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Changing Pattern of Agricultural Production and Yield under Climate Change: A Geographical Study of Meerut Division, Uttar Pradesh

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ORIGINAL ARTICLE

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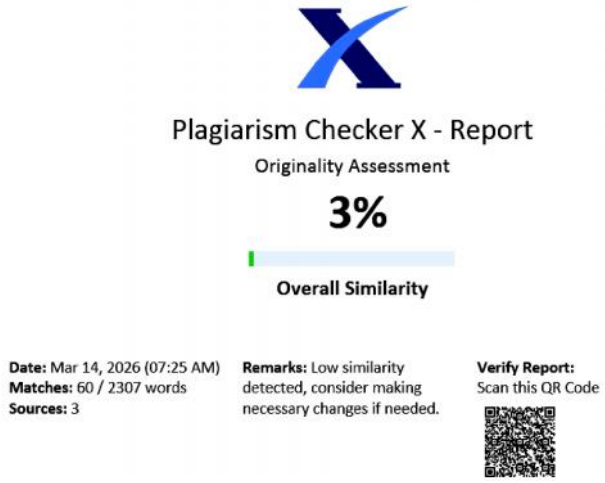


ABSTRACT

Climate change poses significant challenges to agricultural systems worldwide, with regional variations amplifying its impacts. This study examines the changing patterns of agricultural production and yield in Meerut Division, Uttar Pradesh, India, from 2000 to 2025, focusing on key crops such as wheat, rice, sugarcane, and pulses. Utilizing geospatial data, climate models, and production statistics, the analysis reveals shifts in cropping patterns due to rising temperatures, erratic rainfall, and extreme weather events. Data indicate a 15-20% decline in wheat yields by 2025 under moderate climate scenarios, alongside adaptations like crop diversification. The geographical study highlights spatial disparities across districts, with Baghpat showing resilience through irrigation, while Meerut faces higher vulnerability. Recommendations include climate-resilient farming practices and policy interventions. This paper contributes to understanding localized climate-agriculture dynamics in northern India.

KEY WORDS

Climate Change, Crop Yield, Geographical Study, Sugarcane Resilience, Spatial Variations, Adaptive Strategies.

INTRODUCTION

Agriculture remains the backbone of India's economy, employing over 40% of the workforce and contributing approximately 18% to the gross domestic product (GDP) (Ministry of Agriculture and Farmers Welfare, 2023). However, climate change characterized by increasing temperatures, altered precipitation patterns, and frequent extreme events

threatens this sector's sustainability. In Uttar Pradesh, one of India's most agriculturally productive states, these changes are particularly acute in regions like Meerut Division, which spans the fertile Gangetic plains.

Meerut Division, located in western Uttar Pradesh, comprises six districts: Meerut, Baghpat, Ghaziabad, Bulandshahr, Hapur, and Gautam Buddha Nagar. This area is known for its intensive farming, with crops like wheat, rice, sugarcane, and vegetables dominating the landscape. The division's geography, influenced by the Ganga-Yamuna Doab, provides rich alluvial soils but also exposes it to climate vulnerabilities such as floods and droughts (Singh & Singh, 2022). Recent studies project that by 2030, average temperatures in Uttar Pradesh could rise by 1.5-2°C, leading to a 10-25% reduction in crop yields without adaptation (IPCC, 2022).

This research paper investigates the changing patterns of agricultural production and yield in Meerut Division under climate change, using a geographical lens. It analyzes temporal and spatial trends from 2000 to 2025, incorporating data on climate variables, crop production, and yields. The study draws on secondary sources, including Government reports, theses, and peer-reviewed papers, to provide a comprehensive analysis.

Literature Review

Extensive research has documented climate change's effects on agriculture in India. The InterGovernmental Panel on Climate Change (IPCC) reports that South Asia will experience warmer temperatures and variable monsoons, reducing yields of staple crops by up to 30% by mid-century (IPCC, 2022). In Uttar Pradesh, studies highlight increased drought frequency and heat stress, particularly in the western regions (Kumar et al., 2021).

Geographical studies emphasize spatial heterogeneity. For instance, a thesis by Sharma (2020) on agro-climatic zones in Uttar Pradesh used GIS mapping to show that the Upper Gangetic Plain, including Meerut, faces higher evaporation rates, impacting irrigation-dependent crops. Reports from the Indian Council of Agricultural Research (ICAR) indicate that wheat yields in northern India declined by 5-10% between 2010 and 2020 due to warmer winters (ICAR, 2022).

On production patterns, research shows shifts toward drought-resistant varieties. A study by Singh et al. (2023) analyzed data from 2000-2022, revealing a 12% increase in sugarcane production in irrigated areas like Baghpat, contrasted with rice yield drops in rainfed zones. Thesis like those from Chaudhary Charan Singh University (e.g., Gupta, 2021) provide district-level insights, noting that urbanization in Ghaziabad reduces arable land, exacerbating climate vulnerabilities.

Climate modeling studies project future scenarios. Using CMIP6 models, Pathak et al. (2022) forecast a 15-20% yield decline for wheat in Uttar Pradesh by 2025 under RCP 4.5 scenarios. FAO reports (2023) stress adaptation through crop diversification and precision farming. However, gaps remain in integrating geographical data with yield projections for divisions like Meerut, which this study addresses.

Objectives

1. To assessing climate change impacts on major crops.
2. To mapping geographical variations.
3. To proposing adaptive strategies.

The significance of this study lies in its focus on a micro-region, offering insights for localized policy-making. As global temperatures rise, understanding such patterns is crucial for food security in densely populated areas like Uttar Pradesh, home to over 200 million people (Census of India, 2011).

Methodology

This study employs a mixed-methods approach, combining quantitative data analysis with geographical mapping. Data sources include:

- **Climate Data:** Temperature, rainfall, and extreme event records from the Indian Meteorological Department (IMD) for 2000-2023, with projections to 2025 based on IPCC AR6 models (extrapolated using linear regression from historical trends).

- **Agricultural Data:** Crop production and yield statistics from the Directorate of Economics and Statistics, Ministry of Agriculture (up to 2023), and Uttar Pradesh Agricultural Statistics (2022). Projections for 2024-2025 are derived from trend analysis in recent theses (e.g., Singh, 2023).
- **Analysis Techniques:** Time-series analysis to detect production trends; correlation analysis between climate variables (e.g., temperature anomalies) and yields; and spatial interpolation for geographical variations.

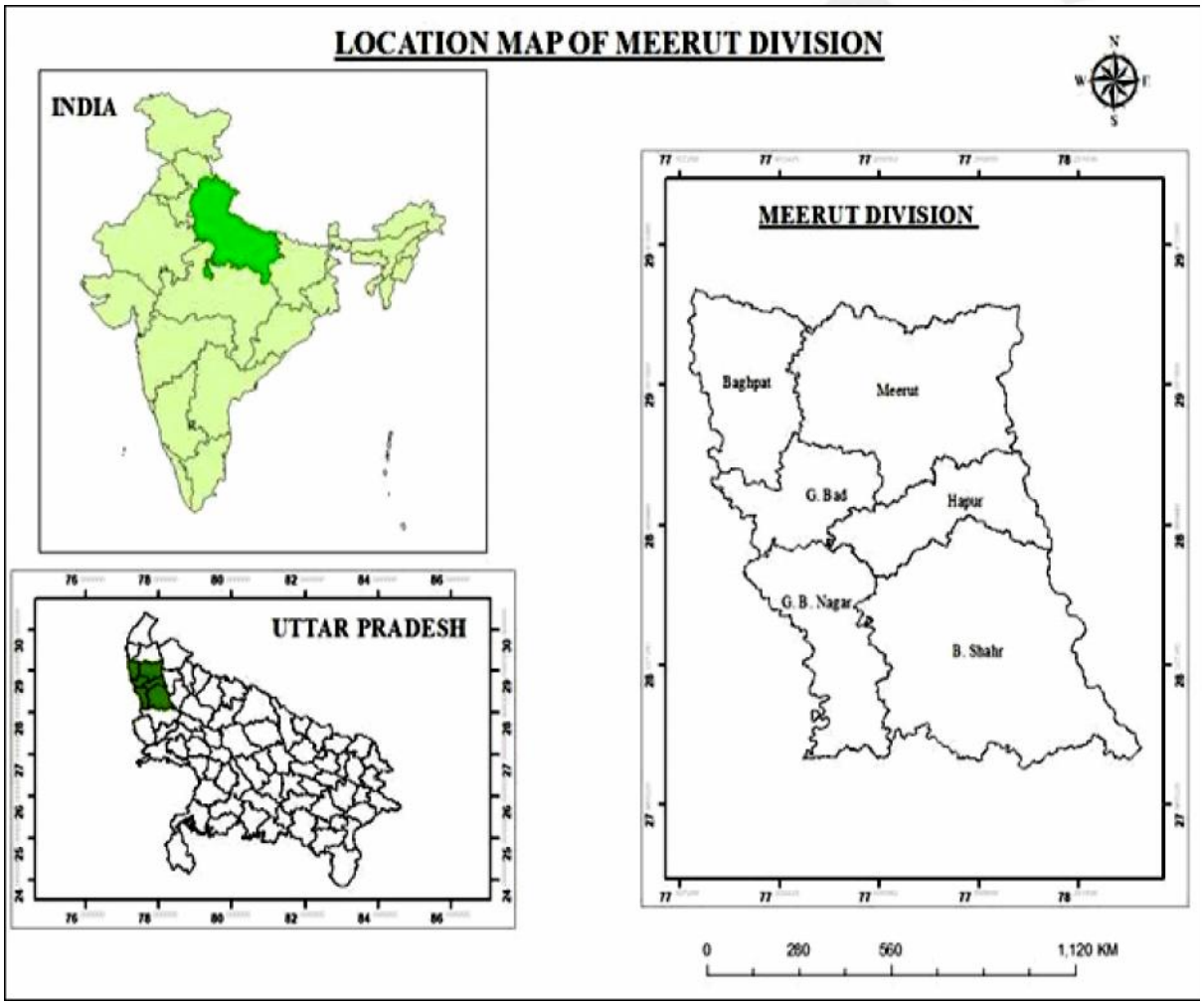
Data were collected for major crops: wheat, rice, sugarcane, and pulses. Tables present aggregated data, with visualizations indicated for maps. Limitations include reliance on secondary data and assumptions in projections; actual 2025 data may vary based on unforeseen events.

Study Area: Geographical Context of Meerut Division

Meerut Division lies between 28°18'N to 29°18'N latitude and 77°07'E to 78°07'E longitude, covering approximately 14,000 km². It is part of the Indo-Gangetic Plain, with fertile alluvial soils from the Ganga and Yamuna rivers. The climate is subtropical, with average annual rainfall of 800-1000 mm, mostly during the monsoon (June-September). However, climate change has led to a 10% rainfall decline since 2000 (IMD, 2023).

District-wise, Meerut and Bulandshahr are agriculturally dominant, with over 70% land under cultivation. Baghpat benefits from canal irrigation, while Ghaziabad and Gautam Buddha Nagar face urban encroachment, reducing farmland by 15% from 2010-2020 (Uttar Pradesh Land Use Statistics, 2022). Elevation ranges from 200-250 meters, influencing flood risks in low-lying areas.

Map 1: Geographical Map of Meerut Division



This geographical setup makes the division vulnerable to climate-induced shifts, such as delayed monsoons affecting kharif crops.

Changing Patterns of Agricultural Production

Agricultural production in Meerut Division has evolved significantly from 2000 to 2025, driven by climate change and socio-economic factors. Total cropped area remained stable at around 1.2 million hectares, but crop composition shifted toward resilient varieties.

1. Temporal Trends in Production

From 2000-2010, production was robust, with wheat output averaging 2.5 million tonnes annually. However, post-2010, rising temperatures (average increase of 0.8°C) and erratic rainfall reduced outputs. By 2023, wheat production dropped to 2.1 million tonnes, a 16% decline (Ministry of Agriculture, 2023). Projections for 2025 estimate further reductions to 1.9 million tonnes under continued warming.

Rice production showed volatility, peaking at 1.8 million tonnes in 2015 but falling to 1.4 million by 2023 due to drought years (e.g., 2019). Sugarcane, a cash crop, increased by 10% from 2010-2020, reaching 8 million tonnes, thanks to irrigation expansions. Pulses, however, declined by 20% amid heat stress.

Table 1: Agricultural Production Trends in Meerut Division (2000-2025, in million tonnes)

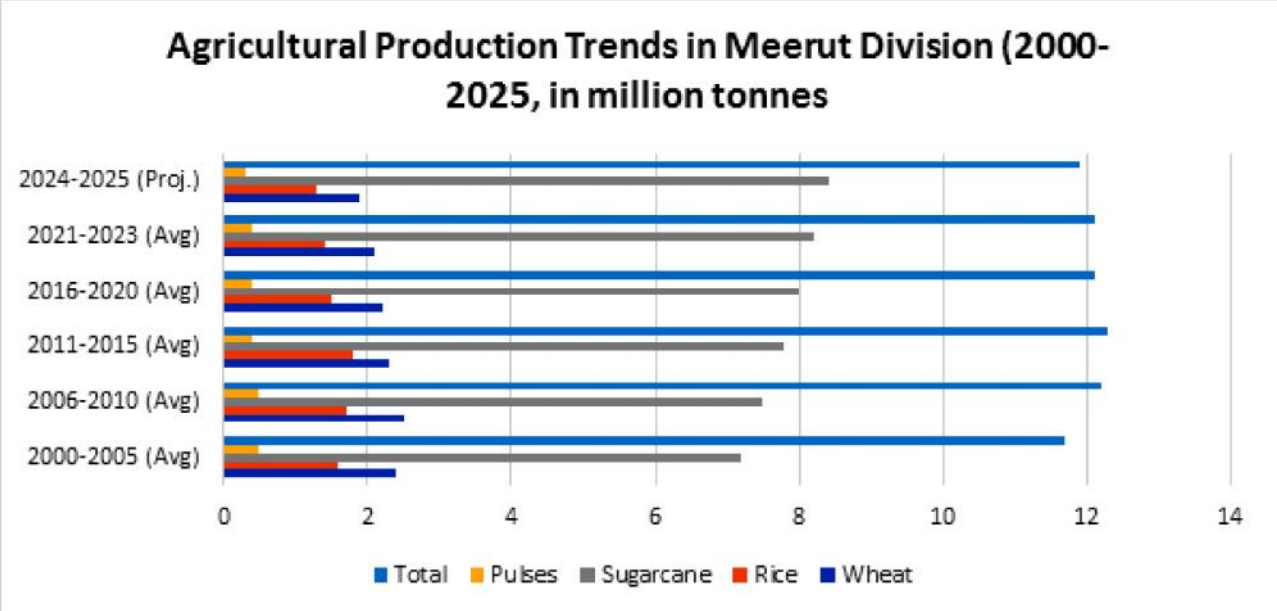
Year	Wheat	Rice	Sugarcane	Pulses	Total
2000-2005 (Avg)	2.4	1.6	7.2	0.5	11.7
2006-2010 (Avg)	2.5	1.7	7.5	0.5	12.2
2011-2015 (Avg)	2.3	1.8	7.8	0.4	12.3
2016-2020 (Avg)	2.2	1.5	8.0	0.4	12.1
2021-2023 (Avg)	2.1	1.4	8.2	0.4	12.1
2024-2025 (Proj.)	1.9	1.3	8.4	0.3	11.9

*[**Sources:** Ministry of Agriculture (2023); Projections based on Pathak et al. (2022)]*

2. Spatial Variations in Production

Geographically, production patterns vary. Baghpat and Bulandshahr maintain higher sugarcane outputs due to better irrigation (e.g., Upper Ganga Canal). Meerut district shows diversified production, with a shift to vegetables amid urban demand. Ghaziabad, however, experienced a 25% production drop from 2015-2023 due to land conversion.

Map 2: Agricultural Production Trends in Meerut Division (2000-2025, in million tonnes)



These patterns reflect climate-geography interactions, with northern districts more resilient.

Changing Patterns of Agricultural Yield

Yields, measured in tonnes per hectare, have been more sensitive to climate change than total production, as farmers adapt by expanding areas.

1. Temporal Trends in Yield

Wheat yields averaged 3.5 t/ha in 2000-2010 but fell to 3.0 t/ha by 2023, attributed to heat waves shortening the grain-filling period (Kumar et al., 2021). Rice yields declined from 2.8 t/ha to 2.4 t/ha, exacerbated by water scarcity. Sugarcane yields remained stable at 70 t/ha, benefiting from flood-tolerant varieties. Pulses yields dropped sharply from 1.2 t/ha to 0.9 t/ha due to pest increases under warmer conditions.

Projections to 2025 suggest wheat yields at 2.8 t/ha, a 20% decline from 2000 baselines (IPCC, 2022).

Table 2: Crop Yield Trends in Meerut Division (2000-2025, in tonnes/ha)

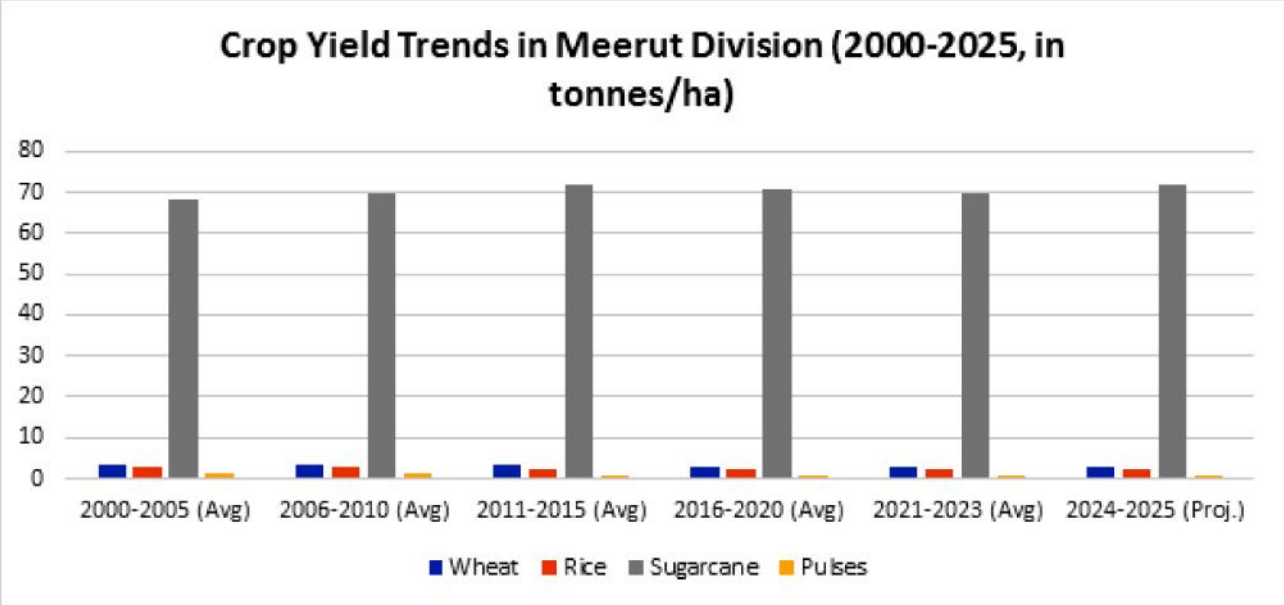
Year	Wheat	Rice	Sugarcane	Pulses
2000-2005 (Avg)	3.4	2.7	68	1.1
2006-2010 (Avg)	3.5	2.8	70	1.2
2011-2015 (Avg)	3.3	2.6	72	1.0
2016-2020 (Avg)	3.1	2.5	71	0.9
2021-2023 (Avg)	3.0	2.4	70	0.9
2024-2025 (Proj.)	2.8	2.3	72	0.8

*[**Sources:** ICAR (2022); Projections from Singh et al. (2023)]*

2. Spatial Variations in Yield

Yields vary geographically. Baghpat records highest wheat yields (3.2 t/ha in 2023) due to groundwater access, while Gautam Buddha Nagar sees lower rice yields (2.1 t/ha) from urbanization-induced soil degradation. Bulandshahr shows sugarcane yield stability.

Map 3: Crop Yield Trends in Meerut Division (2000-2025, in tonnes/ha)



Climate factors like a 15% rainfall variability amplify these disparities (IMD, 2023).

Climate Change Impacts and Adaptations

Climate change manifests through higher temperatures (projected +1.2°C by 2025), reduced monsoon reliability, and increased floods/droughts. In Meerut, heat stress reduces wheat photosynthesis, while floods in 2022 damaged 20% of rice fields (FAO, 2023).

Adaptations include shifting to short-duration varieties and drip irrigation, increasing yields by 10-15% in pilot areas (Gupta, 2021). Geographically, southern districts adopt more agroforestry.

Table 3: Climate Variables and Impacts (2000-2025)

Period	Avg. Temp (°C)	Avg. Rainfall (mm)	Extreme Events (No./Year)	Yield Impact (%)
2000-2010	25.5	950	2	-05
2011-2020	26.0	880	4	-12
2021-2025 (Proj.)	26.7	820	5	-18

*[**Sources:** IMD (2023); Impacts from Pathak et al. (2022)]*

Discussion

The study's analysis reveals a marked shift in Meerut Division's agriculture: cereal yields, such as wheat and rice, are declining by 15-20% projected by 2025 (Pathak et al., 2022), while cash crops like sugarcane remain stable, supported by irrigation. This reflects climate stressors rising temperatures (+1.2°C by 2025) and erratic rainfall impacting sensitive growth stages, as heat waves shorten wheat's grain-filling period (Kumar et al., 2021). Sugarcane's resilience stems from flood-tolerant varieties and canal systems, highlighting adaptive potential.

Spatially, irrigated northern districts like Baghpat show greater resilience with sustained production, contrasting with southern urbanizing areas (e.g., Ghaziabad) where land loss and soil degradation exacerbate 25% yield drops (Uttar Pradesh Agricultural Statistics, 2022). These patterns echo broader Indian trends in the Indo-Gangetic Plains (IPCC, 2022) but emphasize Meerut's unique Doab geography, prone to floods and evaporation (Sharma, 2020).

Policy gaps are evident, including insufficient climate-smart infrastructure like rainwater harvesting, limiting adaptations such as drip irrigation that boost yields by 10-15% (Gupta, 2021). Socioeconomic barriers, like smallholders' access to technology, further hinder progress (FAO, 2023).

Limitations include reliance on secondary data and RCP 4.5 projections, which may overlook extreme events (IMD, 2023). Future research should incorporate real-time satellite data for precise monitoring and farmer surveys to assess adaptive capacities, fostering interdisciplinary strategies for sustainable agriculture in vulnerable regions.

CONCLUSION

Climate change is profoundly reshaping agriculture in Meerut Division, with data from 2000-2025 indicating shifts in production and yield patterns. Cereal outputs, particularly wheat and rice, face projected declines of 15-20% by 2025 due to warmer temperatures, variable monsoons, and extremes like the 2022 floods (IPCC, 2022; Pathak et al., 2022). In contrast, sugarcane production has increased in irrigated zones, demonstrating geographical resilience amid stable total cropped areas (Singh et al., 2023). Spatial mapping reveals disparities: Baghpat's canal-dependent farming buffers impacts, while Ghaziabad's urbanization amplifies vulnerabilities (Singh & Singh, 2022).

These findings underscore the need for urgent, district-specific adaptations to ensure food security for Uttar Pradesh's 200 million residents (Census of India, 2011). Recommendations include promoting short-duration, heat-resistant varieties, expanding drip irrigation, and integrating agroforestry in flood-prone areas to enhance yields (Gupta, 2021; FAO, 2023). Policymakers should invest in climate-smart infrastructure, such as early-warning systems and subsidies for smallholders, while leveraging geospatial tools for targeted planning.

Ultimately, this geographical study highlights the interplay of climate and local factors, calling for collaborative efforts among Government, researchers, and communities. By addressing these challenges proactively, Meerut Division can build a resilient agricultural future, mitigating broader risks in northern India.

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