

Climate-Smart Agriculture as a New policy to Climate Change Adaptation

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Abstract:

The pervasive impact of climate change has detrimentally affected our environmental and agricultural systems. These systems are increasingly proving inadequate in coping with such changes, thus underscoring the urgent need for adopting climate-smart agriculture (CSA). This innovative approach fosters resilience and adaptability in agricultural practices, aiming to elevate productivity and sustainability.

The study concluded that climate-smart agriculture is a new approach that helps adapt to climate change and reduces its negative impacts through smart practices that make agricultural systems more adaptive, resilient and sustainable. However, this approach faces several challenges, particularly high costs and a lack of knowledge about the use of advanced technologies.

Keywords: Climate-Smart Agriculture; Climate Change; Adaptation ; Mitigation; Agricultural Systems.

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INTRODUCTION

Climate change represents a formidable threat to ecosystems and living entities alike. The escalation of global temperatures, alongside the prevalence of droughts, water scarcity, diseases, and extreme weather conditions, poses severe challenges that demand immediate and effective responses.

According to forecasts by the World Meteorological Organization, the global temperature is expected to rise by approximately four degrees Celsius by 2060. Such a rapid escalation could undermine societal stability by disrupting food and water supplies across various regions.

Agricultural systems, which are vitally linked to our food security, are particularly vulnerable to climate variations. As a result, it is crucial to transform these systems to enhance their resilience to climate impacts and to mitigate such effects, thereby securing sustainable food sources. Climate-Smart Agriculture (CSA) offers a ground breaking strategy designed to improve adaptability, minimize greenhouse gas emissions, and maintain food security.

Problem Statement

Climate-smart agriculture has emerged as a vital strategy in the global fight against climate change. This study not only seeks to delineate and elaborate on this concept but also to scrutinize its practical application across various stakeholders. By attempting to answer the following question: **To what extent can climate-smart agriculture achieve adaptation to climate change and mitigate its effects?**

This problem statement encompasses several sub-questions:

- What exactly does climate-smart agriculture entail, and how has it developed over time?
- What are the primary characteristics and goals of climate-smart agriculture?
- Which agricultural practices under the climate-smart framework are best suited to adapt to climate change?
- What are the future directions and potentials of the climate-smart agriculture approach?

Study Hypotheses

To address the underlying issues, we propose the following central hypothesis:

- The more effectively and accurately climate-smart agricultural practices are implemented, the greater the adaptation of agricultural systems to climate change, thus mitigating its detrimental impacts on agricultural crop productivity.

This overarching hypothesis is supported by several sub-hypotheses:

- The greater the integration of digital technology in agricultural practices, the higher their resilience to climate change challenges.

Study Significance

The importance of this study stems from its exploration of the ongoing climate changes on our planet and their adverse effects on agricultural systems. It underscores the critical necessity to adapt these systems to climatic changes through the integration of digital technologies in agricultural practices. This integration is pivotal for adaptation and mitigation, ultimately leading to an increase in the yield of agricultural and field crops.

Study Objectives

The objectives of this study are multifaceted, aiming to:

- Attain a comprehensive understanding of the climate-smart agriculture approach through exploring its definition, evolution, characteristics, and goals.

- Gain insights into the pivotal practices of climate-smart agriculture that are designed to adapt to and mitigate climate change.

- Explore potential future directions of the climate-smart agriculture approach.

Study Methodology

Our study employs a descriptive analytical approach, which is deemed most suitable given the nature of the topic. This approach involves a detailed understanding of the concept of climate-smart agriculture, a description of its practices, and its future orientations.

2- Climate-Smart Agriculture: A Conceptual Study

Climate change refers to changes in the statistical averages and standard deviations of the climate throughout time and space. This is caused to natural or human forces, resulting in an increase in its negative effects on the environment and humans, as seen by the incidence of natural disasters that do major harm to the environment and living things¹. As a result, new formulas and strategies were needed to avoid such negatives while also providing the ability to adapt to climate change and mitigate its effects, which meant developing ecological, social, or economic systems capable of dealing with sudden climate shocks, adapting to them, and evolving accordingly.²

2.1- Origin of Climate-Smart Agriculture (CSA)

Climate-smart agricultural techniques have been implemented to adapt to climate change and lessen its detrimental effects on the environment and living things. This concept was first introduced in 2009 by the Food and Agriculture Organization (FAO) at a workshop in Barcelona, which concentrated on the nexus between agriculture, security, and climate change. The ensuing year witnessed a burgeoning global interest and recognition of CSA, highlighted during the World Conference on Agriculture, Food Security, and Climate Change in The Hague in 2010. This pivotal conference provided the inaugural definition of Climate-Smart Agriculture, marking the launch of a comprehensive initiative spearheaded by the FAO in partnership with the World Bank.

The initiative's aim was to identify systems, practices, and technologies that are ideally suited for the ecological, economic, and social conditions, thereby enhancing resilience and minimizing greenhouse gas emissions. The momentum of international efforts escalated, culminating in 2012 at the Second International Conference on Climate-Smart Agriculture Policies. A significant output of this conference was a reference guide that primarily addressed the ways in which smallholder farmers and vulnerable populations in developing countries could harness smart agricultural technologies. This event marked the crystallization of the methodology and

principles of Climate-Smart Agriculture, which then garnered substantial international and national attention and discourse.³

The rationale for adopting this approach is multi-faceted:⁴

- An estimated 24% of greenhouse gases released worldwide are thought to originate from agriculture, which is a significant percentage.
- Using climate-smart farming techniques to adjust to average temperature increases.
- By reducing greenhouse gas emissions, climate-smart agriculture helps mitigate the negative effects of climate change and adapt to it, which in turn limits global warming.
- Because water supplies are impacted by climate change, particularly drought and desertification, CSA methods ensure that every drop of water is used and not wasted. They also ensure that less water is used than traditional agriculture.

Given that our planet is undergoing climate change, which has a direct impact on food chains, food systems, and ultimately living organisms and the environment, climate-smart agriculture has become more than just a necessity for both developed and developing nations. Climate-smart agriculture practices are viewed as a novel approach that uses cutting-edge technology to offer the best ways to adapt to climate change and lessen its effects.

2.2- Definition of Climate-Smart Agriculture

Climate-Smart Agriculture (CSA) embodies a paradigm for agricultural production and development that is committed to sustainability by enhancing agricultural efficiency, improving adaptability, reducing greenhouse gas emissions, and securing national food security. It seamlessly integrates three critical dimensions: economic, social, and environmental. These components synergistically address the threats posed by climate change to food security and sustainable agricultural development.⁵

Any approach that seeks to manage land, crops, livestock, and forests holistically and integratedly in order to boost crop yield, lessen the consequences of climate change, and adapt to these changes is considered climate-smart agriculture.⁶

The Food and Agriculture Organization (FAO) of the United Nations defines CSA as: "the approach that helps to guide the actions needed to transform and reorient agricultural systems to support development and ensure food security under changing climatic conditions."⁷ Some claim that CSA is a strategy or method used in contemporary agricultural systems, which is a multifaceted approach that aims to eliminate hunger and poverty, improve climate change resilience, lower greenhouse gas emissions, and absorb and sequester carbon⁸.

A new strategy called "climate-smart agriculture" uses cutting-edge technology to provide the best agricultural practices that can both adapt to and mitigate the negative effects of climate change. It aims to make agricultural systems more effective, adaptable, and responsive to environmental changes and food sustainability objectives. From these definitions, it becomes clear that climate-smart agriculture is not merely a standardized global practice, but an integrated scientific approach that considers specific local conditions. It necessitates thorough assessments of all environmental circumstances, avoids detrimental agricultural practices like excessive use of pesticides or chemical fertilizers, and integrates modern technological innovations into traditional practices⁹.

Thus, we can underscore the significance of climate-smart agriculture, which is manifest in several key aspects:

- Climate-smart agriculture contributes to reducing the impacts of climate change, which directly affect soil fertility and productivity. By optimizing irrigation techniques, climate-smart agriculture also helps to rationalize groundwater consumption by preserving soil moisture and preventing soil salinity and dryness¹⁰.

- One of the most crucial climate-smart farming practices is biodynamic and organic farming, which depends on organic and biodynamic fertilization. With the development of digital technology, we can maximize the use and sustainability of natural resources while maintaining the high quality of agricultural and animal products, developing more sustainable and high-quality agricultural systems, and

adjusting to climate change and the needs of preserving a balanced ecosystem.

- By using efficient and effective strategies to cut costs and expenses to the bare minimum, climate-smart agriculture helps farmers and landholders feel less financially burdened. This is accomplished by the application of technology that enhances farming methods, resulting in the most efficient and logical use of livestock and agricultural resources..¹¹

- Enhancing livelihoods and achieving long-term food security by providing sustainable food for millions of people, and increasing support for farmers in developing policies, technical mechanisms, and financial aids in the face of climate variability, particularly for small-scale holders and enterprises, Since they are the most at risk from climate change, particularly in developing nations, climate-smart agriculture is the most crucial strategy for ensuring the safety and effectiveness of their farming systems..¹²

- Agricultural nations, where agriculture is the most significant industry both domestically and internationally, are more impacted than industrialized nations due to the growing effects of climate change and rising temperatures., so climate-smart agriculture is the optimal solution for countries that rely on agriculture as a primary source of livelihood to reduce the impact of climate change on their agricultural products and achieve food security¹³. In the face of growing climate change, climate-smart agriculture offers the best means of conserving, using natural resources sensibly and effectively, and balancing agriculture and ecosystems.

- Achieving food sufficiency through nutritious, high-quality crops that complement producers' and customers' capacities is the goal of climate-smart agriculture, and raising productivity and increasing yield through efficient water management, by rational use of water and nutrients which improves crop yields and irrigation efficiency, thus helping farmers to better manage their water resources¹⁴. It gives crops a steady and consistent supply of irrigation while reducing water waste and preserving sustainable soil moisture.

- Climate-smart farming methods maintain the integrity and health of the soil, making it rich in organic and natural nutrients and fruitful, as environmental tillage, planting diverse cover crops, and reducing excessive

soil exploitation help improve soil health and strengthen it, Therefore, in order to maintain the health and nutritional value of food, farmers turn to a variety of methods, such as covering the soil with organic matter rather than synthetic fertilizers, allowing the soil to rest, and diversifying the crops grown in the same area to naturally nourish the soil.

- Climate-smart agriculture, through its practices that rely mainly on natural materials, reduces the amount of greenhouse gases in the atmosphere emitted by agriculture, as a result of its reliance on organic fertilisers instead of synthetic fertilisers and pesticides, which leads to the conservation of both the atmosphere and the soil.

- By giving farmers access to a wealth of knowledge about climate change and the risk of natural disasters like floods and droughts, CSA practices aim to increase farmers' resilience to the effects of climate change both now and in the future. This helps farmers minimize the negative effects of these changes and increase their resilience, which supports the long-term sustainability of farming practices¹⁵.

2.3- Objectives and Pillars of Climate-Smart Agriculture

The primary aim of Climate-Smart Agriculture (CSA) is to sustainably enhance the productivity and efficiency of agricultural systems, strengthen their adaptability to climate change, and reduce or eliminate greenhouse gas emissions from these systems as much as possible, while also enhancing carbon sequestration capabilities¹⁶, It aims to make agricultural systems more efficient and productive, achieve food sustainability, and preserve the natural ecological balance. The main objectives of CSA are outlined as follows:¹⁷

- **Improving Farmers' Productivity and Livelihoods:** CSA seeks to enhance the overall productivity of agricultural crops, including both field and horticultural varieties, which contributes to achieving food security. This objective is realized by increasing crop production, enhancing livestock wealth, and improving the profitability of farms. This is made possible by farmers' clever soil preparation techniques, sensible water supply management, use of organic fertilizers rather than synthetic ones, diversification of field and agricultural crops, rotation of agricultural cycles, and other methods that boost

field and orchard productivity and support the sustainability of wholesome food.

- **Enhancing Resilience to Climate Impacts:** CSA fortifies agricultural infrastructure to withstand the destructive impacts of global warming, which includes measures to reduce exposure to climate-related threats such as floods, droughts, and extreme heat. By studying the environment and understanding the potential climate impacts, climate-smart agriculture aims to adopt agricultural practices that are more adaptable to climate change. This is achieved by identifying the types of crops that are compatible with the environment and its data. For instance, crops that are resistant to heat and drought are grown in extremely hot regions, while crops that require a lot of water are grown in areas with high precipitation. Each crop is thus adapted to the environment and its variables.

- **Reducing Greenhouse Gas Emissions:** Reducing greenhouse gas emissions from agricultural activities, including methane emissions from rice and animal production and emissions from the use of synthetic fertilizers, is a key objective of CSA. Because conventional agriculture heavily relies on synthetic fertilizers, it contributes significantly to greenhouse gas emissions. Climate-smart agriculture aims to lower these emissions by using environmentally friendly, nature-based organic, biodynamic, and biological farming methods.

To achieve these goals, CSA is built on several foundational pillars:

- **Economic Pillars:** With its goal of maximizing profits for farmers, particularly smallholders, climate-smart agriculture is closely related to the economy. This is because smart agricultural practices rationally utilize natural resources, adjusting them to climate change adaptation and protecting ecosystems. These entail raising agricultural output and revenue from fisheries, crops, and animals in a sustainable manner without having an adverse effect on the environment. This promotes farmers' equitable income growth and advances food security and development.¹⁸

- **Social Pillars:** CSA focuses on adapting and building the capacity of agricultural systems to cope with climate change. It emphasizes the importance of ecosystems and the essential services they provide, which are

vital for maintaining productivity and enhancing human adaptability to climate changes¹⁹. This approach helps reduce farmers' exposure to short-term risks and simultaneously enhances their long-term resilience and adaptability to climate-related shocks²⁰. The focus of climate-smart agriculture is on people and their need for enough wholesome food in a balanced and healthy environment. According to this concept, climate-smart agriculture aims to safeguard communities from the adverse consequences of climate change while also enhancing and maintaining livelihoods.

• **Environmental Pillars:** By reducing greenhouse gas emissions from agriculture, intensifying and protecting forests, expanding green spaces that absorb carbon dioxide and store it in agroforestry systems, using less pesticide, managing soil and water wisely, using organic fertilizer, and adopting environmentally friendly farming practices like organic, biodynamic, and ecological farming instead of industrial agriculture, it aims to protect the environment without lowering agricultural productivity.

3- Implementation of Climate-Smart Agriculture Practices and Their Challenges

Climate-smart agriculture is based on several practices related to the environment in which it is applied, and the potential climate changes that this environment may be exposed to in the present and future; all of these practices are based on carefully studied scientific foundations that assume their ability to adapt to climate change and mitigate its effects; however, there are several challenges faced by farmers in the implementation of climate-smart agriculture.

3.1- Practices of Climate-Smart Agriculture:

Climate-smart agriculture (CSA) approaches are related to precision agriculture in that they focus on understanding the variables that influence crop productivity, soil health, and air pollution. It attempts to provide sound, efficient, and effective agricultural practices that are resilient to the challenges of climate change in order to limit the repercussions on agricultural systems. The practices can be summarized as follows:

3.1.1- Sustainable Soil and Land Management:

The effects of climate change on land quality, soil fertility, and resource productivity necessitate the implementation of sustainable and adaptive soil and land management practices. These practices enable farmers to manage their resources such as water, crops, and livestock, maintain biodiversity, and preserve the biological and physical characteristics of the soil, preventing erosion²¹. Soil management is one of the most important practices of climate-smart agriculture, because all agricultural products rely heavily on the soil's quality, fertility, and proportion of natural nutrients, as well as its ability to sustain these desirable attributes over time. Soil and land management also allows farmers to create smart agricultural systems that can adapt to climate change and mitigate its effects on soil, agricultural, and horticultural crops. This, of course, requires an enabling environment that supplies the essential data through the use of advanced climate-smart digital technologies on a global scale. Key soil management practices include:

- **Conservation Agriculture:** Conservation agriculture is an agricultural system that is based on sustainability and increased crop productivity, based on the integration of the essential nutrients water, carbon and energy to enable it to adapt to climate change²². Conservation agriculture practices are based on the use of natural resources available on the site, whether from the remnants of previous crops or crop rotation in the same area, thus keeping the soil permanently covered, which avoids erosion, erosion and drought issues, and avoids the practice of turning the soil completely, as farmers create slits in the soil commensurate with the size of the seeds to be planted and sufficient to cover them, or resort to covering the remnants of the previous crop. This method avoids totally turning the soil because farmers create crevices in the soil that are large enough to cover the seeds to be planted, or they cover the residues of the previous crop. This approach has numerous benefits for the land, including reduced soil erosion, improved water absorption, preservation of natural nutrients in the soil, keeping the soil moist for an extended period of time, and decreasing the farmer's burden of plowing.

• **Organic Agriculture:** Organic farming was developed to counteract the negative consequences of conventional industrial agriculture, which harms the environment and crops owing to its reliance on synthetic fertilisers and chemical pesticides, disrupting the balance of food systems and the ecosystem. Organic farming is a modern agricultural system based on the application of advanced technology aimed at safeguarding the environment and living organisms, reaching a high degree of quality and productivity of crops, livestock, and forests, and ensuring resource sustainability and sufficiency²³.

Organic farming uses natural elements for fertilization instead of pesticides and synthetic fertilisers, as it recycles animal or plant waste and uses it as organic fertiliser, as well as relying on renewable resources that are always present on the farm and growing nitrogen-fixing crops, and thus it uses self-sourced and inexpensive resources and does not cost the farmer financially, resulting in several advantages over conventional farming. Organic farming has various advantages over conventional farming: it is less expensive, self-sufficient in fertilizer and soil nourishment, produces high-quality, healthy crops, and is regarded environmentally beneficial due to its lack of chemical ingredients.

• **Hydroponics:** In soil farming, the plant obtains its nutrients from the fertile soil, whereas in hydroponics, the plant obtains its nutrients from the water in which it is planted, and this process provides this water with the nutrients required for crop growth while also ensuring the provision of other necessary elements such as sunlight and air.

Seeds are planted directly in water with mineral solutions outside the soil, achieving high efficiency in improving productivity compared to traditional methods. This practice reduces problems of fungi and pests that typically affect plants, as well as the accumulation of heavy metals and insecticides in plant tissues grown in soil²⁴.

Hydroponics allows farmers to produce food anywhere and throughout the year, away from the effects of climate change, as farmers resort to this practice when the soil is not suitable for agriculture, such as desert areas, rocky mountainous areas, and areas that are greatly affected by

climate change and weather fluctuations, thus creating local agricultural systems that consume less water than soil farming, as it can save approximately 98% of water compared to soil farming, and Hydroponic crops mature 25 per cent faster than soil-grown crops

3.1.2- Sustainable Water Management:

Given the negative effects of climate change on water resources, climate-smart agriculture seeks to overcome or mitigate these effects, particularly since water wealth is an important component of the agricultural sector, which consumes approximately 70% of total water wealth. In this regard, climate-smart agriculture employs smart practices to manage water and achieve sustainability in fresh water resources suitable for irrigation, irrigation, and aquaculture.

Sustainable water management contributes to the adaptation and mitigation of climate change's effects on water resources. The demand for freshwater is expected to rise rapidly in the future due to population growth, agricultural land use change, urbanization, precipitation scarcity, increased acid rainfall, increased water pollution, and higher temperatures, which cause significant amounts of water to evaporate... necessitates linking adaptation options to climate change with policies, institutions, investments, and practices in crop and water management²⁵.

Sustainable water management includes:²⁶

- **Management in Irrigated Areas:** We define irrigated areas as agricultural areas that are not dependent on precipitation or rainfall but are irrigated using automatic spraying or drip irrigation technology, and water is managed in these areas by adjusting incentive systems for water management and use to reduce water pollution and rationally exploit groundwater. This method improves farmed systems' resilience to water scarcity.

- **Water Policy Governance:** Making water policies based on the collection of information and data on agriculture's water needs, current and projected future potential, climate change and its projected impacts on agriculture and water resources, that is, linking water and agricultural policies, and achieving a balance between the cost of available water for agriculture and its productivity returns.

- **Increasing Irrigation Efficiency:** Climate-smart farming practices use several advanced technological methods in irrigation and watering of agricultural and field crops, saving time and effort and conserving water, as it seeks to increase irrigation efficiency through sustainable irrigation methods that allow changes in planting schedules and early planting, relying on improved crop varieties that are stress-tolerant, and using sprinkler and drip irrigation systems that provide low amounts of water.

- **Monitoring Water Use with Technology:** Advanced technological techniques are used to manage water resources in terms of the amount of water stored, the amount of water expected to be collected in the coming periods, and the volume of water demand, which is primarily related to environmental factors such as temperature, humidity, drought rate, soil quality, crop nature, climate change, and others, to ensure that water resources are used rationally.

- **Using satellite imagery and precise weather data:** to make informed decisions based on scientific data such as surface soil moisture, seeding areas, and daily and cumulative rainfall.²⁷

3.1.3- Integrated Pest Management (IPM):

IPM is a climate-smart, environmentally friendly strategy that removes weeds from agricultural crops and controls associated pests without the use of excessive pesticides, thereby preserving both human and environmental safety. According to FAO, IPM attempts to maintain the ecosystem and its biodiversity, as well as safeguard crops and soils from the use of toxic pesticides. This method combines numerous strategies in a more biologically, chemically, and physically sustainable manner²⁸.

This strategy provides numerous benefits to farmers, including avoiding the health concerns associated with the use of chemical pesticides, saving them work, time, and money, and making their crops more competitive in the market due to their quality and healthfulness. On the other hand, this climate-smart approach protects the environment, including the atmosphere and soil.

3.1.4- Climate-Smart Crop Production:

Climate-smart crops are those that can adapt to climate change and mitigate its negative effects on crop productivity, such as drought-resistant crops, crops that do not take long to mature and thus use agricultural areas throughout the year, or crops that do not require much care, all using technological methods that help to achieve the goal efficiently and effectively.

The Food and Agriculture Organization (FAO) identifies three pathways to achieve this: intensifying agriculture (more than one crop per year), expanding arable land, and increasing crop density. The first pathway is expected to achieve 93% of the required increase in production, thereby improving productivity through vertical increases in productivity per unit of input (land, water, fertilizers) rather than horizontal expansion²⁹.

These practices are designed to adapt agriculture to the current and future challenges posed by climate change, focusing on sustainable resource use, environmental protection, and enhanced productivity. Climate-smart agriculture encompasses specific approaches to crop production, which include:³⁰

- **Increasing Ecosystem Diversity in Agriculture:** That is, diversifying agricultural systems such that they are not reliant on a single crop and do not require specific seasons for cultivation. This can be accomplished by increasing crop diversity and multiplicity, expanding spatial planting ranges, and planting throughout a variety of time frames.

- **Enhancing Sustainable Soil and Land Management:** The soil becomes naturally nutrient-rich, very productive, and capable of supporting various crops throughout the year without stress. For example, carefully directing the expansion of crop and grazing lands to mitigate the loss of carbon storage due to land use changes.

- **Leveraging Sustainable Technology:** Using technology to achieve proper agricultural management and reduce greenhouse gas emissions from various agricultural processes, by designing methods and products that do not affect the environment, such as using renewable energies and environmentally friendly agricultural systems.

• **Developing Data Collection and Analysis Tools:** climatic-smart farming systems give farmers with very advanced strategies for anticipating climatic changes, average precipitation, wind speed, and other data based on satellites and the Internet of Things to assist their decision-making processes over the medium and long term.

3.1.5- Cultivating Climate-Resilient Crop Varieties:

There is a shift towards cultivating crops that are more resistant to temperature extremes and acidic rainfall to mitigate the effects of climate change. By providing a data bank on the temperature regime and rainfall amount in a specific area, it becomes easier to monitor crops and identify selective practices for crop varieties that are suitable for the local environment³¹. Drought-resistant crops remain the plant varieties most capable of enduring drought and helping farmers maintain or improve their production, even in the face of climate change³².

3.1.6- Sustainable Forestry Management:

Sustainable forestry management balances environmental, economic, social, and cultural factors in its efforts to adapt to and mitigate climate change and achieve food security. This smart practice protects local livelihoods, preserves biodiversity, and the ecosystems provided by forests, reduces rural poverty, and mitigates some of the negative impacts of climate change³³.

3.1.7- Agroforestry:

Agroforestry integrates crop cultivation and livestock raising with forestry, where trees are planted alongside crops or livestock. Trees provide shade, act as windbreaks, and enhance nutrient cycling for crops and livestock. They also sequester carbon dioxide related to agriculture, maintaining biodiversity and soil fertility, and creating more resilient agricultural landscapes³⁴.

3.1.8- Energy Management:

This involves the introduction of renewable energy efficiency applications throughout the food production chain to reduce greenhouse gas emissions and pollutants, provide a high percentage of clean energy, and reduce energy losses, which account for about 33% of the total energy used

in the food chain. Additionally, it includes the recycling and repurposing of agricultural waste into clean energy.

3.2- Five Key Points for Implementing Climate-Smart Agriculture

The Food and Agriculture Organization (FAO) has identified five key action points for implementing climate-smart agriculture, summarized as follows:

3.2.1- Create a data Bank:

This involves collecting data and information related to the agriculture sector to understand the impacts of climate change on agricultural systems, identify strengths and weaknesses in agriculture, and the available institutional mechanisms and financial resources, and climate-smart adaptation and mitigation options. Successful implementation of this stage includes:³⁵

- Identify key climate change alternatives for farmers based on current capacities and institutions.
- Analyse the data and information collected, based on which CSA options are prioritised.
- Examine the applied practices to see their results and evaluate them, draw lessons learnt and share them with farmers.

3.2.2- Supporting and developing enabling policies:

This stage is linked to the legislative aspect and the national policies and plans prepared to activate the role of climate-smart agriculture in facing the challenges of climate change and achieving food security. This is achieved through:³⁶

- Promoting CSA practices through policy, legislation, strategies, and investments at national and local levels.
- Renew or modify policies as needed.
- Ensuring effective and continuous coordination of policy-making processes among the institutions responsible for implementing climate-smart agriculture and achieving food security and land use.

3.2.3- Supporting national and local institutions and enhancing their role:

This stage involves identifying institutions at various levels that support the goals of climate-smart agriculture, mapping institutional

frameworks, and both formal and informal actors responsible for implementing strategies. This allows for a broader information base and a better understanding of the gaps and challenges that need to be addressed.³⁷

This stage is implemented through:³⁸

- Provide full and continuous support to all organisations involved in climate-smart agriculture, and incentivise them to empower farmers to increase their efficiency and productivity.
- Qualifying and training policymakers for successful participation in climate-smart agriculture policy-making at international levels.
- Organizing national and international forums, seminars, and conferences to raise awareness of climate-smart agriculture and its impact on agricultural systems, including adaptation and mitigation strategies.

3.2.4- Identify funding sources and alternatives:

The success of climate-smart agriculture (CSA) largely depends on the financial aspect of implementing its strategies in the field. These financing sources could include national or international governmental financial institutions, as well as the private sector, which contributes by injecting financial resources to develop and implement CSA practices. This includes funding climate change studies, projects linking climate and agriculture, and financing all efforts for adaptation and mitigation, achieved through:³⁹

- Enabling farmers to access the necessary financing required for CSA practices from financial institutions active in this field such as: Green Climate Fund (GCF), Global Environment Facility (GEF), and Official Development Assistance (ODA).
- Enhance governmental or private sector projects that connect climate finance and agriculture investment, and establish innovative linkages to support these initiatives.
- Paying attention to climate change issues and their impact on agricultural systems, taking them into consideration and integrating them into agricultural plans and public budgets.

3.2.5- Field application of climate-smart Agriculture practices:

The Food and Agriculture Organization (FAO) in its guide on CSA outlines several factors that should be considered when implementing CSA practices at the field level:⁴⁰

- Engaging local farmers and utilizing their knowledge to understand their needs and priorities to identify appropriate CSA options for implementation.

- For successful implementation, the process should be supported by strong stakeholders such as farmers, herders, fishermen, project managers, and local institutions, built on a participatory process and consultations that incorporate valuable knowledge and networks.

- Local knowledge and priorities, agricultural ecosystems, crops, livestock, and forests should be part of the evidence base used to select practices for this approach.

- Knowledge generation during and after the implementation of CSA practices can contribute to creating a feedback loop from phase five back to phase one of CSA implementation.

3.3- Challenges in Implementing Climate-Smart Agriculture Practices:

Understanding the challenges imposed by climate change on agricultural systems is crucial for implementing CSA practices. However, these challenges vary from region to region on both local and national levels, and information about these challenges is still insufficient. Farmers face several challenges in adopting CSA, including:⁴¹

3.3.1- Limited information and lack of awareness:

A lack of awareness, information, and experience about CSA practices among farmers is a barrier to the success of this approach, making them unable to implement it on their farms even if they are interested. Farmers struggle to adopt an effective CSA method due to a lack of understanding and familiarity with all of the requirements.

3.3.2- High Costs:

Introducing modern technology into agricultural systems requires significant, costly investments that many farmers, especially in third-world

countries, cannot afford. This includes the costs of acquiring precision farming equipment and training for farmers and staff, particularly smallholders. This complicates the implementation process and necessitates significant finance from public or private financial institutions related to agricultural projects.

3.3.3- Crop Marketing Difficulties:

The market for CSA products is quite small, making it difficult for farmers to find clients for their smart products due to higher costs compared to conventional products, making it impossible for them to meet expenditures while maintaining a profit margin. This is why many farmers reject these smart approaches in favor of traditional practices that offer low quality, competitive prices, market breadth, competitiveness, and good financial returns.

3.3.4- Inadequate policies and legislation:

These are linked to local agricultural policies that may not align with CSA approaches and the adaptive policies required, facing several regulatory hurdles (restrictions on using certain technologies) or financial (lack of government financial support), making it difficult to implement practices in the field.

3.3.5- The nature of the society and the prevailing culture:

Some CSA techniques may be incompatible with the current community culture, which regards them as harmful to traditional traditions, making it difficult for farmers to adopt them. Aside from the character of the civilization, whether agricultural or industrialized, agricultural techniques decrease and are replaced by industrial ones.

3.3.6- Fluctuating precipitation and temperatures:

Continuous increases in long-term variability in rainfall and temperature levels, as well as a lack of rainfall during agricultural seasons, negatively affect the adoption of smart agricultural technologies. This has a negative impact on the soil and its quality, increasing its dryness or moisture content, as well as affecting the yield of agricultural crops, particularly those that are sensitive to climate change.

4- Future Trends in Climate-Smart Agriculture

With the increasing technological advancements and the introduction of artificial intelligence in various fields, including agriculture, CSA is likely to be positively influenced by these developments. Future trends in CSA can be outlined as follows:

4.1- Utilising advanced technology to enhance agricultural information security:

Climate-smart agriculture is increasingly leveraging advanced technological techniques, including:

4.1.1- Utilising remote sensing technology:

Advanced technology is extensively used in various fields to monitor and track large areas of the Earth's surface simultaneously. Data is rapidly and accurately gathered from satellites or drones, utilizing sensor capabilities to detect targets within the electromagnetic spectrum⁴². In the realm of climate-smart agriculture, this technology enables precise monitoring of crops by assessing the health of the plants and estimating their nutrient and water needs. It also assists farmers in selecting the best-suited crops for a specific region and predicting their productivity, the technology also helps to predict climate change in a region so that farmers have the opportunity to mitigate its effects by taking all necessary measures.

4.1.2- Applying the Internet of Things (IoT) technology in climate-smart farming practices:

The Internet of Things (IoT) comprises a vast network of interconnected computing devices and sensors, all linked to the internet. The data collected by these sensors is processed and analyzed to facilitate decision-making⁴³. In climate-smart agriculture, IoT technology is primarily utilized in several crucial aspects:

- **Apply precision farming practices:** Input schemes are tailored based on detailed data about plant conditions in order to improve efficiency and crop output. Satellites, sensors, artificial intelligence, and GPS systems are used to collect this data, deciding what inputs, such as fertilizer and pesticides, are required, as well as when and where they should be applied.

- **Use greenhouse devices and apply indoor farming automation:** By implementing technology in indoor and protected indoor farming within

greenhouses equipped with advanced technology that enables climate control, supplemental lighting, ventilation, and air conditioning...

• **Monitor weather fluctuations and track the state of the environment:** Smart sensors are used to identify threats connected with frost, drought, floods, and desertification, allowing for preemptive management.

• **Smart Water and Irrigation Management:** Many advanced technologies are used in water management in order to rationalise the use of water resources and utilise precipitation water, enabling moisture levels to be maintained, improving automated drip irrigation systems, understanding crop cycles, and monitoring plant growth stages to ensure efficient water usage.

For the future enhancement of IoT in climate-smart agriculture, several considerations must be taken into account:⁴⁴

- **Adaptability:** The IoT system should be flexible and adaptable to local conditions.
- **Effectiveness:** IoT deployment must be robust, ensuring network connectivity is maintained under all conditions.
- **Security:** It is critical that IoT in climate-smart agriculture is secure to protect both data and operational integrity.

4.1.3- Widespread adoption of artificial intelligence.

Climate-smart agriculture is increasingly incorporating artificial intelligence (AI) into its practices. AI analyzes and integrates data from various agricultural fields to facilitate plant recognition, predict harmful weed occurrences, forecast crop production, estimate greenhouse gas emissions, and anticipate climatic conditions. This enables the multiplication of crop yields and ensures their quality and health. Farmers can transform traditional agricultural practices into highly advanced, data-driven systems with the help of AI tools⁴⁵.

4.2- Improving Crop Patterns and Management Techniques

Future directions in climate-smart agriculture include adopting multiple crop patterns and no-till farming. These methods utilize organic enhancers, like bio char, to improve soil quality and increase crop

productivity while reducing greenhouse gas emissions. Climate-smart agriculture also supports practices aimed at soil protection, such as using crop residues, improving nitrogen use efficiency, and minimizing tilling. These practices lead to increased crop yields, enhanced water conservation, reduced greenhouse gas emissions, and overall resource conservation, thus advancing environmental protection and achieving sustainability.

Climate-smart agriculture, on the other hand, is increasingly adopting climate-smart crops that can adapt to and alleviate the consequences of climate change. This approach will allow farmers to minimize crop damage caused by climate change, as well as limit the yield of agricultural and horticulture crops, while also assisting in food security.

4.3- Adoption of the 'Internet + Weather' service

By 'Internet+Weather', we imply connecting all meteorological operations to the Internet and incorporating modern digital technology into all climate-related studies, allowing for very accurate and dependable weather forecasting and monitoring.

Future climate-smart agriculture will utilize internet technology to effectively provide meteorological services to meet farmers' needs. Implementing the "Internet + Weather" service will enhance the quality of agricultural services, improve weather forecasting, monitoring, and early warning capabilities, and achieve climate-smart agriculture goals. Programs like "Agrio" provide farmers with accurate local weather predictions, helping them schedule spraying and manage pests and diseases more effectively, plan efficient growing seasons, save money, and develop stronger, healthier plants.

4.4- Weather Index-Based Agricultural Insurance

In light of the continuous and increasing climate change, and the negative effects of these changes on crops and thus on agricultural yields and farmers' financial returns, the Agricultural Weather Index insurance came to help farmers minimise their losses due to climate change, so that they are financially compensated according to the damage caused.

In this direction, Agriculture faces significant challenges related to climate change, necessitating a comprehensive and adaptive approach to crop insurance. Agricultural weather indices are used as motivational

mechanisms in agricultural insurance, known as weather index-based insurance, to mitigate the negative effects of natural hazards on agricultural production. This type of insurance is used in areas where traditional insurance is unfeasible due to lack of farm-level data or high costs. Insurance companies are responsible for compensating for climate-related damages if losses exceed a predetermined threshold. For crop insurance to be effective against climate change, intensive, continuous, and comprehensive cooperation between governments, insurance companies, and farmers is essential⁴⁶.

4.5- Building Climate-Smart Villages

The Climate Smart Village (CSV) is a plan or method that combines numerous established and effective agricultural projects that have already been implemented in specific regions. These efforts are founded on scientific and participative concepts of establishing climate-resistant agricultural practices and developing relevant technologies to deploy them on the ground to adapt to climate change.⁴⁷

Climate-smart villages incorporate the majority of climate-smart strategies used in agriculture, such as weather-related technologies, sustainable irrigation practices, seed quality improvement techniques, soil and crop management, organic and precision farming techniques... Through the data collected, climate-smart villages help build land use plans based on current weather forecasts and future climate changes, help build the capacities of local communities to read weather fluctuations in real time, and reveal shortcomings at the legal and legislative level in the field of climate-smart agriculture. The climate-smart village model has proven its effectiveness in addressing climate change challenges in the regions where it has been applied and has contributed to enhancing food security in many countries that have applied it.

Conclusion

Climate-smart agriculture is a new, comprehensive strategic strategy meant to address the multiple and rising issues that farmers face as a result of climate change. It is based on three fundamental goals: increasing agricultural output, strengthening resistance to climate change, and

reducing greenhouse gas emissions from agricultural activities. This method seeks to transform agricultural systems into sustainable practices that can adapt to climate change.

However, climate-smart agriculture does not advocate for a one-size-fits-all approach. It needs unique adaptations to suit individual conditions, including growing climate hazards that differ between agricultural communities and ecosystems. As a result, climate-smart agriculture is frequently a novel but difficult adaptation strategy in disadvantaged rural communities.

Effective implementation of climate-smart agricultural practices at the grassroots level should not only concentrate on understanding the functionalities of these practices but also on comprehending the complex and interrelated network of cultural, economic, environmental, and technological factors that influence these adaptive practices.

From this study, we have derived several conclusions:

- Climate-smart agriculture practices have the ability to adapt to climate change and mitigate its adverse effects through their distinctive ecological agricultural properties, increasing biological diversity and the resilience of agricultural ecosystems.
- Climate-smart agriculture aims to efficiently utilize and conserve natural resources (water and land) and reduce greenhouse gas emissions, representing an environmentally friendly approach.
- Climate-smart agriculture contributes to transforming traditional agricultural systems into sustainable ones, through increasing the productivity of field crops and sustainably increasing income.

To enhance the adoption of climate-smart agriculture for adapting to and mitigating climate change, we offer the following recommendations:

• **Providing Information Banks and Extension Services:** Governments should provide digital platforms and local channels to supply farmers with data for each region, best agricultural practices, and available new technologies.

• **Encouraging the Adoption of Climate-Smart Agricultural Practices:** Governments should offer incentives, subsidies, training programs, and finance for agricultural research, adopt projects in this field,

encourage scientific research, and technological development in climate-smart agriculture.

• **Financing Climate-Adaptable Agricultural Projects:** Facilitating farmers' access to credit and sufficient financial services to invest in climate-resilient agricultural projects, directing funds towards modernizing irrigation systems, developing drought-resistant seeds, preparing storage facilities, and transitioning to clean energy.

• **Creating a Favourable Political Environment:** This environment should encourage climate-smart agricultural practices and enhance cooperation between government agencies, non-governmental organizations, and research institutions.

• **Organizing Workshops and Capacity-Building Seminars and Monitoring Progress:** This would enhance farmers' knowledge and develop their skills in climate adaptation and mitigation, as well as implement regular monitoring and evaluation to assess the effectiveness of climate-smart agriculture outputs.

• **Creating an Enabling Environment for Educating Farmers and Improving Their Level:** Encouraging farmers to use new technological practices in their agriculture and supporting them with the necessary resources.

References:

- 1- Riad Mousawi, Rafik Yousfi, "The Contribution of Climate-Smart Agriculture to Achieving Food Security in the Arab World", Human Sciences Journal, Volume 8, Issue 1, March 2021, p. 910.
- 2- Mary Nyasimi et al, Adoption and Dissemination Pathways for Climate-Smart Agriculture Technologies and Practices for Climate-Resilient Livelihoods in Lushoto, North east, 2017, p. 02.
- 3- Lipper L et al, "Climate Smart Agriculture: Building Resilience to Climate Change, Springer Nature Publishing", FAO, Volume 52, 2018, p. 18-20.
- 4- FAO, Addressing Climate Change through Climate-Smart Agriculture, Rome, 2017, p.13.
- 5- Junfang Zhao, Dongsheng Liu, and Ruixi Huang, A Review of Climate-Smart Agriculture: Recent Advancements, Challenges, and Future

- Directions, Sustainability 2023, <https://doi.org/10.3390/su15043404>, accessed 15-02-2024, p. 03.
- 6- Climate Smart Agriculture: Practices And Their Adoption, published 30-06-2023, <https://eos.com/blog/climate-smart-agriculture>, accessed 20-04-2024.
- 7- Timothy O. Williams et al, Climate Smart Agriculture in the African Context, an action plan for African agricultural transformation, Feeding Africa 21-23 October 2015, Dakar, Senegal, p. 2.
- 8- Ibid.
- 9- Hiyam Abdel Fattah, Smart Agriculture: Egypt's Hope in Preserving the Environment and Natural Resources, published August 7, 2018, at <https://alfallahalyoum.news>, accessed June 3, 2023, at 16:00.
- 10-Halima Bousiki, Lakhmissi Ouar, “Climate-Smart Agriculture as a Mechanism to Reduce Unsustainable Agricultural Practices in Algeria”, Journal of Financial, Accounting, and Administrative Studies, Volume 09, Issue 02, December 2022, p. 1130.
- 11-Arab Organization for Agricultural Development, Climate-Smart Agriculture: A Better Future for Arab Agriculture and Conservation of Natural Resources, 2018, p. 2.
- 12-Halima Bousiki, Lakhmissi Ouar, Op.Cit, p. 1130.
- 13-Ghadamsi Aisha, “Climate-Smart Agriculture and Climate Change”, Journal of Money and Business Economics, Volume 3, Issue 2, December 2018, p. 76.
- 14-Terra Drone Agri, Climate-Smart Agriculture: Benefits and Challenges Farmers Face, published December 12, 2022, <https://www.linkedin.com>, accessed October 10, 2023.
- 15-Ibid.
- 16-Junfang Zhao, Dongsheng Liu, and Ruixi Huang, Op.Cit, p. 03.
- 17-What Is Climate-Smart Agriculture?, Last updated, published January 21, 2021, <https://www.rainforest-alliance.org>, accessed January 22, 2023.
- 18-Hamdani Mehieddine, “Climate-Smart Agriculture and Food Security”, Algerian Review of Economy and Finances, September 10, 2018, p. 16.
- 19-Leslie Lipper et al,” FAO, Climate Smart Agriculture: Building Resilience to Climate Change”, Springer Nature Publishing, Volume 52, 2018, p. 1068.
- 20-Aisha Ghadamsi, Op.Cit, p. 73.

- 21-FAO, Climate-Smart Agriculture Implementation in Agricultural Production Systems and Food Systems, <https://www.fao.org/climate-smart-agriculture-sourcebook>, accessed February 11, 2024.
- 22-Riad Mousawi, Rafik Yousfi, Op.Cit, p. 915.
- 23-What is Organic Farming? – Definition of Organic Farming and Examples, <https://wikifarmer.com/ar/2>, accessed June 12, 2023, at 18:00.
- 24-Mohamed Sanajla, Hydroponics: New Technology Will Solve the World's Food Problem, published November 03, 2021, <https://www.aljazeera.net>, accessed June 12, 2023, at 18:30.
- 25-FAO, Climate-Smart Agriculture Implementation in Agricultural Production Systems and Food Systems, Op.Cit.
- 26-Riad Mousawi and Rafik Yousfi, Op.Cit, p. 916, 917.
- 27-Climate Smart Agriculture: Practices And Their Adoption, Op.Cit.
- 28-Food and Agriculture Organization of the United Nations, Pest Management and Pesticides, <https://www.fao.org/>, accessed June 12, 2023, at 19:00.
- 29-Riad Mousawi, Rafik Yousfi, Op.Cit, p. 917.
- 30-FAO, Climate-Smart Agriculture Implementation in Agricultural Production Systems and Food Systems, Op.Cit.
- 31-Climate Smart Agriculture: Practices And Their Adoption, Op.Cit.
- 32-Terra Drone Agri, Climate-Smart Agriculture: Benefits and Challenges Farmers Face, published December 12, 2022, <https://www.linkedin.com>, accessed February 15, 2024.
- 33-General Phosphate Company, Sustainable Forestry Management, <https://www.forestprotection.net>, accessed June 11, 2023, at 10:00.
- 34-Climate Smart Agriculture: Practices And Their Adoption, Op.Cit.
- 35-FAO, Climate-Smart Agriculture Case Studies 2021, Projects from Around the World, Rome, <https://doi.org/10.4060/cb5359en>, accessed February 10, 2024.
- 36-Ibid.
- 37-FAO, Climate-Smart Agriculture Implementation in Agricultural Production Systems and Food Systems, Op.Cit.

- 38-FAO, Climate-Smart Agriculture Case Studies 2021, Projects from Around the World, Rome, Op.Cit.
- 39-Ibid.
- 40-Ibid.
- 41-Terra Drone Agri, Op.cit.
- 42-Junfang Zhao, Dongsheng Liu, and Ruixi Huang, Op.Cit, p. 09-11.
- 43-Moko Smart, Internet of Things in Climate-Smart Agriculture, <https://www.mokosmart.com>, accessed May 05, 2024, at 16:00.
- 44-Junfang Zhao, Dongsheng Liu, and Ruixi Huang, Op.Cit, p. 09-11.
- 45-Food and Agriculture Organization of the United Nations, World Food Forum: The Pivotal Role of Artificial Intelligence and Digital Tools in Making Agricultural and Food Systems Resilient to Climate, published October 19, 2023, <https://www.fao.org/>, accessed May 07, 2024, at 14:30.
- 46-Junfang Zhao, Dongsheng Liu, and Ruixi Huang, Op.Cit, p. 09-11.
- 47-Vandana Chauhan, “Climate Smart Agriculture: A Key to Sustainability”, parliament library and reference, research documentation, and information service (larrdis), No 02/ RN/Ref/ January 2022, p. 6.