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SUSTAINABLE FOOD SYSTEM TRANSFORMATION IN A CHANGING CLIMATE

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Abstract
In recent years, several major drivers such as population growth, shocks, and changing climate have put the world off track to ending hunger, malnutrition, and meeting global food demands. Temperature increase, changes in rainfall pattern, drought, flooding, and the occurrence of pests and diseases negatively impact our food system. The situation seems to be the worst in Sub-Saharan Africa, where farmers are slow in changing their farming practices such as bush burning and deforestation, mainly because they lack the requisite education, information, and training necessary to mitigate and adapt to climate change. The question is whether the current food systems in Sub-Saharan Africa can produce enough food in the future to meet the demands of a growing population that is predicted to double by 2050 amid climate change. Food systems need to transform in a sustainable way to limit their environmental impact, contribute to building more sustainable diets and at the same time adapt and become more resilient to climate change. The purpose of this review is to increase the understanding of the nature of climate change's effects on the food system and emphasize the need to adapt science-based technological and innovative approaches to address these challenges. Understanding climate change challenges on food system is pivotal to sustainable food security in Africa.

***Keywords:** Adaptation, Food System, Food Security, Climate change, Sustainable*

Introduction

Global hunger is on the increase, and the world is currently off track in meeting the global food demands (FAO, 2021), with climate change, shocks, and population growth threatening the progress made so far towards achieving sustainable food security. Around the world, people are increasingly exposed to extreme weather events, economic crises, infectious diseases, political conflicts, and food crises (Romm, 2011; Worldbank, 2021). Recently, climate change has received special attention as a major disruptive challenge to food systems and constitutes more threat to food security, hunger, and poverty reduction efforts (FAO, 2021; IPCC, 2014). Temperature increases, drought, cyclones, flooding, rising sea levels, water temperature, ocean acidification, changes in rainfall pattern, and incidence of pests and diseases due to changing climate impact agricultural production and food system in Africa. While coping with the increased food insecurity due to changing climate, the agricultural sector in sub-Saharan Africa faces many other challenges of feeding a growing and urbanising population that is predicted to increase from 1.08 billion in 2020 to 1.76 billion by the end of 2050 (UN, 2019). Extreme weather events have pushed millions of people over the food cliff into hunger and poverty (Romm, 2011; Koebler, 2012). The number of people without enough food to eat has recently increased from 777 million to 815 million (FAO, 2021; Worldbank, 2021; Conway, 2012), and an additional 100 million could die from climate change impacts before 2030 (Koebler, 2012). In 2020, 16.7 million people were acutely food-insecure (FAO, 2021), and projections indicate a further worsening of the food and nutrition situation in the

coming years (Conway, 2012). The increase in food demand and severity of food insecurity is higher in developing countries, including sub-Saharan Africa (FAO, 2021; Kotir, 2011). The region still has the highest prevalence of undernourished people, with one in every four people being food insecure (FAO, 2021) and 10.9 million children below five years dying from hunger-related causes (UNICEF, 2009). The resulting food insecurity in Africa has affected the economic systems (Parry *et al*., 2005) and local food systems and their farmers that stand at the basis of food production (IPCC, 2014). The main concern is whether today's food systems are capable to meet the demands of feeding the growing global population sustainably in the future. Africa's food systems are not yet out of the hook of climate change (World bank, 2021). However, they are becoming worse, unpredictable, and uncontrollable. The extreme weather events resulting from climate changes have a high cost and threaten crops and livestock, thereby risking Africans' food system and food security outcomes (GCA, 2019, Worldbank, 2021). The recent outbreak of the global COVID-19 pandemic has further exacerbated the situation of food insecurity in the continent and exposed Africa's food systems to system-level shock (Worldbank, 2021). Hunger was already trending upward even before the COVID-19 pandemic, which worsened existing effects from extreme climate events, conflict, and other shocks, resulting in lower incomes and higher prices of foods, thereby putting food out of reach of many homes. With these increasing uncertainties and current challenges, food systems need to transform to limit their impact on the environment, contribute to building more sustainable diets and become more resilient to climate change (IPCC, 2014; Antle and Capalbo, 2010; FAO, 2012). Without such appropriate responses, climate change is likely to constrain economic development (Parry *et al*., 2005; Allen, 2017) and poverty reduction efforts towards achieving the sustainable development goal of the United Nations (IPCC, 2014; UN, 2019). The purpose of this report is not only to present a menu of solutions in advancing food security in an era of climate change but also to increase understanding of the nature of climate change challenges on food systems. Understanding climate change impacts and well-designed adaptation and mitigation strategies can offer ways out towards a sustainable food system.

Food Security is the outcome of Food systems

A food system comprises all processes and infrastructures involved in satisfying a population's food security (Vermuelen *et al*., 2012; FAO, 2018). The system encompasses all the activities in food production, which are cropping, harvesting, storing, packaging, transporting, processing, retailing, consumption, and waste of food, and their impacts on nutrition, health, and the environment (FAO, 2012; Vermuelen *et al*., 2012; OECD, 2021). It also involves a complex network of practices and policies that determine how food is produced, distributed, and consumed. Food security at the other hand, is a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (HLPE, 2014; FAO, 2019). The food system, food security, and climate change are multifaceted topics. Their interactions as well are complex and are affected by a wide range of environmental and socioeconomic factors. Climate change affects food systems to alter food security outcomes (Brown *et al.*, 2015; Ericksen *et al*., 2010). Changes in determinants of the food system will give rise to differences in food security outcomes because both are interwoven in such a manner that activities involved in the food system lead to direct outcomes in food security and environmental factors (Ericksen *et al.,* 2010). Food security itself involves food availability, food access, utilization, and stability. Food availability is food production and its readiness for use through storage, processing, distribution, sale and exchange. Food Access is the ability to obtain food, including the effects of price (FAO, 2012; FAO, 2018). Food utilisation means achieving food potential through nutrition and health, while stability is the continuous availability and access to food without disruption. Food security is also related to nutrition; therefore, food insecurity directly impacts malnutrition due to malnourishment. However, as described by Food and Agriculture Organization (FAO, 2018), not all malnourishment arises from food insecurity per se, as households may have access to healthy diets but choose to eat unhealthily or it may also arise from illness. In many parts of the world, poverty and food insecurity are mainly linked to poor diets and malnutrition (Parry *et al.,* 2005; FAO, 2018). The relationship between poverty and poor diets may also be related to unhealthy food systems and environments (IPCC, 2014; Gamba *et al.,* 2015). Food production is a significant component of the food system, an essential aspect of food security (Ericksen *et al.,* 2010; Hatfield *et al*., 2011). The evidence that climate change has affected food production in the food system implies a direct effect on food security.

Food System is Expected to Deliver on Certain Challenges

Sustainability has been described as the use of resources at rates that do not exceed the capacity of the earth to reproduce them (FAO, 2021). A sustainable food system globally is expected to deliver and meet specific requirements despite the various formidable challenges facing the system (IPCC, 2014; OECD, 2021). The first requirement is to ensure food security and nutrition for a growing population; the second is to provide livelihoods to farmers and people working in food supply chains and promote rural development. The third is to build and ensure environmental sustainability by reducing greenhouse gas emissions while adapting and helping to mitigate climate change (OECD, 2021) and, finally, to ensure the good health and well-being of the populace. However, these requirements are a long way from being attained because these are amplified by a combination of various challenges (Figure 1) that have led to food systems failure and inability to deliver as expected. Many factors apart from climate change influence future food systems and food security such as;

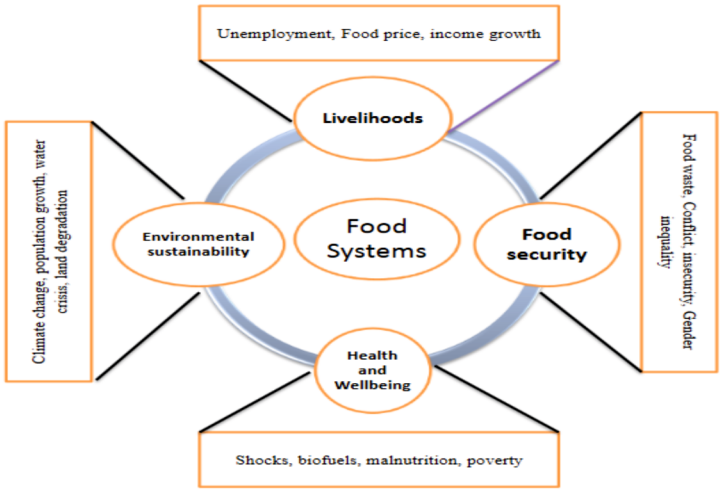

Figure 1: Factors Challenging the Food System Demands
Source: Authors' own

(1) Shock: Africa's food systems are vulnerable to shocks, stresses, and disruptions due to the impact of drought, increased temperature, flooding, erosion, inflation, and conflict (IPCC, 2014; Ainsworth and McGrath, 2010). Shocks can cause significant strains on the functioning of food systems and significantly affect people's ability to access safe and affordable food. Poverty, unemployment, and insufficient food reserves further limit the capacity of our food systems to cope with these shocks and stresses (Gregory *et al.,* 2005). For instance, the sudden outbreak of the Covid-19 crisis in early 2020 has highlighted the importance of improving the resilience of food systems worldwide (Worldbank, 2021).

(2) Conflict/Insecurity: Conflict reduces food availability, disrupts food and health care access, and undermines social protection systems (FAO, 2018). Countries with the highest hunger levels are usually with conflict (FAO, 2018; OECD, 2021). Similarly, insecurity can cause food shortages and the severe disruption of economic activities where it exists, threatening the survival of entire populations and limiting people's access to food, which negatively impacts the food and nutritional status of all populations (IPCC, 2014).

(3) Biofuels: Thirdly, the use of plant and edible crops for biofuels production has profound effects on the food system by directly affecting food security. Bio-fuels are mainly produced from edible plants like corn and sugarcane, which are emerging to tackle energy and climate change problems. However, this practice decreases the number of grains available for food, which drives up the prices of such grains (Solomon, 2010). The growing demand for biofuels is also responsible for the increase in deforestation in many countries, thereby risking flooding and further threatening food security.

(4) Population Growth: Another factor challenging the food system is population growth. The global population is on the increase, and it's forecasted to exceed 10 billion by 2050 (U.N., 2019; Conway, 2012), leading to increasing demand for food and placing further pressure on the food system. It has been proposed that global food production will need to increase up to 60% by 2050 to feed this growing population in a safe, responsible, and sustainable way (FAO, 2019). Feeding a growing population and achieving food security has been defined as one of the most significant challenges on food system sustainability without zing our natural resources' future (FAO, 2018).

(5) Food waste: Food waste and losses also put unnecessary pressure on the food system (HLPE, 2014; FAO, 2019; Parfitt *et al*., 2010). The number of food-insecure populations remains unacceptably high while most of the food we produce never gets eaten and ends up in landfills as waste. In addition, massive quantities of food are lost each year due to spoilage and infestations on the journey to consumers (Sturat, 2009; Parfitt *et al*., 2010). If less food is wasted, more people can feed adequately, and the global prevalence of hunger and malnutrition will be reduced.

(6) Gender inequality: Women play critical roles in food production systems in Africa, such as in processing, distribution, and marketing (FAO, 2011; Ajani *et al*., 2013; Alston, 2014). However, women face discrimination in access to land, credit, and limited education and are not viewed as equal players in the household and community (FAO, 2011). If women had the same access to productive resources as men, women could boost food production yields.

(7) Climate change: As mentioned earlier, the most fundamental impact of global climate change on the human population is its impact on the food system (FAO, 2012; IPCC, 2014). Extreme weather events such as droughts, salinity, acidification, and floods are forecast to increase due to change in the climate. These will have a range of effects on agriculture and food production systems. It is important to understand how climate changes affect the provision of food and food

safety practices now for the future.

(8) Other Factors: Degradation of land (Ma and Ju, 2007), scarcity of water (Ruane *et al.,* 2008), and energy for food production (OECD, 2021) also affect the ability to produce enough food. Approximately 40 percent of the world's agricultural land is seriously degraded (FAO, 2012; Ma and Ju, 2007). Intensive and continuous farming on the same land often leads to a vicious cycle of soil fertility depletion and, consequently, a decline in agricultural yields. Other causes of land degradation also include overgrazing and over-exploitation of vegetation. Regionally, the Sub-Saharan Africa region has the most significant number of water-stressed countries of any place globally (Ruane *et al*., 2008). Water scarcity translates to a food security failure, thereby posing a challenge to food systems. If current land degradation trends and soil fertility depletion continue, Africa might just be able to feed only 25 % of its population by 2050 (IPCC, 2014; FAO, 2018).

Understanding the Impact of Climate Change on Food System

Global agriculture and food system are vulnerable to climate change (IPCC, 2014; Padgham, 2009). Climate change negatively affects all four pillars of food security (availability, access, utilization, and stability) directly or indirectly (Figure 1) (OECD, 2021). Food availability may be reduced by negative climate change impacts on crop productivity, livestock, and fish due to increased temperature and changes in rainfall patterns (IPCC, 2014; Vermuelen *et al.,* 2012). Food access and stability may be affected by disruption of markets, prices and infrastructure, transport and retail, and the food purchasing power of low-income consumers (HLPE, 2014; ICP, 2011). Climate change may directly affect food utilization due to increased food safety concerns, rising temperatures, and increased frequencies of extreme events and directly through its effects on health (IPCC, 2014; Tirado *et al.,* 2015). Extreme events, for example, flooding, will directly affect the stability of food supply through disruption of transport and markets. The effects of climate on soil quality may be due to depletion of soil organic carbon pool (Lai, 2013), a decline in water capacity (Ruane *et al*., 2008) and reduction in soil fertility, efficiency in the use of nutrients, accelerated soil erosion and salinisation (Vineis and Khan, 2012). Climate change may also affect the nutritional proportions of some crops (Ainsworth and McGrath, 2010; Tirado *et al.,* 2015). Research has found that under conditions of elevated carbon dioxide levels, the concentrations of minerals in some crops can be up to 8 to 10 percent lower than normal (Hatfield *et al*., 2011; Ainsworth and McGrath, 2010). Higher temperature and less rainfall will make clean water less available in many areas, compromising hygiene and facilitating the spread of waterborne pathogens (FAO, 2021; OECD, 2021).

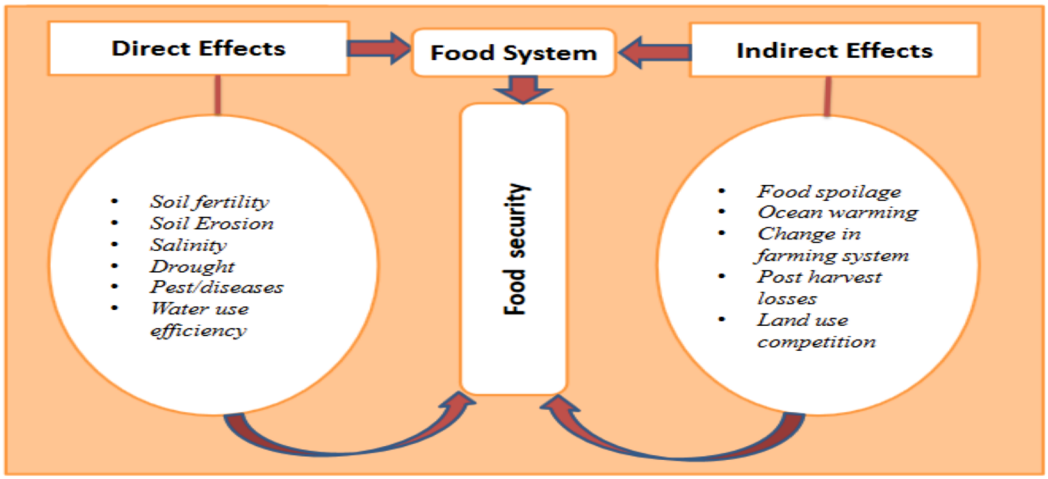

Figure 2: Effects of Climate change on Food System (Adapted from: IPCC, 2014)

There may also be numerous indirect effects of climate change on food systems, such as changing farming systems and deciding what type of crops to cultivate (IPCC, 2014; OECD, 2021). The warming of oceans may also threaten food security indirectly (Funk and Brown, 2009). There are also numerous implications of climate change to the incidence of pests, pathogens, and weed infestation (Smil, 2000). Climate change-induced salinity can adversely affect human health as well (Vineis and Khan, 2012). Effects of climate change on crop production may also be highly heterogeneous because of variations in soil type, topography, and rainfall distribution (IPCC, 2014; GCA, 2019). Climate change also causes huge post-harvest losses within the food systems (FAO, 2019; Parfitt *et al*., 2009; Atanda *et al*., 2010). We lose more than half of what we produce, which significantly impacts the environment (IPCC, 2014; FAO, 2012). Post-harvest food losses result from inefficient functioning of the food systems (Hodges *et al*., 2012). More than one-third of the food we produce is

lost or wasted in post-harvest agricultural operations at a time when the food demand of a growing population is a major concern globally (FAO, 2012). In some African countries where tropical weather and poorly developed infrastructure contribute to the problem, food losses and wastage can regularly be as high as 40-50% (SPORE, 2011). Hence, one significant way to strengthen the food system in a changing climate is by reducing the losses after harvest.

Food System is also a Key Contributor to Climate Change

Food systems are major driver of environmental effects, including climate change (Brown *et al*., 2015). Agricultural activities and local food systems emit substantial amounts of greenhouse gases (GHG) (IPCC, 2014; Brown *et al.,* 2015), contributing to environmental degradation and climate change. GHG emissions from food production vary across food types and practices (Figure 2) (Clune *et al.,* 2017). For example, producing animal-sourced food (e.g., meat and dairy) emits more GHG emissions than growing crops (OECD, 2021). Also, food systems are the most significant driver of biodiversity loss, water pollution, and deforestation (HLPE, 2014; Forgione *et al.,* 2009). At the same time, climate change and environmental degradation pose significant risks to food system performance (IPCC, 2014; Dury *et al*., 2019). Usually, when it comes to tackling climate change, the focus tends to be only on finding alternative clean energy solutions. Indeed, energy accounts for the majority of GHG emissions globally. However, the global food system, which encompasses production, processing, and distribution, is also a pivotal contributor to emissions, and it is a problem for which we do not yet have viable technological solutions.

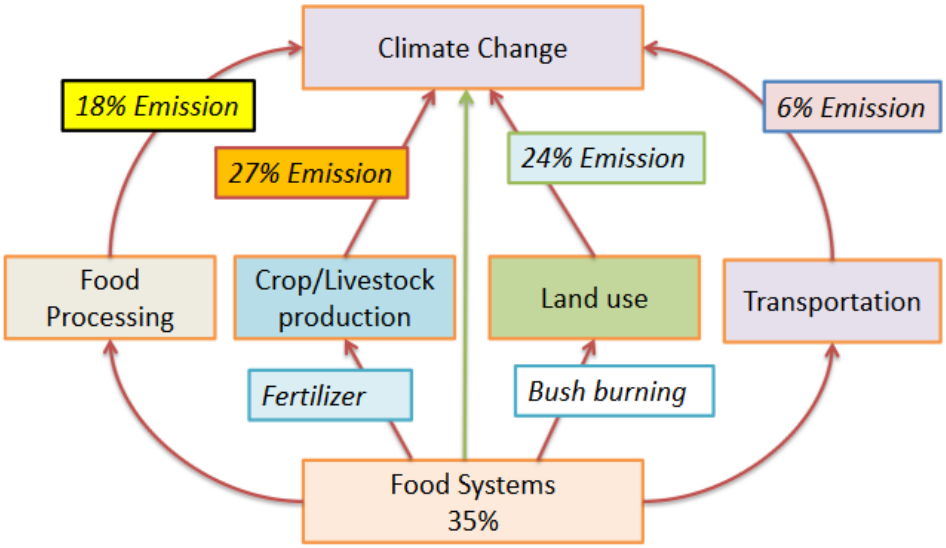

Figure 3: Impact of Food Systems on Climate Change
Source: Authors' own

The food system is responsible for approximately 35 percent of the global GHG emissions (Vermuelen *et al*., 2012; Brown *et al.,* 2015; OECD, 2021). Food production alone contributes to eutrophication (the pollution of waterways with nutrient-rich pollutants), acid rain, and biodiversity depletion (HLPE, 2014). Ruminant livestock (especially cattle) produce methane through their digestive processes known as enteric fermentation into the environment. Crop production accounts for 27 % of food emissions (Vermuelen *et al*., 2012; Clune *et al.,* 2017), which includes elements such as the release of nitrous oxide from the application of pesticides, fertilizers, and manure, methane emissions from cattle and rice production and carbon dioxide from agricultural machinery (OECD, 2021). In addition, half of the phosphorous and nitrogen that ends up in the sea due to human activity is attributable to agriculture (IPCC, 2014; Brown *et al*., 2015). Land use accounts for 24% of food emissions (Vermuelen *et al*., 2012). Supply chains account for 18%, while food transportation contributes 6 % of total emissions from agriculture which is the least (Brown *et al*., 2015; Dury *et al*., 2019). Rockström *et al.* (2019) opined that agriculture had become the single largest driver of environmental change and, at the same time, is the most affected by these changes. Reducing emissions from food production will be one of our greatest challenges in the coming decades because how we can decarbonise agriculture are less clear, unlike in the energy sector (OECD, 2021). We need fertilisers to meet growing food demands, and we cannot stop cattle from producing methane during digestion. So what is the way out?

Determinants and Drivers of Sustainable Food System

The demand for food continues to increase rapidly as a result of various drivers. Therefore, in our search for sustainable ways of improving food production in a changing climate, it is important to first understand the determinants and drivers of sustainability and failure in the food system to enable us to measure the impacts. We are striving to achieve a global food system that is not only safe, accessible and nutritious but also that our food

is authentic, sustainable and ethical (FAO, 2021; OECD, 2021). Food security is a right that all countries should embrace, irrespective of their level of technical, economic, and social development (FAO, 2018). This section discussed the determinants and drivers of food systems that are highly interrelated and interact with each other, influencing the food system, and its food security outcome.

Food availability: Food availability as a driver of sustainable food security is achieved when sufficient quantities of food are consistently available to all individuals within a country (FAO, 2019). Improved access to food through increased agricultural productivity and incomes is essential to meeting the food needs of a growing population.

Education: According to De Muro and Burchi (2007)**,** education is regarded as a key to food security, especially for rural populations in developing countries. Education is crucial to achieving a sustainable food system and food security and eradicating extreme hunger and poverty. It influences food security through information on best agricultural production, nutrition, and sanitation, increased efficiency, increased production, and better decision making (De Muro and Burchi, 2007). The role of education in sustainable food security is to ensure that the wheels of food systems and the entire value chain are adequately oiled with the necessary knowledge and skills. The lack of this knowledge and learning opportunities is directly linked to rural poverty and hunger.

Socio-cultural factors are also other drivers of food security**.** Food is intimately related to human culture (Kittler *et al*., 2011). Improving our understanding of cultural aspects of food security is an important part of moving towards sustainable and nutritious diets. The perception and meaning of food in a different culture can affect the availability and utilization of food in that culture. Food is processed, consumed, and stored is strongly determined by culturally transmitted food processing and storage techniques (Kittler *et al*., 2011). More generally, cultural models of eating may drive food waste behaviour as well**.**

The economic situation is also considered a determinant factor of food system sustainability**.** Hunger is increasing in countries facing slow or declining economic growth (FAO, 2021; Parry *et al*., 2005). Economic downturns often lead to a rise in unemployment and job losses, and a decline in wages limit access to food for vulnerable people. The World Bank (2021) and Food and Agriculture Organization of the United Nations (FAO, 2021) pointed out that enhancing the productivity and incomes of smallholder farmers, investment, and social protection is key to progress.

Political Instability: Food distributions are primarily shaped by political factors that prevent the food from getting to where it is mostly needed. Hence, food availability does not necessarily address the problem of accessibility to that food (OECD, 2021). Famines occur and have occurred in the past in countries in which food is readily available and plentiful due to political instability and insecurity. Food security and political stability are often related, although the relationship is not direct and not necessarily causal. However, evidence suggests that food security can be entirely disrupted by a lack of political stability (FAO, 2019). In previous years, significant malnutrition and famine have been associated with the disruption of food supplies through wars and civil strife in many countries.

Government Policy: Africa's food insecurity and malnutrition problems are also a result of inappropriate development, strategies and government policies (OECD, 2021). The development of dynamic farming systems capable of adapting to the challenges of climate change requires a conducive and stable policy environment. The policy affects all components of food systems through a range of instruments such as laws and regulations, investments, and subsidies (IPCC, 2014). Although most countries in Africa have agricultural investment policies, only a few have food policies or limit them to food availability (Dury *et al.,* 2019). Weak infrastructure and inconsistency in government policies are major challenges in developing agriculture in many developing nations.

Food Purchasing power: Food prices have become a key determinant of food and nutrition security, with households increasingly depending on the market to access food (ICP, 2011; Allen, 2017). Food purchasing power is usually defined as a household's economic ability to obtain food which is determined by measuring the income allocated for the purchase of food and the price of food consumed (FAO, 2021). Food security will become more difficult due to higher food costs and lower purchasing power (Allen, 2017). In places with higher food prices, rates of household food insecurity are higher. As a result, food price levels and price variations directly impact food and nutrition security (ICP, 2011). According to World Bank (2021), we can expect more price spikes in food in the coming years due to climate change impacts and current global shocks on food security from the Covid-19 pandemic. Therefore, investments promoting food value chain productivity will substantially impact prices, farmers' incomes, and food affordability.

Technology, Innovations, and Infrastructure: Innovation, technology, and infrastructure are major drivers of food systems. They accelerate transformations in food production, consumption, and policy (OECD, 2021; Altieri *et al*., 2017). Technology and infrastructure provide opportunities for improving the efficiency of production, process and developing more sustainable and resilient food value chains (FAO, 2012; DB, 2014; Wakjira, 2018). They can play a critical role in producing more food by creating plant varieties with improved traits and optimizing the inputs needed to make agriculture more productive (HLPE, 2014;

Wakjira, 2018). For example, biotechnological modification of plant varieties can be used for nutrient fortification, tolerance to drought, herbicides, diseases, or pests, and higher yields. These technologies can hasten the completion of a task at a lower cost but should also ensure high-quality, and safe food products for consumption.

Food System Sustainability and Hunger Eradication: What is fair?

Achieving food security, ending hunger, and promoting sustainable agriculture is the second goal out of 17 sustainable development goals of the United Nations. Therefore, it is up to every individual, civil society, family, groups, organisations, corporations, institutions, researchers, and government agencies (Figure 4) to work towards achieving this goal and eradicating hunger within the stipulated time frame. With the growing challenge of increased demand for food and agriculture in a changing climate, there are a number of solutions we can all work together to combat hunger which is highlighted in this section.

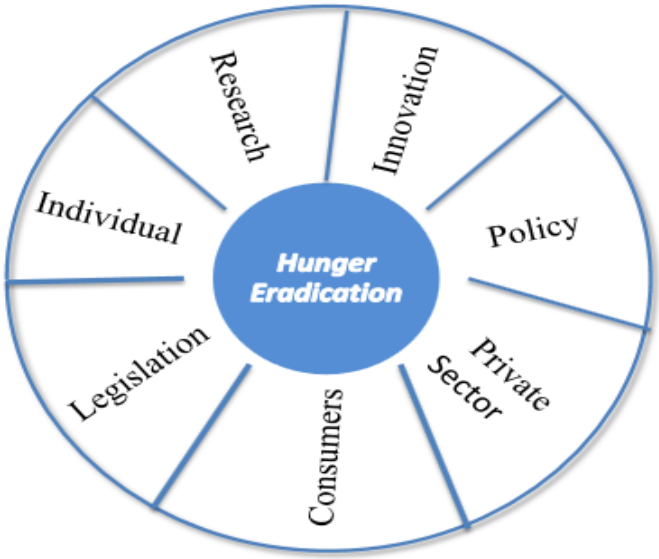

Figure 4: Contributors towards hunger eradication
Source: Authors' own

Improve existing infrastructural programs: Some farmers fail to get their produce to the market because of poor infrastructure, including inadequate roads, lack of storage facilities and food processing equipment (HLPE, 2014; OECD, 2021). Therefore, the food products rot in the farms rather than being taken to those who need it or for processing. If the infrastructure is improved, more food will be available in the market for the consumers, and food insecurity and food wastage will reduce.

Promote diversification: Focusing on a particular food crop or staple can produce terrible outcomes for food insecurity reduction (FAO, 2018). In order to ensure sustainable food production, there is urgent need to educate farmers on the importance of cultivating different varieties of crops that can withstand changes in climate. With more varieties of food and an educated community, there will be sufficient staple foods available in the markets for the consumers.

Close the yield gap: Most farming lands are drained of their natural fertility levels and cannot produce as much as they did years ago (Ma and Ju, 2007; IPCC, 2014). To close the gap, governments and agricultural institutions in charge have to develop strategies and programs for improving crop yields (OECD, 2021; Tilman and Clark, 2015), such as soil management and land improvement.

Work towards defeating climate: There is no doubt that climate change is severely affecting our lives and food production. If we fight against climate change and farm sustainably, we will ensure there is enough food for us and future generations.

Reduction of food waste: As mentioned earlier**,** food is wasted mainly because of inadequate preparation, bad roads, over-selective customers, and insufficient storage facilities (Parfitt *et al*., 2009, FAO, 2019). When we waste food, we waste a startling amount of resources, energy, and money invested in producing and processing the world. Suppose storage facilities are improved using modern technology and there are adequate preparations for using the food. In that case, less food will be wasted, and there will be a more food secure community (FAO, 2019).

Optimise agricultural land use: Another promising approach is to implement land-sparing strategies (combining high yield agriculture with habitat protection) that optimize land use for agriculture (IPCC, 2014; OECD, 2021). Boosting yields on semi-dry lands

through improved soil and water management practices can reduce overall water and energy consumption while growing more with less land (HLPE, 2014). By implementing strategies to utilise our land more efficiently, we can achieve higher agricultural yields that sustainably feed the growing population without compromising biodiversity (Godfray *et al*., 2010).

Food system policies: The dominant role of food systems in ensuring food security and shaping the future health of people and the planet implies a need for a broader set of policies beyond agriculture (Antle and Capalbo, 2010). Current agricultural policies are not effective at addressing the challenges of food systems (OECD, 2021). Various African governments tend to consider food issues through the lens of agricultural policy, which tends to focus only on food availability. Current transformations highlight the need for adjusting the policy to the new realities of the food sector which is catalytic in shaping the performance and resilience of food systems in Africa.

Encourage a sustainable variety of crops: Today, across the globe, four crops, namely; rice, wheat, corn and soy, represent 60 % of all calories consumed (FAO, 2018). Addressing the challenges of climate change and food availability will require helping farmers explore and identify a more diverse range of crops (IPCC, 2014, OECD, 2021). To achieve this, we must work with farmers to ensure they have access to the necessary tools and skills and build a market by educating communities about the nutritional importance of eating a wide range of foods.

Technology and Innovation: If hunger is to be eradicated, then rural resilience must be supported through investing in new technologies that enable farmers to connect with infrastructure and institutions with access to information, markets, and financial services (FAO, 2019). The availability and use of technology should include a large number of trained professionals with the expertise needed in the different areas. Training will be required as well, but without this, there will be very little research and innovation to provide the required sustained output of knowledge, skills, and products

Mitigation and Adaptation Strategies

Climate change adaptation and mitigation strategies in the food system require finding more sustainable, resilient, and efficient ways of producing, trading, distributing, marketing, and consuming diverse and nutritious foods (IPCC, 2014; FAO, 2012; Tirado *et al*., 2015). Agricultural adaptation aims to effectively manage potential climate risks over the coming decades as climate changes. Mitigation actions involved directly reducing emissions or enhancing carbon sinks necessary for limiting long-term climate damage. In contrast, adaptation is necessary to limit potential risks of the unavoidable residual climate change now and in the coming years (FAO, 2012). The benefits of adaptation choices will be realized almost immediately, whereas the benefits of mitigation may only be realized decades from now and become relevant later (OECD, 2021; HLPE, 2014). There are many potential adaptation and mitigation approaches available (Table 1). Changes in management practices and strengthening of seed systems are two critical approaches to adapting food and agricultural systems to climate change in sub-Saharan Africa (Ingram, 2011).

Table 1: Climate Change mitigation and Adaptation Strategies

Mitigation practices	Adaptation practices
Practicing agroforestry for carbon sequestration	Reduction of food waste and post-harvest losses
Dietary shifts to less intensive animal products	Technological practices for water use efficiency
Use of energy-efficient methods for production	Use of climate-resilient crop varieties
Adoption of organic farming by avoiding pesticides	Adjusting planting date to early or late planting
Application of biotechnology methods in agriculture	Improving infrastructure program and policy
Capturing and utilisation of methane from cattle	Effective education and capacity building
Access to post-harvest techniques to reduce losses	Use of integrated pest management methods

Source: IPCC, 2014

With the adoption of improved technology, more people by 2050 can be fed with a nutritious diet while also restoring soil and water and mitigating climate change (IPCC, 2014). Beyond dietary changes, such as reducing food waste, changes in the consumer behaviour can also positively affect overall greenhouse gas emissions from the food system (Aleksandrowicz *et al*., 2016; IPCC, 2014). Consuming regional and seasonal food can reduce GHG emissions (Garnett, 2011) if grown efficiently.

Practicing agroforestry can promote soil carbon sequestration while improving agroecosystem function and resilience to climate extremes by enriching soil fertility and soil water retention.

Adoption of organic farming by using organic sources of nutrients and avoiding chemical pesticides can help reduce the emissions and environmental impacts of the food system. If widely adopted and implemented, these practices singly or in combination will have substantial potential to offset negative climate change impacts on our food system.

Conclusion

This review has highlighted the critical nature of climate change and other challenges faced by Africa's food system in meeting food demands, including population

growth, and system shocks. Despite positive advances in science, we are still facing the ongoing threat of climate change to our food system, which threatens to reverse the progress made so far in the fight against hunger in recent years. Extreme weather events such as temperature increase, drought, flooding, salinity, pests, and diseases affect the global food system and its ability to feed the growing population. On the other hand, farmers have been slow in changing their farming practices. They lack the necessary education and training to mitigate and adapt to these climate changes to ensure a sustainable food production system. To ensure sustainable food system, much attention should be focused on reducing the rate of food waste and postharvest losses. . Additionally, improving existing infrastructure programs and policy, practicing agroforestry, using energy-efficient farming methods, adopting organic farming, and using varieties resistant to stress and education show propensity towards resilience or adaptation. It is essential to prioritise the climate change adaptation needs now for future food security

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Conflict of Interest
The authors declare no conflict of interest

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