

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

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 well-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.

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.

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

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.

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:

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.

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.

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