



Smart Agriculture: Adapting Farming Practices to Climate Change

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In the twenty-first century, shifting consumption patterns, population increase, and competition for natural resources like land, water, and energy are posing severe challenges to food systems around the world. Agriculture, livelihoods, and food security are all seriously threatened by climate change, especially for the millions of smallholder farmers who are most at risk from its effects. In addition to speeding up global warming, rising greenhouse gas emissions from deforestation, land degradation, and unsustainable farming methods have also decreased ecosystems' natural ability to absorb carbon (Lipper *et al.*, 2014). Traditional agricultural intensification, which prioritized yield maximization over sustainability, has resulted in major environmental issues across the globe. In order to ensure the long-term sustainability of agriculture, the Sustainable Intensification (SI) concept highlights the necessity of increasing food output from current acreage while reducing environmental impacts (Pretty & Bharucha, 2014).

Goals and Principles

It has emerged as a holistic approach to address the interconnected challenges of productivity, resilience, and environmental sustainability (FAO, 2013). CSA is not a new production system but a framework for identifying locally suitable farming practices and institutions that best respond to climate challenges. It emphasizes three core goals:

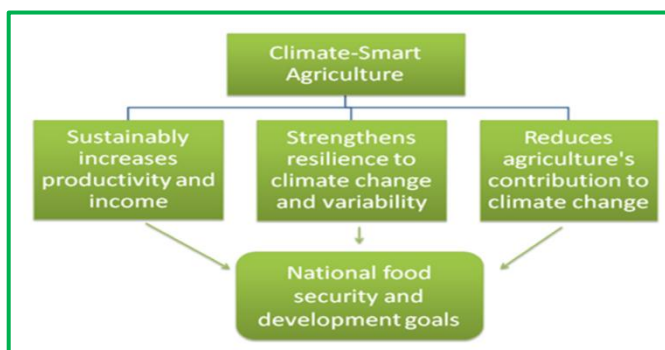
- Increasing agricultural productivity to support food security and rural incomes.
- Enhancing adaptive capacity at farm, community, and national levels.
- Reducing GHG emissions while increasing carbon sequestration (Lipper *et al.*, 2014; FAO, 2019).
- CSA strengthens livelihoods by promoting efficient resource use, ecosystem management, and adoption of climate-resilient technologies. It also integrates climate considerations into national agricultural policies, investments, and programs, ensuring that strategies are sustainable in the long run (Campbell *et al.*, 2016).
- Importantly, CSA applies an integrated landscape approach, linking agriculture with biodiversity conservation, water management, and energy efficiency, thereby creating synergies while addressing potential trade-offs (Thornton *et al.*, 2018).

Future

The idea of CSA emphasizes the critical connection between addressing climate change through agricultural development and attaining food security (FAO, 2018). It helps smallholder farmers manage risks associated with climate change, increase their capacity for adaptation, and lessen their vulnerability (Campbell *et al.*, 2016). CSA encourages both mitigation and adaptation strategies by emphasizing ecosystem management and sustainable land-use planning, which makes it a successful strategy for agricultural development going forward. Additionally, CSA supports Sustainable Intensification by making sure that the expansion of food production does not compromise social justice or environmental health. When combined, SI and CSA greatly enhance global food and nutritional security while

supporting sustainable development goals and global climate goals (Pretty and Bharucha, 2014; Lipper *et al.*, (2014). In this sense, CSA offers a route to a climate-resilient future while simultaneously guaranteeing farming communities' resilience.

Given these threats, there is an urgent need to rethink traditional farming models and adopt systems that are more resilient, sustainable, and environmentally responsible. This is where the concept of Climate-Smart Agriculture (CSA) emerges as a practical solution. Introduced by the Food and Agriculture Organization (FAO), CSA is not a single technology but a holistic framework that integrates three key objectives:



Benefits of climate-smart agriculture

Predicted Impacts of Climate Change on Agriculture

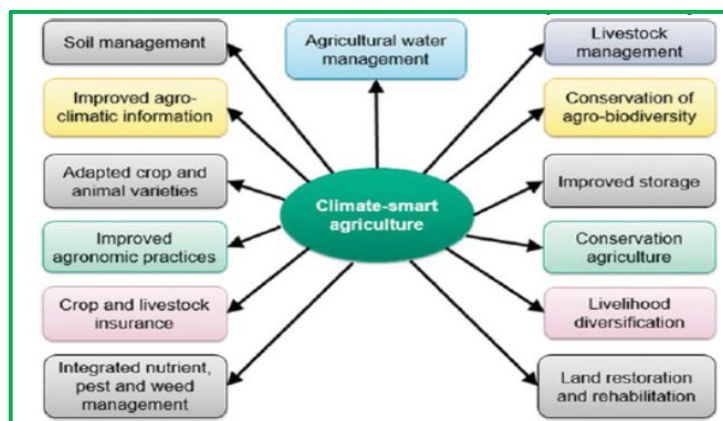
Agriculture, being a climate-sensitive sector, is one of the most severely affected domains under global warming and climatic variability. The impacts are multidimensional, influencing not only crop growth and productivity but also natural resources, pest dynamics, and the socio-economic well-being of farmers. Below are the major ways in which climate change disrupts agriculture:

S.No.	Climatic Element	Expected Changes by 2050s	Effects on Agriculture
1	CO ₂ level	Increase from 360 ppm to 450–600 ppm	Good for some crops; enhances photosynthesis; decreases water use
2	Temperature	Rise by 1–2 °C; more frequent heat waves; winters warming more than summers	Heat stress risk; more evapotranspiration; shorter and earlier growing seasons; crops shifting to north & higher altitudes
3	Precipitation	Seasonal changes by $\pm 10\%$	Drought stress in some areas; flooding in others; affects soil workability, irrigation supply, and transpiration
4	Sea level rise	Increase by 10–15 cm in south (offset in north by natural subsistence)	Flooding, coastal erosion, land loss; increased soil salinity and groundwater salinization
5	Storminess	More intense rainfall; higher frequency of strong winds (esp. north)	Lodging of crops; increased soil erosion; reduced rainfall infiltration
6	Variability	Increases across most climatic variables; predictions uncertain	Higher risks of droughts, floods, heat waves, and frost damaging crops and livestock

Predicted impact of climate change on agriculture (Brijesh *et al.*, 2017)

Climate-Smart Farming Practices

Climate-Smart Agriculture (CSA) is built on a set of farming practices that simultaneously improve productivity, enhance resilience, and reduce greenhouse gas emissions. These practices are not isolated techniques but integrated approaches that can be tailored to local environments. Here are some of the key climate-smart practices.



Climate-Smart Farming Practices (Hussein, A. 2024).

Pillars of Climate Smart Agriculture

- Increased agricultural productivity and incomes over time: (To ensure food security and improve livelihoods).
- Adaptation and building resilience to climate change: (Helping farmers cope with climate-related stresses like droughts, floods, pests).
- Reduction and/or removal of greenhouse gas (GHG) emissions: (Mitigating climate change through practices like agroforestry, conservation tillage, efficient input use).

Policy and Institutional Support

The success of Climate-Smart Agriculture (CSA) depends not only on farm-level innovations but also on strong policy frameworks and institutional backing. Farmers, particularly smallholders in developing countries, often lack the resources, knowledge, and financial capacity to adopt advanced practices on their own. Therefore, supportive policies, institutional mechanisms, and enabling environments are crucial to ensure large-scale adoption of CSA.

- a) **Subsidies and Incentives for CSA Technologies:** High initial costs of climate-smart technologies such as drip irrigation, sprinkler systems, solar pumps, precision machinery, and IoT-based tools discourage farmers from adopting them. Governments can bridge this gap by offering subsidies, tax exemptions, and low-interest loans. For example, India's Pradhan Mantri Krishi Sinchai Yojana (PMKSY) provides financial assistance for micro-irrigation, while various state governments subsidize solar pumps to promote renewable energy. Incentive schemes encourage farmers to adopt sustainable methods without being burdened financially.
- b) **Crop Insurance Schemes to Protect Against Climate Risks:** Climate change has made farming increasingly uncertain, with crop losses due to droughts, floods, and pest outbreaks becoming more frequent. Crop insurance provides a safety net by compensating farmers for yield losses, reducing distress and financial instability. India's Pradhan Mantri Fasal Bima Yojana (PMFBY) is a landmark initiative that insures crops against climatic risks. Similarly, in developed nations, weather-indexed insurance schemes link payouts to measurable parameters like rainfall or temperature, ensuring quick relief. Insurance not only reduces vulnerability but also encourages farmers to adopt riskier but more productive climate-smart practices.
- c) **Capacity-Building and Farmer Training Programs:** Even when technologies are available, farmers often hesitate to adopt them due to lack of knowledge and confidence. Capacity-building programs, farmer field schools, training workshops, and digital advisory platforms play a critical role in spreading awareness about CSA practices. Institutions such as the Krishi Vigyan Kendras (KVKs) in India, agricultural universities, and NGOs regularly conduct training sessions on soil health management, integrated pest management, organic farming, and modern irrigation methods. Building farmer capacity ensures that CSA practices are not just introduced but also effectively implemented at the grassroots level.
- d) **Investment in Renewable Energy and Green Infrastructure:** Energy is a key driver of modern agriculture, but dependence on diesel pumps and coal-based electricity contributes significantly to greenhouse gas emissions. Investments in renewable energy solutions, such as solar-powered irrigation pumps, biogas plants, and wind-powered water-lifting devices, reduce both costs and emissions. For example, India's Kisan Urja Suraksha Evam Utthaan Mahabhiyan (KUSUM) scheme promotes solar irrigation systems, enabling farmers to irrigate crops while selling surplus energy back to the grid. Similarly, investments in climate-resilient infrastructure such as rainwater harvesting systems, check dams, and climate-proof storage facilities strengthen long-term adaptation.
- e) **Institutional Coordination and Policy Integration:** CSA requires coordination across multiple sectors-agriculture, water, energy, forestry, and rural development. Policies must therefore be integrated and holistic. For instance, promoting agroforestry should align

with forest policies, while promoting efficient irrigation must be connected with water management programs. International frameworks such as the Paris Climate Agreement and national climate action plans emphasize agriculture as a central element of climate mitigation and adaptation strategies. Multi-stakeholder collaborations between governments, research institutions, private companies, and farmer cooperatives create an enabling ecosystem for CSA.

Conclusion

Climate-Smart Agriculture (CSA) is an integrated approach to food security and environmental challenges that simultaneously tackles the problems of hunger, climate change, and environmental degradation by making agriculture more productive, more resilient, and more sustainable. Adoption of practices such as conservation agriculture, precision farming, agroforestry, and renewable energy not only ensures the livelihood of farmers, but also the stability of ecosystems; large-scale adoption (especially among smallholders) requires policy support, financial incentives, and farmer capacity-building. In India and many other countries, CSA is a necessity for food and nutritional security, natural resource conservation, and sustainable development goals. CSA ultimately becomes the pathway to transition agriculture into a climate-resilient, resource-efficient, and environmentally responsible sector.

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