Sustainable Agricultural Development and Natural Resource Management in Block Gaur (District Basti): A Critical Review

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Abstract
Eastern Uttar Pradesh, representing one of India's most densely populated agrarian regions, faces a profound paradox: intensive agricultural practices have led to stagnating productivity, declining soil health, and deteriorating natural resource baselines despite increasing input costs. This review paper critically examines the state of sustainable agricultural development and natural resource management in Block Gaur, District Basti—a representative microcosm of the challenges facing the Indo-Gangetic Plains. Synthesizing evidence from peer-reviewed literature, government policy documents, and institutional reports, this paper identifies three interrelated crises: (1) the erosion of indigenous farming knowledge alongside incomplete adoption of sustainable alternatives; (2) deteriorating groundwater tables and soil organic carbon deficits; and (3) institutional fragmentation limiting integrated watershed management. The review evaluates existing policy frameworks including the Per Drop More Crop (PDMC) initiative, watershed development programs, and the One District One Product (ODOP) scheme promoting Kala Namak rice as a high-value, low-water indigenous variety. Drawing on successful models from Bundelkhand and Andhra Pradesh, we propose an integrated framework combining regenerative agriculture principles, community-based water harvesting, and revitalized extension services tailored to smallholder contexts. The paper concludes with actionable recommendations for researchers, policymakers, and development practitioners seeking to transition Block Gaur toward climate-resilient, economically viable, and ecologically sustainable agricultural systems.

Keywords: Sustainable agriculture, natural resource management, eastern Uttar Pradesh, Kala Namak rice, watershed management, regenerative agriculture, smallholder farmers, indigenous knowledge, gender dynamics, climate resilience

Introduction

Background and Rationale: Agriculture in India stands at a critical crossroads. The Green Revolution, which transformed the nation from a food-deficit to a food-surplus economy, achieved its successes through high-external-input technologies—synthetic fertilizers, chemical pesticides, and high-yielding varieties—that have inadvertently sowed the seeds of long-term ecological degradation (**Bharamappanavara et al., 2024**). Nowhere is this paradox more evident than in eastern Uttar Pradesh, where smallholder farmers face rising cultivation costs, stagnating yields, and diminishing returns from conventional practices. Basti district, situated approximately 180 kilometers east of Lucknow between the

Ghaghara and Amy rivers, exemplifies these challenges (**One District One Product, 2020**). The district's agricultural landscape is dominated by the rice-wheat cropping system, the backbone of South Asian food security, yet increasingly recognized as ecologically unsustainable. Depleting groundwater tables, declining soil organic carbon, and the escalating costs of chemical inputs threaten the viability of smallholder agriculture, which constitutes over 80% of farming households in the region (**Gulati et al., 2025**).

Block Gaur, as an administrative and agroecological unit within Basti district, provides an appropriate scale for critical analysis. The block-level perspective enables examination of the interplay between biophysical constraints, farmer decision-making, institutional arrangements, and policy implementation—offering insights applicable to similar contexts across the Indo-Gangetic Plains.

The Imperative for Sustainable Agricultural Transformation: Sustainable agricultural development, as conceptualized in this review, encompasses three interconnected dimensions: environmental integrity (soil health, water conservation, biodiversity preservation), economic viability (profitable farm enterprises, reduced input costs, market access), and social equity (smallholder inclusion, gender sensitivity, food security). The urgency of transitioning toward sustainability is underscored by mounting evidence:

- Soil health crisis: Analysis of 1,768 smallholder farms in eastern Uttar Pradesh reveals widespread misapplication of organic fertilizers and over-reliance on chemical inputs, with declining soil organic carbon emerging as a critical constraint (Mishra et al., 2026).
- Water scarcity: Groundwater extraction rates in the Ghaghara basin exceed recharge capacities, threatening the long-term viability of irrigated agriculture. Systematic review data indicate that transitioning from flood irrigation to conservation agriculture can save 20–60% of water while improving soil organic carbon by up to 38% (Shah et al., 2025).
- Economic distress: Rising input costs coupled with stagnant productivity have reduced profit margins, particularly for marginal farmers operating less than two hectares (Gulati et al., 2025).

Yet, within these challenges lie opportunities. The region possesses distinctive assets: indigenous rice varieties like Kala Namak that command premium prices and require less water than conventional varieties (Government of UP, 2025); traditional knowledge systems that, when properly understood and applied, offer low-cost sustainable alternatives (Mishra et al., 2026); and emerging policy frameworks that support micro-irrigation, watershed development, and farmer-producer organizations.

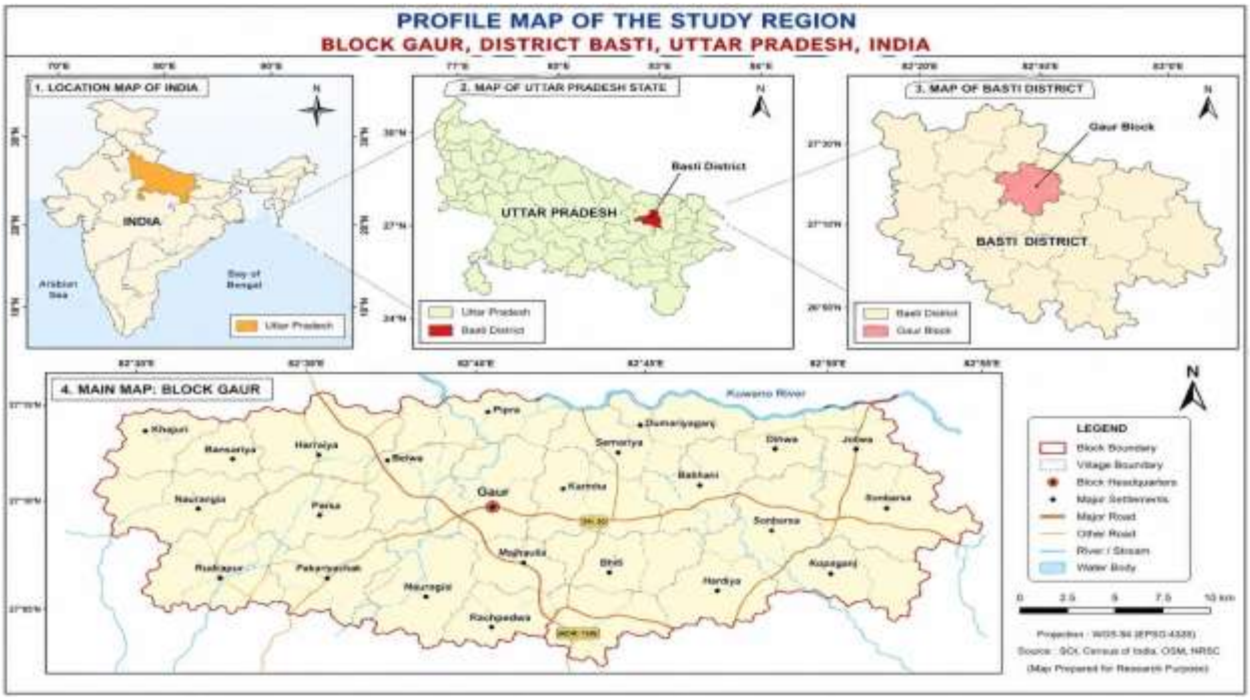
Review Objectives and Scope: This critical review addresses the following research questions:

1. What are the current patterns of agricultural practice and natural resource use in Block Gaur, and what are their sustainability implications?
2. What policy and institutional frameworks govern agricultural development and natural resource management in the region, and how effectively are they implemented?
3. What barriers—technical, economic, social, and institutional—constrain the adoption of sustainable practices?
4. What successful models from comparable contexts can inform interventions in Block Gaur?
5. How do climate adaptability of indigenous crops and gender dynamics influence sustainable transition pathways?

The scope encompasses: cropping systems and input use patterns; soil and water resource management; biodiversity and agroecological assets; farmer knowledge systems and extension services; policy architecture and program implementation; market linkages for sustainable products; climate resilience of indigenous varieties; and gender-sensitive extension approaches.

Methodology: This review synthesizes peer-reviewed journal articles (2015-2026), government reports, policy documents, and institutional publications from sources including Springer, Frontiers, ICRISAT, ICRIER, ICAR, Elsevier, and PIB. The geographical focus is eastern Uttar Pradesh, with specific emphasis on Basti district. Evidence is contextualized within broader national and international sustainable agriculture literature to identify transferable insights and locally relevant strategies.

Profile of the Study Region: Block Gaur, District Basti



Geographical and Agroecological Context: Basti district lies in the northeastern alluvial plains of Uttar Pradesh, characterized by fertile Gangetic alluvium deposited by the Ghaghara river system. The region falls within Agroclimatic Zone IV (Middle Gangetic Plains region), characterized by:

- **Climate:** Subtropical with average annual rainfall of 1,000-1,200 mm, approximately 85% received during the southwest monsoon (June-September)
- **Temperature:** Summer maximum 40-42°C; winter minimum 4-7°C
- **Topography:** Flat to gently sloping alluvial plains with elevation ranging from 80-100 meters above mean sea level
- **Drainage:** Ghaghara river forms the southern boundary; Kuwani and Manorama are minor rivers (One District One Product, 2020)

Demographic and Agrarian Structure: The agrarian structure of Basti district—and by extension Block Gaur—is characterized by small and marginal landholdings, high population density, and intensive land use. Table 1 presents key demographic and agrarian indicators based on district-level data extrapolated to block-level patterns.

Table 1: Agrarian Structure Indicators for Basti District

Indicator	Value	Source
Total geographical area	2,688 km²	District Census
Net sown area	78.5% of total area	District Agriculture Office
Gross cropped area	200%+ (multiple cropping)	Estimated
Average landholding size	0.82 ha	Agricultural Census
Marginal farmers (<1 ha)	68% of holdings	Agricultural Census
Small farmers (1-2 ha)	22% of holdings	Agricultural Census
Irrigation coverage	85% of net sown area	Minor Irrigation Census
Groundwater dependency	92% of irrigated area	Estimated

Note: Block-specific data were not available in public sources; district-level indicators provide reasonable approximation given agroecological homogeneity.

The predominance of marginal holdings has profound implications for sustainable technology adoption. Smallholders face acute liquidity constraints, risk aversion, and limited capacity for investment in long-term natural resource improvements (**Gulati et al., 2025**).

Cropping Systems and Land Use: The rice-wheat cropping system dominates the agricultural landscape, occupying approximately 75% of the gross cropped area during kharif (rainy) and rabi (winter) seasons, respectively. Sugarcane occupies significant area, processed into gur (jaggery) and, uniquely, vinegar—a distinctive cottage industry product of Basti district (**One District One Product, 2020**). Oilseeds, pulses (chickpea, lentil, pigeon pea), and cotton are cultivated on smaller areas. Table 2 presents the indicative cropping pattern for the district.

Table 2: Cropping Pattern in Basti District (Indicative)

Crop	Season	Area (% of GCA)	Productivity (q/ha)	Market Orientation
Rice (kharif)	June-Nov	45%	22-25	Subsistence + market
Wheat	Nov-March	40%	28-30	Subsistence + market
Sugarcane	Annual/12-18 month	8%	550-600	Commercial (gur/vinegar)
Pulses (chickpea, lentil)	Nov-March	4%	8-10	Subsistence + local sale
Oilseeds (mustard)	Nov-March	2%	10-12	Local sale
Kala Namak rice	June-Nov	<1% (niche)	15-18	Speciality (premium)

Sources: District Agriculture Office estimates, One District One Product (2020), Gulati et al. (2025)

The Kala Namak Opportunity: Kala Namak (literally "black salt") rice represents a distinctive agroecological and economic asset for Basti district. This indigenous aromatic rice variety, with black husk and distinctive fragrance, has been cultivated in the Terai regions of eastern Uttar Pradesh for over 2,600 years—legendarily offered to Lord Buddha after his enlightenment (**Lokmat Times, 2022**).

The variety has received significant policy attention under the One District One Product (**ODOP**) scheme. While cultivation area declined to less than 0.5% by 2002, aggressive state intervention has revived Kala Namak to approximately 18,000 hectares across nine districts, with the Saryu canal command area proving particularly suitable (**Government of UP, 2025**). Critically, Kala Namak now holds a Geographical Indication (**GI**) tag covering 11 districts including Basti, ensuring legal protection and premium market realization (**Lokmat Times, 2022**).

Three characteristics position Kala Namak as a strategic crop for sustainable development:

1. **Lower water requirement:** Requires approximately 30-40% less water than conventional high-yielding rice varieties, making it suitable for water-constrained conditions (Government of UP, 2025)
2. **Premium market price:** Commands 4-5 times the price of basmati rice, offering significant income potential
3. **Cultural and geographical indication value:** GI registration provides branding and marketing support, creating barriers to counterfeit competition

However, Kala Namak cultivation remains limited in Block Gaur specifically (<1% of rice area), constrained by lower per-hectare productivity (15-18 q/ha vs. 22-25 q/ha for modern varieties), limited seed availability, and underdeveloped market linkages. These constraints represent opportunities for targeted intervention.

Climate Adaptability of Kala Namak Rice: A critical dimension of the Kala Namak opportunity—often underemphasized in policy discourse—is its superior climate adaptability compared to modern high-yielding rice varieties. Emerging evidence suggests that indigenous aromatic rice varieties possess stress tolerance traits that are increasingly valuable under climate change scenarios.

Drought tolerance: Kala Namak's root architecture enables access to deeper soil moisture, allowing sustained growth under intermittent drought conditions that cause yield collapse in conventional varieties (**ICRISAT, 2026**). This trait is particularly relevant for Block Gaur, where monsoon variability has increased over the past decade.

Flood tolerance: Unlike modern dwarf rice varieties that suffer complete submergence mortality within 7-10 days, traditional tall indica types including Kala Namak can withstand partial submergence for 14-21 days, recovering normal growth upon water recession (**ICRISAT, 2026**).

Heat tolerance: With terminal heat stress becoming increasingly common during grain-filling stages (March-April), Kala Namak's longer duration and slower grain-filling physiology provides resilience compared to short-duration modern varieties that experience spikelet sterility under heat stress.

Low input responsiveness: Perhaps most significantly for sustainability transitions, Kala Namak performs optimally under moderate fertility conditions rather than requiring the high nitrogen inputs essential for modern semi-dwarf varieties. This trait reduces both production costs and environmental nitrogen pollution (**Government of UP, 2025**).

For Block Gaur farmers facing climate uncertainty, Kala Namak thus offers not merely a premium price opportunity but a risk management strategy—diversifying away from climate-vulnerable modern varieties toward an indigenous crop with inherent stress tolerance. The policy implication is clear: Kala Namak promotion should be framed not solely as an ODOP commercial intervention but as a climate adaptation priority.

Critical Analysis of Natural Resource Management

Soil Health and Nutrient Management: Current Status and Trends- The sustainability of agricultural production in Block Gaur is fundamentally constrained by deteriorating soil health. Research from eastern Uttar Pradesh documents a concerning pattern: declining soil organic carbon (SOC), multi-nutrient deficiencies, and emerging micronutrient limitations (**Mishra et al., 2026**). The ICRIER scoping study on Uttar Pradesh agriculture identifies "improving soil organic carbon" and "balancing soil nutrients" as two of four priority interventions for sustainable intensification (**Gulati et al., 2025**). The study notes that continuous cereal-cereal cropping, residue burning or removal, and imbalanced fertilizer application have depleted SOC to critical levels (<0.5% in many areas), impairing soil structure, water-holding capacity, and nutrient availability.

Fertilizer Use Patterns and Imbalances: The Green Revolution legacy manifests in characteristic fertilizer use patterns: heavy reliance on nitrogenous fertilizers (particularly urea), inadequate and imbalanced application of phosphorus and potassium, and minimal micronutrient supplementation. This pattern is driven by subsidy regimes that artificially lower nitrogen prices, extension messaging that prioritized nitrogen-responsive varieties, and farmer perceptions that associate "greenness" and vegetative growth with nitrogen application.

The consequences of imbalanced fertilization are well-documented:

- Declining fertilizer use efficiency (nitrogen use efficiency often below 40%)
- Progressive mining of soil P and K reserves
- Emergence of multi-nutrient deficiencies (Zn, B, S in rice-wheat systems)
- Groundwater nitrate contamination

Recent research on the Eastern Indo-Gangetic Plains demonstrates that simple agronomic adjustments—specifically, early wheat sowing before the third week of November—can improve Nitrogen Use Efficiency by 5–8%, reducing both farmer costs and environmental pollution (**Environment, Development and Sustainability, 2025**). This finding has direct relevance for Block Gaur, where delayed wheat sowing following late rice harvest is common.

Organic Fertilizer Use: Awareness Without Application: A critical finding from recent research in eastern Uttar Pradesh—directly relevant to Block Gaur—is the paradox of "awareness without application" regarding organic fertilizers. In a survey of 1,768 smallholder farmers across Varanasi and Mirzapur, while 60% reported using organic fertilizers, many applied them incorrectly—improper decomposition, inappropriate application rates, and improper timing—substantially reducing their effectiveness (**Mishra et al., 2026**).

This finding highlights a crucial gap in the agricultural extension system: the distinction between awareness and competent practice. Farmers may possess fragmentary knowledge of traditional practices but lack the structured technical guidance to implement them effectively. **As Mishra et al. (2026) note**, "awareness without application—especially in the absence of extension support—leads to the persistence of unsustainable practices." Table 3 synthesizes constraints to soil health management in the region.

Table 3: Constraints to Soil Health Management in Eastern Uttar Pradesh

Constraint Category	Specific Constraints	Severity*	Evidence Source
Technical	Improper organic manure decomposition	High	Mishra et al. (2026)

Technical	Lack of knowledge on balanced fertilization	High	Gulati et al. (2025)
Technical	Soil test unavailability/unaffordability	Medium	Inference
Economic	High fertilizer cost	High	Gulati et al. (2025)
Economic	Subsidy-driven N overuse	Medium	Shah et al. (2025)
Institutional	Ineffective soil health card scheme	Medium	Primary evidence lacking
Institutional	Weak extension on Integrated nutrient management	High	Mishra et al. (2026)
Social	Preference for visible N response	High	Inference

Severity rating based on author synthesis of available evidence

Water Resources and Irrigation Management: Groundwater Crisis- The Ghaghara basin, despite surface water availability from the river system, has witnessed progressive groundwater depletion driven by three factors: (1) the shift to high-yielding rice varieties requiring continuous submergence; (2) the spread of diesel and electric pump technology enabling extraction; and (3) the decoupling of irrigation from rainfall patterns. A systematic review of the rice-wheat system across the Indo-Gangetic Plains confirms that conventional puddled transplanted rice consumes 1,500-2,000 mm of water per season, of which only 30-40% is actually utilized by the crop—the balance lost to evaporation, deep percolation, and surface runoff (**Shah et al., 2025**). The review further documents that transitioning from flood irrigation to conservation agriculture (CA) practices can achieve water savings of 20–60%, while simultaneously improving soil organic carbon by up to 38% (**Shah et al., 2025**). Figure 1 presents a conceptual model of the groundwater balance in the region.

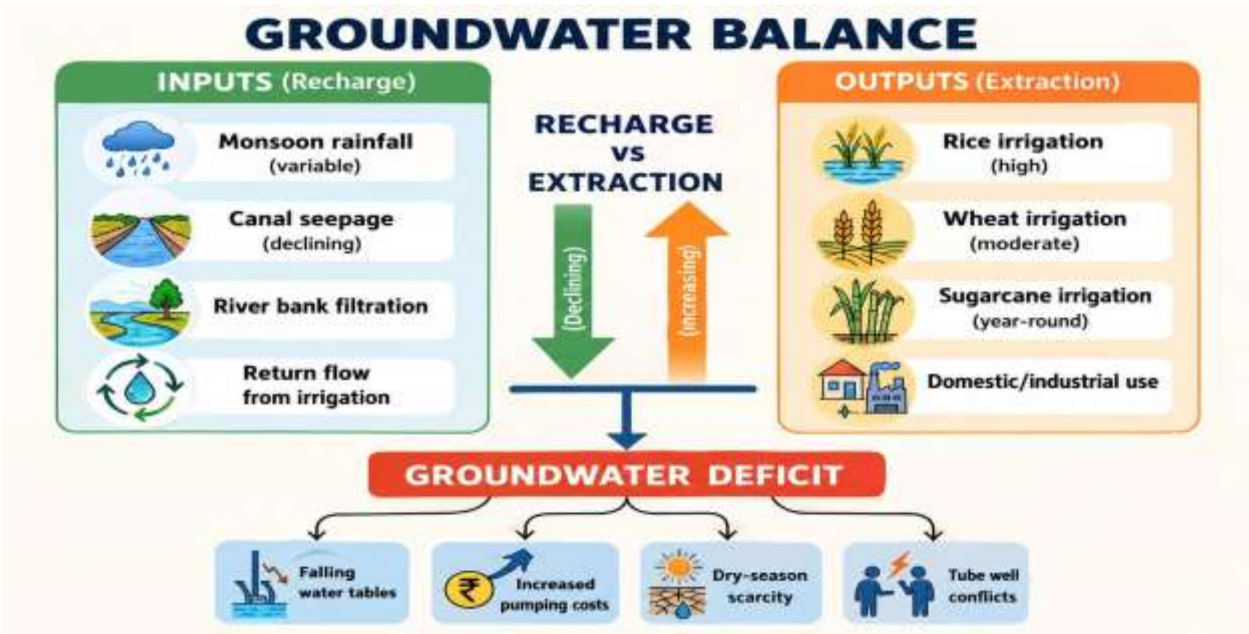


Figure 1: Groundwater Balance Dynamics in Ghaghara Basin
Source: Author synthesis, informed by Shah et al. (2025)

Micro-Irrigation and the PDMC Scheme: The Government of India's Per Drop More Crop (**PDMC**) scheme, implemented under Pradhan Mantri Krishi Sinchayee Yojana (**PMKSY**), represents the flagship program for improving water use efficiency. In October 2025, the Ministry of Agriculture and Farmers Welfare introduced enhanced flexibility under PDMC, allowing states to exceed previous funding limits (20% of allocation for most states) for "Other Interventions"—micro-level water storage and conservation projects including diggi (farm pond) construction and water harvesting systems (**Press Information Bureau, 2025**).

This policy shift is particularly relevant for eastern Uttar Pradesh, where:

- Micro-irrigation (drip and sprinkler) adoption remains low despite demonstrated water savings of 30-50%
- Smallholders lack capital for individual water storage structures
- Community water harvesting could provide irrigation supplementation during critical dry spells

For Block Gaur, the opportunity lies in integrating PDMC flexible funds with watershed planning to create a mosaic of individual and community water conservation interventions.

Crop Water Footprint Analysis

Table 4 presents indicative water footprints for major crops grown in the region, highlighting the efficiency case for crop diversification.

Table 4: Indicative Water Footprint of Major Crops

Crop	Season	Irrigation Water Requirement (mm/season)	Water Productivity (kg/m³)	Relative Efficiency
Rice (conventional)	Kharif	1,500-2,000	0.15-0.25	Very Low
Rice (Kala Namak)	Kharif	800-1,000	0.20-0.30	Medium
Rice (CA method)	Kharif	600-800	0.35-0.50	High
Wheat	Rabi	300-400	0.70-1.00	High
Chickpea	Rabi	150-250	0.50-0.70	High
Sugarcane	Annual	2,000-2,500	0.20-0.30	Very Low

Sources: Compiled from Shah et al. (2025), IWMI, ICAR

The data reveal the extraordinary water demand of conventional rice and sugarcane, and the efficiency gains possible through crop substitution (Kala Namak replacing conventional rice), method shifts (conservation agriculture), and crop diversification (shifting area to pulses and oilseeds).

Biodiversity and Agroecological Assets: Indigenous Varieties and Genetic Resources- Beyond Kala Namak rice, the broader Terai region possesses significant agrobiodiversity including indigenous pulse varieties, millets, oilseeds, and vegetable landraces. This genetic diversity represents an adaptation resource—traits for drought tolerance, pest resistance, and local adaptation that may prove valuable under climate change.

ICRISAT's recent capacity-building programs under the ICRISAT-Uttar Pradesh Council of Agricultural Research (**UPCAR**) initiative have focused directly on regenerative agriculture for climate resilience, with explicit recognition that "traditional varieties hold untapped genetic potential for stress tolerance" (**ICRISAT, 2026**). The initiative has trained extension personnel and farmers in the documentation, preservation, and utilization of indigenous germplasm.

However, as documented by **Mishra et al. (2026)**, traditional seed preservation and exchange systems have eroded, with farmers increasingly reliant on purchased hybrid seeds. This transition increases input costs (hybrid seeds cannot be saved for next season), reduces genetic diversity, and undermines farmer autonomy.

Agroforestry and Tree Cover: Basti district possesses notable tree cover including teak (Sagaon), haldu, sal, shisham, mahua, bamboo, neem, jamun, and mango (One District One Product, 2020). Agroforestry interventions—boundary plantations, block plantations on marginal lands, silvopastoral systems—offer multiple benefits: additional income from timber/fruit, microclimate regulation, soil conservation, and carbon sequestration.

The "Bundelkhand model" developed by ICRISAT demonstrates the viability of integrated agroforestry within watershed development frameworks, achieving enhanced groundwater recharge alongside diversified farmer income (**ICRISAT, 2025**). This model holds transferable lessons for eastern Uttar Pradesh.

Gender Dynamics in Agricultural Extension and Sustainable Practice Adoption

The Invisible Workforce: Any critical review of sustainable agriculture in eastern Uttar Pradesh must address the gender dimensions of agricultural production and natural resource management—dimensions systematically underemphasized in both policy and research. Women constitute approximately 75% of the agricultural labor force in Uttar Pradesh, yet their contributions remain largely invisible in extension programming, land records, and credit access (**Kumar et al., 2025**).

In Block Gaur, as elsewhere in the region, women perform the majority of: seed selection and preservation; organic manure preparation and application; weeding and intercultural operations; post-harvest processing (threshing, winnowing, storage); and livestock management. These are precisely the tasks most relevant to sustainable agriculture transitions—yet extension programs continue to target male household heads as the primary decision-makers.

Barriers to Women's Participation in Sustainable Agriculture: Empirical research from western Uttar Pradesh on Integrated Farming Systems (IFS) reveals significant gender disparities in technology access and benefit distribution (**Kumar et al., 2025**). Key barriers include:

Land rights: Women's documented land ownership in eastern Uttar Pradesh is less than 15%, undermining their ability to access credit, subsidies, and extension services linked to landholding status.

Extension exclusion: The public extension system overwhelmingly engages with male farmers during morning hours when women are occupied with domestic responsibilities. Female extension agents constitute less than 10% of the agricultural workforce.

Knowledge asymmetry: While women possess extensive traditional knowledge about organic practices, seed preservation, and pest management, this knowledge is rarely solicited or integrated into formal extension curricula (**Mishra et al., 2026**).

Time poverty: Women's dual domestic and agricultural responsibilities limit their availability for training programs, field demonstrations, and farmer meetings, which typically occur at times and locations inconvenient for them.

Opportunities for Gender-Responsive Extension: The transition to sustainable agriculture offers opportunities to address these gender inequities-

- Soil health and organic manure management: Women's traditional expertise in composting and organic application positions them as natural leaders for manure quality improvement programs (**Mishra et al., 2026**).
- Seed systems: Revival of indigenous seed preservation—traditionally women's domain—could be structured as women-led community seed banks, generating income while conserving genetic resources.
- Livestock integration: Dairy and goat rearing, primarily women's responsibility, can be intensified as part of Integrated Farming Systems, with women retaining income from milk and manure sales (**Kumar et al., 2025**).
- Climate resilience: Women's knowledge of drought-tolerant varieties and water-conserving practices, accumulated through generations of experience, has direct relevance for climate adaptation programming (**ICRISAT, 2026**).

For Block Gaur, a gender-transformative approach to sustainable agriculture would include: (1) targeted inclusion of women in PDMC and soil health card trainings; (2) formation of women-led Farmer Producer Organizations for Kala Namak processing and marketing; (3) flexible timing and location of extension activities; and (4) documentation and integration of women's indigenous knowledge into formal recommendations.

Integrated Farming Systems: A Pathway for Smallholder Resilience

Evidence from Western Uttar Pradesh: While this review focuses on eastern Uttar Pradesh, evidence from western districts provides validated models for diversification away from the rice-wheat monoculture. In a comprehensive study of Integrated Farming Systems (**IFS**) across Meerut, Muzaffarnagar, and adjacent districts, **Kumar et al. (2025)** documented that combining crops, dairy, and aquaculture on 1.38 hectares generated net annual returns of approximately ₹5.5 lakh (US$6,600), substantially exceeding returns from conventional rice-wheat farming on equivalent area.

The IFS model components included:

- **Component 1:** High-value crops (vegetables, fruits) on 0.4 ha
- **Component 2:** Dairy (2-3 crossbred cows) with fodder production
- **Component 3:** Pond aquaculture (fish) utilizing recycled farm water
- **Component 4:** Boundary agroforestry (timber + fruit trees)
- **Component 5:** Vermicomposting unit utilizing dairy and crop residues

Crucially, the study found that women's participation was significantly higher in IFS than in monocropping systems, with women controlling income from dairy, poultry, and vegetable sales (**Kumar et al., 2025**). For Block Gaur, IFS offers a template for transitioning marginal farmers from vulnerable rice-wheat systems to diversified, resilient, and more profitable production models.

Relevance to Block Gaur: The applicability of the western UP IFS model to eastern UP requires consideration of differences in: market access (western UP is closer to Delhi NCR markets); irrigation infrastructure; and landholding size (eastern UP holdings are smaller on average). However, the underlying principles—diversification, recycling of on-farm resources, integration of livestock, and women's economic empowerment—are universally relevant.

For Block Gaur specifically:

- The Ghaghara river and its distributaries provide water resources suitable for small-scale aquaculture
- Sugarcane cultivation (widespread in Basti) generates abundant green fodder and crop residues for dairy integration
- The ODOP-promoted Kala Namak rice can serve as the crop anchor for an IFS package
- Women's established role in livestock management provides a foundation for dairy intensification

Policy and Institutional Framework: **National and State-Level Policies**

Table 5 synthesizes the major policy frameworks governing sustainable agriculture and natural resource management in the region.

Table 5: Key Policy Frameworks

Policy/Program	**Nodal Agency**	**Key Provisions**	**Relevance to Block Gaur**
PDMC (PMKSY)	MoA & FW	Micro-irrigation subsidy; water harvesting	Water efficiency in rice
Soil Health Card	MoA & FW	Soil testing; nutrient recommendations	Addressing imbalances
Watershed Development	DoLR/MoA & FW	Integrated land-water management	Landscape-level planning
RKVY-RAFTAAR	State Govt	Flexibility for state priorities	Sustainable agriculture
ODOP	State Govt	Product-specific value chains	Kala Namak promotion
Natural Farming Mission	MoA & FW	Non-certified organic promotion	Reducing input costs

Abbreviations: MoA&FW - Ministry of Agriculture & Farmers Welfare; DoLR - Department of Land Resources

The Rashtriya Krishi Vikas Yojana - Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (**RKVY-RAFTAAR**) provides particularly relevant flexibility, explicitly mandating that "the local needs/crops/priorities are reflected in the agricultural plans of the states" (**Government of Meghalaya, 2026**). For Block Gaur, this enables tailoring of interventions to the specific Kala Namak value chain, groundwater challenges, and smallholder constraints.

Institutional Architecture: The institutional landscape for agricultural extension and natural resource management in Uttar Pradesh is characterized by:

Line Departments:

- Department of Agriculture (crops, extension, input supply)

- Department of Horticulture (fruits, vegetables, spices)
- Department of Irrigation (canal water, PDMC implementation)
- Department of Soil Conservation (watershed programs)

Research and Extension:

- Acharya Narendra Deva University of Agriculture and Technology, Ayodhya (research, extension)
- Krishi Vigyan Kendras (KVKs) at district level (farmer training, demonstrations)
- ICAR institutes (limited direct presence in Basti)

Financial Institutions:

- NABARD (watershed funding, farmer producer organizations)
- Commercial banks (credit, subsidy disbursement)
- Cooperative societies (input supply, marketing)

The multiplicity of institutions creates coordination challenges. Research from Ballia district—agroecologically similar to Basti—documented that "non-availability of agricultural inputs at the proper time" and "non-availability of required seeds in cooperative societies" ranked among the most pressing constraints for farmers (**Chaudhary et al., 2025**). These implementation gaps reflect institutional fragmentation rather than resource scarcity per se.

Extension System Constraints: The agricultural extension system in eastern Uttar Pradesh confronts severe capacity constraints. **Mishra et al. (2026)** note "high farmer-to-agent ratios and limited rural infrastructure" that have made "public extension services less accessible, particularly in remote or marginalized areas." Consequently, "while farmers may retain fragments of indigenous knowledge, they lack the structured guidance to improve or adapt these practices effectively."

The consequences of extension failure are evident in:

- Knowledge gaps: Lack of information about improved crop varieties and scientific production techniques (**Chaudhary et al., 2025**)
- Misapplication: Improper use of organic fertilizers despite reported awareness (**Mishra et al., 2026**)
- Low technology adoption: Limited uptake of micro-irrigation, integrated pest management, and conservation agriculture (**Shah et al., 2025**)

This extension deficit represents both a critical constraint and an opportunity for intervention—whether through revitalized public extension, para-extension models, farmer-to-farmer networks, or digital advisory services.

Adoption of Sustainable Agricultural Practices: **Regenerative Agriculture and Natural Farming-** Regenerative agriculture—an approach emphasizing soil health, biodiversity, and ecosystem function restoration—has gained traction in India through state-level programs including Andhra Pradesh's Community Managed Natural Farming (APCNF). The four principles of natural farming—Amruthams (fermented microbial solutions), Kashayas (botanical extracts), mulching, and acchadana (soil cover)—have demonstrated cost reductions and maintained productivity in rice-based systems (**Bharamappanavara et al., 2024**).

For Block Gaur, regenerative approaches offer particular promise because:

1. Cost reduction: Natural farming reduces purchased input costs, critical for liquidity-constrained smallholders
2. Risk management: Diverse systems buffer against crop failure
3. Resource conservation: Soil building and water conservation align with long-term sustainability

However, adoption faces barriers including lack of technical knowledge, transition period yield concerns, and limited market recognition. As Bharamappanavara et al. (2024) note, despite support for sustainable production, "there remains a critical need for ICT services, postharvest management, and processing support" and "establishing stable and efficient marketing channels is essential."

Indigenous Knowledge: Erosion and Revival Potential- The erosion of indigenous agricultural knowledge in eastern Uttar Pradesh is extensively documented. Mishra et al. (2026) found that while 60% of farmers still report using organic fertilizer, "many apply them incorrectly, reducing their effectiveness and potentially affecting soil health and fertility over time." Most farmers follow monocropping systems, rely heavily on chemical inputs, and exhibit "a critical gap between awareness and correct agronomic application of traditional practices."

The drivers of knowledge erosion include:

- Generational transition: Younger farmers distanced from traditional practices
- Extension bias: Historical focus on Green Revolution technologies
- Market pressures: Commodity markets indifferent to agroecological practices
- Knowledge fragmentation: Loss of holistic understanding of practice integration

Yet, revival is possible. Mishra et al. (2026) recommend "community-driven approaches and future action research focused on farmer training, participatory awareness programs, and extension engagement to strengthen the revival of indigenous practices." This aligns with agroecological principles emphasizing the co-creation of knowledge through participatory processes.

Adoption Constraints Analysis: Understanding adoption constraints is essential for intervention design. Adapting the framework from **Chaudhary et al. (2025)**, we categorize constraints into five types:

Table 6: Adoption Constraints in Sustainable Agriculture

Constraint Type	Specific Constraints	Severity	Intervention Implication
Technical	Lack of knowledge on correct practice	High	Enhanced extension + demonstration
Technical	Input quality (organic manure, bio-fertilizers)	Medium	Quality assurance systems
Economic	Higher upfront costs (transition period)	Medium	Incentives/compensation
Economic	Price risk (uncertain market for sustainable products)	High	Market linkage + certification
Institutional	Input unavailability at proper time	High	Supply chain strengthening
Institutional	Limited access to credit	Medium	Micro-credit + interest subvention

Social	Risk aversion (fear of yield loss)	High	Demonstration + insurance
Social	Gender barriers to extension access	High	Gender-sensitive programming
Social	Labour shortages (peak seasons)	Medium	Mechanization sharing

Source: Adapted from Chaudhary et al. (2025) with author modifications

The "input unavailability at proper time" constraint—identified as most pressing for chickpea growers in Ballia—is likely generalizable to sustainable inputs (organic manures, bio-fertilizers, indigenous seeds) across the region. Addressing this requires supply chain mapping and investment in decentralized production.

Successful Models and Transferable Lessons: **The Bundelkhand Watershed Model**

ICRISAT's "Bundelkhand model" for landscape rejuvenation, implemented in partnership with the Government of Uttar Pradesh, demonstrates the viability of science-led integrated watershed development in highly degraded landscapes (ICRISAT, 2025). Key features include:

- Science-based planning: Use of Land Resource Inventory and socio-economic analysis to target interventions
- Digital tools: Geospatial planning and monitoring
- Participatory governance: Community involvement in planning, implementation, and management
- Integrated interventions: Rainwater harvesting, soil conservation, crop diversification, agroforestry

Observed outcomes include "enhanced groundwater recharge, which enables diversified farming, agroforestry, and improved livelihoods, leading to greater income and nutritional security for local communities" (**ICRISAT, 2025**).

For Block Gaur, the Bundelkhand model offers transferable principles: treat watershed as planning unit, integrate biophysical and socioeconomic data, and ensure community ownership. The model's "scalable framework for system-level transformation" is particularly relevant given Eastern UP's similar smallholder-dominated, water-stressed landscapes.

Andhra Pradesh Natural Farming Scale-Up: Andhra Pradesh's Community Managed Natural Farming (APCNF) program, reaching approximately 800,000 farmers, represents the world's largest agroecological transition (Bharamappanavara et al., 2024). The model demonstrates that natural farming can achieve comparable yields to conventional systems while substantially reducing costs. Key success factors include:

- Community institutions: Farmer groups providing mutual support and learning
- Dedicated extension: Community resource persons trained in natural farming techniques
- Phased transition: Gradual conversion of area, managing risk
- Market linkage: Premium prices for naturally grown produce

While Andhra Pradesh differs from Uttar Pradesh in agroecology and political economy, the institutional model—community-based scaling through dedicated support structures—offers lessons for Block Gaur.

Western Uttar Pradesh Integrated Farming Systems

As the above IFS model documented by Kumar et al. (2025) provides a validated template for diversification. The study's finding that IFS achieved significantly higher returns per unit area than conventional systems—₹5.5 lakh net annual return from 1.38 ha versus ₹2.8 lakh from rice-wheat—provides compelling evidence for farmers considering transition.

Critically, the study was conducted across multiple districts (Meerut, Muzaffarnagar, Ghaziabad, Bulandshahr, Baghpat, Hapur) with similar smallholder profiles to Block Gaur, strengthening transferability (**Kumar et al., 2025**).

Climate-Resilient Agriculture under ICRISAT-UPCAR: The ICRISAT-Uttar Pradesh Council of Agricultural Research (UPCAR) program, launched in 2025-2026, specifically focuses on "regenerative agriculture for climate resilience in Uttar Pradesh" (ICRISAT, 2026). The program's components include:

- Capacity building: Training of master trainers and progressive farmers in climate-resilient practices
- Demonstration: Establishment of climate-resilient villages showcasing integrated interventions
- Knowledge management: Documentation and scaling of successful practices
- Policy engagement: Evidence generation for state-level policy formulation

The program's explicit focus on traditional varieties including Kala Namak aligns directly with Block Gaur's agroecological assets. Engagement with this program would provide access to technical resources, training materials, and policy networks.

Integrated Framework for Block Gaur

Conceptual Framework: Synthesizing the preceding analysis, Figure 2 presents an integrated framework for sustainable agricultural development and natural resource management in Block Gaur.

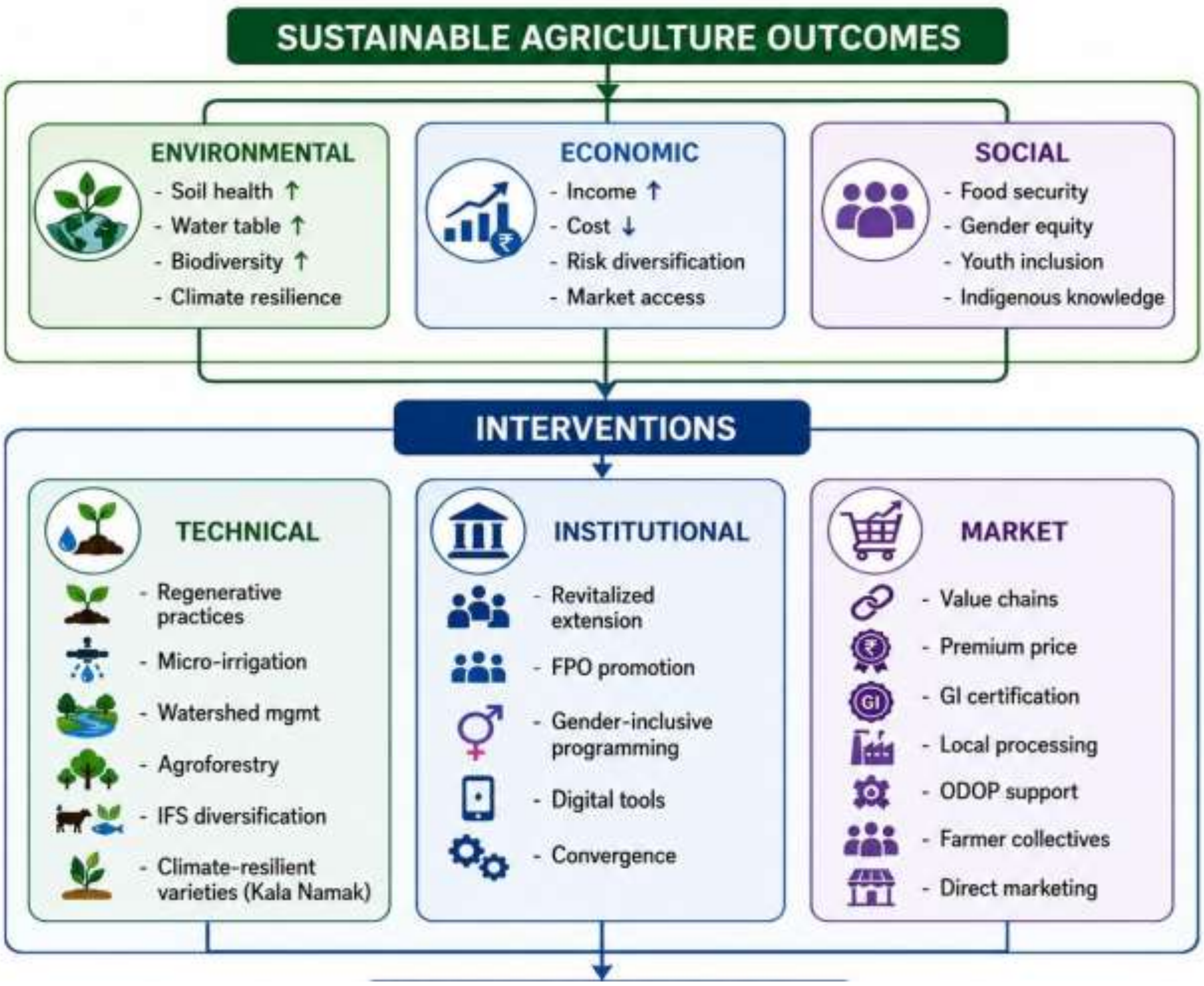


Figure 2: Integrated Framework for Block Gaur
Source: Author synthesis

Priority Interventions: Based on the framework, we identify seven priority interventions for Block Gaur:

- **Water Conservation and Micro-Irrigation**
  - Construct community water harvesting structures (diggi, ponds) using PDMC flexibility (Press Information Bureau, 2025)
  - Promote drip and sprinkler irrigation for vegetables, pulses, and sugarcane
  - Shift rice establishment from puddled transplanting to direct-seeded rice (DSR) and alternate wetting and drying (AWD)—practices demonstrated to save 20-60% water (Shah et al., 2025)
  - Integrate conservation agriculture principles into extension messaging
- **Soil Health Restoration**
  - Strengthen soil health card scheme with block-level soil testing lab
  - Promote balanced fertilization through nutrient-based subsidy orientation (Gulati et al., 2025)
  - Scale vermicompost and NADEP composting with quality assurance
  - Incentivize crop residue retention (no burning) with mulching equipment
  - Address the "awareness without application" gap identified by Mishra et al. (2026) through structured practical training
- **Crop Diversification and Integrated Farming Systems**
  - Expand Kala Namak rice area through seed systems and market linkage (Government of UP, 2025; ICRISAT, 2026)
  - Replace some rice area with millets, pulses, and oilseeds
  - Promote summer green gram as catch crop after wheat
  - Adopt the IFS model from Kumar et al. (2025), integrating dairy, aquaculture, and agroforestry
- **Climate-Resilient Agriculture**
  - Promote Kala Namak rice for its drought, flood, and heat tolerance (ICRISAT, 2026)
  - Implement early wheat sowing (before third week of November) to improve nitrogen use efficiency (Environment, Development and Sustainability, 2025)
  - Document and integrate women's traditional knowledge of climate-adaptive practices
  - Link with ICRISAT-UPCAR climate-resilient village program (ICRISAT, 2026)
- **Institutional Strengthening**
  - Revitalize agricultural extension through Farmer Friend (Kisan Mitra) para-extension model
  - Establish Farmer Producer Organizations (FPOs) for Kala Namak and vegetables
  - Create block-level convergence platform for line departments

- Introduce digital advisory services (WhatsApp, IVRS, mobile apps)
- Strengthen input supply chains to address the "unavailability at proper time" constraint (Chaudhary et al., 2025)

- **Gender-Responsive Programming**
  - Ensure minimum 40% women's participation in all extension trainings (adapted from Kumar et al., 2025)
  - Establish women-led community seed banks for indigenous varieties
  - Train female community resource persons as para-extension agents
  - Schedule extension activities at times and locations accessible to women
  - Document and integrate women's indigenous knowledge into formal recommendations
- **Market Development**
  - Leverage GI registration for Basti Kala Namak for premium price realization (Lokmat Times, 2022)
  - Develop organic certification pathways (PGS-India)
  - Establish direct marketing channels to urban consumers
  - Support value addition (parboiling, milling, branding)
  - Link farmer collectives with e-NAM and other digital market platforms

Implementation and Monitoring: Effective implementation requires: (1) phased approach with pilot villages demonstrating proof-of-concept; (2) participatory planning ensuring community ownership; (3) multi-stakeholder governance involving farmers, line departments, panchayats, and civil society; and (4) robust monitoring using GIS-based tracking of intervention locations and outcomes.

Indicators for monitoring should encompass:

- Biophysical: groundwater levels, soil organic carbon, irrigation water use
- Agronomic: crop yields, cropping intensity, input use efficiency
- Economic: net returns, cost reduction, income diversification
- Social: adoption rates by gender, women's participation, food security scores
- Climate: frequency of climate-induced crop failure, adoption of stress-tolerant varieties

Conclusion and Recommendations

Summary of Findings: This critical review has examined the state of sustainable agricultural development and natural resource management in Block Gaur, District Basti, within the broader context of eastern Uttar Pradesh. **Key findings include:**

1. The sustainability crisis is real and urgent. Declining soil organic carbon, groundwater depletion, and imbalanced nutrient management threaten the long-term viability of the dominant rice-wheat cropping system (**Gulati et al., 2025; Shah et al., 2025**).
2. Knowledge erosion compounds resource degradation. Indigenous farming practices that historically sustained soil fertility are disappearing or being misapplied, while extension systems lack capacity to provide alternative guidance (**Mishra et al., 2026**).
3. Policy frameworks exist but implementation lags. Programs including PDMC, RKVY-RAFTAAR, and ODOP provide enabling support, but fragmented delivery and weak convergence limit effectiveness (**Press Information Bureau, 2025; Lokmat Times, 2022**).

4. Climate-resilient indigenous varieties offer strategic opportunities. Kala Namak rice, with its stress tolerance traits and GI certification, provides both economic and adaptation benefits (**Government of UP, 2025; ICRISAT, 2026**).
5. Integrated Farming Systems demonstrate economic viability. Evidence from western Uttar Pradesh shows IFS generating substantially higher returns than monocropping while enhancing resilience and women's participation (**Kumar et al., 2025**).
6. Gender disparities constrain sustainable transitions. Women perform most sustainable agriculture tasks but remain excluded from extension, credit, and decision-making—an equity issue with efficiency consequences.
7. Success models offer transferable principles. The Bundelkhand watershed model, Andhra Pradesh natural farming scale-up, Kala Namak GI marketing, and western UP IFS demonstrate pathways to sustainable transformation (**ICRISAT, 2025; Bharamappanavara et al., 2024; Kumar et al., 2025**).
8. Integration is essential. No single intervention—technological, institutional, or market-based—suffices. Sustainability requires holistic approaches addressing biophysical, economic, and social dimensions simultaneously.

Recommendations

For researchers:

1. Conduct block-level baseline surveys of soil health, water resources, and farmer practices to establish evidence base for intervention
2. Document indigenous knowledge systems before further erosion, with explicit attention to women's knowledge (Mishra et al., 2026)
3. Undertake participatory action research on Kala Namak agronomic optimization and IFS adaptation to Block Gaur conditions
4. Evaluate the impact of PDMC and soil health card schemes at the block level
5. Quantify the economic returns to sustainable practices under local conditions

For policymakers:

1. Prioritize Block Gaur for integrated watershed development under new generation guidelines (ICRISAT, 2025)
2. Allocate PDMC flexible funds for community water harvesting in the block (Press Information Bureau, 2025)
3. Strengthen extension capacity through Farmer Friend scheme and digital platforms (Chaudhary et al., 2025)
4. Accelerate GI registration and marketing support for Basti Kala Namak (Lokmat Times, 2022)
5. Integrate climate-resilient variety promotion into state climate adaptation plans (ICRISAT, 2026)
6. Mandate gender-inclusive extension programming with minimum participation quotas

For development practitioners:

1. Organize farmer field schools and demonstration trials on regenerative practices (Bharamappanavara et al., 2024)
2. Facilitate farmer producer organizations for Kala Namak and other high-value crops
3. Establish seed multiplication and organic manure production at village level

4. Link farmers to certification and premium markets
5. Implement gender-transformative approaches including women-led seed banks and flexible training schedules (Kumar et al., 2025)
6. Adapt the IFS model for local conditions (Kumar et al., 2025)

For farmers and communities:
1. Organize into self-help groups and farmer collectives for knowledge sharing and input access
2. Experiment with sustainable practices on small plots before full conversion
3. Participate in water user associations for community resource management
4. Preserve and exchange indigenous seeds through community seed banks
5. Ensure women's equal participation in farmer organizations and decision-making bodies

Limitations and Future Research: This review is limited by the absence of block-specific secondary data, necessitating extrapolation from district and regional studies. Primary research in Block Gaur—quantitative surveys, qualitative interviews, biophysical measurements—is urgently needed. Specific research priorities include:
1. Baseline assessment: Soil health mapping, groundwater monitoring, and agronomic surveys specific to Block Gaur
2. Adoption studies: Evaluation of existing sustainable practice adoption rates by crop, farmer category, and gender
3. Impact evaluation: Rigorous assessment of PDMC, soil health card, and ODOP scheme impacts at household level
4. Value chain analysis: Kala Namak and other speciality product value chains, including women's participation
5. Institutional analysis: Mapping of extension and input delivery systems, identifying bottlenecks and opportunities
6. Climate vulnerability assessment: Block-level climate risk mapping to target adaptation interventions
7. Action research: Participatory trials of IFS and conservation agriculture under Block Gaur conditions

Concluding Remarks

Block Gaur stands at a crossroads. The conventional agricultural model—intensive, input-dependent, monocrop-based—has reached ecological and economic limits. Yet the region possesses distinctive assets: indigenous crop genetic resources (Kala Namak with GI certification and climate resilience), traditional knowledge awaiting revival, supportive policy frameworks (PDMC, ODOP, RKVY-RAFTAAR), validated success models (Bundelkhand watershed, western UP IFS, Andhra Pradesh natural farming), and emerging institutional support (ICRISAT-UPCAR climate resilience program). The pathway to sustainability is clear: integrate water-saving technologies (micro-irrigation, conservation agriculture), soil-building practices (balanced fertilization, composting, residue retention), crop diversification (Kala Namak expansion, IFS), institutional strengthening (gender-inclusive extension, FPOs), and market development (GI branding, organic certification). This integration must be participatory, evidence-based, and adaptive—tailored to the specific conditions of Block Gaur while drawing on proven principles from comparable contexts. With concerted effort from researchers, policymakers, practitioners, and farmers—and with explicit attention to the gender dimensions of agricultural transformation—Block Gaur can transition from a landscape of resource degradation to a model of sustainable, climate-resilient, equitable, and prosperous smallholder agriculture. The imperative is urgent. The opportunity is real. The time for action is now.

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