



Climate Smart Agriculture for Food Security, Adaptation, and Migration: A Review

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ABSTRACT

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Climate Smart Agriculture (CSA) is an integrated approach that transforms the agri-food system and mitigates climate change. They connect the use of farming techniques in order to increase food productivity, Climate resilient practice, and decrease greenhouse gases. The main aim of this review is to demonstrate the typical interrelationship between climate and agriculture and get knowledge regarding this. In addition, focus on traditional agriculture along with its mitigating measures for climate agriculture. They approach collective development practices through the efforts of individuals in order to manage agriculture and the food system under climate change. Therefore, there is an increasing need for a strategic plan to balance agriculture and the food system.

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Introduction

In many developing countries, agriculture is the most important economic sector (Branca et al., 2011). Climate change is one of the most contentious socio-ecological and economic issues of the twenty-first century (Singh and Singh, 2017). Climate change poses a serious threat to current and future agriculture (Tong et al., 2019). Climate change will have an impact on crop distribution and production, as well as the risks that come with farming. Crop yields have already been negatively impacted, emphasizing the need for adaptive measures (Scherr et al., 2012). Climate smart agriculture has arisen as a framework for capturing the idea that agricultural systems can be developed and implemented to increase food security, rural lives at the same time, facilitate climate change adaptation, and provide mitigation benefits as research and policy links between climate change and agriculture have progressed (Scherr et al., 2012). Climate change is emerging as a major threat to

the agriculture, food security and, livelihood of millions of people in many places of the world (Dwivedi et al., 2017). The Food and Agricultural Organization (FAO) introduced Climate Smart Agriculture (CSA) in 2010 as an innovative cleaner production alternative to conventional farming that aimed to increase natural resource efficiency, resilience, and productivity of agricultural production systems while lowering greenhouse gas emissions. CSA practices and technologies can help to mitigate the negative effects of climate change on cotton production at the farm and regional level (Imran et al., 2018). According to FAO (2010), "CSA is agriculture that increases productivity in a sustainable manner, reduces climate change vulnerability, reduces emissions that cause climate change, while protecting the environment from degradation and enhancing food security and improved livelihood of a given society" (Onyeneke et al., 2018). FAO has urged a sustainable agricultural

production system, i.e. Climate Smart Agriculture (CSA), as an alternative to conventional agriculture, due to social, environmental, and economic problems caused by climate change and conventional agriculture. CSA increases natural resource efficiency, agricultural resilience and productivity, and reduces greenhouse gas emissions. CSA is a technology or practice that helps to increase productivity and farm income while also improving water and nutrient use efficiency, climate change resilience, and greenhouse gas emissions reduction. The negative impact of climatic variability on agriculture can be significantly reduced by implementing CSA practices and technologies individually or in combination (Imran et al., 2018). CSA promotes environmentally friendly intensification of farming systems, herding systems, and the efficiency of sustainable gathering systems while simultaneously improving social and ecological resilience (Nwajiuba et al., 2015).

Degradation of natural resources and recent climate change impacts (drought, seasonal variability, floods) have made it difficult to increase productivity and ensure food security for the growing population (Onyeneke et al., 2018). Agricultural production systems are expected to produce food for a global population that will amount to 9.1 billion people in 2050 and over 10 billion by the end of the century to secure and maintain food security, agricultural systems which need to be transformed to increase the productive capacity and stability of smallholder agricultural production (McCarthy et al., 2011b). Projected and observed impacts of climate change on agriculture, food security, and poverty are raising global concerns (Nyasimi et al., 2017). According to a recent World Bank report, 'annual economic damage from climate change in Caricom countries has been estimated at around US\$11 billion by 2080, or 11 percent of the gross national product (GDP), with about 17 percent of the losses (around 1.9 percent of GDP per year) due to the specific effects of sea-level rise – loss of land, tourism infrastructure, housing, buildings and other infrastructure (Little, 2014). Climate risks are weather-related production issues caused by climate change and variability (Bell et al., 2018). Agriculture has been impacted by rising heat waves, erratic rainfall, and other extreme events (flooding). Unless nations and peoples adopt CSA on a large scale, they will be subjected to the effects of extreme and variable weather, which will result in lower average crop yields, increased population pressures, and land/water scarcity (Onyeneke et al., 2018). Temperatures worldwide are projected to increase by an additional 1.5–5.8°C by the end of the 21st century (Nancy McCarthy et al., 2011b). The latest report of the Intergovernmental Panel on Climate Change attests to strong evidence of global climate change and its impacts. Climate change and agriculture are inextricably linked (Olayide et al., 2016). Much of the greenhouse gases contribution from agriculture comes from industrial agriculture production methods and rich-country consumption patterns. Emissions from the agriculture sector of methane and nitrous oxide these gases together amount to between 10 and 12% of these two total global greenhouse gas emissions (Stabinsky, 2014). Climate change is expected to radically reshape the developmental landscape of Caribbean small states, given their size constraints and economic dependence on climate-sensitive sectors such as agriculture and tourism, which are vulnerable to global instabilities (Northover, 2012). As per FAO estimate, by the year 2050 world population will

increase by one-third and food required for food security by 60% (Dwivedi et al., 2017). By 2050, Africa needs to produce much more food than at present to avoid potentially widespread starvation among an expected population of 1.8 billion – this against a background of decades of declining food production per capita and stagnant cereal yields (Climate and development, 2011). The recent increase in the global number of food poor individuals, along with crop failures caused by adverse weather, has made world leaders increasingly conscious that future climate change may severely impair our ability to feed the growing population by 2050 (Synnevag and Lambrou, 2012). Cooper et al. (2008) divide climate adaptation strategies into three categories: ex-ante risk management options, in-season adjustment of management options in response to specific climate shocks, and ex-post risk management options that reduce the effects of adverse climate shock on one's livelihood (N. McCarthy, 2014). Key knowledge gaps regarding the tradeoffs and synergies between food security, adaptation, and mitigation caused by alternative transformation routes for smallholder agriculture, as well as the possible consequences of policies on accomplishing these three goals, must be addressed (Nancy McCarthy et al., 2011a). Conventional forms of agricultural production are often unsustainable, pollute the environment and depletes the natural resources on which production relies over time (Braumoh, 2013). Low agricultural productivity is often associated with poverty, food insecurity, and nutrient depletion in Africa, where just 4% of smallholder farmers use improved seeds, the average fertilizer application is 9 kg per hectare, and only 1% of arable land is under irrigation (Braumoh, 2013). Climate resilience in the context of rural agricultural-dependent communities is comprised of ecological resilience, social resilience, and economic resilience (Nyasimi et al., 2017). Climate-smart agriculture (CSA) was established as a worldwide development aim to steer the transformation of agricultural systems that integrate adaptation, mitigation, and food security. CSA is not designed to provide a new set of sustainability principles, but rather to provide a mechanism of incorporating adaptation and mitigation specificities into sustainable agricultural development policies, programs, and investments. The major goals of CSA are to reduce greenhouse gas (GHG) emissions while lowering the susceptibility and resilience of agricultural systems to climate change (Brandt et al., 2017). Climate Smart Agriculture (CSA) aims to solve the problem of food insecurity and improve rural livelihoods while minimizing negative environmental impacts (Azadi et al., 2021).

Inter-relationship between Climate and Agriculture

Agriculture is also a major factor to global warming. Total non carbon dioxide (CO₂), greenhouse gas (GHG) emissions from agriculture in 2010 are estimated at 5.2-5.8 gigatonnes of CO₂ equivalent per year, making up about 10-12% of global anthropogenic emissions (Dwivedi et al., 2017). Meeting food demand for a growing population is already a tough problem for agriculture, but climate change will worsen it. Climate change is projected to cause greater temperatures, extreme weather events, water shortages, increasing sea levels, ecological disruption, and biodiversity loss, significant effects on the different dimensions and determinants of food security by affecting

the productivity of rainfed crops and for-age, reducing water availability and changing the severity and distribution of crop and livestock diseases. The FAO, World Bank, and developed country government promoters of “climate-smart” agriculture such as the Netherlands and the United States have since developed a more sophisticated political approach to sell the concept, through a new initiative called the Global Alliance for Climate-Smart Agriculture (Stabinsky, 2014). Farmers who are unable to adapt to climate change may have to seek alternative employment or remain impoverished. Others may become resilient by developing alternative systems of production that will help them cope with the changing climate (Olayide et al., 2016). Agriculture has become a high-risk profession- farmers increasingly prefer to migrate which has a direct impact on the socio-economic process. Nutrition-smart agriculture relates to a move from a crop- or livestock-specific viewpoint to a farming systems perspective that includes the farming household (Beuchelt and Badstue, 2013). Climate Smart Agriculture (CSA) contributes to agricultural production, resilience to climate change, and climate change mitigation (Rimhanen et al., 2012). Effective climate change adaptation requires appropriate technological and institutional innovations, including an enabling policy environment that can reduce the farmer’s vulnerability to climate-related risks by creating economic opportunities that build livelihoods and increase resilience (Nyasimi et al., 2017). Globally, three-quarters of all malnourished people depend on agriculture and would be directly affected by international mitigation agreements aimed at agriculture. Various “climate friendly” agricultural solutions have already been proposed: they include biochar and no-tillage agriculture (Andreas Gattinger et al., 2011) Implementing CSA, REDD+ and Energy+ will involve collaboration across sectors and a range of actors at multiple spatial and temporal scales. CSA entails the effective agriculture and

climate change policies which can also boost green growth, protect the environment and contribute to the eradication of poverty (Synnevag and Lambrou, 2012). Already the cumulative impact of climate change since the last decade affects productivity. Despite farmers’ awareness of global environmental deterioration and commitment to adaptation, there is still a pressing need in the region to improve their meteorological, climate, and climate change expertise (Akponikpe et al., 2010).

Climate-smart agriculture: Principles and Objectives

Three goals underpin the CSA approach. They are

- Productivity

Improving agricultural productivity in a sustainable manner to support a more equitable increase in income, food security, and development. This is critical for agriculture-dependent communities who rely on agriculture and agribusiness for a large portion of their income (Tumwesigye et al., 2019).

- Adaptation

Increasing shock adaptive capacity and resilience at all levels, from farm to national; and increasing shock-adaptive capacity and resilience at all levels, from farm to national; CSA aims to reduce farmers’ exposure to short-term risks while also boosting their resilience by increasing their ability to adapt and thrive in the face of shocks and longer-term stressors. Protecting the ecosystem services that ecosystems provide to farmers and others receives special attention (Tumwesigye et al., 2019).

- Mitigation

Reducing GHG emissions and increasing carbon sequestration wherever possible. This means that for every calorie or kilo of food, fiber, or fuel produced, we reduce emissions (Tumwesigye et al., 2019).

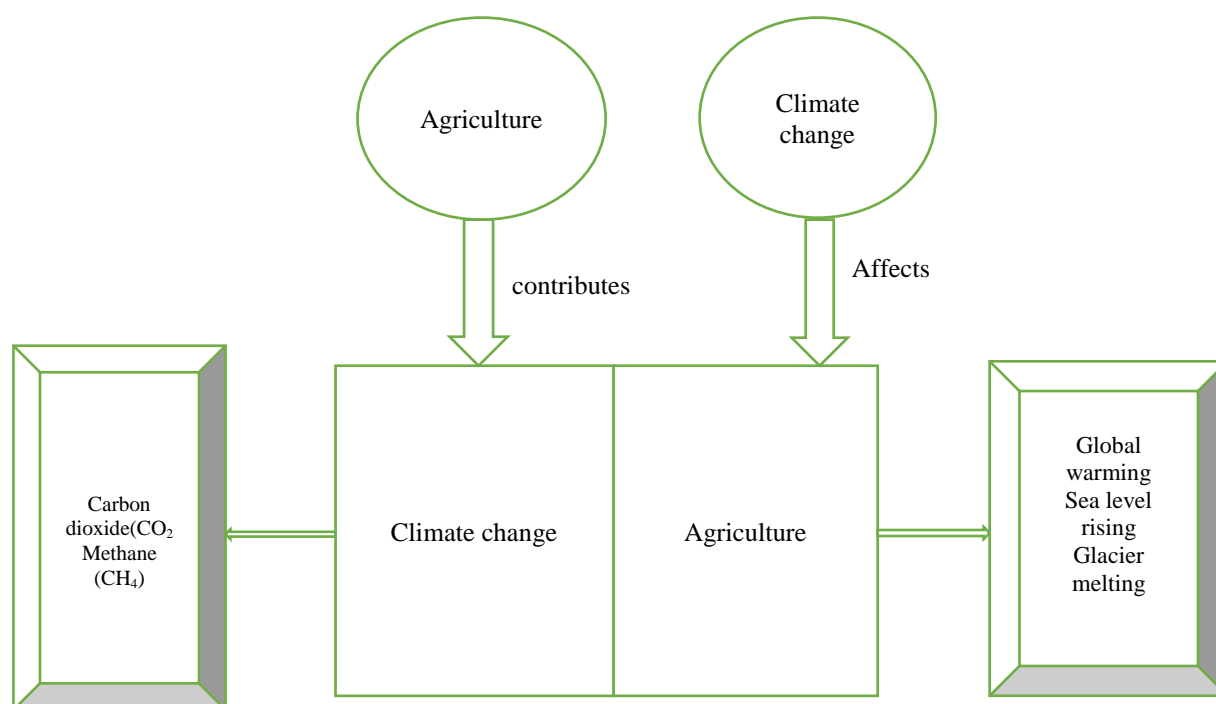


Figure 1. Correlation between agriculture and climate change. Modified from (Singh and Singh, 2017).

Expected Effects of Climate Change on Agriculture

Food security and climate change are two of the most pressing issues confronting humanity today. Agriculture has a significant impact on both. Climate change adaptation is expected to be a growing issue for agriculture and food security in the coming decades. At the same time, agriculture is part of the solution to climate change: by reducing and sequestering terrestrial greenhouse gas emissions, agricultural interventions can reduce human-caused net greenhouse gas emissions. Climate change is likely to adversely affect global food security in terms of food availability, food stability, food utilization, and food access (Scherer and Verburg, 2017). Climate change is reducing food yields, increasing water scarcity, causing biodiversity loss and the loss of natural assets provided by ecosystems, and introducing new disease patterns and increasing respiratory illnesses, and possibly has become one of the triggers of migration and new patterns of conflict (Mitchell et al., 2010). Climate change is estimated to have already reduced global yields of maize and wheat by 3.8% and 5.5% respectively, and several researchers warn of steep decreases in crop productivity when temperatures exceed critical physiological thresholds whereas increased climate variability exacerbates production risks and challenges farmers' coping ability (Lipper et al., 2014). Biomass burning, enteric fermentation, nitrogen fertilization, manure management, and agronomical procedures that release carbon from disturbed soil are all agricultural processes that contribute to GHG emissions. Coupled with the negative impacts of climate change, concerns of agricultural GHG emissions have led to the emerging paradigm of climate-smart agriculture (Bagley et al., 2015). In some cases, boosting the production capacity of diversified agroforests, complex woodland-fallow-and-crop mosaics, and other more large but less diverse systems will be the most viable pathways for sustainable and equitable development but high carbon and high biodiversity production systems (Wollenberg et al., 2011). Changes in agricultural practices affect crop and livestock output, and include the introduction of new crop types and animal breeds, as well as soil and land management practices, water conservation technologies, and improved fodder production (Nyasimi et al., 2017). Unless we change our approach to planning and investment for agricultural growth and development, we risk misallocating human and financial resources, generating agricultural systems incapable of supporting food security and contributing to increasing climate change (Lipper et al., 2014). Climate-friendly agricultural practices focus on increasing the carbon content in soil (Example: by using cover crops, farming with perennials, reduced tillage or rotational grazing), minimizing the need for chemical fertilizers (responsible for nitrous oxide emissions) and managing livestock systems to reduce methane emissions (Chatterjee, 2011).

At the same time, climate change and increased climate variability will enhance the pressure on agricultural production systems and forests, and thus important sources of energy for many of the world's poor, making people more vulnerable if no adaptation practices are implemented (Bogdanski, 2012). So, Climate Smart Agriculture should be started to meet following objectives: sustainably increasing food security through increases in productivity and incomes, building resilience and adapting to climate change, and reducing greenhouse gas emissions compared to a business as usual or baseline scenario (Lipper et al., 2014).

Traditional Agriculture: An Alternative Practices For Climate Change Mitigating

Under water stress, limited resources, and low technology, traditional farming systems promote agroecosystem sustainability by conserving soil, harvesting water, and cropping varieties of crop (Singh and Singh, 2017). Traditional knowledge is holistic in nature, with applications in agriculture, climate, soils, hydrology, plants, animals, forests, and human health, to name a few. Traditional agriculture evolved over thousands of years as a result of the lessons learned from local farming practices. Through their agroecological characteristics, traditional agricultural practices have the potential to adapt to and mitigate climate change. They boost agrobiodiversity and agroecosystem resilience. They're also inexpensive, energy-efficient, and based on locally available resources. Traditional agricultural knowledge is guarded by indigenous people. In a changing climate, traditional agriculture can be used as an alternative method of producing sustainable food (Singh and Singh, 2017).

- Agroforestry

Agroforestry is the name given to a land use system based on the centuries-old practice of growing crops alongside trees and animals on the same plot of land. It combines agriculture and forestry on the same piece of land, either concurrently or sequentially. Agroforestry is a sustainable land use system and practices in which woody perennials (trees and shrubs) are purposefully planted on the same land unit as agricultural crops or animals, either in spatial or temporal sequences (Zerssa et al., 2021).

In other words, agroforestry is a system of intensive land use management that maximizes the benefits (physical, biological, ecological, economic, and social) from biophysical interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock.

Home gardens, treecrop intercropping, parkland or scattered trees in croplands, and shaded perennial-crop systems, alley cropping are all examples of agroforestry (Zerssa et al., 2021). It encompasses a wide range of practices (for example, farming with trees on contours, intercropping, multiple cropping, bush and tree fallows, establishing shelter belts and riparian zones/buffer strips with woody species, and so on) that can improve land productivity by providing a favourable microclimate, permanent cover, improved soil structure and organic carbon content, increased infiltration, and improved fertility (Branca et al., 2011). The mitigation potential of agroforestry systems is strongly influenced by the system type (agropastoral, silvopastoral, agrosilvopastoral) and the species used (Bogdanski, 2012). Soil organic matter (SOM), agriculture productivity, carbon sequestration, water retention, agrobiodiversity, and farmer income are all improved by agroforestry (Singh and Singh, 2017). Agroforestry is used as a land-use management system all over the world, but it is most common in tropical areas. In Southeast Asia, Latin America, and Equatorial Africa, it is a common practice (Singh and Singh, 2017). Because of its potential for climate change mitigation, adaptation, crop productivity, and food security, it is widely used as a climate-smart practice (Singh and Singh, 2017). Farmers practiced agroforestry for a variety of reasons, the

most common of which was increased agricultural land fertility (about 40%) (Zerssa et al., 2021).

- Intercropping

It is one of the most productive agricultural systems (Hu et al. 2017). Because different crops have different climatic adaptability, intercropping reduces climate-driven crop failure. Intercrops increase biodiversity, productivity, resilience, and stability of agroecosystems by efficiently utilizing natural resources such as land, light, water, and nutrients (Singh and Singh, 2017).

- Crop rotation

Growing different crops in succession on a piece of land over a set period of time with the goal of maximizing profit with the least amount of investment while preserving soil fertility is simply a crop rotation. For Example, Rice-Wheat-Moong .Crop rotation has re-captured global attention as a way to address growing agroecological issues like declining soil quality and climate change caused by short rotation and monocropping (Singh and Singh, 2017). (When rice was grown in rotation with corn and sweet sorghum in the dry season, Cha-un et al. (2017) found a significant reduction in GHG emissions (combined CH4 and NO2 in CO2 equivalent) of 68–78% when compared to double rice cultivation. Crop rotation improves soil quality and crop productivity by modifying soil structure and aggregation, SOC concentration, nutrient cycling, and pest and disease management (Singh and Singh, 2017). Crop rotation is a cost-effective method of producing a sufficient amount of food at a low environmental cost. Crop species selection criteria should be based on optimizing the use of soil resources, which is usually the limiting factor for crop production. Crop rotation methods can improve soil organic carbon content by extending crop cover periods, reducing the number of crops planted, and reducing tillage intensity (Kumari et al., 2019).

- Cover cropping

Cover cropping is a long-term strategy for improving soil health, microbial biomass, and agroecosystem services like nutrient cycling, water storage, weed and pest management, and carbon sequestration. Cover crops can be harvested before main crop planting or grown alongside main crop planting to provide living mulch. Leguminous (pea, vetch, and clover) and non-leguminous (rye, sorghum, and brassicas) cover crops are available. Cover

crop species such as rye, oat, pea, vetch, clover, sun hemp, velvet bean, and sorghum are commonly grown to improve soil fertility and carbon sequestration (Singh and Singh, 2017). Growing a cover crop all year is an important concept for improving water and nutrient cycling, soil health, soil protection, and organic matter building. Cover crops aid in the formation of surface soil aggregates, the reduction of ponding by increasing water infiltration, and the breaking through of compaction layers deeper in the soil. Some cover crops, such as cereal rye, can help suppress certain weeds, such as marestail, while also allowing for a more efficient forage harvesting system. Cover crops can be designed to use a lot of water to dry out the soil before the next planting (Kumari et al., 2019).

- Conservation agriculture

Conservation agriculture (CA) is a farming system that prevents cropland loss and reduces soil degradation while restoring degraded lands (Zerssa et al., 2021). It is based on three main principles: (I) minimizing soil disturbance through direct seeding, minimal or no tillage, and avoiding excessive compaction by machinery, animals, or humans; (II) ensuring permanent soil cover through crop rotations and the use of cover crops and mulch; and (III) diversifying cropping systems (Gjengedal, 2016; Mohammed, 2016; Tsegaye et al., 2017).

No tillage

Soil organic carbon, which is critical for soil fertility and structure, can be increased with minimal or no tillage (Zerssa et al., 2021). Reduced tillage can improve aggregate stability, water holding capacity, and soil moisture, protecting the soil from erosion and compaction (Bai et al., 2019; Singh et al., 2020; de Arañjo et al., 2016).

Water harvesting entails collecting and storing rainwater (from rooftops and local catchments) as well as seasonal floodwaters (from local streams) and watershed management (Zerssa et al., 2021; Awulachew and Ayana, 2011).

- in-situ water conservation practices, which primarily refers to the collection of water in small basins, pits, and bunds/ridges, and
- runoff-based systems, which primarily refers to the collection of water from the catchment and roadside ditches (Mengistie and Kidane, 2016).

Table 1. Management practices. Modified from (IPCC, 2007*

| S.N. | Management Practices | Details of Practices | Remarks |
|------|--------------------------|--|-----------------------|
| 1. | Agronomy | Use of cover crops Improved crop varieties Crop rotation Use of legumes crops Green manure | (IPCC, 2007) |
| 2. | Conservation Agriculture | Minimum tillage Zero tillage | (Branca et al., 2011) |
| 3. | Water Management | Irrigation Water harvesting | (Branca et al., 2011) |
| 4. | Agroforestry | Alley cropping Trees Home Garden | (Tanga et al., 2017) |
| 5. | Stress Tolerant Crops | Crop diversification Drought tolerant varieties | (Tanga et al., 2017) |

*(Branca et al., 2011; Tanga et al., 2017)

Conclusion

Mainly rainfall and temperature patterns are getting irregular therefore, there is dramatical changes in agricultural production which directly and indirectly affects the livelihoods of poor people. Additionally, they disrupt the food markets system too. Climate Smart Agriculture comprises different field and farm practices along with agroforestry, intercropping, crop rotation, cover cropping, conservation agriculture and water harvesting schemes. IN addition Climate Smart Agriculture plays a crucial role in combating climate change and achieving food security. Hence, they include the right practice for the implementation of policies, planning and investment. Moreover, it results in the decrease of food insecurity, poverty and climate change.

Abbreviation

CO₂- Carbon dioxide
 CSA- Climate Smart Agriculture
 FAO- Food and Agricultural Organization
 GH-Green house Emission

Author declaration

The authors declare no conflicts of interest. All authors contributed equally in all stages of preparation of this manuscript. Similarly, the final version of the manuscript was approved by all authors.

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