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Climate-smart Agriculture: A Pathway to Food Security and Climate Resilience- A Review

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ABSTRACT

Agricultural intensification is crucial for meeting the demands of a growing population and ensuring food availability, but it also poses significant environmental challenges. Unsustainable agriculture practices, such as conventional tillage, soil erosion, chemical misapplication and overuse of irrigation, can lead to soil degradation, water wastage, and a declining water table. These environmental consequences increase the sensitivity of farm systems to climate variability and encourage the transition to sustainability practices. Climate resilient agriculture (CRA) addresses these issues by focusing on conserving and optimizing soil resources through methods like conservation tillage, crop rotation, cover cropping and precision irrigation. CRA also promotes biodiversity, remote sensing technologies and data driven farming. The article emphasizes the importance of a system approach in CRA, considering soils, water, and biodiversity as building blocks in agroecosystems with resilience. This approach counters the harmful effects of current agricultural activities against nature, thereby enabling sustainable food production and mitigating the negative effects of climate change. A comprehensive road map for agriculture development is provided to become eco-friendly and climate-resilient. In the following article, the environmental consequences of unsustainable agricultural practices are systematically reviewed highlighting the need for CRA as a sustainable pathway to address these challenges and enhance resilience to climate-related impacts.

Key words: Climate-Smart Agriculture, Food security, Greenhouse gas mitigation, Resilience, Sustainable agriculture.

Climate change increases the vulnerability of agriculture worldwide. Food security is urgently needed due to rising weather variability, depletion of resources and ecological disturbances, which make it highly challenging to ensure sustainable and reliable food supplies for the growing global population. Climate-Smart Agriculture has therefore emerged as a transformative approach to meet these challenges. It includes three primary objectives: increasing agricultural productivity, promoting resilience to climate variability and reducing greenhouse gas emissions. It helps provide locally relevant solutions to deal with the effects of changing climate conditions and promote food security through the adoption of new practices such as conservation agriculture, agroforestry and integrated pest management, among others (FAO, 2013). Research by Lipper *et al*. (2014) on CSA shows its potential to bridge the gap between food security and climate adaptation, while underlining its role in providing sustainable solutions for small farmers, who are most sensitive to climate variability. In addition, Smith *et al*. (2018) present evidence of how CSA promotes reduced greenhouse gas emissions and resilience under a range of agro-ecological conditions, pushing for extensive use of these practices, with benefits extending beyond poverty alleviation and improved livelihood. This finding identifies the strategic importance of CSA in fostering resilient food systems that solve both present and future world problems. This article explores the impact of Climate-Smart Agriculture on food security, its role in mitigating the effects of climate change and the potential it holds for ensuring sustainable food systems.

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How climate change impacts agriculture

Climate change has affected agriculture worldwide at various times and ranging from crop yield to animal health, significantly contributing to severe food insecurity. These are climatic changes, incsing patterns of extreme weather conditions and other climate change-related events. Here, there is a detailed account with supporting evidence.

Weather pattern changes

• Crop growth impact

This is so because the direct relationship between the rainfall and temperature conditions causes the effect of crop growth development. Changes in the length of growing seasons, earlier planting and harvesting periods and reduced rainfall reliability have negatively impacted traditional farming methods.

Lobell *et al*. (2011) found that high temperatures have severely affected wheat and maize crops in the tropics. The wheat yield declines by 5.5% with each increase of 1°C.

• Crop heat stress

High heat stress at flowering and grain fill stages reduces crop productivity and crop quality. Schlenker and Roberts (2009) project that if the trend continues, heat stress may lead to U.S. corn yields dropping by as much as 30% by 2050.

More frequent and intense natural disasters

• Flooding and soil erosion

The increased occurrence of floods means fertile topsoil gets washed away, sowing calendars get disrupted and crops are marred. South Asian floods in 2019 devastated more than 8 million hectares of agricultural land whose production losses affecting millions (FAO, 2020).

• Droughts

Long spells of drought stress the water resources by lowering the soil moisture and therefore, low productivity is observed in agriculture.

According to IPCC (2014) drought was one of the key sources of yield variability in sub-Saharan Africa, although it also reports that maize yields fell by up to 20% in the driest areas.

Pests and diseases

• Increased pest infestation

Changes in precipitation paired with higher temperatures increase the areas of pest and disease habitat, resulting in increased loss.

Deutsch *et al*. (2018) claim that for every degree Celsius of warming, the global maize, rice and wheat losses to pests could increase up to 10-25%.

• Livestock health

With rising temperatures, the vector-borne diseases like bluetongue and Rift Valley fever, which kill livestock are expected to increase. Thornton *et al*. (2009) estimated that the prevalence of livestock diseases is most likely to rise by 20-50% in East Africa.

Sea level rise and salinization

• Coastal agriculture

Saltwater influx into freshwater systems and lands results in soil fertility and crop productivity degradation in crops and coastal regions as the sea level rises. Nicholls and Cazenave (2010) have found that the saline intrusion caused by sea level rise greatly increased the risk of severe yield losses in Bangladesh’s rice-growing areas.

Reduced nutritional value

• Lower intake of essential nutrients

High carbon dioxide concentration in the atmosphere has been reported to reduce protein, zinc and iron content in most staple grains, including rice and wheat, thereby increasing the risk of malnutrition. Myers *et al*. (2014) found that the protein content in rice decreases by 8% and the zinc content in wheat decreases by 5% since it was grown at elevated levels of CO_2.

Water deficit

• Irrigation issues

With the increased temperature and decreased rain, evaporation processes increase that contributes to the fall in the table of water level, affecting irrigation-based agriculture, in general and mostly in arid and semi-arid regions. According to UNESCO (2019) “a full 70 per cent of irrigated agriculture worldwide is now within the purview of water scarcity due to warming and decreasing rainfall.”

Thus the above discussion on the impact of aberrant climatic change highlights multifaceted challenges for agriculture, ranging from crop and livestock production all the way to nutritional value and soil health. In this context, one critical challenge is the adoption of Climate-Resilient Smart Agriculture (CSA), water conservation and soil conservation to ensure food security in an uncertain world.

Understanding Climate-Smart Agriculture

Climate Smart Agriculture (CSA) provides an integrated approach to landscape management for agricultural landscapes: addressing the interrelated problems of food security and climate change. The Food and Agriculture Organization (FAO) states that CSA enables agriculture to contribute to global development goals by supporting the three dimensions of sustainable development: increasing agricultural productivity, strengthening resilience and reducing climate change impacts (FAO, 2013).

• Increase agricultural productivity and income

CSA promotes practical and sustainable agricultural practices that enhance crop and livestock productivity. Some approaches, such as improved seed varieties, precision farming and management of resources including water, ensures food supplies while increasing farmer incomes. These practices improve productivity, stabilize farmers’ incomes and reduce their vulnerability to market and climate uncertainties, as stated by Vermeulen *et al*. (2012).

• Resilience to climate change

CSA looks at improving agricultural systems and their resilience to climate-driven stresses such as drought, flood, high temperature and changing rainfall patterns. Core practices include crop diversification, conservation agriculture and integrated pest management that reduce vulnerability and enable farmers to adapt to changing environmental conditions. Lipper *et al*. (2014) identify that such interventions are the way forward to food security in changing climatic situations.

• Greenhouse gas mitigation

Reduction/Removal of greenhouse gas emissions: another critical aspect of CSA is reducing its carbon footprint.

Compared to the others, it has low emission of greenhouse gases through agroforestry, optimized fertilizer applications and water conservation approaches. According to Smith *et al*. (2008), such practices not only emit fewer greenhouse gases but also tend to have good soil and biodiversity health, thus creating a positive feedback in a sustainable agriculture.

In fact, CSA is not only flexible to a changed climate but also proactively minimizes agro-environmental impacts while ensuring food security. Therefore, CSA seems to be an essential agenda in achieving global food security in the face of climate uncertainties: adaptation and mitigation purposes both.

The role of climate smart agriculture in addressing food security

Food security is therefore linked with the reliability of food production systems that have increasingly come under threats from climate change. Erratic weather patterns such as irregular and unpredictable rainfall, extreme temperature conditions and natural disasters such as floods and droughts interfere with crop production of staple crops, leading to food shortages and price hikes that threaten access to food in particular vulnerable regions (FAO, 2013). Climate Smart Agriculture responds to the above problems by promoting practices that enhance crop and livestock productivity in spite of climate adversities. Improved seed varieties, agroecological practices and sustainable water management improve farmers' capacity to maintain their productivity in extreme weather event-prone areas (IPCC, 2014). Enhancing diversified farming systems that are less vulnerable to climate-related risks contributes to stabilizing food production systems (Lipper *et al*., 2014).

• Improving agricultural resilience

It will be able to improve the resilience of agricultural systems to enhance food security, especially in the heavily rain-fed areas. It promotes an adaptive approach which includes crop diversification, soil health management and integrated pest management. It makes it resilient to climate variability, but it further enhances its long-term sustainability (Pretty *et al*., 2014). For instance, CSA allows drought-resistant crop varieties and irrigation infrastructure with high efficiency, including the mulching and no tillage to maintain soil moisture thus lowering erosion risks (Smith *et al*., 2018). Through CSA, agricultural systems gain the ability to produce more food in a changing climate by experiencing fewer crop losses and available food supply the entire year (FAO, 2013).

• Nutritional security

Food security does not only address calorie availability but also that of nutrients. Changes in carbon dioxide concentration, temperature and precipitation patterns resulting from climate change changes the nutritional content in crops (Myers *et al*., 2014). CSA facilitates this by emphasizing nutrient-enriching crops such as legumes, vegetables and fruits, which form the core in addressing malnutrition (Lipper *et al*., 2014).

Besides, CSA promotes agroforestry and intercropping, which are central to diet diversity. The higher intensification in animal and crop production systems is balanced by diversifying a wide range of food stuffs, including milk, meat and eggs, the basic units for nutritious diets (FAO, 2013; Pretty *et al*., 2014).

Mitigating climate change through climate-smart agriculture

Reducing greenhouse gas emissions

Agriculture is a major source of emissions, primarily methane from livestock and rice paddies and nitrous oxide from synthetic fertilizers (IPCC, 2014). CSA hopes to mitigate these through sustainable agriculture that lowers farming's carbon footprint. For example, CSA promotes sustainable animal husbandry practices such as rotational grazing that encourages healthy soils and reduces methane emissions into the atmosphere (Smith *et al*., 2017). Organic farming is another practice promoted by CSA and uses lesser synthetic fertilizers that release nitrous oxide into the atmosphere (FAO, 2013). Another important attribute of CSA is agroforestry where trees are integrated in a farming system that captures carbon dioxide from the atmosphere while enhancing soil fertility and biodiversity (Lipper *et al*., 2014).

Sustainable water management

Since agriculture is the largest consumer of water in the world, CSA aims at water conservation. Consequently, efficient water use is a key focus of CSA practices, aiming to address both water scarcity and the effects of climate change. Other such practices include drip irrigation among others, harvesting rain water and drought - resistant crop varieties. Such practices conserve water as well as energy which will be used in irrigation and also water pumping thereby reducing its GHG emissions (Pretty *et al*., 2014).

In drought-prone regions, CSA encourages soil conservation techniques that enhance water-holding capacity, decrease evaporation and increase the retention of water in the soil. Mulching and cover cropping ensure crops are moist during dry spells thus making agricultural systems more resilient with the capacity to maintain food production even in adverse climatic conditions (Smith *et al*., 2017).

Challenges and obstacles to the use of climate smart agriculture

Although CSA has tremendous potential to improve food security and counter climate change, many obstacles hinder its large-scale adoption.

Economic obstacles

Most small-scale farmers in developing countries find it financially unfeasible to adopt CSA practices. The startup costs for introducing climate-smart approaches are very expensive, such as procuring drought-resistant seeds, irrigation equipment and soil enhancements (FAO, 2013). Limited access to cheap credit or financing compounds the challenge, as farmers often cannot invest in CSA practices or realize their long-term benefits (Lipper *et al*., 2014). The financial constraints therefore hugely reduce the scalability and impact of CSA on food security.

Lack of knowledge and training

Adopting CSA requires technical skills and knowledge about sustainable farming practices and climate adaptation strategies from the farmers. Lack of appropriate training and extension services, more so in rural areas, is creating a knowledge gap. This constrains farmers' ability to realize some of the benefits of CSA in food security and climate change mitigation (Pretty *et al*., 2014). Tailored capacity-building programs address this barrier for wide adoption.

Policy and institutional support

Strong government policies are necessary to facilitate the adoption of CSA practices. However, most agricultural policies that exist today do not respond to the challenges of climate change or offer enough incentives to implement climate-smart practices (Smith *et al*., 2018). The absence of subsidies, tax incentives, or dedicated research funding under weak policy frameworks restricts the promotion and adoption of CSA (IPCC, 2014). These gaps must be addressed through targeted policy interventions to scale up CSA and realize its full potential.

CONCLUSION

- Climate-smart agriculture (CSA) has the potential to revolutionize the global food system in three key areas: making it more sustainable, more resilient and better adapted to climate change. While it addresses both climate change and food insecurity at a holistic level and thereby concurrently addresses the two great challenges globally. This builds more resilience towards climate change as well as reduces greenhouse gas emissions from agriculture by improving practices, thereby increasing productivity to meet future food demands.
- The universal adoption of CSA, however, faces significant challenges. To overcome it requires concerted efforts of these actors: governments, international agencies, researchers and the people. Key actions include offering financial incentives to farmers, upgrading provision of knowledge and training services among farmers and crafting appropriate policies that promote the adoption of climate-smart agricultural practices.
- A strategic blend of supporting policies, innovative technologies and active involvement of stakeholders could put Climate-Smart Agriculture at the centre to bring about a transformation in mitigating the intensifying impacts of climate change toward ensuring global food systems.

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Conflict of interest

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