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Building Resilient and Robust Food Systems for a Hungry, Growing, and Changing World – Case Study of 2nd Topmost Ranked African Union and European Union Project at the West Africa Centre for Crop Improvement (WACCI)

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Abstract

The world's population is projected to rise from 7.7 billion to 9.7 billion in 2050, with sub-Saharan Africa contributing half of this increase. A growing population signifies an increase in the demand placed on our food and limited natural resources. With the food demand expected to increase by 50% in the next 40 years, there is the urgency to make our food production systems more resilient and sustainable. The COVID-19 pandemic exposed the weak links in our current food systems: unsustainable; the trade-off between efficiency and resilience; highly centralized; increase in malnutrition and obesity; and income disparity. This paper discusses the impact of population growth on our environment, and the challenges in our food systems. We further expound on what the ideal food system is, and how we can transform our current food systems to make them more resilient and sustainable. Creating an ideal food system, able to meet our present and future needs requires sound partnerships between all actors of the food system. This is represented by a case study on the West Africa Centre for Crop Improvement (WACCI) human capacity development programmes geared towards the transformation of Africa's food systems. The "human" aspect is a key element of food systems. In order to build resilient and sustainable food systems, it is critical for human resource to be equipped to learn, adapt, identify problems and implement changes as and when needed. As part of its core objectives, WACCI is dedicated to the capacity building and training of the next generation of scientists that would lead the transformation of the food system, especially in Africa. WACCI has trained so far 105 plant breeders from different countries in Africa and seeks to promote gender equality by advocating for more female scientists to be trained in the field. The role of gender in food security and sustainability cannot be undermined. WACCI is determined to contribute to food and nutrition security in Africa through human resource empowerment and partnerships that can create more resilient and sustainable food systems. Specifically, we highlighted in this article the outputs, outcomes and impact of an African Union – European Union project on "*Crop and Soil Health improvement for sustainable agricultural intensification towards economic transformation in West Africa*" which is the 2nd topmost ranked project in terms of results achieved in innovations, potential for scalability and impact.

Keywords: Global population growth; Food systems; Climate change; Resilience; Sustainability; COVID-19; Food system actors/stakeholders; Sustainable development goals.

1. Introduction

We live in a world that faces political, climatic, economic, social, and environmental instability on a daily basis. These factors have rendered our food systems vulnerable. Climate change, economic depression, rapid population growth, and the recent COVID 19 pandemic are among some of the major stressors of food and nutrition security [1,2]. According to the High Level Panel of Experts on Food Security and Nutrition [HLPE], "a food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes" [15] (p. 5). These elements interact with each other such that, any structural changes imposed on one element affects the other (Hanh Nguyen, 2018). For example, food systems rely heavily on natural resources, however, mismanagement of these non-renewable resources have impacted negatively on our environment, affecting our ability to support upcoming generations. Moreover, the estimated increase in food demand due to increased population growth is expected to aggravate the issue of global environmental degradation, health, and income security of people, posing a risk to our food systems [3,4]. Africa is expected to account for half of the global population growth. Nonetheless, the COVID-19 pandemic has exposed the fact that, the world, especially most African countries, do not have the right structures in place to support the growing population. There is therefore an urgent need for transformation of our global and local food systems [5,6].

Climate change is known to be one of the biggest threats to global food security. However, factors such as poverty, lack of property rights, bad policies, and poor market access leaves most African countries at a greater disadvantage in terms of the impacts of climate change and affect their ability to adapt (Connolly-Boutin & Smit, 2016; Vermeulen et al., 2012). It is projected that Africa would experience about 10-20 % reduction in crop yield due to climate change, which has been linked to higher temperatures, increase in extreme weather occurrences such as drought and flooding, changes in rainfall patterns, among others. Aside that, there is expected reduction in arable land, and changes in growing seasons (Connolly-Boutin & Smit, 2016).

The ability to adapt (learn from past experience and adjust responses accordingly) and transform (create a new system) are both key to achieving resilience (Folke et al., 2010). A resilient food system which maintains the capacity to meet the needs of the population, even in challenging times, must also be sustainable. In other words, it must have the ability to still function efficiently in the distant future [2]. Some actions that can be taken to achieve that include: adopting sustainable agricultural practices; creating resilient food supply chains; biodiversity protection and restoration; promoting inclusiveness; and incorporating artificial intelligence and machine learning into our food systems [3].

Our traditional food systems tend to focus more on increasing production, while overlooking other areas such as value chains and stakeholder involvement, policies, health, and the environment, which are also key to addressing the food and nutrition challenge [7]. Food systems contribute about 19% - 29% of global greenhouse gases of which agriculture contributes up to 86% globally. This has negative implications in light of climate change. To address the problem of failing food systems, governments and policy makers must adopt a food systems approach, whereby the roles of all the actors (farmers, transporters, traders, processors, women, youth, and relevant private and public institutions), and the impact that their activities and interactions have on the system, environment, and society, are considered in the policy making process [1,7].

The objective of this study is to provide an overview of available and relevant literature on population dynamics and its implications on the energy, water and food requirements of the growing population; to highlight the challenges and shortcomings of our current food systems; to give an outline of what the ideal food system should look like; and to suggest the approaches to be used in the successful transformation of our food systems to build a resilient and robust food system, with a focus on Africa. We also discuss the key role of actors of the food system in providing transformation via the creation of strategic partnerships.

2. Materials and Methods

This review employed the use of literature from past and current publications that are relevant to the topic. A review of selected literature such as journal articles, book publications, web pages of institutes, and various published reports from research centres, institutes, organizations, among others, was performed to generate the final review paper. The scope of the research included global food systems and population data, with much emphasis on Africa. Search engines such as Google Scholar. The keywords used to gather data concerning the topic included global population growth, food systems, food systems transformation, climate change, resilience, sustainability, food system actors/stakeholders, sustainable development goals, economic impact of Covid-19, loss of biodiversity, partnerships, diversity, buffers, etc. All data used in the review were searched from different electronic databases such as Scopus, Springer, Science direct, and other online libraries. All in all, forty-four publications were used to develop the final review based on the research objectives. The case study on WACCI and the 2nd topmost ranked African Union – European Union project was presented using information from reports on the project.

Results and Discussions

3. Current population and growth rate of the world and Africa

Since 2019, the world´s population stands at about 7.7 billion. This is projected to increase by 10% (8.5 billion) in the year 2030, and by a whopping 26% (9.7 billion) by 2050 [8]. On the other hand, the world´s population growth rate has been steadily declining at a rate of <1.1% per year since 2015, and this is the expectation for the next foreseeable future [9]. Figure 1 below is a graph showing global population trends (size and growth rate) from 1950 to 2020, and its projections (from 2020 to 2100). Due to factors such as birth fertility, mortality and international migration which affect global population estimates, the ranges are given with a 95% certainty. While the world's population may be growing, the decline in birth rate may mean that the population size could remain in equilibrium by the end of 2100.

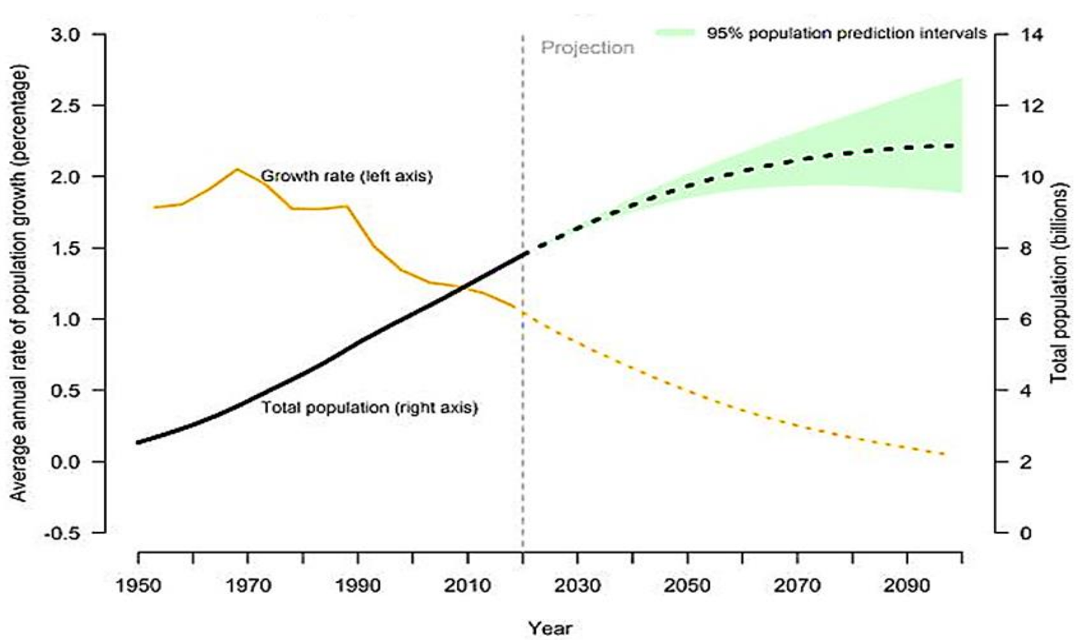

Figure 1. Population size and annual growth rate for the world: estimates, 1950-2020, and medium-variant projection with 95% prediction intervals, 2020-2100. Source: (United Nations Department of Economic and Social Affairs Population Division, 2019b).

Fertility, mortality, migration, and urbanization (especially in developing countries) play determining roles in a country´s population dynamics. High fertility coupled with low death rates, and an upsurge in migration between and within countries (rural to urban) are all factors that increase the population size of a nation (Figure 2) [10,9].

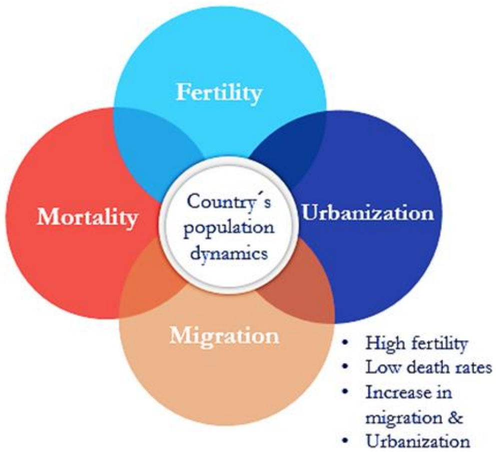

Figure 2. Factors that influence the population dynamics of a country. Source: Adapted from Nyamongo & Shilabukha, 2017; UNDESA, 2019a.

It is believed that the greatest percentage of the world's population growth, about 52%, would be in sub-Saharan Africa. Thus, approximately 1.5 billion people out of the estimated 2.0 billion to be added to the global population by 2050 would be born in sub-Saharan Africa (Figure 3). Meanwhile, the population growth rates for other world regions is likely to increase by 2050 as follows: Oceania (not including Australia/New Zealand) - 56% (19 million), Northern Africa and Western Asia - 46% (237 million), Australia/New Zealand - 28% (38 million), Central and Southern Asia - 25% (505 million), Latin America and the Caribbean - 18%, Eastern and South-Eastern Asia - 3%, and Europe and Northern America - 2% (Figure 3) [8].

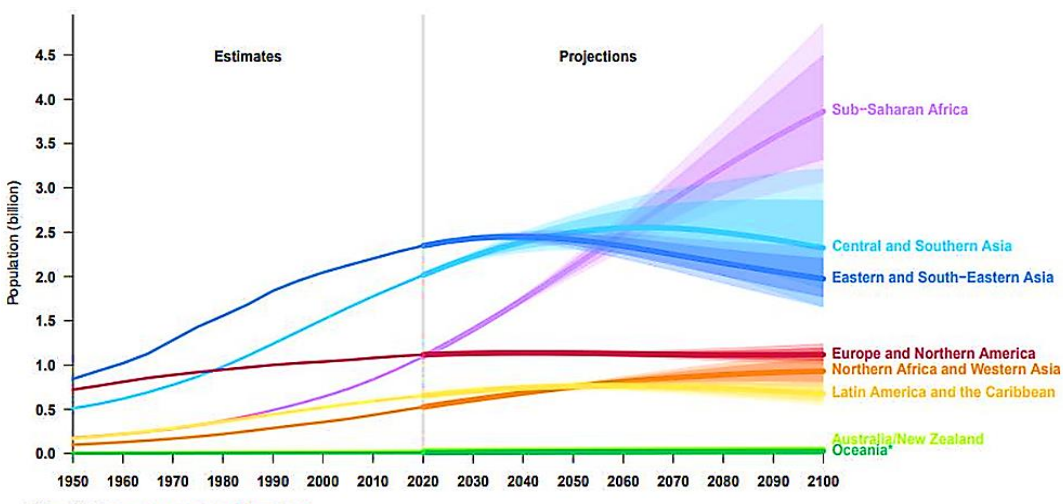

Figure 3. Population by SDG region: estimates (1950-2020), medium-variant projections (2020-2100), with 80% (darker shades) and 95% (lighter shades) prediction intervals. Oceania in this context excludes Australia and New Zealand. Source: (United Nations Department of Economic and Social Affairs Population Division, 2019a).

The demographic data of Africa as at 2016 showed that about 4% of the population were above 65 years, while those under the age of 15 were approximately 41%, implying a predominantly young population [10]. As the fastest growing population in the world, Africa has the greatest demographic potential. Nonetheless, its current developmental course is not likely to support this rapid increase in population and may consequently worsen its state as one of the world's poorest and least-developed continents [6]. It is apparent that most of the world´s poorest countries have the largest growing populations. This poses a great challenge when it comes to fulfilling a number of the SDGs such as SDG 1 (poverty eradication), SDG 2 (zero hunger and malnutrition), SDG 3 (Good health and wellbeing), SDG 4 (quality education) and SDG 5 (gender equality) [6,8]. However, effective predictions of demographic trends in population growth and age structures, and the implementation of good policies are able to reduce poverty, and generate a demographic dividend that can promote economic growth, as was the case for Asia [11]. With the certainty of an increase in the world´s population, especially in sub- Saharan Africa over the coming decades, the need for a global discourse, and the execution of planned actions concerning the resilience and sustainability of the world´s food systems, have never been more pertinent.

4. Energy, Water, and food requirement of the growing population

Man´s ecological footprint is a function of the population size, amount of goods and services consumed per individual, and the environmental effect of the technology used in production. An increase in human population, and the need for improved standards of living imply an increase in per capita consumption, creating intense pressure on the environment. One of the greatest challenges facing humanity now is the capacity to meet the demands of a constantly growing population without destroying the worlds ecosystems (Figure 4) [12].

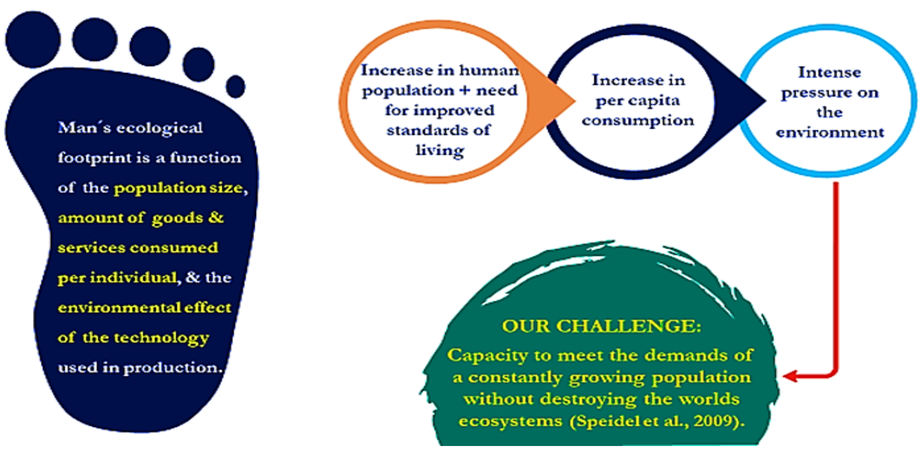

Figure 4. Effect of population growth on the environment and implications for future generations. Source: Adapted from Speidel et al., 2009.

In an attempt to satisfy the rise in demand for food, clean water, fuel, and other resources, human activities have resulted in drastic and rapid changes in the earth´s ecosystem in the past 50 years than in any other period. This is evident when we look at the natural habitats and lands that have been converted to farmlands in the first half of the 20th century as compared to the 18th and mid-19th century combined. Moreover, our forest cover has shrunk about 50% since the pre-agricultural times, while land degradation, desertification, higher temperatures, and drought threaten to reduce crop yields and destroy biodiversity. Aside all that, water pollution and over-fishing threaten the protein source of more than 2.9 billion people who rely on fish as a source of protein [13,12]. Countries with already limited resources and poor policies stand the risk of a declining economy and several social challenges when faced with increased population growth [11]. Africa as a continent is evolving in terms of its demographic, economic, technological, urban and socio-political structure. While these changes are generally creating access to a brighter future for the continent, this is not the case everywhere, nor for everyone [6]. An increase in population is directly related to increased demand for food and water (which partly depends on changing diets). Demand for food is expected to rise to about 50% in the next 40 years [13]. The fact that half of the expected growth in the global population is coming from Africa warrants the need for governments to put in place the right measures to address the anticipated pressures on food, energy, and water resources [11].

Africa´s agriculture sector represents almost 70% of its employment and contributes about 30% to GDP. However, yields have not improved for years, and demand exceeds production, resulting in several countries relying on food imports. Population growth and climate change presents a great challenge to agriculture, which is predominantly rain-fed, about 70%, and subject to erratic precipitation [13,14], (Connolly-Boutin & Smit, 2016). The economic impact of the COVID-19 pandemic has been felt by every country, family, and individual across the globe, though at varying degrees. Africa faces its first recession in half a century after its GDP contracted by 2.1 percent in 2020. It is feared that about 39 million Africans, most being women, may have fallen into extreme poverty as at the end of 2021 if the necessary structures were not put in place [5]. This will further exacerbate the problem of accessibility to food, water, and other important resources.

5. What are food systems?

ur food system is an iceberg that covers more than the distance from field to fork, but also includes activities such as research, plant breeding, food waste management, nutrient recycling, governance, institutions, policies and regulation (Figure 5) [16].

Figure 5. Elements of the food system: from research to waste management.

A sustainable food system is "a system that ensures food security and nutrition for all without compromising the economic, social, and environmental bases of such systems for future generations" [14] (p. 3). Nevertheless, our existing food systems are unsustainable. Most of our food production, distribution and consumption practices are eroding our non-renewable resources and polluting the environment; a large percentage of the world's population are malnourished; urbanization has led to changes in dietary patterns (over-processed, high calorie diets which are low in nutrients), causing an increase in obesity and diet-related chronic diseases; and our food systems are creating disparity in income and wealth, profiting only a minor percentage of the food system actors [14,17,18].

Holden [17], refers to the food we eat as "fossil food" since its production is dependent on the burning of fossil fuel, depletion of non-renewable mineral resources and aquifers, and land degradation. Recent studies show that food production accounts for 19% to 29% of the world´s greenhouse gas emissions [19]. According to the UN's environment programme (UNEP), food systems account for 70% of water taken from nature, 60% of loss in biodiversity and produce almost a third of human greenhouse gas emissions [20]. These pitfalls in our food systems urgently need to be addressed in order to realise a sustainable food system [18]. A food system can be characterized as being local, regional, national, or global. The global food industry contributes about 10% of GDP, and has an $8 trillion worldwide supply chain which provides employment for approximately 1.5 billion people. It therefore goes without saying that any shock to this network would have serious repercussions on the health and socioeconomic wellbeing of all actors involved [21].

Food systems are complex webs of interconnected elements that are propelled by drivers, components and outcomes as portrayed in Figure 6 [16]. They are at the core of human, socioeconomic, and environmental well-being. Acknowledging these interactions help to protect the world's economy from shocks such as climate change and global population growth [22]. Sustainable food systems are essential when it comes to achieving all the Sustainable Development Goals (SDGs), and is therefore at the heart of the United Nations 2030 Agenda for Sustainable Development [15]. However, the COVID-19 pandemic served as a litmus test for exposing the weak links in our food systems. One of the weaknesses in our food systems is that they are highly-centralised, and focus more on efficiency rather than resilience. This is evident in the increase in number of people suffering from starvation or malnutrition after the pandemic, suggesting that our food supply chains are subject to external threats such as natural disasters and economic stresses [23,2].

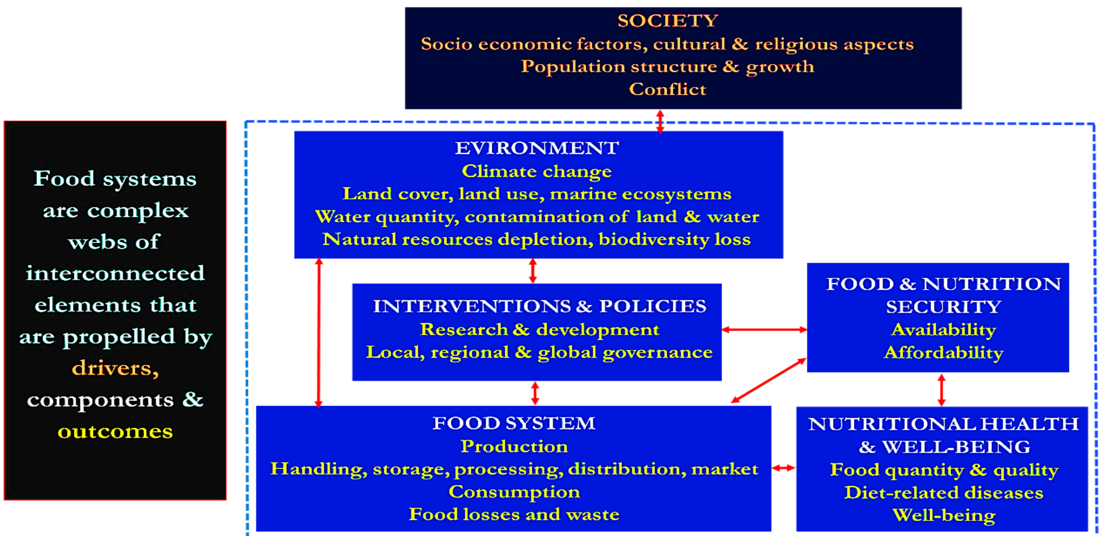

Figure 6. The food system web. Source: Glover & Sumberg, 2020; Lindgren et al., 2018

The amount of food produced globally is able to feed the entire population. Nonetheless, several families face challenges when it comes to feeding their household. The World Food Programme's world hunger map suggests that about 1 in 10 people go hungry, while 1 in 3 are malnourished [24]. After the negative impact of COVID on the global economy, transforming our food system should be the primary concern of all policy makers, with the aim of restoring our economies and realising the SDGs at the national and international level [25]. Figure 7 gives a summary of the challenges faced in our food systems.

Figure 7. The current state of our food systems.

6. Approaches for food systems transformation

Transformability is defined as "the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable" [26] (p. 3). Providing the growing population with equal access to food while ensuring environmental safety and socioeconomic health calls for innovation, experimentation and transformation in our food systems. Specialization and efficiency comes at the cost of low resilience, despite the increase in food production. Characteristics such as diversity in crops produced, flexibility in supply chains, and landscape multi-functionality are all necessary for stability in the global food system [25,23].

The following are approaches that can be adopted for food systems transformation:

- ***Adopting sustainable agricultural practices:*** We need to make industrial agriculture more sustainable and inclusive while merging it with a more streamlined traditional food system, by diversifying our food production and consumption [14]. Vertical farming is a good example of sustainable agriculture that requires less labour and energy, thereby leaving a smaller environmental footprint as compared to conventional farming [22].
- ***Make dietary changes:*** Emphasis should be placed on healthy and nutritious diets, such as meals with less animal protein and more plant-based foods. This would help reduce the greenhouse gas emissions, water and land use, and decrease the chances of diet-related health problems [28]. Some scientists have started researching on substituting animal proteins for non-animal alternatives, such as those derived from plants, insects, seaweeds, or cellular agriculture. A few companies that have successfully released such animal protein-substitutes include Impossible Foods, Beyond Meat, and Just [22].
- ***Create resilient food supply chains:*** This can be achieved by decentralising the supply chain, diversifying farms and agricultural lands, and upgrading the rural sector (empowering small producers and retailers and involving them in the food system economy to create healthy competition). A flexible supply chain (regional and international) serves as a buffer against any form of shock to the system and enhances the availability and consumption of diverse foods needed for a healthy diet [25,28,29].
- ***Cut down on food waste and loss:*** About 40% of the food we produce for consumption is wasted or lost. We need to modify our storage, transport, and retail supply chains to curb the amount of food lost before reaching our plates [30].
- ***Biodiversity protection and restoration:*** Protecting our environment and natural resources should be a major concern for all. Technological and ecological tools can be adopted to promote soil and water conservation practices by producers, processors and consumers in the food chain [30].
- ***Incorporating artificial intelligence (AI) and machine learning technologies into our food systems:*** AI-based technology such as drones and automated machines, can be used to enhance

crop production, augment human labour, and improve real-time monitoring, harvesting, processing and marketing [31,32].

- ***Strengthening infrastructure:*** For most African countries, the recent pandemic exposed the sorry state of their infrastructure and policies. Building basic infrastructure (roads, markets, storage facilities, processing factories…) and adopting good policies is one of the key pillars to ensuring a thriving food system [30].
- ***Embracing new market avenues such as E-Commerce:*** Another lesson from COVID is that online marketing and delivery services are beneficial tools for transforming our food system into a more resilient one. It also creates the opportunity for small holder farmers to generate a market base for their produce when the local markets are locked up [33].
- ***Promote inclusiveness:*** For a holistic food systems transformation, there is the need for governments to embrace inclusive and participatory approaches that empower consumers, farmers (small-scale), and women [18]. For instance, an integrated gender approach is necessary for designing policies and innovative responses that take into account the influence of gender in small-scale agriculture, and other sectors of the food system [34]. Also, a bottom-up approach creates the opportunity for "development initiatives to fit into the local context, and responds to the needs of the people, instead of forcing into application foreign values and approaches, which can result in harmful unintended consequences" [29]. Another approach is to create platforms for the transfer of knowledge among several actors [35].

7. The ideal food system

The ideal food system should be both sustainable and resilient. Food systems should be able to meet today´s needs without compromising the capacity to satisfy tomorrow´s needs. Concurrently, they should have the ability to continue meeting the population´s needs in the face of adverse situations and shocks [2]. This is echoed in the Economic Community of West Africa Agricultural Policy (ECOWAP) 2015-2025 vision for the next ten years on sustainable food systems in West Africa, which is, to develop "a modern agro-sylvo-pastoral and fisheries sector that is competitive, inclusive and sustainable, guaranteeing decent jobs, food security and nutrition, and food sovereignty" [14] (p. 12). Some of the characteristics of an ideal food system that supports food security include:

Robustness/Resilience: It must flourish despite challenges, climate change and other shocks that may threaten to breakdown the system or cause food insecurity [2].

Flexibility: It must be flexible in size and scale. That is, support several forms of food production, distribution, marketing, consumption, disposal and transformation practices at diverse scales (local, regional, national and global). This will help it recover from any loss in food security [2].

Resourcefulness and adaptability: It should have the ability to manage risk and adapt to change when needed to quickly recover from the impact of shocks [2].

Promotes health: It should support the physical and mental wellbeing of all actors (from farmers to consumers) in the system and consider the health impacts across the food system chain (from production to waste management) [36].

Sustainable: It must protect and restore the environment and natural resources. The ability to meet the needs of future generations must not be compromised while trying to meet today's needs [36].

Diverse: It should take into account the geographic differences in natural resources, climate, and traditions; Acknowledge and supports several cultures, socio-demographics, and lifestyles; and Provide consumers with a variety of healthy food choices [36].

Equitable: It must promote fairness in conditions and economic opportunities among all actors (including women), and equal access to resources and healthy food and lifestyle [36].

Transparent: Information on activities carried out in the food system must be easily accessible to the actors of the food system, and they must be encouraged to actively join in discourse and in decision making in all areas of the system [36].

8. Partnerships needed to achieve transformation in our food systems

One of the characteristics of a sustainable and resilient food system is inclusiveness. It guarantees the economic and social inclusion of all food system actors. Inclusive and sustainable food systems are rooted in partnerships that promote fairness, diversity and unity. These partnerships may be between public, civic and private agents, and also between private sector producers and industries [14].

Food system actors include all individuals, groups and organisations that are connected to food supply chain such as: farmers, retailers, processors, consumers, groups, organisations, governments, NGO's, and universities/research institutes (Figure 8). Their interactions shape, and adjust the food system. Knowing who the actors are, how and why they interact, gives a better understanding of the system, and the partnerships needed to achieve the ideal food system. Food system actors must partner to create a more locally based, and self-reliant food economy [37].

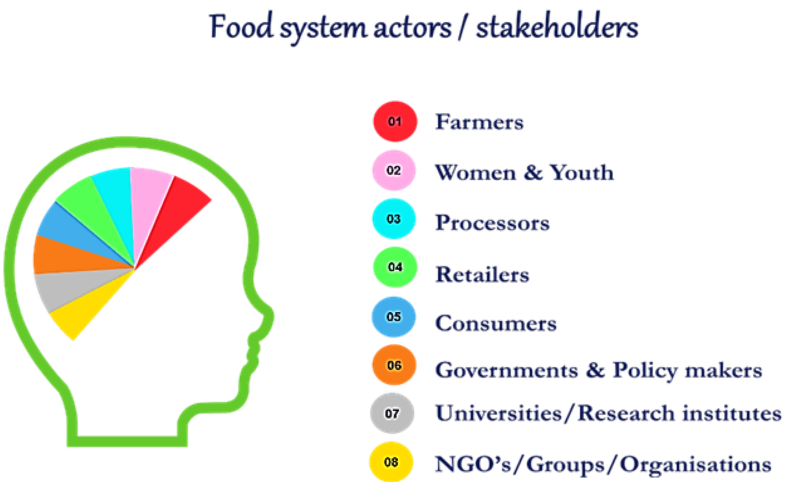

Figure 8. The various actors of the food system.

To form effective partnerships, project members should:

a) Know which sector of the food system each partner is directly linked to create a balance and to cover all areas in the food chain. It is important to include at least one Public institution, University, and Local organisations involved in various stages of the food chain.
b) Identify organisations that are authorised to carry out projects and/or implement policies.
c) Know in which capacity each partner is able to serve or operate (expertise, resource etc.), that would satisfy the needs of the project [38].

Some key roles food system actors play includes:

Women: Women are key to realising all of the SDGs, however, a large percentage of the world´s poorest people are women [39]. That is why promoting gender equality in development policies will have a huge impact on the economy. An example is, "if women farmers were given the same access to resources (such as finance and land), women's agricultural yields could increase by 20 to 30 percent; national agricultural production could rise by 2.5 to 4 percent; and the number of malnourished people could be reduced by 12 to 17 percent" [40]. Aside that, women in sub-Saharan Africa play major roles in both informal and formal stages of the food value chains, as producers, processors, traders and consumers [34]. Women should therefore, be included in the food systems discourse, and given key roles to play in the transformation of our food systems. Empowering women will help make the process of building resilient food systems successful [29]. Farmers and fishermen: A large percentage of agriculture in developing countries is dominated by small-scale farmers and fishermen. About 56% of agricultural production is carried out on small farms, and roughly 120 million people rely on fisheries-related activities. Nonetheless, majority of smallholders remain poor and unable to increase their productivity. They face numerous challenges such as inadequate infrastructure, poor access to technology, knowledge, capital, quality seeds, good markets etc. As major actors in the food system chain, smallholders need the right assistance to help them increase productivity per unit land area without destroying their environment [41].

Youth: The youth is currently the largest demographic, and mostly concentrated in low and middle-income countries. They are the ones to face the greater effect of environmental and climate change which are likely to accelerate and intensify during their lifetimes and those of their children [16]. With the majority of sub-Saharan Africa's population being young, governments will have to invest greatly in education, healthcare, skills development, and the creation of jobs for the growing future working population. Refusal to do this will increase the risk of social and political instability. Countries with a large working force are likely to have higher demographic dividend that can bolster productivity and economic growth [6].

Consumers: Consumers, the last target group in the food chain, help mould food production through their purchasing choices (which is greatly dependent on the food available, income and the food environment). In developing countries, the growing middle class are key influencers when it comes to changes in dietary patters [41]. Consumer awareness must be created on sustainable food consumption. Western-oriented diets that encourage increased intake of meat, and over-processed foods that are high in calories and consume much resources, add to the stress on food systems. Policy makers can subsidise healthy foods and tax unhealthy ones, while promoting educational programmes and healthcare systems that encourage better diets [41].

Government and Policy makers: Governments should invest in agricultural transformation as it is the foundation of many African economies. This would help such countries achieve food security, build sustainable food systems, transform their economies, alleviate poverty and integrate into the global economy [14]. Policy makers need to design strategies that tackle major agricultural and developmental issues in a holistic manner. Innovative programmes must be developed to reinforce the relationship between agriculture, infrastructure and finance and to foster agricultural value chains and markets at regional, national and international levels [14].

Food companies, food service and retail: large, mid-sized and small food companies and retailers make up the largest economic sector in many regions such as the European Union. The activities of food companies, retailers, restaurants, and food vendors shape the food environment and ultimately the consumer`s choices. To increase profit and reduce cost, food companies have resorted to ultra-processed foods, which are often rich in sugars, fat and salt, and lead to poor health conditions. This food environment needs to be changed to promote healthier diets and reduce food waste [41].

Non-governmental and other civil society actors: Non-Governmental Organisations (NGOs) and other civil society groups play active roles that fashion our food systems and protect our natural resources at regional, national and international levels. These include reinforcing the role of smallholders and women in the food systems, advocating for socioeconomic wellbeing, and promoting human and environmental health. In addition, NGOs can help shape public policy and opinion, and influence the behaviour of companies (especially multinationals) [41].

Examples of partnerships that promote food systems transformation include:

- Partnerships between private organizations/companies and educational/research institutions to develop scientific and technological innovations to support the agricultural and food industry [18].
- Farmers can test agro-ecology and alternative agricultural practices by integrating traditional knowledge, shared knowledge, technological and scientific innovation [18].

- International trade negotiations must engage various stakeholders (including women & the youth) in discourse and policy making. They should also emphasise local and rural agricultural practices [18].
- Government and policy makers must include all actors in the food industry (including women and the youth) in policy development [18].
- Partnerships between organizations and educational institutions to create platforms for educating farmers on adopting modern and unconventional food production practices such as Community supported agriculture (CSA) and community gardens; and for educating consumers on healthy alternative food practices [18].
- Governments and policy makers can acknowledge and promote traditional and indigenous knowledge, and sustainable innovation in food systems [18].
- Figure 9 gives a summary of the kinds of partnerships that can be established to bring about transformation of our food systems.

Figure 9. Partnerships that facilitate transformation of the food systems. Source: Adapted from Weber et al., 2020.

Partnerships for transformation – A case Study:
Capacity Development and Research Programmes for Food Security in Africa: The case of an African Union – European Union funded Project at the West Africa Centre for Crop Improvement (WACCI), University of Ghana.

WACCI's human capacity development for food systems transformation.
WACCI was established on the foundation of a partnership between the University of Ghana (Ghana) and Cornell University (USA) in June 2007, with support from the Alliance for a Green Revolution in Africa (AGRA). The centre was mandated to train plant breeders in Africa to work on improving African crops in their communities for farmers in Africa [42]. Plant breeding programmes are needed to utilise all available tools to address the problems of African agriculture and food security. However, a major limitation to plant breeding in sub-Saharan Africa is that most of Africa's indigenous crops such as sorghum, millet, cassava, yam, plantain, cocoyam, taro, bambara, groundnut and cowpea are of little or no importance to researchers in the developed world and so have been research-neglected and underdeveloped (therefore called ‘‘orphan crops’’).

It is against this background, and in view of the existing need to train plant breeders in West and Central Africa, that WACCI was established at the University of Ghana, to be a parallel Centre to the African Centre for Crop Improvement (ACCI), a regional Centre located at the University of Kwazulu-Natal, South Africa that trains African plant breeders on African crops in Africa. The establishment of WACCI is important because the West and Central African sub-region remains critically short of plant breeders and most of the crops grown in the region are staple crops in many African countries and remain relatively unimproved.
The ultimate goal of WACCI is to improve food security and build resilience in the food systems in West and Central Africa through human and institutional capacity development. The approach is to equip plant breeders with the knowledge and skills to develop superior varieties of indigenous crops, using both conventional and modern technologies. The overall aim of WACCI is to train the next generation of West and Central African plant breeders in an African university, to breed crops in national agricultural research stations for production systems in the two sub-regions. The specific objectives are to:

1. significantly improve the quality of PhD level training in plant breeding offered to students from universities in West and Central Africa.
2. create opportunities to develop improved local varieties of the staples grown by smallholders in the sub-regions, using the advances in plant breeding science and molecular biology, and informed by farmers' stated preference.
3. provide the necessary skills to direct and manage local plant breeding programmes to meet local needs, and to respond to indigenous demands.
4. develop breeding techniques appropriate to address some of the unique breeding/crop improvement objectives for the sub-regions.
5. create a de facto network of functioning plant breeders and their local co-supervisors from the sub-regions.

WACCI has enrolled 160 PhD students including 58 females since its establishment and has graduated 105 PhDs students (36 females) that are championing breeding programmes in their respective home countries. Recognizing the need for a strong and vibrant seed industry, WACCI under the World Bank programme launched the Mphil Seed Science and Technology (SST) programme and has since enrolled 90 Mphil students (29 females) and graduated 40 (15 females).

The PhD graduates of WACCI are leading breeding programmes in National Agricultural Research Institutes in their home countries. Some of the graduates are Directors, Deputy Directors and Coordinators of national research programmes in their home countries whilst others are lecturers in various Universities. Over sixty million dollars has been attracted by the alumni to their respective institutions in the form of grants, thereby highlighting the fact that investments in human capacity development translates to institutional development and greater impact. These funds are being utilized for cutting edge research for improving staple crops in Africa in order to transform agriculture and build resilience in food systems. This is possible because of the innovative curriculum and modules that teach WACCI students to use cutting edge genomics, quantitative genetic methods and biotechnologies appropriate in crop improvement based on sound value chain analysis and food systems thinking. More than 259 publications have been produced by the 105 graduates so far. More importantly, the WACCI graduates have in total developed 279 improved varieties of staple crops on the African continent in their respective countries. They have developed improved varieties of rice, sweet potato, maize, cassava, taro, sorghum, soybean, cowpea, groundnut and pearl millet. These varieties are suited to African soil and weather conditions thus, increasing Africa's food production to feed itself.

WACCI's Transformation of African Food Systems
WACCI has started a number of programmes and created partnerships with key stakeholders in the food and agricultural industry. Examples are its maize, legume and tomato improvement programmes. These programmes have several project activities which bring together food system actors from different sectors: Researchers (Plant breeders and geneticists, Biometricians, Agronomists, food scientists, Horticulturists, Plant biologists, etc.); Institutions (National Institute of Agricultural Botany (NIAB), University of Illinois

Urbana-Champaign (UIUC); Soybean Innovation Lab (SIL)); Organisations [AGRA, African Union (AU), European Union (EU), United States Agency for International Development (USAID), Syngenta Foundation for Sustainable Agriculture]; Farmers; Processors; Transporters; Bankers; Policy Makers and many others. WACCI organised a series of value chain workshops on the "Sustainable Intensification of Cowpea and Maize production for value chain development in Ghana" in 2019. The aim was to create a platform where farmers and other actors along the cowpea/maize value chain (stakeholders) involved in the breeding, production, processing, and marketing of cowpea, could interact with each other. During the workshops, pertinent issues such as farmer and consumer trait preferences, challenges faced by farmers, among others were discussed. It was concluded that there was the need for a 5 to10-year cowpea development plan between the private sector and government for cowpea improvement. As a result, maize and cowpea breeding programmes have been initiated to address the challenges identified. Also, policy briefs have been developed with key recommendations to government.

African Union – European Union funded Project at WACCI titled: *"Crop and Soil Health Improvement for Sustainable Agricultural Intensification towards Economic Transformation in West Africa"*

This project aimed to address issues related to the food security objectives of the African Union research initiatives through sustainable crop production intensification and the delivery of research outputs for direct yield improvements on-farm. The challenge addressed through this initiative was to empower and support African farmers to increase farm yields of key food security crops. Farmers were trained through participatory approaches such as farmer field schools, value chain workshops and exposure to the use of superior germplasm/improved seeds that are adaptable to the changing climates, tolerant to abiotic stresses with resistance to prevailing pests and diseases. The need to empower resource-poor farmers across the continent also required the development of resources necessary for breeding efficiency through effective genetic resource management, pre-breeding, and mapping and introgression of genes of agronomic importance into farmer preferred varieties as well as other supporting activities.

The African Union – European Union project implementation commenced in January 2018 and ended in February 2022. 99% of planned activities in this project were carried out in the respective target countries i.e., Ghana, Burkina Faso, and Nigeria. A total of about 116 farmer field schools (FFS) were conducted across 40 sites where the demonstration trials were established. About 3,938 (2,950 males and 998 females) farmers have been trained under the FFS programme with about 244 Agricultural Extension Agents (AEAs) engaged to facilitate knowledge sharing at FFS. 1,179 value chain actors have been engaged in value chain workshops organised on Cowpea, Maize, Tomato and Rice in the target countries. As part of the implementation of Farmer Field Schools training programmes, baseline studies were organised in Nigeria for selected Tomato farmers, Burkina Faso (Rice farmers) and Ghana (Maize and Rice farmers). These farmers targeted under the baseline studies were involved in the on-field farmer field schools training programmes across the various project sites. Key challenges identified for necessary interventions were formulated and implemented. All research activities on Maize, Rice and Cowpea under the project were conducted and deliverables were achieved. This project has led to the development of several new research programmes such as the Maize improvement for resistance to the Fall Army Worms through gamma rays mediated mutagenesis and screening in Ghana for farmers in the West African subregion and for the SSA in general.

Breeding and Release of Climate Smart Tomato Varieties in Nigeria

The devastation of crops due to pests has been felt strongly in Nigeria, a country that grows about 1.5 million tonnes of tomatoes every year, making it the 14th biggest producer in the world. However, the incidence of Tuta absoluta for the first time in Nigeria happened so suddenly when Nigeria was least ready to efficiently curtail the devastation. The damage was so devastating that farmers nick-named it "tomato ebola". Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) is a very harmful leaf-mining moth with a strong preference for tomatoes (Lycopersicon esculentum Mill.). It occurs on eggplants, sweet peppers as well as potatoes and various other cultivated plants. It also occurs on weeds of the Solanaceae family (Solanum nigrum, Datura spp.). The larvae damage the leaves creating perforations in the form of galleries since they feed on mesophyll tissues. New shoots, flowers and fruits are also attacked. Damage can reach up to 100 percent and occurs throughout the entire growing cycle of tomatoes. Under this project, the first of its kind ground-breaking research has been conducted leading to the development of lines resistant to the tomato ebola pest in Nigeria. Four lines were found to be resistant to the pest. These four lines are wild tomato genotypes that have not been domesticated and adapted to cultivation. Hence there are many unwanted traits like small fruit sizes and shape which needs further breeding to improve for acceptability by the farmers. Four other tomato lines from NIHORT collection were evaluated and showed moderate tolerance to the tomato ebola pest and these lines will be advanced for release and commercialization to help curb the losses due to the pest. Preliminary yield trials and multi-locational trials of the selected tomato varieties will be carried out. Through this project, these tomato lines have been nominated for the release and registration of the first indigenously bred tomato varieties in Nigeria.

Breeding and Release of Climate Smart Maize Varieties in Ghana

Crop health management is a key factor that can limit the productivity of staple crops and sustainable intensification efforts which is one of the key priority areas for this project. Pests and disease management is an essential step in the improvement of crop health management. In Ghana where the WACCI has developed and released maize hybrids yielding 11 – 13 tons/ha, there is a recent attack by Maize Streak Virus diseases. This disease has devastated some of the farms in the region and farmers have complained bitterly about the outbreak of these diseases. These outbreaks have affected breeding activities and demonstrated the need for urgent action in breeding tolerant varieties for release to farmers in target countries to ensure sustainability. MSVD is caused by MSV, a member of the genus Mastrevirus, family Geminiviridae. Transmission of the virus is by several species of leafhoppers in the genus Cicadulina (Homoptera: Cicadellidae). MSVD can cause yield loss of up to 100%. The diversity of vectors that can transmit MSVD poses challenges for the screening and identification of resistant lines. At least 11 major MSV strains (MSV-A to MSV-K) have been identified. MSV-A causes important economic damage. The MSV-A strain has 5 strain variants (MSV-A1, MSV-A2, MSV-A3, MSV-A4 and MSV-A6) occupying different geographical ranges. MSV-A1 and MSV-A4 have been found to be responsible for more than 95% of all MSVD. MSV-A1 (most wide-ranging strain) in all sub-Saharan African regions. Phylogenetic strains isolated from various agro-ecological zones in Ghana showed that they belong to the highly virulent MSV-A1 subtype [Oppong et al. 2014]. Under this project 40 lines: including 15 from IITA, 4 from IRAD, and 21 from CIMMYT were screened for MSVD resistance and CML 202, a known MSV resistant inbred line was used as a check. Out of the 40 lines, 19 of them were found to be MSVD resistant and eight lines had more favourable alleles than the resistant check CML 202. In total fourteen lines were also identified to be tolerant to MSVD and six were susceptible.

Breeding and Release of Climate Smart Rice Varieties in Ghana

Rice is the number one source of calories in West Africa. The consumption of rice is increasing faster than any other crop in the region due to rapid urbanisation and changing diets. However, there is a huge gap between the demand for rice and the volumes produced in the region resulting in a massive import bill. Currently, the annual consumption of rice in Ghana amounts to 749,000 metric tons (milled rice) of which about 45% is imported (SRID-MoFA, 2014). A similar situation applies in Burkina Faso where 50% of the rice consumed is also imported. There is therefore the need to increase rice production in the two countries in order to achieve self-sufficiency and save the millions of scarce foreign exchange spent on rice imports every year. The reduction in imports of rice due to increased production will enable these countries to save foreign currency and use available funds for other developmental projects. Even though Breeders have developed rice varieties with an average yield of 6 MT per hectare, yields on farmers' fields range from about 1.5 – 4.5 MT. The huge yield gap is due to the poor agronomic practices adopted by farmers as well as abiotic and biotic stresses in the environment that affects the stability of the varieties. This is further aggravated by climate change with its attendant effects of high temperatures, erratic rainfalls, long periods of drought, sporadic floods, and the emergence of new diseases and pests. Under this project 8 rice lines: 3

from CSIR-CRI, Ghana and 5 from INERA, Burkina Faso were screened for yield across 7 environments in Ghana with two checks: one regional check from Africa rice and one national check from Ghana. Four rice lines were identified as high yielding with climate-smart attributes. These lines will be further evaluated for release and commercialization.

Breeding and Release of Climate Smart Rice Varieties in Burkina Faso

Production of breeder seed to meet the demand of foundation and certified seeds within the framework of this project in Burkina Faso, particular emphasis has been placed on the maintenance and continued production of first-generation rice seeds. The aim is to ensure better availability and accessibility of improved rice seeds by smallholder farmers in real-time. The contribution of this project has enabled the INERA/CREAF Kamboinsin rice breeding team in Burkina Faso to ensure the maintenance (in vivo) in the greenhouse and seed multiplication of six commonly cultivated rice varieties that are preferred by farmers and consumers (FKR62N, FKR64 (TS2), FKR60N, FKR56N, ORYLUX6 and FKR19). In 2019, four newly released varieties (KBR2, KBR4, KBR6 and KBR8) have been added to the programme aimed at producing breeder seeds to meet the demand for foundation and certified seeds. More than one hundred (100) kg of breeding seed (G1) and five hundred (500) kg of breeding seed (G2-G3) are produced annually at the Kamboinse research station.

Breeding Fall Armyworm Resistant Maize in Ghana and Human Capacity Development

Fall armyworm (FAW) was first reported in Africa in 2016 and has now spread throughout the continent. It has become a major economic pest of maize that can cause more than 50% yield reduction due to the defoliation of leaf area reduction limiting photosynthesis. Almost all varieties of maize on the market are susceptible to the damage of FAW. There was therefore the need to generate resistant germplasm from which resistant varieties can be developed. Realising the need for the development of resistant varieties to FAW, the WACCI Maize breeding programme requested permission from the Principal Investigator to reallocate funds meant for Maize Lethal Necrosis resistance breeding to the FAW resistance breeding programme. The gamma irradiation technique was therefore employed to generate putative mutants that have been screened under heavy infestation of FAW. Three maize inbred lines: 1368, 9006 and TZMI 760 were exposed to 150gy, 200gy and 250gy radiation dosages using cobalt 60 as a mutagen. Radiation was conducted at the Radiation Technology Centre of the Ghana Atomic Energy Commission (GAEC). Irradiated seeds were planted and selfed to generate M_2 seeds. The M_2 seeds were planted in an augmented design and each healthy-looking plant was inoculated with seven FAW larvae whilst those showing some damage were inoculated with three larvae and those showing extensive damage were not inoculated (advice from entomologist). A rating scale of 1-9 (Davis and Williams, 1992) was used to score for maize FAW resistance. Plants that scored 1, 2 or 3 and 4 were assumed to be putatively resistant, moderately resistant and tolerant respectively. Selected plants (rating 1, 2, 3 and 4) were selfed and M_3 seeds planted and again selfed to generate M_4 seeds. Out of the 2,376 mutant kernels from the three irradiated maize inbred lines, only twenty-four (24) plants expressed resistance to FAW, while 42 plants expressed moderate resistance and 33 plants were tolerant to the FAW. Most of the other traits expressed were undesirable agronomic traits except that of increased plant height in maize line TZMI 760 at all levels of irradiation compared to its control. The study identified one exceptional mutant, 1368_200Gy (34), which had seven exceptionally clean resistant plants to FAW and another, TZMI 760_200Gy (13) which had a total of 26 plants and all these plants stood through to harvest. The Maize line TZMI 760 at all levels of radiation especially at 150Gy and 200Gy was identified to have the best agronomic traits such as uniformity within an entry, good cob appeal, and very good plant architecture. The identified resistant lines with desirable agronomic traits would be tested for combining the ability to generate resistant hybrids to FAW for release to farmers. This will reduce the need for the abusive use of insecticides and toxic chemicals in an attempt to control the FAW pests. Genotyping of the maize mutants using next-generation sequencing platforms established under this project for cowpea research will be carried out after the project ends to support the discovery of the locations of the mutations in the maize genome that is conferring the FAW resistance.

Cowpea Research for Higher and Drought Tolerant Varieties

Under the AU-EU project a reverse genetics platform was established and used for screening alleles of agronomic importance and investigating gene functions by focusing on the genes controlling the number of seeds per pod. The platform was used to screen the TCP5 gene involved in the development of the ovule, which is the main determinant of the number of seeds per pod in cowpea. The seeds per pod are determined by the number of fertile ovules per ovary, that develop into seeds and are regulated by abortion. The TCP5 genes originated from the early evolutionary establishment of the different plant families, where it plays a pivotal role in the control of the morphogenesis of shoot organs. TCP5 is positively charged, serine-rich and has a relatively short half-life. Protein functional motifs identified include N-glycosylation site, Casein kinase II phosphorylation sites, Protein kinase C phosphorylation sites, N-myristoylation sites, Allatostatin, a Serine-rich region and residue repeats. Changes and deficiencies in these motifs result in a corresponding change in the biological function(s) of the protein. One putative mutant from a collection of 727 M_2 mutant families was obtained and was non-synonymous. SIFT analysis predicted the mutation (N234S) to be intolerant. Vegetative stage screens of the putative mutant M_2 family line revealed an intermediate growth habit compared to the semi-prostrate growth habit of the control. Subsequent screens of the reproductive phenotypes revealed early flowering, longer pods, more locules per pod and a greater number of seeds per pod in the putative mutant family than in the wild type. The mutants generated from the present study have a potential for food and non-food applications and are an ideal resource of breeding material for developing novel traits in this species.

About 400 M_3 mutants including top-performing lines have been selected, characterised and advanced to the M_4 generation where they will be further characterised for morpho-agronomic traits and the stability as well as the heritability of the traits discovered at the first two preceding generations. Most of the agronomic traits discovered at the M_1 and M_2 have been confirmed for their stability in the M_3 generation.

New Projects as a Result of the AU-EU Project

As a result of the successful implementation of the AU-EU project, key outputs and outcomes have attracted a number of donors and partner organisations to increase support towards the initial project objectives. A number of newly funded projects and other projects that may attract funding are presented here:

- WACCI has won a project grant of Fifty Thousand Euros (€ 50,000) from the International Atomic Energy Agency's (IAEA) to participate in the Coordinated Research Projects (CRPs) titled "Radiation-induced crop diversity and genetic associations for accelerating variety development". The 5-year project is on "Mapping of Genetic Associations of Number of Pods Per Plant and Number of Seeds Per Pod in Cowpea". The funds are meant to support research work at WACCI for the development of improved varieties of Cowpea for higher yields.
- Maize mutagenized (gamma irradiated) population developed under the project has generated about 30 fall army worm resistant inbred lines. These will be tested in combination with other maize inbreds to generate hybrids that will be higher yielding. This mutant population is a resource for more research into other areas or the discovery of new traits of agronomic importance. EMS mutants developed for maize need to be characterised. Pre-breedingplatformsestablishedtodevelopnutritiousandclimate-resilientvarieties will be sustained by rendering commercial services to researchers in West Africa.
- Through the value chain workshops, Banks and creditors are only willing to fund commercial crops such as cassava, maize, rice etc and not Cowpea. They intimated that Cowpea requires new products to create the needed demand for increased production and assurance of demand and contract-based farming leading to consistent cash flow, a prerequisite for loans. Therefore, WACCI dedicated seed monies at WACCI to initiate a series of food products development for Cowpea to increase the demand for the product, create a new industry based on the processing and new value addition methods. In these new initiatives, we have developed SHITOR which is a food product based on Cowpea for spicy pepper products that can be packaged and marketed. This initiative is aimed at attracting bankers and financiers into supporting farmers to scale up Cowpea production. New

research is required to validate commercial viability and support the creation of start-ups to take the innovations to markets.

- The maize hybrids developed by WACCI that are yielding 10 tons averagely need to be scaled up to reach more farmers. Many more outputs can be scaled out into national programmes for greater impact.
- NewKersting'sgroundnutbreedingprogrammesinitiatedinGhana.
- Also, the sequencing platform established will create opportunities for many more projects.

Lessons learned, how they are utilised and disseminated by WACCI and partners

The following are key lessons learned during this project:

Farmer field schools have created awareness on improved varieties in communities across Ghana, Burkina Faso, and Nigeria. There is therefore the need to scale up activities under the farmer training programmes. Scaling up will be achieved through sustained action and support by donors, governments, and other interested partners.

Theneedforupscalingfarmerfieldschoolstrainingprogrammesrequirestheshowcase of impact of AU-EU/WACCI Farmer field schools to key stakeholders including donors, governments, private sector actors etc. WACCI will conduct an impact assessment of the project and showcase this to governments and private sector actors for further support.

PrivatesectorinvestmentsarecriticallyneededinAfricanagriculture.Inordertoattract private sector investments for research, WACCI and partners must showcase products and innovations to the private sector. WACCI will conduct an impact assessment of the project and showcase this to governments and private sector actors for further support.

African agriculture remains primitive and needs modernization urgently if we are to meet the United Nations Sustainable Development Goals. This can be achieved through increased adoption of innovative technologies, improved seeds, good agronomic practices, appropriate scale mechanisation and engineering to meet local needs of smallholder farmers. WACCI will lead efforts to create the needed awareness for stakeholder action to transform our agriculture and this has continuously been done through advocacy.

Through value chain workshops, WACCI and partners learned that the research- extension-farmer-market linkages across the target countries and crops were very weak and needed to be strengthened continuously. Consultative engagements on each crop value chain must be conducted at least once a year. Policy briefs that have been developed are being disseminated to key stakeholders via our website and direct contacts.

There is the need to improve seed systems (including: the certification, quality seed, capacity building for seed industry players, timely availability of seeds to meet the rains, affordability, and accessibility of certified seeds) for agricultural transformation in Africa. Awareness is being created on these issues through stakeholder engagements.

7. Urgent need to improve land tenure system (ownership rights) to promote investment in the agricultural sector. Awareness is being created on these issues through stakeholder engagements.

8. There is the need to develop and enforce market standards for trading rice, tomato, cowpea, and maize in our local markets. This will be communicated to the right authorities (National Standards Boards).

9. Access to agricultural finance for value chain actors must be expanded, guaranteed, and well insured for increased production of target crops. Awareness is being created on these issues through stakeholder engagements.

10.In order to accelerate the dissemination of the newly released rice varieties in Burkina Faso, the seeds were distributed in the form of mini kits to 1000 farmers in 15 localities of the country. Bagré (476), Bama (65), Banzon (60), Bingo-Kaligrafi (35), Bingo- Sapelo (33), Dano (30), Di (35), Douna (35), Karfiguela (30), Korsimoro (45), Koubri (45), Mogtédo (30), Niassan (34), Temnaoré (45), Ndorola (40).

9. Road maps to realising the ideal food system

The realisation of resilience is dependent on the ability of food systems to anticipate, prevent, absorb, and adapt to the impacts of shocks and stressors. The complex nature of the relationships (natural, political, economic, social and cultural) within the system makes it a challenging task to achieve [25]. However, listed below are steps that can be taken to help build a resilient and sustainable food system:

Ensuring human agency: Human agency refers to the ability of people to decide on a course of action and implement it. This is crucial in determining how individuals and societies respond to changes, disruptions and crises. Human agency moves humanity from playing the role of passive victims to drivers/actors of change/adaptation. We are able to adapt, learn, anticipate and prevent. Human agency is at the core of resilient food systems [25]. Some areas where human agency can be applied are employing risk management strategies and restructuring of food systems to suit present needs [29].

Creating Buffers: Though buffering may come at a cost, and its benefits may only be felt in the long term, it is essential in building resilience in the food system. It increases the absorbability of the system as it is done in anticipation of a shock or stressor. This could be in the form of climate change, conflict and political insecurity, economic depression and market fluctuations, and other unexpected shocks such as pandemics and pest outbreaks [25].

Stimulating Connectivity: Building, maintaining and strengthening relationships within the system will help build resilience and avert undesirable effects of local and global shocks. Strengthening the links in agricultural value chains increase the adaptation and transformation capacity of the food system. Connectivity can be in the form of physical infrastructure (roads, storage facilities, airports, etc.), communication infrastructure (internet access), and economic, political and social relationships between actors and nations [25].

Enhancing Diversity throughout the system: Diversity is another pillar of resilience. It implies flexibility and redundancy where one resource can be replaced with another. A lack in one area can be complemented by excess in another area. Research done on the resilience of ecosystems have shown that biodiversity plays a huge role in the stability and continuity of systems [25]. "Together, a varied and balanced diet, a wide range of crops and foodstuffs, and a diverse system of production and distribution, make a more resilient, stable and healthier food system" [25] (p. 4).

Learn from the Covid-19 crisis: Covid-19 laid to bare the inequalities in our food systems, hence, the need for building a resilient food system. It is clearly evident how much the vulnerable groups were at risk. While the poor became poorer, the rich could not have the usual access to the same goods and services as before the pandemic. Countries affected the most were those with already existing poor policies, infrastructure, and failing systems, even on a good day. The pandemic is definitely an impetus for a reform in government policies, agricultural and business practices [29].

10. Conclusion

Food systems encompass a set of activities from food production to consumption and waste management that fall within a social (socio-economic, cultural, and religious aspects, policies and laws) and environmental (water, land, air, and climate) context. This makes food systems essential to realising all the sustainable development goals, especially food and nutrition security (SDG 2), good health and wellbeing (SDG 3), poverty eradication (SDG 1), and gender equality (SDG 5). An ideal food system must therefore be economically, socially and environmentally sustainable. In other words, it should: provide income or be economically viable for all actors and stakeholders along the value chain; contribute to the socio-cultural wellbeing (health, nutrition and employment) of each and every actor or stakeholder, especially vulnerable groups such as women and the youth, without bias; and finally, ensure that its activities have an overall positive impact on the environment.

For a successful transformation of our food systems, there is the need for the incorporation of resilience and sustainability in a holistic manner, and with a future-oriented mindset. Food system actors are key agents of change, and their roles in shaping and adjusting the food system must not be underestimated. Therefore, the various actors along the food chain must form strategic and innovative partnerships, while considering the impact that drivers, components and outcomes of the system have on the entire food system. This is the bedrock of the food systems approach.

The COVID-19 pandemic has presented us with a unique opportunity to re-evaluate and restructure our current food systems; an opportunity to build back and build better. Hence, the impact that institutions such as the West Africa Centre for Crop Improvement (WACCI), University of Ghana, contributes towards food systems transformation through human and institutional capacity building and the development of innovations in the form of improved seeds to meet the needs of farmers and other value chain actors is momentous.

The Alliance for a Green Revolution in Africa (AGRA), the World Bank, African Union, European Union, USAID and many other donors actively supporting food security interventions and programmes need to be lauded for the impact they are making through Centres of Excellence such as WACCI. Donor fatigue although a challenge remains an obstacle to sustainability of projects such as WACCI however with funding support that is to accelerate the scaling up and commercialization of products and innovations from initial investments, sustainability and long-lasting impact is assured.

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