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Assessment of cropping systems in Gorakhpur district: Rice-wheat dominance and prospects for diversification

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Abstract

The rice-wheat cropping system (RWCS) has long served as the agricultural backbone of Gorakhpur district in Eastern Uttar Pradesh, playing a pivotal role in regional food security and livelihood generation. However, mounting evidence suggests this mono-cropping pattern is approaching ecological and economic unsustainability due to deteriorating soil health, groundwater depletion, yield stagnation, and declining profitability. The comprehensive assessment examines the current status of RWCS in Gorakhpur through the lens of agricultural sustainability, evaluating both the systemic constraints and viable diversification alternatives. Evaluation of alternative cropping sequences reveals that high-value systems, such as rice-potato-cowpea and the resurgence of the Geographical Indication (GI) tagged Kalanamak rice, offer significantly higher net returns and improved benefit-cost ratio compared to the traditional cereal sequence. However, the transition is hindered by structural barriers including small and fragmented landholdings, inadequate cold storage infrastructure, and market volatility. The paper proposes a multi-pronged strategy for sustainable agricultural transition in Gorakhpur, emphasizing phased implementation, integrated policy interventions, and context-specific farmer support mechanisms. The study provides evidence-based recommendations for stakeholders seeking to balance food security objectives with the urgent need for ecological resilience.

Keywords: Rice wheat cropping system, crop diversification, ecological consequence and Krishi Vigyan Kendra (KVK)

1. Introduction

Agriculture remains the primary economic engine of the district, supporting the livelihoods of a majority of the population. However, the agrarian structure is heavily skewed towards marginalization. The data from the Krishi Vigyan Kendra (KVK) Gorakhpur reveals that approximately 88.10% of landholdings belong to marginal farmers (owning less than 1 hectare), while small farmers (1-2 hectares) constitute another 8.43% and large farmers (< 2 hectares) constitute 3.47%. This shows fragmentation of land, limits the capacity for capital investment and mechanization, compelling farmers to adopt risk-averse strategies that favour the established Rice-Wheat Cropping System (RWCS) over more profitable but volatile. Over the past half century, the region underwent a profound transformation during the green revolution, adopting a high-input, cereal-centric model that prioritized food self-sufficiency. This model solidified the hegemony of the rice-wheat cropping system (RWCS), which now dictates the socio-economic rhythms of millions of small and marginal farmers in the district.

The prevailing agricultural scenario is defined by a high cropping intensity of approximately 154.4%, driven largely by the sequential cultivation of paddy in the kharif season and wheat in the rabi season. While this system has played a pivotal role in ensuring regional food security, it is increasingly beset by stagnation in productivity, diminishing economic returns, and severe ecological consequences. The depletion of soil fertilities, and challenge of groundwater depletion in some blocks. The continuous monocropping of rice and wheat has led to a deterioration of soil structure, a buildup of resistant weeds, and reliance on chemical fertilizers that has failed to keep nutrient reserves. Furthermore, the regional climate is undergoing a shift; the studies indicate a trend of increasing maximum and minimum temperatures coupled with a reduction in total rainfall and a rise in extreme point rainfall events. These anomalies threaten the traditional sowing and harvesting cycle. The need for agricultural diversification is underscored by the shrinking size of operational land holdings, which average just 0.39 hectares in the region. For such small land holders, the traditional cereal rotation often yields marginal profits that are insufficient to meet

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the rising costs of living and production. Diversification into high-value horticultural crops, legumes, and specialty grains like Kalanamak rice presents an opportunity to break this cycle of subsistence. Integrated grains, oilseeds, vegetables and feed crops into agricultural practice can improve the economic conditions of small and marginal farmers and increase incomes. This diversification strategy not only contributes to economic prosperity, but also optimizes the use of resources such as irrigation water and labour in the summer. This approach improves productivity, profitability and food security. After the rainy season, not only economically, but also economically and resource-efficiently, pulses, oilseeds, vegetables and feed crops have proven to be beneficial. The efficient use of irrigation water and other inputs leads to sustainable and profitable agricultural systems. This diversification strategy promotes the general economic situation of farmers, particularly those with limited resources. As the third crop in the summer season, legumes, as a rice-wheat sequence, greatly improved the yield of the rice system. This suggests that the integration of legumes into the summer crop system can increase overall productivity.

2. Literature Review

The constant adoption of RWCS, especially in the Indo-Gangas Plains, has led to soil fertility declines, the emergence of several micronutrient deficiencies, excessive greenhouse gas emissions and water level declines, etc. (Mal *et al.* 2018, Shahane and Shivay 2019) ^[7, 8]. Thus, sustainability of this cropping system is threatened (Nawaz *et al.* 2019) ^[9] and requires remedial measures. One of these measures could be the adoption of an entirely alternative crop system to overcome these problems. Different crops provide a source of food and income for farmers, increase the productivity of their land, and minimize unpredictable risks, such as the accumulation of insects and diseases common in rice monocultures (Saha *et al.* 2020) ^[10]. Diversification of the rice-wheat system will help to preserve India's long-term soil fertility, crop productivity, and profitability, and reduce the gap between current yields and currently used yields of cultivars (Shahane and Shivay 2019, Saha *et al.* 2020) ^[8, 10]. For example, Introduction of summer legumes such as moonbeam into rice-wheat cropping systems before harvesting wheat and mustard and rice transplants, and planting corn, feed corn and wheat grain may increase the productivity of these crops (Nawaz *et al.* 2019) ^[9]. Therefore, keeping the above facts in view, a field experiment was conducted to find out the more productive and profitable cropping systems that can replace the existing rice-wheat cropping system.

3. Study Area

The agricultural landscape of Gorakhpur district, situated in the fertile Terai belt of North Eastern Uttar Pradesh, represents a complex interplay of ecological abundance and structural constraints. Geographically positioned between latitude 26° 13' N and 27° 29' N and 83° 05'E and 83° 56' E longitude, the district forms a critical part of Trans-Saryu plains of the middle Ganga plain. Total population of the district is 6.73 lakh with a literacy rate of 75.4%. The total geographical area is 3483.8 sq km, out of this total cultivated area is 248723 ha, forest 6031 ha, land under non agriculture 45875 ha, Pasture 211 ha and cultivable waste land 2255. Annual average rainfall is 1100 mm. Maximum temperature goes up to 43.5 °C in summer and minimum temperature 6.1 °C goes in winter. The region is characterized by sandy loam soil 70%, clay loam soil 10% and

silty loam soil 20% of total area and a riverine ecosystem dominated by the Rapti, Rohini, Ami, and Ghaghara rivers.

4. Objective and Methodology

The primary objective of this assessment is to conduct a comprehensive evaluation of the current cropping systems within the Gorakhpur district to identify the underlying causes of rice-wheat dominance and the potential pathways for sustainable diversification.

- To assess the current extent of rice-wheat cropping dominance in Gorakhpur district.
- To identify environmental and socio-economic constraints limiting crop diversification.
- To evaluate potential crops diversification systems to increase profitability and sustainability.

The assessment employs a mixed-methods approach combining secondary data analysis from Krishi Vigyan Kendra (KVK) Gorakhpur, and synthesis of empirical research in contexts of rice wheat cropping systems dominance and prospects for crop diversification in Gorakhpur districts.

5. Results and Discussion

The assessment of the current cropping systems in Gorakhpur and analyse the agronomic and economic drivers of the rice-wheat dominance, evaluates the ecological consequences of the monoculture, and systematically explores the prospects for diversification.

The Dominance of the Rice-Wheat Cropping System (RWCS)

The Rice-Wheat Cropping System (RWCS) is the backbone of Gorakhpur's food security and rural economy. Covering nearly 80% of the gross cropped area, this system has evolved from a subsistence necessity to a structurally ingrained monoculture.

Table 1: Area, Production, and Productivity of Major Crops in Gorakhpur (2024) ^[1]

S. No.	Crop	Area (ha)	Production (MT)	Productivity (Qtl/ha)
1	Paddy	152497	202895	15.26
2	Wheat	190499	448884	23.89
3	Sugarcane	3955	209034	528.53
4	Potato	5000	125490	250.90
5	Arhar	8659	4978	5.75
6	Maize	3299	4281	12.98
7	Mustard	3492	2373	6.80
8	Pea	2766	3587	12.97
9	Lentil	2275	2067	9.08
10	Ground Nut	2547	1508	5.92
11	Barley	708	1388	19.60
12	Gram	668	544	8.15
13	Bajra	369	617	16.72
14	Til	75	12	1.62
15	Linseed	47	02	4.20
16	Jowar	27	37	13.70
17	Urd	24	09	3.73
18	Moong	02	01	2.77

Source: Krishi Vigyan Kendra (KVK) Gorakhpur 2024

The data indicates a stark disparity, wheat occupies nearly 1.9 lakh hectares and paddy occupies nearly 1.52 lakh hectares, while pulses like Arhar, Pea & Lentil and oilseeds like mustard occupy negligible areas in comparison. The productivity levels,

particularly for paddy (15.26 Qtl/ha) and wheat (23.89 Qtl/ha), are significantly lower than the averages achieved in western Uttar Pradesh or Punjab, indicating an extensive yield gap. This low productivity is attributed to late sowing, poor seed replacement rates, and suboptimal nutrient management.

(A) Drivers of Persistence

The persistence of the RWCS in Gorakhpur, despite its diminishing marginal returns, is driven by a complex matrix of socio-economic and technological factors:

- **Risk resistance and Food Security:** For the 88% of farmers who are marginal landholders, the primary mandate is household food security. Rice and wheat constitute the staple diet, and producing them ensures survival before market surplus. The risk associated with diversifying into perishable vegetables or price-volatile cash crops is often perceived as too high for subsistence households.
- **Assured Marketing (MSP):** Procurement infrastructure in Eastern UP has historically lagged behind Western UP, the Minimum Support Price (MSP) mechanism remains most active for Wheat and Paddy. The certainty of a buyer, even if procurement centers are inefficient, provides a psychological safety net that is absent for crops like maize or oilseeds.
- **Adoption of technology:** The entire agricultural ecosystem from machinery to input supply chains is tailored to the RWCS. The widespread adoption of combine harvesters, while solving labour shortages, has reinforced the cycle by creating tight turnaround times that favour the mechanical sowing of wheat immediately after rice.
- **Labor Constraints:** Diversified crops, particularly vegetables and certain pulses, are labour-intensive. With significant out-migration of male from Gorakhpur to urban centers, farm labour has become scarce and expensive. The RWCS, being highly amenable to mechanization, offers a solution to this labour deficit.

(B) Ecological Consequences of Monoculture

The intensification of the Rice-Wheat system over the past four decades has exerted immense pressure on Gorakhpur's natural resource base. The ecological footprint of this monoculture is visible in soil degradation, hydrological imbalances, and biotic stresses.

- **Soil Health Crisis:** The continuous cultivation of exhaustive cereal crops has led to a negative nutrient balance in the soil. The RWCS is a heavy feeder; a typical sequence yielding 10 tonnes of grain per hectare removes over 600 kg of NPK nutrients from the soil annually. In Gorakhpur, where fertilizer application is heavily skewed towards Urea (Nitrogen) due to subsidies, this has resulted in severe imbalances.
- **Soil Organic Carbon (SOC):** The practice of burning crop residues, particularly paddy straw, to clear fields for timely wheat sowing, has severed the organic carbon cycle. With the decline in livestock populations per household, the application of Farm Yard Manure (FYM) has decreased. Consequently, SOC levels in many intensively cultivated plots have fallen below the critical threshold of 0.5%, adversely affecting soil structure and microbial activity.

- **Water Table Fluctuations:** The heavy reliance on groundwater for irrigating rice and wheat has led to localized declines in the water table. Observations from 2024 indicate that while the overall district status is safe, specific peri-urban and intensively farmed blocks are witnessing a pre-monsoon water level decline of 0.5 to 1.0 meters annually.

(C) Prospects for Diversification

The ecological ceilings and economic stagnation of the RWCS, diversification into high-value, restorative, and resilient cropping systems is imperative. The research identifies four primary pathways for diversification in Gorakhpur: i. Vegetable-based systems, ii. Pulse intensification, iii. Industrial crops (Maize), and iv. Heritage varieties.

(a). Vegetable-Based Cropping Systems

The integration of vegetables offers the highest potential for increasing per-unit area profitability, particularly for smallholders with family labour.

- **Rice-Cauliflower-Okra:** This has been identified as a high-performance alternative. It achieves a Rice Equivalent Yield (REY) of 18.63 t/ha/annum, with net returns of approximately 160,443 per hectare. This is nearly triple the returns of the conventional ₹ Rice-Wheat system.
- **Rice-Potato-Cowpea (Vegetable):** This leverages the short duration of potato and the nitrogen-fixing ability of cowpea. It recorded the maximum profitability of 727/ha/day ₹ and net returns of 265,435/ha. ₹

(b). Pulse and Oilseed Intensification

Reintroducing legumes into the crop rotation is essential for restoring soil health and reducing the nitrogen fertilizer bill.

- **Pigeon Pea (Arhar):** New short-duration, high-yielding varieties like IPA-203 and NA-2 have been successfully demonstrated by KVK Gorakhpur. These varieties fit better into the rotation and have shown yield increases of over 14% in Frontline Demonstrations (FLDs) compared to local cultivars.
- **Lentil and Gram:** These Rabi pulses are less water-intensive than wheat. They are particularly suitable for the tail-end areas of canal commands where water supply is unreliable for wheat.
- **Zaid Crops:** The inclusion of Summer Moong (Green gram) or Cowpea in the window between wheat harvest and paddy sowing utilizes the fallow period. This practice, known as Zaid intensification, provides additional income and improves soil organic nitrogen.

Mustard: Mustard is a viable competitor to wheat in the Rabi season. Economic analysis indicates that while the cost of cultivation for Mustard is higher per quintal, the net returns per hectare are competitive due to lower irrigation needs and higher market prices. The Rice-Mustard-Green gram sequence is highlighted as a nutrient-efficient system that breaks the cereal disease cycle.

(c). Industrial Crop Potential

Maize is emerging as a strategic crop for diversification, driven by industrial demand rather than just direct human consumption.

- **Winter Maize:** Cultivating maize in the Rabi season (Winter Maize) offers higher yield potential than Kharif maize due to the long, cool growing season and absence of waterlogging. It requires significantly less water than Boro rice and wheat, making it a water-smart industrial crop.
- **System Efficiency:** Maize-based systems like Maize-Potato-Onion have shown high system productivity. Maize residues can also be used as fodder or mulch, contributing to circular farm economy.

(d). Reviving Heritage: Kalanamak Rice

A unique diversification strategy for Gorakhpur involves value-based rather than just volume-based agriculture through the promotion of Kalanamak Rice.

The Buddha Rice Renaissance

Kalanamak, a scented rice variety indigenous to the Terai belt (including Gorakhpur, Siddharthnagar, and Basti), is renowned for its aroma and nutritional profile (high in Iron and Zinc). Historically, its cultivation declined due to low yields and lodging issues. However, recent interventions have reversed this trend.

- **Improved Varieties:** New dwarf varieties (e.g., Kalanamak 101, 102) developed by research institutions have addressed the lodging problem and reduced the crop duration, making it agronomically viable.
- **Economic Superiority:** Under the Uttar Pradesh government's One District One Product (ODOP) scheme, Kalanamak is being aggressively promoted. The economic math is compelling: while common paddy sells for 2,000-2,200 per quintal (MSP), Kalanamak ₹ paddy commands prices of 4,000-6,000 per quintal. ₹
- **Export Potential:** The ODOP initiative has linked Kalanamak farmers to export markets (e.g., Singapore, Nepal), creating a high-value niche that decouples farmer income from land size.

(D) Constraints and Challenges to Diversification

Despite the clear economic rationale, the adoption of diversified systems is impeded by structural, market, and environmental bottlenecks.

Marketing Infrastructure and Post-Harvest Losses

- **Price Volatility:** Diversification into vegetables exposes farmers to extreme price volatility. Unlike wheat/paddy, which have MSP protection, vegetable prices fluctuate daily. A bumper crop of cauliflower in Gorakhpur often leads to a market crash where prices drop below harvesting costs, forcing farmers to destroy their crop.
- **Cold storage:** Gorakhpur has some cold storage capacity (primarily for potatoes), there is a critical lack of multi-commodity cold storages and pre-cooling facilities at the farm gate. Post-harvest losses in vegetables like tomato and brinjal are estimated to be between 20-30% due to poor handling and lack of storage.
- **Market Intelligence:** Farmers lack real-time information on demand in distant markets. They often produce based on last year's prices, leading to the "cobweb cycle" of glut and scarcity.

Socio-Economic Constraints

- **Small Holding Size:** With 88% of farmers being marginal, the capacity to invest in the specialized machinery required for potatoes or planting materials for orchards is limited.
- **Small plot sizes** also make it difficult to achieve the economies of scale necessary for bargaining with traders.

Environmental Constraints

- **Flood Prone Topography:** A significant portion of the district (approx. 20%) is floodprone. In these areas, the Kharif cropping choice is severely restricted. High-value crops like maize or pigeon pea cannot survive water stagnation.
- **Soil Constraints:** The widespread micronutrient deficiency (Zn, S, B) limits the potential yield of diversified crops. For instance, oilseeds planted in Sulphur-deficient soils yield seeds with low oil content, fetching lower market prices.

(E) Institutional Interventions

The transition towards a diversified agrarian economy is being actively catalysed by government policy and civil society interventions.

- **One District One Product (ODOP):** The inclusion of Kalanamak Rice (shared with Siddharth Nagar) under ODOP. The scheme provides support for common facility centers (CFCs), and marketing, helping to create a distinct identity for Gorakhpur's produce.
- **Soil Health Card (SHC) Scheme:** By providing farmers with plot-specific nutrient status, the SHC scheme is slowly changing fertilizer behaviour. Reports indicate a gradual reduction in excess urea use and an uptake in micronutrient application in blocks where the scheme is active.
- **National Food Security Mission (NFSM):** Through cluster frontline demonstrations (CFLDs) on pulses and oilseeds, NFSM is showcasing the viability of new varieties. KVKs act as the implementing arm, bridging the lab-to-land gap.

(F) Recommendations and way forward

To break the stagnation of the Rice-Wheat system and unlock the potential of diversification, a multi-pronged strategy is required:

- **Maize-Poultry Cluster:** Facilitate the establishment of a maize drying and processing cluster in Gorakhpur. Linking FPOs directly with poultry feed manufacturers will provide the market assurance needed for farmers to switch from wheat to maize.
- **Cold storage:** Investment in localized cold storage and micro-processing units to reduce post-harvest losses and encourage the cultivation of perishables.
- **Kalanamak Export Hub:** Strengthen the seed value chain for Kalanamak. Ensure the availability of certified seeds of improved varieties (Kalanamak 101/102) to maintain genetic purity and export quality standards.
- **Promote Resource Conserving Technologies (RCTs):** Scale up the use of Super Seeders and Zero Tillage machines. These technologies allow for the sowing of wheat directly into rice stubble, solving the residue burning issue, reducing costs, and mitigating heat stress by ensuring timely sowing.

- **Micronutrient Mission:** Launch a targeted campaign for Zinc and Sulphur application. Subsidized supply of zinc sulphate and gypsum to farmers with deficient Soil Health Cards can yield immediate productivity gains in both cereals and oilseeds.
- **Summer Intensification:** Target the 30-40% of land left fallow in summer (Zaid). Promote short-duration pulses (Moong) or green manure crops which improve soil health for the subsequent paddy crop.
- **FPO Incubation:** Move beyond FPO registration to FPO Incubation. Provide professional management support to FPOs to handle business operations, credit linkages, and regulatory compliance.

6. Conclusion

The dominance of the Rice-Wheat system, historically significant, has reached its ecological and economic limits. The study indicates that shifting towards high-value vegetables, industrial maize, and heritage crops like Kalanamak is not just viable but highly profitable. However, this transition requires a shift from a production-centric approach to a market-centric, supported by robust infrastructure and collective action through FPOs. By leveraging its rich water resources and fertile soils with smart, diversified choices, Gorakhpur can transform into a model of resilient and remunerative agriculture for the entire Eastern Gangetic Plains. The prospects for diversification are not only viable but essential for the survival of the district's marginal farming community. The resurgence of Kalanamak rice, supported by the ODOP scheme and improved genetics, offers a high-value entry into global markets. Simultaneously, the intensification of horticulture involving potato and other can significantly enhance net returns per unit area. However, for these transitions to take place on a large scale, the technological and infrastructural gap must be bridged.

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