Review Article

Impact of Climate Change on Cropping Pattern in Maharashtra

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Abstract

A significant centre of agriculture in India, Maharashtra is more vulnerable to the effects of climate change. With a focus on soybean, cotton, wheat, and gram, this study examines the anticipated impact of shifting weather patterns and rising temperatures on the state's major crops. It clarifies the challenges caused by unpredictable rainfall, heat stress, and other climate-related phenomena by drawing on pertinent research findings and data that is accessible. The study examines how these changes affect crop phenology, lead to more insects and disease infestations, reduce soil nutrient levels, and ultimately result in yield losses that compromise food security. Maharashtra is an important part of India's agricultural environment because of its different Agro-climatic zones. However, the state's agriculture industry is becoming more and more susceptible to the negative effects of climate change. In order to fully evaluate the possible effects of climate change on Maharashtra's agriculture, this research paper will look at important crops, food security, and farmer livelihoods.

Keywords: - Climate change, cropping pattern, temperature, crops, rainfall, Maharashtra.

Introduction

Agriculture constitutes a critical pillar of India's economy, accounting for approximately 30% of national income, providing livelihood opportunities to a substantial portion of the workforce, and supplying essential raw materials to agro-based industries (Pagar, 2018). Given the constraints of finite land resources, optimizing land use and implementing scientifically informed cropping patterns are essential for sustainable agricultural productivity and food security.

Maharashtra, located in the northern sector of peninsular India, spans an area of 3.08 lakh square kilometers and supports a population of 11.24 crore, with 45.2% residing in urban centers. Geographically, the state is bounded by the Arabian Sea to the west, Gujarat and Madhya Pradesh to the north, Madhya Pradesh to the east, and Karnataka and Andhra Pradesh to the south. It extends between latitudes 15.6°N and 22°N and longitudes 72.6°E and 80.9°E. The state experiences a tropical monsoon climate, with annual rainfall varying regionally and occasionally exceeding 400 cm. Major rivers include the Krishna, Bhima, Godavari, Tapi-Purna, and Wardha-Wainganga, supporting both irrigation and ecological functions. Maharashtra is physiographically categorized into three divisions: the Konkan coastal region, the Plateau, and the Western Ghats, including associated hill ranges.

Agriculture in Maharashtra is predominantly rainfed, with approximately 82% of cultivated land dependent on rainfall. The state exhibits high vulnerability to drought, with 52% of the area classified as drought-prone. Analysis of historical climate and simulation studies indicates that out of 36 districts, 21 experience recurrent drought, with rainfall deficits occurring every five years and severe drought events once every 8–9 years. In particular, Marathwada and Vidarbha are highly susceptible, with rainfall deficits ranging from 20% to 40%, and over 90% of the cultivated area under dryland farming, which is sensitive to fluctuations in climatic variables (Pawar & More, 2018; Radhakrishnan Committee, 2007). These regions are also characterized as 'double exposure' areas due to the concurrent challenges posed by globalization and climate change. Frequent drought events have led to crop failures, indebtedness, and, in extreme cases, farmer suicides (Anonymous, 2015).

Long-term temperature records indicate a significant warming trend in Maharashtra, with increases in both maximum and minimum temperatures between 1969 and 2006, consistent with global surface temperature trends (Misra & Puri, 2011). Climate projections suggest that agricultural incomes may decline by 15–25%, with rainfed areas being the most affected, and semi-arid regions likely to experience heightened frequency and intensity of droughts (IPCC, 2007; Anonymous, 2023–24).

Cropping patterns, defined as the selection, sequence, and proportion of crops cultivated in a given region, are critical determinants of agricultural output and reflect both agro-climatic and socio-economic conditions (Akhtar & Acharya, 2015). In Maharashtra, shifts in rainfall patterns, water scarcity, and temperature variability have adversely affected crop productivity (Husain et al., 2019). Diversification of cropping systems is recommended as a risk management strategy to enhance resilience to climatic and biological uncertainties.

Key crops in Maharashtra include:

- **Sunflower:** A tropical crop that performs optimally at 25–38°C with around 100 mm rainfall, currently occupying 0.47% of gross cropped area.
- **Jowar:** Grown in kharif season, tolerates 23–28°C and 700–800 mm rainfall, covering 7.1% of the area (2013–14).
- **Bajra:** Cultivated on 1032 ha (7.08% of gross cropped area).
- **Udid:** Sown in June–July and harvested in September–October on medium-deep soils, occupying 3.3% of area.
- **Soybean:** Covers 2729 ha (18.73%), contributing to soil fertility and reducing costs for subsequent crops.
- **Cotton:** A principal kharif cash crop, grown on 3942 ha (27.06%).
- **Mung:** Requires 21–30°C and 600–750 mm rainfall, sown in June and harvested by September–October, covering 3.8% of area (Gade, 2024; Ghuge, 2018).

Strategic adoption of climate-resilient cropping practices, including diversification and alignment with local agro-climatic conditions, is essential to sustain productivity, enhance food security, and support farmer livelihoods in Maharashtra's drought-prone regions.

Discussion

Maharashtra is a major agricultural state, producing crops such as rice, wheat, sugarcane, pulses, sorghum, and red gram. Although over half of the state's land is under cultivation with vegetation covering 62% of the cropped area and 55% of the net sown area it faces serious challenges including famine, water scarcity, land degradation, and the highest proportion of drought-prone land in India. Among Maharashtra's five regions, Marathwada in the south-central part of the state was selected for this study due to its extreme vulnerability to drought. This region receives less than 600 mm of average annual rainfall and is characterized by high temperatures, severe aridity, and critical water shortages (Kamble et al., 2024).

Historical data indicate a clear warming trend in Maharashtra over the past century, affecting both maximum and minimum temperatures. Previous research shows that studies on cropping patterns across India have been extensive and diverse, addressing multiple variables and regional contexts. Given the high variability in crop patterns, combinations, and diversification within the state, further research is needed to enhance agricultural profitability. Aligning crop production with consumer demand and promoting agribusiness can make farming more sustainable and economically rewarding (Rao et al., 2005).

Cropping pattern changes by changing the climate in Indian Agriculture

Agriculture accounts for nearly a quarter of India's Gross National Product and continues to be a vital component of the nation's economy (Sunilkumar et al., 2019). It provides livelihoods for about 70% of the population, making it highly sensitive to changes in climate. Global shifts in temperature and rainfall patterns are likely to affect local farming systems, which in turn could influence food availability worldwide. Researchers have examined these impacts across various regions, but uncertainties remain, particularly regarding the extent of temperature rise and how rainfall patterns may change. These factors directly influence water availability and crop requirements in an atmosphere with higher carbon dioxide levels.

Forecasting the future of agriculture is complicated by the interactions between natural ecosystems and socio-economic factors that shape global food production and distribution (Sanodiya et al., 2024). Rising greenhouse gas concentrations are expected to drive global warming, altering rainfall patterns and water cycles (Rao et al., 2005). Changes in temperature, sunlight, and precipitation will affect both crops and livestock. Additionally, climate change will influence farm income, commodity prices, trade, and regional production advantages. The severity and location of these impacts may challenge our ability to expand food production to meet the needs of an estimated 10 billion people by the mid-21st century (Athare et al., 2024).

Climate change on cropping pattern and Maharashtra

From 2000 to the present, Maharashtra's cropping pattern has shifted towards high-value crops like cotton, sugarcane, and soybean, alongside a diversification into horticulture, while also seeing a decline in the cultivation of certain coarse cereals. (Anonymous, 2023)

The changes of cropping pattern in different region of Maharashtra and results revealed that, over the period of study in Vidarbha region area under kharif jowar over base year showed negative absolute and relative change in area (Thakre *et al.* 2024). Soybean cultivation recorded an increase in area, both in absolute terms and relative to other crops. In contrast, the area under cotton declined, showing negative changes on both counts. In the Marathwada region, compared to the base year, the area under rabi jowar and wheat also decreased, reflecting negative absolute as well as relative changes. . The absolute and relative change for area in soybean was positive. While, in Western Maharashtra region except kharif Pearl millet and *Rabi* Sorghum all the selected crop showed positive absolute and relative change in the area over base year. Sugarcane is one of the cash crops grown in Western Maharashtra region, the absolute and relative change in area was positive.n the Konkan region, the area under kharif paddy declined, showing negative changes in both absolute and relative terms. Changes in the cropping pattern were examined by assessing the proportion of land allocated to different crops in relation to the gross cropped area at both regional and state levels across major crop categories in Maharashtra. Previous studies have noted that cotton growers in the black soil regions of the Deccan Plateau were among the most severely affected by agrarian distress in rural India after the mid-1990s (Ramkumar et al., 2017). Overall, Maharashtra's cropping pattern has been characterized by a predominance of foodgrain crops, which accounted for more than half of the gross cropped area, although their share has gradually declined over time. The decline in foodgrain crops was due to reduction in area under major cereal crops *viz.,* sorghum, pearl millet, ragi and other cereals (Rupe *et al.,* 2024). Whereas, the maize crop was gaining importance due to increasing demand for diversified uses. The area of oilseeds and pulses started expansion during nineties. Soybean crop occupied a prominent place in oilseeds however; the area under all other oilseeds was reduced drastically over the period of time. Commercial crops such as cotton, sugarcane, fruits, and vegetables recorded an increase in their share of the state's gross cropped area. In contrast, the area under foodgrains declined, while non-foodgrain crops expanded. This indicates a gradual shift in the state's cropping pattern from foodgrains towards non-foodgrains. Despite a reduction in area under cereal crops, cereal production showed positive growth, mainly due to improvements in yield. Among the cereals, sorghum, pearl millet and ragi showed negative growth in area whereas paddy and wheat showed positive growth. Maize is emerging as an important cereal crop, showing significant growth in area, production, and yield at both the state and regional levels. Yield improvement was major feature for an increase in production of pulse crops coupled with area expansion. Maximum area expansion of pulses observed in Vidarbha region and maximum growth in production noticed in Marathwada region (More and Khairnar, 2023). The encouraging performance of chickpea and pigeonpea has ultimately led to significant expansion of pulses in Maharashtra. Oilseed crops showed positive growth in area, production and yield during entire study period and production growth was combined effect of area expansion and yield improvement. With the emergence of soybean, the area and production of other oilseed crops declined after the 1990s. During the second period, cotton, sugarcane, fruits, and vegetables recorded substantial growth in production. Among the major crop groups, maize in cereals, chickpea in pulses, and castor seed in oilseeds exhibited the highest levels of production instability. Instability in area and production of cotton and sugarcane at state and regional level was increased over the period. More and Khairnar 2023 noticed that temporal changes in cropping pattern revealed crop diversification leading to commercialization and agricultural development in the Maharashtra state. The study shown that the farming pattern further emphasizes the agricultural diversification of the state, shifting from less profitable or impoverished crops to more profitable or commercial ones. (Rupe *et al.,* 2024). The study was carried out in the Vidarbha and Marathwada regions of Maharashtra, India, areas that have witnessed a high incidence of farmer suicides. The crisis is driven by multiple factors, among which climate change has emerged as a significant underlying cause (Tikadar and Kamble, 2024).

Area and production of non-foodgrain crops was more unstable than area under food grain crops in the state and across the regions. Konkan region showed maximum specialization in the cereal group whereas, Marathwada region was found more specialized in pulses in entire period. Oilseed cultivation was most highly concentrated in the Marathwada and Vidarbha regions. Soybean showed the highest level of specialization in both Vidarbha and Marathwada. Additionally, the location quotient for cotton was highest in the Vidarbha region, indicating a strong regional specialization in cotton cultivation. However, Western Maharashtra region was highly specialized in sugarcane and vegetable crops in entire period. In the case of fruit crops, the Konkan region exhibited the highest level of specialization. Among cereal crops, wheat emerged as a more versatile crop, while ragi was found to be the least versatileAmong pulse crops, chickpea and pigeon pea were more versatile while, black gram was less versatile crop in entire period. However, groundnut was more versatile crop and Niger seed was less versatile in oilseed crops.

In commercial and horticultural crops, cotton was more versatile crop whereas tobacco crop was less versatile crop in overall period. As per district versatility index, Parbhani district was found more versatile district amongst all the districts of Marathwada. The state demonstrated a significant level of diversification in cereal cultivation, with all regions except Konkan showing a shift towards greater crop variety. In contrast, pulse cultivation at the state level tended to become more specialized. Since 1990, diversification in oilseed crops declined markedly, largely due to the dominance of soybean within the oilseed group. At both the state and regional levels, diversification in non-foodgrain crops increased over time. Overall, Maharashtra has maintained a high level of crop diversification (Parida et al., 2023).

Regional Variations:

Vidarbha: *Kharif* sorghum was the most stable crop during 2001-02 to 2010-11, while soybean was the most stable crop between 2011-12 and 2020-21 due to climate change effect these cropping pattern will be change. Marathwada: Cotton was the most stable crop during the study period (2001-02 to 2010-11 and 2011-12 to 2020-21) but the seasonal climatic influence it will replace the soybean crop. Western Maharashtra: *Kharif* maize was a comparatively stable crop. Konkan: *Kharif* paddy retained a significant share of its area. Specific Crop Changes: Wheat was replaced by cotton (75 %), Sugarcane was replaced by Jowar (74%), Oilseeds (19%) and Vegetables (7%), Fruits was replaced by Pulses (100%) while Vegetables was replaced by Wheat (100%) due to different climatic factors viz., rainfall, temperature, frost, ill distribution of rainfall and frost (Jadhav *et al.,* 2014).

Direct effects from changing climatic patterns to crop production

A review of greenhouse experiments conducted in 1993 reported that doubling the atmospheric CO_2 concentration enhanced the growth of 156 plant species by an average of 37 percent. However, the response varied widely across species. While several crops showed substantial growth gains, a few experienced reduced growth. For instance, a greenhouse study from 1979 observed that under doubled CO_2 levels, the dry weight of 40-day-old cotton plants nearly doubled, whereas the dry weight of 30-day-old maize plants increased by only about 20 per cent (Kelkar et al., 2019).

Higher yields due to CO_2 fertilization

Rising concentrations of atmospheric carbon dioxide are not only expected to influence crop yields but may also compromise the nutritional value of several important food crops. Research suggests that wheat grown under elevated carbon dioxide conditions tends to contain lower levels of protein and certain essential minerals. Crops that follow the C3 photosynthetic pathway—such as wheat, rice, and oats—appear particularly vulnerable, with anticipated declines in protein content as well as micronutrients like iron and zinc. Projections indicate that, by mid-century, commonly consumed food crops could experience reductions in protein, iron, and zinc ranging from approximately 3% to 17% when grown under carbon dioxide concentrations expected around 2050 (Swami et al., 2018).

These conclusions are supported by large-scale analyses that draw on datasets from the Food and Agriculture Organization of the United Nations and other publicly available sources. In one such assessment, nutritional trends were evaluated across 225 staple food items, including cereals such as wheat, rice, and maize, as well as vegetables, roots, and fruits, highlighting the widespread nature of this emerging nutritional concern (Kumar and Gautam, 2020).

Projected effects from temperature increase to the crop production

Climate change is expected to shift the regions where farming is viable. Hotter temperatures and reduced rainfall will particularly affect dry and semi-dry areas. In tropical regions, even a modest temperature increase of 1–2°C during the first half of this century could lead to a decline in crop productivity (Swaminathan & Kesawan, 2012). Later in the century, continued warming may reduce yields across nearly all regions, including northern North America.

Crops are often very sensitive to heat. Soybean seedlings are highly sensitive to heat, and can die when temperatures exceed 36°C (97°F), while corn pollen may lose its fertilization ability under such conditions (Akhter & Acharya, 2015).Groundnuts are also vulnerable; higher temperatures reduce pollen viability, slowing growth and seed development, and resulting in smaller and fewer pods (Lakhram et al., 2017). Overall, rising heat and changing rainfall patterns can lower yields through droughts, floods, and heatwaves, increasing the risk that multiple regions experience crop failure at the same time (Anonymous, 2023–24).

Impact of Climate Change on Cropping Pattern in Maharashtra

Rising temperatures and increasingly unpredictable rainfall patterns associated with climate change are expected to substantially alter crop production across regions. In India, grain-based agriculture is particularly sensitive to these climatic shifts. Evidence suggests that staple crops such as wheat, rice, oilseeds, pulses, as well as fruits and vegetables, are likely to experience gradual declines in productivity over time (Ghuge, 2018).

In contrast, research indicates that certain coarse cereals including millets, sorghum, and maize demonstrate greater tolerance to climate variability. The yields of these crops tend to fluctuate less from year to year and show comparatively smaller reductions during periods of drought. Rice, which remains India's dominant food crop, is far more susceptible to climatic extremes and often suffers substantial yield losses under heat stress and erratic rainfall conditions (Kamble et al., 2024).

Although climate change poses serious risks to overall agricultural output, its effects are not uniformly negative.

Some crops may benefit under specific regional conditions, with studies indicating potential yield improvements in soybean, chickpea, groundnut, coconut along the western coast, and potato cultivation in parts of Punjab, Haryana, and western Uttar Pradesh (Hashemi et al., 2019).

Potential of Climate Resilient Crops under climate change scenario

Climate-resilient crops offer an effective pathway to counter the adverse impacts of climate change by enabling agriculture to adapt to increasingly extreme environmental conditions. Farmers can further reduce climate-related risks through improved agronomic practices, including intercropping and multiple cropping systems, diversified crop rotations, temporary shifts toward non-farm livelihoods, and the use of insurance mechanisms. The adoption of resource-efficient technologies such as solar-powered irrigation pumps, drip irrigation, and sprinkler systems also plays a crucial role in minimizing climate exposure and enhancing farm resilience (Choudhari, 2024).

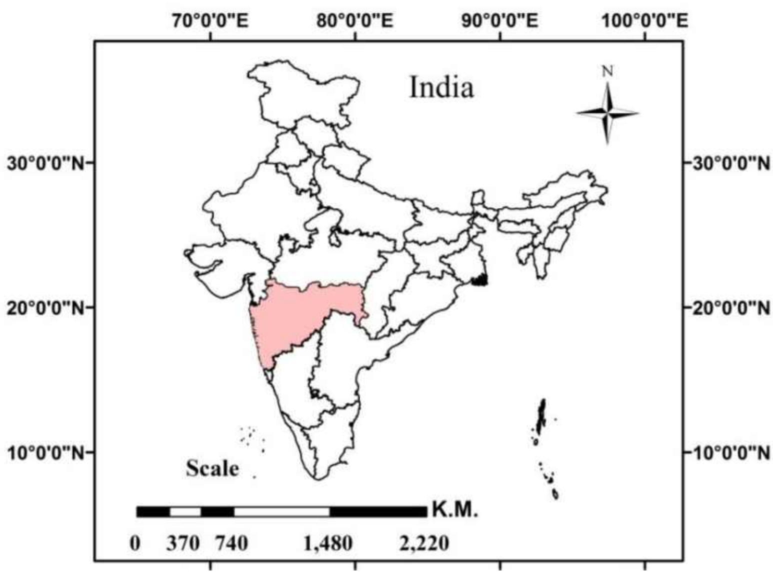
Many climate-resilient crops possess inherent resistance to pests and diseases, thereby reducing yield losses caused by infestations. In addition, these crops tend to use inputs such as water and fertilizers more efficiently, leading to higher productivity while lowering production costs. Beyond adaptation benefits, they also contribute to climate change mitigation by helping reduce carbon emissions from agricultural activities (Todmal, 2023).

Despite these advantages, widespread adoption remains limited in India. The dominance of subsistence farming and reliance on traditional practices often slow the uptake of climate-smart agricultural technologies. A substantial knowledge gap persists among agricultural scientists, policymakers, and farmers, making rapid shifts in cropping patterns difficult. Furthermore, insufficient institutional support, delayed policy interventions, and limited research-driven outreach efforts have constrained farmer motivation to diversify crops and adopt climate-resilient alternatives (Mahesh, 1999).

Current scenario of impact of climate change on Indian Agriculture and government future strategies

Climate change has emerged as a central concern for agricultural sustainability in India, and its implications for farmers' livelihoods are now well recognized at the national level. To understand these risks, agricultural researchers across the country have undertaken long-term field observations alongside simulation-based assessments, drawing on data from diverse agro-climatic zones. These studies have relied on crop simulation models that incorporate future climate projections, particularly for mid-century and late-century scenarios, to estimate how changing temperature and rainfall patterns may influence crop performance.

Findings from these assessments suggest that crop productivity in India could decline substantially if no adaptive measures are adopted. Rainfed rice systems appear especially vulnerable, with simulations indicating sharp reductions in output under future climate conditions, particularly toward the end of the century. Even irrigated rice, which is generally more buffered against climate stress, is expected to experience measurable yield declines. Wheat production shows even greater sensitivity, with projected losses



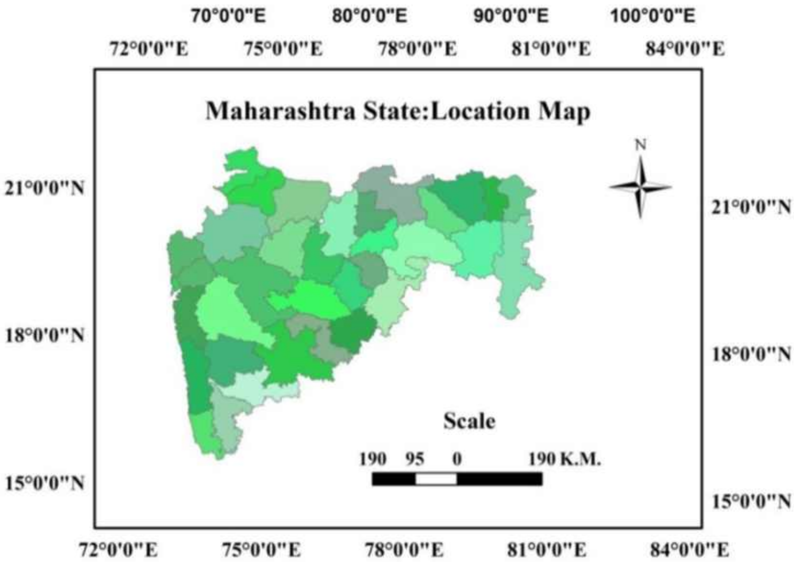


Figure 1. Map of Maharashtra state (*www.wikipedia.com*)

intensifying over time and varying considerably across regions and growing seasons (Wang et al., 2018). Similar trends have been observed for kharif maize, where productivity is expected to decline steadily under projected climate scenarios. Beyond yield losses, climate stress is also associated with deterioration in the nutritional quality of food crops. Extreme weather events such as prolonged droughts further compound these challenges by disrupting food availability, dietary intake, and income security for farming households.

Recognizing these growing risks, the Government of India has introduced a range of policy initiatives aimed at strengthening the resilience of the agricultural sector to climate variability (Anonymous, 2023–24). One of the key policy responses has been the integration of climate resilience into national planning frameworks through the National Mission for Sustainable Agriculture, which operates under the broader National Action Plan on Climate Change. This mission focuses on improving adaptive capacity within farming systems by promoting climate-responsive technologies and management practices.

At the institutional level, the Indian Council of Agricultural Research, under the Ministry of Agriculture and Farmers Welfare, initiated a major research programme in 2011 titled *National Innovations in Climate Resilient Agriculture* (NICRA) (Tikadar and Kamble, 2024). Rather than adopting a one-size-fits-all approach, this initiative concentrates on regions that are repeatedly exposed to climatic extremes such as droughts, floods, heat waves, frost, and cyclones. Through a combination of field demonstrations and long-term research, the programme seeks to equip farmers with practical solutions that enhance their ability to cope with climatic stress.

The scope of NICRA extends beyond crop production to include horticulture, livestock, fisheries, and poultry systems, reflecting the interconnected nature of rural livelihoods (Anonymous, 2015). Its core activities include identifying climate-vulnerable districts, developing crop varieties and management practices suited to future climatic conditions, and evaluating climate impacts on allied agricultural sectors to design appropriate adaptation pathways. Since 2014, this sustained research effort has resulted in the development of a large number of climate-resilient crop varieties, along with several location-specific technologies that have been field-tested and promoted for wider adoption among farming communities (Akhtar and Acharya, 2015).

Conclusion

This analysis highlights that shifts in cropping patterns do not occur due to a single cause but result from a network of interconnected factors operating within farming systems. Evidence from earlier studies indicates that multiple drivers influence farmers' crop choices. Among these, technological progress and input availability, changing climatic conditions, infrastructure expansion, and evolving market demand emerge as the most influential forces shaping cropping patterns. At the same time, other factors such as opportunities for off-farm employment, access to agricultural extension services and training, policy interventions, and demographic changes including population growth and migration from rural to urban areas also play an important role in driving these transitions.

Expanding the cultivation of alternative grains in India offers significant advantages, including improved nutritional outcomes, reduced water consumption, lower energy use, and a decline in greenhouse gas emissions associated with agricultural production. The Intergovernmental Panel on Climate Change, in its Sixth Assessment Report on *Global Warming at 1.5°C*, strongly emphasizes the need to reinforce existing adaptive capacities and maintain firm commitment to the goals of the Paris Agreement (Toppo et al., 2024). In this context, there is an urgent requirement to enhance farmer awareness, strengthen the role of Krishi Vigyan Kendras and other grassroots institutions, and allocate dedicated financial resources for climate education and risk-management strategies. Given the wide-ranging and layered impacts of climate change, addressing its effects on agriculture will require an integrated and forward-looking approach rather than isolated interventions.

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