Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 02 (MAR-APR, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Climate Smart Agronomy: Strategies for Sustainable Crop Production in India

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Indian agriculture is facing an era of unprecedented change. Rising temperatures, unpredictable monsoons, depleting water resources, and declining soil fertility are already influencing how crops are grown and how much they yield. For a country where millions of livelihoods depend directly on farming, these challenges are not only environmental but also economic and social. To sustain productivity while protecting natural resources, agriculture must transition from conventional, input-heavy practices to more resilient and knowledge-driven systems. Climate Smart Agronomy (CSA) offers such a pathway. Climate Smart Agronomy focuses on producing more with fewer resources while adapting to climate risks and reducing environmental damage. It integrates practices such as conservation tillage, crop diversification, integrated nutrient management, efficient irrigation, agroforestry, and the use of stress-tolerant crop varieties. These approaches improve soil health, enhance water-use efficiency, lower greenhouse gas emissions, and help stabilize yields even under erratic weather conditions. Modern tools like weather-based advisories, precision farming, and digital decision-support systems further strengthen farmers' ability to respond to climate variability. In India, several national initiatives are promoting climate-resilient agriculture, yet wider adoption requires awareness, training, and supportive policies. Climate Smart Agronomy is not merely a set of technologies it represents a shift toward sustainable intensification, ensuring food security, farmer profitability, and environmental conservation for future generations.

Keywords: Climate-smart agriculture; Sustainable farming; Climate resilience; Resource-use efficiency; Conservation practices.

Introduction

Agriculture has always been closely tied to climate, but in recent decades the relationship has become increasingly uncertain. Indian farmers, who once relied on relatively stable seasonal patterns, now face delayed monsoons, sudden heavy rains, prolonged dry spells, and rising temperatures. Such variability disrupts sowing schedules, reduces crop yields, and increases the risk of crop failure. Because a large share of Indian agriculture is still rainfed, even small climatic shifts can have serious consequences for national food production and rural livelihoods (IPCC, 2022).The remarkable gains of the Green Revolution helped India achieve food self-sufficiency, yet the long-term overuse of fertilizers, water, and intensive tillage has strained soils and ecosystems. Many regions now show declining productivity, groundwater exhaustion, and loss of soil organic matter (Jat *et al.*, 2020). These realities highlight the need to rethink how crops are produced not just to increase output, but to sustain it over time. Climate Smart Agronomy has emerged as a practical response to this challenge. Rather than focusing solely on yield, it promotes a balanced approach that improves productivity, strengthens resilience, and reduces agriculture's environmental footprint (FAO, 2021). By

blending traditional wisdom with modern science, CSA supports farming systems that are both economically viable and ecologically sound.

Major Climate Smart Agronomic Strategies

1. Conservation Agriculture: Protecting the Soil:

Healthy soil is the foundation of sustainable farming. Conservation agriculture encourages minimal soil disturbance, retention of crop residues, and diversified crop rotations. These practices reduce erosion, conserve moisture, and build soil organic carbon. Over time, the soil becomes more fertile and better able to withstand drought and heat stress. Farmers adopting zero tillage in regions like the Indo- Gangetic Plains have reported reduced costs and improved soil structure (Jat *et al*., 2020).

2. Crop Diversification: Reducing Risk:

Relying on a single crop makes farming vulnerable to climate shocks. Diversifying with pulses, oilseeds, and climate-resilient millets spreads risk and improves nutritional security. Millets, for example, require less water, tolerate heat, and grow well in marginal soils, making them suitable for semi-arid regions (Government of India, 2023). Including legumes also enriches soil nitrogen naturally, reducing dependence on chemical fertilizers.

3. Integrated Nutrient Management: Feeding the Soil Sustainably:

Excessive fertilizer use not only raises costs but also harms soil health and contributes to greenhouse gas emissions. Integrated Nutrient Management (INM) combines organic manures, crop residues, compost, and bio-fertilizers with balanced chemical inputs. This approach improves nutrient-use efficiency and restores soil biological activity, ensuring long-term fertility (Ladha *et al*., 2020).

4. Smart Water Management: Every Drop Counts:

Water scarcity is becoming a defining issue for Indian agriculture. Climate-smart practices promote efficient irrigation systems such as drip and sprinkler irrigation, laser land leveling, and water-saving rice cultivation techniques. These methods deliver water directly to plant roots, reducing wastage and increasing productivity per unit of water (Kumar *et al*., 2021). Rainwater harvesting and farm ponds further strengthen resilience in drought-prone areas.

5. Climate-Resilient Crop Varieties:

Plant breeders have developed crop varieties capable of tolerating drought, salinity, flooding, and heat stress. These improved cultivars help maintain yields even when weather conditions are unfavorable. Institutions like ICAR continue to release region-specific climate-resilient varieties suited to India's diverse agro-ecologies (ICAR, 2022).

6. Agroforestry: Farming with Trees:

Integrating trees into farming systems provides multiple advantages. Trees improve microclimates, reduce soil erosion, enhance biodiversity, and capture atmospheric carbon. They also provide additional income through fruits, timber, or fodder, helping farmers diversify their livelihoods (Dhyani *et al*., 2021). Agroforestry thus supports both climate adaptation and mitigation.

7. Digital Tools and Precision Agriculture:

Technology is becoming an important ally in climate-smart farming. Mobile-based weather forecasts, satellite imagery, and precision nutrient tools enable farmers to make timely decisions about sowing, irrigation, and pest management. Such information-driven agriculture reduces uncertainty and optimizes resource use (Singh *et al*., 2023).

8. Integrated Farming Systems: Recycling for Sustainability:

Integrated Farming Systems combine crops with livestock, poultry, fisheries, or composting units. Waste from one enterprise becomes an input for another, reducing external dependence and improving overall farm efficiency. These systems enhance income stability while promoting ecological balance, particularly for smallholders.

Conclusion

Climate change is reshaping the realities of Indian agriculture, making it essential to move beyond traditional production models. Climate Smart Agronomy provides a holistic

framework that combines productivity, resilience, and environmental stewardship. Through practices such as conservation agriculture, efficient resource management, diversification, and technological integration, it enables farmers to adapt to uncertainty while safeguarding the natural resource base. Adopting climate-smart approaches is no longer optional it is necessary for ensuring food security, sustaining farmer livelihoods, and protecting ecosystems. By embracing these strategies, India can build an agricultural system that is not only productive today but also sustainable for generations to come.

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