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Dynamics of Crop Diversification and Cropping Pattern Shifts in the Eastern Plain Zone of Uttar Pradesh

Jitendra Ojha[1], Sumit Kumar Shukla[1], Himanshu Trivedi[1], Uma Sah[2], Bhanu Prakash Mishra[3] and N.K. Bajpai[3]

[1]Chhatrapati Sahu Ji Maharaj University, Kanpur Nagar, UP
[2]ICAR-Indian Institute of Pulses Research, Kanpur Nagar, UP
[3]Banda University of Agriculture and Technology, Banda, UP

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ABSTRACT

The study examines crop diversification and cropping pattern shifts in the Eastern Plain Zone of Uttar Pradesh during 2003-2004 to 2022-2023 using the Simpson Index of Diversification (SID) and Markov Chain Analysis. The results of the study revealed that the moderate to high level of diversification in *Ballia, Jaunpur, Barabanki* and *Sultanpur* districts exhibiting higher SID values, while *Mau* and *Chandauli* districts identified less diversified. The Markov analysis revealed that rice and wheat are the most stable crops, retaining large areas, though a gradual shift toward pulses, oilseeds, and cash crops was noted.

Introduction

Agriculture is the backbone of the Indian economy, providing livelihoods by ensuring national food security. Uttar Pradesh state is an important state having 240928 Km2 geographical area, diverse agro-climatic zones and significant contribution to the production of cereals, pulses, oilseeds and cash crops. The state can be divided in to nine agro climatic zone (Singh et al., 2022). The Eastern Plain Zone of state consisting Barabanki, Faizabad, Ambedkarnagar, Sultanpur, Pratapgarh, Jaunpur, Azamgarh, Mau, Ballia, Sant Ravidas Nagar, Ghazipur, Banaras and Chandauli districts is particularly important as it not only supports a dense rural population but also contributing substantially to the state's overall food grain production (Government of Uttar Pradesh, 2024). Despite its agrarian strength, the region is characterized by small and fragmented landholdings, heavy reliance on monsoon rainfall and a high degree of pressure on natural resources, making the analysis of cropping patterns and crop diversification especially relevant (Jose et al., 2022). Crop diversification is a strategy for improving farm income and enhancing sustainability in agricultural systems (Mihrete and Mihretu, 2025). It refers to the reallocation of agricultural resources from a few dominant crops to a more varied portfolio, including pulses, oilseeds, vegetables, fruits and cash crops (Islam et al., 2024). In India, crop diversification has been promoted as a pathway to address regional disparities, nutritional insecurity and environmental degradation (PIB, 2022). Shifts in cropping patterns, on the other hand, reflect both structural and dynamic changes in farmers' decision-making, often driven by factors such as input availability, profitability, market access, technological adoption and government policies (Neogi and Ghosh, 2022). In the context of the Eastern Plain Zone, these shifts are often influenced by the dominance of rice-wheat systems, supported by procurement mechanisms, but challenged by

Corresponding author;
Email: shuklasumit100798@gmail.com

growing concerns over soil fertility depletion, groundwater stress and climate variability (Dhanda et al., 2022).

The available literature has emphasized the importance of diversification for agricultural sustainability in India. Studies have shown that excessive focus on cereals, particularly on rice and wheat, has contributed to resource degradation and reduced system resilience (Ladha et al., 2007). Conversely, diversification into pulses, oilseeds, and horticultural crops has been associated with better income stability, enhanced soil health and reduced environmental costs (Alekhya et al., 2025). However, empirical evidence suggests that despite policy incentives, the pace of diversification remains slow, especially in regions dominated by the rice-wheat cropping system (Barman et al., 2022). This paradox is best illustrated by the Eastern Plain Zone, where there has been little shift to high-value crops and the farming system is still heavily focused on cereals.

For a number of reasons, it is essential to comprehend the dynamics of crop diversification and cropping pattern changes. Diversification is a means of reducing risk from the standpoint of livelihood in small dominated farming systems, which are particularly susceptible to market volatility and climate shocks (Jackson et al., 2025). From an environmental standpoint, diversification reduces pressure on water and nutrient resources, thereby conserving natural resources and minimizing the ecological footprint of agriculture. From a policy perspective, analysing changes in cropping patterns over time provides valuable evidence for assessing the effectiveness of existing policies and identifying gaps that hinder diversification. The Eastern Plain Zone serves as an ideal case for studying these dynamics due to its fertile alluvial soils, favourable climatic conditions, and long-standing dependence on cereal-based farming systems. Despite its importance, there aren't many thorough studies that use quantitative techniques like Markov chain analysis to assess crop transitions and diversification in Uttar Pradesh's Eastern Plain Zone. There is a knowledge gap regarding district-level variances and long-term changes in cropping systems because the majority of current research is either on specific crop groupings or on more general state-level patterns. Furthermore, there is a dearth of methodical research that connects diversification trends to sustainability issues, which is becoming more and more important in light of resource restrictions and climate change.

In this context, the present study analysed the status of crop diversification and the shifting patterns of crops in the Eastern Plain Zone of Uttar Pradesh over the last two decades (2003-2004 and 2022-2023). The study aims to identify the major crops that act as stable or absorbing states, assess the extent of transition among different crop groups and evaluate the implications of these changes for sustainability and diversification.

Material and Methods

The present study employed quantitative techniques to assess the extent of crop diversification and the dynamics of cropping pattern shifts in the Eastern Plain Zone of Uttar Pradesh. Two methodological approaches as Simpson Index of Crop Diversification and Markov Chain Analysis.

The Simpson Index of Crop Diversification (SID) was used to measure the extent of diversification across different crops. The index is expressed as:

$$SID = 1 - \Sigma (Pi^2)$$

Where, P_i denotes the proportionate area under the i^{th} crop in relation to the gross cropped area. The value of the index ranges between 0 and 1. A value closer to 0 indicates specialization (low diversification), while a value approaching 1 indicates higher diversification. The Simpson Index of Crop Diversification was computed separately for the base year (2003-2004) and the reference year (2022-2023) for assessment of changes in the extent of diversification over time.

In addition, Markov Chain Analysis was employed to study the transitional probabilities of crop area shifts between the two time periods.

The transitional probability matrix (TPM) was constructed by estimating the probability of retention or substitution of each crop. The diagonal elements of the TPM represent the probability of crop retention, whereas the off-diagonal elements represent the probability of transition from one crop to another.

The transition probability from crop i in the base year to crop j in the subsequent year is given by:

$$P_{ij} = A_{ij} / \Sigma A_{ij}$$

Where:

P_{ij} = probability of shifting from crop i to crop j,

A_{ij} = area shifted from crop i to crop j,

m = total number of crops.

Each row of the Transition Probability Matrix (TPM) satisfies:

$$\Sigma P_{ij} = 1$$

Together, these two approaches provide a comprehensive framework for understanding both the extent of diversification and the direction of cropping pattern shifts in the study area. The Simpson Index captures the overall degree of diversification, while the Markov Chain Analysis provides insights into the structural dynamics and stability of specific crops within the production system.

Result and Discussion:

Status of Crop Diversification:

Simpson Index of Diversification (SID) for the thirteen districts under Eastern agro-climatic zone of Uttar Pradesh during the period 2003-2023 revealed important insights into

the extent and dynamics of crop diversification in the region. The SID in almost all districts fall within the moderate to high diversification range, indicating that farmers are increasingly adopting a more varied cropping pattern instead of relying on single crops.

In similar lines, Ambedkar Nagar district reported SID values between 0.59 and 0.66 across the study period. This revealed the slow but steady diversification trend, possibly due to farmers' inclination towards risk minimization by cultivating a mix of cereals, pulses and oilseeds. Similarly, Azamgarh displayed relatively stable SID values ranging from 0.59 to 0.62, with no major fluctuations. This indicates a balanced but less dynamic cropping system where diversification exists but has not expanded significantly over the years.

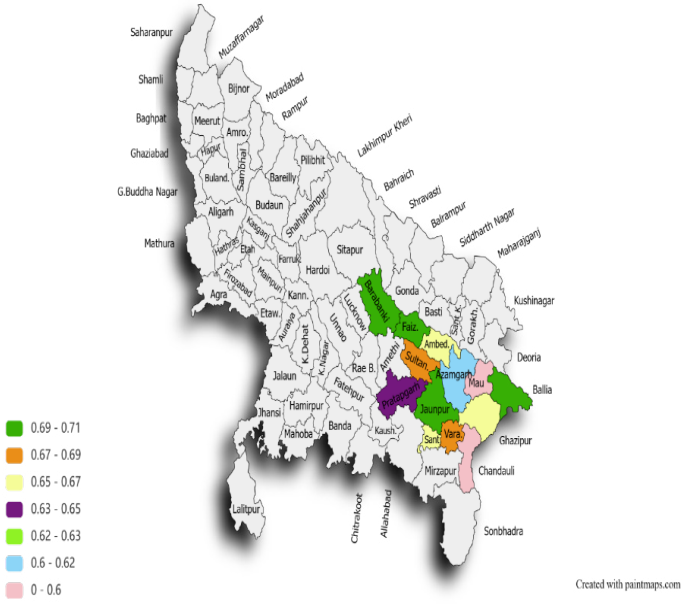
Ballia stands out as one of the most diversified districts, consistently reporting high SID values in the range of 0.65-0.71. The district recorded values above 0.70 in multiple years, reflecting strong crop diversification and the lowest degree of crop concentration among the study districts. The relatively high diversification in Ballia may be attributed to favourable agro-climatic conditions, better access to markets, and farmers' orientation towards diversified cropping for higher profitability. A similar trend was observed in Barabanki, where SID values showed consistent improvement over the years. Beginning with 0.66 in 2003-04, the values gradually increased to 0.70 by 2022–23, suggesting a clear upward trajectory of diversification, likely due to improved irrigation infrastructure and increased adoption of cash crops alongside food grains.

In similar sense, Chandauli, district displayed comparatively lower SID values, fluctuating between 0.58 and 0.61. This indicates a higher degree of crop concentration, possibly reflecting the predominance of paddy cultivation in the district and lower adoption of diversified crop rotations. In similar lines, Ayodhya district showed a more encouraging trend with values ranging from 0.59 to 0.70. The district recorded a notable jump in diversification during the later years (2020-23), suggesting farmers' shift towards mixed cropping systems, likely influenced by changing market demands and government programs promoting diversification.

Ghazipur reported moderately high SID values ranging from 0.62 to 0.70. While some fluctuations were observed, the overall trend points to a sustained diversification practice. Jaunpur consistently showed high diversification, with SID values between 0.67 and 0.71 throughout the study period, highlighting the stability of diversified cropping in the district. In contrast, Mau district consistently reported the lowest diversification, with SID values between 0.57 and 0.61. This indicates persistent crop concentration, reflecting limited diversification and possibly the dominance of a few staple crops due to soil or resource constraints.

In similar lines, Pratapgarh exhibited moderate levels of diversification, with SID values generally ranging between 0.60 and 0.65. The district did not show significant upward movement, indicating that while diversification exists, it has remained largely stable over the years without much expansion. In similar sense, Sant Ravidas Nagar recorded relatively high diversification, with values fluctuating between 0.63 and 0.68. Minor variations were observed across the years, but the overall trend remained positive. Sultanpur also exhibited a strong diversification pattern, with SID values ranging from 0.64 to 0.69, showing continuous improvement over the two decades. Finally, Varanasi reported moderately high diversification, with SID values generally between 0.64 and 0.69. The district maintained stable diversification levels throughout, reflecting consistent adoption of mixed cropping practices.

The analysis highlights that Ballia, Jaunpur, Sultanpur, and Barabanki are among the highly diversified districts, consistently maintaining higher SID values above 0.67, while Mau and Chandauli are the least diversified, indicating higher crop concentration. The remaining districts fall within the moderate diversification range, showing gradual but consistent improvements over time. These findings underline that, despite belonging to the same agro-climatic zone, the extent of crop diversification varies across districts depending on agro-ecological suitability, irrigation facilities, access to markets, and farmers' socio-economic conditions. The overall increasing trend in SID values across most districts indicates a positive shift towards diversified agriculture in Eastern Uttar Pradesh, which can enhance farm income, reduce risk, and contribute to sustainable agricultural development.



Map 1: Sympson Index of Diversification of districts of Eastern Plain Zone of UP

Transitional Probability matrix for analysis of shifting in cropping pattern

The Markov Transitional Probability Matrix (TPM) revealed in-depth understanding of crop stability and substitution patterns between 2003-2004 and 2022-2023. The diagonal values of the matrix represent the probability of retention, while the off-diagonal values capture the likelihood of transition from one crop to another. The analysis revealed that wheat and rice exhibit the highest stability, with probabilities of 0.44-0.48 and 0.33-0.37, respectively. This indicated that these two cereals function as absorbing states within the cropping system, consistently retaining large proportions of area and attracting land from other crops. Such dominance reinforces the persistence of a cereal-centric production structure across the study region.

Moderate levels of stability were observed for crops such as pigeon pea (0.34), pearl millet (0.32), chickpea (0.35), and mustard (0.37). Although these crops retain a portion of their cultivation area, their relatively lower probabilities suggest a high risk of substitution by paddy and wheat. In contrast, crops such as barley (0.37), sorghum (0.34), lentil (0.38), field pea (0.36), potato (0.35), and sugarcane (0.36) exhibit weaker retention, with significant shares of their area shifting towards the dominant cereals. The transition probabilities from almost all minor and cash crops to rice and wheat are relatively high, underscoring the limited diversification of the agricultural system.

The overall results point towards the structural predominance of rice and wheat, which continue to overshadow other crops in the region. While the concentration on these cereals aligns with food security goals and reflected farmer preferences for stable procurement and pricing support. The declining stability of pulses and oilseeds is particularly alarming, given their critical role in improving soil health and meeting nutritional requirements. Similarly, the reduced area retention for crops such as sugarcane and potato highlights the vulnerability of market-dependent crops in the face of fluctuating prices and profitability. The continued expansion of rice and wheat has significant implications for long-term sustainability, as these crops demand high levels of water, fertilizers, and energy, thereby exacerbating resource depletion and increasing the system's vulnerability to climate change.

Table 1: Transitional probability matrix for shifting in cropping pattern

	Pigeon pea	Pearl millet	Barley	Gram	Sorghum	Maize	Lentil	Field pea	Mustard	Rice	Urad bean	Wheat	Potato	Sugarcane
Pigeon pea	0.02	0.03	0.01	0.01	0.01	0.03	0.01	0.02	0.03	0.34	0.01	0.45	0.02	0.02
Pearl millet	0.03	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.32	0.01	0.48	0.02	0.01
Barley	0.02	0.02	0.01	0.01	0.01	0.03	0.02	0.01	0.02	0.37	0.00	0.45	0.02	0.02
Gram	0.02	0.02	0.01	0.01	0.01	0.03	0.01	0.02	0.03	0.35	0.01	0.45	0.02	0.03
Sorghum	0.02	0.03	0.00	0.01	0.01	0.02	0.01	0.02	0.03	0.34	0.01	0.44	0.02	0.03
Maize	0.02	0.01	0.01	0.01	0.01	0.07	0.02	0.01	0.04	0.33	0.01	0.43	0.02	0.01
Lentil	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.01	0.05	0.38	0.01	0.41	0.02	0.02
Field pea	0.02	0.02	0.00	0.01	0.01	0.02	0.01	0.02	0.03	0.36	0.01	0.44	0.02	0.03
Mustard	0.01	0.01	0.00	0.01	0.01	0.02	0.02	0.01	0.05	0.37	0.01	0.40	0.02	0.05
Paddy	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.03	0.37	0.01	0.44	0.02	0.03
Urad bean	0.02	0.03	0.00	0.01	0.01	0.03	0.01	0.02	0.04	0.33	0.01	0.44	0.02	0.02
Wheat	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.03	0.36	0.01	0.44	0.02	0.03
Potato	0.03	0.03	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.35	0.01	0.45	0.02	0.02
Sugarcane	0.02	0.03	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.36	0.01	0.45	0.02	0.02

Conclusion

The study of crop diversification in the Eastern Plain Zone of Uttar Pradesh, using the Simpson Index of Diversification (SID) and Transition Probability Matrix (TPM), shows that diversification has increased modestly over the past two decades, though with uneven progress across districts. Higher SID values in Faizabad, Ambedkar Nagar, Barabanki,

Jaunpur, and Sultanpur indicate significant diversification, while Chandauli, Mau, and Azamgarh remained stagnant. The TPM results confirm the dominance and stability of cereals such as rice and wheat, yet also highlight gradual shifts towards pulses, oilseeds, and commercial crops in some areas. Overall, the combined analysis suggests that although diversification is occurring, it remains partial and region-specific, underlining the need for supportive policies, infrastructure, and market incentives to accelerate a more balanced and sustainable cropping pattern.

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