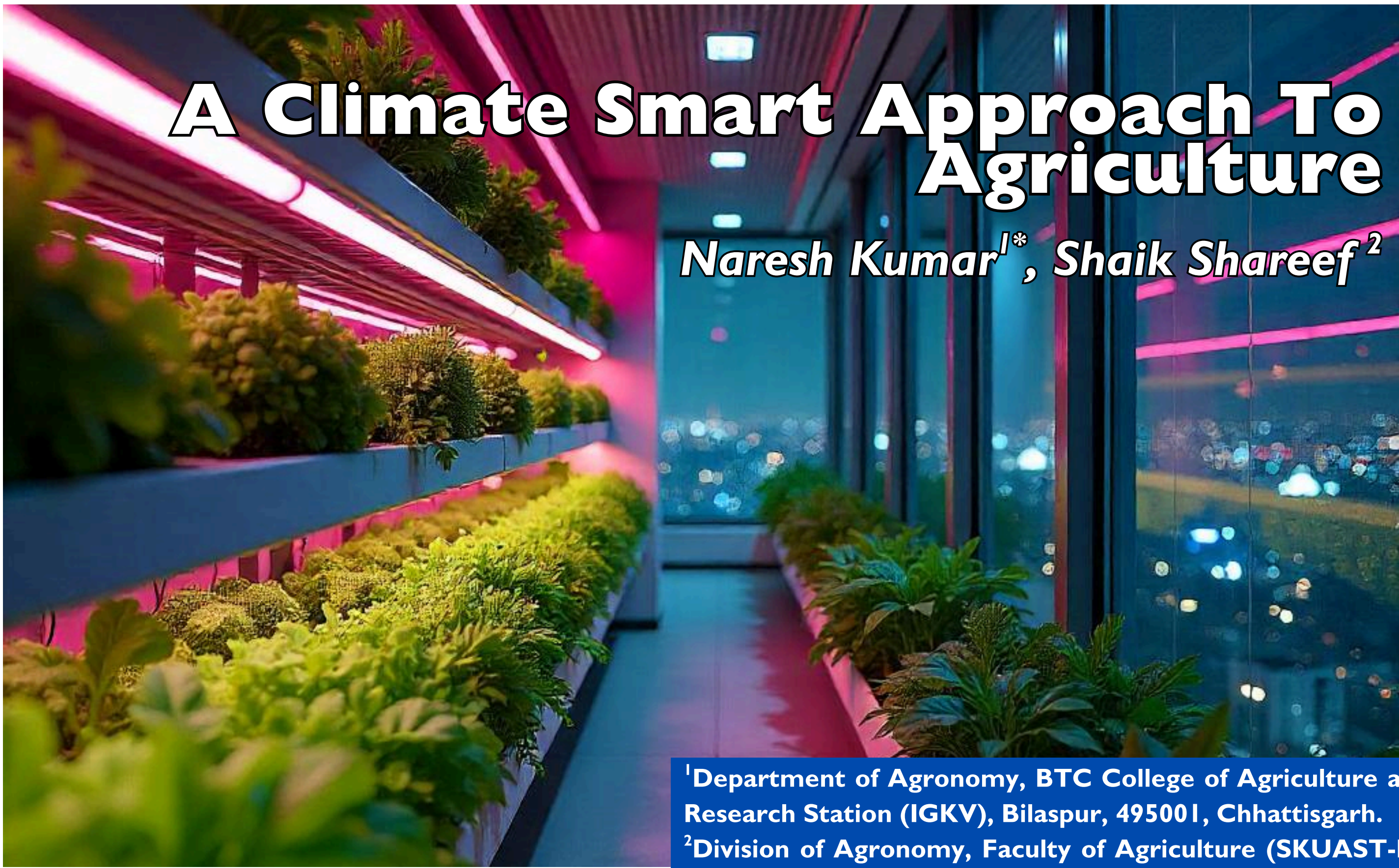
ENLIGHTEN Agriculture

ISSN: 3049-3293
Volume: 1, Issue: 2, April 2025
Article No.: 06

A Climate Smart Approach To Agriculture

Naresh Kumar[1*], *Shaik Shareef*[2]

[1]Department of Agronomy, BTC College of Agriculture and Research Station (IGKV), Bilaspur, 495001, Chhattisgarh.
[2]Division of Agronomy, Faculty of Agriculture (SKUAST-K), Wadura, Sopore, 193201, J&K.
*Email: nareshthappa671@gmail.com



Abstract

As we experienced in our daily life that human population are increasing enormously while our resources for livelihood are limited like land, fresh water. Accordingly, we have to think wisely for our future generations also. CSA is a holistic approach that integrates sustainability, resilience and productivity to address the challenges of food security and climate change. Its main aim to transforming the agricultural systems to be more productive, resilient and sustainable in the face of climate change e.g., use of drought resilient varieties, conservation agriculture, crop diversification, soil conservation techniques, use of drones and sensors for precision farming, carbon sequestration and reduce pollution by minimising the use of fertilizers and pesticides.

Key words: Climate-smart agriculture, sustainability, climate resilience, adaptation strategies, digital agriculture.

Introduction

Agriculture stands at the intersection of two of the most serious global challenges of the future generations ensuring their sustainable growth in food security for a growing population and minimise the harmful impacts of climate change. As the global population is projected to reach nearly 10 billion by 2050, the demand for food is expected to increase significantly. As emphasized by FAO (2021), climate-smart agriculture constitutes innovations which are aligned with three purposes: (a) Increase in sustainable productivity of crops; (b) enhance the resilience of crops against mighty change of climate and (c) minimise the greenhouse gas emissions. However, climate change give a significant threat to agricultural productivity, as increasing temperatures cause a remarkable decline in wheat production worldwide due to rise of temperature in early February coincide with flowering. Recent studies carried out in India

ISSN: 3049-3293
Volume: 1, Issue: 2, April 2025
Article No.: 06

highlights the possible loss of 4-5 million t/ha in wheat production with every 1°C increase in temperature (Aggarwal et al., 2008), unpredictable precipitation patterns and a higher occurrence of intense disastrous weather events interfere with global food systems.

Need of CSA Adoption

The importance of adopting CSA practices is underlined by the divergent impact of climate change on vulnerable communities, particularly small land holder farmers in the developing countries. These farmers, who contribute significantly to global food production, often lack the resources and technologies needed to cope with climate-related risks. CSA provides a framework to empower these communities through research and development, innovative implementation of the paramount practices such as conservation agriculture, natural farming, agroforestry, precision farming, and improved package of practices all of which enhance productivity while minimising environmental footprints.

Challenges

Global warming is the steady rise in the surface average earth's temperature which significantly increase the levels of greenhouse gases in the atmosphere. These gases are mainly CH_4, CO_2, N_2O and O_3.

According to the IPCC (2007), these GHG emissions could rise by 25 – 90% by 2030 relative to 2000 and the earth could warm by 3 °C at the end of this century.

The Intergovernmental Panel on Climate Change (IPCC) forecasts that even a temperature increase of 1-2.5°C will lead to severe adverse effects, including the decline in crop yields in tropical and subtropical regions, increase the risk of food shortages, proliferation of climate-sensitive diseases like malaria, and an elevated threat of extinction for 20–30% of Earth's biodiversity.

Since the pre-industrial era, human-induced emissions have significantly elevated atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The harmful and detrimental impact of climate change on global crop production has been extensively documented. (e.g., Challinor et al., 2014; Kuwayama et al., 2019; Lachaud et al., 2021; Miller et al. 2021; Schmitt et al., 2022).

For example, the Latin America and the Caribbean study by Lachaud et al., (2021) showed that climate change reduces farm productivity by 9.03–12.7% in 2015–2050. Analyzing a half-decade panel dataset, Amale et al., (2022) demonstrated that delayed monsoon onset harms crop production in India. The adverse impacts of global climate change, coupled with the imperative to enhance agricultural productivity, necessitate the adoption of Climate-Smart Agriculture (CSA) practices to alleviate climate-induced challenges. However, the widespread implementation of CSA is impeded by several factors, including substantial initial investment requirements, limited access to technological innovations, and insufficient policy support. Additionally, the success of CSA initiatives often depends on the integration of local knowledge, stakeholder collaboration, and supportive institutional frameworks.This review paper aims to explore the principles, practices, and policies underpinning climate-smart agriculture, critically analyse its benefits and limitations, and highlight opportunities for scaling up its implementation.

Resolution of challenges

By integrating the traditional knowledge of research which are usually based on natural practices and existing along with the role of emerging technology i.e., artificial intelligence for providing better and sustainable future for the farming communities, so that farmers get maximum benefits while utilizing optimum resources. It also aims to identify gaps in current knowledge and propose directions for future research, with the ultimate goal of informing policymakers, researchers, and practitioners in their efforts to build climate-resilient food systems.

ISSN: 3049-3293
Volume: 1, Issue: 2, April 2025
Article No.: 06

In a world grappling with the dual crises of climate change and food insecurity, climate-smart agriculture offers a beacon of hope, bridging the divide between environmental sustainability and agricultural productivity.

Overview of Climate-Smart Agriculture (CSA)

Climate smart agriculture is a holistic approach that integrates various components and make a way for the sustainable food security, climate resilient varieties, adaptation towards drought and stress. It is generally based on three important points.

1. Increasing Agricultural Productivity and Incomes: CSA aims to sustainable increment in crop yields to fed the growing demand for food while improving farmers' livelihoods status. It is clear, if the farmer of a country are satisfied with the government decisions and they earned surplus production then the country revenue enhanced by manifolds especially in developing countries like India. So we have to assure our farmers by giving them maximum benefits such as by implementing various government schemes and MSP for their products.

2. Adaptation and Resilience: CSA focuses on building the capacity of agricultural systems to resist climate-related shocks, such as stress, droughts, floods, and extreme weather conditions.

3. Reduce the emissions of the Greenhouse Gases: There are several factors which significantly contributes towards GHGs emissions such as emission of CH_4 from the paddy field, N_2O emits from fertilizers industry and cattle livestock, O_3 emission pose serious health impacts on living beings.

Management

- Reduce dependency on synthetic nitrogen fertilizers like urea, the highest contributor of GHG emission due to its widespread uses.
- To effectively manage N_2O emissions from livestock, major focus on improving the nitrogen use efficiency and reduce nitrogen input.
- To manage CH_4 emission from paddy field, adopt Alternate wetting and drying method which saves water also.

The idea of Climate-Smart Agriculture (CSA) arose from the understanding that conventional farming methods are inadequate to tackle the problems posed by climate change. By incorporating climate-related factors into agricultural planning and practices, CSA offers a comprehensive approach to achieve the goal of especially Zero hunger SDG 2 and Climate Action SDG 13.

Key Practices and Technologies in CSA

I. Sustainable Farming Practices

II. Better practices of land and water management

III. Technological Innovations

I. Sustainable Farming Practices

a.) Conservation Agriculture: Conservation agriculture involves minimal soil disturbance, use of zero tillage, soil cover with green manure or crop residue (mulching), and crop rotation to improve soil structure, porosity, and organic matter accumulation while saving fuel, time, and labour. Conservation tillage improves soil fertility, water, and crop productivity, while no-tillage provides better soil protection than conventional tillage, which leaves only 1-5% of the soil surface covered with crop residues

b.) Agroforestry: Integrating trees into farming systems increases biodiversity, sequestration of carbon, and provides additional income sources for farmers such as timber, fuel, food, fodder, medicines etc.

c.) Integrated Pest Management (IPM): Reducing reliance on chemical pesticides by using biological controls like neem oil for altering the behaviour of insects and crop diversification minimizes environmental impacts.

d.) Crop diversification and crop intensification: Crop diversification is to alternatively sow different crops in a sequence in the same piece of land in the same year to next year. And crop intensification is that instead of doing one crop, grow two crops and instead of two crops grow three crops in a sequence in same year.

II. Better practices of land and water management

Improving land and water management is important for sustainable agriculture, eco-friendly environment and tackle the threats of soil degradation, climate change and water scarcity. The following practices are as:

Land management

1. Crop rotation: It is the rotation of different crops on the same piece of land generally cereals are followed by legumes and tap root system crop by shallow rooted crop.

It plays an important role in climate smart agriculture as it maintains the soil fertility, soil structure, increased water holding capacity of soil and soil organic matter content.

2. Zero tillage: In which the primary tillage is completely avoided and secondary tillage is restricted to row zone only. It's a key component of CSA helps by reducing the emissions of GHGs as lower fossil fuel use, enhancing the carbon sequestration in soil and maintains the microbial population of the soil.

3. Agroforestry: It supports CSA by enhancing the overall agricultural productivity and diversification, enhance the carbon sequestration, increase resilience to climate change.

4. Zero budget natural farming: Focus on locally available inputs where one enterprise becomes the output of other enterprise. It maintains the soil fertility by restricting the use of synthetic fertilizers, minimise vulnerability to climate change impacts, also reduce environmental pollution.

5. Cover cropping: such as cowpea has a large canopy protects the soil from erosion, fixes atmospheric nitrogen in the root nodules, enhance nutrient availability to the succeeding crops.

Water management

1. Drip irrigation: Drip irrigation can be defined as the process of slow application of water in the form of discrete, continuous drop, tiny streams or miniature sprays through mechanical devices called emitters. Modern drip technology was invented by Simcha Blass in Israel. It is also known as trickle system. Drip system has the greatest potential where water is scarce or expensive.

Advantages of Drip irrigation

- 40-70% saving of water
- 25-100% increase in yield
- 50% saving in energy by reducing pumping hours and friction losses.
- Drip is better for saline soils not for saline water.

2. Sprinkler irrigation: Sprinkler irrigation is a method of applying water to crops mimicking natural rainfall. It is suited to topographic or hilly areas. It is evolved in 1946. Also known as overhead irrigation.

It is not used if the wind speed is greater than 15Km/hr. It is not ideal for crops, sensitive to fungal disease.

Advantages:

- It saves 25-50% water
- It increases irrigable area 1.5-2 times to that of surface irrigation at the same amount of water.
- Water use efficiency can be increased 3-4 times with sprinkler over irrigating sandy soil with flooding

3. Mulching: It has been referred to the gardener's straw and leaves used as soil cover (Jacks et al,1955). Mulching is the technique of covering the soil surface around the plants with an organic or synthetic material to create congenial conditions for the growth and development of plant and efficient production. (Bakshi et al. 2015).

Advantages of Mulching:

- It maintains the soil temperature.
- It controls the evaporation loss.
- It suppresses the weed growth.
- Increase the infiltration of water.
- Improves microbial activity.
- It controls salinity development.

4. Rainwater harvesting: It is the process of collecting, storing and utilizing rainwater for various purposes such as irrigation, domestic use or groundwater recharge. This sustainable technique helps to conserving water and reduce the impact such as soil erosion especially where erratic rainfall occurs.

III. Technological Innovations

- Precision Agriculture: Using GPS, remote sensing, and data analytics to optimize input use (e.g., fertilizers, water) increases efficiency and reduces

ISSN: 3049-3293
Volume: 1, Issue: 2, April 2025
Article No.: 06

environmental impacts.

- Renewable Energy: Solar-powered irrigation pumps and biogas systems reduce reliance on fossil fuels and lower greenhouse gas emissions.
- Digital Tools: Mobile apps and online platforms provide farmers with real-time weather forecasts, market prices, and advisory services.

Policy and Institutional Frameworks

- **Global Initiatives:** FAO's CSA Framework: The Food and Agriculture Organization (FAO) has been a key advocate for CSA, providing guidelines and technical support to countries.
- **Paris Agreement:** Under the United Nations Framework Convention on Climate Change (UNFCCC), many countries have included CSA in their Nationally Determined Contributions (NDCs) to reduce emissions and enhance resilience.
- **National Policies :** At the global level, the United Nations Framework Convention on Climate Change (UNFCCC) addresses issues related to CSA through a number of frameworks such as REDD+(Reducing Emissions from Deforestation and Forest Degradation, conservation and sustainable management of forests, and enhancement of forest carbon stocks) as well as the Ad-Hoc Durban Platform, National Adaptation Plans, and technology transfer (Campbell et al., 2014).
- **Subsidies and Incentives:** Governments can promote CSA by providing financial incentives for adopting sustainable practices and technologies.
- **Capacity Building:** Training programs and extension services help farmers understand and implement CSA practices.
- **Research and Development:** Investing in agricultural research fosters innovation and the development of climate-resilient technologies.
- **Challenges in Policy Implementation Lack of Funding:** Limited financial resources hinder the scaling up of CSA initiatives.
- **Coordination Issues:**Fragmented efforts among stakeholders (e.g., governments, NGOs, private sector) can reduce the effectiveness of to CSA programs.
- **Policy Gaps:** Inconsistent or inadequate policies may fail to address the specific needs of vulnerable communities.

Benefits and Impacts of CSA

a.) Environmental Benefits

- **Carbon Sequestration:** Practices like agroforestry and conservation agriculture capture and store carbon in soils and vegetation.
- Carbon sequestration potential of agroforestry in India. The CO_2 reduction in atmosphere can only be achieved by shifting from lower biomass land uses (e.g., grasslands, crop fallows etc.) to treebased systems such as agroforestry, forests, and plantation forests (Roshetko et al., 2007). There are ample evidences to show that the overall (biomass) productivity, soil fertility improvement, soil conservation, nutrient cycling, microclimate moderation, and carbon sequestration potential of an agroforestry system is generally greater than that of an annual system (Dhyani et al., 2009). According to Pandey et al., (2002) carbon sequestration in Indian agroforests varies from 19.56 Mg C/ha/yr in north Indian state of Uttar Pradesh to a carbon pool of 23.46–47.36 Mg C/ha/yr in tree-bearing arid agro-ecosystems of Rajasthan.
- Carbon sequestration in terrestrial pools include the above ground plant biomass, such as timber, fuelwood and belowground biomass such as roots, soil microorganisms, and all the forms of organic and inorganic C in soils including deep root zone. In agroforestry systems, two major components i.e., trees and crops are mainly responsible for CO_2 sequestration. The total amount sequestered in each component differs greatly and is dependent largely on a number of factors that includes the type of system (and the nature of components and age of plant), site quality, and previous land-use (Albrecht and Kandji et al., 2003, Newaj and Dhyani et al., 2008).
- **Biodiversity Conservation:** Diverse cropping systems and integrated farming approaches enhance ecosystem resilience.
- **Soil Health:** Improved soil management practices increase organic matter and reduce degradation.

b.) Economic Benefits

- **Increased Yields:** CSA practices often lead to higher productivity, improving farmers' incomes. In agroforestry, nowadays it has a great potential to reduce the impact of climate change alongside increase the income of the farmers

- **Cost Savings:** Efficient use of inputs (e.g., water, fertilizers) reduces production costs. For example, if we intercrop a pulse crop like cowpea in between eucalyptus trees, both have different root depth and growth habit. Cowpea has a shallow root system while eucalyptus has a deep tap root system.
- **Market Access:** Certification schemes for sustainable products can open new markets for farmers. Although International market like Europe and North America get their eco-friendly and sustainable product from India such as jute textiles, renewable energy sources and growing capabilities in biodegradable packaging.

c.) Social Benefits

- **Food Security:** By enhancing resilience and productivity, CSA contributes to stable food supplies. In agroforestry system, we got many products as timber, fuel, food, fodder etc.
- **Gender Empowerment:** Green jobs and the promotion of a green economy are crucial to achieve economic and social development in an environmentally sustainable manner. When aligned with decent work principles, particularly gender equality, they lay a strong foundation for a well-balanced approach to sustainable agriculture and rural development. Sustainable agriculture has the potential to be a net creator of jobs that provide higher returns to labour inputs than conventional agriculture. Rural women are significantly involved in crucial green economy sectors such as agriculture and energy, and clearly they can potentially benefit by turning their reliance on natural resources into opportunities for green and decent jobs. For instance, rural women can participate in a wide array of newly emerging employment opportunities, from running small, resource-based businesses and the environmental maintenance of nurseries and forests to engaging in water and land management, rural ecotour ism, or bio-fuel production based on small-scale, low-in put agriculture.CSA initiatives involve women farmers can improve gender equality and livelihoods.

Community Resilience: Strengthened local capacities enable communities to better cope with climate shocks.

Challenges and Obstacles to CSA Adoption

- **Financial limitations:**High upfront costs for technologies and infrastructure (e.g., irrigation systems, renewable energy) can be prohibitive for smallholder farmers.
- **Knowledge and Awareness Gaps:** Limited understanding of CSA practices and their benefits hinders adoption.Inadequate extension services and training programs exacerbate this issue.
- **Socio-Cultural Factors:** Traditional farming practices and resistance to change can slow the uptake of CSA. Gender disparities may limit women's access to resources and decision-making.
- **Institutional and Policy Barriers:** Weak governance, lack of coordination, and insufficient policy support can impede CSA implementation.

Case Studies and Success Stories

a.) Sub-Saharan Africa

I.In Kenya, the adoption of drought-tolerant maize varieties has increased yields and improved food security for smallholder farmers.

The Drought Tolerant Maize for Africa project aims to mitigate drought and other constraints to maize production in sub-Saharan Africa, increasing maize yields by at least one ton per hectare under moderate drought and with a 20 to 30 percent increase over farmers' current yields, benefiting up to 40 million people in 13 African countries. The project brings together farmers, research institutions, extension specialists, seed producers, farmer community organizations and non-governmental organizations. It is jointly implemented by CIMMYT and the International Institute for Tropical Agriculture, in close collaboration with national agricultural research systems in participating nations. Millions of farmers in the region are already benefiting from the outputs of this partnership, which includes support and training for African seed producers and promoting vibrant, competitive seed markets.

II. In Niger, farmer-managed natural regeneration (FMNR) has restored degraded lands and enhanced resilience to climate change.

b.) South Asia

I) In India, the System of Rice Intensification (SRI) has reduced water use and increased rice yields. Field experiments conducted in many parts of India have shown the significant effect of SRI on root growth, tillering, yield, grain qualities, nutrient uptake and microbial dynamics.

Economics and the adoption pattern by farmers have also been studied. Higher grain yield and straw yield coupled with lowered cultivation costs, leave farmers with higher net income (Stoop et al., 2002; Uphoff et al., 2002; Thiyagarajan et al., 2005; Rajendran et al., 2005).

II. In Bangladesh, floating gardens have enabled farmers to grow crops in flood-prone areas.

c.) Latin America

I. In Brazil, integrated crop-livestock-forestry systems have improved productivity while reducing deforestation and emissions.

Future Directions and Opportunities

a.) Emerging Trends

I. Digital Agriculture: Advances in artificial intelligence, blockchain, and IoT offer new opportunities for precision farming and supply chain transparency.

II. Circular Economy: Integrating waste recycling and resource efficiency into agricultural systems can enhance sustainability.

b.) Research Priorities

The actual aim of farmers and government institutions behind agroforestry was improving rural livelihood and meeting various needs, viz. food, fuel, timber, fodder of the farmers. But in recent era of climate change, agroforestry became economically and ecologically very attractive tool for mitigating harmful effect of GHGs. Since, the Kyoto Protocol allowed industrialized countries with a GHG reduction commitment so as to invest in mitigation projects in the developing and least developed countries under the Clean Development Mechanism (CDM) and there is an attractive opportunity for major practitioners of agroforestry, especially the resource poor farmers (Nair et al., 2009).

I. Interdisciplinary Approaches: Combining agronomy, ecology, economics, and social sciences can provide holistic solutions. Crop productivity is apparently influenced by genetic potential, cultivation practices and climatic factors; of which genetic potential is very important with respect to crop and varietal adaptability under specific conditions. Arid region demands crops and varieties having high tolerance to moisture stress and high temperature stress under limited nutrient availability for climate resilience. The inherent potential of pearl millet, moong bean, moth bean and cluster bean to survive under hot arid conditions made them the principal crops of the region occupying maximum acreage. Earliness in crop varieties is an important trait to add climate resilience in arid environment.

II. Long-Term Studies: More research is needed to assess the long-term impacts of CSA practices on productivity, resilience, and emissions.

c.) Policy Recommendations

- Scaling Up CSA: Governments and international organizations should prioritize funding and capacity-building for CSA.
- Inclusive Policies: Policies should address the needs of marginalized groups, including women, youth, and smallholder farmers.
- Global Collaboration: Strengthening international cooperation can facilitate knowledge sharing and technology transfer.

Conclusion

The study's results offer valuable insights into the impact of CSA adoption. Regarding the first CSA goal to sustainably increase agricultural productivity and incomes, our analysis reveals that CSA adoption enhances farm productivity and incomes through increased crop yields and productivity, income, and technical and resource use efficiency. Addressing the second CSA goal of fostering resilience in people and agrifood systems against climate change, our findings demonstrate that CSA adoption bolsters individuals' resilience by boosting food consumption, dietary diversity, and food security. Moreover, at the system level, CSA adoption enhances agrifood system resilience by mitigating production risks and decreasing vulnerability. Concerning the third CSA goal of lowering GHG emissions, our review establishes that CSA adoption contributes to reducing emissions, including CO_2, N_2O, and CH_4. In addition, CSA adoption promotes carbon sequestration in soils and biomass, thereby improving soil quality.

Reference

Aggarwal, P. K et al., (2008). Global climate change and Indian agriculture: impacts, adaptation and mitigation. Indian Journal of Agricultural Science. 78, 911-919.

Albrecht, A. & Kandji S. T et al., (2003). Carbon sequestration in tropical agroforestry systems. Agriculture, Ecosystems and Environment 99: 15–27.

ISSN: 3049-3293
Volume: 1, Issue: 2, April 2025
Article No.: 06

Amale, H. S., Birthal P. S & Negi D.S et al., (2022) Delayed monsoon, irrigation and crop yields. Agric Econ (United Kingdom):1–18.

Bakshi, P., Wali, V. K., Iqbal, M., Jasrotia, A., Kour, K., Ahmed, R. & Bakshi, M et al., (2015). Sustainable fruit production by soil moisture conservation with different mulches: A review. African Journal of Agricultural, 10(52): 4718-4729.

Campbell et al., (2014). The Role of Agriculture in the UN Climate Talks CCAFS Info Note CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark.

Challinor A. J, Watson J & Lobell D.B et al., (2014). A meta-analysis of crop yield under climate change and adaptation. Nat Clim Chang 4:287–291.

Dev, P., Khandelwal. S., Yadav. S. C., Arya. V., Mali, H. R., Poonam, Yadav., K. K et al., (2023). Conservation Agriculture for Sustainable Agriculture. International Journal of Plant & Soil Science. (35): 3-6.

Dhyani, S. K., Newaj, R. & Sharma, A. R et al., (2009). Agroforestry: its relation with agronomy, challenges and opportunities. Indian Journal of Agroforestry 54(3): 249–66.

FAO (2021) Climate-smart agriculture case studies 2021.
Intergovernmental Panel on Climate Change (IPCC) (2007). Climate change 2000: The Scientific Basis. Oxford University Press, Oxford.

Jack C. V., Brind W. D. & Smith R et al., (1955). Mulching Tech. Comm. No. 49, Commonwealth Bulletin of Soil Science.
Kuwayama, Y., Thompson, A., Bernknop, R et al.,(2019). Estimating the impact of drought on agriculture using the U.S. Drought Monitor Am J Agric Econ 101:193–210.

Lachaud, M. A., Bravo-Ureta, B. E., Ludena, C. E et al., (2021). Economic effects of climate change on agricultural production and productivity in Latin America and the Caribbean (LAC). Agric Econ (United Kingdom):1–12. https://doi.org/10.1111/agec.12682.

Lipper, L., Thornton, P., Campbell, B. M et al., (2014). Climate-smart agriculture for food security. Nature Climate Change 4:1068–1072.

Miller, N., Tack, J., Bergtold, J et al., (2021). The impacts of warming temperatures on US sorghum yields and the potential for adaptation. Am J Agric Econ 103:1742–1758.

Nair, P. K., Kumar, B. M & Nair, V. D et al., (2009). Agroforestry as a strategy for carbon sequestration. Journal of Plant Nutrition and Soil Science 172: 10–23.

Newaj R. & Dhyani S. K et al., (2008). Agroforestry for carbon sequestration: Scope and present status. Indian Journal of Agroforestry 10: 1–9.

Pandey, D. N et al., (2002). Carbon sequestration in agroforestry systems. Climate Policy 2: 367–77.

Roshetko, J. M., Lasco, R. D & Angeles, M. S. D et al., (2007). Small holder agroforestry systems for carbon storage. Mitigation and Adaptation Strategies for Global Change 12: 219–42.

Schmitt, J., Ofermann, F., Söder, M et al., (2022). Extreme weather events cause significant crop yield losses at the farm level in German agriculture. Food Policy 112:102359.

Solanki, R. K., Mahla, H. R., Kakani, R. K et al., (2018). Stress tolerant crop varieties of major arid zone crops to promote resilience to climatic stresses. Indian Farming 68 (09): 41-45.

Zaman, M., Kleineidam, K., Bakken, L et al., (2021). Climate-Smart Agriculture Practices for Mitigating Greenhouse Gas Emissions. International Atomic Energy Agency, Vienna.

***