrigation and climate adaptation	SDG 6, 13, 16, 17	Rani ki Vav; Gujarat: Johads – Rajasthan; Ahar-Pyne – Bihar; Bamboo Drip Irrigation – Meghalaya;
Muhurat & Panchang-Based Agriculture	*Panchang,* seasonal calendars, local ecological observations and traditional timing of agricultural activities	Farmer community-based decision-making and intergenerational transmission of knowledge	Climate adaptation, preservation of local agricultural knowledge and sustainable farming	SDG 2, 12, 13	Traditional agricultural calendars – Karnataka, Maharashtra and other regions;
Community Forest Governance	Local knowledge of forests, plants, wildlife and sustainable harvesting	Village institutions, customary rules and collective forest management	Forest conservation, biodiversity protection and livelihood support	SDG 10, 13, 15, 16, 17	Van Panchayats – Uttarakhand; Community Forest Management – Odisha
Indigeneous Knowledge and Benefit Sharing	Medicinal Knowledge possesses by tribal communities	Kani Samudaya Kshema Trust	Royalty for community development, Acknowledgement of Tribal Knowledge, Community Development	SDGs 10	Kani Tribe, Kerala

Source: *Author*

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Table 2 shows how traditional Indian ideas of governance can be useful today. These ideas can support good, responsible and inclusive governance.

- **Dharma – Doing the right and ethical thing:** Dharma teaches us to do the right thing and fulfil our responsibilities. It is linked to **responsible governance** today.
- **Lokasangraha – Welfare of all:** It means focusing on the well-being of the whole society. It supports the idea of **including everyone in development**.
- **Passing on knowledge – Shruti tradition and learning from experience:** It focuses on learning through oral traditions and experience and passing knowledge to the next generation. Today, this can help **protect and use traditional knowledge**.
- **Sarve Bhavantu Sukhinah – May everyone be happy:** It means that the benefits of development should **reach everyone**. It supports the idea of equal welfare for all.

Thus, traditional Indian ideas can provide a foundation for good and sustainable governance. They focus on doing the right thing, the welfare of all, protecting knowledge and sharing the benefits of development.

Table 2: Indigenous Governance and Sustainability

Dimension	Indigenous Principle	Contemporary Governance Relevance
Ethics	*Dharma*	Responsible Governance
Collective welfare	*Lokasangraha*	Inclusive Development
Knowledge transmission	*Shruti Paramapara (oral tradition)*, Experiential learning	Knowledge preservation and documentation for sustainable practices
Happiness	*Sarve Bhavanti Sukhinah*	Welfare for all

Source: *Author*

Traditional practices also have some limitations. They should not always be seen as sustainable or suitable for present conditions. Population growth, changing livelihoods, urbanisation, climate change and commercialisation have created new challenges for these practices. The value of indigenous knowledge in governance should not be judged only by the presence of traditional practices. It should also be assessed on the basis of participation, equality, accountability, sustainable use of resources, knowledge transfer, community benefits, conflict resolution and links with formal institutions. Table 3 presents these dimensions and suggests possible indicators for assessing the governance value of Indigenous knowledge.

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Table 3: Possible Indicators for Evaluating Indigenous Governance

Dimension	Key Question	Indicator
Participation	Who participates in decisions?	Community participation
Equity	Are benefits fairly distributed?	Benefit distribution
Accountability	Who is responsible for decisions?	Transparency and responsibility
Resource Sustainability	Are resources maintained for future generations?	Forest/water/biodiversity condition
Knowledge Transmission	Is knowledge transferred to younger generations?	Youth participation and knowledge transfer
Community Benefit	Does the system improve community welfare?	Livelihood and social benefits
Conflict Resolution	How are disputes addressed?	Local conflict-resolution mechanisms
Institutional Linkage	Does it work with formal institutions?	Community -government cooperation

Source: *Author*

There may also be conflict between traditional institutions and formal government institutions.

Indigenous governance is closely linked to the local environment and community relations. Formal government systems provide legal rights, administrative support and scientific and technical help. Therefore, one system should not replace the other. Both should work together. The inclusion of IKS in present governance requires careful assessment, community participation, scientific validation where needed, legal recognition and protection from misuse or commercialisation. Thus, the study does not suggest replacing formal government institutions. It aims to improve local relevance, participation, equality and sustainability in resource governance.

CONCLUSION

The selected cases demonstrate institutional mechanisms through which Indigenous and community knowledge can contribute to sustainable resource governance. However, it needs to be understood that merely having traditional knowledge that were at places centuries ago will directly be implemented in the present context. This is because of the increasing population pressure, rapid urbanisation, fast changing land-use pattern and remarkable shift from need to greed. The ethical foundations on which Indian knowledge system is based that promoted Dharma, ethical governance, community participation, respect for nature, collective responsibility and the sustainable use of natural resources.

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Sustainability cannot be achieved only through laws and modern technologies. It also requires state institutions and values that encourage people to see natural resources as shared responsibilities rather than unlimited commodities. Indian Knowledge Systems can contribute to this transformation by providing a body of ideas, practices and institutional experiences that connect human well-being with ecological responsibility. The future of governance lies in creating a collective cooperation between knowledge systems. Such a cooperation can help build governance that is more participatory, inclusive, ecologically responsible and sustainable.

Limitation and Future Scope

This study is based on ideas and available information. It does not use data to measure the direct effect of traditional governance on sustainable development. The study is limited to selected books, research papers, government documents, Indian knowledge traditions and a few examples.

Future researchers can take this study further. They can add new areas based on different communities, environments and governance systems. These areas have not yet been tested in the field or through data. Future research can use surveys, interviews and field studies to study this topic in more detail. Data and economic methods can also be used to understand the actual effect of traditional governance on sustainable development.

REFERENCES

Anon (2022). *A Comprehensive Review of the Potential of Stepwells as Sustainable Water Management Structures*. Water. MDPI

Borah, M. S., Mudoi, N. G., Goswami, T. S., & Tiwari, A. (2026). Indian knowledge system research: A systematic literature review and bibliometric analysis (2015–2026). *International Journal of Agriculture Extension and Social Development, 9*(3), 314–320. https://doi.org/10.33545/26180723.2026.v9.i3e.3399

Chandran, M. S. (1997). On the ecological history of the Western Ghats. *Current science*, 146-155.

Danino, M (2020). *Water Management in Ancient India*. INFLIBNET. Inflibnet Ebooks

Dawson, N. M., Coolsaet, B., Sterling, E. J., Loveridge, R., Gross-Camp, N. D., Wongbusarakum, S., Sangha, K. K., Scherl, L. M., Phan, H. P., Zafra-Calvo, N., Lavey, W. G., Byakagaba, P., Idrobo, C. J., Chenet, A., Bennett, N. J., Mansourian, S., & Rosado-May, F. J. (2021). The role of Indigenous peoples and local communities in effective and equitable conservation. *Ecology and Society, 26*(3), 19. https://doi.org/10.5751/ES-12625-260319

Garnett, S. T., Burgess, N. D., Fa, J. E., Fernández-Llamazares, Á., Molnár, Z., Robinson, C. J., Watson, J. E. M., Zander, K. K., Austin, B., Brondizio, E. S., Collier, N. F., Duncan, T., Ellis, E., Geyle, H., Jackson, M. V., Jonas, H., Malmer, N., McGowan, B., Sivongxay, A., & Leiper, I. (2018). A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability, 1*, 369–374. https://doi.org/10.1038/s41893-018-

Greenwood, L., Bliege Bird, R., McGuire, C., Jadai, N., Price, J., Skroblin, A., van Leeuwen, S., & Nimmo, D. (2024). Indigenous pyrodiversity promotes plant diversity. *Biological Conservation, 291*, 110479. https://doi.org/10.1016/j.biocon.2024.110479

Hoffman, K. M., Davis, E. L., Wickham, S. B., Schang, K., Johnson, A., Larking, T., Lauriault, P. N., Le, N. Q., Swerdfager, E., & Trant, A. J. (2021). Conservation of Earth's biodiversity is embedded in Indigenous fire stewardship. *Proceedings of the National Academy of Sciences, 118*(32), e2105073118. https://doi.org/10.1073/pnas.2105073118

IKS Division, Miinistry of education, GOI (2023) https://iks.aicte-india.org/about.php

IPBES. (2022). *Methodological assessment report on the diverse values and valuation of nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES Secretariat.

Jain—Neubauer, J. (1999). The stepwells of Gujarat. *India International Centre Quarterly*, *26*(2), 75-80.

Jamir, S. A., & Pandey, H. N. (2002). Status of biodiversity in the sacred groves of Jaintia Hills, Meghalaya. *The Indian Forester, 128*(7), 738–744

Ladner, K. L. (2003). Governing Within an Ecological Context: Creating an AlterNative Understanding of Blackfoot Governance. *Studies in Political Economy / Recherches En Économie Politique*, *70*(1), 125–152. https://doi.org/10.1080/07078552.2003.11827132

McElwee, P., Ngo, H. T., Fernández-Llamazares, Á., Reyes-García, V., Molnár, Z., Guèze, M., Aumeruddy-Thomas, Y., Díaz, S., & Brondízio, E. S. (2020). Including Indigenous and local knowledge in the work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment: Outcomes and lessons for the future. In T. F. Thornton & S. A. Bhagwat (Eds.), *The Routledge handbook of Indigenous environmental knowledge* (pp. 343–355). Routledge. https://doi.org/10.4324/9781315270845-30

Meghalaya Biodiversity Board. (2018). *Sacred groves*. Government of Meghalaya. https://megbiodiversity.nic.in/sacred-groves

Mukherjee, B. B., & Kaur, G. (2025). Reimagining Sustainability: Integrating Indian Knowledge Systems with Global Discourses on Growth, Ecology and Communication. *Higher Education for the Future*.

Nene, Y. L., & Choudhary, S. L. (2002). Agricultural heritage of India. Asian Agri-History Foundation.

Popova, U. (2014). Conservation, Traditional Knowledge and Indigenous Peoples. *American Behavioral Scientist*, *58*(1), 197-214.

Posey, D. A., & Dutfield, G. (1996). Beyond intellectual property: Toward traditional resource rights for indigenous peoples and local communities. International Development Research Centre.

Pretty, J. (2003). Social capital and the collective management of resources. *Science, 302*(5652), 1912–1914. https://doi.org/10.1126/science.1090847

Priya, T. (2010). Protecting the Tangible and Intangible Heritage of Rani ki Vav: A Unique Subterranean Step Well in Gujarat. *Advanced Materials Research, 133-134*, 1057 - 1064.

Sadhale, N. (Trans.). (1999). Krishi-Parashara (Agriculture by Parashara). Asian Agri-History Foundation.

Sharma, N., Trivedi, M. & Choudhary, M. From tradition to transform: SDGs and the role of the Indian knowledge system in india's growth through ESE (Environment, Social and Economic) factors. *Discov Sustain* 6, 1110 (2025). https://doi.org/10.1007/s43621-025-01905-3

Shawoo, Z. (2019). The UN Local Communities and Indigenous Peoples' Platform: A traditional ecological knowledge-based evaluation. *WIREs Climate Change*. https://doi.org/10.1002/wcc.575

 ISBN: 978-93-49666-59-7 (eBook)

Shroff, B. (2025). Indian Knowledge Systems (IKS) and environmental sustainability: Integrating tradition with Sustainable Development Goals (SDGs). *International Journal of Political Science and Governance, 7*(8), 20–26. https://doi.org/10.33545/26646021.2025.v7.i8a.616

Ten Kate, K., & Laird, S. A. (1999). The commercial use of biodiversity: Access to genetic resources and benefit-sharing. Earthscan.

Tiwari, B. K., Barik, S. K., & Tripathi, R. S. (1998). Biodiversity value, status and strategies for conservation of sacred groves of Meghalaya, India. *Ecosystem Health, 4*(1), 20–32. https://doi.org/10.1046/j.1526-0992.1998.00068.x

Torri, M. C., & Herrmann, T. M. (2011). *Indigenous Knowledge of Water Management, Biodiversity Conservation and Local Development in Rural India: A Case Study of the Thanagazi Region, Rajasthan*. Nie India

UNESCO. (2025). *Local and Indigenous Knowledge Systems and climate change*. UNESCO.

UNESCO. (2026). *Biodiversity: Local, Indigenous and scientific knowledge*. UNESCO.

Vipat, A., & Bharucha, E. (2014). Sacred groves: The consequence of traditional management. *Journal of Anthropology, 2014*, Article 595314. https://doi.org/10.1155/2014/595314

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Chapter

27

Strengthening Community-based Adaptation through the Marketing of Handloom Industry: A Study with Reference to Bodo Handloom

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ABSTRACT

Handloom weaving is one of the most important elements of the socio-cultural and economic life of any community. It not only contributes in livelihood, it also represents the tradition, cultural identity of the particular community and the relationship of that community with their surroundings. However, in the era of modernization, competition from powerlooms and inadequate adoption of modern marketing practices creates challenges for the handloom weavers. The current study is based on a particular community, i.e., the Bodo community, the largest ethnic group of a north eastern state of India, Assam. Bodos also settle in neighbouring countries of India, Nepal and Bangladesh. The present study explores the traditional designs/Agor depicted in the Bodo handloom products and investigates the contribution of modern Marketing practices in handloom Industry in strengthening community-based adaptation and sustainable livelihoods among Bodo handloom weavers. The study follows both descriptive and exploratory research design, which is based on primary data. The primary data were collected from 50 handloom weavers and handloom enterprises of Bodoland, Assam, through personal interviews. The findings of the study reveal that the Agor or designs the Bodo community depicts in their handloom products are inspired by the nature and things they use in their daily life. They depict motifs of flora and fauna, some of these designs are Mwswo hathai agor, Khangkhrai agor, Bema agor, Thamphwi agor, Sun bibar agor, Dingkhiya bijwo agor, Pharwo megon agor etc.

Keywords: Handloom, Agor, Community-based Adaptation, Sustainable Livelihood

INTRODUCTION

Community-based adaptation has become an important approach in today's era for strengthening the capacity of communities to respond to today's changing social, economic,

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market and environmental conditions. Community-based adaptation emphasises local communities use their knowledge and skills for tackling the emerging problems, which represents that the communities possess valuable indigenous knowledge that can help them respond to changing circumstances and sustain their livelihood. The Bodo community, majority residing in the Northeast India has a rich tradition of handloom weaving, in which traditional textiles represent their cultural identity. Traditional textiles of Bodo community include different kinds of designs that are related to patterns of things they use in their daily life, flora and fauna. Designs are mainly called as 'Agor' in the Bodo language. So, for the indigenous communities like Bodo community, the community-based adaptation is closely associated with the sustainability of their traditional practices and livelihood system. The concept of sustainable livelihood is a very important part of community-based adaptation. A livelihood can be called sustainable when it is capable of fulfilling current needs and withstands shocks without reducing options for the future generations. For communities depending on traditional practices, strengthening livelihood opportunities can improve their capacity to deal with changing environment in today's era of modernisation.

The handloom sector is considered as the second largest economic activity of India. The handloom industry provides source of livelihood for many communities in India. Handloom production includes traditional knowledge and skills, cultural expressions of a particular community. Different communities have their unique skills and techniques of weaving and also have different kind of designs representing their culture. The handloom weavers, particularly the weavers belonging to socially marginalised sections like Scheduled Tribes such as Bodo people can face challenges due to the technology upgradation, digitalisation, changes in customer preferences, changes in availability of resources, competition from powerloom and machine-made products, increasing production costs, limited market access and inadequate adoption of modern marketing practices. These challenges can affect the economic sustainability of weaving households and may also effect the transmission of traditional weaving knowledge to younger generations. In this context, strengthening the community's existing traditional knowledges, practices and skills by introducing appropriate innovations can serve as an important foundation for community-based adaptation without losing cultural identity.

The preservation of the traditional Agor and its continuation are very important for the economic sustainability of handloom weaving. If handloom weaving does not provide adequate livelihood opportunities, younger generations will become less interested in acquiring traditional weaving skills. Therefore, strengthening the market for Bodo handloom products will not only contribute to income generation but also help the preservation and transmission of indigenous knowledge.

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STATEMENT OF THE PROBLEM

Due to modernisation, changing market needs, and digitalisation, it has become important to investigate the community-based adaptation of the different communities and how their traditional skills and indigenous knowledge can be strengthened to deal with the emerging problems. Though, Handloom weaving helps the communities preserve their tradition and cultural heritage, it also serves as a source of livelihood for the tribal people mainly residing in rural areas of northeast India. So, it is necessary to have economic sustainability in handloom weaving. If their will be no economic sustainability in the handloom weaving, future generation will be less interested in it.

Traditional Bodo textiles incorporate unique Agor that reflects cultural knowledge, community identity and elements of the surrounding environment. However, the sustainability of this traditional occupation is increasingly influenced by changes in consumer preferences, competition from machine-made products, changing market conditions, rising production costs and limited access to wider markets. Limited branding, inadequate product promotion, dependence on intermediaries and insufficient digital marketing can restrict the ability of handloom weavers to reach mass consumers, which results in the continuation of traditional weaving as a livelihood more challenging. At the same time, traditional Agor are valuable cultural resources that can potentially distinguish Bodo handloom products in competitive markets. However, there is a need to understand how these designs are represented, what they signify and how they can be appropriately presented to contemporary consumers. Modern marketing provides opportunities through social media, digital platforms, branding, storytelling, exhibitions and product diversification. Nevertheless, the extent to which these practices contribute to livelihood resilience and community-based adaptation among Bodo handloom weavers requires greater attention.

Therefore, there is a need to study about the traditional agor of handloom products of Bodo community and modern marketing practices to strengthen community-based adaptation.

Review of Literature

Basumatary and Khawzawl, (2024) explored relationship between Bodo folklore and the practice of weaving with the intention of providing insight into the culturally significant fabric that has been influenced by women's expertise. Weaving is an important form of cultural expression through which Bodo women keep and hand down cultural knowledge, values, beliefs and traditions from one generation to another. The authors note that weaving is more than just a way to make clothes; it also holds stories, images, feelings, and cultural meanings. Through folk songs, stories, proverbs, and riddles, the study specifically talks about how women keep the weaving tradition alive. What it talks about is how traditional Bodo agor (designs) are connected to things in nature, like birds, animals, trees, and flowers.

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Narzary and Boro, (2024) studied the traditional knowledge of weaving design of the Bodo people and the categories of Bodo agor. There are motifs of man-made objects, nature, flora and fauna that the Bodo people depict in their handloom products. Motifs of man-made objects include sorthea agor, jong agor and thakhamala agor. This habit of depicting motifs related to the nature into their handloom products reflects a deep connection towards their surroundings and the creativity of the Bodo community.

Goyary and Chanu, (2024) examined the marketing practices of handloom-based enterprises in terms of product, place, price and promotion. The clothes woven by the handloom weavers across different states of Northeast India vary widely from each other as they largely deal in traditional attires. A few number of the weavers sell their goods outside the state; the majority sell in weekly or daily markets. However, the weavers sell their goods directly to the local market because of lack of facilities to supply outside the nation, and they are unaware of internet platforms.

Brahma and Lahary, (2025) explored Bodo traditional textile designs and their connection to ecological themes. The study highlighted that Bodo textile designs represent not only aesthetic and cultural identity but also traditional ecological knowledge and the community's close relationship with nature. Using a descriptive-analytical approach, the authors examined textiles such as Dokhona, Fasra and Aronai and identified several ecological motifs derived from native flora. The researchers examined the role of Bodo traditional textile design in promoting biodiversity conservation, ecological balance, and sustainable livelihoods, where the study identified motifs such as Dingkhiya bilai Agor (fern leaf), Phami bibar Agor (lotus), Lewa Agor (creeper), Bwigri bibar Agor (jujube flower), and Thaigir bibar Agor (elephant apple flower). These designs are associated with biodiversity, seasonal changes, traditional knowledge, cultural practices and ecological consciousness. These motifs serve as more than decorative elements; they preserve cultural memory and communicate the Bodo community's relationship with its natural surroundings. Furthermore, the researchers also analysed the techniques, material used in Bodo traditional textiles, assessing significance and sustainability, and explored challenges and opportunities for the preservation and revitalization of Bodo traditional textile design practices in the era of modernization, globalization, and environmental change. The study highlights the sustainable aspects of Bodo textile production, including using locally sourced materials and natural dyes.

Mushahary, (2025) investigated the origin of the Bodo community and highlighted their traditional weaving patterns, and also explored the traditional designs and motifs of Bodo community and its changes over a period. In the findings, it is revealed that Bodo people are maintaining their age-old traditional process of weaving from centuries and also the weaving process among them is continuing from generation to generation. Bodo people weaves the designs inspired from their surroundings like pharwo megon agor, dingkhiya agor, and hajw agor.

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Paliwal and Kaur, (2025) Artificial Intelligence can support a more sustainable, inclusive, and competitive handloom fashion ecosystem. Its biggest impacts are in waste reduction, defect detection, sustainable use of materials, demand forecasting, inventory control, digital design, branding, market access, traceability, skills development, and cultural archiving. It does not allow us to see AI as a substitute for craftsmanship. Rather its value is in enhancing human creativity, enabling artisan agency and increasing access to information and markets. Future research should focus on participatory system design, culturally relevant data sets, region-specific sustainability metrics, transparent algorithms, and long-term field research. The success of AI integration will rely on the ability of the artisans to keep control of their knowledge, designs, narratives and economic value. The key challenge, then, is not only the adoption of advanced technology, but the establishment of an ecosystem in which innovation, cultural integrity, environmental responsibility and social equity complement each other.

Yadav and Jena, (2025) investigated drivers and barriers affecting e-commerce adoption among handloom weavers through the use of Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT is very useful in examining factors influencing e-commerce adoption among the handloom weavers because UTAUT incorporates social and psychological elements, enhancing its predictive and explanatory power. There are nine factors influencing adoption of e-commerce, and these factors are effort expectancy, social influence, performance expectancy, children's support, relative advantages, institutional support, behavioural beliefs, and perceived risk. These variables may influence actual adoption of e-commerce among handloom weavers negatively or positively. The adoption will impact the "Business performance" of handloom weavers in two ways: market performance and financial performance.

RESEARCH GAP

The existing study reviewed (Basumatary and Khawzawl, 2024), (Narzary and Boro, 2024) (Brahma and Lahary, 2025) (Mushahary, 2025) mainly focused on the traditional knowledge, traditional designs, category of Bodo agor, the origin of the Bodo community, traditional weaving patterns, documented the ecological themes embedded in Bodo traditional textile designs and highlighted their significance for cultural heritage, ecological consciousness and sustainable livelihoods but their study does not examine how these ecological designs and associated traditional knowledge can be strategically marketed in contemporary markets. (Goyary and Chanu, 2024) focused on the marketing practices of handloom-based enterprises with regard to product, place, price and promotion, and where and how the handloom weavers sell their products. (Paliwal and Kaur, 2025) studied how Artificial Intelligence can support a more sustainable, inclusive, and competitive handloom fashion ecosystem in the era of modernisation by contributing in waste reduction, defect detection, sustainable material use, demand forecasting,

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inventory control, digital design, branding, market access, traceability, skills development, and cultural archiving. (Yadav and Jena, 2025) investigated drivers and barriers that affects the adoption e-commerce among handloom weavers by using the Unified Theory of Acceptance and Use of Technology (UTAUT).

Though, there are literatures studied about economic importance of handloom activities and the livelihood contribution of weaving among rural and tribal communities. Yet, comparatively a few research has examined handloom marketing as a mechanism for strengthening community-based adaptation. The community-based adaptation is generally means the ability of local communities to respond to social, economic and environmental changes by utilizing their local knowledge, resources, skills and traditional practices. Traditional handloom weaving in Bodo communities can potentially contribute to such adaptation through livelihoods, indigenous knowledge, women's participation and cultural and ecological links. But, the relationship between marketing of handloom products and community-based adaptation is underexplored. Furthermore, limited attention has been given to how traditional Bodo designs or Agor depicting elements of nature, biodiversity, animals, insects, plants and other cultural symbols can be incorporated into contemporary handloom products and effectively communicated and marketed to consumers. There is therefore a need to examine whether the commercialization and marketing of these culturally and ecologically significant designs can create economic opportunities while simultaneously supporting cultural preservation, sustainable livelihoods and community resilience.

Thus, the current study attempts to fill this gap by examining the traditional designs/ Agor depicted in selected Bodo handloom products and exploring how their marketing can contribute to strengthening community-based adaptation and sustainable livelihoods among Bodo handloom weavers.

OBJECTIVES

1. To explore the traditional designs/Agor depicted in the Bodo handloom products.
2. To investigate the contribution of modern Marketing practices in handloom Industry in strengthening community-based adaptation and sustainable livelihoods among Bodo handloom weavers.

RESEARCH METHODOLOGY

The present study followed both qualitative and qualitative research approach, and the study is based on primary data. The present study is descriptive and exploratory in nature. The primary data were collected from 50 Bodo handloom weavers and handloom enterprises of Bodoland Territorial Region, Assam. Personal interviews was carried out to collect the data from the respondents. A convenience sampling technique was used to select the 50 Bodo handloom weavers.

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FINDINGS AND DISCUSSIONS

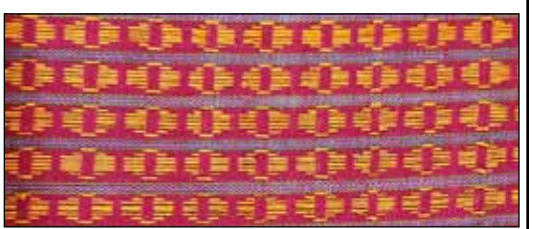
Traditional designs/Agor Depicted in the Bodo Handloom Products

The study found that traditional Agor constitutes an important component of Bodo handloom products. Traditional Agor depicted in handloom products of the Bodo community represents their cultural identity and indigenous knowledge. These agor reflects the elements of nature and the relationship of the Bodo community with their surrounding environment. The Bodo people depict the Agor inspired from their surroundings, which includes patterns of nature-based designs. The motifs do not only represent the creativity and relationship with nature, but also represents the traditional knowledge and cultural significance of those particular motifs. The Agor that the Bodo community depict in their handloom products, which are found during the field survey, are: Khangkhrai agor, Bema agor, Dingkhiya bijwo agor, Sunbibar Agor, Pharwo megon Agor, Thamphwi Agor, Laao begor Agor, Mwswo hathai Agor, Gudam Agor, Hagra bijwo Agor, Khangkhrikola Agor.

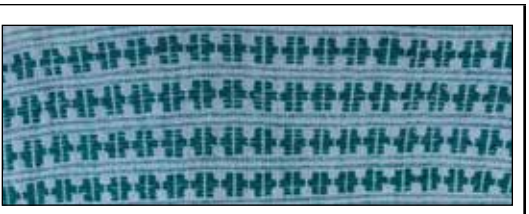
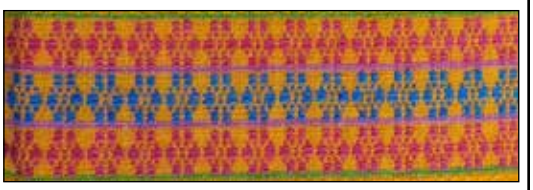
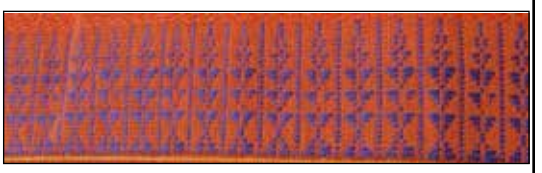
Table 1: Traditional Bodo Agor

Name of Design	Image of Design
Khangkhrai Agor: Khangkhrai means crab, and the Khangkhrai Agor represents the design of crab. Though crab is a edible species the Bodo handloom weavers use this as an agor in their handloom products. This depiction of the water species as an agor in the handloom products by the Bodo handloom weavers reflect the creativity and connection with their surroundings.	 **Fig. 1:** Khangkhrai Agor
Sunbibar Agor: Sunbibar means the sunflower, and Sunbibar agor represents the design of sunflower, which the Bodo weavers depicts in their handloom products. The Sunbibar Agor demonstrates the connection between Bodo handloom design and the natural environment, where the form of a flower becomes a source of inspiration for textile design.	 **Fig. 2:** Sunbibar Agor

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Pharwo megon Agor: Pharwo megon means the eye of a pigeon. As the Pharwo megon Agor is inspired by the appearance of the eye of a pigeon, it demonstrates how specific visual features of birds can be abstracted and reproduced as textile motifs. The use of a bird-related motif reflects the close observation of the natural world embedded within traditional design knowledge of Bodo people. Instead of reproducing the entire bird, the design focuses on a particular feature—the eye—and converts it into a decorative textile pattern.	 **Fig. 3:** Pharwo megon Agor
Thamphwi Agor: Thamphwi Agor represents the design of housefly. Its presence in traditional handloom design illustrates that motifs may be derived not only from visually attractive elements such as flowers and plants but also from small insects commonly observed in everyday surroundings. It reflects the ability of traditional Bodo handloom weavers to translate observed natural forms into textile designs.	 **Fig. 4:** Thamphwi Agor
Laao begor Agor: The Laao Begor Agor represents the design inspired by the shape of bottle gourd seeds. It demonstrates the influence of everyday agricultural and plant knowledge on Bodo textile traditions. It also indicates that the traditional design inspiration can originate from small and commonly observed elements of plants.	 **Fig. 5:** Laao begor Agor

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Mwswo hathai Agor: Mwswo hathai Agor is inspired by the appearance or arrangement of the cow teeth. The motif represents another example of how traditional Bodo textile designs draw inspiration from animals and their physical characteristics.	 **Fig. 6:** Mwswo Hathai Agor
Gudam Agor: Gudam Agor represents a button-like form incorporated into the Bodo handloom design. Unlike motifs that are directly inspired by plants or animals, Gudam Agor demonstrates how objects associated with everyday material culture can also become sources of textile inspiration.	 **Fig. 7:** Gudam Agor
Hagra bijwo Agor: Hagra bijwo Agor is inspired by the form of Durva grass. The motif demonstrates how commonly observed vegetation can become a source of traditional textile design and reflects the close relationship between the community and its surrounding plant environment.	 **Fig. 8:** Hagra Bijwo Agor
Khangkhrikola Agor: Khangkhrikola Agor is inspired by the appearance of the spiny gourd. The Khangkhrikola Agor reflects the connection between Bodo handloom and local plant and food resources and demonstrates how agricultural biodiversity can be represented through textile design.	 **Fig. 9:** Khangkhrikola Agor

Source: *Field Survey*
P.C: Sabitri Bala Goyary.

Contribution of Modern Marketing Practices in Handloom Industry in Strengthening Community-based Adaptation and Sustainable Livelihoods among Bodo Handloom Weavers

The study found that modern marketing practices have the potential to strengthen the adaptive capacity and livelihood opportunities of Bodo handloom weavers by connecting

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traditional production with changing market conditions. The study establishes a connection between traditional Bodo knowledge and modern marketing. Traditional Agor provide the cultural foundation, while modern marketing provides the mechanism through which this cultural resource can be converted into wider market opportunities. The modern marketing practices respondents use to market their handloom products are Digital and Social Media Marketing, Branding and Product Identity, Exhibitions and Direct Marketing. These modern marketing practices contributes in Women's Economic Participation, Sustainable Livelihoods, helps in strengthening Community-Based Adaptation, and Preservation of Traditional Knowledge.

Table 2: Use of Digital and Social Media Marketing Practice by Bodo Handloom Weavers and Handloom Enterprises

Response	Frequency(f)	Percentage (%)
Yes	35	70
No	15	30
Total	50	100

Source: *Primary data collected by researcher*

Digital and Social Media Marketing

The findings revealed that 70% of Bodo handloom weavers and Handloom enterprises of the respondents use digital and social media marketing to market their handloom products. The use of social media provides opportunities for weavers and handloom entrepreneurs to display their products beyond their immediate local markets, which reduce excessive dependence on local customers and intermediaries. Platforms such as Facebook, Instagram and WhatsApp facilitates product promotion, customer communication and direct interaction with potential buyers.

Table 3: Use of Branding and Product Identity Practice by Bodo Handloom Weavers and Handloom Enterprises

Response	Frequency(f)	Percentage (%)
Yes	12	24
No	38	76
Total	50	100

Source: *Primary data collected by researcher*

Branding and Product Identity

It is found that only 24% of the respondents use the branding and product identity practice to market their handloom products, and other respondents are unaware of this

practice. It is found that Branding strengthens the identity of Bodo handloom products. Communicating the Bodo origin, traditional weaving technique, Agor, craftsmanship and cultural significance differentiates the products from mass-produced textiles.

Table 4: Use of Exhibitions and Direct Marketing practice by Bodo Handloom Weavers and Handloom Enterprises

Response	Frequency(f)	Percentage (%)
Yes	19	38
No	31	62
Total	50	100

Source: *Primary data collected by researcher*

Exhibitions and Direct Marketing

The findings revealed, as per the table-4 shows, that only 38% of the respondents use Exhibitions and direct marketing practices. Participation in exhibitions, fairs and cultural events provides opportunities for direct interaction between weavers and consumers. Direct marketing improves product visibility and potentially reduces dependence on intermediaries. This helps them adapt to changing market conditions by expanding their customer base, and direct interaction with buyers helps them in modifying products according to changing demand. Exhibitions provide opportunities to display traditional Agor and helps in increasing consumer awareness of Bodo cultural heritage by explaining meaning and story behind each design.

The modern marketing practices followed by the Bodo handloom weavers and handloom enterprises, such as Digital and Social Media Marketing, Branding and Product Identity, Exhibitions and Direct Marketing, contribute to Sustainable livelihoods, strengthen community-based adaptation, help in preservation of traditional knowledge, and women's economic participation.

Contribution to Sustainable Livelihoods

Modern marketing practices contributes to sustain livelihoods by offering more market prospects and enhancing the visibility of handloom items. Increased market access helps the Handloom weavers earn more income which helps them to continue weaving as a livelihood. But the sustainable livelihoods are not just about the greater sales but also about the fair pricing, availability of raw materials, production costs, regular demand and continuity of weaving skills.

Contribution to Community-Based Adaptation

The present study revealed that the modern marketing practices supports community-based adaptation by enabling Bodo handloom weavers to respond to shifting market

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conditions while using their existing traditional knowledge and skills carried out from generation to generation.

Preservation of Traditional Knowledge

The study also reveals that the economic sustainability of handloom contributes to the continuation of traditional weaving knowledge and skills, traditional agor that the Bodo handloom weavers depict in their handloom products. Because when the traditional designs are of commercial value, the younger generations of the community will be more motivated to learn and preserve traditional weaving methods and the traditional designs.

Women's Economic Participation

Since women play a significant role in Bodo handloom production as they weave to help financially to their family, strengthening marketing opportunities potentially enhances their participation in income-generating activities. Greater involvement in product development, pricing, promotion and direct selling further strengthen their position within the handloom value chain.

CONCLUSION

Community-based adaptation provides a useful framework for understanding how local communities can respond to changing economic, social and environmental conditions by building upon their own knowledge, skills, resources and institutions. In the case of handloom weaving of the Bodo communities, traditional weaving and Agor constitute important cultural and livelihood resources that contribute to this adaptive capacity. The study demonstrates that Bodo handloom should not be viewed only as a traditional craft or source of income. It represents a combination of cultural identity, indigenous knowledge, craftsmanship and livelihood potential. Traditional Agor provide Bodo handloom with a distinctive cultural identity and can serve as an important basis for product differentiation. At the same time, traditional knowledge alone is not sufficient to ensure the economic sustainability of the handloom sector in changing markets. Modern marketing practices such as social media marketing, digital selling, branding, exhibits and direct marketing help to link conventional products to modern day consumers. The main point of the study is that marketing can be a method for community-based adaptation, when it enhances the capacity of Bodo handloom communities to respond to changing markets while retaining their traditional knowledge and cultural identity. Thus, sustainable marketing of Bodo handloom should be directed not only toward increasing sales but also toward ensuring fair returns to weavers, documenting traditional designs, encouraging younger generations to continue weaving, strengthening women's participation and promoting the cultural story behind each product. Therefore, via improving the marketing of Bodo handloom we may promote economic resilience and cultural sustainability. The future of

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the Bodo handloom sector lies in forging a balanced relationship between tradition and innovation – where traditional Agor and indigenous knowledge form the core and modern marketing practices help these products reach wider markets and generate sustainable livelihood opportunities.

REFERENCES

Basumatary, R., & Khawzawl, T. L. (2024). Folklore of the Himalayan Foothills: Weaving Traditions in Bodo Folklore. *Rupkatha Journal on Interdisciplinary Studies in Humanities*, *16(2).*

Brahma, K., & Lahary, B. (2025). Ecological Themes in the Bodo Traditional Textile Designs. *Sotsiologicheskiy Zhurnal*, *15(4),* 60-65.

Goyary, S. B., & Chanu, A. I. (2024). Marketing of Small Business with Regard to Handloom Sector. *REST Journal on Banking, Accounting and Business, 3(3),* 80-84. DOI: https://doi.org/10.46632/jbab/3/3/13

Mushahary, E. (2025). The Patterns and Techniques of Weaving Among the Bodo Tribe of Assam. *International Journal of Multidisciplinary Educational Research, 14 (11(2)),* 94-97.

Narzary, S., & Boro, I. (2024). An Introduction to the Bodo Agor (Weaving Design). *Educational Administration: Theory and Practice, 30(1),* 4115-4117.

Paliwal, P., & Kaur, A. (2025). Artificial Intelligence in Handloom Fashion: Advancing Sustainability, Empowerment, and Cultural Revival. *Journal of Emerging Computer Research and Applications,* 59-64.

Yadav, S., & Jena, B. B. (2025). Building a Conceptual Framework to Study Factors Influencing E-commerce Adoption by Handloom Weavers. *NIFT Journal of Fashion, 4,* 184-2023.

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Chapter

28

On the Margins of the Plateau: Cultural Geographies and Environmental Adaptation of the Shadowed Marngar Community of Northeast India

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ABSTRACT

People living in peripheral zones, borders or transitional geographic spaces often experience socio-cultural and economic marginalization. They remain largely in the shadows in academic and developmental discourses. They are often found to negotiate between traditionality and development. In the northern foothills of the Khasi Plateau of Northeast India resides the lesser-known Marngar community, with distinctive cultural practices and rich indigenous knowledge. Drawing on cultural geography and the man–environment relationship, the study explores how the Marngars negotiate their livelihood and culture in relation to the environment and socio-spatial conditions.

To understand the life of the Marngars, books and reports were reviewed alongside intensive field investigation comprising household surveys and interactions with community members, village elders and traditional leaders for institutional information. The study also includes GIS-based analysis of land use/land cover and terrain characteristics.

The findings reveal that the Marngars possess a mixed cultural-linguistic character. They are a Scheduled Tribe situated within a Khasi-dominated administrative framework. Despite their peripheral location and identity, Marngars maintain strong socio-ecological resilience through customary institutions, traditional livelihood practices and community-based conservation such as the customary protection of aquatic fauna in Marngar Lake and sustainable resource management. The study also highlights that the community faces severe marginality, economic vulnerability to flooding and interstate border disruptions, and gradual erosion of culture and tradition. The paper argues that preservation of Marngar culture requires recognizing their customary governance, securing their identity, protecting their material culture, and integrating their indigenous ecological knowledge into participatory spatial planning for inclusive rural development.

Keywords: Marngar, Marginality, Cultural Geography, Man–Environment Relationship, Indigenous Knowledge, Livelihood

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INTRODUCTION

Tribal and indigenous communities in India occupy a distinctive position within the nation's social and cultural landscape, with nature-based livelihood systems based on agriculture, forests and local natural resources. With time, many tribal societies in India have undergone various socio-cultural transformations and economic developments. Education have played a key role in these tribal societies, bringing development in their societies. However there are many lesser known tribes in India which are still living in socio-spatial marginalization. They exist at the margins of academic attention and development policies. This marginalization is evident among tribes and indigenous communities living in peripheral or transitional geographic spaces, such as remote borders. These conditions lead to their economic vulnerability, identity crisis and cultural erosion.

In Northeast India, there are more than 200 major tribes with distinct cultural identity and geographical spaces. Yet there are some tribes in the region whose identities are still undocumented. One such tribe is the Marngar tribe, who resides in the Northern foothills of the Khasi Plateau between the states of Assam and Meghalaya. Very little is documented about this tribe. Marngars, the Assamese-speaking Scheduled Tribe, occupy a unique socio-cultural niche in Meghalaya, the state mainly known as home of Khasis, Garos and Jaintias. While the Marngars share linguistic affinities with Assamese of Assam, the bordering state of Meghalaya, they conform to the customary laws of the Khasi tribe of Meghalaya.

This current study is on the socio-spatial dynamics of the Marngar Tribe, a marginalized communities of peripheries of Northeast India. The study draws upon the unique cultural characteristics of the lesser-known Marngar tribe of the Assam-Meghalaya border. The study is mainly conducted with an aim to bring out the identity of the Marngar tribe to the world outside and provide them a significant position among the major tribes of Northeast India. In this context, the current study examines (i) the cultural identity of the Marngars within the transitional geographies of two different states with contrasting socio-cultural characteristics. (ii) the livelihood pattern and resource utilization of the Marngars in response to environmental adaptions (iii) the customary laws and socio-ecological resilience of the Marngars(iv) socio-economic vulnerability and cultural erosions of the Marngars in their geographic space.

LITERATURE REVIEW

The cultural geography of peripheries and marginalized communities needs to be understood through a human- environment relationship approach to help analyze how space, livelihood, culture and customary laws of a cultural landscape are intrinsically related.

Human-environment relationship and its spatial dimensions have been the very foundation of human geography since ages. Previous approaches highlighted on how

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environment determines human actions. Gradually the idea shifted to the thought of 'Possibilism' a pillar laid by Paul Vidal de la Blache in 1926 who gave the idea that nature provides endless opportunities to mankind but it's the choice, needs and culture of mankind that shape their adaptations, resilience and cultural landscape. This idea of Blache was formalized further by Carl o Sauer (1925) who described human culture is an agent that acts upon the natural environment which can be considered as a medium to produce a cultural landscape that we see. This cultural landscape is thus the product or outcome of the culture (agent) acting upon the natural environment (medium).

Sauer (1925) formalized this agency through the concept of the *cultural landscape*, arguing that culture acts as the agent, the natural area is the medium, and the cultural landscape is the result. Within this framework, landscapes are not merely physical backdrops but are dynamic palimpsests inscribed with social norms, cultural traditions, and settlement histories. This cultural landscape is not static. It is a continuous process of the dynamic interaction of human culture and environment shaping settlements, societies, history and customary laws and traditions.

Expanding the thought further, Steward (1955) propounded the theory of cultural ecology where he focused on adaptations of societies in response to the ecological conditions of the place they live. Julian Steward expressed his thought on human adaptions to specific ecological niches which arise from functional utilisation of the space they live. He also further expressed that adaptation process is continuous and reciprocal where human beings continuously change the environment by activities such as agriculture, settlement, cultural practices while at the same time adapting to the environment they live.

Tuan (1977) highlighted on the concept of meaningful "place" (*topophilia*). According to Tuan indigenous communities are attached to their cultural space that comprises of sacred forests, cemetaries, ancestral homes etc., which serve as their emotional anchors that consists of collective memory and shared cultural space and their natural heritage. For them, it's a space against external pressures.

The greatest treasures of Indigenous or Tribal communities are their traditional ecological knowledge. Their societies are enriched by the common pool resource governance or shared resource governance such as community owned land, community conservation practices through their customary laws. Ostrom (1990) explains that communities can develop effective self-governing institution to manage Common Pool Resources (CPRs).

Northeastern Region of India is a home of multiple ethnicity with diverse socio-cultural background (Baruah, 1999; Karlsson, 2011). In the borders and spaces of transition , ethinicty often integrates leading to hybridity and liminality(Misra, 2000; McDuie-Ra,

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2012). Indigenous communities of the transitional space often relies on cross- border commodity flows and markets(*haats*). As a result the local economies become highly vulnerable to interstate conflicts, climatic hazards such as floods , economic disruptions etc(Bhattacharjee, 2019; Das, 2021).

While dominant ethnic groups in Meghalaya (Khasi, Garo, and Jaintia) have been extensively documented (e.g., Gurdon, 1914; Bareh, 1985; Nongkynrih, 2002), smaller demographic pockets—such as the Assamese-speaking Marngar community in Ri-Bhoi—remain largely absent from mainstream academic literature. This study addresses this empirical and conceptual gap by examining how the Marngars navigate socio-spatial marginality, sustain customary ecological conservation, and adapt their livelihoods across a transitional foothill landscape.

Several scholarly articles in Meghalaya have highlighted the Khasis, Garos and Jaintias as the major tribes of Meghalaya and received academic attention so far Gurdon, 1914; Bareh, 1985; Nongkynrih, 2002). Marngar tribe has not received much academic attention so far. Hence the study current study tries to address this gap and studies the lives of the marginalized tribe of the peripheries.

METHODOLOGY

The current study is based on preliminary field observation and is an attempt to provide a first-hand understanding of the life of Marngars at the peripheries and their challenges. The study is mainly done with the conversation with the community members while trying to understand their day to day practices and associated challenges.

Secondary data were compiled from Census of India reports and reports on the Marngars. The Shuttle Radar Topography Mission (SRTM) terrain data and high-resolution Google Earth images were processed in ArcGIS to produce a land use and land cover (LULC) layer, drainage layer, slope layer, aspect and contour layers for the study area. Qualitative record was supplemented by photographic/ video documentation of everyday practices and festivals and resource use activities, providing a visual archive for later verification.

STUDY AREA: THE MARNGAR INHABITED REGION

The study focusses on the Marngar inhabited area of Umpling in the Ribhoi district of Meghalaya close to the borders of Assam. The study area extends between 25°15'N–26°15'N and 91°45'E–92°15'E which is a transitional geography of the Khasi hills and the Assam plains. The circle extends over approximately 5,915 hectares (59.15 sq. km) and comprises sixteen recorded revenue villages, namely Barkhatsari, Borgang, Himpala, Khmar, Lalumpam, Mawphrew, Mawryngkang, Nalapara, Nangagang, Parangang, Purdua, Sarikhushi, Tamonpo Anglong, Umtham, Umwang Nongbah and Umwangthem, together

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with two newly emerging settlements whose formation reflects the continuing mobility of population within the circle. The 2016 Gram Sevak Circle demographic profile records 790 households and a population of 4,936 persons, comprising 2,431 males and 2,505 females, with 3,369 literates against 1,567 illiterates.

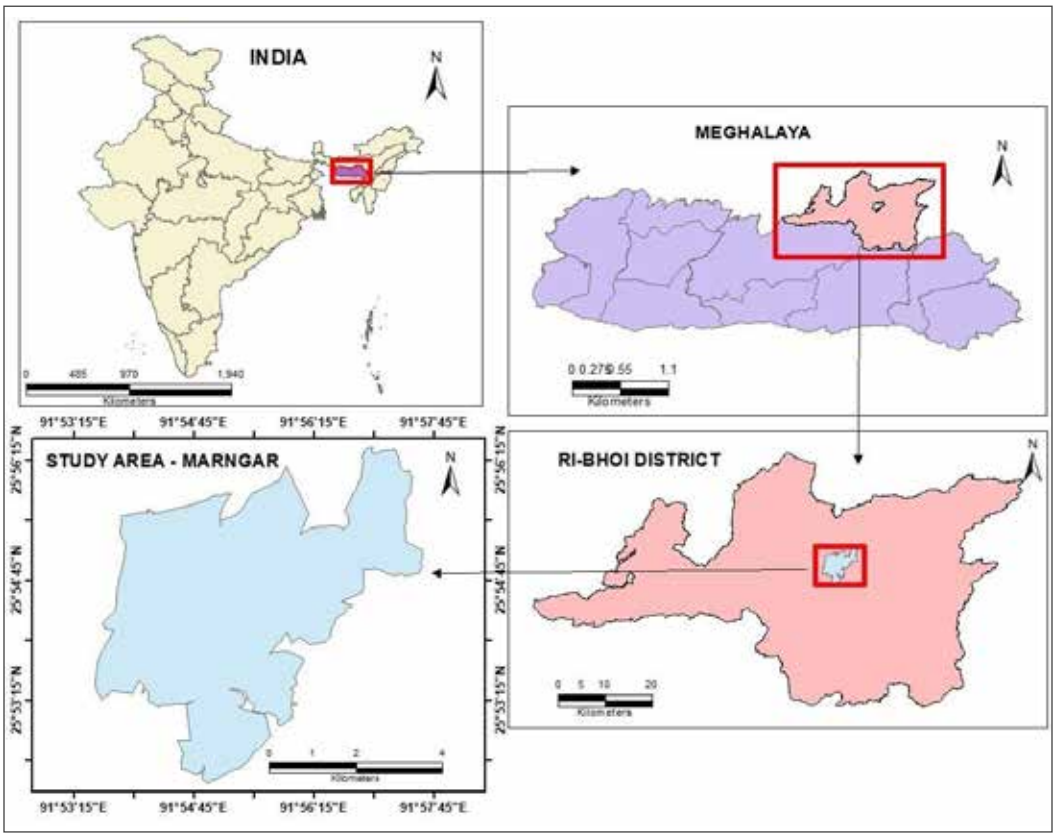


Fig. 1: Location map of Marngar Inhabited Area

The economy of this region is largely rainfall dependent agricultural that sustains paddy cultivation alongside broom grass, pineapple and vegetable farming on the gently sloping and low lying tracts, while the steeper and forested terrain remains comparatively less utilised and are a source of forest produce. The proximity of Marngar inhabited area to the Assam border, and particularly to Khanapara and its adjoining markets, is open for cross border trade. Hence climate and terrain controlled agricultural practises, forest produce, agriculture mainly ceonventional in nature and market at the borders makes the Marngar circle a suitable setting to examine the interaction between physical environment, customary laws and livelihood adaptation.

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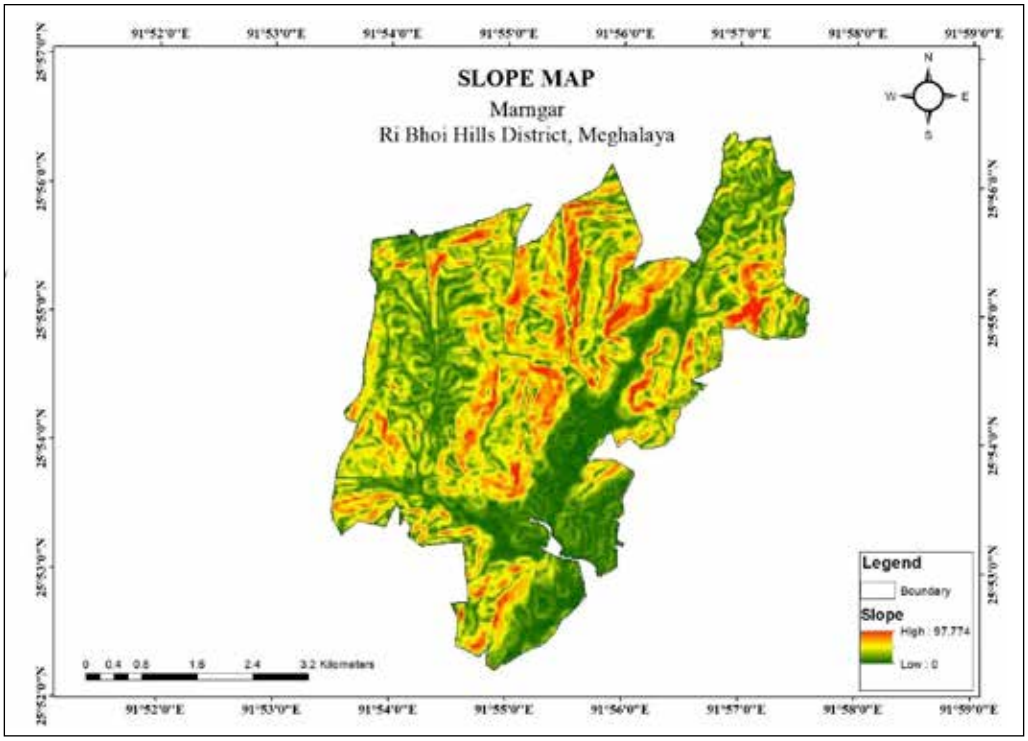


Fig. 2: Landuse/Landcover Map of Marngar Inhabited Area

Source: *Digitized in Google Earth Pro and processed in ArcGis*

The above cover map highlights the following pattern of Landuse Land cover in the Marngar inhabited region as per Table 1.

Table 1: Shows the Area in Hectares of the Landuse/Landcover Map Marngar

LULC	Area (Ha)
Cropland	539.20
Marngar Lake	3.47
Moderately Dense Forest	595.18
Open Forest	910.18
Paddy Cultivtion	351.81
Road	17.46
Settlement	18.15
Water body	35.66

Source: *Derived from Land Use Land Cover Map analysis*

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The Marngar inhabited area has a very challenging terrain which reflects their challenge of environmental adaptation in their livelihood.

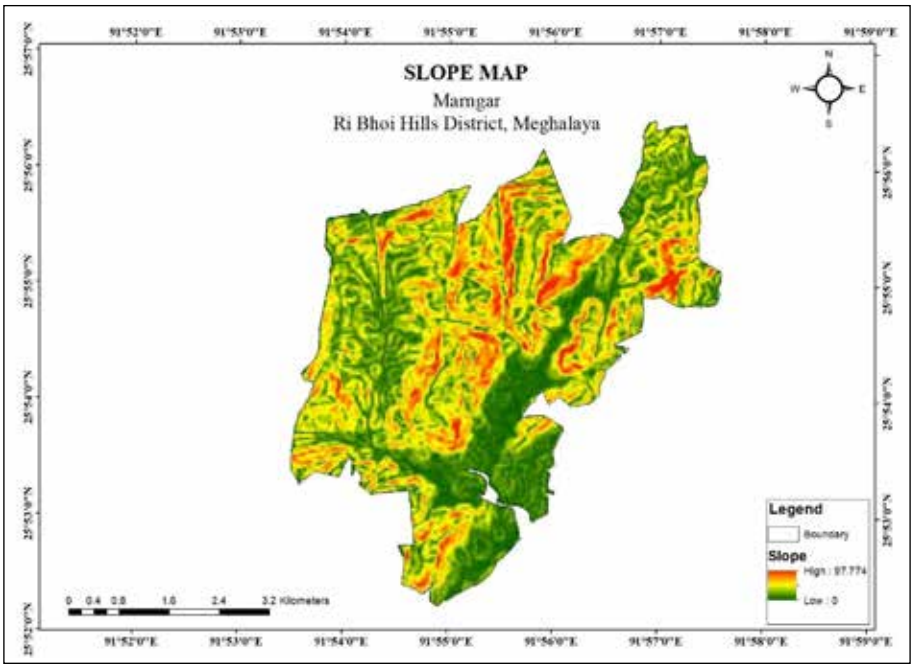


Fig. 3: Slope Map of Marngar Inhabited Region

Source: *SRTM DEM 30m Resolution, USGS*

The slope map of Marngar inhabited region shows significant variation in the terrain from gentle slopes to moderately steep and steep hill slopes. The terrain of the region is highly undulating. The lower slope areas, shown in green shades, are found mainly in the southern and some central portions of the village. These areas are comparatively more suitable for settlement and agricultural activities, particularly paddy cultivation, because of easier accessibility, better soil retention, and lower risk of erosion. Many of the inhabited areas and cultivated lands are concentrated in the gentle slope.

RESULTS AND DISCUSSION

Marngars: Historical Background

It is believed that Marngars have been living in the region for ages. Many generations have lived in and shaped the cultural space in the northern peripheries of the Khasi Hills. However their origin can be recorded from the oral traditions and local narratives. Due to lack of written records, it is difficult to trace their exact migration pattern and historical origin. Moreover, the current population do not have any trace of written documentations on their historical roots.

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Due to proper records, the community remained one of the least known tribe of Northeast India and less addressed in academic discourses. In 1992, Marngar region got a socio-cultural recognition in June 1992 when Ribhoi district carved out of East Khasi Hill District. This helped the Marngars receive identity in their cultural space.

Marngars today possess a strong sense belongingness to their native space. Despite the challenges of economic peripheries and transitional cultural space, Marngars exhibit a strong cultural bond within themselves and an example of strong resilience. They speak mostly Khasis , Assamese, Nagamese and reflect a blend of linguistic features due to their inhabitance in the cultural peripheries of Assam and Meghalaya. The Marngars have their own cultural festivals, attires, food habits, customary laws and beliefs which has built a strong resilience in the tribe to cope with changing time, economy and developmental processes.

Ethno-Linguistic and Cultural Identity

Marngars reflect a cultural blend of Khasis and Assamese. There is integration between the culture of Meghalaya, where they live, and that of Assam, which is less than 3 kilometers away from their inhabited area. Ramirez (2011) highlighted that the Marngar tribe of Meghalaya has distinct socio-cultural characteristics. They officially are scheduled tribe of Meghalaya but their culture reflect a distinct socio-cultural character within the region. They largely exhibit Mongoloid features which is common to all Himalayan and Northeastern tribes, indicating their ethnic linkages to Mongolia and other parts of Southeast Asia.



Fig. 4: Community Participation in Pulao Mara Festival

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Marngars are deep worshippers of nature, and this continues. Their reverence for nature is highly reflected in their customary laws of conservation and indigenous ecological practices. Despite modernity has touched the Marngar land, they continue to follow many traditional systems and customs and thereby preserving their cultural identity till date. Most of the Marngars practice Christianity today. They celebrate festivals such as Shad Lukhmi, Pom Blang, Tong Dohkha, Pulao Mara, Beh Huleng and Domahi.

Economic Structure and Literacy

The traditional livelihood practice of the Marngars is paddy cultivation, vegetable farming, pine apple cultivation. Agriculture forms the backbone of the economy of the Marngars. Nature has gifted the land abundantly with fertile soil, network of rivers and conducive climatic conditions. Although the terrain is hilly, the Marngars have very suitably resorted to sustainable agricultural practices combined with their traditional beliefs and customary practices. Agricultural Census 2021-22 data of Umling Block shows clear spatial variation in agricultural practices within the Marngar inhabited areas of Ri Bhoi District. These variations are due to terrain and vegetation of the region.



Fig. 5: Traditional Wooden Handlooms Operated by Local Weavers in Marngar Village

Another interesting finding of the study is that women involvement is livelihood practice is quite high. This underscores the matrilineal society akin to the Khasis of Meghalaya. Women of Marngars are found to be more active in livelihood and in fact women cultivators of paddy are higher than men. The study also finds that apart from cultivation women are engaged in forestry, weaving, livestock, and household management.

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Livelihood diversification is clearly visible in the economy of Marngars today. Tourism, vegetable vending, and government employment are other source of income in the area. Literacy rates for the Marngar G.S. Circle (3,369 literates against 1,567 illiterates) ref comparatively encouraging educational progress.

The economic structure of the Marngar tribe is gradually diversifying. While agriculture continues to dominate, some members of the community are employed in modern professions such as teaching, nursing, engineering, medicine, and professorship. Others are engaged in transportation-related occupations including taxi driving, sumo driving, and auto-rickshaw driving. Small-scale trade and market activities are also common among the people. Many individuals, especially women, sell vegetables and local produce in nearby markets to generate income for their households.

Customary Laws, Indigenous Knowledge and Ecological Resilience

Traditionally, villages of Marngars were administered by the village chief called '*Syiem'*, and a *Myntri* (minister) who looks after the implemention of the rules and regulations in the village as per the direction of the *Syiem*. This customary law reflects a strong self-governance (Lyngwa,1993).

Customary laws related to Land ownership in Marngar society involves clan land and community land. Land was considered as *Ri Raid*, or community land. Every member of the community had the right to utilize community land as per the customary laws of Marngars. Land is never considered private property that can be freely bought or sold. This practice is still prevalent among the Marngars, which reflects the community bonding with the tribe.

In regard to laws of inheritance, the Marngars reflect a mixed practice of Khasis and Assamese. The Khasis are matrilineal in nature, while Assamese societies are patrilineal. Being inhabited in a transitional space, Marngars are found to follow both matrilineal and patrilineal norms in their societies. The inheritance law among the matrilineal ones follows property inheritance through the female line, with the largest share of property being inherited by the youngest daughter. On the other those following the patrilineal norms follows the inheritance practice to the male heirs.

Marngars have Customary laws of social behaviours and community participation too violation of which may lead to penalties and punishments. For example a Marngar if refuses to cooperate in communal activities such as community harvesting and construction of house are required to face the due penalies. These reflects a strong governance and social responsibility among the Marngars.

Marngars are also rich in indigenous ecological knowledge and conservation practices. The Marngars lake in R ibhoi district is the soul of Marngar society. Conservation of the

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ecosystem in Marngar lake and the lives therein are done by the Marngars as customary practice. This is now growing as a centre of tourism in Ribhoi. Marngars exibit a very close relation with nature and their intrinsic bond.



Fig. 6: Traditional house of the Marngars

Marngars reflect a strong socio-ecological resilience due to the presence of strong customary practices and governance. Despite residing at the remote peripheries with minimal exposure to the outside world, Marngars exhibit a strong socio-ecological resilience. Community conservation practices at the Marngar Lake, shared resource utilisation, community owned land and sustainable resource management provide a strong base for resilience of the Marngars. Apart from that gender roles show how women play substantial roles in economy.

Socio-Economic Vulnerability and Community Resilience

Despite being resilient in socio-ecological aspects, Marngars are found to be economically vulnerable as their agriculture is still traditional in practice. They have no exposure to advanced mechanisms to enhance their production. The Marngar cultivators sale their produce in the nearest market of Nongpoh by vending in the streets. They are heavily dependent on buyers of Nongpoh or travellers of Assam and neighbouring states. They lack fixed market space and shops. Such an informal structure of economy has largely led to economic vulnerability to the tribe. However, irregular monsoons, border conflicts, tourist lean season often leads to reduction of sale; thus causing economic vulnerability.

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Alongside economic vulnerability, Marngars also exhibit a socio-cultural vulnerability dur to modernization, westernization and changing mindset of the youths. Young generations often do migrate for better economic opportunities and thus show less affinity towards their customary practices. This has caused tremendous vulnerability to the Marngar culture.

Westernization has also influenced the Marngar community through changes in clothing styles, religious practices, education systems, and patterns of living. Christian missionary influence, modern education, and exposure to urban lifestyles have introduced new cultural values and practices. Many traditional rituals are no longer practiced in the society as the new generations are now more involved in Church activities. However the core cultural festivals, traditional livelihood practices, customary laws have remained unchanged reflecting a strong resilience of the Marngars in fast-changing times of modernization and westernization.

Conclusion and Recommendation

The case study of Marngar community is a representative of the socio spatial marginality experienced by small and border adjacent indigenous community in North East India. Marngars are members of the Assamese-speaking ST group living in a region dominated by the majority of Khasi tribe. They live in the peripheries of two states. Culturally and linguistically different from the Khasis, they have remained largely underdeveloped and unattended in academic and developmental discourses. This peripheral position however, helped them build a strong resilience. The challenges of living in peripheries, economic vulnerability, border disputes, hilly terrain have led to marginalization of the tribe. However the community's customary law, community based conservation practices, and sustainable management of local resources represent the story of human-nature harmony and a strong socio-ecological resilience.

Hence the study therefore recommends that:

i. Customary laws of Marngar must be strengthened and be given formal recognition in local governance as it plays an important role is sustainable management of natural resources.

ii. Preserve and secure the cultural identities of Marngars through documentation of their customary laws, rituals, traditional ecological knowledge, folklore and tangible cultures, language, and festivals.

iii. Protect and properly conserve the ecological resources of the Marngar inhabited area and promote sustainable tourism development for livelihood diversification and economic development of the area. However proper care must be given towards any negative impact on the culture and economy.

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iv. Enhance the agri-economy of the Marngars by facilitating their market access and thereby reduce economic vulnerability. Government intervention in weaving and cultivation-based livelihoods will help the Marngars to overcome the challenge of economic distress.

v. The indigenous knowledge system of the Marngars must be duly recognized and must receive a place in policymaking and developmental policies.

vi. Empower women by capacity building, skill enhancement and access to education to diversify livelihood opportunities.

This study underscores the importance of studying peripheral geographies and the journey of resilience of the tribes of peripheries. Marngars must receive a proper recognition in academic discourses. In-depth research on their cultural landscape transformation, indigenous knowledge systems and comparative studies with neighbouring communities would enrich understanding of this peripheral tribal community of Northeast India.

REFERENCES

Bareh, H. (1985). *The history and culture of the Khasi people*. Spectrum Publications.

Baruah, S. (1999). *India against itself: Assam and the politics of nationality*. University of Pennsylvania Press.

Berkes, F. (2018). *Sacred ecology* (4th ed.). Routledge. https://doi.org/10.4324/9780203123843

Bhattacharjee, P. (2019). Borderlands, livelihoods, and market dependencies in Northeast India. *Journal of Borderlands Studies*, 34(4), 589–605. https://doi.org/10.1080/08865655.2017.1399832.

Block Development Office, Umling C&RD Block. (2025). *Statistical report of Umling Community & Rural Development Block* (Provisional Report). Ri-Bhoi District, Government of Meghalaya.

Das, M. (2021). Agrarian vulnerability and interstate trade friction in the Assam-Meghalaya foothills. *Economic & Political Weekly*, 56(18), 45–52.

Dudgeon, D. (2000). The ecology of tropical Asian rivers and streams in relation to biodiversity conservation. *Annual Review of Ecology and Systematics*, 31(1), 239–263. https://doi.org/10.1146/annurev.ecolsys.31.1.239

Fernandes, W. (2003). Tribal land alienation in the Northeast: An introduction. In W. Fernandes & S. Barbora (Eds.), *Changing land relations and ethnic conflicts in Northeast India* (pp. 1–20). North Eastern Social Research Centre.

Gadgil, M., Berkes, F., & Folke, C. (1993). Indigenous knowledge for biodiversity conservation. *Ambio*, 22(2/3), 151–156.

Gurdon, P. R. T. (1914). *The Khasis*. Macmillan and Co.

Haokip, T. (2013). The politics of marginalization: Sub-tribes and identity assertion in Northeast India. *Asian Ethnicity*, 14(2), 226–238. https://doi.org/10.1080/14631369.2012.722434

Karlsson, B. G. (2011). *Unruly hills: A nature of culture in the Khasi Hills of Northeast India*. Orient Blackswan.

Lyngwa, C. (1993). *The Marngar of the Bhoi area: An anthropological study* (Doctoral dissertation).

Malhotra, K. C., Gokhale, Y., Chatterjee, S., & Srivastava, S. (2001). *Cultural and ecological dimensions of sacred groves in India*. Indian National Science Academy.

McDuie-Ra, D. (2012). *Northeast migrants in Delhi: Race, refuge and retail*. Amsterdam University Press. https://doi.org/10.5117/9789089644022

Misra, U. (2000). *The peripheries strike back: Challenges to the nation-state in Assam and Nagaland*. Indian Institute of Advanced Study.

Nongkynrih, A. K. (2002). *Khasi society of Meghalaya: A sociological understanding*. Indus Publishing Company.

Ormsby, A. A., & Ismail, S. A. (2015). Cultural and ecological importance of sacred groves for biodiversity conservation in India. *Current Science*, 109(4), 720–726.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press. https://doi.org/10.1017/CBO9780511807763

Ramirez, P. (2011). Belonging to the borders: Uncertain identities in Northeast India. *The Politics of Belonging in the Himalayas Local Attachments and Boundary Dynamics*, *4*, 77-97.

Reyes-García, V., Paneque-Gálvez, J., Luz, A. C., Gueze, M., Macía, M. J., Bogado, M., & Manuel, T. (2014). Cultural change and traditional ecological knowledge: An empirical analysis from the Bolivian Amazon. *Human Ecology*, 42(4), 531–544. https://doi.org/10.1007/s10745-014-9664-8

Sauer, C. O. (1925). *The morphology of landscape*. University of California Publications in Geography, 2(2), 19–53.

Sten, P. D. (2026). *Social characteristics of the indigenous Marngar tribe* (Master's thesis). Department of Geography and Geoinformatics, The Assam Royal Global University.

Steward, J. H. (1955). *Theory of culture change: The methodology of multilinear evolution*. University of Illinois Press.

Tuan, Y.-F. (1977). *Space and place: The Perspective of Experience*. University of Minnesota Press.

Vandenhelsken, M., Barkataki-Ruscheweyh, M., & Bengt, G. K. (Eds.). (2016). *Geographies of Difference: Identity, Hybridity and Alterity in Northeast India*. Routledge.

Vidal de la Blache, P. (1926). *Principles of human geography* (M. T. Bingham, Ed.; I. C. Bourne, Trans.). Henry Holt and Company.

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Chapter

29 Curriculum Restructuring for Sustainability: Challenges and Opportunities

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ABSTRACT

The twenty-First century has brought unprecedented environmental challenges, resource depletion, climate change, biodiversity loss, scarcity of resources, increasing population and many socioeconomic challenges. To meet these challenges, there is a need to rethink the role of education in fostering sustainable development. It requires the shifting of traditional education into dynamic, integrated and system-based learning. Education acts as a catalyst that creates responsible citizens and innovative thinkers to address these complex challenges. Education encompasses the knowledge, skills, values and attitudes required to make informed decisions that promote environmental stewardship, social equity, and economic resilience. Every nation should integrate these competencies into the curriculum so that every citizen can contribute effectively to sustainable societies. The curriculum restructuring for sustainability is a strategic investment in future generations.

The present paper is an attempt to shed light on challenges and opportunities associated with the implementation of policy frameworks in the process of restructuring the curriculum. By aligning coursework with the Sustainable Development Goals (SDGs) institutions prepare students to tackle real-world challenges while meeting rapidly involving industry demand.

Keywords: Curriculum Restructuring, Resource Depletion, Biodiversity, Scarcity of resources, Environmental Stewardship, Economic Resilience.

INTRODUCTION

The prominence of education in fostering sustainability became relevant in 1992. The Earth Summit held in the year 1992 in Rio de Janeiro highlighted education as an essential element of sustainable development. This was reiterated when the United Nations approved the Sustainable Development Goals (SDGs) in September 2015. The UN emphasized the role of education as a vital component for achieving many other sustainable development goals. Sustainable Development Goal 4 entails providing

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inclusive and equitable quality education, while Sustainable Development Goal 4.7 emphasized the need for learners to acquire knowledge and skills that will enable them to achieve sustainability. Achieving sustainability is a continuous process that involves starting from primary education to secondary and tertiary education. Thus, there is a need to restructure our traditional education into a modern education. The challenge is that when including sustainability in policy documents, there is a requirement to include climate change, biodiversity or sustainable development in the curriculum. UNESCO's recent monitoring shows that while environmental and sustainability content is present in many national curriculum frameworks, the inclusion of climate change and biodiversity is uneven across subjects and levels of education. Curricular restructuring not only involves the inclusion of environmental chapters but also requires rethinking of educational objectives, subject boundaries, teaching methods, assessment systems, teacher preparation and the relationship between educational institutions and their communities.

UNESCO's recent Greening Curriculum Guidance emphasis an action-oriented, holistic, scientifically accurate and justice-driven approach to climate change and sustainability. It also proposes learning outcomes across age groups and encourages addressing sustainability issues across subjects rather than being confined to one area of study.

The burning question is how the curriculum can be restructured in a way that is meaningful, practical, inclusive and capable of bringing about desirable changes in knowledge, attitudes and behaviour.

OBJECTIVE OF THE STUDY

1. To analyse the need for curriculum restructuring for sustainability
2. To identify the major challenges
3. To analyse the opportunities

METHODOLOGY

The present research paper is conceptual and descriptive research design to examine the challenges and opportunities associated with restructuring curriculum for sustainability. The study uses a systematic literature review approach to identify, analyse and synthesize relevant literature on sustainability education, curriculum reform, sustainability competencies, and institutional transformation.

Meaning of Curriculum Restructuring

Curriculum restructuring refers to a systematic reconsideration and redesign of curriculum goals, content, learning experiences, teaching methods and assessment practices. It goes beyond the mere revision of a textbook or introduction of a new subject.

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A curriculum is not just a list of topics. It embodies a particular understanding of what knowledge is important, what skills learners need, what values society wants to promote and what kind of citizens education aims to develop.

Therefore, curriculum restructuring for sustainability entails redesigning the curriculum so that learners develop the knowledge, skills, values and attitudes necessary to understand sustainability. It demands an epistemological shift towards systems thinking, interdisciplinary collaboration and trans formative action-oriented learning.

Context of the Study

Curriculum restructuring is not just about adding environmental topics to the existing syllabus. But it represents a fundamental shift from knowledge transmission towards sustainability-oriented competencies, critical thinking, problem solving, collaboration, ethical reasoning and responsible action. Education systems worldwide face pressure to address the Sustainable Development Goals and the escalating climate crisis, yet most curricula remain siloed, treating sustainability as an add-on rather than a core competency. Traditional disciplinary boundaries make it hard for students to grasp interconnected environmental, social, and economic challenges. This gap has pushed policymakers and educators to reconsider how sustainability is taught not as a standalone subject, but woven into the fabric of curriculum design across disciplines. Adding environmental subjects to the current syllabus is only one aspect of curriculum revision. However, it signifies a significant change from the dissemination of knowledge to competencies focused on systematic thinking, critical thinking, problem-solving, teamwork, ethical reasoning and responsible action. The SDGs and the growing climate disaster are pressing issues for education systems around the world, yet most curricula still treat sustainability as an add-on rather than a fundamental skill. Students find it challenging to understand interconnected environmental, social, and economic concerns because of traditional disciplinary barriers. This disparity has forced policymakers and educators to reevaluate how sustainability is taught, integrating it into curriculum design across disciplines rather than treating it as a stand-alone subject.

Significance of the Study

Curriculum plays a critical role in shaping the future, as it gives shape to knowledge, attitudes, values and competencies, which form the base of human capital. In the changing scenario of the economy, there is an urgent need to restructure the curriculum according to the need of the day. It can help policymakers, educators and institutions to be better aligned with contemporary sustainability challenges.

LITERATURE REVIEW

The literature on curriculum restructuring for sustainability has expanded significantly as education systems increasingly recognise the need to respond to environmental,

social and economic challenges. Sterling (2001) argued that sustainability requires a transformation of educational thinking rather than simply adding environmental topics to existing curricula. He suggested that education should move from conventional transmission of knowledge towards participatory, critical and trans formative learning.

Lozano (2006) examined the integration of sustainability into university curricula and emphasised that sustainability should not be confined to individual courses. Instead, it should be incorporated across disciplines and institutional activities. The study highlighted the importance of interdisciplinary approaches in developing students' understanding of complex sustainability issues.

Barth et al. (2007) focused on sustainability competencies in higher education and argued that universities should prepare students not only with knowledge but also with the ability to apply that knowledge to real-world sustainability problems. Their work established the importance of competence-oriented curriculum development.

Vare and Scott (2007) distinguished between different approaches to Education for Sustainable Development (ESD). They argued that effective sustainability education should encourage learners to critically examine existing practices and develop the capacity to create alternative and more sustainable futures.

Cotton et al. (2007) examined sustainability education in higher education and highlighted the importance of participatory and active teaching methods. Their findings suggested that traditional teacher-centred approaches may not be sufficient for developing the critical and practical skills required for sustainability.

Shephard (2008) argued that sustainability education should address cognitive, affective and behavioural dimensions of learning. According to the study, merely providing information about environmental problems does not necessarily lead to sustainable behaviour; therefore, curriculum design should also address values, attitudes and action.

Tilbury (2011) emphasised that ESD should promote participatory, experiential and action-oriented learning. She argued that curriculum restructuring should provide learners with opportunities to engage with real-world sustainability problems rather than relying exclusively on classroom-based theoretical learning.

Wiek et al. (2011) developed a framework of key sustainability competencies, identifying systems-thinking, anticipatory, normative, strategic and interpersonal competencies as particularly important. Their work has become influential in sustainability curriculum design because it demonstrates the competencies students need to address complex sustainability challenges.

Rieckmann (2012) further highlighted the importance of sustainability competencies and argued that education should enable learners to understand complex systems, anticipate future consequences, make responsible decisions and participate actively in sustainability transitions.

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Lozano et al. (2013) examined sustainability initiatives in higher education institutions and found that although many universities formally recognise sustainability, implementation is often limited by institutional structures, inadequate resources and insufficient integration across university functions. The study indicates that curriculum restructuring requires broader institutional support.

Wals (2014) argued that sustainability education requires a transformation of the learning environment itself. He emphasised social learning, experimentation, participation and collaboration and suggested that universities should become spaces where sustainable practices are experienced rather than merely discussed.

Cebrián et al. (2015) investigated approaches to developing sustainability competencies in higher education and highlighted the importance of embedding sustainability within learning outcomes, teaching strategies and assessment practices. Their findings suggest that curriculum restructuring must be accompanied by changes in pedagogy and evaluation.

Leal Filho et al. (2015) examined sustainability practices in higher education and identified the importance of institutional commitment and integration. Their work suggests that sustainability cannot be achieved through isolated curriculum initiatives without appropriate organizational structures and leadership.

Chakraborty et al. (2016) examined barriers to restructuring university curricula for a sustainable future. The study highlighted challenges such as institutional constraints, limited faculty preparedness, inadequate resources and difficulties in integrating sustainability into existing disciplinary structures. This study is particularly relevant for understanding the challenges faced by Indian higher education institutions.

UNESCO (2017) provided learning objectives for ESD linked to the Sustainable Development Goals. The framework emphasized competencies such as systems thinking, critical thinking, collaboration, problem-solving and responsible decision-making. It demonstrated the need for curricula to move beyond conventional academic knowledge towards competencies required for sustainable development.

Rieckmann (2018) further emphasized that sustainability competencies should be incorporated into educational programmes at different levels. The study identified critical thinking, systems thinking, collaboration, strategic thinking and problem-solving as important competencies for sustainable development.

Filho et al. (2018) examined the relationship between higher education and the Sustainable Development Goals and argued that universities have an important role in translating the SDGs into educational, research and institutional practices. Their findings support the integration of sustainability throughout university curricula and institutional activities.

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Brundiers et al. (2021) used an international Delphi process to refine sustainability competencies and highlighted the importance of students' ability to analyse complex systems, envision sustainable futures, work collaboratively and develop strategies for change. The study provides a useful foundation for competency-based curriculum restructuring.

Lorente-Echeverría et al. (2022) systematically reviewed research on curriculum sustainability and found that sustainability curriculum research increasingly focuses on teaching methodologies, curriculum integration and the development of sustainability competencies. However, the study also identified challenges associated with institutional structures and implementation.

Parry (2022) identified several barriers to learning for sustainability, including disciplinary silos, high-stakes assessment, inadequate professional development, limited time, insufficient funding and shortages of appropriate curriculum materials. The study demonstrates that curriculum reform requires changes beyond curriculum documents themselves.

Recent research continues to highlight the importance of teachers in sustainability curriculum implementation. Studies examining teachers' perceptions of ESD suggest that teachers' knowledge, attitudes, confidence and professional development opportunities strongly influence whether sustainability principles are successfully translated into classroom practice. Therefore, curriculum restructuring without corresponding investment in teacher education may have limited effectiveness.

Almusharraf (2026) identified governance limitations, inadequate funding, weak stakeholder collaboration, curriculum-integration difficulties and institutional capacity gaps as recurring barriers to sustainability implementation in higher education. The study demonstrates that sustainability curriculum reform is strongly influenced by broader institutional and governance conditions.

Lorente-Echeverría et al. (2026) reviewed a large body of higher-education sustainability research and observed that curriculum and pedagogy remain central areas of research. However, institutional inertia, fragmented policies and difficulties in translating sustainability commitments into actual practices continue to restrict progress.

The reviewed literature indicates that curriculum restructuring for sustainability is a multidimensional process rather than a simple modification of syllabus content. The studies consistently emphasize the need for interdisciplinary learning, sustainability competencies, experiential pedagogy, teacher professional development and innovative assessment. At the same time, curriculum rigidity, disciplinary silos, inadequate resources, lack of teacher preparedness, institutional resistance and weak leadership remain major challenges.

An important gap emerges from the literature. While considerable research has examined Education for Sustainable Development, sustainability competencies and sustainability in

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higher education, comparatively less attention has been given to an integrated framework that simultaneously examines curriculum content, pedagogy, assessment, teacher preparedness, institutional support and stakeholder participation. Furthermore, there is scope for more context-specific research in developing countries, particularly India, where educational institutions face considerable variations in resources, institutional capacity and regional sustainability challenges. The present study therefore seeks to address this gap by examining the challenges and opportunities associated with restructuring curricula for sustainability and by exploring how curriculum, pedagogy, assessment and institutional practices can be aligned with sustainable development objectives.

Challenges Faced in Restructuring the Curriculum

Curriculum restructuring for sustainability is a significant educational reform, but it is difficult to accomplish because sustainability is multidisciplinary and calls for adjustment to teaching strategies, evaluation, teacher preparation, and institutional procedures in addition to curriculum content. Many research results show that the transition from conventional curriculum to sustainability-oriented education faces several interconnected challenges.

Rigid curriculum: Our traditional education system is rigid in nature. It only focuses on specified subjects, examination oriented and degree completion. It is very perceived to add sustainability as an additional topic rather than an integral dimension of existing subjects.

Disciplinary Isolation: Disciplinary isolation creates difficulties in addressing sustainability holistically. Our educational systems are frequently organised into separate academic disciplines, whereas sustainability problems involve environmental, economic, social and ethical dimensions. Such educational disciplinary silos make interdisciplinary curriculum development and collaboration difficult.

Inadequate teacher knowledge and Professional development: The teacher must capable to transit sustainability policies into classroom practices, but due to lack of pedagogical approach and professional development, effective restructuring is far away. There should be professional development training and opportunities for educators to develop sustainability competencies.

Traditional teaching and assessment Practices: Our conventional education system often prioritises memorisation, but when the idea of sustainability came, it requires critical thinking and action-oriented learning. UNESCO described these transversal competencies as important for educators so that they tackle complex sustainability problems.

Institutional supports are inadequate: Inadequate institutional support and leadership can prevent curriculum reforms from becoming sustainable. Curriculum change requires supportive leadership, appropriate policies, financial resources, faculty participation and collaboration among different stakeholders.

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Lack of Infrastructure: Lack of infrastructure becomes a barrier in the implementation of curriculum restructuring. Resources are limited, and it is difficult to allocate resources to meet the requirements of curriculum restructuring for sustainability.

Lack of teaching resources: Lack of teaching resources acts as an obstacle in the way of restructuring the curriculum.

Conceptual ambiguity surrounding sustainability creates another challenge. Sustainable development encompasses environmental, social and economic dimensions, and its complexity can make it difficult for teachers and curriculum designers to establish clear learning outcomes.

OPPORTUNITIES

Curriculum restructuring for development opens up powerful opportunities to change education from a system focused mainly on knowledge to one that builds the skills, values and behaviour needed to tackle complex environmental, economic and social problems. Sustainable development demands individuals who can think clearly, see connections and help create solutions. That is why reworking the curriculum offers a chance to bring education in line with the values of sustainable development and the Sustainable Development Goals (SDGs).

One key opportunity is to weave sustainability throughout all subjects. Instead of treating it as just one subject, sustainability can be included in economics, science, geography, political science, commerce and sociology. For example, in economics, students can learn about consumption, green growth and the circular economy. In science, topics like climate change, renewable energy and biodiversity can be explored. This kind of interdisciplinary approach helps students see how different areas of life are connected when it comes to sustainability.

A second major opportunity is building sustainability competencies. Curriculum reform can help move from rote learning and focus on skills like critical thinking, systems thinking, problem-solving, teamwork, communication, creativity and future-oriented planning. These skills allow students to examine real-life sustainability issues and come up with solutions.

Curriculum reform also opens the door to ways of teaching and learning. Methods like project-based learning, experiential learning, problem-based learning, fieldwork and community-based learning help connect classroom lessons with real-world situations. Students can work on projects related to waste management, water conservation, protecting biodiversity, energy efficiency and sustainable farming. These methods encourage hands-on involvement and deeper understanding.

Another important opportunity is preparing students for jobs. As economies grow more focused on energy, sustainable agriculture, green technology and circular production,

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education can help students enter these new fields. Colleges and universities can offer courses in management, sustainable finance, green entrepreneurship and sustainable business practices.

Technology also plays a role in advancing sustainability education. Digital tools like simulations, online learning platforms, geographic information systems, virtual labs and environmental monitoring systems can help students grasp topics more easily. Technology can also connect students, teachers, researchers and communities, enabling collaboration and shared learning.

Curriculum restructuring can also bring indigenous knowledge into the classroom. Many sustainable solutions work best when they take into account conditions and traditional wisdom. Including community knowledge, regional environmental issues and case studies from areas makes the curriculum more relevant and meaningful. In India examples related to water systems, farming, forests, livelihoods and rural development can enrich sustainability education.

Another benefit is the ties between universities, communities and industries. Educational institutions can partner with governments, NGOs, businesses and community groups. These partnerships can give students access to field research, internships and sustainability projects. Such collaborations help close the gap between theory and practice.

Finally, curriculum restructuring can support a whole-institution approach to sustainability. Schools and colleges can align their teaching, research, campus operations and community outreach with sustainability principles. When a college teaches waste management and also practices waste segregation on campus, students get a real-life example of what sustainability means.

In short, curriculum restructuring is not just about adding topics to the old syllabus. It is about changing the purpose, content, teaching methods, assessment and culture of education. With trained teachers, proper resources, institutional support, and the right policies, curriculum restructuring can help create citizens who care about the environment, are socially aware and capable of contributing to the future.

CONCLUSION

Structuring the curriculum for sustainable development is a crucial step in transforming education into a robust tool for tackling current environmental, economic, and social issues. Conventional curricula typically focus on disciplinary knowledge and exam-driven learning, while sustainable development necessitates skills such as critical thinking, problem-solving, collaboration, innovation, and responsible decision-making. By restructuring the curriculum, we can create opportunities to weave sustainability into various disciplines, foster experiential and project-based learning, cultivate green skills, promote digital innovation,

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and align education with the needs of local communities. Nonetheless, the successful transformation of the curriculum encounters several obstacles, including inadequate teacher training, limited financial and technological resources, institutional resistance, inflexible curriculum frameworks, and a lack of coordination among stakeholders. Thus, curriculum reform should extend beyond merely adding sustainability topics to current syllabi. It demands a comprehensive approach that encompasses curriculum content, teaching methods, assessment practices, teacher training, institutional policies, and community involvement. The effectiveness of restructuring the curriculum with a sustainability focus relies on robust policy backing, ongoing professional development for educators, sufficient resources, and active engagement from students and communities. Educational institutions should also strive to serve as exemplars of sustainable practices. In summary, curriculum restructuring poses both challenges and significant opportunities to cultivate sustainability competencies and equip learners to effectively address future challenges. A thoughtfully designed and context-aware curriculum can ultimately lead to more inclusive, resilient, and sustainable societies.

REFERENCES

Barth, M., Godemann, J., Rieckmann, M., & Stoltenberg, U. (2007). Developing key competencies for sustainable development in higher education. *International Journal of Sustainability in Higher Education*, 8(4), 416–430.

Bianchi, G. (2020). *Sustainability competence development in higher education: An analysis of the literature*. 12(23), 10393.

Brundiers, K., Wiek, A., & Redman, C. L. (2010). Real-world learning opportunities in sustainability: From classroom into the real world. *International Journal of Sustainability in Higher Education*, 11(4), 308–324.

Cebrián, G., & Junyent, M. (2015). Competencies in education for sustainable development: Exploring the student teachers' views. *Sustainability*, 7(3), 2768–2786.

Cotton, D. R. E., Warren, M. F., Maiboroda, O., & Bailey, I. (2007). Sustainable development, higher education and pedagogy: A study of lecturers' beliefs and attitudes. *Environmental Education Research*, 13(5), 579–597.

Lozano, R., Barreiro-Gen, M., Pietikäinen, J., Gago-Cortes, C., & others. (2022). Adopting sustainability competence-based education in academic disciplines: Insights from 13 higher education institutions.

Rieckmann, M. (2012). Future-oriented higher education: Which key competencies should be fostered through university teaching and learning? *Futures*, 44(2), 127–135.

Rieckmann, M. (2018). Learning to transform the world: Key competencies in Education for Sustainable Development. In A. Leicht, J. Heiss, & W. J. Byun (Eds.), *Issues and trends in education for sustainable development* (pp. 39–59). UNESCO.

Shephard, K. (2008). Higher education for sustainability: Seeking affective learning outcomes. *International Journal of Sustainability in Higher Education*, 9(1), 87–98.

Sipos, Y., Battisti, B., & Grimm, K. (2008). Achieving transformative sustainability learning: Engaging head, hands and heart. *International Journal of Sustainability in Higher Education*, 9(1), 68–86.

 ISBN: 978-93-49666-59-7 (eBook)

United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. United Nations.

UNESCO. (2017). *Education for sustainable development goals: Learning objectives*. UNESCO.

UNESCO. (2020). *Education for sustainable development: A roadmap*. UNESCO.

Vare, P., & Scott, W. (2007). Learning for a change: Exploring the relationship between education and sustainable development. *Journal of Education for Sustainable Development*, 1(2), 191–198.

Lozano, R. (2022). Developing a sustainability competences paradigm in higher education or a white elephant? *Sustainable Development*, 30(5), 870–883.

Choker, K. B. (2010). Higher education and curriculum innovation for sustainable development in India. *International Journal of Sustainability in Higher Education*, 11(2), 141–152.

Ravindra nath, M. J. (2007). Environmental education in teacher education in India: Experiences and challenges in the United Nation's Decade of Education for Sustainable Development. *Journal of Education for Teaching*, 33(2), 191–206.

Priyadarshini, P., & Abhilash, P. C. (2019). From piecemeal to holistic: Introducing sustainability science in Indian universities to attain UN-Sustainable Development Goals. *Journal of Cleaner Production*, 232, 1313–1321.

D'Souza, C., Brahme, M., & Babu, M. S. (2020). Environment education in Indian schools: The search for a new language. *Journal of Education for Sustainable Development*, 14(2), 174–189.

Alexandar, R. (2012). Environmental education for sustainable development in selected schools of Puducherry and Cuddalore regions, India [Doctoral dissertation, Pondicherry University].

Rajput, N. (2019). Education for sustainable development: A theoretical model of sustainable education for India. *Journal of the Gujarat Research Society*, 21(14).

Yadava, S. (2022). Education for sustainable development in India: Reality check on ground zero. *International Education and Research Journal*.

Kaur, A. (2026). Integrating sustainability in higher education system: An Indian policy review. *Humanities and Social Sciences Communications*, 13, 713.

Joseph, S., Patil, K., Kulkarni, A. V., & John, M. (2025). *Sustainability education in India*. In The Routledge handbook of global sustainability education and thinking for the 21st century (pp. 876–899).

Nannavare, N. R., Kharade, V. B., & Khatriya, P. R. (2023). A study on India's New Education Policy in science education: Aligning curriculum with sustainability goals. *International Journal of Food and Nutritional Sciences*, 12(7), 644–652.

Kumar, P., Caporarello, L., & Agrawal, A. (2024). Research from the Global North and South on HEIs as a driver for SDGs. *In Higher education for the Sustainable Development Goals: Bridging the Global North and South*. Emerald Publishing.

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Chapter

30

Preserving Traditional Ecological Knowledge in Arunachal Pradesh: The Role of Folklore and Cultural Practices

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INTRODUCTION

Arunachal Pradesh, located in the Eastern Himalayas, is one of India's most biodiverse regions and a critical part of the Indo-Burma biodiversity hotspot. The state is home to 26 major tribes and over 110 sub-tribes, each with distinct languages, customs, and ecological practices. These communities have developed sophisticated Traditional ecological knowledge systems over centuries, encoded in oral traditions, rituals, and customary laws that govern their relationship with nature.

In an era of accelerating climate change, biodiversity loss, and ecological degradation, global recognition is growing that Indigenous knowledge systems offer valuable insights for sustainable resource management and conservation. Yet, in Arunachal Pradesh, as in many parts of the world, these systems face existential threats from modernisation, market forces, and the erosion of intergenerational knowledge transmission (Chaudhuri, 2008).

This paper investigates how folklore and traditional cultural practices in Arunachal Pradesh function as mechanisms of ecological governance. Through detailed case studies of some of the major tribes such as the Adi, Nyishi, Galo, Monpa, Apatani, and Aka tribes, it demonstrates that folk beliefs, whether sacred or secular, encode practical rules for sustainable resource use, biodiversity conservation, and climate adaptation. The study also examines the challenges these systems face and proposes pathways for integrating indigenous wisdom into contemporary environmental policy and education.

RESEARCH OBJECTIVES

This paper aims to:

- Document how folklore, myths, rituals, and taboos encode ecological knowledge among tribal communities in Arunachal Pradesh.

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- Analyse the role of sacred groves and customary institutions in biodiversity conservation.
- Examine case studies from multiple tribes to illustrate the diversity and specificity of ecological knowledge systems.
- Assess the threats posed by modernisation, climate change, and cultural erosion to these knowledge systems.
- And lastly, propose policy recommendations for integrating Indigenous ecological knowledge into conservation and development frameworks.

METHODOLOGY

This research draws on ethnographic studies, participatory rural appraisals, and community workshops conducted with tribal communities across Arunachal Pradesh. Data sources include published academic research, government reports, and field studies. Case studies were selected to represent diverse ecological zones (alpine, temperate and subtropical) and cultural traditions (Animist, Buddhist and Hindu-influenced).

THEORETICAL FRAMEWORK: FOLKLORE AS ECOLOGICAL ARCHIVE

Folklore and Traditional Ecological Knowledge

Folklore encompassing myths, legends, folktales, songs, proverbs, and ritual narratives functions as a living repository of Traditional Ecological Knowledge. Unlike written texts, oral traditions are dynamic, adapting to changing environmental conditions while preserving core ecological principles. They encode observations on seasonal patterns, animal behaviour, plant phenology, weather indicators, and resource management practices accumulated over generations (Singh, 2011; Murtem & Chaudhry, 2014). Scholars distinguish between the cognitive dimension of folklore (knowledge about the environment) and the normative dimension (rules governing human-nature interaction). In Arunachal Pradesh, these dimensions are deeply intertwined: myths explain why certain trees are sacred, taboos prohibit hunting specific animals during breeding seasons, and rituals ensure sustainable harvesting of forest.

Biocultural Diversity

The concept of biocultural diversity recognises the co-evolution of biological and cultural diversity. In Arunachal Pradesh, tribal communities have developed unique bonds with their ecosystems, expressed through language, customs, agricultural practices, and spiritual beliefs. This biocultural diversity is mediated through five distinct climatic zones (alpine, temperate, sub-temperate, tropical, and subtropical), each with corresponding traditional knowledge systems and subsistence strategies (Singh et al., 2011). Biocultural processes vary across ecosystems according to the scale and space of culture and overall species

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diversity. For example, the Adi practice jhum (shifting cultivation) adapted to steep slopes, while the Apatani developed sedentary wet-rice cultivation integrated with pisciculture in valley lands. These practices are not merely economic activities but are embedded in cosmologies that regard nature as sacred and interconnected with human well-being.

Ecological Jurisprudence and Customary Law

Among many tribes in Arunachal Pradesh, customary law extends beyond interpersonal relations to include non-human entities such as forests, rivers, mountains, and landscapes. This ecological jurisprudence is enforced through ritual practices, taboos, and ancestral belief systems that limit ecological exploitation (Lex Localis Journal, 2025). For the Nyishi, for example, spirits, sacred groves, and taboos serve as normative agents that regulate land use, shifting cultivation, and forest management. Such systems represent forms of informal environmental governance that predate modern state institutions. They are grounded in kinship ethics, clan obligations, and reciprocal relationships between humans and nature (Murtem & Chaudhry, 2014). Understanding these systems is essential for designing conservation policies that respect Indigenous rights and leverage local knowledge.

CASE STUDIES

The Adi Tribe: Biocultural Diversity and Climate Adaptation

The Adi, one of the largest tribal communities in Arunachal Pradesh, concentrated in East and Upper Siang districts, maintain livelihoods that integrate jhum cultivation, agroforestry and hunting-gathering, supported by an extensive body of Traditional ecological knowledge that informs agricultural cycles, ethno-medicine, forest resource management and ritual practice. Ethnobotanical surveys document the Adi use of over 120 plant species in their pharmacopoeia, notably Litsea cubeba for febrile conditions, Zanthoxylum armatum for gastrointestinal disorders and Alpinia nigra for anti-inflammatory applications. Adi communities also employ biometeorological indicators like cloud types, wind patterns, animal behaviour and plant phenology to anticipate rainfall, drought and temperature variation, using such signals to schedule agricultural operations and cultural activities; for example, the flowering and fruiting of Gymnocladus burmanicus (dekang) traditionally signals the appropriate period for hunting during the Solung festival (Singh et al., 2011). Ridin, a sacred creeper used to ward off evil spirits, is believed to have emerged from the placenta of Pedong Nane, the mother of all living beings. During the Abang (ballad), it is narrated: “Keyum Pedonge Rindo Si / Rindo Torgo Em Torge Bomye / Keyum Donie Aji Me / Aji E Einem Dutum Bomye” This ballad reveals that Ridin, originating from Pedong Nane’s placenta, guards and protects mankind from misfortune (Chaudhuri, 2008).

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Local knowledge holders report pronounced climatic and ecological change over the past three to four decades. Elder informants recall abundant wild food plants during floods until the 1970s, whereas contemporaneous observations indicate reduced availability of these resources even in relatively undisturbed forest patches. Aquatic biodiversity in forest streams and seasonal water bodies has declined, and broader species diversity in both aquatic and terrestrial ecosystems appears reduced, trends attributed to increased siltation and temperature fluctuations. These biotic and phenological shifts have tangible socio-economic and cultural consequences, such as the dekang's altered flowering and fruiting phenology disrupting hunting schedules and festival timing; key wild foods such as wild chestnuts (anke), wild jackfruit seeds (belang), Arenga obtusifolia (tasat) and Cyathea andersonii (taste) are less available during drought periods; and populations of wild fauna including mithun (Bos frontalis), arboreal squirrels (Ratufa spp.) and multiple avian species have declined (Singh et al., 2011). Agricultural systems are concurrently stressed, with jhum fallows losing moisture more rapidly or becoming prone to severe erosion under intense precipitation, thereby increasing labour inputs and production costs.

In response to these intersecting ecological and livelihood vulnerabilities, Adi communities have expressed substantial interest in formal conservation measures. Participatory workshops involving 700 participants across 14 villages revealed extensive support for designating segments of virgin community forest as Community Reserve Forests (CRFs) linked to REDD (Reducing Emissions from Deforestation and Forest Degradation) initiatives (Singh et al., 2011). Workshop participants articulated seventeen selection criteria for CRF sites, prioritising a minimum forest area (10–12 hectares), species richness and endemism, low prior degradation, the socio-economic importance of forest products and demonstrable community commitment to conservation. A majority favoured reserving virgin community forest land under CRF status within REDD frameworks conditional on the provision of incentives and equitable benefit-sharing mechanisms, and both scientists and community members advocated collaborative management arrangements with transparent benefit distribution.

The Nyishi Tribe: Customary Law and Ecological Stewardship

The Nyishi are the largest tribal community in Arunachal Pradesh, inhabiting the five Districts of Arunachal Pradesh. They are characterized by a patrilineal and patrilocal kinship model, with inheritance, marriage customs, and family obligations governed by orally transmitted customary laws. Nyishi customary law incorporates ecological ethics through ritual practices, taboos, and ancestral belief systems (Lex Localis Journal, 2025). These legal-ethical codes extend beyond interpersonal relations to include non-human entities such as forests, rivers, and landscapes. Practices such as widow inheritance, clan exogamy, and patrilineal succession intersect with ecological responsibilities,

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particularly in regulating land use, shifting cultivation, and forest management. Their worldview constitutes a form of ecological jurisprudence in which spirits, sacred groves, and taboos serve as normative agents limiting ecological exploitation. For example, certain plants like Tattong, Taapit, and Tan are considered sacred, believed to have sprung from the bones of Kari Bote, a great mythical hunter. These trees are rarely cut unless necessary. They believe that forests are abodes of numerous gods and spirits, both benevolent and malevolent (Chaudhuri, 2008). Huge trees like Rotne are considered homes of evil spirits (Epom/Yapom), and cutting them requires rituals involving pig and fowl sacrifices to appease the displaced spirit (Chaudhuri, 2008). Similarly, cane, bamboo, and leaves for thatching are never cut indiscriminately. Epoeng (big bamboo) is felled only during Ruruk—the dark fourth night after the full moon when it is believed to be free from Takit insects that reduce its longevity. They observe various taboos related to resource use. After childbirth or death funerals, people abstain from cutting plants or visiting areas where bamboo shoots sprout, as it may damage new shoots. These restrictions, rooted in spiritual beliefs, effectively regulate harvesting and protect regenerating vegetation.

Ethnobotanical surveys document over 120 plant species in the Nyishi pharmacopoeia, with selective harvesting and processing techniques that ensure sustainability (Murtem & Chaudhry, 2014). Their knowledge encompasses agricultural cycles, ethno-medicine, forest resource management, and ritualistic traditions that reinforce community cohesion and environmental stewardship.

The Galo Tribe: Wildlife Taboos and Sustainable Hunting

The Galo, another major tribe of Arunachal Pradesh, inhabit the West Siang and Siang districts and the other surrounding areas. They are known for their hunting traditions and elaborate taboos governing wildlife interaction (Chaudhuri, 2008). Among them, killing a tiger is taboo. If someone kills a tiger by mistake or due to unavoidable circumstances, not only the individual but the entire village must undergo restrictions and perform rituals. A tiger hunter cannot consume certain types of birds, fish, or meat and must prepare his own food for a month. Moreover, consumption of local onion (Dilap) and ginger (Takee) is tabooed for life. They believe that man, tiger, and elephant originated from the same stock, fostering a sense of kinship with these species. They also refrain from killing certain seasonal birds considered sacred and perceived as agents of new seasons and symbols of good productivity. While hunting is an important aspect of Galo livelihood, there are numerous restrictions related to the consumption of hunted animals. Hunters must undergo taboos, restricting the eating of spices like onion, chilli, and certain leafy vegetables. They cannot touch or use domestic utensils and cannot prepare meat inside the house. These practices, while rooted in spiritual

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beliefs, effectively regulate hunting pressure and promote sustainable use of wildlife resources. They also reinforce community accountability, as violations require collective rituals and restrictions.

The Monpa Tribe: Buddhist Sacred Groves in Tawang

The Monpa are a Buddhist tribe inhabiting the Tawang and West Kameng districts of Arunachal Pradesh. Unlike many other tribes, they do not sacrifice animals in rituals, instead using animal products and motifs in their oral and performing art traditions (Chaudhuri, 2008). They have a well-developed system of sacred groves, many designated as Gonpa Forest Areas (GFA) affiliated with Buddhist monasteries. These groves are tended by Lamas (monks) and the Monpa community, serving as repositories of biodiversity and spiritual sanctuaries. Arunachal Pradesh has a total of 110 holy groves and 58 GFAs reported from Tawang and West Kameng districts. Tawang alone has 36 GFAs, including Sangdok Palri Gonpa Forest, Dungarmani Gonpa Forest, and Khartang Pharmang Forest (International Journal of Novel Research and Development, 2025).

Sacred groves in Tawang preserve endangered and rare species, offering refuge to uncommon flora and fauna. The customary beliefs and indigenous practices among the Monpa have not only nurtured the traditional knowledge system but also aided in the conservation of indigenous plants in the region. These groves are characterised by dense canopy cover, diverse flora (including medicinal herbs, orchids, and rare endemic plants), and unique fauna. They serve as crucial habitats for birds, insects, and small mammals, contributing significantly to local ecosystem biodiversity. For them, sacred groves are not merely biodiversity hotspots but centres of cultural identity and traditional knowledge (Scribd, 2025). Protection of these groves is intricately linked to religious rituals and community practices that emphasise conservation and sustainable use of natural resources. The belief that these groves are inhabited by deities or spirits has played a crucial role in safeguarding their biodiversity over generations.

The Apatani Tribe: Sedentary Agriculture and Agroforestry

The Apatani inhabit the Ziro or Apatani valley in Lower Subansiri district of Arunachal Pradesh. They practise sedentary wet-rice cultivation integrated with pisciculture and rural forestry. This system, unique among Northeast Indian tribes, has maintained sustainable productivity levels and is highly energy-efficient. The Apatani's cultural landscape, identified by its wet-rice cultivation system combining rice, millet, and fish cultivation in valley land about 1,600 meters above sea level, exemplifies sophisticated resource management. UNESCO has recognised the Apatani/Ziro Valley as a potential World Heritage Site due to its rich traditional ecological knowledge and sustainable practices (Rai, 2005). They practice agroforestry, planting fruit trees, jackfruit, and

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other species around kitchen gardens and fields. They grow local ginger, turmeric, brinjal, paddy, *okjok* (Bauhinia variegata), finger millet, foxtail millet and cucurbit crops according to different slopes and soil depths (Singh et al., 2011). Beans and cover crops are planted on the highest slopes to prevent soil erosion and conserve moisture during rainfall shortages. Their sedentary agriculture minimises the ecological impact of shifting cultivation, reducing deforestation and soil erosion. Their integrated rice-fish system enhances biodiversity, providing both food security and ecological resilience.

These people of Arunachal Pradesh practice sophisticated sustainable agriculture centred on integrated water management, soil conservation, and crop diversity. They harvest mountain water through bamboo channels and wooden sluice gates, distributing it across terraced rice fields with precision. Living fences of banana, bamboo, and *okjok* trees protect bunds from erosion while providing resources. Their farming system features remarkable varietal diversity in rice, millet, and vegetables across micro-environments, combined with integrated rice-fish cultivation that enhances nutrition and resilience. Sacred groves protect water sources, while community governance ensures equitable water sharing and maintenance. This holistic approach has sustained the Apatani for generations, demonstrating indigenous ecological wisdom that buffers against climate variability and ensures food security through traditional knowledge and cooperative resource management.

The Aka Tribe: Sacred Mountains and Water Bodies

The Aka inhabit the West Kameng district of Arunachal Pradesh. They have a concept called , referring to forest lands and water resources (ponds/lakes) considered sacred. The highest mountain peak in the Aka-inhabited area, *Wojo Phu*, is considered a sacred mountain. Extraction of any resources from this mountain and hunting are strictly prohibited. The Aka believe that breaking this taboo will lead to bleeding from the nose and mouth, ultimately causing death. As a result, even today, this mountain retains a huge dense forest cover (Chaudhuri, 2008). They also have the concept of a sacred pond (*Wojo Phu*) located near Nechiphu pass, about 5,000 feet above sea level. People worship this pond, and plucking even leaves from plants surrounding it is taboo. They believe that if someone plucks leaves from this pond, they will lose direction on the way back home, reaching the same place repeatedly. These beliefs and taboos have effectively protected sacred mountains, forests, and water bodies from exploitation. The *Wojo Phu* Mountain and *Nearma Husu* pond remain relatively undisturbed, preserving biodiversity and ecological integrity.

MECHANISMS OF ECOLOGICAL GOVERNANCE

Indigenous communities in the eastern Himalayas deploy culturally embedded mechanisms that align social norms, ritual practice, and institutional authority with

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ecological sustainability. These mechanisms operate through narrative, ritual prohibition, spatial sanctity, and customary governance, collectively constituting an informal but effective system of ecological governance.

Myths and Legends as Ecological Instruction

Myths and legends encode ecological norms and moral instruction, translating environmental ethics into memorable, culturally resonant narratives. Among the Adi, certain trees are believed to have sprung from the bones of mythical ancestors, rendering them sacred and off-limits for cutting. Similarly, the Nyishi ballad of Ridin, the sacred creeper, teaches that nature protects humankind when respected, thereby reinforcing reciprocity between humans and the nonhuman world. Such narratives serve didactic, normative, and identity-forming functions. They impart lessons on social conduct and resource use, establish rules and taboos regulating human–nature interaction, reinforce cultural identity and place attachment.

Rituals and Taboos as Regulatory Mechanisms

Rituals and taboos function as informal regulatory mechanisms that limit resource exploitation through spiritually sanctioned prohibitions. Harvesting restrictions, such as cutting bamboo only during specific lunar phases to avoid insect infestation, embed ecological timing within ritual calendars (Chaudhuri, 2008). Hunting taboos protect certain animals such as tigers, gibbons, and seasonal birds through spiritual prohibitions, while post-event restrictions following childbirth or death prohibit cutting plants or visiting bamboo shoot areas. Although rooted in spiritual belief, these practices effectively promote sustainability and biodiversity conservation by reducing overharvesting and safeguarding vulnerable species and life stages (Kuey Journal, 2024).

Sacred Groves as Biodiversity Reserves

Sacred groves operate as community-managed biodiversity reserves that protect endangered and rare species through culturally enforced exclusion. In Tawang, 36 Gonpa forest areas preserve indigenous plants and provide habitats for birds, insects, and small mammals (International Journal of Novel Research and Development, 2025). In West Kameng, sacred groves (Deopahars) are rich in medicinal herbs, orchids, and endemic plants (Scribd, 2025). Their key characteristics include dense canopy cover that protects understory vegetation and maintains microclimates; high species richness of flora and fauna, including rare and endemic taxa; and cultural protection via belief in deities or spirits that deters exploitation.

Customary Institutions and Community Governance

Customary institutions like village Kebangs (Adi), Nyele village councils (Nyishi), and monastic authorities (Monpa) play crucial roles in environmental governance by

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regulating resource use, resolving conflicts, and enforcing taboos (Chaudhuri, 2008; Singh et). These bodies set rules for hunting, fishing, and harvesting; mediate disputes over land, water, and forest resources; and impose social and spiritual sanctions on violators. In the Adi's Community Reserve Forest (CRF) initiative, village-level committees and customary institutions are proposed to manage community forests collaboratively with scientists and government agencies, illustrating a hybrid governance model that integrates local norms with formal conservation frameworks (Singh et al., 2011).

CHALLENGES AND THREATS

Modernization and Market Forces

The last two decades have seen a boom in timber trade in Arunachal Pradesh, leading to indiscriminate exploitation of forest resources that contradicts traditional conservation ethics. This exploitation has been facilitated by the active nexus of powerful elites, even as people in interior villages continue to uphold traditional belief systems. Market forces and globalisation have introduced narrow individualism and instant culture, eroding the sense of collectivism, respect, and reciprocity with the surrounding ecosystem. Materialist development paradigms prioritise economic growth over ecological sustainability, undermining traditional values.

Climate Change and Environmental Anomalies

Climate change poses significant threats to biocultural diversity and livelihood security in Arunachal Pradesh. Traditional knowledge holders report: Erratic rainfall, Unpredictable floods and droughts disrupt agricultural cycles and resource availability (Singh et al., 2011). Rising temperatures affect plant phenology, animal behaviour, and water availability. Species diversity in aquatic and terrestrial ecosystems is declining due to heavy silting, temperature fluctuations, and habitat degradation, leading to Biodiversity loss. If current trends continue, 95.64% of traditional knowledge holders believe that biocultural diversity and the sustainability of subsistence livelihoods would be threatened.

Erosion of Oral Transmission

Younger generations are increasingly disconnected from elders and traditional knowledge holders, risking the loss of intergenerational knowledge transmission (Murtem & Chaudhry, 2014). Urbanisation, formal education, and migration to towns for employment contribute to this erosion. Now, younger generations consume adulterated market foods and drink dirty town water, leading to increased diseases. The alarming rate of erosion in knowledge about biodiversity and culture among the younger generation aggravates the threat of climate change to their culture and biodiversity.

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Policy Gaps and Institutional Neglect

Government policies in Arunachal Pradesh have been remiss in joining hands with Indigenous communities to gain an understanding of their time-tested traditional environmental knowledge (Singh et al., 2011). Despite the recognised importance of Traditional ecological knowledge in biodiversity conservation and climate adaptation, indigenous voices are often absent in academic, policy, and public discourses. Even IPCC reports have not adequately considered the role of Indigenous peoples in climate change mitigation. In Arunachal Pradesh, state developmental and environmental policies have not integrated Traditional Ecological Knowledge into planning and implementation.

POLICY RECOMMENDATIONS

Documentation and Safeguarding of Traditional Ecological Knowledge

Systematic ethnographic fieldwork, audiovisual recording, and community mapping are urgently needed to preserve Traditional Ecological Knowledge before it disappears (Murtem & Chaudhry, 2014). Initiatives should include Oral history projects such as recording elders' knowledge of plants, animals, weather indicators, and cultural practices. Establishing Community archives as local repositories of traditional knowledge managed by tribal communities. Also creating Digital platforms as accessible databases of Traditional Ecological Knowledge for education and research, with community consent and benefit-sharing.

Integration into Conservation Policy

Traditional Ecological Knowledge should be integrated into environmental policy and conservation planning. A few recommendations include:

Community Reserve Forests

Expand the CRF model across Arunachal Pradesh, linking Indigenous-managed forests with Reducing Emissions from Deforestation and Forest Degradation (REDD) and other conservation incentives (Singh et al., 2011).

Co-management Agreements

Establish collaborative management of protected areas involving tribal communities, customary institutions, and government agencies (Singh et al., 2011).

Legal Recognition

Provide legal recognition for sacred groves and customary conservation areas to protect them from exploitation (International Journal of Innovative Research and Technology, 2023).

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Education and Capacity Building

Traditional ecological knowledge should be incorporated into formal and non-formal education systems through strategies such as:

Curriculum Integration

Including Traditional Ecological Knowledge in school curricula, teaching students about local biodiversity, traditional practices, and environmental ethics (Kuey Journal, 2024; International Journal of Innovative Research and Technology, 2023).

Intergenerational Learning

Facilitating knowledge exchange between elders and youth through community workshops and cultural programs (Singh et al., 2011; Murtem & Chaudhry, 2014).

Training Programs

Providing formal training to tribal communities on climate change adaptation, sustainable agriculture, and forest management, building on their existing knowledge (Singh et al., 2011).

Reviving Cultural and Religious Beliefs

Reviving and reawakening cultural and religious beliefs with ecological significance can act as a powerful deterrent against exploitation. A few suggestive initiatives are:

Rituals and Festivals

Supporting community-led rituals, festivals, and ceremonies related to nature conservation (Chaudhuri, 2008; International Journal of Innovative Research and Technology, 2023).

Spiritual Education

Incorporating ecological ethics and spiritual values into religious teachings and community discourses (International Journal of Innovative Research and Technology, 2023).

Cultural Revitalization

Promoting traditional arts, music, dance, and storytelling that encode ecological knowledge (Murtem & Chaudhry, 2014; Kuey Journal, 2024).

Equitable Benefit-Sharing

Conservation initiatives must ensure equitable benefit-sharing with tribal communities through some recommendations such as:

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Reducing Emissions from Deforestation and Forest Degradation (REDD) Incentives

Ensuring that rewards and incentives from REDD and other conservation programs reach community members who manage forests (Singh et al., 2011).

Fair Compensation

Providing fair compensation for ecosystem services provided by Indigenous-managed lands (Singh et al., 2011).

Community Ownership

Respecting community ownership and control over CRFs and sacred groves, avoiding government appropriation (Singh et al., 2011; International Journal of Innovative Research and Technology, 2023).

CONCLUSION

This research paper has demonstrated that folklore and tradition in Arunachal Pradesh function as sophisticated systems of ecological governance, encoding practical knowledge about forests, water, plants, animals, and sustainable resource use. Through case studies of the Adi, Nyishi, Galo, Monpa, Apatani, and Aka tribes, it has shown how myths, rituals, taboos, and sacred groves regulate human interaction with the natural world and protect biodiversity.

However, these knowledge systems face existential threats from modernisation, climate change, and the erosion of oral transmission. The boom in timber trade, market forces, and materialist development paradigms have undermined traditional conservation ethics, while younger generations are increasingly disconnected from elders and traditional knowledge holders. To safeguard ecological knowledge, it is essential to safeguard folklore itself. This requires systematic documentation, integration into conservation policy, education and capacity building, revival of cultural and religious beliefs, and equitable benefit-sharing with tribal communities. As the Adi traditional knowledge holders warned, if current trends of climate variability and cultural erosion continue, the future of their ethnicity, food habits, and culture is uncertain. The question is not merely whether they will be able to conserve their food habits, agricultural practices, and knowledge-nurturing institutions, but whether the broader society will recognise and support the value of Indigenous ecological wisdom in addressing the global challenges of climate change and biodiversity loss.

Safeguarding folklore is inseparable from safeguarding ecological knowledge itself. In Arunachal Pradesh, as elsewhere, Indigenous knowledge systems offer not only cultural richness but also practical solutions for sustainable resource management and

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environmental conservation. Integrating this wisdom into contemporary policy and education is not merely an act of cultural preservation but a strategic imperative for ecological resilience and human well-being in the 21st century.

REFERENCES

Banerjee, S. (2024). Traditional knowledge systems of the Nyishi tribe in Arunachal Pradesh: A socio-cultural exploration. *School of Social Sciences Journal*. https:/soss.wbnsou.ac.in/journals/SoSS/2024/13.

Blackburn, S. H. (2008). *Himalayan tribal tales: Oral tradition and culture in the Apatani Valley*. Brill.

Chaudhuri, S. K. (2008). Folk belief and resource conservation: Reflections from Arunachal Pradesh. *Indian Folklife*, 28. https://www.sahapedia.org/sites/default/files/2019-

Dowerah, V. Oral Traditions and Folk Histories as Repositories of the Indigenous Knowledge System of the Tribes of Arunachal Pradesh. NEW MAN.

International Journal of Innovative Research and Technology. (2023). Dwindling forests and sacred groves as conservation strategies in Arunachal Pradesh. *International Journal of Innovative Research and Technology*. https://ijirt.org/publishedpaper/IJIRT168920_PAPER.pdf

International Journal of Novel Research and Development. (2025). Sacred groves and biodiversity: The traditional ecological knowledge and the conservation of biodiversity in Tawang. Internation https://www.ijnrd.org/papers/IJNRD2506218.

Kuey Journal. (2024). *Folklore, traditional ecological knowledge, environmental conservation. Kuey Journal*. https://kuey.net/index.php/kuey/article/view/9902

Lex Localis Journal. (2025). *Customary law, family system, and environmental bonding among the Nyishi tribe of Arunachal Pradesh*. https://lex-localis.org/index.php/LexLocalis/article/view/801308

Murtem, G., & Chaudhry, P. (2014). Sacred groves of Arunachal Pradesh: Traditional way of biodiversity conservation in Eastern Himalaya of India. *Journal of Biodiversity Management & Forestry*, 3(2). https://www.scitechnol.com/sacred-groves-of-arunachal-pradesh-traditional-way-of-biodiversity-conservation-in-eastern-himalaya.

Rai, S. (2005). The *Apatani cultural landscape and traditional ecological knowledge*. UNESCO.

Singh, R. K., Bhowmik, S. N., & Pandey, C. B. (2011). Biocultural diversity, climate change and livelihood security of the Adi community: Grassroots conservators of eastern Himalaya Arunachal Pradesh. *Indian Journal of Traditional Knowledge*.

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Chapter

31 Performing Sustainability: *Phumdigi Tantha* as Cultural Intervention

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ABSTRACT

Phumdigi Tantha is a dance drama from Manipur in Northeast India. Directed by Wangkhem Lokendrajit Singh, a Sangeet Natak Akademi awardee, the production premiered at the Chorus Repertory Theatre, Imphal, on 20 April 2018. The name, *Phumdigi Tantha*, combines phumdi (floating biomass of soil, vegetation, and organic matter unique to Loktak Lake) with tantha (a narrative, tale, or drama in Manipuri usage). This dance drama re-imagines indigenous narratives within a contemporary theatrical framework. It draws significantly on mythic motifs of water goddesses, folklore, and community life to depict the ecological crisis affecting Loktak Lake. While dance drama itself is a modern art form, its creative strength lies in how it mobilizes traditional idioms, cultural myths, and ritual resonances to interrogate present realities. This raises a critical inquiry: *In what ways can culturally rooted performance practices be reimagined to generate ecological consciousness in the face of the ecological disruptions of modernity?*

Keywords: Manipuri theatre, Phumdigi Tantha, Ecological Crisis, Loktak Lake, Sustainability

INTRODUCTION

Manipur is one of the northeast states of India. It is especially noted for its freshwater lake called Loktak Lake. This Lake is in the southern part of Manipur in the district of Moirang. It is the home to the endangered brow-antlered deer, locally known as Sangai. Loktak Lake has *phumdis* or the floating biomass. Interestingly, phumdis are unique. They are not found elsewhere. Only in Manipur, these naturally growing phumdis are seen in Loktak Lake. The phumdis cover almost half of Loktak Lake and provide a natural habitat to Sangai deer.

Both Loktak Lake and Sangai deer have been a presence in the myths of Manipur. The Lake is considered to be the abode of Water Goddess and the bountiful sustenance that people receive from the Lake in the form of fish and others is regarded as the divine grace of the

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Goddess. People perform rituals and make offerings to get the divine blessing. Sangai deer is associated with the story of Kadeng Thangjahanba and Tonu Laijinglembi. In the story, Kadeng waits eternally for his beloved Tonu. This has inspired the storytellers of Manipur to relate the eternally waiting of Kadeng with Sangai by calling it "the animal in waiting". It has become a symbol of love and sacrifice.

The Sangai is often called the "Dancing Deer of Manipur". The name has come from the graceful movement of the Sangai across the phumdis of Loktak Lake. The deer has to maintain a soft and delicate step while navigating across phumdis because the phumdis are not hard and stable like the ground in the forest areas. At one point, Sangai was thought to be an extinct species but fortunately in the 1950s, it was rediscovered and from then onwards, the conservation and protection of Sangai has been a priority for the people of Manipur. At present, Sangai is the State animal and with Loktak Lake, they have been the insignia of cultural tourism.

Despite the efforts of the government to protect the lake and the deer, there is a lack of awareness among the people, especially the modern generations. They often view the place and the animal with curiosity but without concern. The uniqueness and the beauty of them has collapsed amidst the amnesia of their cultural past and the enforcement of modern life that ignores ecological sensitivity.

Dance Drama of Manipur

It is in this context that the Manipuri dance drama, *Phumdigi Tantha* becomes relevant. The history of dance drama in Manipur can be traced back to the ancient time when the ritual of *Lai Haroaba* was performed for the prosperity of the people and the land. In this ritual, the *maibis* (ritual specialists) enact the creation myths. Later, dance drama is also evident in the *Ras Lila* ritual where the story of Radha-Krishna is enacted by the *Rasdhari*. In modern Manipur, dance drama has shifted from the ritual space to the secular one. It is often associated with theatre personalities like Ratan Thiyam and Rajkumar Singhajit Singh. Dance drama as a genre in modern Manipur has been a vehicle for socio-political issues. It encourages people to reflect about their conditions of living in society. Furthermore, the elements of bodily performances especially dance and song have been a prominent form of expression in cultures of India.

In the West, the Greek philosopher, Aristotle is considered an important figure for the study of theatre because of his detailed analysis of tragedy. In his book, *Poetics*, Aristotle considers spectacle the least important element of tragedy, and song though it contributes to the embellishment, it is not as vital as plot, character, or thought. For that reason, he devoted comparatively little space and discussion to them in the text. According to him, a good dramatist primarily focuses on plot and then pays attention to character and diction. In India, the dramatists have understood the significance of dance, song and the overall

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aspect of spectacle. The enduring popularity of dance drama as a genre in theatre is a signpost of this emphasis that Indian cultures have shown for generations.

The rise of the theatre of roots in modern India finds its Manipuri expression in the dance dramas of Ratan Thiyam. Dance drama, as theatre of roots, brings together the tradition and the modern elements in the performances. The dance drama captures the attention of the audience because of this unique blend of the traditional values and modern aspirations. The audience feel connected to the past while moving ahead into the modern world. The question remains, can the knowledge of the past help resolve the problem of the present? The dance dramas of Manipur in the hands of theatre personalities like Ratan Thiyam, Rajkumar Singhajit Singh and Wangkhem Lokendrajit Singh have sought to answer this pertinent question in the most relevant manner – through *tapasya*. The human body is put to the task of constant inquiry for the realisation of the highest Truth.

Phumdigi Tantha

Phumdigi Tantha is a dance drama from Manipur, choreographed and directed by Wangkhem Lokendrajit Singh. It premiered at the Chorus Repertory Theatre in 2018. The title of the dance drama, *Phumdigi Tantha*, translates into the tale, narrative or drama (*tantha*) of the floating biomass (*phumdis*). *Phumdi* represents the ecosystem of Loktak Lake. The dance drama is about Loktak Lake, the *phumdis*, the Sangai and the people of Manipur. *Phumdigi Tantha* opens with a captivating prologue. A familiar sound of bell ringing introduces us to a young boy and we immediately recognise the sound as that of the school bell. The young student *remembers* the words spoken by his teacher. The teacher narrates the beauty of Loktak Lake and draws the attention of the young mind towards it. The scene with the young boy and the teacher emphasises the role and significance of a teacher in the act of learning. A teacher is someone who shapes our perspective of life around us. Interestingly, the thought of Loktak Lake came to the mind of the young student as he is haunted by the differences he sees in front of him regarding the present condition of the lake. There is a gap between what has been described by his teacher and what he has seen of the lake. There is deterioration and destruction of the very beauty that his teacher has exalted in his lecture.

Sacred Geography of Loktak Lake

As the first act begins, Loktak Lake is shown with the seven goddesses – the water spirits. They are the guardian of the lake. They protect and nurture the lake. The mingling of natural (lake) and supernatural (Goddess) is to disrupt the false demarcation that people at present have developed in terms of sacred and secular. In cultures of India, such demarcation is understood as *mythya* – a false illusion. When the veil of ignorance falls and the illusion gets removed, the person comes to face the reality that every place is sacred; every being is sacred. The presence of seven goddesses indicates the sacredness of

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the lake itself. These water spirits do not exist solely as separate and independent entities. They are immanent in the lifeworld of the lake. They take the form of birds or fish that are found in the lake. As if by divine grace, the leaves on the lake transform into the unique biomass or the *phumdis* and they float and drift on the surface of the lake. In short, the life processes on the lake seem to be guided by the divine force.

Within the discourse of nature/culture, the human being has put himself at the centre claiming growth and progress to the world. Now, man is the master of nature and the creator of culture. In this dance drama, the actions of the goddesses disrupt the centrality of the human in the processes of nature. Nature responds to larger and complex dimensions and not only the narrow human needs. The human, too full of himself, has become oblivious of this condition.

Legends and Loss

In the second act, the mother of the young boy tells him about Loktak Lake. There is a parallel drawn between the teacher and the mother in these two acts. They are shown as guiding figures of our society. The mother tells her young son about legends and folklore of gods, goddesses and ordinary people associated with the lake. The mother figure is shown as a guardian of traditional truths. She teaches the young ones by sharing these truths. In this way, the young ones are shown the proper way to live with nature. The birds that were once seen in abundance on the lake have disappeared now. The legends and folklores are almost forgotten. In *Lai Haraoba* ritual, there is an occasion where *Laisna* (the mother figure) tells the *pena sheishak* (the traditional fiddle player) that people have forgotten the names of their fathers and that they should be reminded. She entrusts this task to remind people to *pena sheishak*, who sings songs and tells stories with music.

In modern times, a similar task has come upon those who still carry the traditional truths. They can be the storytellers, the poets and the dramatists. It also means that traditional truths are never *completely* erased from the social memory of the people. In this dance drama, *Phumdigi Tantha*, the school teacher through his academic and traditional knowledge ignites the interest of the young mind and then, the mother expands the interest through her traditional knowledge. The teacher and the mother, as shown in the dance drama, are not echoes from the past but they are lively voices of the present. They belong to the modern time. Nonetheless, the traditional truths are with them. And they passed on their knowledge to the next younger generation.

The Modern Time and the Modern Mind

It should be a matter of concern as to what has been taught to the younger generations at school and at home. These two spaces have been strongly influenced by modern thought that perceives the world and its beings as objects for commercial benefit. Human being is

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separated from the world precisely by the rationale that the world is in existence for him and subsequently, any form of exploitation of the world is inherent in the nature of this relation. This way of looking at the world, even if it has come from a particular school of thought, has now become universal owing to the event of colonisation and globalisation.

The modern mind is guided by the principle of profit and many a time, this profit is earned by ignoring the ethical benchmark. A huge support system is built to enhance the modern idea of progress through the development of science and technology. Unfortunately, the field of science and technology comes with a lesser value based critical approach (as in when compared to Humanities). Martha C Nussbaum in her *Not for Profit: Why Democracy Needs the Humanities* argues that Humanities inculcates critical thinking among students, which in turn helps in developing diverse perspectives, a sense of inclusivity and moral imagination. According to her, philosophy can foster empathy and ethical reflection. Undoubtedly, ethics is an important element of philosophy. Still, there are philosophers like Emmanual Levinas who argue that the entire Western Philosophy has an egological approach and therefore, it fails to give proper attention to the Other. In short, Levinas claims that Western Philosophy alienates the Other in its engagement with the world.

As such, for long, the exploitation of nature through science and technology in the name of modernity and progress continued in a quick pace without much hindrance from the ethical ground. We do not pause to reflect on what we have done. In fact, we are living in an era defined by the term – "burnout society" – coined by the philosopher Byung-Chul Han to indicate how people of today are obsessed with achievement. They are driven endlessly in the pursuit of maximising productivity. It leads to exhaustion of the mind and erosion of the ability to reflect deeply in a sustained manner.

Timeless Traditional Values

In contrast to the Western Philosophy, the Indian knowledge system has been devoted to the dissolution of the boundary between Self and Other – seeing oneself in the Other. Our ancestors were closer to nature because they were taught that human beings share a similar life force – the *jiva atma* – as others. As such, they approached nature with reverence. When they "used" something from Mother Nature, they exhibited a sense of gratitude and not the ego of exploitation. In fact, this sense of gratitude comes with an understanding that the gift of nature can never be fully appreciated. These timeless traditional values of reverence, gratitude and care have been nurtured within a system of knowledge where practices promote these values and vice versa. For instance, an event is narrated about a king called Luwang Ningthou in the *Lai Haraoba* ritual of Manipur. For the purpose of making a royal boat, a big and beautiful tree is cut down, a ritual is performed before the act of cutting the tree and through this ritual, an expression of gratitude is shown towards

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the tree. However, the traditional understanding of the entire event goes even beyond this "expression of gratitude" and a ritual song called *Hiching Hilao* is sung when *Lai Haraoba* is performed as if to remind the people of how the expression of gratitude is not enough; that the expression of gratitude cannot be the closure of the act of "using" the other. One can never fully repay the debt owed towards the other.

The traditional knowledge system has been kept alive by the cultural custodians for generations. Earlier, they were patronised by the royal families and the people. However, the scenario is different at present. Slowly, cultural custodians are dwindling even the *maibis* who are supposedly chosen by deities. In this condition, learning centres – school, college and university – play a significant role in upholding the timeless traditional values. Even family spaces share the role in sustaining these values.

Two Sides of Progress

In modern times, the measurement of growth and progress in a society is done primarily through the scale of scientific advancement. Human beings have finally managed to create "the brave new world" for himself. This new world is apparently the source of his comfort and convenience but unfortunately, the same world turns out to be for himself *alone.* It isolates and alienates him from all others in nature. The migratory birds which frequent the lake have now stopped coming over. Even the local ones, *kakyen* (kite) and *wainu* (heron), are no longer seen in abundance. Such changes have happened due to multiple reasons and the prominent ones among them are climate change and environmental degradation.

A recent report highlights the extreme weather conditions in an unprecedented manner in Manipur. The report also mentioned that the last one decade from 2015 to 2024 had been the warmest on record. The Director, Environment and Climate Change, Dr T. Brajakumar Singh says: "Manipur is among several places around the globe which have seen consistent increase in surface temperature. The State is projected to experience an increase in annual mean temperature above 1.7 degree Celsius by mid 2030s." (Staff Reporter, 2025)

These changes are not natural rather they are forced ones due to human activities. The large-scale deforestation in both hills and plain has contributed to the climate change in Manipur. Many wetlands (or *pats*) in the plain areas of Manipur have disappeared and only their names as markers of the places have remained, evoking a sense of nostalgia of the bygone days.

Furthermore, there is an upsurge in the mindless pollution of the rivers which then come to the lake bringing along the pollutants in large amounts. People have ceaselessly used and dumped non-biodegradable items without paying attention to the harmful effects. Despite repeated calls for curbing the use of them by the government and other bodies,

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people have continued using and misusing them. The irony is that even educated people are involved in the continuation of the environmental degradation. The gift of sciences can also be a curse for humanities if we cease to be critical of what we do and how we do.

The dance drama, *Phumdigi Tantha*, in its third and the final act, employs plastic as a symbol of double-faced science. Plastic is one of the remarkable inventions of human beings. The credit for it goes to the advancement of science. It has become a popular household name. Right from the birth till the last moment of a person, plastics serve his need in many forms. This reveals the stark dependency of human beings on plastic. Unfortunately, plastic is also a significant source of pollution and our mindless use of it has only added the pollution factor. It is clear that we cannot do away with plastic use but what we can do is alter our practices.

It is our traditional knowledge system that can assist in changing our practices for a better sustainable environment. Alienated from nature, man in his isolation fails to comprehend the larger impact of his activities. First and foremost, man has to learn or in fact, re-learn that every being around him is connected in one way or another. Like an intricate structure, when a single building block is removed, the entire edifice collapses. This concept of interconnectedness comes in the profound Vedic concept of *vasudhaiva kutumbakam* or the world is one family. Often scholars have seen this concept to efface differences among human beings in terms of caste, class and religion. However, in a deeper sense, it can be extended to indicate that all the species on earth are related as members of a single family. There is a spiritual bonding among all of us.

This idea is reiterated by Rachel Carson in her 1962 text, *Silent Spring*. She writes about ecological interdependence. Her central argument is that no species on earth can be considered in isolation. The fate of even a single species has an impact on the whole system. Our own survival therefore depends upon respecting this interdependence. There will be a fatal ecological collapse if this interdependency is ignored. Overall, she is speaking for an ethical responsibility towards others.

In Search for an Epilogue

Phumdigi Tantha includes an epilogue which instead of closing the drama opens a dialogue about the future of Loktak Lake, Sangai and human beings after all. What will be the destiny of Loktak Lake if humans continue to dump waste into it? A lake where phumdis are gone and overtaken by plastics. Where will the dancing deer, Sangai go? This endangered deer is one among the only three species found in Southeast Asia and the number of them is still very small. The conservation efforts are working hard but if people at large do not understand and participate in sustaining the ecology, it will not be far when Sangai will merely be a symbolic presence. The Manipur government organises the

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cultural and tourism event called Sangai Festival every year. Indeed, Sangai represents the culture of Manipur and invites people to come over to Loktak Lake. This invitation is also a reminder for ecological reflection. If only, people could do so besides the merriment of the Sangai Festival.

The dance drama, *Phumdigi Tantha*, has a serious tone. The dance and the song elements in it are solemn without embellishment. All these are meant for the audience to sense the stark realities of what is happening in Loktak Lake. The construction of the dam around the lake has improved the power supply of Manipur and neighbouring States. It has made the lives of people more convenient. The use of plastic too has made our lives more comfortable. But all these at what cost? *Phumdigi Tantha* asks this relevant question.

The remedy for the modern malaise lies within – in self-disciplining. The Indian tradition speaks of *sanyam* which translates as "self-control, restraint, discipline over one's senses". *Sanyam* is achieved by balancing pleasure of desire and pain of duty. In pursuit of unwavering desire, without a sense of duty towards others, human beings have been responsible for the extinction of numerous species on earth. Our tradition teaches each one of us to practice *sanyam* in our thoughts and practices, and more so when the element of desire is involved. When this is transgressed, the traditional stories remind us, the person faces karmic downfall, and suffering.

The modern mind might be deluded to think that with scientific advancement, we can escape these "karmic downfall, and suffering". This has not been the case so far. Nature has shown its overpowering strength over us many times. Consider the recent floods in Nepal. This disaster has left hundreds dead and many more missing. Many families have been displaced as their homes are swept away. Communities are grappling with widespread loss and destruction. This tragic event underscores how vulnerable human life becomes when confronted with the forces of nature.

Phumdigi Tantha – A Responsibility

The proponents of dance drama have used this medium to put across the important message of eco-sensitivity. Dance drama, as mentioned earlier, focuses on dance, music and song. It does not have dialogues or a good plot development. It plays with a concept and takes labour in *showing* the concept. Therefore, dance drama comes out to be different in terms of experiencing it. The present generation is heavily exposed to the western plot-based drama with ample dialogues for exposition to the audience. It does not feel comfortable with dance drama. The symbolism of dance drama appears vague; the song and dance, estranged. The meaning is lost in the medium. Nonetheless, the proponents have not deterred from more production of dance drama. *Phumdigi Tantha* is one such untiring effort in the long list of dance dramas from Manipur.

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Dance drama or, for that matter, any drama associated with theatre of roots has a future in the context where the traditional knowledge system is meaningfully incorporated into the educational system. In other words, the ecosystem of dance drama needs to be nurtured so that the audience is better trained to appreciate it. This task is challenging. The persistence of colonial consciousness has blocked our minds and actions – our insight – to perceive anything else than what it dictates. It has deprived us of the critical thinking required for reclaiming one's own space. Decolonisation is the task ahead. It comes through incessant unlearning and relearning the mode of thinking and doing for a more inclusive world.

Phumdigi Tantha, therefore, is a task – a responsibility towards ourselves and others for a sustainable future by embracing the wisdom inherited from the past in fencing off the present malaise.

REFERENCES

Aristotle. (1987). *Poetics* (R. Janko, Trans.). Hackett Publishing. (Original work published ca. 335 BCE)

Awasthi, S., & Schechner, R. (1989). "Theatre of Roots": Encounter with Tradition. *TDR (1988-)*, *33*(4), 48–69. https://doi.org/10.2307/1145965.

Carson, R. (1962). *Silent spring*. Houghton Mifflin.

Devi, R. S., Satapathy, K. B., & Kumar, S. (2024). Loktak Lake of the state Manipur: A review to educate the intellectuals and awareness on its biowealth. *Educational Administration: Theory and Practice*, 30(5), 6936–6947. https://doi.org/10.53555/kuey.v30i5.4064

Han, B.-C. (2015). *The burnout society* (E. Butler, Trans.). Stanford University Press. (Original work published 2010)

Jawaharlal Nehru Manipur Dance Academy. (2026). *50 years of production unit, 1976–2026*. Imphal, Manipur: Sangeet Natak Akademi.

Levinas, E. (1969). Totality and infinity: An essay on exteriority (A. Lingis, Trans.). Duquesne University Press. (Original work published 1961)

Nussbaum, M. C. (2010). *Not for profit: Why democracy needs the humanities*. Princeton University Press.

Parratt, S. N. A. (1997). *The pleasing of the gods*: Meitei Lai Haraoba. Vikas Publishing House.

Singh, A. L., & Khundrakpam, M. L. (2011). Phumdi proliferation: A case study of Loktak lake, Manipur. *Water and Environment Journal*, 25(1), 99–105. https://doi.org/10.1111/j.1747-6593.2009.00197.x

Singh, W. L. (Director). (2018, April 20). *Phumdigi Tantha*. Chorus Repertory Theatre, Imphal, Manipur, India.

Staff Reporter. (2025, February 26). Manipur reeling under climate change spell: Experts predict more heatwaves, floods and droughts–I. *The Sangai Express.* https://www.thesangaiexpress.com/Encyc/2025/2/26/By-Our-Staff-ReporterIMPHAL Feb-26-Consistently-Manipur-has-experienced-heat-waves-drought-like-situati.html

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Chapter

32 Indigenous Traditions and Sustainable Futures in the Western Himalayas

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ABSTRACT

The Western Himalayas hold an abundance of resources that have helped sustain the lives and livelihood of the hill folk. The communities have co-existed not only with the human, but also with the non-human, forming a delicate balance, carried forward across generations through indigenous knowledge systems. The forests, lakes and rivers are not merely physical spaces but living entities embedded within systems of belief, ritual and customary law. The sacred traditions have historically shaped patterns of resource use, regulated the access to natural spaces and also encouraged forms of ecological stewardship that support both biodiversity and community well-being.

However, these traditional systems are being challenged by expanding tourism, commercialization of sacred and cultural events and changing media representations that often prioritize spectacle over cultural meaning. Such "developments" have contributed to environmental degradation, excessive pressure on local resources and gradual transformation of indigenous practices into market-oriented performances.

This study, based on fieldwork covering select regions of Himachal Pradesh intends to explore the role of customary institutions, community participation and indigenous knowledge systems, in sustaining both cultural heritage and fragile mountain ecosystems, while analysing the influence of media in shaping public perceptions of sacred spaces and their impact on tourism-driven development. By situating local experiences within broader discussions on cultural sustainability and conservation, the study argues that effective preservation requires approaches that recognize indigenous knowledge systems as central to environmental governance. The findings aim to contribute to policy discussions on sustainable tourism, cultural heritage management and community-led conservation in the Himalayan region while highlighting the continued relevance of sacred traditions in addressing contemporary ecological challenges.

Keywords: Folklore, Orality, Environment, Western Himalayas, *Nag Devta*

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INTRODUCTION

The Western Himalayas constitute one of the most ecologically fragile mountain regions, where human communities have historically developed ways of negotiating the demanding and unpredictable environments. In Himachal Pradesh, forests, rivers, springs, pastures, mountains and valleys have provided not only the material basis of life but have simultaneously acquired social, cultural and sacred significance. Here, landscapes are embedded with oral traditions, customary practices, ritual systems and collective memory. The intimate relationship between landscape and the sacred is depicted in the land being called *Dev Bhoomi*, or the "Land of the Gods,". Across the region divine presences reside, *devis* and *devtas* continue to occupy an important place in community life, not merely as objects of worship but as institutional authorities connected with territory, social organisation, customary practices and collective identity.

The Institution of Divinity or the *devi-devta* institution is particularly significant in understanding the relationship of the people to the landscape. Scholarship on Himalayan religion has demonstrated that local deities cannot be understood exclusively through the framework of temple worship or individual belief. William S. Sax's work on Himalayan deity traditions, for instance, draws attention to the political and social authority exercised by local gods and their relationship with territorial communities. Ehud Halperin's ethnographic study of the Kullu Valley examines the deity institution as a dynamic system in which religion, political organisation and social life intersect. Asaf Sharabi's observations of the cult of Mahasu throws light on the ever-evolving nature of these cultures and how contemporary pressures are moulding ancient practices. Studies conceptualize the *devi-devta* institution through the notions of agency and sovereignty, demonstrating how divine authority is sustained through networks of human actors and community practices.

Within the institution which operates through a specialised body of ritual and administrative functionaries, the *gur* occupies a particularly important position as the medium through whom the deity is believed to communicate with the community. During ritual consultations, functioning as an important ritual intermediary, it is believed that the *gur* enters a state of possession or divine embodiment and the deity's responses are conveyed through him. The *pujari* performs ritual and worship-related duties and the *kardar* assumes administrative and organisational responsibilities. Their roles and nomenclature vary across regions and individual deity institutions, but collectively these functionaries sustain the institutional presence and authority of the deity. The *devi-devta* system is therefore not a static religious structure but a living social institution reproduced through ritual performance, oral transmission and community participation.

Its significance extends beyond the strictly religious sphere. A deity's territorial jurisdiction encompasses forests, water sources, pastures, agricultural land and mountains, creating

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a relationship between sacred authority and the regulation of natural resources. Sacred prohibitions concerning the cutting of trees, access to forests, use of water bodies, grazing or entry into particular landscapes establish culturally meaningful limits upon resource extraction. The sacred, therefore, functions as a principle of restraint. As documentation of sacred groves in Himachal Pradesh suggests, deity institutions and their custodians have historically contributed to the protection of vegetation, water sources and local biodiversity through customary restrictions and sacred prohibitions (Himachal Pradesh State Biodiversity Board, n.d.; Thaplyal & Verma, 2015). Recent research similarly demonstrates that sacred groves such as Hurang Narayan Dev Van support biodiversity conservation through community-enforced beliefs, taboos and restrictions on resource use (Verma & Kumar, 2025).

Such practices represent an important dimension of indigenous environmental knowledge. This knowledge was not necessarily codified as an independent ecological science, rather, it was embedded within folklore- ritual obligations, customary law, oral narratives and everyday practices. Communities learned not only how resources could be used but also when, where and to what extent they could be accessed. Sacredness consequently transformed the environment from a collection of exploitable resources into a morally regulated landscape. The protection of fragile ecosystems was thus intertwined with cultural and cosmological understandings of human responsibility towards place.

However, these relationships are increasingly being transformed by tourism, infrastructure development, commercialisation of festivals and the expanding reach of digital media. Sacred landscapes are becoming tourist destinations, while rituals and festivals are increasingly circulated as visual and cultural spectacles. Greater visibility may generate appreciation, but it can also detach practices from the customary systems of knowledge and restraint within which they have historically operated. The increasing commodification of sacred spaces therefore raises questions about both cultural continuity and ecological sustainability.

Based on qualitative fieldwork and interviews with communities and custodians of the *devi-devta* tradition in selected regions of Himachal Pradesh, this paper examines the relationship between sacred institutions, indigenous environmental knowledge and changing patterns of tourism and cultural mediation. It argues that the ecological significance of the divine institution lies in its capacity to connect resource use with responsibility, access with restraint, and landscape with cultural obligation. At a time when Himalayan ecosystems and traditional cultural practices face increasing pressures, these indigenous knowledge systems warrant attention not as remnants of an obsolete past but as living frameworks that may offer valuable principles for sustainable and place-sensitive environmental stewardship.

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INDIGENOUS KNOWLEDGE, SACRED LANDSCAPES AND ENVIRONMENTAL SUSTAINABILITY

Traditional Knowledge Systems emerge from sustained interaction between communities and the environments in which they live. They are therefore fundamentally place-based: knowledge is accumulated through repeated observation of particular forests, mountains, rivers, springs, lakes, pastures, agricultural fields, animals, plants, and seasonal cycles. Such knowledge is not produced independently of lived experience but develops through generations of engagement with specific ecological conditions. Berkes, Colding, and Folke (2000) locate "Traditional Ecological Knowledge" within precisely such an integrated relationship between knowledge, practice, belief and environment. Drawing on earlier scholarship, they observe that "traditional knowledge is a knowledge–practice–belief complex" (p. 1252). They subsequently formulate this as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (p. 1252). This definition is significant for understanding Himalayan knowledge systems because it does not isolate ecological knowledge from the cultural and social structures through which it is produced, transmitted, and enacted.

Traditional knowledge, in this sense, is not simply information about the natural world. It encompasses ways of behaving towards that world. Knowledge of a water source, for instance, is inseparable from the customary rules governing its use, knowledge of a forest may be accompanied by restrictions on cutting particular species, knowledge of a pasture may be embedded in seasonal patterns of access and knowledge of a sacred landscape may be transmitted through stories concerning the deity or sacred presence associated with it. Berkes et al. (2000) note that traditional management systems include "multiple species management, resource rotation, succession management, landscape patchiness management" (p. 1251). Such practices demonstrate that ecological management can be embedded within everyday cultural institutions rather than operating as a separate, formally codified system of environmental governance.

The Western Himalayas provide a particularly important context for examining this relationship because ecological knowledge is frequently articulated through the institution of the *devi-devta*. Here, the *devis* and *devtas* are not understood simply as idols representing supernatural beings. They are experienced as sacred presences associated with the elements of the landscape, extending their significance beyond ritual worship. The deity functions as a cultural authority through which relationships between the community and its environment are regulated. The sacred landscape is consequently not merely a space in which religious activity occurs, it is a framework through which ecological behaviour is understood and disciplined.

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This relationship is especially visible in traditions surrounding *Nag* deities. Across the Himalayan region, *Nag* deities are frequently associated with water, springs, lakes, streams. Within the communities encountered during fieldwork, these deities are understood not only in terms of ritual reverence but also as protectors of water resources. The association is significant because water in mountain environments is simultaneously an ecological necessity, a livelihood resource and a culturally charged element of the landscape. The protection of water therefore becomes both a practical and moral obligation. Polluting, damaging or disrespecting a water source can be understood not merely as an environmental offence but as a violation of the relationship established between the community and the deity.

The relationship between deity, landscape and ecological knowledge is particularly apparent in Sangla. Local traditions recorded during fieldwork hold that the sisters of *Baering Nag* manifest in the region in the form of waterfalls. The community's relationship with these waterfalls is consequently articulated through kinship: the waterfalls are understood as the *devta's* sisters rather than as anonymous physical features. When the *devta* is carried to these waterfalls, the journey is described as a visit to his sisters. Such a narrative transforms the physical landscape into a relational landscape. A waterfall is no longer simply a flow of water descending through the mountain, it becomes part of the social and sacred world of the community. The ecological feature acquires identity, memory, kinship and moral significance.

This form of traditional knowledge is important because it demonstrates how ecological relationships can be sustained without being expressed in the terminology of modern environmental science. The community does not necessarily need to describe a waterfall as a water resource in order to recognize its importance. Its protection may instead be articulated through a cultural vocabulary of kinship, sacredness, obligation and respect. The ecological and the sacred consequently become mutually reinforcing categories. The landscape is protected because it is meaningful, and it is meaningful partly because the community has learned to understand its ecological significance through inherited cultural narratives.

The tradition associated with *Devi Buddhi Nagin* and the Sereolsar Lake provides another striking example. In the local account recorded during fieldwork, this lake associated with her is kept remarkably clean through the presence of the *aabhi* bird. It is believed that when a leaf or other natural debris falls upon the surface of the lake, the bird swoops down, removes it and carries it away. The significance of the story lies less in establishing whether the narrative is empirically verifiable than in the ecological ethic encoded within it. The story teaches that the sacred water body must remain clean and that even apparently insignificant pollution is incompatible with its sacred status.

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The narrative thus functions as an ecological lesson transmitted through oral tradition. The *aabhi* becomes a cultural figure of ecological responsibility where if even a bird is represented as responsible for maintaining the purity of the lake, human beings are implicitly expected to exercise an even greater degree of care. The story transforms cleanliness from a contemporary environmental recommendation into an inherited moral principle. The lake is not simply a body of water that humans happen to use, it is a sacred space whose integrity must be maintained.

Such examples demonstrate why sacred spaces should be understood as part of Traditional Knowledge Systems rather than treated exclusively within the domain of religion. Sacredness can establish boundaries around particular environments and can influence how, when and whether those environments may be used. A sacred spring may be approached according to particular rules, a lake may be protected from physical intrusion, a forest associated with a deity may be subject to restrictions on extraction and a mountain landscape may be treated as a domain of the deity rather than as unrestricted territory. These practices create culturally embedded forms of environmental regulation. Their effectiveness does not depend solely upon material calculation because the consequences of violating them are understood simultaneously in ecological, social, and moral terms.

This is where Berkes et al.'s understanding of traditional ecological knowledge as adaptive management becomes particularly relevant. They identify traditional systems in which local ecological knowledge is used to respond to environmental feedback and they note that such systems resemble adaptive management through their emphasis on learning and their recognition of "uncertainty and unpredictability intrinsic to all ecosystems" (Berkes et al., 2000, p. 1252). The importance of this observation for Himalayan communities lies in the fact that mountain ecosystems are inherently dynamic and vulnerable to environmental fluctuations. Seasonal changes, variations in precipitation, water availability, landslides, changes in vegetation and pressures upon agricultural and pastoral resources require continuous adjustment. Traditional knowledge develops precisely through such long-term engagement with ecological variability.

The sacred, therefore, should not be understood as opposed to the ecological. In many traditional Himalayan contexts, the sacred provides one of the cultural mechanisms through which ecological relationships are maintained. Sacred narratives encode behavioural expectations, while rituals reproduce relationships between communities and places and oral traditions preserve ecological memory. The *gur*, *mali*, *kardar*, priests, elders and other custodians transmit knowledge through participation and performance. What is preserved through these traditions is not only a belief in a deity but also a way of inhabiting a landscape.

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This perspective also makes it possible to understand why certain places acquire sacred status. Sacredness may operate as a form of cultural restriction that places particular landscapes beyond unrestricted exploitation. Once a forest, spring, lake or mountain is understood as belonging to or inhabited by a sacred presence, its use becomes subject to culturally defined limits. Such limits can function as what may be termed cultural conservation, environmental protection is embedded within belief, customary authority, oral tradition, and ritual practice rather than separated into an externally imposed conservation regime.

The fieldwork suggests that such systems should neither be idealised nor dismissed. Traditional communities have always altered their environments, and not every traditional practice can be assumed to be ecologically sustainable. The significance of Traditional Knowledge Systems lies instead in the adaptive principles that they contain: locally accumulated observation, limits on extraction, seasonal regulation, respect for particular ecological sites, collective responsibility and responsiveness to environmental change. The lesson of these systems is therefore not that the past offers a perfect model for contemporary conservation, but that ecological sustainability can emerge from cultural institutions that connect human behaviour with the continuity of the resource base.

This becomes increasingly significant in the contemporary Western Himalayas, where tourism, infrastructure development, commercialisation, construction and increasing pressure on water and land are transforming relationships with sacred landscapes. When a sacred waterfall becomes a tourist attraction, a sacred lake becomes a destination for uncontrolled visitation, or a landscape previously regulated by customary authority becomes available for commercial use, the transformation is not merely economic. It can also weaken the cultural institutions through which ecological limits were historically communicated. The erosion of sacred restrictions can consequently produce an ecological as well as a cultural loss.

The rediscovery of Traditional Knowledge Systems is therefore not an exercise in nostalgia. It involves recognising that ecological knowledge can exist within stories, rituals, kinship relations, customary restrictions, sacred geographies and oral traditions. The stories of *Baering Nag* and his sisters, the association of *Nag* deities with water sources, and the folklore of Buddhi Nagin demonstrate how ecological relationships can be encoded within sacred narratives. Such narratives make the environment intelligible through culturally meaningful relationships and, in doing so, can encourage forms of restraint that contemporary environmental discourse often seeks to establish through legislation, scientific management or regulation.

Traditional Knowledge Systems thus offer an important conceptual bridge between cultural preservation and ecological sustainability. In the Western Himalayas, the

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protection of sacred spaces cannot be separated from the preservation of the knowledge systems that give those spaces meaning. To protect the sacred landscape is, in many cases, also to protect the oral traditions, customary institutions, ecological memories and ethical relationships through which communities have historically understood their environments. The challenge posed by contemporary development is consequently not simply how to conserve particular forests, lakes, waterfalls, or springs, but how to sustain the cultural systems that have historically taught communities why these places matter.

TOURISM AND THE TRANSFORMATION OF SACRED LANDSCAPES

Tourism has created new economic possibilities in Himachal Pradesh, but its expansion has also altered relationships between communities and their environments. The Himachal Pradesh Tourism Policy 2019 recognizes both the economic importance of tourism and the need to conserve the state's natural and cultural heritage. The policy emphasizes sustainable tourism, protection of tangible and intangible heritage, and benefits for local communities (Government of Himachal Pradesh, 2019).

The difficulty lies in translating these principles into practice. A landscape can be formally identified as culturally significant while simultaneously being exposed to tourism practices that undermine its ecological and sacred character.

Yula Kanda

Yula Kanda, located in Kinnaur, Himachal Pradesh, offers a significant case for examining the relationship between Traditional Knowledge Systems, sacred landscapes and contemporary religious and tourism practices. Situated at approximately 3,900 metres above sea level, Yula Kanda has increasingly been popularised as the location of one of the highest Krishna temples. However, this contemporary representation does not fully capture the older local sacred geography of the site. According to oral traditions documented during fieldwork, the lake is associated with a *Nag Devi* who is believed to reside within it. The sacredness of Yula Kanda therefore extends beyond the temple and is embedded in the natural landscape itself.

This distinction between religion and the sacred is central to understanding the changes taking place at the site. Traditional Knowledge Systems are often place-specific, sustained through oral traditions, customary practices and relationships between communities and particular ecological features. At Yula Kanda, the lake is not simply a water body surrounding a temple it constitutes part of the sacred presence of the landscape. Such a relationship differs from a standardised religious practice that can be reproduced across locations. The sacred here is inseparable from place.

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Historically, Yula Kanda remained a secluded and relatively offbeat pilgrimage site. Its remoteness naturally limited human movement and helped maintain a restrained relationship between pilgrims and the landscape. The recent influx of trekkers, however, has produced significant socio-ecological changes. During fieldwork, long lines of visitors were observed around the site, accompanied by increasing concerns regarding plastic pollution, soil erosion and water contamination. In a fragile high-altitude ecosystem, these pressures cannot be dismissed as merely aesthetic problems. Increased footfall, waste generation and disturbance of the surrounding terrain place additional stress upon an environment with limited capacity for rapid ecological recovery.

A recent *bhajan* programme at the site further illustrates the transformation. Conducted in temperatures of approximately −6°C and involving microphones, loudspeakers and temporary arrangements, the event is significant not merely as an instance of religious devotion but as an example of mainstream religious practice being layered upon an older sacred ecology. The concept of a palimpsest is useful here, the newer religious layer does not necessarily erase the older tradition but partially covers and transforms it. The increasingly visible Krishna-centred religious identity of Yula Kanda exists alongside the local belief in the *Nag Devi* associated with the lake.

The distinction matters because organised religious practice and indigenous sacred practice may embody different relationships with landscape. A *bhajan* can be conducted at numerous locations, whereas the sacred presence of the *Nag Devi* is fundamentally tied to this particular lake. The former may require sound systems, temporary structures and larger congregations whereas the latter is rooted in the recognition of the landscape itself as sacred and therefore subject to restraint. The ecological implications of these different modes of religious engagement consequently become important.

Yula Kanda demonstrates how the transformation of a sacred landscape can occur through both tourism and religious standardisation. The site remains sacred, but the ways in which that sacredness is represented and experienced are changing. What is at stake is therefore not simply the preservation of a temple or ritual. It is the survival of a place-based knowledge system in which water, deity, folklore, landscape and ecological responsibility are interconnected. Protecting Yula Kanda consequently requires recognising the lake not merely as a destination for pilgrimage and tourism but as a living sacred ecology whose preservation is inseparable from the preservation of the traditional knowledge through which its significance has been transmitted.

Raulane and Sangla Holi

Sangla Holi and *Raulane* are both festive celebration in District Kinnaur and have gained immense popularity in contemporaneity. The festivities illustrate how increasing tourism can transform the relationship between a community and its sacred celebrations. During

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one of the interviews conducted for this study, local participants expressed a striking concern, they have increasingly been pushed to the periphery of their own celebration while tourists occupy the centre. Visitors arrive to participate in Holi, often interpreting the festival through a mainstream understanding of colour, entertainment and public celebration. In the process, ritual practices embedded within local histories and relationships with the *devta* risk being reinterpreted as tourist spectacle.

For the local community, Sangla Holi is not simply an occasion for recreational colour-play. Its significance is rooted in inherited ritual practices, collective memory and the presence of the *devta*. The outsider may encounter movement, costume, colour, music and ritual action as components of a cultural performance, but the community experiences them as practices carrying meanings that cannot be separated from their sacred context. The distinction between participating in a sacred tradition and consuming it as an experience consequently becomes increasingly important. Tourists participate in colour-play and other visible aspects of the festival, but such participation does not necessarily imply access to its deeper ritual meanings. This distinction can be understood through MacCannell's (1973) concept of staged authenticity, in which tourists seek experiences perceived as authentic, "touristic consciousness is motivated by its desire for authentic experiences" (p. 597). The paradox is that the tourist search for authenticity can itself transform the cultural practice being encountered. In Sangla, what the tourist sees as a cultural performance remains, for the community, a tradition embedded in memory, belief and relationships with the *devta*.

The displacement described during the interview also represents a shift in cultural authority. When tourists equipped with cameras and recording devices occupy the centre of the celebration, local participants can become spectators to a ritual that their community has historically maintained. Cultural visibility therefore produces an unexpected paradox-the festival becomes more widely recognised while those who sustain its meanings may exercise less control over how it is experienced and represented.

A similar tension can be observed, in passing, in the *Raulane* festival, where growing media and tourist attention has brought concerns regarding the intrusion of outsiders into ritual spaces and the recording of ritual figures whose identities have traditionally been protected. In both cases, increased visibility risks privileging the spectator's interpretation over the community's understanding of the sacred. The central issue is not tourism alone, but the displacement of local ritual authority. The preservation of such festivals requires more than documenting or promoting them; it requires ensuring that the communities who have historically carried their knowledge remain participants, custodians and interpreters of their own sacred traditions.

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TOURISM, PERFORMANCE AND THE NEED FOR RESPONSIBLE ENGAGEMENT

The rise of digital media has intensified the visibility of Himalayan festivals and sacred practices. Dean MacCannell's (1973) concept of staged authenticity is useful in understanding this process. Tourists often seek experiences they perceive as culturally authentic, yet their presence can alter the very practices through which authenticity is sought.

Victor Turner's (1969) concepts of liminality and communitas further clarify this distinction. Ritual temporarily creates relationships and experiences that cannot be understood through ordinary social structures. Its meaning therefore lies not merely in what is visually available but in the collective experience of those who share its cultural framework. Cameras and digital circulation can capture the visible body of a ritual while leaving its cultural knowledge inaccessible. Ritual creates forms of collective experience that cannot be reduced to what an external observer can see. In this sense, the tourist may encounter the surface of the ritual without entering its cultural structure. Participation at the level of colour, costume, movement or photography does not necessarily constitute participation in the knowledge system itself.

Yet tourism should not be understood solely as a destructive force. Fieldwork indicates that local communities are aware of the economic possibilities created by tourism and have, in many cases, strategically accommodated visitors and benefited from the opportunities generated by increased visibility. The problem arises when economic participation becomes unchecked environmental consumption. The distinction is particularly evident in the Parvati Valley, where large-scale music and rave events have increasingly placed pressure on forested landscapes. In June 2026, a five-day event near Kasol reportedly attracted thousands of people to a forested area. The Himachal Pradesh High Court noted that sound permission had been granted despite a prior police warning concerning possible narcotics use and other unlawful activities (Himachal Pradesh High Court, 2026; Parashar, 2026).

The issue, therefore, is not tourism itself but its scale, regulation and ecological consequences. Himalayan destinations cannot indefinitely absorb increasing footfall, waste, construction, noise and commercial events without consequences. Responsible tourism must consequently incorporate carrying capacity, waste management, regulation of events, protection of forests and water sources, and meaningful community authority.

International models demonstrate that tourism can be regulated without eliminating its economic benefits. Bhutan's tourism policy, for instance, has explicitly adopted a "High Value, Low Volume" approach, seeking to regulate tourism according to the absorptive capacity of its natural environment, sociocultural values and infrastructure (Department of Tourism, Bhutan, n.d.). Costa Rica provides another model through its Certification

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for Sustainable Tourism (CST), which evaluates tourism enterprises according to environmental, social, economic and cultural criteria and encourages local-community participation in tourism development (Instituto Costarricense de Turismo, n.d.). The Galápagos Islands demonstrate a more restrictive model in which tourism operates within a protected-area framework. Visitors are required to use authorised operators and guides, remain on designated trails and comply with regulations designed to minimise ecological disturbance, demonstrating how visitor access can be reconciled with the conservation of ecologically vulnerable landscapes (Galápagos National Park Directorate, n.d.). The lesson for Himachal Pradesh is not to reproduce these models mechanically, but to recognise that tourism policy must place ecological limits alongside economic objectives.

The challenge is therefore not to prevent people from encountering Himalayan culture, but to ensure that cultural visibility does not become ecological excess. Tourism can support local economies, it must not consume the landscapes and traditions upon which those economies depend.

These cases also demonstrate that tourism should not be represented through a simple binary of community versus outsider. Local communities have recognised the economic opportunities generated by tourism and have actively negotiated its expansion. Increased visibility can provide livelihoods and economic development. The more urgent concern is therefore the ecological scale of tourism and the absence of adequate limits. The 2026 Kasol case illustrates the danger particularly starkly. This demonstrates that tourism becomes environmentally destructive when commercial activity exceeds the ecological and administrative capacity of a landscape.

The cases collectively suggest that sustainable tourism must therefore move from destination-centred promotion towards community and ecosystem-centred governance. Sacred spaces should not automatically become tourism commodities. Communities should retain authority over participation, recording and access to ritual spaces, while tourism planning should incorporate both ecological and cultural carrying capacity. Waste, noise, alcohol consumption, commercial filming, temporary infrastructure and visitor numbers must be considered together rather than separately.

Traditional Knowledge Systems offer principles that remain relevant to this challenge restraint, reciprocity, collective responsibility, respect for place, seasonal regulation and recognition of ecological limits. The objective is not to romanticise the past or exclude outsiders, but to ensure that tourism does not consume the cultural and ecological foundations that make these landscapes meaningful in the first place. In the Western Himalayas, sustainable tourism must therefore recognise that a sacred lake is more than a destination, a ritual is more than a performance, and cultural visibility does not automatically constitute cultural access.

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CONCLUSION

The sacred landscapes of Himachal Pradesh demonstrate that sustainable futures cannot be imagined through environmental management alone. Traditional Knowledge Systems reveal how ecological responsibility can be embedded within cultural memory, customary restrictions, sacred beliefs and community authority. Forests, lakes, springs, mountains and pastures were sustained not simply as resources but as living landscapes with which communities maintained reciprocal relationships.

Contemporary tourism presents both opportunity and risk. Increased visibility can strengthen local economies and create new livelihoods, yet unchecked visitation, commercialisation, and the transformation of sacred practices into spectacles can undermine the ecological and cultural systems that sustain these landscapes. The experiences of Yula Kanda, Sangla Holi, and *Raulane* demonstrate that conservation must therefore address both environmental pressure and the erosion of local control.

A sustainable future for the Himalayas requires moving beyond the assumption that every sacred landscape must become accessible, consumable and promotable. Tourism must operate within ecological limits and respect community-defined boundaries of participation, access, and representation. Local knowledge holders must be recognised as active custodians and decision-makers rather than merely subjects of cultural display.

The future, therefore, lies neither in rejecting tourism nor in romanticising the past, but in learning from the principles of restraint, reciprocity, collective responsibility and respect for place embedded within Traditional Knowledge Systems. Sustainable Himalayan futures will depend upon ensuring that economic development does not come at the cost of the ecological and cultural foundations upon which these communities have long depended.

REFERENCES

Berkes, F. (2012). *Sacred ecology* (3rd ed.). Routledge.

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications, 10*(5), 1251–1262. https://doi.org/10.1890/1051-0761(2000)010[1251:ROTEKA]2.0.CO;2

Bisht, G., & Manta, D. (2014, October 10). Age-old tradition broken as Kullu Dussehra concludes without animal sacrifice. *Hindustan Times*. https://www.hindustantimes.com/chandigarh/age-old-tradition-broken-as-kullu-dussehra-concludes-without-animal-sacrifice/story-GQw0eh1msV4HRaHC4rDGQP_amp.html

Department of Tourism, Bhutan. (n.d.). *Tourism policy of Bhutan*. https://www.visitbhutan.com/page.php?id=3

Eliade, M. (1959). *The sacred and the profane: The nature of religion* (W. R. Trask, Trans.). Harcourt.

Galápagos Conservancy. (n.d.). *Galápagos National Park rules*. https://www.galapagos.org/travel/park-rules/

 ISBN: 978-93-49666-59-7 (eBook)

Government of Himachal Pradesh, Department of Environment, Science & Technology. (n.d.). *Environment policy guidelines*. https://dest.hp.gov.in/?q=environment-policy-guidelines

Government of Himachal Pradesh, Department of Tourism and Civil Aviation. (2019). *Himachal Pradesh tourism policy, 2019*. https://himachaltourism.gov.in/wp-content/uploads/2019/09/Himachal-Pradesh-Tourism-Policy-2019.pdf

Halperin, E. (2019). *The many faces of a Himalayan goddess: Haḍimbā, her devotees, and religion in rapid change*. Oxford University Press. https://doi.org/10.1093/oso/9780190913588.001.0001

Himachal Pradesh High Court. (2026, June 24). *Deshinder Khanna v. Mr. Sidharth Jalta & others*. Indian Kanoon. https://indiankanoon.org/doc/120979794/

Himachal Pradesh State Biodiversity Board. (n.d.). *Sacred groves of Kullu and Shimla*.

Instituto Costarricense de Turismo. (n.d.). *Certification for sustainable tourism (CST)*. https://ict.go.cr/en/sustainability/cst.html

MacCannell, D. (1973). Staged authenticity: Arrangements of social space in tourist settings. *American Journal of Sociology, 79*(3), 589–603. https://doi.org/10.1086/225585

Malhotra, M. (2026, March 14). Social media put Himachal's Raulane festival on the map, but not without drawbacks. *India Today*. https://www.indiatoday.in/lifestyle/what-s-hot/story/raulane-festival-2026-himachal-pradesh-social-media-overtourism-2880807-2026-03-14

Parashar, S. (2026, August 11). Himachal rave party row: Top officers transferred, probe points to laxity in implementing rules. *The Indian Express*. https://indianexpress.com/article/cities/chandigarh/himachal-pradesh-kasol-rave-party-case-probe-report-permissions-rules-10828391/

Sax, W. S. (1991). *Mountain goddess: Gender and politics in a Himalayan pilgrimage*. Oxford University Press.

Sax, W. S. (2003). Divine kingdoms in the Central Himalayas. In N. Gutschow, A. Michaels, C. Ramble, & E. Steinkellner (Eds.), *Sacred landscape of the Himalaya* (pp. 177–194). Austrian Academy of Sciences Press.

Sax, W. S. (2009). *God of justice: Ritual healing and social justice in the Central Himalayas*. Oxford University Press.

Sharabi, A. (2023). *The biography of a god: Mahasu in the Himalayas*. Amsterdam University Press. https://doi.org/10.5117/9789463726658

Sharma, S. (2015). *Kullu Dussehra of Himachal Pradesh*. Sahapedia. https://www.sahapedia.org/kullu-dussehra-himachal-pradesh-0

Thaplyal, V., & Verma, A. (2015). Sacred groves of Himachal Pradesh: A traditional community practice of biodiversity conservation and testimony of religious beliefs. In *Biodiversity conservation—Challenges for the future*. Bentham Science Publishers.

Turner, V. (1969). *The ritual process: Structure and anti-structure*. Aldine.

Verma, M., & Kumar, S. (2025). Traditional belief system in biodiversity conservation: A case study of Hurang Narayan sacred grove in Himachal Pradesh (N.W. Himalaya). *Journal of Medicinal Plants Studies, 13*(6), 22–36.

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Chapter

33

Oral Traditions as Ecological Archives: Cultural Preservation and Spiritual Stewardship in Northeast India

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ABSTRACT

"Myths are clues to the spiritual potentialities of human life." (Campbell & Moyers 2011, p. 5). Viewed from this lens, the folktale traditions of the northeastern tribal communities are found to preserve ecological knowledge, collective memory and ethical systems through oral narratives. By employing mythopoeic, archetypal and structural approaches, this paper argues that folklores of Northeast India serve not merely as decorative storytelling but as an indigenous knowledge system. Through this system the communities articulate origins, regulate conduct, narrate suffering and maintain relationships with rivers, forests, mountains, animals and ancestral presences. Within the selected corpora, recurring narrative patterns associate moral disorders with ecological disruption, grief with memorial landscapes and ritual practice with the restoration of social and cosmic balance. Water emerges as a particularly significant symbolic and ethical medium, as rivers, springs and waterfalls and pools preserve memory, mark transgression, regulate movement and connect communal life to a morally responsive environment. By interpreting northeastern folktales as oral historiographies rather than isolated tales, the study illustrates that cultural preservation in these traditions is intrinsically linked to spiritual stewardship, where ecological care is embedded in reciprocity, restraint sacred accountability and more than human relations.

Keywords: Folklore, Indigenous Knowledge System, Ecological Disruption, Spiritual Stewardship, Oral Histography

INTRODUCTION

Folktales in many indigenous communities are not merely narratives intended for entertainment. They function as repositories of collective memory, ethical frameworks and communal identity. Folklores in Northeast India must be read as major system of cultural memory, indigenous knowledge and ethical world-making rather than mere ornamental oral residues. Within this framework stories, myths, ritual narratives and place-based tales emerge as primary media through which communities sustain relations

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with land, water, kinship networks, sacred power and historical continuity. This argument is especially significant for the present paper, as its thematic focus on cultural preservation and spiritual stewardship presupposes a framework in which oral tradition is understood simultaneously as archive and as practice.

This paper analysis selects folk tales from Khasi, Adi, Nyishi and Galo traditions to illustrate how each community constructs a distinctive ideological universe through or oral narrative. They further demonstrate that ecological thought in these communities is inseparable from cosmology and social life. Rivers, forests, stones, mountains, springs and animals recur as moral actors, witnesses, judges or bearers of memory, suggesting that the environment is not conceived as passive matter but as a responsive field of relations. What modern discourse tends to separate into ecology, ethics, religion and law is held together in these folktale traditions through narrative form. These communities preserve ecological knowledge by encoding principles of coexistence, use, restraint and environmental consequence within memorable narrative structures. Second, this ecological knowledge remains durable because it is grounded in spiritual stewardship, understood here as the obligation to maintain right relations among humans, nonhumans, ancestors and sacred landscapes.

Folklore as Ecological Knowledge

The Oral traditions of Northeast Indian tribal communities preserve a profound ecological awareness and an intricate spiritual relationship with forest, rivers and mountains. Stories, songs and ritual narratives, function as primary media through which ethical values and ecological knowledge are transmitted across generations, shaping how communities perceive, inhabit, and care for their environment. This proposition is further elaborated in folklores where conceptualization forms an integral part of oral histography and works as a "living curriculum" that instructs community on how to inhabit the world through movement, cultivation, hunting, mourning, ritual practise and social reciprocity. In this sense, oral tradition operates not only as record of the past, but also as pedagogical and normative framework for ongoing collective life.

This ecological knowledge is not abstractly systematised in the manner of formal scientific discourse. Rather it is embedded in narrative matrices organised around themes such as migration, kinship, reciprocity, ecological balance, spiritual accountability and collective ethics. These matrices structure practical understandings of how landscapes are inhabited, how scarcity is negotiated, how responsibilities to kinship and neighbours are enacted and how violence against humans and non-humans reduces communal consequences. They also articulate how violations of balance reverberate through water, crops, animals, weather and memory, thereby linking environmental disturbance to moral failure and social disorder. Narrative thus becomes a key technology of environmental governance, translating cosmological principles into everyday practises of restrained care and repair.

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Within this broader archive, the riverine framework is especially central. Brahmaputra or Siang is simultaneously presented as deity, ancestor, judge, lover, guardian and prognostic force, foregrounding the river as a sentient presence that observes, remembers and responds. Dreams of crossing, fishing, flood and hearing the river's sound are interpreted as signs of prosperity. Danger, conflict or success and thus enter into communal decision-making and risk perception. The river is therefore not merely a physical waterway but an episematic structure through which environment, emotion, morality and collective life are interpreted together. By reading about the Brahmaputra or Siang in this way, it is demonstrated how indigenous riverine imagine unsettled modern separations between nature and culture, infrastructure and kinship, hydrology and ethics and instead foreground relational ontology in which water, land, spirits and humans co-produce both knowledge and history.

Spiritual Stewardship

As discussed in the previous section That folklore preserves ecological knowledge but it does so because the natural world is imagined as spiritually and ethically animated. The folktales across Khasi, Adi, Nyishi and Galo traditions repeatedly demonstrate that nature listens, remembers, punishes, mourns and transforms, thereby rendering the environment a participant in ethical life, rather than a silent background in human action. Within this framework, spiritual stewardship may be defined as the obligation to sustain balance among human, ecological and sacred orders, such that moral conduct is always already environmental conduct.

In the folktales several recurrent narrative structures can be identified, that support the reading where ethical casualty, symbolic mediation, the moral animation of nature, the public conversion of private emotion and folklore as a mode of convergence are seen. Taken together the structure shows that ecological disorder is consistently narrated as the consequence of moral excess, greed, betrayal, neglect, failures or reciprocity. Environmental crisis is thus framed not simply as disruption of natural processes, but as the outcome of damaged relationships among humans, non-humans and spiritual forces. The implication here is clear that stewardship is not an optional environmental virtue but a cosmological demand embedded in everyday conduct.

This is visible in the narrative regulation of behaviour. Folklore functions as a form of law without formal institutions, because stories authorise limits on hunting, greed, violence, inheritance, secrecy and misuse of communal resources, while also preserving ritual means of restoration when balance has been broken. Through warning exemplarity and ritual instruction, such narratives map the boundaries of permissible action and outline procedures for repair. Spiritual stewardship thus operates through narrative authority rather than through abstract environmental doctrine, binding cosmology, ethics and resource use within a shared imaginative frame.

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Khasi Narratives

The Khasi folktales disclose a narrative world in which the environment records moral life with striking intensity. Foundational narratives such as "The Seven Clans" and "The Purple Crest" construct a cosmos in which social disorder threatens both ecological and cosmic equilibrium, whereas humility, reciprocity, and ritual mediation restore balance. These stories already configure stewardship as a precondition of coexistence, rather than as a supplementary or belated environmental concern, by presenting care for land, water, and nonhuman beings as intrinsic to the maintenance of social and spiritual order._

This logic becomes more intimate and affective in tales such as "Ka Likai", "U Manik Raitong", and "The Death of Lapalang the Stag". In these narratives, grief is transmuted into waterfall, injustice into spring and tree, and the killing of an animal into a communal catastrophe marked by mourning rather than triumph. Landscape is thus shaped by emotion and wrongdoing, and the traces of suffering are materially inscribed in rivers, rocks, and forests. Khasi ecological knowledge is preserved through stories that teach that water remembers, land bears witness, and nonhuman life cannot be violated without destabilising the moral fabric of the community. The environment becomes an archive of injury and care, in which every alteration in topography potentially encodes an ethical history.

The Khasi corpus is especially important for the theme of spiritual stewardship because it demonstrates how emotional, social, and ecological registers become inseparable. What is ethically suppressed or disavowed by institutions reappears through landscape, and what is done to animals or rivers remains active in memory through named sites, springs, waterfalls, and sacred stories. Preservation, in this context, is not a matter of static remembrance or nostalgic reference to the past; it is a continuing moral habitation of a storied geography, in which movement through place entails constant encounter with narratives of responsibility, loss, and repair. Folklore thereby sustains an ongoing practice of accountability in which the land itself participates in monitoring, recalling, and reorienting human conduct.

Adi Narratives

The Adi understanding of the Siang "as the heart of all rivers" foregrounds a cosmology in which water is not merely a natural resource, but the primary medium through which power value and judgement circulate. River lore among the Adi links judicial practise, dream-belief, beauty, strength and moral testing, such that the Siang becomes at once a place of adjudication, a source of visionary knowledge and an aesthetic and effective presence. In this framework the river is both lifeline and tribunal as it sustains agricultural cycles, travel and everyday livelihood, while simultaneously functioning as a moral witness that registers, remembers and responds to human conduct. Ecological knowledge is therefore preserved not as abstract information, about hydrology or resource management, but as a

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lived and narrated awareness that water is aesthetically powerful, spiritually charged and ethically responsive. The river's flow, clarity, turbulence and seasonal transformations are read as signs of its disposition towards the community, indexing the quality of ritual, observance, social harmony and ethical restraint. Adi folklores thus illuminate a form of stewardship in which the river occupies the centre of communal order, symbolic value and ethical judgement. To act against the river in form of polluting it, ignoring its ritual prohibitions which governs its use or to fail in offerings and respect, is not simply a damage an ecosystem. It is to disrupt the very matrix that organises justice, dreams, kinship, obligations and collective well-being. Transgressions against the river threaten to withdraw its protection, diminish its fertility and invites forms of misfortune that are simultaneously ecological and moral.

In this sense Adi's spiritual stewardship is fundamentally riverine. It binds legal practise, visionary experience and ecological care, into a single flowing moral field in which social authority, spiritual sanction and environmental processes are mutually implicated. Stewardship emerges as a relational discipline that humans must continuously negotiate with a sentient river that can bless, warm or chastise and whose sensuality to Adi life ensures that questions of law, memory and survival are always already questions of how one inhabits and honours the Siang.

Nyishi Narrative

Nyishi narratives, by contrast, foreground polluted abundance, scarcity, famine, and the fragility of communal survival as central moral and cosmological concerns. The chapters show that water in Nyishi folklore is consistently figured as condition, witness, and test: it is the material ground of life, the observing medium that registers human conduct, and the site at which ethical character is tried and revealed. Rivers and streams nourish, irrigate and connect dispersed settlements, enabling subsistence, mobility, and communication across a challenging terrain. Yet the same waters also expose the ethical state of the community when greed, contamination, or ritual neglect disturb ecological balance. Fluctuations in water quality, flow, and availability are not treated as merely climatic or accidental; they are interpreted as responses to human actions, thereby binding hydrological change to moral accountability.

Within this representational frame, scenes of overfishing, careless disposal of waste, or failure to perform requisite rites do not merely result in physical degradation. They precipitate famine, illness, and social breakdown that lay bare the fault-lines of communal life—revealing who has hoarded, who has neglected obligations, and where relations between humans, nonhumans, and spiritual forces have been strained or broken. Environmental crisis thus becomes a diagnostic medium for ethical disorder. Narratives repeatedly emphasise that suffering does not fall randomly but follows from cumulative

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acts of excess, indifference, or ritual abandonment, and that restoration requires not only technical adjustment but moral and ritual repair.

In these tales, stewardship is inseparable from restraint, because the misuse of shared waters constitutes both a social and a spiritual violation with long-term communal consequences. Water is a shared and sentient commons whose degradation signals a breakdown in reciprocity—between households, between generations, and between humans and the spirits who also claim the rivers and streams. Nyishi spiritual stewardship is therefore framed in terms of limits and vulnerability: the community's survival depends on its capacity to curb extraction, observe taboos, and maintain ritual attentiveness to the agencies inhabiting water. To respect water is to acknowledge that its generosity is conditional and revocable, that abundance can harden into scarcity when disrespected, and that ecological security is always precariously held within an ethical economy of self-limitation, remembrance, and care.

Galo Narrative

The Galo corpus preserves ecological knowledge through a dense network of narratives concerned with clay creation, dangerous appetite, scarcity, environmental devastation, and ritual mourning. Stories such as *Takam Unga*, *Tangu Tar*, *Tani and Yapom*, and *A Worthy Father's Worthy Son* consistently link ecological disturbance to ethical excess, failed reciprocity, and inherited responsibility, thereby framing environmental crisis as the consequence of moral and relational breakdown rather than as a merely natural event. Creation from clay already signals a world in which humans and earth share material kinship: bodies are formed from the same substance that constitutes the wider landscape. Within such a cosmology, environmental harm is not simply external damage to a backdrop or resource base, but a form of self-injury that fractures the very conditions of human existence and continuity.

Subsequent tales of hunger, overconsumption, and defiance elaborate this premise by tracing how desire, when unregulated, leads to the depletion of resources, the disruption of social order, and the suffering of future generations. Episodes of insatiable appetite, refusal of advice and transgression of prohibitions dramatize the ways in which individual or familial choices reverberate across temporal and ecological scales. The land responds to such excess by withdrawing its fertility, altering its abundance and rendering formerly dependable environments hostile and barren. In this narrative universe, scarcity and devastation are not random misfortunes; they are legible as outcomes of cumulative failures in restraint, reciprocity, and intergenerational responsibility.

At the same time, these narratives do not foreclose the possibility of moral renewal. Ritual response and communal memory are imagined as crucial modalities through which damaged relations might be acknowledged and partially repaired. Mourning rites for lost

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children, kin, or landscapes, commemorative practices that recall specific transgressions and their consequences, and didactic storytelling that repeatedly rehearses these episodes all work together to name the wrong, articulate shared complicity and imagine forms of restitution. Such practices transform grief into a pedagogical resource, ensuring that suffering is not forgotten but mobilised to cultivate vigilance, humility, and care in subsequent generations.

Galo stewardship is therefore both disciplinary and reflective. It is disciplinary in that the environment is represented as capable of withdrawal, retaliation and mourning in response to human wrongdoing in form of crops failure, animals' disappearance and familiar terrains become threatening when ethical limits are ignored. Yet it is also reflective, insofar as the community's continued existence is shown to depend on its willingness to narrate its relation to those limits again and again, subjecting its own desires, histories and modes of use to sustained scrutiny. Spiritual stewardship here takes the form of an ongoing dialogue with a responsive landscape that both punishes and teaches. Through this dialogic relationship, ecological care is inseparable from moral self-examination and the work of living with the land is cast as a continuous process of remembering, recalibrating and renewing the obligations that bind humans to the earth from which they are made.

Comparative discussion

A major strength of the uploaded chapters lies in their comparative argument that Khasi, Adi, Nyishi, and Galo traditions remain distinct while participating in a broader symbolic grammar of spiritual stewardship. In the Khasi materials, this grammar appears through the intimate binding of emotion, landscape, and moral consequence: waterfalls, hills and animals become enduring records of loss, injustice, and restored balance. In the Adi corpus, the same grammar is articulated through river-centred imaginaries in which the Siang functions simultaneously as source of life, juridical authority and medium of visionary knowledge. Nyishi narratives foreground the precariousness of abundance, making water the site at which the ethics of restraint and the dangers of contamination are most starkly staged. Galo stories, finally, elaborate a clay-based ontology in which environmental devastation is inseparable from dangerous appetite and intergenerational responsibility, and in which ritual mourning enables partial restoration.

Across these traditions, a shared symbolic grammar emerges that includes recurrent relations between moral disorder and ecological crisis, between landscape and memory, between suffering and transformation, and between story and governance. Moral failures like greed, betrayal, neglect and refusal of reciprocity, are consistently narrated as precipitating environmental disturbance, whether in the form of receding rivers, polluted streams, infertile land and grieving animals. Conversely, acts of humility, ritual mediation

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and renewed reciprocity restore or at least recalibrate relations among humans, nonhumans and spiritual forces. Yet such recurrence does not flatten difference. Instead, it reveals how multiple traditions articulate related philosophies of coexistence through different tonal and narrative emphases: Khasi tales privilege the affective and memorial dimensions of storied landscapes; Adi narratives elaborate riverine jurisprudence; Nyishi stories underscore scarcity, pollution, and the ethics of restraint; and Galo accounts centre on creation, appetite, and mourning. Together, they demonstrate that spiritual stewardship in Northeast Indian folklore is not a marginal or modern overlay on "nature," but a fundamental cosmological condition organising law, emotion, and ecological knowledge.

COMPARATIVE ANALYSIS OF THE TRIBAL FOLKLORES

Taken together, the four tribal folklore traditions demonstrate that each develops a distinct ecological locus of Khasi landscape, Adi river, Nyishi shared water and Galo clay/forest and extreme weather, as the primary theatre in which spiritual and ethical questions are staged and negotiated. These are not interchangeable "natural" backdrops but carefully differentiated media through which moral life is imagined, tested and remembered. The spiritual and ethical logics that emerge across the corpus within restraint, reciprocity, accountability and mourning, are broadly shared and are consistently inflected by the particular ecological medium through which they are expressed. In the Khasi materials, for example, landscapes and animal life are configured as affective archives that record grief and repair; in Adi narratives, the riverine environment functions as juridical forum and visionary channel; Nyishi stories locate ethical crisis and discipline at the site of shared and polluted waters; and Galo accounts mobilize clay, forests, and climatic volatility to index appetite, loss and ritual renewal. The "narrative results" identified in the matrix thus trace how stories convert these ecological loci into what might be termed moral technologies: landscapes become archives, rivers operate as courts, ecological collapses serve as diagnostic instruments of communal failure, and storms or scarcity act as disciplinary reminders of moral limit.

Across these traditions, folklore can therefore be understood as performing at least three interrelated preservative functions. First, it stores environmental knowledge in highly memorable, affectively charged forms like details about rivers, forests, weather patterns, animal behaviour and agricultural risk which are embedded within plots, characters and motifs that facilitate intergenerational transmission. Second, it legitimizes ethical conduct by linking it to a sacred or cosmological order, such that practices of restraint, sharing, ritual observance and mourning are not merely pragmatic adaptations but obligations grounded in relationships with deities, spirits, ancestors and nonhuman others. Third, it transmits communal hermeneutics for reading ecological disturbance as socially meaningful rather than random or merely "natural" events. Droughts, floods, pollution and species withdrawal are rendered interpretable as indices of moral imbalance, failed

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reciprocity and neglected ritual responsibility. On this view, "cultural preservation" cannot be reduced to the protection of discrete identity markers, aesthetic forms and textual artefacts. It entails the survival of a narratively sustained ecological consciousness which is a lived repertoire of stories, interpretive habits and affective orientations that continually rearticulate how communities understand the entanglement of spiritual order, social conduct and the more-than-human world.

CONCLUSION

The paper thus demonstrates that the folklore of the Khasi, Adi, Nyishi, and Galo communities preserves far more than discrete mythic motifs or ethnographic detail. Taken together, these narrative traditions operate as indigenous knowledge systems in which ecology, spirituality, ethics, law and memory are structurally intertwined rather than analytically separable. Ecological knowledge persists because it is narratively embedded in stories of rivers, forests, animals, grief, scarcity and ritual accountability along with spiritual stewardship, which in turn, secures this knowledge as a continuing moral obligation within collective life, rather than as inert information about the past.

The central implication here is that cultural preservation in Northeast Indian tribal contexts cannot be equated with documentation or textual collection alone. Any serious account of preservation must also address the oral, ritual, performative, and landscape-based conditions through which ecological knowledge is enacted, interpreted, and renewed across generations. To preserve folklore, in this sense, is to sustain a mode of dwelling in the world in which nature is encountered as living, relational, sacred, and ethically consequential. This study therefore argues that attention to Khasi, Adi, Nyishi and Galo storytelling practices is not simply a matter of cultural or literary interest, but a necessary component of understanding and supporting the narratively sustained ecological consciousness that underlies indigenous philosophies of coexistence in Northeast India.

REFERENCES

Angu, Ering, Ponung. *Doying: A Collection of Myths and Folktales of the Adis*. Notion Press, 2017.

Bauman, Richard, editor. *Folklore, Cultural Performances, and Popular Entertainments: A Communications-centered Handbook*. Oxford University Press, 1972.

Bezbaruah, Ranju, et al. North-East India: *Interpreting the Sources of Its History*. Indian Council of Historical Research, 2008.

Bhattacharjee, J. B. "*Supplementing Archival Materials: Search for Alternatives*." In Insight: A Collection of Articles. Gauhati University, 2003.

Bora, D. K. Myths and Tales of the Nishis of Arunachal Pradesh. Directorate of Research, GoAP, 1995.

Chaudhuri, S. Sucheta. *Beads of Arunachal Pradesh: Emerging Cultural Context* . Niyogi Books, 2016.

Dabi, T. *Inaugural Address of a National Seminar on Folk Culture and Oral Literature from North-East India*. New Delhi: Mittal Publications.2004.

 ISBN: 978-93-49666-59-7 (eBook)

Das, Jogesh. *Folklore of Assam*. National Book Trust India, 1972.

Das, S. T. *Tribal Life of North-Eastern India*. Gian Publishing House, 1986.

Dundes, Alan. "*Folklore as a Mirror of Culture*." The Meaning of Folklore: The Analytical Essays of Alan Dundes, edited by Simon J. Bronner, Utah State UP, 2007, pp. 53–66.

Dutta, B. *Folklore and Historiography*. National Folk-lore Support Centre, 2002. During, Simon. Cultural Studies A Critical Introduction. Taylor and Francis, 2005.

Eliot, T. S. "*The Three Senses of Culture*." Notes Towards a Definition of Culture. Faber & Faber, 1958, pp. 21-34

Elwin, Verrier. *A Philosophy of NEFA: Itanagar*. Himalayan Publisher, 1957.

Geertz, Clifford. "*Thick Description: Towards an Interpretive Theory of Culture*." The Interpretation of Cultures. Basic Books, 1973, pp. 310-323.

Goswami, Praphulladatta. *Songs and Tales North-East India*. The Folklore Society of Assam, 1976.

Geyi, Goken. *My Stories: Recollected and Recreated Stories based on Galo Folktales*. Bodhi Prakashan, 2001.

Heimendorf, C. F. *Tribes of India: The Struggle for Survival*. Oxford University Press, 1985.

Ilaiah, Kancha. Why I am Not a Hindu:A Sudra Critique of Hindutva Philosophy, Culture & amp; *Political Economy*. Bhatkal & Sen, 2005.

Joyce, James. *A Portrait of the Artist as a Young Man*. Wordsworth Editions, 1992.

K.Nayar, Pramod. *An Introduction to Cultural Studies*. Viva Books, 2008.

Khubchandani, Lachman, M. *Tribal Identity*. Indian Institute of Advanced Study, 1992.

Laloo, Betty. *Folktales of North-East India*. DBCIC Publications, 2009.

Lévi-Strauss, Claude. "The Structural Study of Myth." *The Journal of American Folklore*, vol. 68, no. 270, 1955, pp. 428–444.

Mahanta, Amrit Jyoti, and Tilottoma Misra. "*North-East Literature: An Assamese Dissent*". Indian Literature, vol. 56, no. 1, 2012, pp. 241–52.

Nongkynrih, Sing, Kynpham. *Around the Hearth: Khasi Legends* (Folktales of India). Penguin India, 2007.

Propp, Vladimir. Morphology of the Folktale. *Translated by Laurence Scott*, revised by Louis A. Wagner, 2nd ed., University of Texas Press, 1968.

Taku, Pudom. Dojang Napong and other Classic Nyishi Folk Tales & Fables. *Invincible*, 2021.

ISBN: 978-93-49666-59-7 (eBook)

Chapter

34

Culturally Sensitive Development: Bridging Policies, Cultural Preservation and Tribal Identity with an Emphasis on Maternal-Child Health in Wayanad, Kerala

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ABSTRACT

This study examines culturally sensitive development among tribal communities in Wayanad, Kerala, with particular emphasis on maternal and child health, tribal identity, traditional knowledge, and state-led welfare interventions. Despite Kerala's relatively favourable health indicators, tribal communities in Wayanad continue to experience substantial challenges related to child malnutrition, infant mortality, maternal health, and access to healthcare. The study investigates whether existing policies and legal frameworks adequately recognise tribal identities, customary practices, and traditional knowledge systems, or primarily follow a top-down integration approach. Particular attention is given to early marriage, living arrangements, dietary practices, traditional healthcare knowledge, and their implications for maternal and child health. A mixed-methods approach is proposed, combining structured surveys, semi-structured interviews, focus group discussions, and documentary analysis of government policies and relevant legal frameworks. The study seeks to identify gaps between policy implementation, cultural practices, and community needs and proposes a balanced approach integrating recognition with redistribution.

Keywords: Tribal Identity, Maternal-Child Health, Traditional Knowledge, Infant Mortality, Culturally Sensitive Development.

STATEMENT OF PROBLEM

A critical analysis of the tribal communities in Kerala, particularly in Wayanad, from the multifaceted perspective of culture, health, and law reveals a complex scenario. The tribal communities, comprising more than one per cent of the state's population and 37 diverse tribes, Wayanad, home to a significant portion of Kerala's tribal population (151,443

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people), and seven scheduled tribes residing, experience disproportionately high rates of child malnutrition and mortality compared to the state and national levels. Even though Kerala has a higher nutritional standard and lower infant mortality rate than other states, the condition is not similar in tribal areas. The most populated tribal area district, Wayanadu, has shown 22.5% underweight, 31.3% stunting, and 16.1% wasting among under five years tribal children.

Child malnutrition and infant mortality emerge as significant concerns, posing threats to future generations and underscoring the profound disconnection between traditional ways of life and modern legal and political structures. Many tribal populations still inhabit forested areas and adhere to traditional customs and knowledge systems.

The state has implemented welfare policies and laws to integrate tribal communities into the societal mainstream. However, these initiatives have predominantly employed a top-down approach, neglecting tribal people's identity, culture, and traditions. This lack of alignment between government integration efforts and tribal identity has resulted in problematic tribal integration.

The issue of infant mortality in tribal communities exemplifies this problematic integration. While the state has primarily focused on nutritional schemes to address infant mortality, such initiatives have not substantially reduced mortality rates. Furthermore, the correlation between maternal and child health has sometimes been overlooked. Unhealthy mothers can contribute to the vulnerability of their offspring, yet the state has failed to consider this connection in its policies. Factors such as early marriage, cohabitation, and polygamous unions, prevalent in tribal communities, impact maternal and child health but remain inadequately regulated by existing laws.

The development and implementation of tribal health policies require reassessment to address tensions between tribal knowledge, traditional practices, health interventions, and legal frameworks such as the POCSO Act and the Prohibition of Child Marriage Act. While culturally significant, practices like early marriage and polygamy have detrimental effects on maternal and child health, necessitating careful consideration in policy formulation.

It is essential to analyse the role of the state in tribal integration, with a focus on recognising tribal identity rather than merely redistributing resources. Researchers should evaluate whether state policies and legal frameworks addressing infant mortality are based on recognition or redistribution theories and strive to balance these theories in formulating policies and schemes.

RELEVANCE OF RESEARCH

This study is significant in the field of knowledge as it focuses on the customary, cultural, and traditional practices of tribal communities in Wayanadu. It particularly examines the conflicts arising from state-sponsored development policies, legal frameworks, and tribal communities' traditional knowledge systems.

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While previous studies have delved into the root causes of increased child mortality rates, they have primarily focused on issues related to implementing state-sponsored development policies. However, there remains a gap in the literature regarding the relationship between infant mortality and the traditional practices prevalent in tribal areas, such as early marriage, living arrangements, traditional knowledge, and dietary habits. These traditional practices and knowledge systems may either positively or negatively influence infant mortality rates. All the studies related to tribal integration have biased the Western ideas of colonization of tribal areas and the application of Western epistemology in the integration process. The Western epistemology has wholly overlooked the traditional knowledge system of tribal communities and artificially formulated top-to-bottom level policies for tribal integration. This study has not focused on redistribution since the redistribution policies are fundamentally economic; here, the researcher will focus on theories of "recognition" and a balanced approach to recognition and redistribution to address the problem of child mortality in tribal areas.

This study examines the root causes of infant mortality through the lens of traditional practices and state-led policies and regulations. Additionally, it seeks to analyse the legal framework concerning early marriage and minor sexual relationships, exploring their conflicts with customary practices and their impact on child mortality.

By addressing these gaps, the study aims to provide valuable insights into the complexities surrounding infant mortality in tribal communities, shedding light on the intersections between traditional practices, legal frameworks, and state-led policies.

LITERATURE SURVEY

Marriage and Family among the Tribals of Kerala: A Study of the Mannans of Idukki District

The study delves into marriage practices and familial structures within the Mannan tribal community of the Idukki district. It examines the dynamics of marital relationships and the influence of various marriage forms on tribal settlements. Notably, the Mannan community adheres to monogamy, mirroring non-tribal societal norms and eschewing practices such as living relationships and polygamy. State-led interventions and reformative initiatives have significantly altered traditional marriage patterns within Mannan settlements.

However, the study's methodology reflects a Western-centric perspective on tribal communities, viewing them solely as passive recipients without significant contributions to tribal conceptualisation. It overlooks the richness of cultural practices and the intrinsic tribal identity, instead peripherally highlighting state intervention. Furthermore, the study fails to analyze the institution of marriage and family structures in relation to infant mortality rates, thus neglecting a crucial aspect of tribal health and well-being.

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Prevalence of Malnutrition in under Five Age Group of the Tribals in Wayanad District of Kerala, South India: A Community-based Cross-sectional Study

This cross-sectional study was conducted within tribal communities in Wayanad. It identified a higher susceptibility to malnutrition and mortality among children under the age of five. However, the research did not delve into the underlying causes of malnutrition and infant mortality. Furthermore, it failed to analyse the impact of state policies and legislation on child health and infant mortality rates.

Prevalence of Undernutrition among Tribal Preschool Children in Wayanad District of Kerala

The study briefly touches upon cultural practices like breastfeeding and weaning foods. Still, a more in-depth exploration of how these practices influence nutritional status could offer valuable insights. Investigating traditional food preparation methods, cultural beliefs surrounding certain foods, and their impact on child nutrition could provide a deeper understanding of nutritional patterns within tribal communities.

Additionally, given the significant role of cultural factors in shaping health outcomes, research on culturally sensitive healthcare delivery models tailored to tribal communities could be fruitful. Assessing the acceptability and effectiveness of culturally adapted interventions to improve nutrition and health outcomes could pave the way for more effective healthcare delivery in these communities.

Exploring Maternal and Child Health Among Tribal Communities in India: A Life Course Perspective

This study constitutes a cross-sectional examination of maternal and child health within a Madia Gond tribal community in Maharashtra. It acknowledges the inherent limitation that each tribe may harbour distinct reservations and concerns regarding maternal and child health. However, the research overlooks the impact of government policies and regulations to reduce infant mortality rates. Additionally, while the study explores nutritional deficiencies among tribal communities and the benefits of government-implemented policies, it fails to adequately substantiate why significant maternal and child health improvements have not been realized despite several government initiatives.

Furthermore, the study neglects to consider the importance of traditional practices within the tribe in relation to nutritional benefits. Moreover, it does not delve into the mental health of mothers and its potential impact on child health outcomes. Additionally, there is a gap in analysing the intervention of various statutes and policies regarding access to healthcare, prevention of regressive practices, and the overall enhancement of maternal and child health.

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Future research endeavours should aim to examine the collaborative efforts between government agencies, non-governmental organisations, and community stakeholders in bolstering maternal and child health outcomes within tribal communities. Such exploration could offer valuable insights into practical strategies for addressing the multifaceted challenges faced by these communities and ultimately contribute to improved health outcomes for mothers and children.

RESEARCH QUESTIONS

1. Why did the state-sponsored development activities fail to reduce the infant mortality rate?
2. Whether the state-sponsored welfare policies and legal framework had recognized the traditional knowledge system and tribal identity regarding the concerns of infant mortality
2. Whether early marriage, child marriage and living relationships among tribal communities in Wayanad impact the health outcomes of adolescent mothers and their children, thereby contributing to child mortality rates within these communities?
3. What legal and policy interventions are in place to address the concerns of maternal health and child mortality within tribal communities in Wayanad, and how effective are these interventions in protecting the rights and health of mothers and children?
4. How does the lack of recognition of tribal identity and their traditional knowledge contribute to infant mortality?
5. How do factors such as lack of education, resources, and livelihood contribute to the infant mortality rate?

RESEARCH HYPOTHESIS

Hypothesis 1: Traditional practices such as early marriage, polygamous practices and living relationships within tribal communities contribute significantly to the increase in infant mortality rates.

Hypothesis 2: The absence of recognition and integration of tribal identity and traditional knowledge systems correlates with higher infant mortality rates within tribal communities.

RESEARCH METHODOLOGY

Study Design

This research will use a mixed-methods approach, combining qualitative and quantitative techniques to comprehensively investigate the multifaceted dynamics influencing maternal-child health outcomes among tribal communities in Wayanad.

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The quantitative part will be a structured survey conducted among tribal people in selected areas of Wayanad to collect quantitative data on maternal age during marriage, prevalence of early marriages, maternal health indicators, child mortality rates, socioeconomic status and access to healthcare services, etc. and Qualitative part will be a Semi-structured interviews will be conducted with crucial focus groups including tribal community leaders, healthcare providers and government officials to gain insights into the cultural practices, traditional knowledge systems and perceptions regarding maternal-child health.

Focus Group Discussions

Focus group discussions will be organised with community members to explore cultural beliefs, attitudes, and practices related to childbirth, infant care, and maternal health-seeking behaviours.

Documentary Analysis: Government reports, policy documents, and legal frameworks related to tribal welfare, maternal-child health programs, and laws such as the POCSO Act and the prohibition of Child Marriage Act, 2006, will be analysed to understand the regulatory landscape and its implications for tribal communities.

- Sampling Strategy (Purposive sampling method)-Tribal communities will be purposively selected based on their geographic distribution and representation of various cultural practices.
- Sample Size Determination- This will be based on the population size of the particular tribal communities and the chosen level of precision for statistical analysis.

Tentative Chapterization

1. Introduction
2. Analysing the Root Causes of Infant Mortality Among Various Tribal Communities
3. Conceptualising Traditional Knowledge Systems in Various Tribal Communities in Wayanad Related to Maternal and Child Health
4. Traditional Cultural Practices Prevalent Among Tribal Communities Related to Marriage, Sexual Relationships, and Family Dynamics
5. Intervention of State-Sponsored Welfare Activities and Legal Frameworks in Tribal Communities in Relation to Maternal Health and Child Mortality
6. Findings, Suggestions, and Conclusion

REFERENCES

Population statistics 2011 census | Scheduled Tribes Development Department (kerala.gov.in)

International Journal of Community Medicine and Public. Health Krishna A et al. Int J Community Med Public Health. 2022 Oct;9(10):3811-3815 http://www.ijcmph.com pISSN 2394-6032 | eISSN 2394-6040

National Family Health Survey-5 Wayanad. Factsheet: 2019-2021.

The Problematics of Tribal Integration Voices from India's Alternative Centers, ISBN 978-81-929930-3-4 . The Shared Mirror Publishing House, Hyderabad SR Bodhi, Bipin Jojo

JACOB JOHN KATTAKAYAM, Journal of Comparative Family Studies , AUTUMN 1996, Vol. 27, No. 3

Arun Krishna S. R.*, Parameswari Srijayanth ,International Journal of Community Medicine and Public Health.

International Journal of Advanced Medical and Health Research · January 2015 DOI: 10.4103/2349-4220.159135.

Glob J Health Sci. Author manuscript; available in PMC 2024 Jan 17,

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Chapter

35

Addressing Cognitive Barriers through Education to Promote Sustainable Lifestyles: A Pathway to Sustainable Development

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ABSTRACT

Sustainable development has become a global imperative in response to escalating environmental degradation, climate change, resource depletion, and persistent social inequalities. Achieving this goal requires not only technological and policy innovations but also transformative changes in individual attitudes, values, and behaviours. Education plays a pivotal role in this transformation by fostering environmental awareness, sustainability literacy, critical thinking, and responsible decision-making. It equips individuals and communities with the knowledge, skills, and values necessary to adopt sustainable lifestyles that balance environmental protection, social equity, and economic well-being while safeguarding resources for future generations. However, cognitive barriers such as limited environmental understanding, habitual behaviours, resistance to change, and the gap between knowledge and action often hinder the adoption of sustainable practices. This paper examines how education can address these cognitive barriers through Education for Sustainable Development (ESD), transformative learning, and learner-centred pedagogies that promote behavioural change and sustainability competencies. It further explores the relationship between education and sustainable lifestyles, highlighting how knowledge dissemination, value formation, and behavioural transformation contribute to achieving the Sustainable Development Goals (SDGs). The paper also discusses key challenges in integrating sustainability into educational systems, including curriculum limitations, inadequate teacher preparation, and policy implementation gaps, and proposes recommendations for strengthening sustainability-oriented education. By positioning education as a catalyst for behavioural transformation and sustainable living, this paper underscores its critical role in empowering individuals and communities to make informed choices that support long-term environmental sustainability, social responsibility, and inclusive economic development.

Keywords: Sustainable Development, Sustainable Lifestyles, Education for Sustainable Development (ESD), Cognitive Barriers, Environmental Education, Sustainability Literacy, Behavioural Change, Critical Thinking, Environmental Awareness, Sustainable Development Goals (SDGs).

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STATEMENT OF PROBLEM

Sustainability has gained worldwide importance due to increasing environmental and social challenges. Unsustainable consumption patterns, pollution, deforestation, and climate change threaten the balance of ecosystems and human well-being. To address these problems, societies must adopt sustainable lifestyles that promote responsible use of natural resources and social equity. Education is observed one of the most effective mechanisms for achieving sustainability. It equips individuals with knowledge, skills, values, and attitudes necessary to make environmentally responsible decisions. Educational institutions play a central role in developing awareness about sustainability and encouraging positive lifestyle changes. Sustainable development refers to meeting present needs without compromising the resources and opportunities available for future generations to meet their needs. In this context, promoting sustainable lifestyles has become essential for protecting natural resources and ensuring social and economic well-being. Education plays a pivotal role in promoting sustainable development. It helps individuals understand environmental problems, adopt eco-friendly practices, and develop values that support responsible living. Educational institutions, governments, and communities all contribute to spreading sustainability awareness and encouraging positive behavioural changes. Education for sustainable development goes beyond classroom learning. It involves practical experiences, critical thinking, and participation in environmental activities that help individuals become active contributors to sustainability. By promoting awareness and responsibility, education can transform society toward sustainable living practices.

COGNITIVE BARRIERS: UNDERSTANDING THE PSYCHOLOGICAL OBSTACLES TO SUSTAINABLE LIFESTYLES

The transition towards sustainable lifestyles is influenced not only by external factors such as policies, infrastructure, and economic conditions but also by the way individuals think, interpret information, and make decisions. Although environmental awareness has increased significantly in recent decades, many people continue to engage in behaviours that contribute to environmental degradation. This disconnects between environmental knowledge and everyday actions are largely explained by **cognitive barriers**—the psychological factors that shape people's perceptions, judgments, and behavioural choices. These barriers influence how individuals understand environmental issues, assess risks, respond to sustainability messages, and ultimately decide whether or not to adopt sustainable practices. Therefore, recognizing and addressing cognitive barriers is essential for designing effective educational interventions that promote sustainable lifestyles and support sustainable development.

Knowledge Deficit

One of the most fundamental cognitive barriers is the **knowledge deficit**, which refers to a lack of adequate understanding of environmental issues and sustainable practices.

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Individuals who have limited knowledge about climate change, biodiversity loss, resource conservation, or sustainable consumption often fail to recognize how their daily actions affect the environment. As a result, they may unintentionally engage in unsustainable behaviours. Although increasing knowledge alone does not automatically lead to behavioural change, it provides the essential foundation upon which attitudes, values, and responsible actions are developed. Education plays a crucial role in addressing this barrier by improving environmental literacy, enhancing sustainability awareness, and enabling individuals to make informed and responsible decisions.

Confirmation Bias

Another important psychological barrier is **confirmation bias**, which describes the tendency to seek, interpret, and remember information that reinforces existing beliefs while disregarding evidence that challenges them. In the context of sustainability, individuals may selectively accept information that aligns with their personal opinions and ignore well-established scientific evidence. For example, someone who believes that individual actions have little impact on climate change may dismiss information promoting sustainable behaviour. Such selective thinking restricts learning, reduces openness to new perspectives, and limits behavioural change. Educational strategies that encourage critical inquiry, evidence-based discussions, and reflective thinking can help learners evaluate information more objectively and develop a balanced understanding of environmental issues.

Cognitive Dissonance

Cognitive dissonance, proposed by Festinger (1957), occurs when individuals experience psychological discomfort because their behaviour conflicts with their beliefs or values. Many people express concern about environmental problems while continuing to engage in practices that contribute to those problems. For instance, an individual may understand the harmful effects of plastic pollution but continue using single-use plastic products because they are convenient and readily available. Rather than changing their behaviour, people often justify their actions to reduce this internal conflict. Education can help minimize cognitive dissonance by encouraging self-reflection, promoting environmental ethics, and creating learning experiences that align personal values with sustainable actions.

Status Quo Bias

Status quo bias refers to the tendency to maintain familiar habits and routines, even when better alternatives are available. Behavioural change often requires individuals to move beyond their comfort zones, which many perceive as inconvenient or risky. Consequently, people may continue driving private vehicles, wasting energy, or relying on disposable products simply because these behaviours have become routine. Educational

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interventions that provide practical exposure to sustainable practices, demonstrate their benefits, and encourage gradual lifestyle changes can reduce resistance and increase willingness to adopt environmentally responsible behaviours.

Present Bias

Another common obstacle is **present bias**, which reflects people's tendency to prioritize immediate rewards over long-term benefits. Sustainable choices often involve short-term effort, financial investment, or lifestyle adjustments, whereas their positive environmental outcomes become visible only over time. For example, purchasing energy-efficient appliances, reducing water consumption, or using public transportation may require immediate sacrifices despite offering long-term economic and environmental advantages. Education can help individuals develop future-oriented thinking by highlighting the lasting benefits of sustainable behaviour for themselves, society, and future generations.

Low Environmental Concern

The adoption of sustainable lifestyles is also influenced by the level of **environmental concern** individuals possess. Some people perceive environmental issues as distant problems that have little relevance to their own lives or communities. This perception weakens their sense of personal responsibility and reduces motivation to engage in sustainable practices. Educational programmes can address this barrier by linking global environmental challenges with local experiences, encouraging community participation, and helping learners understand how individual actions collectively contribute to environmental protection. When sustainability becomes personally meaningful, individuals are more likely to develop positive environmental attitudes and engage in responsible behaviour.

Limited Critical Thinking

In an era characterized by an abundance of information and misinformation, **critical thinking** has become an essential competency for sustainable decision-making. Individuals with limited critical thinking skills may struggle to evaluate environmental claims, distinguish scientific evidence from misinformation, and understand the interconnected nature of environmental, social, and economic systems. This limitation can result in poor decisions and reluctance to adopt sustainable practices. Educational approaches that emphasize inquiry-based learning, problem-solving, systems thinking, and collaborative learning can strengthen analytical skills, enabling individuals to evaluate complex sustainability issues more effectively and make informed decisions.

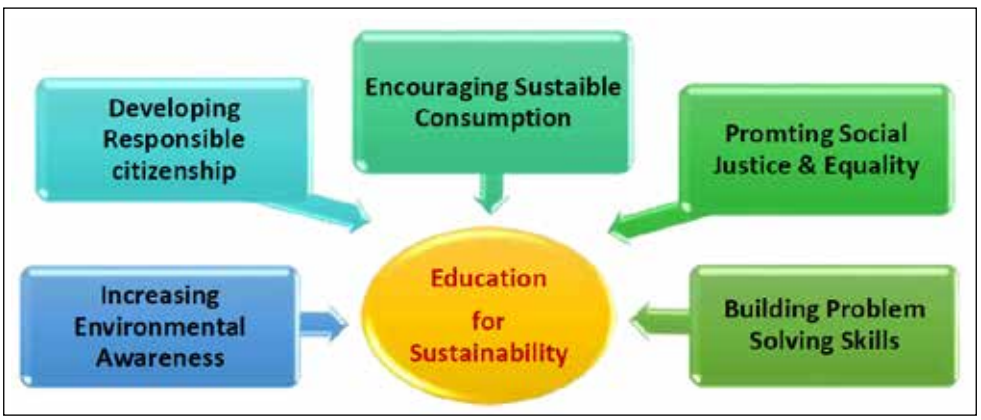
Overall, cognitive barriers demonstrate that promoting sustainable lifestyles involves much more than increasing environmental awareness. Sustainable behaviour depends on how individuals process information, interpret evidence, evaluate consequences, and

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make everyday decisions. By addressing barriers such as knowledge deficits, confirmation bias, cognitive dissonance, status quo bias, present bias, low environmental concern, and limited critical thinking, education can bridge the gap between awareness and action. In doing so, it empowers individuals to make informed choices, adopt sustainable lifestyles, and contribute meaningfully to the achievement of sustainable development.

SUSTAINABILITY ACHIEVED THROUGH EDUCATION

Education for sustainability refers to teaching and learning processes that help individuals understand environmental, social, and economic issues. It encourages people to participate actively in solving sustainability challenge. Education influences both personal behaviour and collective social action.



Promoting Sustainability through Education

Aspect	Description	Examples / Key Points
Curriculum Integration	Inclusion of sustainability concepts in formal education across different subjects.	• Included in Science, Geography, Economics, Social Studies• Helps students understand environmental and social issues• Builds foundational knowledge of sustainability
Experiential Learning	Learning through direct real-life activities and hands-on experiences.	• Nature camps• Community service activities• Recycling projects• Gardening programs• Enhances practical understanding of sustainability
Use of Technology	Use of digital tools to enhance awareness and learning about sustainability.	• Online courses and e-learning platforms• Educational apps• Documentaries and videos• Helps reach a wider and global audience
Teacher Training	Training educators to effectively teach sustainability concepts.	• Professional development programs for teachers• Improves teaching methods• Encourages eco-friendly behaviour among students• Helps integrate sustainability into classroom teaching

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RELATED LITRATURE REVIEW

S.N.	Author(s)	Title	Year	Key Findings
1	Senturk et al.	Attitudes Towards Sport in Early Adolescence: A Scale Adaptation Study for Sustainable Good Health and Well-Being	2026	Positive attitudes toward sports promote healthy lifestyles and long-term well-being.
2	Ahmed & Al Salim	Provision of Quality Physical Education to Enhance the Motive of Physical Activity and its Underlying Behaviour among University Students	2023	Quality physical education encourages active lifestyles and healthy behavioural practices.
3	Pandoy et al.	Students' Environmental Attitude and Sustainable Behavior as Mediated by Social Connectedness	2025	Social connectedness strengthens the relationship between environmental attitudes and sustainable lifestyle behaviours.
4	Pérez-Mesa et al.	Climate Change and Health: A Study of the Attitudes of Future Science Teachers	2024	Climate awareness influences environmentally responsible and health-conscious lifestyle choices.
5	Sharma et al.	Integrating Curriculum, Extracurricular Activities, and Community Engagement	2024	Educational and community activities enhance environmental responsibility and sustainable living practices.
6	Mukhambetaliyeva et al.	Integrating the Chemical Technology Course Based on Sustainable Development Goals	2025	Sustainability-focused education fosters eco-friendly attitudes and responsible consumption patterns.
7	Lazarus et al.	Decolonizing Global Education: A Sustainable Paradigm for Inclusive Knowledge Systems and Equitable Development	2025	Inclusive knowledge systems support socially sustainable lifestyles and community well-being.
8	Li & Gao	Research on the Integration and Innovation of Moral Education Courses in Sustainable Development Education	2025	Moral education promotes ethical decision-making and sustainable lifestyle values.
9	Chakraborty & Thakur	Reflections of Adult Learners on Binge-Watching and Its Detrimental Impact on the Environment in West Bengal, India	2024	Excessive digital consumption negatively affects environmental sustainability; awareness encourages responsible behavior.
10	Romero-Saritama & Simaluiza	Exploring Environmental Engagement: A Multivariable Analysis of Environmental Attitudes and Behaviors in Distance Education University Students	2025	Strong environmental attitudes predict greater engagement in sustainable lifestyle practices.
11	Alexe et al.	Integrative Educational-Somatic Correlations in the Training Process Throughout University Studies	2025	Physical well-being and educational experiences jointly contribute to healthier lifestyles.
12	Al Koni & Mahamda	*The Role of Business Schools in Achieving Sustainable Development Goals*	2023	Sustainability education influences responsible consumption and ethical lifestyle decisions.

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The reviewed studies collectively demonstrate that sustainable lifestyles are shaped by interplay of health-related behaviours, environmental attitudes, social connectedness, ethical values, and educational experiences. The literature indicates that individuals who possess strong environmental awareness and positive attitudes toward sustainability are more likely to participate in responsible consumption, climate-conscious actions, and environmentally friendly behaviours. Furthermore, educational institutions play a vital role in fostering sustainable lifestyles by integrating sustainability concepts into curricula, extracurricular activities, and community engagement initiatives. The review also emphasizes the importance of physical activity and well-being as integral aspect of sustainable living. Research on sport participation and health promotion suggests that healthy lifestyle practices established during adolescence contribute significantly to lifelong well-being and sustainable development goals. Additionally, studies focusing on climate action and environmental engagement emphasize that sustainability is not merely an environmental concern but a multidimensional concept encompassing social responsibility, ethical decision-making, and community participation. Overall, the evidence suggests that sustainable lifestyles can be strengthened through holistic educational approaches, environmental literacy, social support networks, and behaviour-change interventions that encourage individuals to adopt healthier and more environmentally responsible ways of living.

METHODOLOGY / CONCEPTUAL FRAMEWORK

This study draws upon qualitative and conceptual research methodology using secondary sources such as books, research articles, reports, and publications from organizations including United Nations Educational, Scientific and Cultural Organizations. The conceptual framework of this study examines the relationship between education, awareness, behavioural change, and sustainable lifestyles. The framework assumes that education promotes sustainability by influencing knowledge, attitudes, and practices. Educational programs create environmental awareness, which encourages individuals to adopt sustainable behaviours such as resource conservation, waste reduction, and responsible consumption. These behavioural changes collectively contribute to sustainable development goals. The study also examines how formal education, non-formal education, and community-based learning can strengthen sustainability practices. Through thematic analysis, the paper identifies major educational strategies and their impact on promoting environmentally responsible lifestyles and long-term sustainable development.

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RATIONALE / JUSTIFICATION OF THE STUDY

The present study is significant because environmental degradation, climate change, resource depletion, and unsustainable consumption continue to threaten ecological balance and human well-being worldwide. Although awareness of sustainability has increased, many individuals still struggle to translate environmental knowledge into responsible actions due to cognitive barriers such as knowledge deficits, confirmation bias, habitual thinking, resistance to change, and limited critical thinking. These psychological barriers often widen the gap between environmental awareness and sustainable behaviour. Education has the potential to overcome these challenges by fostering environmental literacy, critical thinking, ethical values, and responsible decision-making. By promoting learner-centred and transformative approaches, sustainability education can empower individuals to adopt sustainable lifestyles and contribute to long-term environmental and social well-being. Therefore, this study is relevant for educators, policymakers, researchers, and educational institutions seeking to integrate sustainability into education systems and develop effective strategies for overcoming cognitive barriers while advancing the Sustainable Development Goals (SDGs) at local, national, and global levels.

SUSTAINABLE LIFESTYLE

A sustainable lifestyle refers to a way of living that minimizes environmental damage while supporting economic and social well-being. Sustainable lifestyles aim to meet present needs without compromising the ability of future generations to meet their own needs. It includes practices such as:



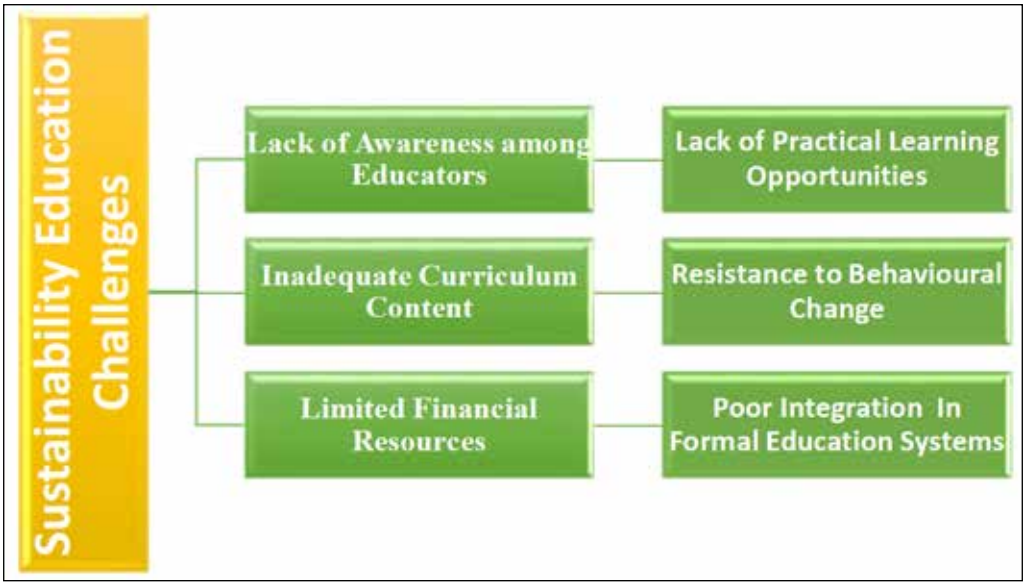
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PROMOTING SUSTAINABLE LIFESTYLES THROUGH EDUCATION

Section	Role of Education in Promoting Sustainable Lifestyles	Key Points
Creating Environmental Awareness	Education helps individuals understand environmental issues and the importance of conservation.	• Increases awareness of global warming, pollution, deforestation, and biodiversity loss. • Provides scientific knowledge about environmental degradation. • Encourages appreciation of nature and conservation efforts.
Encouraging Behavioural Change	Education promotes sustainable habits and responsible behaviour in daily life.	• Saving electricity and water. • Avoiding plastic waste. • Practicing recycling and waste segregation. • Using public transportation. • Planting and protecting trees. • Encourages long-term sustainable lifestyle practices.
Developing Critical Thinking Skills	Education enables learners to analyse and solve sustainability challenges effectively.	• Evaluating environmental problems. • Identifying sustainable alternatives. • Making informed decisions. • Participating in environmental discussions. • Encouraging innovative and practical solutions.
Promoting Sustainable Consumption	Education influences consumer behavior toward environmentally responsible choices.	• Understanding ethical production practices. • Conserving natural resources. • Choosing eco-friendly products. • Making responsible purchasing decisions. • Supporting sustainable industries and reducing waste.
Strengthening Social Responsibility	Education fosters values that support sustainable and inclusive societies.	• Promoting equality and social justice. • Encouraging cooperation and teamwork. • Respecting human rights. • Enhancing community participation. • Building socially responsible citizens.
Supporting Global Sustainable Development Goals	Education contributes to achieving global sustainability objectives.	• Supports SDG 4: Quality Education. • Supports SDG 12: Responsible Consumption and Production. • Supports SDG 13: Climate Action. • Encourages participation in sustainability initiatives and awareness programs.

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CHALLENGES IN PROMOTING SUSTAINABLE LIFESTYLE



RESULTS AND DISCUSSION

The study reveals that education significantly contributes to promoting sustainable lifestyles by increasing awareness and influencing behavioural change. Individuals exposed to sustainability education tend a greater tendency to adopt eco-friendly practices such as recycling, energy conservation, water management, and responsible consumption. Educational institutions play vital role in shaping values and attitudes that support environmental protection and social responsibility. The findings also indicate that sustainability education encourages analytical thinking and problem-solving abilities, enabling learners to address environmental challenges effectively. Schools and universities that include sustainability into their curricula build environmentally conscious citizens who actively participate in community development and environmental conservation activities.

Furthermore, this paper draws attention to the importance of experiential learning methods such as environmental campaigns, community projects, and practical activities. These approaches enhance students' understanding of sustainability concepts and encourage active participation in sustainable practices. However, the study reveals several challenges, including lack of trained educators, insufficient curriculum integration, limited financial constraints, and low public awareness in some regions. Addressing these barriers is important for strengthening sustainability education. Overall, the results demonstrate that education serves as a powerful pathway for achieving sustainable lifestyles and promoting long-term sustainable development.

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EXPECTED OUTCOME AND POLICY IMPLICATION

The paper is expected to contribute significantly to understanding promoting sustainable lifestyles and achieving sustainable development through education. It is one of the major expected outcomes is increased awareness among students, educators, policymakers, and communities regarding environmental protection and responsible resource utilization. Sustainability education can help individuals develop environmentally friendly habits such as reducing waste, conserving energy and water, and supporting sustainable consumption practices.

Another expected outcome is the development of socially responsible and environmentally sensitive citizens who can actively participate in solving sustainability challenges. By integrating sustainability concepts into education, institutions can encourage learners to adopt values such as cooperation, equality, social justice, and environmental ethics. These values are essential for building sustainable societies and enhancing the quality of life for present and future generations. The study also expects that educational initiatives will strengthen critical thinking, innovation, and problem-solving abilities among learners. Students exposed to sustainability education are more likely to support green technologies, renewable energy solutions, and environmentally responsible policies. This can positively influence economic development while ensuring environmental conservation. From a policy perspective, the study emphasizes the need for governments and educational institutions to integrate sustainability education into curricula at all levels. Policies should promote interdisciplinary learning approaches that connect environmental, social, and economic dimensions of sustainability. Teacher training programs should also be strengthened to equip educators with the necessary knowledge and skills to teach sustainability effectively.

In addition, governments should support community-based environmental education programs and awareness campaigns to reach wider populations. Investment in educational infrastructure, research, and technological resources related to sustainability is equally important. Collaboration between educational institutions, non-governmental organizations, and international agencies can further strengthen sustainability initiatives. The study suggests that policymakers should align national educational policies with the Sustainable Development Goals established by the United Nations, particularly Goal 4 (Quality Education) and Goal 13 (Climate Action). Effective implementation of these policies can create long-term positive impacts on environmental conservation, social welfare, and sustainable economic growth.

RECOMMENDATIONS

To strengthen the sustainable lifestyles through education, the following measures are recommended:

1. Integrate sustainability education at all educational levels.
2. Encourage practical and activity-based learning.
3. Organize awareness campaigns and workshops.
4. Promote collaboration between governments, schools, and communities.
5. Use media and technology to spread environmental awareness.
6. Support research and innovation related to sustainability.

CONCLUSION

Education is a key driver of sustainable lifestyles and sustainable development, as it equips individuals with the knowledge, values, and skills needed to make informed and responsible decisions. However, awareness alone does not always lead to sustainable behaviour. Cognitive barriers such as knowledge deficits, confirmation bias, cognitive dissonance, status quo bias, present bias, low environmental concern, and limited critical thinking often prevent individuals from translating environmental awareness into meaningful action. Education for Sustainable Development (ESD) can help overcome these psychological barriers by promoting environmental literacy, critical thinking, reflective learning, and responsible decision-making. Through learner-centred and experiential approaches, education encourages individuals to rethink existing habits, adopt sustainable practices, and actively contribute to environmental and social well-being. Although challenges such as limited curriculum integration, inadequate resources, and insufficient teacher preparedness remain, strengthening sustainability education can significantly enhance behavioural change. Ultimately, integrating sustainability into education systems is essential for bridging the gap between awareness and action, empowering individuals to adopt sustainable lifestyles, and contributing to the achievement of the Sustainable Development Goals (SDGs) for a more resilient and sustainable future.

REFERENCES

Ahmed, A., & Al Salim, B. (2023). *Provision of quality physical education to enhance the motive of physical activity and its underlying behaviour among university students.*

Al Koni, I., & Mahamda, M. (2023). *The role of business schools in achieving sustainable development goals: Palestine as a case study.*

Alexe, D., et al. (2025). *Integrative educational-somatic correlations in the training process throughout university studies, as sustainable perspectives.*

Chakraborty, S., & Thakur, R. (2024). *Reflections of adult learners on binge-watching and its detrimental impact on the environment in West Bengal, India.*

Graffe, A., et al. (2025). *The transtheoretical model for action in the climate crisis.*

Harun, H., & Ibrahim, M. (2022). *Female tertiary education across ASEAN countries.*

Hopkins, C., & McKeown, R. (2002). *Education for Sustainable Development: An International Perspective.*

 ISBN: 978-93-49666-59-7 (eBook)

Lazarus, J., et al. (2025). *Decolonizing global education: A sustainable paradigm for inclusive knowledge systems and equitable development.*

Li, X., & Gao, Y. (2025). *Research on the integration and innovation of moral education courses in sustainable development education.*

Mukhambetaliyeva, A., et al. (2025). *Integrating the chemical technology course based on sustainable development goals.*

Palmer, J. (1998). *Environmental Education in the 21st Century.*

Pandoy, J., Apuya, K. M., Badang, P. S., & Pelobillo, G. (2025). *Students' environmental attitude and sustainable behavior as mediated by social connectedness.*

Pérez-Mesa, J. C., et al. (2024). *Climate change and health: A study of the attitudes of future science teachers.*

Polin, J., et al. (2025). *Reframing smart campus assessment for the Global South: Insights from Papua New Guinea.*

Romero-Saritama, J. M., & Simaluiza, L. A. (2025). *Exploring environmental engagement: A multivariable analysis of environmental attitudes and behaviors in distance education university students.*

Senturk, H. E., Tanir, G., Yuce, U. E., Karatut, A., & Karakaş, E. (2026). *Attitudes towards sport in early adolescence: A scale adaptation study for sustainable good health and well-being*. *Healthcare, 14*(7), 842. https://doi.org/10.3390/healthcare14070842

Sharma, P., et al. (2024). *Integrating curriculum, extracurricular activities, and community engagement.*

Sterling, S. (2001). *Sustainable Education: Re-visioning Learning and Change.*

United Nations Educational, Scientific and Cultural Organization (UNESCO). *Education for Sustainable Development Goals: Learning Objectives.*

United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development.*

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PATHWAYS TO SUSTAINABILITY

Integrating Environment Growth and Indigenous Wisdom

We are living in a world today that seems to be caught between two realities: a dramatic increase of technological innovations and economic power, and a growth of ecological emergencies, socio-economic disparities, and vulnerabilities. The industrial development models based on unlimited resource extraction have failed to create a sustainable future. To meet this need, Pathways to Sustainability: Integrating Environment, Growth, and Indigenous Wisdom offer a comprehensive theory that contends that sustainability is best achieved when all three – scientific solutions, inclusive economic models and traditional wisdom systems – work together. In this volume, rather than opposing high tech solutionism and preservationist nostalgia, the cutting edge tools and traditional ecological practices are shown to reinforce each other in four interwoven thematic domains.

Editors



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