

# Climate-smart agriculture : The role of conservation agriculture in adaptation and sustainability

**Amrit L. Meena\*, Raghavendra Singh, P. C. Jat, P. C. Ghasal, Raghuv eer Singh, Mohd. Arif, Jairam Choudhary, Kamlesh Kumar and Sunil Kumar**

ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh 250 110

*Amid the concern for climate change, climate-smart agriculture (CSA) practices have emerged as a promising solution. CSA is an integrated approach to address the challenges of food security and climate change through sustainable and resilient agriculture systems. Among the various CSA practices, conservation agriculture has emerged as a resource efficient, innovative technology in the changing climate scenario. This approach promotes collaboration among policymakers, farmers, researchers, and institutions to implement context-specific solutions, fostering agricultural systems that are economically viable, socially inclusive, and environmentally sustainable.*

**Keywords:** Climate change, Climate-smart agriculture, Conservation agriculture

**C**LIMATE change is one of the most pressing challenges in the present era especially in the developing nations. Economies that are heavily dependent on agriculture like India and other South Asian Region are particularly vulnerable to climate change, because of the close association of economic stability, employment rates, and food security with climate change. Increased temperature, unpredictable rainfall patterns, extreme weather events have direct impacts on agriculture leading to crop failure, soil

degradation, water scarcity, loss of biodiversity, and decreased yield levels. To tackle these challenges and make transition towards sustainable agriculture, climate-smart agriculture (CSA) has emerged as a vital approach. CSA encompasses strategies that increase resilience to climate change, boost productivity, and reduce greenhouse gas (GHG) emissions. The goal of CSA is to sustainably enhance agricultural productivity, management of water resources, environmental protection, crop diversification and climate change



Pillars of climate-smart agriculture

mitigation. Variety of practices designed to improve the agricultural efficiency, resilience and sustainability are included in CSA.

### Climate-smart agriculture

**Evolution:** The Hague Conference on Agriculture in 2010 organized by Food and Agriculture Organization (FAO) with the aim of discussing the role of climate change on food security played a pivotal role in the inception of CSA. CSA is a comprehensive approach of agricultural production and development and is strategically crafted to facilitate sustainable agriculture efficiency, adaptability to changing environmental conditions, reduction in GHGs emissions and steadfastly securing national food security. This approach represents a rigorous scientific strategy for advancing agriculture that is specifically tailored to adjust agricultural techniques in light of human-induced climate change.

**Objectives:** The crucial aim is to simultaneously achieve the goals of both mitigation and adaptation aspects of climate change concurrently. This approach is designed to effectively support broader development initiatives while safeguarding food security amidst the dynamic issues presented by climate change. CSA incorporates the triad of environmental, economic, and social factors through collaborative efforts to alleviate the repercussions of a changing climate on food security while simultaneously fostering sustainable growth in agriculture. This integration involves the incorporation of institutional, technological, and policy measures, with their effectiveness contingent on the specific spatial and temporal context.

**Key practices:** The range of approaches and practices applicable to agricultural or farming systems at diverse levels are involved in CSA with the amalgamation of emergent and traditional agricultural practices including agroforestry, conservation agriculture and sustainable land management practices. At the small-scale farming system, CSA includes the judicious use of compost, use of improved crop varieties, proficient crop residue management, integration of agroforestry, soil and water conservation measures. Overall, CSA strategies utilize the innovative and sustainable farming practices to alleviate the detrimental influence of climate change.

**The three pillars:** CSA centres around three fundamental pillars: food security, improving strategies for adapting to shifting climatic conditions, and actively contributing to effective mitigation efforts. These three pillars collectively serve as the cornerstones of CSA, with the overarching objective of tackling the challenges presented by climate change and fostering farming systems that are both sustainable and productive. To enhance the resilience of food systems, it is essential to equip them with the capability to adjust with climatic variations, improve carbon sequestration and curtail the GHGs emissions from the agricultural ecosystems.

### Climate smart-agricultural practices and benefits

Several emerging and traditional agricultural practices have been included among the CSA practices.

**Table 1.** Benefits of climate smart agricultural practices

CSA practices	Benefits
Agroforestry	<ul style="list-style-type: none"> <li>Carbon sequestration to capture and store carbon dioxide (CO<sub>2</sub>)</li> <li>Mitigation of GHGs emissions</li> </ul>
Mulching	<ul style="list-style-type: none"> <li>Straw, plastic and bio-mulching serve as efficient techniques in mitigating GHGs emissions.</li> <li>Ensures stable crop production</li> <li>Improves water use efficiency</li> <li>Blocks sunlight and prevent the evaporation, thus maintain soil temperature.</li> <li>Enhances yield and optimizes water utilization efficiency</li> <li>Improve crop production</li> </ul>
Crop rotation	<ul style="list-style-type: none"> <li>Improve soil fertility</li> <li>Improve resilience to hot and dry spells.</li> </ul>
Intercropping	<ul style="list-style-type: none"> <li>Enhances crop yields with low-input systems of farming</li> </ul>
Row planting	<ul style="list-style-type: none"> <li>Reduces seed rates.</li> <li>Provides more space for plant canopy</li> <li>Reduces competition among the seedlings</li> <li>Boots productivity</li> <li>Enhances resilience to climate change impacts</li> <li>High productivity encourages farmers to adopt row-planting techniques, giving them a competitive edge.</li> </ul>
Zero tillage/conservation agriculture	<ul style="list-style-type: none"> <li>Improve soil water content.</li> <li>Improves soil, physical, chemical and biological properties</li> <li>Facilitates soil conservation in long-term</li> <li>Reduces soil compaction and disturbance</li> <li>Reduces input cost and improves total production</li> <li>Mitigate the GHGs emissions</li> </ul>
Improved varieties	<ul style="list-style-type: none"> <li>Enhancing the soil structure</li> <li>Higher crop production</li> </ul>
Water harvesting and irrigation	<ul style="list-style-type: none"> <li>Ensures sustainable agricultural productivity</li> <li>Mitigating the impacts of water scarcity in future.</li> </ul>

Source: S. Bhatnagar *et al.* (2024)

Among the key practices within CSA, conservation agriculture (CA) has gained prominence for its transformative impact on soil health, biodiversity, and carbon sequestration, helping farmers adapt while promoting sustainability.

### Conservation agriculture

Conservation Agriculture is a farming system built on three primary principles designed to improve soil health and increase resilience to climate challenges. Under the different circumstances, the conservation agriculture and its derivatives i.e. minimum soil disturbance, soil cover and species diversification are effective methods for achieving the targets of climate-smart agriculture.

**Minimum soil disturbance (No-till farming):** The reduction or elimination of tillage has demonstrated the favourable effects on various soil aspects i.e. improved soil organic carbon, enhanced C sequestration, reduced GHGs emissions, soil biodiversity conservation, enhanced nutrient cycling and effective soil erosion



Principles of conservation agriculture

control. The improved crop yield in no-till/zero till/reduced tillage soils are attributed to improved soil and water content, increased soil organic matter, including essential nutrients such as nitrogen, phosphorus, potassium and sulphur.



Minimum mechanical soil disturbance



Permanent soil cover

**Permanent soil cover (Cover cropping and mulching):** Cover crops result in the stability of the CA system, not only by the improvement of soil properties but also their capacity to promote an increased biodiversity in the agro-ecosystem. Year-round soil cover with crop residues, cover crops, or mulching techniques helps to protect soil erosion, improve water retention, mobilize and recycle nutrients, effective weed control, protect soil during fallow periods, provide biological tillage and regulate soil temperature.

**Species diversification (diverse crop rotation and intercropping):** The species diversification (crop rotation) functions as biological pump as diverse crops extract the nutrient from different soil depths, provide diverse diet to soil microorganisms, recycle of nutrients from deeper soil layers, work as phytosanitary function due to prevention of crop-specific pest and diseases, and result in diversification of soil flora and fauna.





Species diversification

### Conservation agriculture and climate change adaptation and mitigation

Conservation agriculture is considered as climate-smart agriculture, as strategically it empowers the farmers to adjust and alleviate the negative impacts of climate change while boosting the income and productivity in current farming system. Table 2 illustrates the various measures of climate change adaptation and mitigation through conservation agriculture.

**Table 2.** CA practices for climate change adaptation and mitigation

Climate change	CA strategies	Benefits
Adaptation	Water management	Reduced drought vulnerability Improved crop performances during dry spells.
	Resilient cropping systems	Decreased dependency on single crops/cropping system Improved resilience to climate-induced stresses.
	Erosion control	Improved soil fertility and crop productivity in long-term Reduced vulnerability in extreme weather events.
Mitigation	Carbon sequestration	Improved soil organic carbon acts as C sink
	Reduced emission	Reduced/zero tillage and soil cover reduced the fuel use. Reduces GHGs emission
	Efficient inputs	Precision nutrient management reduces resource wastage and associated emissions.
Sustainability and socioeconomic benefits	Economic viability	Decreased input costs and improved profitability
	Social inclusion	Supports small and marginal farmers through reduced labour, fuel and energy intensive practices.
	Ecosystem services	Improve biodiversity Enhanced water quality Decreases off-site impacts i.e. sedimentation.

### Determinants influencing adoption of climate-smart agriculture

Even with the several beneficial impacts of CSA, adoption of CSA practices in developing countries like India is influenced by a combination of factors i.e. socioeconomic, institutional, environmental, technological, cultural and behavioural, economic context, information and communication, and policy supports. Table 3 contains the determinant and their adaptability.

**Table 3.** Different determinants for adoption of climate smart agriculture

Determinants	Limitations
Socio-economic	<ul style="list-style-type: none"> <li>Poor education and awareness levels of farmers</li> <li>Low-income level of farmers hinders the initial investment in CSA practices</li> <li>Higher number of small and marginal farmers in country</li> <li>Limited accessibility of financial resources to resource poor farmers</li> </ul>
Environmental	<ul style="list-style-type: none"> <li>Increases in climate vulnerability hinders the small and marginal farms to adopt CSA.</li> <li>Poor soil quality and limited water recourses</li> <li>Suitability of CSA has high compatibility issues with local environment</li> </ul>
Institutional	<ul style="list-style-type: none"> <li>Poor extension services limit the awareness of CSA benefits.</li> <li>Absence of Government policies, incentives and subsidies for CSA</li> <li>Poor access to markets by resource poor farmers</li> </ul>
Technological	<ul style="list-style-type: none"> <li>Availability of appropriate technologies for CSA</li> <li>Appropriateness of CSA technologies for the specific farming context.</li> <li>Poor technical knowledge and skills of farmers</li> </ul>
Economic context	<ul style="list-style-type: none"> <li>Poor cost: benefit ratio in the initial years of CSA adoption</li> <li>Inappropriate benefits in terms of yield, profitability and resilience at initial level.</li> <li>Unavailability of premium prices for the products</li> </ul>
Cultural and behavioural	<ul style="list-style-type: none"> <li>Resistance to change from traditional practices</li> <li>Poor access of knowledge sharing by success farmers to others</li> <li>Risk aversion</li> </ul>
Information and communication	<ul style="list-style-type: none"> <li>Unavailability of timely and accurate information</li> <li>Poor accessibility to ICT tools i.e. mobiles, apps, other digital tools</li> </ul>
Policy support	<ul style="list-style-type: none"> <li>Poor accessibility of trainings, funding or resources access.</li> <li>Less involvement of private sector</li> <li>Community collaboration</li> <li>Gender equality</li> <li>Trust in institutions</li> </ul>

### SUMMARY

Climate smart agriculture (CSA) is an integrated approach to address the climate change and food security through sustainable agriculture production, reduced GHGs emissions and building resilience to changing climate impacts. CSA promotes sustainable land management, improved nutrient and water use efficiency, crop diversification and C sequestration through practices i.e. agroforestry, conservation agriculture etc. CA is a climate smart approach to promote the sustainable farming through minimal soil disturbance, permanent soil cover and crop diversification that enhances soil health, biodiversity, water retention and reduction GHGs emissions. CSA emphasizes stakeholder involvement, context-specific solutions, and innovative financing to ensure long-term sustainability. By resilience, enhancing productivity, and environmental health, CSA contributes to global efforts of achieving food security and combating climate change.

\*Corresponding author email: amrit.iari@gmail.com