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CROP MANAGEMENT INNOVATIONS FOR CLIMATE CHANGE RESILIENCE IN THE POST-PANDEMIC ERA: A REVIEW

[1*]Awopegba, T. M., [2]Fayose, C. A. and [3]Adeboye, K. A.

[1,2,3]Department of Agricultural Technology, Ekiti State Polytechnic, Isan-Ekiti, Nigeria.

*Corresponding Author

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ABSTRACT

The wavering nature of environmental conditions caused by human-induced emissions of greenhouse gases (GHGs) and agricultural practices has resulted in global warming, a significant increase in average temperature, deepened by increasingly intensive agriculture, deforestation and increased use of fossil fuels. This often-unsafe anthropogenic interference with the environment has resulted in climate change with many negative impacts, such as, extreme weather phenomena, drought, fires, death of animal and plant species, and disruptions of food chain and destruction of agricultural resources. Therefore, there is a need to embrace environmentally sound crop management innovations to mitigate the negative impacts of climate change on agriculture in the post-pandemic era. To sustain food security propelled by crop management innovations, climate smart agriculture (CSA) and climate resilient sustainable agriculture (CRSA) have to be employed. There is a need for agriculturists to develop crop management innovations that will tackle climate change negative impacts on man, animal and environment by leveraging more on technological innovations through scientific research. Access to good and affordable food products is important to boost herd immune and combat this COVID-19 virus spread within the population. This could only be realized by ensuring proper adaptation of agricultural production to the impacts of the prevailing and imminent climate change scenarios in the post-pandemic era.

Keywords: Crop management innovations, climate change, post-pandemic era, COVID-19, food security.

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1.0 INTRODUCTION

Climate change includes both global warming driven by human-induced emissions of greenhouse gases and agricultural practices, resulting in large-scale shifts in weather patterns. Climate change has direct impact on agricultural production, due to the climate-dependent nature of agricultural systems. This impact is especially important in developing countries where agriculture constitutes employment and financial gain sources for the bulk of the population (Enete and Onyekuru, 2011). There is instability of access to food in Nigeria. The high costs of foodstuffs within Nigeria are attributed to poor agricultural productivity in 2020, because the agricultural sector was gravely affected by the COVID-19 pandemic, climate-induced floods and drought as well as widespread insecurity. The effects of global climate change have an effect on farmers' ability to grow the food crops most desired by the population. Increasingly, volatile weather and more extreme events; like floods and droughts, changes in growing seasons, limited water availability, flourishing weeds and thriving pests and fungi can reduce crop productivity. More so, soil erosion is reducing the quantity of land available for agriculture, and declining biodiversity affects the pollination of crops. At the same time, farmers are under pressure to conserve water and use fewer agricultural inputs (https://www.syngenta.com/en/innovation-agriculture/challenges-modern-agriculture).

Climate change is affecting food security in developing countries, particularly, in Nigeria. Before the COVID-19 started ravaging a large number of nations, most developing countries were already experiencing poor food consumption that resulted in malnutrition due to food insecurity caused by climate change (Awopegba and Adeboye, 2021). Climate change and its effects, such as unpredictability and instability of rain patterns, have affected the agricultural sector, threatening the income of communities and forcing several to migrate in search of complementary financial gain or higher opportunities. Also, health related stressors like COVID-19 have a high impact on the agricultural sector, by revealing the weakness of the food and distribution systems with the destabilization of supply chains and disruption of cross-border trade (Adeboye *et al*. 2021; IOM, 2020). Climate change is really having adverse effects on agricultural production in Nigeria and other places across the world. There was a prolonged effect of climate change on agriculture that resulted into absence of rainfall in Nigeria, this started in early July and it extended to the end of August in 2020 which accounted for dry spell for almost two months in the South-west and North-central zones that affected food production in the era of COVID-19 pandemic. The crop management innovation of moving from rain-fed agriculture is very important to be embraced as the first solution in exploring irrigation technologies in Nigeria through the effective use of numerous available dams.

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Agricultural innovations with the strategies such as Ecological Agriculture (AE), Climate Resilient Sustainable Agriculture (CRSA), Agroforestation and Climate Smart Agriculture (CSA) had been proved to be effective in minimizing the negative impacts of climate change on food production (FAO, 2015). Agriculture also needs more innovative technologies such as agricultural drone, satellite imagery, phase tracking, weather forecasting, automated irrigation, light and heat control, merging datasets, farming software and online data, intelligent software analysis for pest and disease prediction, and soil management and other involved analytical tasks to withstand challenges of climate change. This review examines how crop management innovations could be advanced for climate change adaptation and mitigation for sustainable crop production in the post-pandemic era.

2.0 INNOVATIONS FOR SUSTAINABLE FOOD SYSTEMS

Food systems are under pressure globally and especially in the sub-Saharan Africa (SSA). Climate change and COVID-19 effects have led to a serious and widespread increase in food and nutritional insecurity (Adeboye *et al.*, 2021), affecting vulnerable households in almost every developing country (Awopegba and Adeboye, 2021). Despite agriculture importance to the economy, Nigeria's agriculture sector suffers numerous obstacles that have a negative influence on productivity. Climate change, poor land tenure, low irrigated farming, and land degradation are only a few of them. Low technology, high production costs, and inadequate input distribution are among the others, as are limited financing, large post-harvest losses, and poor market access. Maize, cassava, guinea corn, yam beans, millet, and rice are the main crops grown on Nigeria's 70.8 million hectares of agricultural land. Rice production in Nigeria increased from 3.7 million metric tons in 2017 to 4.0 million metric tons in 2018. Fifty-seven percent of the 6.7 million metric tons of rice consumed in Nigeria each year is produced locally, resulting in a 3 million metric tons deficit that is either imported or illegally smuggled into the nation. In order to boost domestic production, the government banned rice imports in 2019. More so, animal production has remained underutilized. Small ruminants such as goats (76 million), sheep (43.4 million), and cattle (18.4 million) are the most common livestock raised by Nigerian farm families. Despite various initiatives by development partners to boost output and protect against diseases such as transboundary animal diseases, local demand outweighs production here as well. It is impossible to overstate the importance of forestry to agriculture and prosperity in general. According to the FAO's 2018 report, Nigeria's forest ecosystems are threatened by rapid population expansion and economic activities, with yearly deforestation rates ranging from 0.72 to 2.38 percent. Agricultural expansion, a high reliance on firewood and charcoal for energy, unsustainable timber exploitation, urbanization, grazing, bushfires, and infrastructure development are all elements contributing to this trend (https://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/).

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In September 2021 and even till now, food prices in Nigeria increased considerably compared to September 2020. Beans, maize, and oil prices increased the most. In particular, the price of beans increased by almost 60% over the previous year, while the price of palm oil increased by 40%. There was no decrease in the price of any of the selected foods. In fact, Nigeria is among the countries with the highest inflation rate in the world and recorded a fast growing Consumer Price Index (https://www.statista.com/statistics/1226123/percentage-change-in-prices-of-selected-food-products-in-nigeria/). Given ongoing inequality, current trends suggest that the 2030 target of eradicating hunger will not be met (FAO, 2017).

Making our food systems more sustainable will depend on innovative tools and approaches being developed and deployed around the world. To be economically sustainable, these innovations must provide incomes and create jobs. To be socially sustainable, they must include poor and vulnerable communities and reduce levels of hunger and malnutrition. To be environmentally sustainable, they must help us safeguard water, soil and air quality while minimising greenhouse gas emissions, and food loss and waste (https://farmingfirst.org/food-systems#section_4). Composting and vermicomposting of rabbit faeces (in pellet form), cow dung, poultry droppings and other animal manure have become two of the most well known environmentally appropriate technologies for recycling manures under aerobic conditions by transforming them into safer and more stable products (compost and vermicompost), with benefits for both agriculture and the environment. Most especially, rabbit manure compost and vermicompost have been said to be cheap to produce and can be used as organic fertilizer to increase the quantity and quality of the crops produced. It has been proved that rabbit manure contains high amounts of nitrogen (Dianita *et al.*, 2022), high phosphorus and potassium (Dixie, 2016), the amount of minerals that are sufficient to ameliorate the deficient quantities in the soil. More so, rabbit pellets do not pose threat to plants when applied; they have also been found to contain good levels of beneficial micro-elements. Even though, vermicompost has been said to be healthier than any other form of organic fertilizers (Abdulraheem and Onifade, 2021), the use of worm compost (vermicompost) and compost of organic manure have not been embraced by Nigerian farmers.

A change in new technology processes in the economic and food systems is expected to have an impact on food security in all of their forms. Crop management innovative strategies tend to be effective if it enables decision support systems as it helps to make agricultural science more accessible, adaptive and useful for farmers. Nciizah and Wakindiki (2015), stated that there are three achievements of using innovative approaches in addressing climate change, which are increase in agricultural productivity and incomes, crop resilience to climate change and greenhouse gases emissions reduction or elimination. With a projected population of 400 million by 2050 in Nigeria, increased agricultural production through the adoption of new technology

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and innovations would be required to provide food security and nutrition. Support for the federal and state governments' efforts from all partners is critical to accomplishing this aim.

3.0 CLIMATE CHANGE AND FOOD INSECURITY

Agriculture is one of the sectors most sensitive to the climate change impacts such as flood, drought, river erosion and cyclones (Sarkar, 2012). Climate change affects agricultural productivity by increasing temperature and altering water availability, and generating extreme environmental events such as; floods, droughts, storms, cyclones and landslides (Zamasiya *et al.*, 2017). Climate change or food insecurity should not be tackled as separate issues. According to Fayose *et al.* (2022), climate has profound effects on biotic and other abiotic factors of the environment; the animals, microorganisms, and the plant types that grow in an area, and the processes leading to soil formation are all influenced by climatic factors, as a result of which its influence cannot be overemphasized.

Climate change is increasingly altering ecosystems which are the foundations of agricultural productivity worldwide. This has brought about uncertainties in the use of farm inputs as well as food security. According to ATPS (2013), factors that commonly impede agricultural development include: regular soil dryness in certain parts, flooding during heavy rains, poor nature of farm to market roads, the use of rudimentary agricultural tools and the high cost of fertilizers. A major challenge that has a cross-cutting effect on all types of agricultural production in Nigeria is water scarcity. Climate change is the main reason for this water shortage. Climate change has aggravated soil degradation caused by increased urbanization and has resulted in increasing water deficit in plants. Given the unavoidable climate change effects on the production of agriculture, the farmers always look for a new strategy of survival by adopting new technologies of agriculture and adapting to climate change. Unfortunately, the agricultural sector alone cannot effectively combat the climate crisis, as it is a complex problem that requires concerted efforts from many nations and indeed, different sectors of any nation's economy such as transportation and environmental management and development through provision of necessary infrastructures. For instance, climate change resilience strategies include climate change adaptation and climate change mitigation, both of which must be properly synergized. Adaptation involves the alteration of socio-economic processes and adoption of technologies that help cope with climate change. In agriculture, this involves development of crop varieties and animal breeds that can withstand the increased weather variability without significant reduction in the desired yield output. It could also come in form of precise animal and crop management methods, construction and installation of necessary infrastructures including state-of-the-art greenhouses, storage and transportation facilities.

Over the years, agronomists and breeders have developed several improved crop varieties that have short generation time which ensure drought escape and those that pack drought tolerant genes that enable them tolerate low soil moisture contents without significant yield loss. Varieties that are high yielding, disease tolerant and nutritionally fortified have also been

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developed (Badu-Apraku and Fakorede, 2017). This effort is highly commendable, but must be combined with modern climate smart infrastructures in order to achieve the desired results. Mitigation on the other hand involves reduction of GHGs emission and efforts that reduce the concentrations of the already emitted GHGs in the atmosphere such as afforestation. Both climate change adaptation and mitigation must be taken seriously if we must properly cope with impact of climate change and ensure food security.

4.0 CLIMATE CHANGE AND COVID-19 IMPACT ON AGRICULTURE

Agriculture does not only provide food and nourishment, but it is the primary source of livelihood for millions of people in the world. The threats that the climate crisis brings to agriculture and food systems are multiple, multidimensional and interconnected. Climate change affects the conditions of food production through changes in temperature, changes in precipitation, extreme events and, pests and diseases. The COVID-19 pandemic is a health crisis that has aggravated the climate change impacts on the entire food systems. The COVID-19 and climate issues are interconnected directly or indirectly, because agricultural production, transportation and processing affect both human health and climatic conditions in various ways and can therefore catalyze the spread of infectious and zoonotic disease like corona virus (Dobson *et al*., 2020).

Agriculture is fundamentally dependent on the environment. While agriculture is essential for producing food and providing necessary nutrition to maintain human health, it can also affect the environment by polluting air and water, and producing greenhouse emissions (von Braun, 2017). Degraded environment can affect public health and increase health expenditures which in turn affect agriculture and food production (Wu *et al.* 2016). On the other hand, environmentally friendly agriculture and food system can mitigate greenhouse gases emissions and can improve public health, and improve the productive capacity and potential of agricultural systems in the future (Barbier, 2020). Therefore agriculture, food, coronavirus diseases and climate change are interconnected directly or indirectly. Interacting and compounding challenges of climate change (Rasul, 2021).

Both COVID-19 and climate change have impact on agriculture and food systems, the nature and processes by which they do so vary (Schmidhuber *et al*., 2020). While impacts of COVID-19 is sudden, spreads fast and causes immediate high risks, the impacts of climate change builds slowly over a certain period and has long-term term impacts which threaten the very foundations of agriculture, and human health and wellbeing. The impacts of climate change on agriculture are manifested through higher temperatures, variability in rainfall and precipitation, and associated extreme weather events such as droughts and floods, and pests and diseases (Rana and Moniruzzaman, 2021; IPCC, 2019). Climate change also affects public health through greater heat stress, the easier spread of infectious diseases, and extreme events (Watts *et al*., 2020).

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The interlinkages between climate change and COVID-19 demands an integrated approach in dealing with food security in the context of the pandemic and climate change. Unless food, public health and climate change are taken together, the challenge of food security, public health and climate mitigation cannot be effectively addressed sustainably. Public health and climate change need to be addressed in an integrated manner to harness synergies and minimize compromise between food production and climate adaptation and mitigation. Focus need to be given to make agriculture and food system climate sensitive and public health friendly, which produces nutritious and healthy food in environment and climate friendly way to make agriculture and food system climate smart and pandemic smart (The Lancet, 2020).

5.0 INNOVATIONS IN AGRICULTURE IN RESPONSE TO CLIMATE CHANGE AND COVID-19 PANDEMIC

The pandemic has added to the food security challenges posed by climate change and have recently worsened food insecurity. The adverse impact of COVID-19 on the global economy may also result in a renewed risk of accelerated population growth that could place more pressure on the limited food supply. Many responses to the pandemic have resulted in changes in agriculture and food production that may persist in the longer term. In some situations, more emphasis is placed on automation of food production and processing to avoid the risks of using labour that may be unavailable due to illness or due to the restriction on labour migration. This could result in more investment in automation of harvesting and processing, minimizing manual steps in the whole production chain. The automation of food production in these systems could also eliminate the risks of contamination of the food during production. COVID-19 contamination of foods has not been a problem, but other organisms in future pandemics might pose this risk (Henry, 2020).

Accelerated deployment of improved crop varieties using emerging genetic technologies could contribute significantly to the delivery of the productivity gains required to ensure food security. The pandemic has added extra urgency to the need for crop management innovations through agricultural technology advancements, which has recently been driven by the need to respond to climate change. Gene editing technologies have a chance of being more widely accepted and understood than earlier genetically modified approaches and have the potential for very rapid advances in food production if combined with protected cropping. The use of controlled environments for food production allows genetics to focus on enhancing the nutritional value and consumer attractiveness of the food products (FAO, 2020). One of the technologies that have been identified to easily bridge the food gap is greenhouse farming technology. It is a farming technique that enables increased high-quality products all year round (Ibirogba and Wada, 2019). Green house facilities in Nigeria are very few with the highest facilities in Taraba, Ogun, Lagos,

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Kaduna and Edo State. All these facilities put together, do not cover up to 2,000 hectares while Mexico has greenhouse facilities that cover more than 50,000 hectares of land and this has solely made them exporters of food to other countries of the world. Apart from the fact that the use of controlled environment will reduce the negative impact of climate change on agriculture, it will also create alterative source of food production which will curb the continuous clashes between farmers and criminal herdsmen in Nigeria. It is believed that with greenhouse technology, Nigeria can meet her food sufficiency and export to other countries (Ozioruva, 2021). The success of the greenhouse goes together with a careful adoption of hydroponic technology.

Irrigation is critical to a successful green revolution all year long, as well as attaining sustainable development goals in terms of food security. Presently, only 45 percent of the entire irrigation potential of 2.0 million ha is under irrigation. The northern region of the country, where average rainfall is quite low, accounts for 70% of total irrigation potential, while the humid south accounts for 20%, with the balance falling in the central and western plateau areas. With dam projects strewn across the country, the country has enormous irrigation potential. The majority of the government-built dams, on the other hand, are either underutilized for irrigation or abandoned. In Nigeria, there are about 264 dams with a combined storage capacity of 33 billion m^3 of water for multipurpose use that includes water supply, irrigation, hydropower, fisheries and eco-tourism, of which 210 are owned by the Federal Government, 34 by the States and 20 by the private organizations. These dams have combined of about 350,000 ha of irrigable land around the vicinities ready for development. Moreover, there are 27 ongoing small earth dams nationwide with a total potential irrigable land of 2,700 ha. Research has proved that there is an appreciable increase in the yields of agricultural production in irrigated agriculture as compared to rainfed agriculture. Nigeria government need to partner with Food and Agriculture Organization in order to provide the essential framework that will guide the sustainable irrigation development, create an enabling environment, and stimulate private sector investment in irrigation development (Adelodun and Choi, 2018).

Precision agriculture (PA) is an agricultural mechanization strategy that heavily relies on electronics, information technology, and communications, as well as technical ability and people for plant-specific and animal-specific production. Precision agriculture is also known as a type of farm management that employs information technology (IT) to ensure that crops and soil get exactly what they need to thrive and produce at their best. Precision agriculture allows the proper amount of input (fertilizer, pesticide, water, crop, etc.) to be applied at the exact time and place to maximize agricultural returns while reducing chemical use and protecting the environment. Precision agriculture is needed for assessing and managing field variability, for doing the right thing in the right place at the right time, for higher productivity, for increasing the effectiveness of inputs, for maximum use of minimum land unit among others (Abdulhamid and Afunlehin,

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2019). Components of precision agriculture include information (database on soil, crop and climate), technology (application of Global Positioning System (GPS) receivers, Differential Global Positioning System (DGPS), Geographic Information Systems (GIS), Remote Sensing, Variable Rate Applicator and Combine Harvesters with Yield Monitors) and Management (Information management, decision support system (DSS), Identifying a precision agriculture service provider). Farming has been made easy with precision agriculture but application of precision agriculture in farming has not been employed by majority of farmers in Nigeria and this has made tackling of problems pertaining to climate change, soil and crop conditions difficult. Precision agriculture has been considered as a concept in Nigeria without actualization (Adekunle, 2013). The drawbacks to precision agriculture in Nigeria include; high cost of application, lack of technical expertise, heterogeneity of cropping systems and market imbalance. Despite these challenges of its implementation, precision agriculture benefits outweigh its challenges as it is environmentally and economically sound (Abdulwaheed, 2019).

To effectively respond to the myriad of challenges mentioned above, climate smart/precision agriculture must be adopted more in Nigeria as in other countries of the world. These are processes and facilities that are hitherto still very scarce across Nigeria. Nigeria's agricultural system is largely characterized by mono-seasonal crop production with a heavy dependence on rainfall. Consequently, the yield of most crops is low compared to what obtains in other countries with more advanced systems due in part to weather-driven fluctuations. While the burgeoning human population has led to a significant increase in the demand for food on one hand, rapid rates of urbanization has resulted in decrease of agricultural lands on the other hand (EKSPOLY, 2022). These factors along with climate change and COVID-19 pandemic have negative implications on food security in the country. Therefore, it is expedient to fully deploy different technologies to facilitate precision agriculture in order to effectively intensify production per unit area of the constantly reducing agricultural land irrespective of season, and reduce the wastage of scarce and rather expensive agricultural inputs.

The need to respond to the pandemic might contribute to rapid public acceptance of the use of science and technology to revolutionalize Nigerian agriculture to enhance food security. The need to respond to the pandemic might contribute to rapid public acceptance of the use of science and technology to support food security (Henry, 2020). Crop management innovation strategies could be effective in tackling climate change negative impacts in the post-pandemic era, the strategies will be complemented by continued efforts to support traditional subsistence farmers with appropriate extension, policies and agro-technology transfer.

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6.0 CONCLUSION

Climate change is gravely affecting agricultural production and food security through its numerous direct and indirect impacts. The situation is made worse by the ongoing global COVID-19 pandemic. The challenge posed by the COVID-19 needs terribly proactive and decisive actions to make sure food and nutrition security of people coupled with their lives and livelihoods are secured. Crop management innovations and implementation are effective in addressing climate change crisis in the post pandemic era. Therefore, there is the need for government, farmers and stakeholders at all levels of the different sectors of the economy, to embrace crop management innovations and climate smart technologies, and increase investment in agricultural research and development to support and enhance food security despite climate change and the COVID-19 pandemic.

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