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Climate Change, Agricultural Trade and Emerging Technologies in Africa

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Abstract

The increase in extreme natural phenomena such as heavy rains, floods, droughts and heat waves was evidence of the effects of climate change in Africa. These events were the result of increased greenhouse gas emissions globally and particularly affected Africa, although Africa emitted seven times less than Europe and 15 times less than North America. Increasing emissions were disrupting ecosystems worldwide, as illustrated by rising temperatures and ocean levels, acidification of oceans and even reduced availability of arable land. The aims of this study were to analyse the effects of climate change on agriculture and trade and ways ICT and emerging technologies could improve agricultural production and trade. The study made use of extant qualitative literature research. Findings, conclusions and recommendations were drawn from documentary search of books, government publications, journal articles, working papers and theses. Research findings indicated that, climate change was a threat to both agricultural and non-agricultural development in any economy, but more so to food production in developing countries due to heavy reliance on agriculture. Climate change affected agriculture through various means, such as low or excessive rainfall leading to drought and flooding, climate extremes such as heat waves and changes in average temperatures. Climate change also affected trade through trade deficit, price hikes, availability of workers, health risks and export restrictions, among others. However, Information Communication Technology (ICT) and emerging technologies had the potential of improving agricultural production and trade through e-certification and online markets and the application of artificial intelligence (AI), sensors and agricultural drones, among others in crop production.

Key words: Climate Change, Agriculture, Trade, ICT, Emerging Technologies.

Introduction

Climate change was one of the most pressing global concerns of all time and had significant implications for agriculture and food security. Higher average temperatures, changes in precipitation, rising sea levels and extreme weather events could affect harvest levels, animal production and fisheries (Odjo, Traoré & Zaki, 2024). The global average yield across all crops was projected to decline by 2050 due to climate change. The largest declines would be in developing countries, including parts of Africa and would affect staple foods, such as wheat (-17 percent), maize (-5 percent), sorghum (-15 percent) and millet (-10 percent) (Food and Agriculture Organisation (FAO), 2021, p.35). Given its geography, Africa was disproportionately affected by climate change while contributing only minimally to global greenhouse gas emissions. West and Southern Africa were designated climate change hotspots, that is, areas where large adverse physical impacts of climate change coincided with a preponderance of poor people that were least able to cope with these effects. (Richardson, Mabaya, Jayne & Njiwa, 2022:27).

In addition to climate change, Africa's agriculture structurally remained largely underdeveloped, except for a few countries such as Egypt and South Africa. It was characterised by low diversification, production of mainly raw materials, food and other agricultural commodities for domestic consumption. This resulted in many African countries being major importers of agricultural produce. Yet, one of the biggest risks to food security in food-importing countries was climate related catastrophes, which reduced the availability of agricultural produce, leading to export restrictions by exporting countries that curtailed global supply and increased prices. Sadly, Africa was pursuing largely disjointed trade and climate adaptation policies and strategies. One glaring example of this was the absence of any reference to climate change or the environment in the African Continental Free Trade Area (AfCFTA) agreement established in March 2018 and effective from 1 January 2021. (Global Centre on Adaptation, 2021, p.299).

It was against this bedrock that this study analysed the effects of climate change on agriculture and trade and ways ICT and emerging technologies could improve agricultural production and trade. The study made use of extant qualitative literature research. Findings, conclusions and recommendations were drawn from a documentary search of books, government publications, journal articles, working papers and theses. The study was structured into four sections and these included literature review; methodology, research findings and analysis: effects of climate change on agriculture and trade and ways ICT and emerging technologies could improve agriculture and trade. Conclusion and recommendations end the study.

Literature Review

Climate change threatens crops via natural disaster impacts as well as greenhouse gas and increased temperature impacts on quantity and quality of production. (Zhao, Xu, Li, Lu, Huang, Xu, 2023). Climate change also threatened the livestock aspect of agriculture, with increasing temperatures leading to decreases in animal product production and increased mortality and morbidity of livestock (Wollburg, Markhof, Bentze, & Ponzini, 2024). A considerable number of studies found out links between climate change variables and the productivity of the agricultural sector. Iheonu, Asongu, Emeka & Orjiakor (2022) examined the impact of rising temperatures on agricultural productivity in 10 West African countries from 1990 to 2020 in a panel data framework. The findings showed heterogeneity in the impact of rising temperatures on agricultural productivity in West Africa. In particular, the study found out that rising temperatures had a more adverse effect on Togo and Mali. Moreover, in three northern states in Ghana, Amankwah (2019) used data on rainfall and temperature ranging from 1961–2010 to examine the effect of the climate on agricultural productivity in these states. The results showed that climate change was accompanied by increasing temperatures and decreasing rainfall trends across the three regions, with a significant impact on agricultural productivity.

In addition, Grüter, Trachsel, Laube, & Jaisli (2022) confirm that climate change in the form of high temperatures and flooding impedes the growth of coffee, cashew and avocado in Guinea-Bissau. Moreover, Soviadan, Koffi-Tessio, Enete, & Nweze (2019) confirm that climate change has a significant negative impact on cotton production. From the sample of 172 cotton farmers used in the study, they further confirmed that climate change reduced the level of soil fertility in northern Togo.(Emediegwu, Wossink & Hall (2022, p.1) aver those developing regions, such as Sub-Saharan Africa (SSA), are more vulnerable to climatic shifts because of the agriculture-dependent structure of the economy, poverty, credit constraint and the rain-fed character of farm products. FAO (2022) points out that the changing climatic patterns have led to substantial declines in crop yields, affecting the availability and affordability of food, thereby resulting in increased food prices in most emerging economies. For Balcha and Macleod (2017, p.2), food-importing countries are at greater risk of adverse climate change and impacts could have as much to do with changes in world markets as with changes in local and regional resources and the national agricultural economy.

The reviewed literature has generally confirmed the detrimental effect of climate change on the productivity of the agricultural sector. This study deviated from these studies in that it focused on how climate change affected agricultural production and trade and how ICT and emerging technologies could improve agricultural production and trade.

Research Methodology

The research methodology of this study was exploratory in nature. This type of research, according to Haradhan (2018, p.15), was conducted for a problem that had not yet been clearly defined, as questions about solving the mystery kept on popping out. Extant qualitative literature was reviewed and analysed. This approach aimed to comprehend how climate change impacted agricultural production and trade in Africa and how ICT and emerging technology could improve agricultural production and trade. The analysis relied on secondary data as a means of gathering specific and needed information. Findings, conclusions and recommendations were drawn from a documentary search of books, government publications, journal articles, working papers and theses.

Results and Discussion

Impact of Climate Change on Agricultural Production in Africa

Climate change is a threat to both agricultural and non-agricultural development in any economy, but more so to food production in developing countries due to heavy reliance on agriculture. Climate change affects agriculture through various means, such as low or excessive rainfall leading to drought and flooding, climate extremes such as heat waves and changes in average temperatures. (Iheonu, *et al*, 2022, p.1). One study found that, each degree-Celsius increase in global mean temperature would reduce global yields of wheat by 6%, rice by 3.2%, maize by 7.4%and soybean by 3.1%. Furthermore, if global mean temperature increases exceeding three degrees Celsius (3^0C) nearly all existing maize, millet and sorghum growing areas across Africa would become unviable (Mehra, Rael & Bloem, 2024, p.5). The impacts of extreme high temperatures are not limited to crop-based agriculture, but also have impacts on livestock-based agriculture, a crucial component of food systems (Odjo, Traoré & Zaki, 2024, p.158). While the literature on climate impact on livestock is less robust than the literature on crop impact, heat stress has been shown to decrease the production volume and quality of meat, as well as animal byproducts such as milk and eggs. (Mehra, Rael & Bloem, 2024, p.5).

The effects of climate change were being felt in all parts of Africa and had affected agricultural production. For instance, Northern Africa, which includes Algeria, Egypt, Libya, Morocco, the Sudan and Tunisia, was exposed to very similar climate change-induced changes in precipitation and temperature. The northern part of Northern Africa was becoming significantly drier with a precipitation decrease ranging from 6 to 12 percent in the low-warming scenario and more than 18 percent in the high-warming scenario and this had affected agricultural production. (Baarsch & Schaeffer, 2019, p.49). In addition, Central Africa which includes Angola, Cameroon, the Central African Republic, Chad, the Congo, the Democratic Republic

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of Congo, Equatorial Guinea, Gabon and Sao Tome and Principe, was climatically diverse, with climates ranging from desert in the north of Chad to tropical rainforest in the Congo Basin. Central Africa was experiencing the least absolute change in temperature and precipitation of all African regions. The low-warming scenario projects a temperature increase of about 1.2°C to 1.8°C, with the strongest warming in northern Chad (Iheonu *et al*, 2022, p.2).

Moreover, in East Africa, the region experienced severe droughts in recent decades, for example, in Ethiopia and Somalia, which has led to widespread famine. Even though the countries of the region have improved their coping capacity, past decades show that climate-related disasters still have the potential to undermine macroeconomic output and development at the regional level. (Baarsch & Schaeffer, 2019, p.49). In West Africa, the region has the highest share of agriculture in its gross regional product. With such a large share of GDP coming from agriculture, a sector particularly sensitive to droughts and flooding in countries with limited adaptive capacity, climate-related disasters have led to sizeable GDP fluctuations in the past., Western Africa, for example, was affected by droughts 52 times between 1980 and 2015. Only 19 of these events occurred in non-Sahel Western Africa countries, making Sahel countries almost two times more frequently exposed to droughts than coastal West African countries. (Global Centre on Adaptation, 2021, p.302).

In Southern Africa, climate change has caused a significant decline in agricultural production. Cereal production in Southern Africa has significantly declined over the past decade due to global warming and is projected to further decline by over 20% by 2030 (FAO, 2022). Food prices in Southern Africa surged by an average of 23.9% between 2020 and 2022, which was the highest since the 2007/8 global financial crisis. This increasing food import bill for Southern Africa attracted mounting attention and was considered a worrisome trend for a region that was once an agricultural export powerhouse but now food importer. (International Monetary Fund, 2022). More broadly, the adverse impacts of natural disasters tended to disproportionately affect vulnerable groups of society. For example, when a cyclone, flood, or drought hit Mozambique, per capita food consumption dropped by up to 30 per cent, about 0.4 fewer meals per day per person. In Zambia, the drought that accompanied the 2015-16 El Niño, a weather pattern that brings less rainfall, decreased affected households' maize yields by about 20 per cent and their income by up to 37 per cent. (Global Centre on Adaptation, 2021, p.302). This contributed to agricultural trade deficits facing the region over the past decade.

Impact of Climate Change on Agricultural Trade in Africa

Trade Deficit

Climate change became one of the most pressing issues affecting trade in the form of a trade deficit. Large contemporary shocks sometimes increased the amplitude of a shock and undermined the role of international trade in matching supply and demand. Intra-regional trade was much more common within regions in Africa, for example, Southern African countries engaged in a high volume of trade in agricultural produce, as did central African countries, East and West African countries. (Brenton, Chemutai & Pangestu, 2022). However, climate change led to unpredictable weather patterns, droughts, floods and extreme temperatures that have affected the whole region, leading to low agricultural production for each country. (World Food Programme, 2021). Currently, East African countries, including Ethiopia, Kenya and Somalia, were grappling with severe multi-season droughts, some of the worst in recent history, posing a significant threat of starvation to millions. (Mehra, Rael & Bloem, 2024, p.4).

The main concern was that African countries were being affected by climate shocks at the same time, yet they relied on each other through trade to cushion the volatility of food markets by providing a vital flow of supplies to countries that might see a sudden reduction in domestic production of food crops due to a climate shock. (Mehra, Rael & Bloem, 2024, p.4). Another illustration was that of the El Niño event which affected Tanzania, Malawi, Zambia, Mozambique and Zimbabwe and it caused a 24% decline in cereal production, resulting in a shortfall of 7.9 million metric tons, yet these countries relied on each other for grain imports (World Food Programme, 2021). The impacts of extreme weather patterns were not limited to crop-based agriculture, but also had impacts on livestock-based agriculture, a crucial component of food systems. Heat stress was shown to decrease the production volume and quality of meat, as well as animal byproducts such as milk and eggs, leading to trade deficits of these products within regions. (Mehra, Rael & Bloem, 2024, p5).

Shelf Life

Climatic fluctuations were known to affect post-harvest losses and food safety during storage, for example, by causing changes in populations of aflatoxin-producing fungi. It was anticipated that more frequent extreme weather events under climate change damaged infrastructure, with detrimental impacts on food storage and distribution, to which the poor were most vulnerable. (Mehra, Rael & Bloem, 2024, p.5). Products sensitive to heat included mainly vegetables such as tomatoes, onions, carrots, cucumbers, artichokes and some fruits like apples, apricots, cherries and bananas. This was because these products' optimum temperature ranged from 25^0C to 30ºC. Due to climate change, which led to an increase in temperature, agricultural products sensitive to heat became difficult to export due to their limited shelf life. (Odjo, Traoré & Zaki, 2024, p.158).

Beyond fruits and vegetables production, higher temperatures, increased humidity and increased frequency of extreme weather events put additional stress on animals during transportation and worsened conditions for storage and distribution, increasing risks to food quality, safety and shelf-life that put Africa at an added disadvantage in livestock processing. (Bouët, Tadesse, & Zaki, 2021, p.123). Sadly, Africa's geography, characterised by long distances to markets, many landlocked economies and low population densities across climate zones, constituted a powerful barrier to trade for perishables. Furthermore, restrictive border measures, including informal ones like road checks, added to the effects of climate change on shelf life for agricultural products. (Global Centre on Adaptation, 2021, p.300). For example, the time to export (border requirements) was estimated at 296 hours in the Democratic Republic of the Congo and 239 hours in Côte d'Ivoire. (FAO, 2021, p.28).

Price Hikes

One of the reasons why many developing countries were reticent to reduce tariffs on agricultural products was the fear of dependence on an unreliable source of supply. Indeed, one of the biggest risks to food security in food-importing countries is climate related catastrophes, which reduces the availability of agricultural produce, leading to export restrictions by exporting countries that curtailed global supply and increased prices. (Hoskins, 2024). Tariffs on agricultural products remained higher on average than those on non-agricultural goods, with the global average tariff on agricultural products more than 12% compared to around 8% for all other goods. The average tariff on food products, for example, in Morocco, was 29% and Kenya had an average tariff on agricultural products of 25% (International Monetary Fund (IMF), 2022, p.25).

Moreover, the deficits in staple crops like maize, which made up 30% of caloric intake, forced poor rural households to purchase imported maize during the 2015–16 El Niño-induced drought in Southern Africa, the price of which increased sharply because of the drought-induced shortages of maize. (World Trade Organisation, 2022). Another illustration was that dry weather in West Africa damaged cocoa crops and caused global cocoa prices to reach an all-time high in February 2024. This resulted from Ghana and the Ivory Coast, the world's largest producers of cocoa beans, suffering from the effects of El Niño. This resulted in a twofold increase in the price of chocolate's main component since the start of 2023. (Charlotte & Rebecca, 2024). In general, high tariffs limited the size of the global market for agricultural products and hence reduced the incentive to invest in exporting such products.

Export Restrictions

Some global markets were highly concentrated around a few exporting countries and when a crisis occurred, these countries turned to restrictive noncooperative (beggar-thy-neighbour) trade policies, with negative impacts in net importing countries. (Carlin, Arshad & Baker, 2023, p.7). Export bans imposed by exporting countries to ensure domestic supply negatively affected food security in importing countries, as both food accessibility and availability was expected to decrease. Export bans also led to higher world food prices and an increase in price volatility in the country imposing them. (Odjo, Traoré & Zaki, 2024, p.10). During the Southern African drought of 2015–16, policies had spillover effects in neighbouring countries. Export restrictions by major crop exporters amplified the shock. (Global Centre on Adaptation, 2021, p.305). Similarly, during the COVID-19 pandemic, faced with a fall in the availability of essential goods (medical supplies, but also food) in international markets, some countries tried to secure these goods by reducing import barriers while simultaneously restricting exports. For example, Zambia's ban on maize exports represented 8% of maize imports by the other SSA countries and Cameroon's cereal export ban to Nigeria represented 15% of Nigeria's rice import share, though the ban was lifted, (IMF, 2022, p.19).

Informal Trade

The effects of climate change, which reduced agricultural products across Africa over the years led to export restrictions and impositions of high tariffs on agricultural products and this also created informal trade (Carlin, Arshad & Baker, 2023, p.7). Uganda's informal exports of agricultural goods to its five neighbouring countries represented 75% of official agricultural export flows. In the Horn of Africa, that is, Sudan, Ethiopia, Eritrea, Djibouti and North-East Kenya, for some agricultural commodities like livestock and grain, unofficial exports to neighbouring countries in fact exceeded at times official trade by a factor of 30 or more, hence constituting over 95% of total trade in these commodities (Balcha & Macleod, 2017, p.9). In Southern Africa, informal cross-border trade accounts for 30 to 40 percent of total intra-SADC trade, amounting to as much as USD 17.6 billion a year. In Eastern Africa, the informal cattle trade made up 85 per cent of the total cattle trade. Similarly, in Western Africa, official statistics accounted for only one-third of the actual value of the intraregional livestock trade in Mali and Burkina Faso (FAO, 2021, p.28). The growing unregistered cross-border trade in agricultural products between neighbouring countries in Africa proved the effects of climate change on these products and highlighted the need for deeper regional integration and effective regional policy.

Health Effects on Workers

There are many ways in which climate change affected the availability of labour for workers engaged in farming and trade. Perhaps the most obvious was the impact of elevated temperatures on those people working outside and exposed to the sun. (Hertel, 2018, p.1). Ambient heat exposure posed significant health risks, especially to outdoor workers such as women working in farms and involved in trade. The primary concern was the increasing incidence of heat-related illnesses due to elevated temperatures. These conditions could lead to a variety of health problems, including kidney issues, cardiovascular and respiratory complications and heat stroke. (El Khayat, Halwani, Hneiny, Alameddine, Haidar & Habib, 2022).

Moreover, outdoor workers were at a heightened risk of heat stroke, cramps, heat exhaustion, heat rash and other heat-related problems. These conditions could be exacerbated by heavy physical activity and lack of acclimatisation to hot environmental conditions. (Vanos, Guzman-Echavarria, Baldwin, Bongers, Ebi & Jay, 2023). While many farmers in the wealthier regions could avoid heat stress by working inside air-conditioned equipment and transporting their produce the modern way, there remained many traditional farmers without this equipment. Such extreme temperatures threatened livability and the capacity for labour. Research across Burkina Faso, Ghana, Kenya, South Africa and Tanzania indicated significant rises in mortality and healthcare strain during hotter days. (Mehra, Rael & Bloem, 2024, p.4).

Destruction of Infrastructure

Climate change is also increasing the prevalence and strength of extreme weather-related shocks such as storms, floods and droughts, which had wide-ranging implications for agricultural trade, affecting farming, processing and distribution. Climate change could also increased the vulnerability of the supply, transport and distribution chains on which international trade depended and led to significant post-harvest losses. (FAO, 2021, p.35). Exports of food from and imports to, the area affected by extreme weather was directly negatively affected during the crisis and in its aftermath if trade-related transport and logistics infrastructure sustained significant damage. (Odjo, Traoré & Zaki, 2024, p.139).

Longer-term adverse impacts on exports resulted from loss of life and injury to farmers, employees and damage to farms and the inventories of exporting firms. (Carlin, Arshad & Baker, 2023:7). For example, in 2020, above-average rainfall in Zambia destroyed more than 700 hectares of crops in Namwala district alone (a southern province of the country). The same year in Niger, nearly 10,000 hectares of crops were submerged under water. Moreover, the collapse of the Corniche Monument in the Republic of Congo and the Palar Bridge in Cameroon (Maroua), as well as the destruction of infrastructure in Algeria, Madagascar, Mauritius and Morocco, were perfect illustrations (Odjo, Traoré & Zaki, 2024, p.139). Yet, for trade to enhance physical access to food required good infrastructure for storing and moving agricultural produce from food surplus areas to deficit areas.

Trade as an Adjustment Mechanism to Climate-Induced Reductions in Crop Yields

Trade could play a crucial role in supporting Africa's efforts to adapt to a changing climate. Trade cushions the volatility of food markets by providing a vital flow of supplies to regions that may see a sudden reduction in domestic production of food crops due to a climate shock. Over time, trade enabled producers and consumers to adapt to changes in comparative advantage, thereby helping the transformation of Africa's agricultural sector and the diversification of its broader economy. (Global Centre on Adaptation, 2021, p.298). Risk-averse consumers sought stable supply and prices as an essential component of welfare, but there were divergent views on how to achieve this. On the one hand, domestic production might be more volatile than world production, given that domestic production was imperfectly correlated with external shocks and was affected by other domestic factors. In that context, trade could reduce the volatility of domestic food markets and stabilise prices. (Odjo, Traoré & Zaki, 2024, p.9). The adaptation effect of trade was strongest for hunger-affected and import-dependent regions such as SSA. International trade could also help create jobs and raise incomes, which strengthened households' resilience, not least by enhancing their ability to purchase food. (Carlin, Arshad & Baker, 2023, p.7).

To add on, trade played a crucial role when countries imported agricultural inputs in order to boost domestic production. For instance, the great majority of phosphate and potash fertilisers were produced in a few major producing regions that had phosphate and potash resources. While nitrogen could be produced anywhere, major producers tended to be in regions with access to relatively low-priced natural gas or coal. As a result, a large share of fertilisers applied around the world was imported from a limited number of major producing regions. (Odjo, Traoré & Zaki, 2024, p.11). Fertilisers provided essential nutrients to crops and played an important role in increasing agricultural productivity and by extension, food security. Nitrogen, phosphate and potash were essential macronutrients provided by fertilisers. (Carlin, Arshad & Baker, 2023). Most importantly, the availability of agricultural inputs was not the silver bullet to increased agricultural production, but the adoption of new technologies in agriculture such as agricultural drones and sensors, among others. (Shonhe & Scoones, 2022). This was an avenue where trade could provide solutions to the lack of access to the technologies needed to boost agricultural productivity.

The Role of ICT in Improving Agricultural Trade

E-certification

Agricultural trade in general and fruit and vegetable trade in particular, are subject to sanitary and phytosanitary standards (SPS). SPS is necessary due to the food safety issues and health risks associated with perishable products and is motivated by the precautionary principle in high-income importing countries. (Odjo, Traoré & Zaki, 2024). In this regard, e-certification reduced lengthy official clearance processes such as inspection certificates required by food authorities and in turn increased shelf life for agricultural produce during heatwaves caused by climate change. E-certification also streamlined compliance procedures and established accurate and readily accessible food-composition and contaminants databases. (FAO, 2021,p.31). Moreover, e-certification reduced rejection rates of goods at ports of entry and increased regional and international buyers' confidence in country-level product certification systems.

As a result of these improvements, African exporters were in a stronger position to increase export volumes, command higher prices for certified goods and generated wealth and jobs through the expansion of regional and international trade. (Carlin, Arshad & Baker, 2023, p.7). For example, the Economic Community of West African States (ECOWAS) Commission introduced a digital certificate of origin on 25 November 2024 which was the first such initiative by any regional bloc in Africa. It sought to improve intra-regional trade among member states and promoted regional integration. The initiative aimed to simplify the verification of the origin of goods traded within the ECOWAS region and address long-standing challenges related to the manual, paper-based system. The new system encompassed the application and delivery of certificates of origin, digital signing of the certificates, electronic submission to customs authorities for pre-export approval and subsequent digital approval. (Regulatory Alert, 2024).

Online Markets

ICT improved agricultural sector development via improvements in the availability of markets, reduced asymmetric information between farmers and customers and boosted competition and production between the agricultural sectors. (Asongu, 2020). To add on, digital technologies could facilitate the marketing of produce from farmers to consumers both locally and across borders, especially during climate catastrophes or pandemics that posed travel restrictions. Online sales of produce, e-commerce, connected farmers to buyers of produce such as fresh fruits and vegetables and other perishables, allowing farmers to sell directly to consumers while ensuring food safety through digital traceability. (FAO, 2021,p.35).

To add on, mobile phones were the widely used ICT tool within the agriculture sector. The proliferation of mobile phones within the African continent led to the development of mobile-based applications and services within the sector. These services and applications were mostly targeted at farmers and provide a range of agricultural information such as market prices and market demand (USAID, 2023,p.22). In Kenya, for instance, Ken Call which was a farmer's helpline service provided agricultural advice and information to support smallholder farmers. Farmers were provided with information on improved agricultural production, inputs, processing, climate and market information through the medium of a mobile phone (Ayima, Kassahunb, Tekinerdogan & Addison, 2020).

The role of Emerging Technologies in improving Agricultural Production

The increase in agricultural output in many developing countries and especially low-income countries in Africa, were driven by the expansion of cropland rather than yield increases. (FAO, 2021). The question arose how much less land-use change might be necessary to achieve global food security now and in the future. If the available innovative technologies in farming were broadly applied and small farmers had access to the technology, there would be less impact on climate change on agricultural production and less pressure to expand the area for agricultural production. This was an avenue where trade could provide solutions to the lack of access to the technologies needed to boost agricultural productivity and thereby limited land use change while supporting adaptation to changing climatic conditions. Emerging technologies crucial in boasting agricultural production and reducing the impact of climate change on agriculture included AI, nanotechnology, sensors, agricultural drones and geographical information systems, among others (Shonhe & Scoones, 2022).

Artificial Intelligence

One of the most critical emerging disruptive digital technologies include AI. (Zakaria and Hassan, 2023). AI is a software that could initiate logical reasoning, learn and solve complex problems. (Ryan, Isakhanyan & Tekinerdogan, 2023). AI in precision agriculture enables farmers and farm managers to deploy highly targeted and precise farming practices based on site-specific agroclimatic field measurements. AI can help farmers reduce errors and minimise crop failure risks by forecasting and predicting future events. A farmer can take advantage of global climate change to provide accurate and timely weather information that is favourable for planting during times of global climate change. (Odume, 2024). With AI, producers, retailers and most importantly farmers, gain better insights into the whole value chain of agricultural inputs, resulting in a more transparent relationship between all parties. (Zakaria and Hassan, 2023). AI can also help farmers monitor potential threats to agricultural productivity, for example, the occurrence of pests and disease which can be a difficult task to do manually, especially in large acreages. (Parwada & Marufu, 2023).

Sensors

Precision agriculture relies on advanced technologies such as sensors, which collect data on various parameters of the environment and crop conditions. (Bošković, Marina, Pajić & Subić, 2024). This data allows farmers to make timely decisions, optimise the use of resources such as water, fertilisers, pesticides and improve the overall efficiency of agricultural production. Sensors implemented in agriculture play a significant role in soil and plant growth and enable real-time physical and chemical interactions in the environment. Additionally, these sensors provide essential data that can enhance crop growth scenarios, resist biotic and abiotic stresses and improve crop production. (Faqir, Qayoom, Erasmus, Schutte-Smith & Visser, 2024). Integrating internet of things connectivity into soil moisture, sensors can offer prognostic insights for water resource management and agricultural planning. (Wang, Lin, Han, Fu, Huang, & Cheng, 2022). To add on, several potential techniques, such as acoustic sensors, nanostructured biosensors, optoelectronic sensors, electronic sensors and impedance sensors, were suggested for the identification of soil pests. (Rhodes, Bennie, Spalding, French-Constant, & Maclean, 2022).

Nanotechnology

Nontechnology deals with the matter at the nano scale (1-100 nm) dimensions. These materials, when reduced to the nano scale, show some properties which are different from what they exhibit on a macro scale, enabling unique applications. (Elizabath, Babychan, Mathew & Syriac, 2019). Nanotechnology opens a large scope of novel application in the fields of biotechnology and agricultural industries, because nanoparticles have unique physicochemical properties, for instance, high surface area, high reactivity, tunable pore size and particle morphology (Vangala, Das, Kumar, & Alazab, 2021). Nanoparticles can serve as magic bullets containing herbicides, nano-pesticide fertilisers, or genes, which target specific cellular organelles in plants to release their content. (Elizabath, Babychan, Mathew & Syriac, 2019). Nano-biotechnological techniques can benefit diverse processes related to plant biology, including seed germination, plant growth enhancement, plant nutrition improvement, secondary metabolites isolation and protection provision against biotic and abiotic stress factors. (Domguia & Asongu, 2023). To enhance nutrient use efficiency and overcome the chronic problem of eutrophication, nano fertiliser might be the best alternative. Attempts have been made to synthesise nano fertiliser to regulate the release of nutrients depending on the requirements of the crops and it was also reported that nano fertilisers were more efficient than ordinary fertiliser. (Oxford Business Group, 2021, p.23).

Agricultural drones

Drones evolved into integral technological devices that aided various human endeavours. Their applications span military uses, photography, transportation, sports and recreation and notably, agriculture. (Kwao, Owusu, Okyere, Agbenya, Laryea, & Armah, 2024, p.1). Ground-based and aerial-based drones are being used in agriculture to enhance various agricultural practices, that is, crop health assessment, irrigation, crop monitoring, crop spraying, planting and soil and field analysis. From the drone data, farmers drew insights regarding plant health indices, plant counting and yield prediction, plant height measurement, canopy cover mapping, scouting reports, stockpile measuring, chlorophyll measurement, nitrogen content in wheat, drainage mapping, weed and pressure mapping, among others. (Kumar *et al.,* 2023). The adoption of drones could lead to increased crop yields, efficient resource utilisation such as water and pesticides and maximised farm productivity. These capabilities help save time and labour costs, improve resource management, enhance safety by reducing human exposure to hazardous chemicals and combat climate change impacts. (Kwao, Owusu, Okyere, Agbenya, Laryea, & Armah, 2024, p.1).

Geographic Information Systems

GIS is a powerful toolkit that can be used to store, retrieve and alter spatial data for a variety of uses. In the agricultural sector, its ability to analyse and illustrate agricultural settings and workflows has been shown to be especially useful. A farm cannot be productive and successful unless its inputs and outputs are balanced. (Mahanta, Prusty & Saha, 2024, p.287). Spatial data in the field of agriculture were essential in examining the spatial connections between social, physical, agroecological and environmental factors and their impact on the sustainability of agricultural practices. (Trivedi, Rao, Rajwade, Yadav, & Verma, 2022). There are seven distinct application areas of GIS within the field of agriculture. These areas encompass crop yield estimation and forecasting, assessment of soil fertility, analysis of cropping patterns, agricultural monitoring, evaluation of drought conditions, detection and control of pests and crop diseases, implementation of precision agriculture techniques and management of fertilisers and weeds. (Raihan, 2024).

Conclusion and Recommendations

The study analysed the effects of climate change on agricultural production and trade in Africa. The study unpacked that climate change was a threat to both agricultural and non-agricultural development in any economy, but more so to food production in developing countries due to heavy reliance on agriculture. Climate change affected agriculture through various means, such as low or excessive rainfall leading to drought and flooding, climate extremes such as heat waves and changes in average temperatures. Climate change also affected trade through trade deficits, price hikes, availability of workers, health risks and export restrictions, among others. However, ICT and emerging technologies had the potential to improve agricultural production and trade in Africa, as discussed in this study.

It was recommended that measures for climate change adaptation in agriculture should include the development and promotion of drought-tolerant crops and hardy livestock breeds and species, investment in smallholder irrigation and rainwater-harvesting, improved animal feeding systems, enhanced agricultural market integration and performance. Governments should also ensure that the policies they adopt in response to climate shocks, while still achieving better climate and development outcomes, do not undermine the competitiveness and resilience of food producers and consumers in other jurisdictions. Moreover, transparent trade policies are an integral part of a broader strategy to access high-quality, low-cost goods and services that are essential to help the agricultural and other economic sectors adapt to climate change, such as ICT infrastructure. Governments also need the flexibility to be able to temporarily increase support to producers when a shock occurs.

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