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Transport, Technology, and Energy Inefficiencies in West Africa's Small Holder Farms: Implications for Food Security and Socio-economic Development

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Abstract

The paper examines the inefficiencies of transport, technology and energy in West Africa's small-holder farms, with implications for food security and socio-economic development. Particularly, the paper, focused on how efficient transport system, precision and climate smart agriculture can be leveraged through the technology-energy mix to reduce post-harvest food loss and waste (PHFLW), poor production output, and mitigation of climate change challenges on small holder farming in West Africa. By employing documentary method of data collection and Transformation Theory, the study found that there is need for radical and fundamental change of government policies and actions regarding technology, transport and energy sectors in West Africa, particularly in rural areas where small-holder farmers still rely on crude and traditional methods of farming that are unsustainable. The study also found that if the current methods small farm holders employ continues, West Africa will not be able to feed its teeming population that is said to rise to 540million by 2030. The study therefore concludes and recommends that small holder farmers must be adequately educated and sensitized to jettison crude agricultural practices and certain belief systems that are antithetical to agricultural productivity and socio-economic development.

Keywords: Post Harvest Food Loss and Waste**,** Transport, Energy, Technology, Small Holder Farms, Food Security

1.0 INTRODUCTION/PROBLEMATIQUE

The United Nations Sustainable Development Goals (UNSDGs) 1(No poverty), 2(Zero hunger), 3(Good health and wellbeing), 11(Sustainable cities and communities), and 12(Responsible consumption and production) are all directly linked to a sustainable agriculture practices, aimed at guaranteeing food security and to foster socio economic development of nations across the world. In the light of this, several research endeavours from different institutions and scholars (Food and Agriculture Organisation [FAO], 2021, Trendov, Varas and Zeng, 2019; FAO, 2015a; Beyene, 2014; International Fund for Agriculture Development [IFAD], 2013), have considered the agricultural inputs of small holder farm as very crucial, with particular respect to their ability to reduce Post Harvest Food Loss and Waste (PHFLW). According FAO (2015a), 90% of the more than 570million farms globally, are owned and managed by small farm holders, who rely on individual and family labour for input and productivity (United Nations Development Programme [UNDP], 2021; United Nations Conference on Trade and Development [UNCTAD], 2017). These farms are responsible for 80% of food grown and consumed in both Asia and Sub Saharan Africa. Small holder farms are characteristically situated within or less than 2 hectares of land (FAO, 2015b, Beyene, 2014). In terms of job creation in West Africa, small farm holders employ about 32% of the region's workforce. It is also responsible for 35% of regional Gross Domestic Products (GDP), with two out of every three individuals employed, depend on it for their livelihood (Sahel West African Club

[SWAC]/Organisation of Economic Cooperation and Development [OECD], 2021; African Development Bank [AfDB], 2020).

As noted earlier, to guarantee food security, and reduce hunger and poverty, the role of small holder farms in improving productivity and reducing PHFLW, cannot be overemphasised. This is so because, about 795 million people in the world are undernourished, 90 million of which are children under the age of five. Again, of this amount (795 million) that are undernourished, 780 million are resident in Africa and Asia, most of whom are rural dwellers, with small farm holdings (FAO, IFAD, and World Food Program [WFP], 2015). In most regions of the world, including West Africa, people living in rural areas are usually at high risk of food insecurity (FAO, IFAD and WFP, 2015). More than half of these rural dwellers, are small holder farmers who have limited access to credit facilities/financial resources, education and up-to-date agricultural information, food, poor road network, inaccessibility of power and clean energy for cooking, as well as other infrastructure needed for survival and socio-economic development (UNCTAD, 2017)

One of the major global concern of world leaders in the 21st century, is how to guarantee food security by halving PHFLW by 2030, and to ensure provision of safe, sufficient and nutritious food for all. According to the FAO (2016a), food security refers to a situation where all people, at all times, have socioeconomic and physical access to safe, sufficient and nutritious meals that meet their dietary needs and preferences in order to lead an active and healthy life. To attain food security, there are four factors that must be considered viz: availability (prompt supply of food), access to food (ability to afford preferred food), use/utilization (consumption safe and nutritious food) and food stability (ability to obtain food over time) (FAO, 2016b). To make any household fully food secure, all four factors must be met. Food security for households are guaranteed when there is availability of food in post-harvest periods of the year, between June and August and in times of acute food shortages between October - December (Spaling and Vander-Kooy, 2019). To achieve this, critical attention is required in the direction of small farm holders, especially in encouraging them to leverage technology in the adoption of climate smart and precision agriculture. This is because they have the double-edged sword of either guaranteeing food security or to go down the abyss of food insecurity. This, of course, will largely depend on how much needed infrastructure are provided. This, strategically include: land availability and its cultivation, provision of and the deployment pre and post precision agriculture technology, efficient energy supply, and good transport network for distribution and marketing purposes.

Some of the infrastructure needs fingered above are sufficiently required to enable small farm holders thrive in West Africa, especially in ensuring food security and to make the region gradually exit the grim statistics of poverty and hunger (SWAC/OECD, 2021; National Information Technology Development Agency [NITDA], 2020; AfDB, 2020; FAO, 2015c). These aforesaid infrastructures, aid transformation of food production and of consumption. They also help to improve efficiency in food production processes, especially in the area of developing a more reliant and resilient food value chains (SWAC/OECD, 2021). Finally, vital policies and their adequate implementation are better produced through a conscientious provisioning and adoption of these infrastructure for the agricultural survival and sustainability of the region.

It is against this background that this study focuses on the inefficiencies in transport, technology, and energy in West Africa's small holder farms, with a view to ascertaining its implications on food security and socio-economic development in the sub-region. Particularly, the study focused on how efficient transport system, precision and climate smart agriculture can be leveraged through the technology-energy mix to reduce PHFLW, poor production output, and mitigation of climate change challenges on small holder farming in West Africa. Transformation theory was adopted for the study because there is need for radical and fundamental change of government policies and actions regarding technology, transport and energy inefficiencies in West Africa, particularly in rural areas where small holder farmers reside. There is also need for such radical and fundamental change in the ways small holder farmers carry out their day to day agricultural activities, from the crude methods that have been largely unsustainable to a more modernised and technologically driven method that are not just sustainable, but resilient to reduce PHFLW, guarantee food security and promote socio-economic development in the sub-region.

Research Questions

1. How has inefficient transport, technology and energy in West Africa increased post-harvest loses and wastes of small farm holders
2. Has climate smart and precision agriculture enhanced agricultural productivity of small holder farmers

Research Objectives

The objective of this research is divided into broad and specific objectives. The broad objective of the study is to examine how inefficient transport, technology, and energy in West Africa's small holder farms, with specific implications for food security and socio-economic development.

Specifically, the study sought to:

1. Interrogate how inefficient transport, technology and energy in West Africa increased post-harvest loses and wastes of small holder farmers
2. Investigate how climate smart and precision agriculture enhanced agricultural productivity of small holder farmers

2.0 METHODOLOGY

The research design adopted for this study is a qualitative-case study research design (Yin 2014), with the method of data collection primarily documentary, from secondary sources. As a result, theoretical and purposeful sampling (Maxwell, 2012) of documents gathered for the research was employed. The rationale for this is to enable the researcher sieve rich relevant data and documents (from irrelevant ones), that are trustworthy and germane to the case (smallholder farms in West Africa) under study. According to Coleman (2021) and Noble and Smith (2015), qualitative research designs are said to be valid and reliable if the data generated are from trustworthy, dependable, credible and confirmable sources. In light of this, data gathered for this study are mostly from confirmable sources such as United Nations Food and Agriculture Organisation (FAO), United Nations Conference for Trade and Development (UNCTAD), Organisation of Economic Cooperation and Development (OECD), African Development Bank (AfDB), United Nations Development Programme (UNDP), World Bank, National Information Technology Development Agency (NITDA), International Renewable Energy Agency (IRENA), African Energy Portal (AEP), World Food Programme (WFP), amongst others. Data gathered from these prominent institutions and used for analysis, are of recent with most been under 5 years old, were triangulated (comparing from two or more data sources in order to look for patterns of convergence) so as to help corroborate research findings of the study (Coleman, 2021; Fusch, Fusch and Ness, 2018). Furthermore, a content analysis was done on the data obtained from documents in order to search for patterns, regularity and consistency, with a view to arriving at results that are verifiable, generalisable and also, transferable.

Transportation and Good Road Network

In West Africa, the road and transport infrastructure are in deplorable state, thereby affecting mobility of farm produce and of farmers for other socio-economic endeavours. West Africa has a total road network of about 675, 000 kilometres, out of which 107, 875 are paved and 562, 263km are unpaved (Graham, Gbahabo, and Wong, 2020). The above example of poor road infrastructure are why transport systems in West Africa are largely inefficient. This is because, road transport account for more than 90% - 95% of passenger and freight traffic (Graham, Gbahabo, and Wong, 2020). Transportation has been adjudged to be a crucial part of agricultural productivity (Ajiboye and Afolayan, 2009). It allows for the movement of agricultural produce from one point to another, by way of marketing, or by moving them to places where they could be preserved or stored. This, however, limits or reduces post-harvest loses that often characterise small holder farms with poor road and transport network. Good road and transport system also enhance the quality of life of a people, as it tends to enable individuals in a given location have fluid mobility to meet and interact with people, share ideas, innovations, and challenges that are often held by them, with a view to seeking solution and respite. Interaction with other farmers will also expose them to new seed varieties, market information, improved farming technologies, and credit lines available to farmers (FAO, 2015c).

Without good transport network or system, small farm holders, mostly in rural areas, will not be constrained with regard to access to key agricultural information, innovation, skills, education and improved technology that might enrich their agricultural practices.

Energy

In terms of access to clean energy, more than 338 million West Africans lack access to clean energy, with only 25% of its rural population, where small farm holders dwell, have access to electricity (Africa Energy Portal, 2020.) To essentially mitigate post-harvest loses of small farm holders, and to reduce their emission of biomass through burning of fossil fuels, like woods, availability of clean and renewable energy is paramount. This is because it has the capacity to ensure that small farm holders meet their needs for electricity, heating, cooling, storage, and even transport. All these, are mostly geared towards preserving and enhancing food system and security. With this, the goal of drastic reduction of hunger, green house gas emissions, increase in adaptive capacity and income of small farm holders, youth employment, among others, are likely to be achieved (International Renewable Energy Agency [IRENA] and FAO, 2021). One important area where small farm holders might deploy renewable energy to enhance productivity is in irrigation. Through innovation and technology, renewable energy powered irrigation systems have been fashioned to reduce the amount of diesel or fossil fuel being used. In recent times, solar irrigation systems have been found favourable in the developed world because it improves water access to farms both in rainy and dry seasons, enabling multiple cropping cycles and improving resilience to rainfall patterns caused by climate change (IRENA, 2016a; 2016b). For instance, the use of solar irrigation pumps systems in India, have improved small farm holders' income by 50%, and in Rwanda, about one-third increase in yields and productivity have been recorded among small farm holders (IRENA, 2016b). These appear to be lacking in West Africa's small holder farms.

Technology, Science and Innovation

Considering the fact that agriculture in West Africa is predominantly rain fed, climate change challenges of inconsistency in rain fall, erosion and desertification issues, will undoubtedly undermine agriculture output of small farm holders in the region. To prevent this, precision agriculture (PA) and climate smart agriculture (CSA), which are largely powered by technology-energy mix, becomes very critical (IRENA and FAO, 2021; Partey, et al, 2017). Furthermore, smart agricultural practices, through science and technological innovations, have shown that the value chain processes of small farm holders can be optimised and automated for improved productivity, resilience and sustainability. They are also crucial in ensuring that the four dimensions of food security – availability, access, food use, and stability – are achieved (UNCTAD, 2017; FAO, 2016b). For instance, to guarantee food availability, biotic stresses (like diseases, pests, rusts, rodents, etc) that poses a threat to food availability can be addressed through technological and innovative means, such as the cultivation of disease or pest resistant crops, pest resistant eggplants, rust resistant wheat varieties, the use of pesticides, insecticides, etc. These are all technological innovations that makes food system resilient and ensure food security. Beyond this, technology makes information sharing easy between small farm holders and by extension the outside world (SWAC/OECD, 2021)

Theoretical Framework

The study was anchored on transformational theory. The origin of this theory can be traced to scholars like Macgregor (1978). However, the theory has been modified by several other scholars such as Darszko and Sheinberg (2017), Feola (2015), O'Brien and Sygna (2013), O'Brien (2012), Richards and Howden (2012), and Folke, et al (2010). According these scholars, transformation is generally characterised by significant and fundamental change, especially the ones occurring in socio-ecological systems. For decades, if not centuries, calls for transformation and scholarly research in the area has been made by governments, industry and the academia to steer the affairs of society towards sustainability. In recent times, this call has been focused on the agrarian sector where there has been much desire to transform ways in which land and water are being used and managed in order to cushion the harsh effect of climate change on agricultural

activities (Duncan, et al, 2018). Generally, the activities of man, especially its unsustainable use of resources centuries ago, have led to socio-economic, cultural and environmental challenges that calls for transformation towards sustainable practices in all aspects of society. The erstwhile United Nations Millennium Development Goals (MDGs) and its current Sustainable Development Goals (SDGs) are in tandem with general calls for transformation in how we use and manage earth's resources, with science, technology and innovation (STI) as the foremost and widely acceptable tools need in this direction (Duncan, et al, 2018).

The major reasoning of this theory is the identification that a fundamental characteristic of a given system in a society, requires radical changes (Nzeyimana, et al, 2021). To put in another way, a failing aspect of a society requires conscious effort, through resilient thinking to provide a sustainable remedy. One of the ways to achieve this is through complex, but flexible patterns of interaction (Folke, 2016; Feola, 2015), which could only be midwifed through STIs.

According to O'Brien and Sygna (2013), there are three spheres of transformation – political, practical and personal. These, according to them, focus on challenges that are both at the systemic and individual levels. In accordance with O'Brien and Sygna's three spheres of transformation, the researcher sought to find out how the practical application of precision and climate smart agriculture, ably enabled by efficient transport, technology and energy systems, can transform agricultural output to guarantee food security and sustainable development in West African sub region. At the political level, the study investigates whether there are rules, norms, policies of government that could engender such canvassed transformation. Then, at the individual level, focus was on small holder farmers' belief systems, education, behaviours, values and views, and how they have impacted desired change at the personal sphere of transformation.

Politically and in practice, the major challenge of governments, especially in West Africa to transition and direct activities of small holder farms in precision and climate smart agriculture, through efficient infrastructure, is funding. In other parts of the world and even in neighbouring South Africa, funding has been provided to enable financing of critical infrastructures that will drive their agricultural economies. For instance, in the area of energy generation, South Africa alone has a total installed capacity generation of 58, 000 Megawatts (MW), while all West African countries have about 25, 000 MW (United States Agency for International Development [USAID], 2021) The result showed that 87.9% and 79.2% of its urban and rural populations of South Africa have access to electricity (Africa Energy Portal, 2020). However, policies are already on ground in the West African sub-region to address this, and there are visible signs that improvements are being made, even though there is still a lot that needs to be done for the region to meet up with its contemporaries in other climes.

In the energy sector, the West Africa Power Pool (WAPP) was instituted with the aim of providing universal access to electricity in both urban and rural areas. In addition, Economic Community of West African States (ECOWAS) Centre for Renewable Energy and Energy Efficiency (ECREEE) was adopted in 2010, with the aim of improving energy access, energy security, counter climate change and reduction of gas emissions (Adeyemo, 2014). Practically, notable achievement of this body was the securing of €2million to build 41 energy facility projects across the sub-region. Also, the web-based ECOWAS Observatory for Renewable Energy and Energy Efficiency (ECOWREX) and ECOWAS Renewable Energy Investment Initiative (ECREI) were other achievement geared towards providing private and public sectors with information regarding energy investments and businesses, and to support renewable energy investments and projects. In light of this, both private, public and international institutions have invested in the sector, with the aim of deregulating it and making energy accessible in the region (USAID, 2021; Reiss, 2015). Following this, the ECOWAS Renewable Energy Policy (EREP) was made in 2013 to promote policies in renewable energy within the region, and to increase the share of renewable energy supply, especially electricity in the region, upwards of 35% in 2020 and 48% by 2030. By way of complementing EREP, the ECOWAS Energy Efficiency Policy (EEEP) was framed, whose remit is to create additional 2000 MW generation capacity in order to double the rate of improvement and to guarantee energy efficiency (IRENA, 2020). Other policy initiatives include: West Africa Energy Programme (WAEP), ECOWAS Regional Electricity Regulatory Authority (ERERA), and the recently approved Battery Energy Storage Technology (BEST) whose roles are to remove constraints to energy access and facilitate

unfettered energy distribution across the region (USAID, 2021; World Bank, 2021). Practically, the region is yet to reap the benefits of these investments in the energy sector, as it still hosts about 338million people, out of its 400million population, without access to clean energy, as most of its rural population use solid fuel for cooking (Africa Energy Portal, 2020). With the foregoing policies, it is hoped that the energy sector of the region will be transformed positively to meet the demands of small holder farmers in rural areas.

In the area of transportation, the most ambitious effort by leaders of the region is the on-going construction of 4,560kilometers trans-West African highway, all the way from Nouakchott, Mauritania, to Lagos, Nigeria. The aim is to link 15 ECOWAS countries by roads. Ably supported by New Partnership for Africa's Development (NEPAD), the highway project will unify all countries in the region. Relatedly, the Praia-Dakar-Abidjan transport project is underway, which is intended to link 7 West African countries (ECOWAS, 2021), and also, a preparatory funding of about €22.4million to finance the Lagos-Abidjan Highway Corridor is expected to link Ivory Coast, Ghana, Togo and Nigeria (AfDB, 2022). Practically, the region's number of paved roads are still very abysmal in spite of the policies and funding being doled out to revamp the transport sector. Post-harvest loses due to lack of efficient transport system have not abated. When these road projects and transport networks are completed, it is believed that they will have a positive transformative effect on the rural dwellers of the region, especially small farm holders, who will rely on the improved road and transport network to convey their agricultural produce seamlessly to city centres.

In the realm of technology, a couple of countries have taken initiatives to making policies and providing support for technologies that will engender smart climate and precision agriculture in the region. Nigeria for instance, through its Digital Agriculture Strategy, NDAS, (2020 – 2030), intends to increase efficiency in Nigeria's agriculture sector, particularly for small holder farms, and to also create viable eco-system for agricultural start up technology firms to thrive (NITDA, 2020). In view of this, there already transformational success story, as a Nigerian precision farming start-up firm, Zenvus, uses technology to analyse soil temperature, nutrients and vegetative health of crops. Furthermore, submissions made at the West African Forum for Precision Agriculture (WAFPA), show that Burkina Faso and Senegal have led significant research to the utilization of fertilizer deep placement technology for irrigation in rice production system, which have improved yield and reduction in nitrogen losses in soil (Oladele, 2021). In practical terms, small farm holders who focused on the traditional way of farming only get 26% yield and production output from their agricultural endeavours. Where as those who employed mechanisation have 155% yield of output. But those who employed both mechanisation and precision and climate smart agriculture, records 265% yield in output production (Oladele, 2021). This is the fruit of the transformative effect of STIs in the agricultural sector of any nation.

Personally, and at the individual level, transformation is still very far from reach. This is because small farm holders in rural areas of West Africa still lead a traditional lifestyle which are often brought to bear in their agricultural practices. For instance, most small farm holder in the region still adopt local observations of weather patterns and seasonal conditions which are often gleaned from appearance of the moon, the flowering of plants, behaviour of certain wild insects, and cloud formation to predict what the weather would look like (Spear, et al, 2019; Kolawole, et al, 2014). These observed conditions of the weather help them determining when to plant, what to plant, how to plant and even when to weed their farmlands (Kolawole, 2015). Again, the use of solid wood or fossil fuel in cooking, is believed to taste better than the use of clean cooking energy. This, and other traditional held beliefs have persisted due to lack of education and proper enlightenment of small holder farmers. Whilst laudable policies and programmes are well underway to transform West Africa's agriculture into precision and climate smart ones, same energy and attention have not been channelled into education, sensitisation and awareness of small holder farmers in rural areas of the region. This, poses a serious threat to well thought out initiatives to transform agriculture in the region.

Transport, Technology, and Energy Inefficiencies in West Africa's Small Farm Holders

West Africa's inefficiencies in the transport and technology-energy mix has been a bane of small farm holders. With its teeming population of about 400million, which is projected to be about 540million, by 2030 (UNCTAD, 2017), the sub region has a huge task to address the food need of its young population.

Coupled with climate change stress, the challenge however, is how to develop smart, resilient and transformative agriculture food system, especially among small farm holders, that will cater for the needs of the present population without comprising the ability of future generations within the region to meet their own needs. Thus, inefficiencies within the above identified infrastructure will run counterproductive, with dire consequences of acute food insecurity for the region.

As documented earlier, road transport in West Africa is responsible for about 90% - 95% of passenger and freight traffic (Graham, Gbahabo, and Wong, 2020). The poor state of these roads is one of the major causes of barriers to trade, both within and outside the region. In fact, it is the reason for the uncompetitive nature of the region's agricultural produce at international markets, because of high cost of transporting the produce from rural areas to city centres (Medium, 2020). According to Ogunleye, et al (2018), in the absence of good transport system, small holder farmers will also be unwilling to produce in large quantities, since it is unlikely that their produce will get to the market before they go bad, especially, the perishable ones. Hence, they suffer PHFLW. Thus, for the region to be able to feed its teeming population, transportation of farm produce by small farm holders to the urban centres, is very paramount. In another light, it will provide an avenue through which resource persons in the city centres can commute easily to rural farmers, to share vital and recent innovative information, especially on climate smart and precision agriculture methodologies for the benefit of small farm holders (Ogunleye, et al, 2018).

Table 1: Energy access and distribution by African sub-regions
Source: Researcher's compilation and design based on data from African Energy Portal (2020)

African Regions	Pop. In million	Installed capacity MW.	% with access to electricity	Population without access to electricity	Urban	Rural	People without access to clean energy for cooking
Central Africa	189.7m	5, 994	30.2%	72.25million	55.5%	4.9%	127.68million
West Africa	402m	25, 000	54.3%	153.18million	83.1%	25.5%	338.16million
East Africa	445m	17, 527	44.9%	196.4million	78.3%	31.8%	355.8million
North Africa	246m	112, 023	97.4%	4.9million	98.7%	96.1%	3.92million
South Africa	59.3m	58, 000	85.0 %	8.71million	87.9 %	79.2%	8.13million

The above table 1 reveals the energy situation for West Africa. Although, East and Central African regions have grimmer statistics, it is also showing that West Africa has the second highest population of people without access to clean energy. South Africa as a single country, boast of more installed capacity of electricity compared to all the 15 West African countries put together. Inefficiencies in the realm of technology and energy is another daunting challenge to productive agricultural enterprise in the region. Without the solutions provided by technology and renewable energy sources, it will be almost impossible to survive harsh climate conditions in the next decade. Future generations will be unable to meet their nutritional needs, even as present generation are lacking basic nutrients in their meals as a result of inadequate food production in the region.

Table 2: Population of Severely Food Insecure Regions in Africa, 2014 – 2020
Source: Researcher's compilation and design based on data from FAO, (2021)

	2014	2016	2018	2019	2020
West Africa	29.6 million	46.8 million	63.9 million	76.7 million	115.7 million
East Africa	89.9 million	103.2 million	105.6million	113.0 million	127.9 million
North Africa	22.4 million	23.7 million	22.0 million	21.2 million	23.4 million
Southern Africa	11.7 million	12.1 million	12.6 million	12.8 million	15.3 million

From table 2 above, apart from East Africa, West Africa is the next region with an acute food insecurity, with about 115.7million people in need of good nutrition in 2020. In terms of environmental uncertainty, West Africa is one of the most vulnerable regions to climate change conditions, as increase in temperature and inconsistency in rain and weather patterns are already undermining food security, livelihoods, as well

as governance and economic stability (USAID, 2018). Without climate smart agriculture, warming of above 2 degrees are likely to stress crops, leading to 11 per cent decrease in the yields of cereals. The most affected will be maize and rice throughout the inland forest regions (USAID, 2018). This challenge is not likely to be solved through traditional belief systems and patterns applied to agricultural practices by small farm holders in the region.

Inefficient Transport, Technology and Energy in West Africa and Post-Harvest Food Loss and Waste (PHFLW) in Small Holder Farms

Post-Harvest Food Loss and Waste (PHFLW) are both quantitative and qualitative reduction in food production arising from poor management of agricultural harvest along the food value and supply chain (FAO, 2019). According to World Wildlife Fund-US (2021) and FAO (2011), 40% (more than one-third) of food produced for human consumption, are wasted or lost; having undesirable environmental and socio-economic ramifications (Addai, 2021). A report by World Wildlife Fund-UK (2021), notes that global food waste on farms alone amounts to 1.2billion tonnes, annually, and representing 15.3% waste on food production. In Sub-Sahara Africa (SSA), there is annual food loss of 36%; 12.5% of which occurs at harvest, 12.7% occurring during post-harvest, 4.5% during processing and packaging, and 4.6% during distribution (Bamikole, Tahiru and Richardson, 2022). Specifically, African food losses in quantity and caloric value, are estimated at 15.9% and 17% respectively, with outright spoilage amounting to 50% of harvested foods (FAO, 2019). PHL can occur at any stage between the farmer's field at harvest, to the consumer's plate (Sheahan and Barrett, 2017). The causes vary, depending on the stage at which it occurs or the supply chain processes or the location and form of storage. Fundamentally, food losses occur when part of the crops are left behind unharvested, attacked by diseases and pests, split or damaged during transportation (Stathers, et al, 2020). They could also be lost when there is inefficient power supply, kept in poor storage facilities, absence of coolant and refrigerating technologies, poor road network and market access.

In West Africa's small holder farms, food losses are a prevalent occurrence. Huge cereal production losses have been recorded in different West African small holder farms. For instance, Niger recorded 38% loss in cereal production, Burkina Faso (18%), Ivory Coast (10%), Gambia (9%) respectively (WFP, 2022). In Ghana about 20% of cereals, 30% of legumes, 20% of fruits, 50% of vegetables, are lost annually (Agyapong, et al, 2022); meanwhile in Senegal, 30% of the total vegetables are lost before they leave the farm gate (Beye and Komarek, 2021). For Nigeria, it loses and waste about 40% of its total food production annually (World Bank, 2020). Instructively, it is projected that between June-August, 2022, 38 million more West Africans will be food insecure, an increase of 22% in comparison to last year (WFP, 2022)

Figure 1 below shows the various stages in which PHFLW occurs. The *primary stage* which are biological, include infestations of pests, insects, diseases, and animal attacks; and environmental to include to adverse/extreme weather conditions, like high temperature and humidity; poor/crude storage infrastructure like mud or clay silos, drums, cribs or barns to store agricultural produce like grains, fodder and seeds, instead of using hermetic grain storage bags (FAO, 2019). Although, these are easy to construct and inexpensive to maintain. Although, these are easy to construct and inexpensive to maintain. They are however, not resilient to physical, environmental and biological hazards for a long period of time (Sugri, et al, 2021); and processing which include traditional/natural methodologies, like wind and sun, mashing with bare hands, etc.

The *secondary stage* concerns activities happen with the movement of agricultural produce from small farm holders' gate to markets and consumers. This include access to road networks, efficient transport system, proper market information, availability of postharvest infrastructure and services, efficient and effective handling of agricultural produce, and consumer behaviour. The *tertiary stage* focuses on the external factors. This also include poor/lack of transformative government policies towards agriculture, especially in rural areas where small holder farmers reside, poor government investment in agricultural infrastructure in rural areas, poor private sector involvement/investments in agricultural practices of small holder farms, etc.

Taken together, the magnitude of the primary, secondary and tertiary stages of PHFLW determines the severity of their occurrences in small holder farms. Some of the key identified causes of the various stages of PHFLW are inefficiencies in technology, energy and transport systems of small farm holders across West Africa. Upon maturity, the proper technology needed for harvesting crops are virtually non-existent in small holder farms in West Africa. Traditional, crude and manual implements like sticks or bare hands are usually employed with all its attendant clumsiness to harvest agricultural produce. This has led to instant spillage and spoilage of food even before they leave the farm gate. Also, poor energy supply and lack of adequate storage and packaging leads to deterioration and spoilage of crops after harvest. Furthermore, after a clumsy harvest through the use of crude implements, Porter and Reay (2016) observes that small holder farmers in the region package their produce poorly in sacks, woven baskets made from bamboo sticks, wooden crates and so on.

Armachius and Vumilia (2017) identifies poor management and education of small holder farmers in post-harvest handling of produce as one of the major causes of PHFLW. According to them lack of knowledge of/desire to use improved technologies for harvesting, packaging and storage of harvested produce leads to their loss in quantity and quality. In line with the foregoing, Kok and Snel (2019) observe that most food losses and wastages in developed countries usually occur at the secondary level of retailing and consumption (the household). But in developing and underdeveloped countries like West Africa, the major loss and wastage of food occurs at the primary stage due to limited resources and knowledge of small holder farmers, particularly, their "knowledge of causality of problems and potential solutions" (Castelein, et al, 2021, p. 6). Hence, the need for transformative agricultural policies involving both government and private sector interventions in rural areas.

Apart from technology, energy and transport inefficiencies, conflicts and crises are also a major cause of PHFLW in West Africa. For instance, in Nigeria, the farmers-herders clashes led to tonnes of food wastes and losses especially in the Northern region of Benue, Adamawa and Kaduna States and some Southern region like in Ekiti, Enugu, Oyo, Ebonyi, Ondo, etc., leading to the passage of anti-grazing laws in most of the States in Nigeria.

Socio-economic Impacts of PHFLW

When there is massive food loss and waste, there is a corresponding increase in consumer prices, as fewer products makes it to the market, leading to inflation. On the other hand, there will be less profit for small holder farmers who would have made more in the absence of such losses and wastes. According to FAO (2021), consumers will save more if they employ judicious use of foods at home, as they channel their resources to other household needs. Also, consumers will save more if food loss reduction by suppliers makes food cheaper at both retail and wholesale levels. The current high prices for food in some West African countries can be largely attributed to PHFLW discussed earlier. Food price increase in countries like Nigeria, Ghana, Benin, Togo, Burkina Faso, Niger, and Mali have been attributed to food losses and wastes at various stages of the food supply chain (FAO, 2022). For Nigeria, it was attributed to high cost of transportation due to poor road network, which contributes to spillage and spoilage of crops in transit.

PHFLW impacts heavily on the employment status of the sub region. When there is reduction in PHFLW, it creates high demand for labour in terms of harvesting, processing, distribution and marketing. Furthermore, its reduction will mean having enough food for the population and for export, which in turn brings in foreign exchange and revenue for the region. Such revenue can be used to finance other national projects or even reinvest in the agricultural sector to guarantee food security and help achieve several of the SDGs, particularly goals 1 (poverty reduction), 2 (fight hunger), 3 (favourable health and wellbeing) and 12(3) (halving PHFLW by 2030). Agriculture appears to be the lifeblood of the region as it employs almost 100million of its population, as 2 or 3 persons in the region of West Africa are employed under the agriculture food production and supply chain (SWACO/OECD, 2021). This will be seriously hampered if food losses continue unabated. Also, PHFLW leads to increased importation of food by a nation in order to breach the shortfall and deficit back home. For instance, between 2016 and 2019, Nigeria's food importation stood at N3.5trillion, which is four times its food exports (N803billion) for the same period (FAO, 2021b)

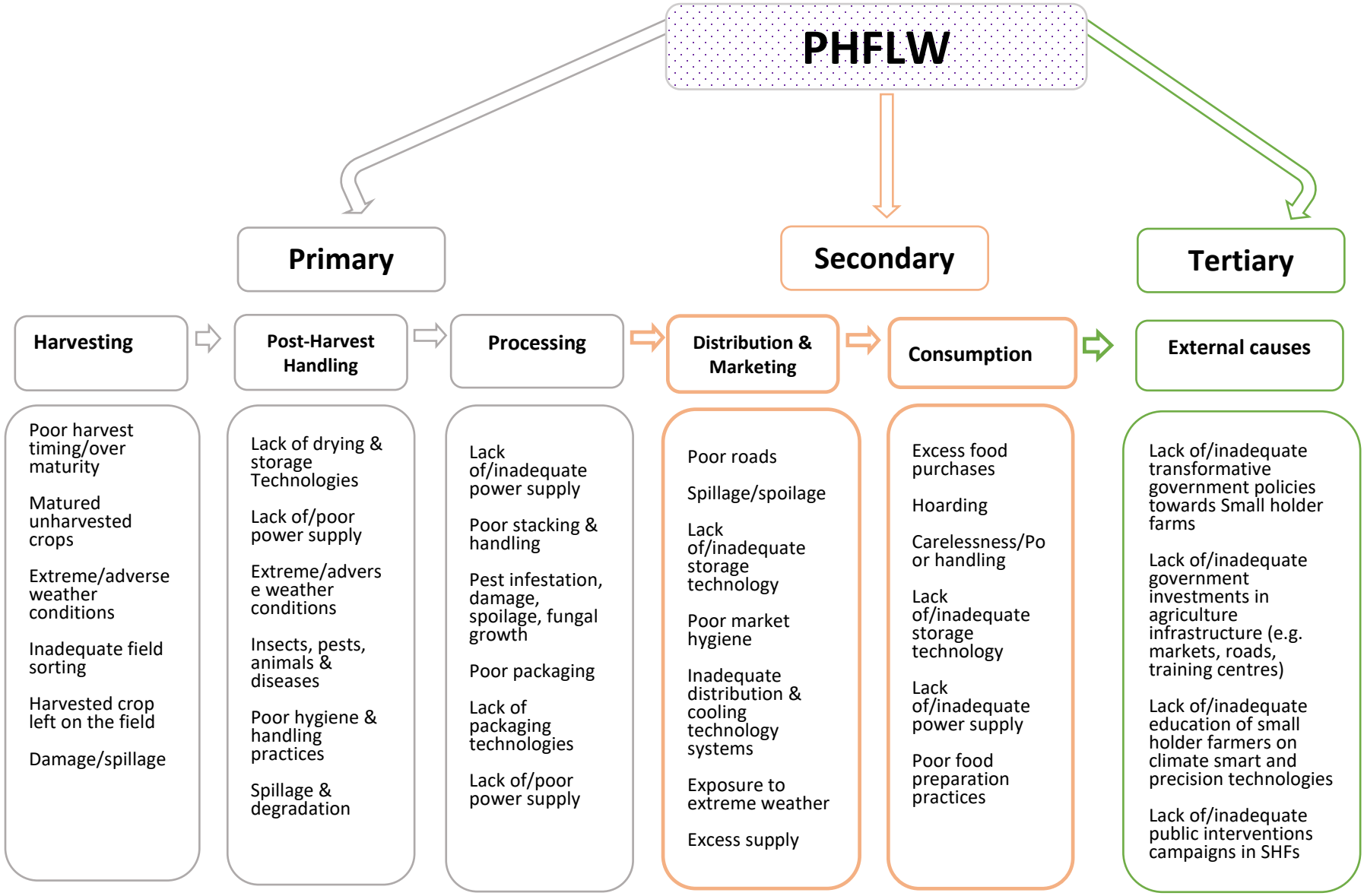


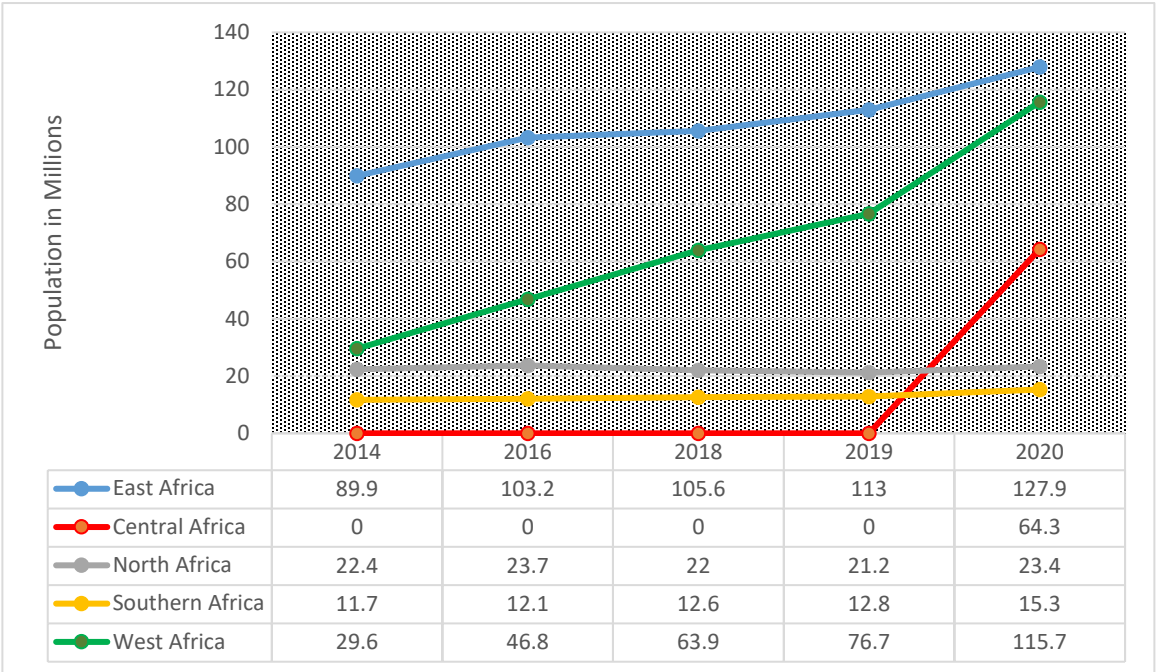
Fig. 1: Stages in Post-Harvest Food Loss and Waste in West Africa's Small Holder Farms
Source: Researcher's design and compilation based on data gleaned from Strecker, Bitzer and Kruijssen (2021); Srugi, et al, 2021; Stathers, et al (2020); Troger, et al (2020); Sheahan and Barrett (2017)

Another impact is that it reduces individuals access to food whenever and wherever it is needed. This creates and exacerbates hunger, leading to undernourishment and food insecurity. According to FAO (2021) hunger is measured in terms of prevalence of undernourishment. Table 3 below reveals the level of undernourishment in various regions of Africa. Specifically, in the absence of comprehensive data for Central Africa, West Africa is the region with the highest percentage of food insecure population in the world. At 68.3%, West Africa food insecurity level is more than twice that of the world average (30.4) and slightly higher than the Africa average (59.6%) respectively in 2020.

Table 3: % of Severely Food Insecure Regions and World Average, 2014 – 2020
Source: FAO, 2021

Regions	**2014**	**2019**	**2020**
World	22.6	26.6	30.4
Africa	47.3	54.2	59.6
West Africa	39.2	54.2	68.3
East Africa	57.7	63.4	65.3
North Africa	29.7	28.9	30.2
Southern Africa	43.8	44.3	49.7

Similarly, fig. 2 below shows that West Africa (115.7million) is poised to overtake East Africa (127.9million) as the region with the highest number of undernourished and food insecure population. PHFLW seriously undermines food availability, accessibility, stability and utility. When this occurs, vast members of West Africa's population will continue to face undernourishment and food insecurity, with negative impacts on health and wellbeing. A well-balanced diet has the potential and capacity to reduce ill-health and diseases on one hand; and on the other, it helps aid recovery from ailments and diseases. The lack of it, therefore, is a negative double-edged sword. This also implies that the sub region is not contributing meaningfully to helping the world fight hunger by 2030, as clearly stated in SDG 2. The data sets and figures revealed above and below also show that the subregion is not making its own contribution to assist the world and the African region to halve food loss and waste by 2030 as stated in SDG 12 (3), and by 2025, as stated in the Malabo Declaration.



	2014	2016	2018	2019	2020
East Africa	89.9	103.2	105.6	113	127.9
Central Africa	0	0	0	0	64.3
North Africa	22.4	23.7	22	21.2	23.4
Southern Africa	11.7	12.1	12.6	12.8	15.3
West Africa	29.6	46.8	63.9	76.7	115.7

Figure 2: Number of Undernourished People in various African Sub-Regions in Millions
Source: Researcher's design and compilation based on data from FAO, IFAD, UNICEF, WFP and WHO (2021)

In addition, a study carried out by Alliance for a Green Revolution in Africa (AGRA), identified four food insecurity hotspots out of seventeen countries studied. Three out of the four were found in West Africa: Burkina Faso, Niger and Mali. Some of the major reasons advanced for this were adverse climatic conditions/extreme weather patterns, especially low rainfalls in the region, as well as conflict, political instability and insurgent activities in the region (AGRA, 2021).

Climate Smart Agriculture (CSA) and Precision Agriculture (PA) as Means of Enhancing Food Security in West Africa's Small Farm Holders

Africa is one of the world's most vulnerable regions to climate change challenges. The last two decades have been hotter than any of the previous years in its history (Fagbemi, 2021). Recently heavy rainfall has led to flooding and rising sea levels in some West African countries, particularly Nigeria. In contrast, when there are limited rainfalls, it led to desertification and prolonged dryness, which are not good for crop yields and agricultural productivity. All climatic conditions seriously affect the livelihoods of small farm holders who rely heavily on agriculture for sustenance (Ramires-Villegas and Thornton, 2015).

In light of the above, there is need for adaptation and transformation in agricultural activities of small holder farmers to modifying production methods in line with current technologies. This will enable them build resilient and efficient sustainable agricultural practices. To this end, education and awareness creation on small holder farmers on the adoption of precision and climate smart agricultural technologies, is at this point, crucial. The West African region is yet to grasp and understand the myriads of advantages that CSA and PA can provide the region (Oladele, 2021). Desertification, one of the consequences of climate change, has led to the constriction of arable lands used for farming in the region. This is especially the case with countries like Nigeria and Niger in the Lake Chad Basin Area. With this challenge, there is need to deploy climate smart techniques to ensure that food production through agriculture goes unhindered. In this regard, hydroponic and aeroponic farming can be adopted. This is a kind of farming by soilless means, with the former being fed more with water rich nutrients, while the latter is fed with air and moist rich nutrient. They are very climate friendly, with healthy crops and robust yields (Bhatnagar, 2021). Below are a few ways CSA and PA can enhance food security for the region.

PA is particularly important as it helps small holder farmers harvest their crops at the right time to avoid PHFLW. Stathers et al (2020), in their study of post-harvest loss reduction in Sub Saharan Africa and South Asia, found that harvested maize cobs with tight husks reduced insect infestations from 20% to 1%, compared to the ones with open husks. Similarly, the World Food Programme study on value chain processes in Burkina Faso and Uganda, noted the importance of moisture at the harvesting stage of maize. According to the study, after maize reaches physiological maturity, it is vulnerable to attacks by pests (Kumar and Kalita, 2017). This implies that harvest must be done at the right time when the maturity moisture content is between 23 to 28 per cent. This is clearly where the need for PA comes in. Technologies that ensures such certainty during harvest of maize must be deployed to reduce infestation and to protect harvest. This will definitely reduce PHFLW, boost productivity, and increase income and profits of small farm holders.

No doubt, a growing world population, projected to reach 9billion by 2050, and a rapid changing diet are steadily driving up demand for food (World Bank, 2021). In fact, the world needs to produce 70% more to feed its teeming population (World Bank, 2020). And for West Africa, it is to plan for the feeding of about 540million people by 2030. With growing vulnerability of agriculture and farming to climatic conditions, the only viable answer to this existential challenge of the peoples of the region is the adoption of STIs that have provided CSA and PA technologies. Its adoption, as stated in table 3 above, will lead to improved productivity to produce more nutritious foods, boost incomes and raise the living standards of small farm holders (World Bank, 2021). According to President of AfDB, Akinwumi Adesina, the agricultural sector will become a $1trillion industry by 2030 (AfDB, 2016). Consequently, only farmers

that have adopted various technological innovations in their farming practices will likely benefit in both the short and long terms. Again, the above show that CSA and PA will enhance the resilience of agricultural produce to climate related shocks and risks, pests, and diseases; improved capacities to crops to grow in spite of erratic weather patterns and conditions. CSA will also help reduce emission of carbons for each kilo and calorie of food produced by identifying how to absorb carbon out of the atmosphere, and to avoid deforestation all together (World Bank, 2021), Beyond the above benefits of CSA and PA, they are also agents of transformative agricultural practices that are not only resilient, but sustainable.

Table 4: Ways Climate Smart Agriculture (CSA) and Precision Agriculture (PA) can benefit small holder farms
Source: researcher's compilation based on data from Bhatnagar (2021), Olaleye (2021), and UNCTAD (2017)

Area of Need	**What can be Achieved**	**Expected results**
Hydroponics farming	➢ Small farm holders can conserve soil resources by growing plants through nutrients and water alone, while using available arable soil for other needed agricultural activities	➢ Faster growth, healthier plants, and bigger yields of crops ➢ Growing confidence of small farm holders in technologies offering climate smart and precision agriculture ➢ Farming without restrictions or borders.
Aeroponics farming	➢ Scarce water resources are conserved and used for other need areas in the agriculture food system	➢ Sustainable and efficient way of farming that produces incredible outputs
Farm Operations	➢ Precision irrigation ensures efficient use of water and promotes unhindered farming activities all year round. ➢ There is also an efficient use of resources in required quantity as may be needed by crops	➢ Profitable farming, which will lead to trust and buy-ins by small farm holders in precision agriculture, backed by technology ➢ More investments will also be favoured
Resilience against climate change	➢ Precision and climate smart agriculture can help protect crops from adverse climatic hazards caused by climate change. The planting of disease and pest resistant crops will ensure that crops are protected from biotic stress ➢ Also, the use of renewable energy from plant waste will help boost agriculture production activities at low costs	➢ Through precision and climate smart agriculture, there will be a drastic reduction of greenhouse gas emissions, while promoting agricultural productivity.
The Health of Plants	➢ Through technological applications used in precision agriculture, small holder farms will be able to know the right quantity of Nitrogen, Potassium and Phosphorus (NPK) fertilizers needed for their soil and crops respectively, without guessing, that often lead to waste or bad development output of plants	➢ This can help to cut down the use of fertilizer by 30%, thus, saving the rest for more productive agricultural endeavours

3.0 CONCLUSION

The study focused on the inefficiencies of transport, technology and energy in West Africa small holder farms, with implication for food security and socioeconomic development. The study advocated the use of technology-energy mix to improve agricultural production of farmers in rural areas in West Africa. More importantly, it stressed the need for good road network and transport systems in the region, as it helps to aid unfettered distribution and marketing agricultural produce of small holder farmers in West Africa. In order to reduce PHFLW, the study noted that PA technologies can be a very innovative

and invaluable aid to small farm holders, because it helps them quantify and be precise with planting and harvesting, in ways that conserve resources and boost efficiency.

In view of the foregoing, it is quite clear that for West Africa to surmount the grim statistics of food insecurity and not overtake or join East and Central Africa in their agricultural inefficiencies, the leaders of the region must improve budgetary allocation and spending to the agriculture sector, particular to small holder farms.

4.0 RECOMMENDATIONS

Although, there are on-going efforts by West African governments to scale up road, power and internet infrastructure in the region as noted earlier in the study; they must however, be conscientious and intentional in their policies in this regard, especially with implementation. They must also ensure that small holder farmers see the need to utilise these infrastructures to their benefit when completed. To this end, proper awareness campaigns must be carried out in rural areas to educate and sensitize them on how to benefit from these infrastructures, because, in the long run, the region will reap its fruits of having sustainable and resilient food production that will generate foreign exchange and revenues.

Notably, for transformation of the current food production architecture in West Africa to be achieved, there should be a conscientization of small holder farmers towards embracing climate smart and precision agriculture. Most of them see the adoption of new technologies as too risky a venture, because they have not been tried and tested. Confidence building measures must be promoted amongst them, so that they can believe and have faith in scientific technology, just like they have with local technology. This is so because, among the three spheres of transformation as espoused by O'Brien and Sygna (2013), the personal and individual level is where West Africa leaders need to do more, especially by consistent engagements with rural based small holder farmers so they can understand and appreciate the wide range of benefits inherent in climate smart and precision agriculture. When they (small holder farms) adapt, this will no doubt ensure food security and improve the socio-economic development and wellbeing of the peoples of West Africa. More importantly there will be a drastic reduction in PHFLW that have characterised small farm holders of the regions for decades, which have ingloriously tarnished their agricultural practices with the infamous phrase- from harvest to dustbin.

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