# Review of Climate Smart Agricultural Technologies Adoption and Use in Nigeria

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## ABSTRACT

Climate-Smart Agriculture Technologies (CSATs) have emerged as innovative solutions that seek to revolutionize traditional agricultural practices by leveraging enabled sensors and automation and using data analytics to boost yields, reduce costs, and increase profitability. With Nigeria's largely agrarian rural population, the adoption of CSATs has the ability to transform the country's agricultural sector significantly. The implementation of CSATs in rural Nigerian communities can enhance the productivity and sustainability of smallholder farmers, particularly in the face of climate change-induced challenges. By utilizing advanced techniques and technologies, farmers can optimize production while minimizing negative impacts on the environment. Furthermore, the integration of digital platforms would enable smallholder farmers to access critical market information, which could lead to better prices for their products. This paper provides a comprehensive review of works that have been done on the potential application and adoption of CSATs in rural Nigeria. The study highlights the importance of creating an enabling environment that incentivizes farmers to adopt these technologies.

**Keywords:** Climate-Smart Agriculture Technologies; Adoption; Use; Agriculture Development; climate change

## INTRODUCTION

Agriculture provides the vast majority of rural Nigerians with their principal source of income, and according to the International Fund for Agriculture Development IFAD [1], approximately 70% of rural people are subsistence smallholder farmers who produce approximately 90% of Nigeria's food crop production on fragmented land with complete reliance on rainfall. According to the Food and Agriculture Organization [2], agriculture has several economic and nutritional benefits for Nigerians. In addition, it is vital to the country's economy, accounting for about 22% of GDP in 2020 ([3], [4]). However, an overemphasis on oil production and rising climate changes challenge the agricultural sector's prominent position in the Nigerian economy.

Temperature, wind, sunshine, and relative humidity are the primary determinants of crop development and production ([5], [6]). According to [7], climate change offers a substantial danger to agricultural productivity in Nigeria, with indications of altering rainfall patterns, severe weather events, and rising temperatures. Continued warming of the atmosphere, decreased rainfall, increased pests due to warming, and other climate change-related effects pose actual and significant dangers to human survival and progress. Climate change affects practically all phases of the farming system, with rural farmers particularly susceptible due to their limited infrastructure and reliance on weather signals for farming activities [8]. This condition is aggravated by global warming, which is anticipated to reach 1.5 degrees Celsius between 2030 and 2052 [9].

In recent years, development agencies have advocated the notion of "Climate Smart Agriculture" (CSA) ([10], [11]). The FAO established the term CSA in 2010 to address the problems of providing food security for a rising population while reducing greenhouse gas emissions from the agricultural and forestry subsectors [11]. Climate Smart Agricultural technology (CSATs) are a set of techniques and technology meant to assist farmers in boosting agricultural output sustainably, particularly in rural regions where farming is the principal source of revenue [12].

CSATs focus on sustainable practices that increase productivity and help attain national food security and the Sustainable Development Goals (SDGs) on food security, conserving forests, combating desertification, and stopping land degradation and biodiversity loss. It reduces agricultural vulnerability, improves farmers' adaptive capability, and boosts food yield while leaving a reduced ecological imprint. CSATs is an integrated landscape management concepts, including rural development, biodiversity protection, and ecosystem services ([13], [14]).

Reference [15] also noted that the CSATs approach makes better use of natural resources such as (land, water, soil, nutrients, and genetic resources) for human needs while considering the environment and minimizing the employment of external inputs, building resilience and capacity of adapting food and cropping systems to climate change, and reduces and removes greenhouse gases (GHGs) while improving national food security ([16]). Therefore, CSAT adoption and utilization have the capability to enhance agriculture in Nigeria by increasing yields, reducing waste, and increasing profitability.

Precision agriculture, vertical farming, and agricultural drones are the latest CSAT technologies globally. Precision agriculture provides farmers with granular information in real-time about soil fertility, nutrient levels, moisture content, and pest infestation levels, allowing them to make knowledgeable judgments on when to plant, fertilize, irrigate, or apply pesticides [17]. Vertical farming is a smart agriculture technology that grows crops in vertically stacked layers utilizing controlled-environment agriculture (CEA) techniques such as LED lighting and hydroponics or aeroponics. It removes the necessity for pesticides and herbicides, saves water, and allows for year-round crop production [18]. Drones in agriculture are Unmanned Aerial Vehicles (UAVs) equipped with sensors, cameras, and GPS technology for precision agriculture, which are used to map and survey farmland to generate high-resolution maps and identify crop stress, soil moisture status, and plant growth patterns [18].

Although these three CSATs can give farmers the tools they need to reduce the negative consequences of climate change. However, their adoption and usage in an emerging nation like Nigeria could be hampered by the high cost of procuring the equipment, as well as a lack of communication infrastructure, access to energy, lack of understanding about the benefits of the technology, and a lack of training on how to operate the equipment and analyze the data obtained. Furthermore, vertical farming is only appropriate for metropolitan locations with limited arable lands.

CSATs most commonly used by farmers in West African countries, according to [19], include enhanced crop varieties, soil and water conservation technologies, agroforestry, traditional parklands, intercropping, citrus orchards, zero tillage, integrated soil fertility management, organic manure or compost, and integrated farming systems, such as intercropping, because farmers observed improved productivity and stress tolerance. According to [20] and [21], since their introduction, CSATs and their practices have sparked debates about developing countries' roles and responsibilities in worldwide greenhouse gas emissions reduction, as well as what types of technologies promote sustainable agriculture.

In 2011, the Consultation Group on International Agricultural Research (CGIAR) Programme on Climate Change, Agriculture, and Food Security (CCAFS) and local partners launched a pilot project in West Africa to test climate-smart settlements. The initiative was carried out in Ghana, Mali, Niger, Burkina Faso, and

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Senegal using participatory action research, a community method in which farmers and scientists research and learn together, emphasizing changing and reflecting. As a result, farmers used better crop varieties, water and soil conservation technology and integrated soil fertility management to boost their yields. Other activities included in the climate-smart village program, according to [19], were tree planting, agroforestry, early sowing or planting, and farmer-managed natural regeneration.

Nigeria was not a participant in the CCAFS program, but it acknowledged that CSATs are essential tools for accomplishing the goals of the agricultural reform agenda. As a result, the Federal Government of Nigeria (FGN) submitted a document to the 2015 United Nations Framework Convention on Climate Change (UNFCCC) intending to boost agricultural production and support equitable increases in farm incomes, improving food security and development, and lowering emissions of greenhouse gases. In addition, the FGN advocated policies such as preventing deforestation and developing agroforestry, estimating total (lifetime) carbon emission reductions from agroforestry to range between 158 and 712 million tonnes [22].

The Agricultural Promotion Policy (APP) was another FGN initiative developed through an inclusive stakeholder consultation involving farmer organizations, academics, and private sector investors. It includes CSATs as one of its thematic approaches to agricultural growth [23]. The strategy encouraged adopting and using good natural resource management in rural farming communities and best climate change adaption practices and mitigation, which can lead to sustained farm production and national food security.

This present study reviewed the work done by researchers to examine the adoption and use of CSATs in Nigeria.

## REVIEW OF LITERATURE

Climate change is a huge concern for Nigeria's agricultural industry; its consequences are severe, resulting in lower crop yields, land degradation, and water scarcity, among other things. CSATs have been adopted and utilized in Nigeria in response to these climatic issues. Literature across Nigeria has established that a number of CSATs have been adopted and used to increase agriculture output while reducing greenhouse gas (GHG) emissions. Below is a literature review of studies examining the various CSATs adopted and used by farmers in Nigeria.

### *Organic Farming and Integrated Soil Management*

Organic agriculture and integrated soil management strategies are critical to supporting sustainable agriculture in Nigeria. These technologies place a premium on environmental stewardship, soil health, and producing nutritious, chemical-free crops. Nigerian farmers may reduce climate change, improve soil fertility, increase biodiversity, and protect human health by practising organic farming and integrated soil management.

Several studies have emphasized organic farming as a CSAT that supports sustainable food production without synthetic pesticides. [24] and [25] highlight the importance of organic inputs and indigenous knowledge systems in boosting agricultural output and soil fertility. These approaches are consistent with organic farming principles and illustrate Nigeria's potential for climate change mitigation and sustainable agriculture.

Integrated soil management technologies incorporate agricultural components, including organic inputs, conservation agriculture concepts, agroforestry systems, and animal management. [26] and [27] examine the use of manure as fertilizer and rotational grazing to reduce livestock greenhouse gas emissions and increase soil fertility. [28] also propose improved feed management and agroforestry to reduce emissions from

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livestock agriculture. These findings highlight the significance of combining livestock management with sustainable agriculture to minimize environmental consequences.

[29] emphasize the necessity of controlling soil fertility. Their research highlights the use of organic fertilizers to boost agricultural yields while lowering emissions caused by synthetic fertilizer use. This is consistent with the wider objective of integrated soil management, in which methods such as organic inputs, conservation tillage, and crop rotations help to improve soil health, nutrient cycling, and environmental impact.

[30], [31], [32] and [33] investigate agricultural conservation strategies such as low tillage, crop rotation, and cover cropping. These approaches have improved agricultural yields, soil health, carbon sequestration, and water conservation. They demonstrate effective climate change mitigation and agricultural sustainability techniques in diverse Nigerian areas.

Their studies shed light on numerous sustainable agricultural approaches, particularly organic farming, conservation agriculture, agroforestry, and integrated soil management. While each research focuses on a different area of sustainable agriculture, there are some similar themes and points of comparison. Overall, the research on the efficiency of sustainable farming techniques in Nigeria is converging. Organic farming, conservation agriculture, agroforestry, and integrated soil management are all methods for mitigating climate change, improving soil fertility, lowering greenhouse gas emissions, and increasing agricultural production. The findings highlight the significance of using these sustainable practices to develop sustainable and resilient farming systems in Nigeria.

**Crop Rotation**

Crop rotation is the systematic cultivation of various crops on the same piece of land in a predetermined order. This approach has several benefits, including reduced soil erosion, more significant soil carbon sequestration, and better soil fertility. [34] emphasized crop rotation’s function as a sustainable agricultural technology in Nigeria and its potential advantages in reducing climate change. Farmers can disrupt the cycles of pests and illnesses that target certain crops by rotating crops. Crop rotation aids in managing and reducing pests and diseases, resulting in greater crop health, less reliance on synthetic pesticides, more effective use of nutrients in the soil, optimized nutrient cycling, and less nutrient depletion.

Another significant advantage of crop rotation, according to [34] is its ability to improve soil carbon sequestration. Crops differ in their ability to sequester and store carbon from the environment. Diversifying crop species can boost carbon inputs to the soil, resulting in greater soil organic carbon levels. Higher soil organic carbon levels contribute to carbon sequestration, which helps balance greenhouse gas emissions which has a beneficial impact on climate change mitigation. The research underlines the relevance of crop rotation as a sustainable agricultural technique that can help to mitigate climate change and enhance long-term agricultural sustainability in Nigeria.

**Intercropping**

Intercropping is the simultaneous growth of two or more crops on the same piece of land during the same growing season. [35] found various advantages to this approach. Intercropping can improve biodiversity on the farm, as [35] notes. Intercropping enhances species variety by growing diverse crops together, which can help with pest and disease control. Because various crops attract different pests and have distinct vulnerabilities, more than one crop can interrupt pest cycles and prevent pest and disease build-up. This can help to create a more balanced agroecosystem and minimize the need for chemical pesticides. Furthermore, through symbiotic partnerships with leguminous crops, intercropping can improve soil fertility, promote efficient nutrient consumption, limit nutrient loss from the soil, and enhance nitrogen fixation. The study also implies that intercropping might help with climate change mitigation. Intercropping, albeit not expressly discussed in this research, has the potential to minimize greenhouse gas emissions. Intercropping can boost carbon sequestration in the soil by increasing biodiversity and improving soil fertility, contributing to removing carbon dioxide from the atmosphere. When crop rotation and intercropping are compared, both techniques offer advantages for sustainable agriculture in Nigeria. They do, however, differ in their approach and distinct benefits. Crop rotation is sequential cultivation, whereas intercropping is simultaneous cultivation. Nigerian farmers may improve sustainability, reduce climate change, and create more resilient and productive farming systems by implementing these methods into their agricultural systems.

**Cover Cropping and Crop Diversification**

Cover cropping and crop diversification have some parallels in their advantages for sustainable agriculture in Nigeria. Both approaches help to improve soil fertility, reduce erosion, and boost resistance to climate change. According to [36], cover cropping is growing certain crops during fallow seasons to cover the soil. This method has several advantages. It increases soil fertility by fixing nitrogen, decreasing nutrient leaching, and boosting organic matter content. Cover crops also operate as living mulch, shielding the soil from wind and water erosion, thereby minimizing soil erosion.

On the other hand, [37] underline the relevance of crop diversity as a technique for farmers to adapt to changing climatic circumstances. Crop diversification is cultivating several crops on the same land in a specified order over time, which has numerous advantages. The practices reduce the risk of relying on a single crop because different crops may have different tolerances to specific climate conditions or pests and diseases, increase soil fertility by reducing nutrient depletion, and improve resistance to climate change by promoting biodiversity and ecosystem stability.

There are, nevertheless, significant distinctions between the two practices. Cover cropping focuses on soil health and carbon sequestration, whereas crop diversity focuses on risk reduction, soil fertility enhancement, and climate adaptability. The decision between cover cropping and crop diversification is influenced by a number of factors, including the farmer's individual goals, available resources, and local circumstances. Farmers may choose one or both approaches based on their aims and the practices' fit for their agricultural systems.

[36] and [38] emphasize sustainable agricultural techniques in Nigeria that might reduce climate change and increase agricultural resilience. While [39] explore the benefits of cover cropping, [40] discuss crop diversity as a strategy of adapting to changing climatic circumstances. Nigerian farmers may increase the sustainability and productivity of their agricultural systems while also contributing to climate change mitigation and adaptation efforts by following these strategies.

**Agroforestry**

[41], [42], and [43] all explore the benefits and possibilities of agroforestry systems in Nigeria, namely enhanced agricultural yields, better soil health, carbon sequestration, and climate change mitigation. While they both advocate for agroforestry, the exact features they highlight differ.

[41] emphasize the benefits of incorporating trees into agricultural systems. They discovered that this method raised crop yields, improved soil health, provided shade, and reduced soil erosion. Their research focuses on the practical implementation of agroforestry in Nigeria, notably in the south.

Their findings indicate that agroforestry has the potential to increase agricultural output while also improving environmental sustainability.

[42] study the carbon sequestration capacity of Nigerian agroforestry systems. Their research looks at specific soils in agroforestry systems in two agroecological zones. They reveal that these systems can store considerable amounts of carbon, suggesting their potential contribution to Nigeria's climate change mitigation. Their findings highlight the relevance of agroforestry in solving global climate concerns through carbon sequestration within agricultural landscapes.

[43] present an evaluation of the carbon stock potential of Nigerian agroforestry systems. Their analysis demonstrates how improved agroforestry systems may store carbon while increasing agricultural output. They underline the need to recognize Nigeria's agroforestry as a feasible alternative for carbon management and climate change mitigation methods.

While [44] focus on the successful adoption of agroforestry in Nigeria and the benefits it brings, [45] and [46] provide more specific insights into the carbon sequestration potential and the role of agroforestry in climate change mitigation. These studies show that agroforestry has several benefits, including increased agricultural output, soil health, carbon storage, and environmental sustainability.

**Drought-Resistant Varieties**

Another potential strategy used in Nigeria is the introduction of improved crop varieties, such as drought-tolerant types, which minimize crop loss and increase farm resilience to climatic variability. The benefits of adopting better seed types, mainly drought-resistant kinds, are discussed in studies by [47], [48], [49] and [50]. While both focus on using modified seeds to raise agricultural yields and minimize climate-related difficulties, the areas they address differ.

[50] present a thorough analysis, emphasizing the benefits of improved seed varieties, such as enhanced agricultural yields, decreased land needs, and environmental benefits. [48], [50], and [47] focus on the adoption of drought-resistant cultivars and the favourable effects in terms of higher agricultural yields, especially in drought-prone regions.

While [48] and [50] discuss the broader implications of improved seed adoption, [51] and [52] focus on the adoption of drought-resistant maize varieties and their positive effects on crop productivity in drought-prone areas. These studies highlight the necessity of adopting better seed types, particularly drought-resistant cultivars, to increase agricultural production, decrease climate-related risks, and contribute to sustainable agriculture practices in Nigeria.

**Improved Irrigation Techniques**

[53], [54], [55] and [56] investigate several elements of irrigation techniques in Nigeria and their consequences for agricultural productivity, water conservation, and climate change mitigation. [53] emphasize drip irrigation systems' potential as a climate-smart solution for increasing crop yield in Nigeria. According to their findings, drip irrigation may considerably help water conservation, boost agricultural yields, and cut water usage by 60% compared to traditional irrigation systems. [54]. investigate using solar-powered irrigation systems to assist farmers in adapting to shifting rainfall patterns while reducing emissions associated with diesel-powered irrigation. They underline the significance of renewable energy alternatives in irrigation techniques.

[55] explore using several reclamation strategies on salt-affected soils for agricultural production, with a particular emphasis on drip irrigation. According to their findings, drip irrigation has enhanced crop yields while decreasing water usage in Nigeria. [56] investigate the sustainability of farm-level practices among

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Nigerian cassava growers, emphasizing water management. They discovered that better water management strategies, such as rainwater gathering, irrigation, and water-efficient crops, can assist farmers in adapting to shifting rainfall patterns and lowering emissions connected with water consumption.

When these four studies are compared, they all acknowledge the necessity of improving water management methods in Nigeria's agriculture industry. They stress the potential for these techniques to increase crop yield, save water resources, and minimize the effects of climate change. [57] and [58] emphasize the advantages of drip irrigation systems, emphasizing their potential for water saving and enhanced agricultural yields. [59] underline the relevance of solar-powered irrigation as a long-term alternative to diesel-powered systems, emphasizing adaptability and emissions reduction. [53] explore the more extensive features of water management methods, such as rainwater collecting and growing water-efficient crops, to improve sustainability and lower emissions.

These studies highlight the need to improve irrigation technology and water management practices in Nigeria to solve water shortages, boost agricultural yield, and contribute to climate change mitigation and adaptation efforts.

**Integrated Pest Management (IPM)**

In their study, [60] emphasized the efficiency of combining multiple pest control measures and the possibility of lowering dependency on chemical pesticides. According to [61], implementing IPM methods can reduce pesticide usage and emissions while preserving crop yields, underlining the relevance of IPM in enhancing agricultural sustainability and livelihoods. According to [62], implementing IPM measures has resulted in lower pesticide use and higher crop yields. Their research stresses the benefits of IPM adoption regarding environmental sustainability and agricultural output.

These studies emphasize the significance of implementing IPM strategies in Nigeria's agriculture industry. They highlight the potential benefits of IPM, such as lower pesticide usage, higher agricultural yields, and enhanced environmental sustainability. [63] concentrate on integrating cultural, biological, and chemical control approaches within IPM, emphasizing their usefulness in lowering pesticide usage and increasing crop yields. [61] highlight the broader effects of IPM adoption on pesticide consumption, emissions, and agricultural yield improvement.

They emphasize the need to use IPM tactics in Nigeria as an effective pest management strategy. IPM can potentially reduce dependency on chemical pesticides, reduce environmental hazards, increase production, mitigate the effects of climate change, and improve the sustainability of Nigeria's agricultural systems.

## CONCLUSION

It can be deduced that the CSATs adoption of usage in Nigeria can potentially revolutionize the country's agriculture sector. Conservation agriculture, crop rotation, intercropping, conservation tillage, cover cropping, drought-resistant varieties, improved irrigation techniques, agroforestry, and Integrated Pest Management (IPM) were among the most commonly adopted and used CSATs and these technological practices have been effective in enhancing agricultural productivity, reducing waste, increasing profitability as well as promoting soil health, water use efficiency and environmental sustainability in Nigeria.

## RECOMMENDATION

The benefits of these CSATs are too great to ignore. With the right policies and investments, Nigeria can leverage these technologies to drive economic growth and enhance food security for its citizens. Future research should continue to monitor the effectiveness of these CSATs in various agroecological regions of the country. To ensure the successful adoption of these technologies, a collaboration between public and private institutions and providing accessible financing options, infrastructure, and training is necessary.

**Conflicting Interests**

There is no conflict of interest.

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