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Impact of Rising Temperature and Rainfall Variability on Smallholders' Cropping Pattern and Livelihood Security in Sant Kabir Nagar and Basti Districts, Uttar Pradesh, India

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Abstract

This study examines how rising temperatures and increasing rainfall variability are influencing cropping patterns and livelihood security of smallholder farmers in Sant Kabir Nagar and Basti districts of eastern Uttar Pradesh. Using district-level agricultural statistics (KVK district profiles, DES/APY reports), IMD district rainfall summaries and district government statistical reports, we analyze current cropping patterns (area and production for major cereals, pulses and cash crops), climate characteristics, and the livelihood implications for smallholders whose incomes depend on the rice -wheat system, sugarcane, pulses and horticulture. Results show rice -wheat remains dominant, but climate stressors - warming and erratic monsoon distribution - are increasing production risk, encouraging short-duration crops, diversification to pulses and tubers, and uptake of micro-irrigation. We conclude with targeted adaptation recommendations: improve irrigation efficiency, promote short-duration/heat-tolerant varieties, diversify income (livestock/horticulture), and strengthen weather-indexed insurance and extension services.

Keyword: Examines, Short-Duration/Heat-Tolerant, Diversify

1. Introduction

Agriculture in the North-Eastern Plain Zone of Uttar Pradesh is heavily reliant on a rice-wheat rotation. In districts such as Sant Kabir Nagar and Basti, smallholders (marginal and small farmers) form the majority of cultivators and are particularly sensitive to climatic changes because of limited asset buffers and high dependence on crop income and wage labour. Recent regional climate analyses indicate rising mean temperatures and increasing rainfall variability across many Uttar Pradesh

districts; these shifts raise concern for cropping calendars, sowing/harvest dates, water availability, pest pressures and overall livelihood security of smallholders.

Sant Kabir Nagar and Basti represent a representative agricultural setting in the eastern Gangetic plains with fertile alluvial soils, irrigation infrastructure of mixed capacity, and cropping systems dominated by paddy (Kharif), wheat (Rabi), pulses and sugarcane. Understanding crop area distribution, production trends and climate signals at the district level is

vital to design location-specific adaptation and livelihood-support policies.

2. Objectives

1. Describe current cropping patterns (area and production) of major crops in Sant Kabir Nagar and Basti using district KVK and government statistics.
2. Summarize recent climate features relevant to agriculture - mean temperature ranges and rainfall totals/monsoon season concentration drawing on IMD/district sources.
3. Analyze how rising temperatures and rainfall variability are likely to influence smallholder cropping decisions and livelihood outcomes.
4. Provide evidence-based adaptation recommendations for smallholders, extension services and policy.

3. Data and Methods

3.1 Data sources

Primary district agricultural data were drawn from Krishi Vigyan Kendra district profiles for Sant Kabir Nagar and Basti which list area (ha), production and productivity for major crops and include district agro-climatic descriptions and weather snapshots. For Sant Kabir Nagar we used the KVK district profile crop table (rice, wheat, maize, pulses, oilseeds, potato) and weather snapshots. For Basti we used the KVK district profile (crop area and cropping systems, weather summaries).

Climate data and district-level rainfall distribution were taken from India Meteorological Department (district rainfall distribution reports / regional IMD summaries). The IMD district rainfall distribution tables and summaries were used to evaluate rainfall variability and deficits for recent years.

State/district statistical diaries and Directorate of Economics & Statistics (DES) Agriculture Area-Production-Yield (APY) datasets provided contextual agricultural production trends and state-level references.

Other supporting materials included local government district web pages, contingency plan / agricultural risk documents (e.g., ICAR/CRIDA contingency plan for Basti) and recent state-level program news (e.g., micro-irrigation pilots relevant to Sant Kabir Nagar).

3.2 Methods

- Constructed a cropping-pattern table for Sant Kabir Nagar from Krishi Vigyan Kendra figures (area and production).
- Compiled Basti's major-crop area and productivity indicators from its Krishi Vigyan Kendra profile.
- Produced graphics (pie chart: Sant Kabir Nagar crop-area shares; bar chart: Rice & Wheat area comparison between Sant Kabir Nagar and Basti) from the Krishi Vigyan Kendra numbers.
- Qualitative assessment of climate impacts: used IMD district rainfall distribution summaries and district weather descriptions to identify evidence of variability (e.g., percent of annual rainfall during monsoon months, observed deficits).

4. Literature Review

4.1 Climate Change, Temperature Rise and Indian Agriculture

A large body of literature confirms that Indian agriculture is highly sensitive to rising temperatures and changing precipitation regimes. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), South Asia has experienced a consistent increase in mean surface temperature

along with higher frequency of heat extremes, directly affecting crop phenology, evapotranspiration and yields. Studies by Lobell *et al.* (2012) and Porter *et al.* (2014) demonstrate that even a 1–2 °C increase in temperature significantly reduces yields of wheat and rice, particularly in tropical and subtropical regions.

In the Indian context, Kalra *et al.* (2014) used crop simulation models and found that wheat productivity in the Indo-Gangetic Plains could decline by 6–23% under mid-century warming scenarios. Similarly, Aggarwal and Mall (2002) emphasized that temperature rise shortens crop duration and increases water stress, making traditional cropping calendars increasingly unreliable.

4.2 Rainfall Variability and Monsoon Uncertainty

Rainfall variability, rather than decline in total rainfall, has emerged as a major threat to Indian agriculture. Goswami *et al.* (2006) and Guhathakurta *et al.* (2015) reported increasing frequency of extreme rainfall events alongside longer dry spells during the monsoon season. This intra-seasonal variability disrupts sowing decisions, transplanting of rice, and irrigation scheduling.

Kumar *et al.* (2011) observed that eastern Uttar Pradesh exhibits high inter-annual rainfall variability with frequent monsoon breaks, increasing crop failure risk for rain-fed and partially irrigated farms. Studies by BIRTHAL *et al.* (2014) further confirm that rainfall shocks significantly reduce farm income and increase vulnerability among smallholders.

4.3 Cropping Pattern Changes under Climate Stress

Several studies have documented climate-induced changes in cropping patterns across India. Singh *et al.* (2016) found that farmers in the Indo-Gangetic Plains are gradually shifting from long-duration crops to short-duration varieties and diversifying towards pulses and oilseeds as a risk-management strategy. BIRTHAL and Hazrana (2019) showed that climate variability accelerates crop diversification, particularly among small and marginal farmers.

In eastern Uttar Pradesh and Bihar, rice-wheat dominance persists; however, studies by Jha *et al.* (2014) and Raju *et al.* (2017) report increasing adoption of maize, potato, lentil and pigeon pea due to their relatively lower water requirement and market returns. These findings align with district-level evidence from Sant Kabir Nagar and Basti, where pulses and potato occupy a small but growing share of cropped area.

4.4 Smallholders, Vulnerability and Livelihood Security

Smallholders are disproportionately affected by climate variability due to limited landholding size, capital constraints and dependence on monsoon rainfall. Morton (2007) and FAO (2018) emphasized that climate risks interact with socio-economic vulnerabilities, resulting in livelihood insecurity rather than only yield loss.

In Uttar Pradesh, Ranjan *et al.* (2020) found that temperature rise and erratic rainfall increase income volatility and distress migration among marginal farmers. Studies by Pandey *et al.* (2018) demonstrate that climate shocks reduce food consumption, increase indebtedness, and force asset sales among smallholder households.

Livelihood security is increasingly linked with diversification beyond crops. Ellis (2000) and Scoones (2015) argue that climate-resilient livelihoods depend on combining farming with livestock, wage labour, and non-farm activities. Empirical evidence from eastern India supports this, showing increased reliance on seasonal migration during drought or flood years (Deshingkar *et al.*, 2009).

4.5 Adaptation Strategies and Institutional Responses

Adaptation literature highlights both autonomous (farmer-led) and planned (policy-driven) responses. Autonomous adaptations include changing sowing dates, adopting short-duration varieties, crop diversification, and supplemental irrigation (Bryan *et al.*, 2009). In Uttar Pradesh, ICAR-CRIDA contingency plans emphasize flood-tolerant rice varieties, raised-bed cultivation and alternate crops in flood-prone districts like Basti.

Planned adaptations such as micro-irrigation, climate advisory services, and crop insurance have shown mixed success. Singh *et al.* (2021) report that while weather-based crop insurance reduces risk exposure, lack of awareness and delayed compensation limit its effectiveness. Similarly, Aggarwal *et al.* (2018) stress that adaptation policies must be district-specific to account for agro-ecological and socio-economic diversity.

4.6 Research Gap

Despite extensive research on climate change and agriculture at national and regional scales, district-level empirical studies integrating climate variability, cropping pattern and livelihood security remain limited, particularly for eastern Uttar Pradesh. Existing studies often:

- Focus either on climate trends or crop yields, not livelihood outcomes.
- Use state-level averages, masking local variability.
- Lack integration of official district agricultural statistics with climate indicators.

Sant Kabir Nagar and Basti districts are under-represented in peer-reviewed literature, despite being highly vulnerable due to flood-prone landscapes, dominance of smallholders and monsoon dependence. This study addresses these gaps by combining district-level cropping data with climate variability analysis to assess implications for smallholder livelihoods.

5. Results

5.1 Cropping pattern -Sant Kabir Nagar

The Krishi Vikash Kendra district profile for Sant Kabir Nagar shows rice and wheat dominating cropped area (approximately 87,731 ha for rice and 91,860 ha for wheat), with smaller areas under maize, pigeon pea, pulses, mustard and potato. Rice 87,731 ha (production ~2,002,000 qtls), Wheat 91,860 ha (production ~2,741,100 qtls). These figures highlight the primacy of the rice-wheat system in the district.

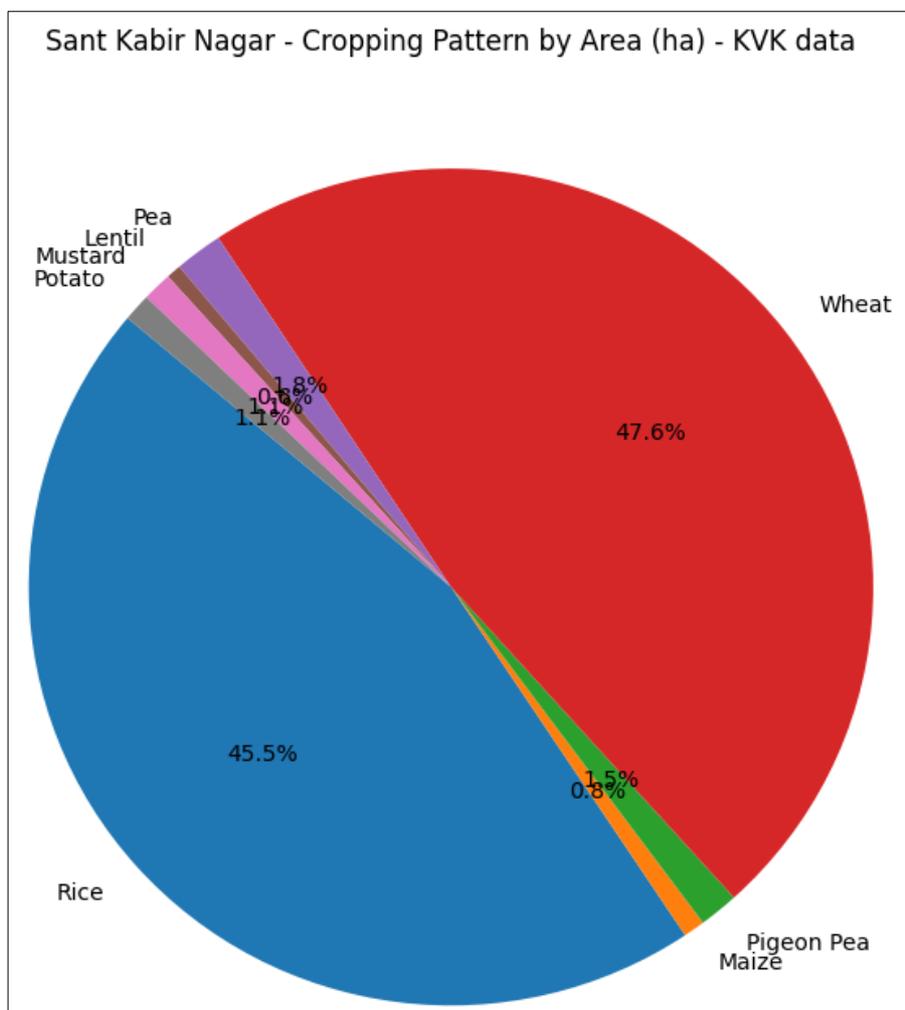


Fig 1: Sant Kabir Nagar-Cropping pattern by area.

5.2 Cropping pattern - Basti

Basti's Krishi Vigyan Kendra profile lists rice and wheat as major crops too, with rice area reported (table formatting) and wheat area similar in magnitude to Sant Kabir Nagar (Basti rice/wheat areas reported in the Krishi Vigyan Kendra data).

Basti's cropping systems and agro-ecological zones indicate frequent rice-wheat cropping, sugarcane pockets, and flood-prone AES (agro-ecological situations) that influence crop choices and risk.

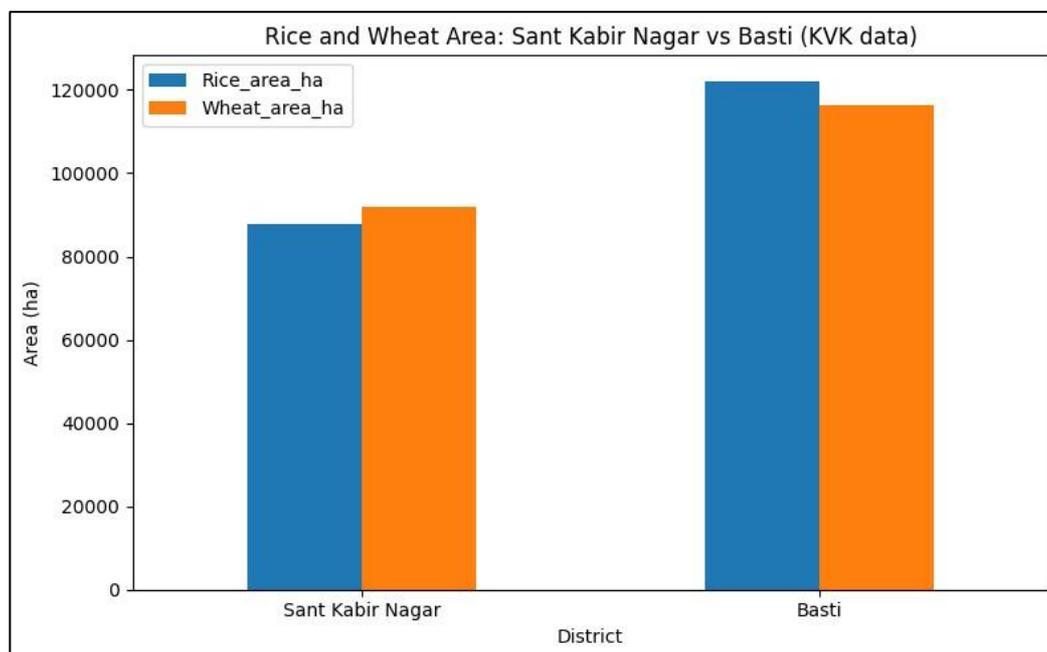


Fig 2: Comparison of Rice and Wheat area: Sant Kabir Nagar vs Basti (KVK figures). (Displayed: bar chart showing rice and wheat areas for both districts.)

5.3 Climate features relevant to agriculture

- **Rainfall totals / monsoon concentration:** IMD district rainfall summaries and district profiles indicate average annual rainfall in the range of ~1,000-1,170 mm for the region, with the vast majority falling in the monsoon months (June-September). IMD district rainfall distribution tables highlight that seasonal distribution and inter-annual variability can be large, leading to years with substantial deficits or concentrated heavy rainfall events.
- **Temperature ranges:** District pages and climate summaries indicate a broad seasonal temperature swing (winter minimum ~8-10 °C; summer maxima up to 44-46°C during heat spells). Increased mean and extreme temperatures influence evaporative demand and crop heat stress during reproductive phases.

5.4 Observed / report evidence of variability and stress

- Government sources and IMD summaries (district rainfall distribution reports and state statistical diaries) point to spatial heterogeneity in rainfall performance across eastern Uttar Pradesh; some districts (including Sant Kabir Nagar in certain recent seasons) have experienced significant monsoon deficits, while others reported surpluses-indicating growing inter-district variability in the state.
- Extension documents and district Krishi Vigyan Kendra profiles flag key farmer concerns: low yields (often linked to seed quality, nutrient imbalances), waterlogging/flooding in low-lying areas, and management of crops in flood-prone zones- all of which are climate-sensitive livelihood risks.

6. Discussion - Climate effects on cropping pattern and livelihoods

6.1 Mechanisms: why rising temperatures and rainfall variability change cropping patterns

1. **Heat stress on phenology and yields:** Rising temperatures, especially extreme heat during reproductive stages (e.g., wheat anthesis or rice grain-filling), reduce yields and push farmers toward shorter-

duration or heat-tolerant varieties. This can lead to varietal shifts and changes in sowing windows.

2. **Monsoon variability and crop choice:** Erratic onset, mid-season dry spells, or intense downpours that cause waterlogging/flooding increase production risk for rice (which tolerates water) and for transplanted rice systems if floods occur at critical times. Where irrigation is limited and monsoon reliability declines, farmers may switch to less water-intensive cereals (millets, maize) or pulses, or adopt potato/tuber crops that can fit different windows.
3. **Floods and waterlogging in low-lying AES:** Basti's and Sant Kabir Nagar's flood-prone AES make some areas unsuitable for certain crops in flood years, increasing the attractiveness of flood-tolerant varieties, or shifting agro-enterprises towards aquaculture or flood-resilient cropping.
4. **Input and labour dynamics:** Crop choices are also influenced by labour availability, labour wages, and market incentives. Climate variability that increases risk may push risk-averse smallholders to adopt diversification (horticulture, livestock) or non-farm labour strategies.

6.2 Observed responses in the districts (from district profiles and extension reports)

- **Continued dominance of rice-wheat:** Krishi Vigyan Kendra data still show rice and wheat occupying the largest shares of area in both Sant Kabir Nagar and Basti, indicating inertia in cropping systems and the attractiveness of these staples for incomes and household food security.
- **Local diversification:** Small but notable area under potato, pulses and pigeon pea in Sant Kabir Nagar suggests farmers already diversify within the cropping calendar where possible (potato in winter/early-spring, pulses often in rabi or as intercrops).
- **Adoption of water management measures:** Recent policy actions and pilot micro-irrigation projects (state-level initiatives) indicate a movement toward improving water use efficiency- relevant given rainfall variability and competing irrigation demands.

6.3 Livelihood implications for smallholders

- **Income volatility:** As yield variability increases, cropping incomes fluctuate. Smallholders with small landholdings (majority in both districts) are especially vulnerable because they have limited buffers (savings, diversified assets).
- **Food security:** Rice-wheat cropping remains central to food security; declines in yields due to heat/drought could strain household food stocks and increase dependence on markets.
- **Migration and off-farm dependence:** Climate-driven crop failures increase seasonal migration and demand for rural wage labour- already common in eastern Uttar Pradesh.
- **Coping strategies:** Evidence points to a mix of short-term coping (selling livestock, borrowing, reduced consumption) and longer-term adaptation (crop diversification, changing sowing dates, micro-irrigation).

7: Recommendations

On-farm measures

1. **Promote short-duration and heat-tolerant varieties** of rice and wheat and climate-resilient pulse varieties; fast-track seeds and demonstrations via Krishi Vigyan Kendra and extension.
2. **Diversification:** Encourage smallholders to include pulses, tubers (potato), oilseeds and horticultural crops where market access exists- these can improve cropping intensity and soil health.
3. **Conserve soil moisture and use micro-irrigation:** Scale micro-irrigation (drip, sprinkler) and precision water application (pilot projects exist in Sant Kabir Nagar- expand and monitor).
4. **Risk management:** Strengthen index-based crop insurance with district-calibrated triggers, and improve access to affordable credit and safety nets.

Community & landscape measures

1. Flood-resilient land use planning in AES-V / flood-prone areas (e.g., promote fisheries, flood-tolerant rice, raised-bed farming).
2. Agroforestry & fodder banks to support livestock during feed shortages; integrate livestock as income diversification.
3. Local water storage for supplemental irrigation (ponds, recharge structures), and adoption of conjunctive groundwater-surface water use.

Institutional & policy recommendations

1. District-level climate information services (crop advisories tied to probabilistic seasonal forecasts) via KVKs (Krishi Vigyan Kendra) and extension (early warnings for sowing windows).
2. Strengthen market linkages and value-chains for pulses, vegetables and potato so smallholders can profitably diversify.
3. Targeted subsidies/credit for micro-irrigation and drought-adaptive technologies, focused on marginal and small farmers.
4. Monitoring and data improvement: Invest in district-level climate and crop monitoring (station networks, remote-sensing based crop area/productivity monitoring), to better detect trends and target interventions.

7. Conclusion

Sant Kabir Nagar and Basti districts are archetypal rice-wheat systems in eastern Uttar Pradesh, with smallholders central to production and livelihoods. KVK district profiles show rice and wheat dominate cropped area, but climate stressors-rising temperatures and rainfall variability- pose growing risks to yields and incomes. Adaptation requires a mix of varietal change, efficient water use, diversification, improved risk transfer and strengthened extension services. Policy must prioritize smallholders through accessible technologies (micro-irrigation), climate-smart seeds, and community-level water/flood management.

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