



Agricultural Innovations for Climate Change Adaptation and Food Security in Nigeria, Sierra Leone and Liberia: Empirical Evidence

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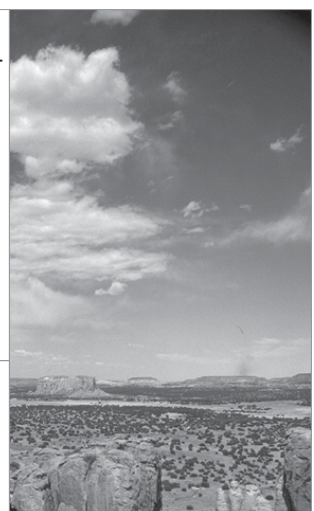


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Abstract

The study ascertained climate change adaptation and food security situations in Nigeria, Sierra Leone and Liberia using the Agricultural Innovations System Framework. Data were collected through the use of semi structured interview schedule, key informant interviews and focus group discussions (FGDs). The collected data were analysed using percentages, mean scores and trend analysis. The findings showed that only 1.8% of respondents from Nigeria, 2.5% of respondents from Sierra Leone and 0.7% of respondents from Liberia possessed special training on climate change adaptation and food security issues. Findings also revealed a positive growth in the manpower strength of farms in Nigeria over the past five years, while Liberia had a positive growth up till 2008 and a downward trend in the 2009 with Sierra Leone having an unstable manpower trend (both upward and downward trend) over the past five years. The study also revealed, that there was a non-existence of overseas collaborations with farmers; though there was a perceived increase in the trend of linkage between the farmers and the R & D institutions in Nigeria between 2007 and 2009, with a linkage index of more than 2. There was also an increasing higher linkage index (of more than 2) between farmers and the technology delivery institutions in Nigeria than in Sierra Leone and Liberia. Also, the respondents perceived food situations in their various countries not to have changed considerably. The innovation systems revealed poor generation of innovations across the three countries and poor domestic support for climate change adaptation and food security in the region.

1. Introduction

In many African countries, food security at both the national and household level is a dismal. Africa has the highest prevalence of under nourishment. In 2004, whereas 14% of the global population was undernourished, 27.4% of the population in Africa as a whole was undernourished (Babatunde, Omotesho and Shotoalan, 2007). In some countries, the rate of under nourishment is above 40%, while it exceeds 50% in those countries experiencing or emerging from armed conflict (Todd, 2004). In West African sub-region, Liberia and Sierra Leone are among those with the highest rate of under nourishment in the continent with 1.4 and 2.3 million undernourished people respectively in 2002 (Babatunde et. al.,2007). In Nigeria, the most populous country in Africa, the majority of households are food insecure, especially the rural farming households.

Climate change is a serious risk to poverty reduction and threatens to undo decades of development efforts through direct negative effects on production and indirect impacts on purchasing powers (African Development Bank (ADB) Report (2003)). As the Johannesburg Declaration on Sustainable Development states, “the adverse effects of climate change are already evident, natural disasters are more frequent and more devastating and developing countries more vulnerable.” While climate change is a global phenomenon, its negative impacts are more severely felt by poor people and poor countries because of their high dependence on natural resources, and their limited capacity to cope with climate variability and extremes. Experience suggests that the best way to address climate change impacts on the poor is by integrating adaptation responses into development planning (ADB, 2003). This is fundamental to achieve the Millennium Development Goals, including the over-arching goal of halving extreme poverty by 2015, and sustaining progress beyond 2015

Africa remains one of the most vulnerable continents to climate change because of multiple stresses (resulting from both politics and economic conditions), the continent's dependence on natural resources and its weak adaptive capacity. According to the Intergovernmental Panel on Climate Change 4th Assessment Report (2007) between 75 and 250 million people may be exposed to increased water stress due to climate change by 2020 in Africa and this will adversely affect livelihoods in the region. The area suitable for agriculture, the length of growing seasons and yield potentials, are expected to decrease due to climate change. Yields from rain-fed agriculture in some countries could be reduced by up to 50%. Thus, climate change may have particularly serious consequences in Africa, where some 800 million people are undernourished.

In the West Africa sub region, the report showed that agriculture is critical to the economy. While the world average contribution of the agriculture sector to the Gross Domestic Product (GDP) is only 4.5 %, the sector's contribution is about 30 % in West Africa. In addition to the above, over 65 % of the population in the region is rural, and about 90 % of the rural population directly depends on rain-fed agriculture for income and food security. Therefore reduction in rainfall as predicted by various climate models translates to threat to the livelihood of the population and the economy of the sub-region.

Unfortunately, research data from Nigeria, Sierra Leone and Liberia show that the performance of the agricultural sector continue to be relatively disappointing in the sub-region as growth has been increasingly on the decline. Traditionally, the agricultural research systems in the region are characterized by a top-down, centralized, monolithic and isolated structures. Linkages, interactions and learning mechanisms among the component actors are notably weak and/or often non-existent. Empirical evidence revealed several linkage gaps and missing links among and between the actors in the systems (Agbamu, 2000; Egyir, 2009). Institutions, for example, universities and research institutes innovate in isolation and although research were taking place at various national and international organizations, the coordination is dysfunctional, and poorly linked to the productive sector. Besides, farmer innovations were not being included in the knowledge system because traditional approaches such as the NARS (National Agricultural Research System) perspective and AKIS (agricultural knowledge and information system) depict research as the sole source of innovation. Without research, it implies, there is no innovation.

According to Roling, (2007) farmers are very quick to take up opportunities. The recent increase in the Free On Board (FOB) price of cocoa in Ghana from 40 to 70% led to a doubling of cocoa production without any technological breakthrough. Hence, if farmers are to cope, compete, and survive, they need to innovate continuously. African farmers are not only innovating in terms of component technologies, but also in terms of farming systems. Farmers often know more than scientists when it comes to the characteristics and dynamics of the environment in which they farm, including risks of water logging, drought, pests, climate change and adaptation measures, thieves, and so forth. However, emerging issues such as high food prices, climate change, and demands for bio-fuels require complementary knowledge from formal agricultural research and development (R&D) and support from policies and other institutions (Asenso-Okyere and Davis, 2009). Hence, formal and informal knowledge and innovation must therefore be linked to accelerate sustainable agricultural development in the West African sub-region.

By adopting an AIS perspective, bigger issues come into focus than when adopting a more limited NARS or AKIS concept. By starting at the knowledge-application end, the question of why farmers innovate or why they don't becomes a major issue for debate and research. What are the constraints that hold them back? Is it the prices in the market, for example, or the lack of (or lack of access to) technology? Are farmers passive recipients of technology or do they actively search for innovations? What are the roles of input suppliers, cooperatives, traders, processors, NGOs, and government-extension services in technology diffusion? What are the relative strengths and weaknesses of existing collaborations? How can they be improved and what can be done to reach more farmers? This study therefore sought to identify and document innovation capacity of Nigeria, Sierra Leone and Liberia as regards climate change adaptation and food security using the Agricultural Innovation System Framework.

1.1 Objectives

The over all objective of this research is to determine the innovation capacity of Nigeria, Sierra Leone and Liberia as regards climate change adaptation and food security using the Agricultural Innovation System Framework. Specifically, the study sort to:

1. ascertain the manpower and specialization (training, experience and skills) of surveyed enterprises;
2. ascertain the intensity and trends of collaboration among key actors in the climate change and food security innovation system;
3. determine respondents' perception of household food security issues in the various countries;
4. ascertain the performance of the system on the basis of innovation generation; and
5. determine respondents' perception of domestic environment support for climate change adaptation and food security.

1.2 Rationale of the Study

Innovation system approach offers a more holistic, multidisciplinary and comprehensive framework for analyzing innovation processes for climate change adaptation and food security, as well as the roles of science and technology actors and their interactions because of its emphasis on wider stakeholder participation, linkages and institutional context of innovation and processes.

Whilst climate change is presenting specific additional challenges to development, it cannot be addressed in isolation. Unless concrete and urgent steps are undertaken to reduce vulnerability and enhance adaptive capacity of poor people, and unless these actions are integrated in national strategies for poverty eradication and sustainable development, it may be difficult to meet some MDGs by 2015. Adaptation which refers to consciously planned adjustments in a system to reduce, moderate, or take advantage of the expected negative impacts of climate change (Smit, Burton, Klein and Wandel, 2000) aims to reduce the vulnerability of individuals and communities by building on and strengthening their existing coping mechanisms with specific measures.

Hence, the starting point for addressing the critical issues for policy should be an analysis of existing agricultural, environmental and food security policies in these countries as well as documentation of effective agricultural innovations for climate change adaptation and food security in the West African sub-region and the consequences of climate change for different rural communities. Since adaptation can help farmers achieve their food, income and livelihood security,

negligence will have devastating implications for development and livelihood. Moreover, mainstreaming climate issues into national development policies ensures consistency between the needs of adaptation and poverty eradication. Separation of the two runs the risk of adaptation policies inadvertently conflicting with development and poverty policies, or conversely, development policies inadvertently increasing vulnerability to climatic factors. Accordingly, this research project is critical to the successful eradication of poverty and needs to be undertaken.

2. Literature Review

2.1 Food Security Situations in West Africa: The Case of Nigeria, Sierra Leone and Liberia

Almost 33 percent of the population of Sub-Saharan Africa (SSA), or close to 200 million people, is undernourished, at the same time, the region as a whole remains susceptible to frequent food crises and famines which are easily triggered by even the lightest of droughts, or floods, pests, economic downturns or conflicts (FAO, 2006), and which is also projected to be exacerbated by the impact of climate change. Studies indicate that while the world food supply does not appear to be seriously threatened by the projected global changes in climate, food insecurity in Africa will worsen and the population at the risk of hunger will increase both in terms of percentage and absolute numbers during the coming century (Downing, 1992; Fischer et. al., 1996).

According to FAO (2000) food insecurity is among the developmental problems facing Nigeria. Recent poverty assessment survey has shown that over 70% of the populations are living on less than a dollar per day and over 50% are food insecure (Babatunde, Olorunsanya and Adejola, 2008). The survey also revealed that poverty and food insecurity is especially higher in rural areas where majority of the people are resident and deriving livelihood from agriculture (National Bureau of Statistics, 2006).

Food and Agriculture Organization (FAO) in its State of Food Insecurity in the World, (2006) had indicated that Nigeria had about 12 million people reported as undernourished as at 2003. The proportion of the country's population depicted as undernourished had however been declining with the percentage reducing from about 13% from 1990 - 1992 to about 9% from 2001 - 2003. In fact, the FAO

report indicated that Nigeria is moving towards reaching the target of halving the undernourished population by 2015 set by the World Food Summit in November 1996. The report was explicit about policy interventions that may result in hunger reduction. Such policies must:

- a) Enhance productivity of small holder agriculture
- b) Create an environment conducive to private investment
- c) Combine poverty reduction with increased provision of global public good
- d) Make trade work for the poor by enhancing domestic competitiveness through policy and institutional reforms, and
- e) Coordinate domestic and international resources for agriculture and rural development.

In sub – Saharan Africa, there have been substantial increases in agricultural productivity in recent years (Adewujon, 2006; FAO, 2001). From an average of 100 around 1990, the index of agricultural productivity increased to 156 in Nigeria, to 142.9 in Burkina Faso and to 142 in Guinea in 1999. This notwithstanding; there are countries in the sub-region that saw a declining trend. Between 1988 and 1999, food production per capita actually declined in the Gambia, Guinea Bissau, Mauritania, Senegal and Sierra Leone (FAO, 2001; ADB, 2001/2002). According to Adewujon (2006), in 1998 the daily calorie supply per capita varied between 1,966 kilo calories in Niger Republic and 2,288 kilo calories in Nigeria; while the per capita daily supply of protein varied between 35 kilo calories in Liberia and 64 kilo calories in Nigeria. Furthermore, there was a general improvement in nutritional status in most countries with regard to total calorie intake per capita, during the period from 1970 to 1998. The notable exceptions were Liberia, Sierra Leone and Senegal. However, compared to other parts of the world, the standard of nutrition in West Africa is still very poor. While the depth of hunger, measured by the average dietary energy deficit of undernourished people, expressed in kilocalories per person per day varies from 110 to 160 in the developed countries, it varies in West Africa between 210 for Nigeria, and 390 for Liberia (FAO, 2000).

2.2 Nexus Between Climate Change and Food Security

Climatic variability and change are a major threat to food security in many regions of the developing world (Archer, 2003), like Nigeria, Sierra Leone and Liberia, which are largely dependent on rain- fed and labour intensive agricultural production because of the limited amount and uneven distribution of rainfall.

Hence, linking climate change impacts to food security is significant to understand the implications on economic growth. Climate change impact on food security, health and disaster management forms a complex labyrinth of network that has strong correlation with socio-economic growth and development. For instance, it has long been acknowledged that the health status of the population of any place or country influences development. It can be a limiting factor, as generally poor individual health can lower work capacity and productivity; this impact can severely restrict the growth of economies (Philips and Verhasselt, 1994). Similarly, poor diet as a result of food shortage leads to protein and vitamin deficiency which in turn results to Kwashiorkor, Marasmus, rickets and Berry-Berry sicknesses. In aggregate, this increases expenditure and low work capacity of poorer communities-further complicating local economic growth (Morlai, Mansaray and Vandy, 2010).

Climate change influence on food productivity is already impacting on humanity. Around 800 million people are currently at risk of hunger (approximately 12% of the world's population) (Parry, 2004), and malnutrition causes around 4 million deaths annually. Studies reveal that temperature rises of 2 to 30C will increase the people at risk of hunger, potentially by 30-200 million (if carbon fertilization effect is small) (Warren et. al., 2006). In fact temperature increase by 30C will put additional 250 – 550 million at risk – over half in Africa and Western Asia. However, if crop responses to CO₂ are stronger, the effects of warming on risk of hunger will be considerably smaller.

Poor communities are especially vulnerable to health outcomes resulting from the impact of climate change. Climate change is expected to alter the distribution and incidence of climate-related health impacts ranging from a reduction in cold-related deaths to greater mortality and illness associated with floods, droughts and heat stress. In particular, climate change will augment health disparities between rich and poor parts of the world. It will change the geographic incidence of illnesses such as malaria. Climatic change places a strain on the transport system needed to move produced food from the point of production to the point of consumption. During droughts, people are known to move to marginal lands, which may not have good access roads, and transporting food from such marginal farms poses a huge challenge. Drought reduces food availability, which decreases the rate of available food, and so the meal frequency decreases and

the balance of nutrients can be inadequate. This leads to malnutrition in children (Ziervogel, Nyong, Osman, Conde, Cortes and Downing, 2006).

The World Health Organization (WHO) estimates that climate change since the 1970s is already responsible for over 150,000 deaths each year through the increasing incidence of diarrhea, malaria and malnutrition (Table 1) predominantly, in Africa and other developing regions (McMichael et al, 2004). Just a 10C increase in global temperature above pre-industrial temperature could double annual deaths from climate change to at least 300,000 (Patz et. al, 2005). It has been an established fact that the distribution and abundance of disease vectors are closely linked to temperature and rainfall patterns, and will therefore be sensitive to changes in regional climate in a warmer world. For instance, changes to the mosquito distributions and abundance will have profound impacts on malaria prevalence in affected areas. Mosquitoes need access to stagnant water in order to breed, and adults need humid conditions for viability. Warmer temperatures enhance vector breeding and reduce the pathogen's maturation period within the vector organism. However, very high and dry conditions can reduce mosquito survival (WHO, 2003).

Table 1: Estimates of extra deaths (per million people) from climate change in 2000

Disease/ Illness	Annual Deaths	Climate Change Components (Death/ % total
Diarrhoeal Diseases	2.1 million	47,000/ 2%
Malnutrition	3.7 million	77,000/ 2%
Malaria	1.1 million	27,000/ 2%
Cardiovascular Disease	17.5 million	Data not provided on total heat/cold
HIV/AIDS	2.8 million	There is no climate change element here
Cancer	7.6 million	There is no climate change element here

Provided there is no change in malaria control efforts, an additional 40 to 60 million people in Africa could be exposed to malaria with just a 20C increase in temperature, increasing to 70 million to 80 million at 3-40C (Warren et al, 2006).

Also many diarrhea diseases vary seasonally, suggesting sensitivity to climate. Diarrhea diseases typically peak during the rainy season in tropical regions. Both floods and droughts increase the risk of diarrhea diseases. As stated by WHO (2003), major causes of diarrhea linked to heavy rainfall and contaminated water supplies are cholera, typhoid, hepatitis A, E-coli infections, shigella, etc. In 2006, WHO also estimated that 2% (47,000 deaths) of the total global annual death from diarrhea disease are climate-related.

One important thing to note also is that global climate change will be accompanied by increased frequency and intensity of heat waves, as well as warmer summers and milder winters. Extremes of temperature can kill. For instance, death rates during the winter season in temperate countries are 10-25% higher than those in the summer. In July 1995, a heat wave in Chicago, USA, caused 514 heat-related deaths (12 per 100,000 population) and 3,300 excess emergency admissions (WHO, 2003). Deaths resulting from thermal extreme are mostly seen in people with pre-existing disease, especially cardiovascular and respiratory disease. The very old and very young are most susceptible.

2.3 The Innovation System Perspectives

Innovation system approach emerged in the mid 1980s as a Schumpeterian perspective that drew significantly from the literature on evolutionary economics and system theory (Speilman, 2005). However, more comprehensive description was first set forth by Lundvall (1985) and applied to national comparisons of innovation system by Freeman (1987 and 1995), Nelson (1988 and 1993) and Edquist (1997) with empirical application focusing primarily on national industrial policy in Europe, Japan and several East Asia countries that were experiencing rapid industrialization during the 1980s. Metcalfe (1995) and Roseboom (2004) further confirmed that the concept of innovation system was first mentioned in the industrial literature in the late 1980s and later entered into the vocabulary of national and international policy makers in the industrialized world. In recent times the concept is gradually spilling into policy making circles in developing countries.

The Innovation System thinking represents a significant change from the conventional linear approach to research and development. It provides analytical framework that explore complex relationships among heterogeneous agents, social and economic institutions, and endogenously determined technological and institutional opportunities. It demonstrates the importance of studying innovation as a process in which knowledge is accumulated and applied by heterogeneous agents, through complex interactions that are conditioned by social and economic institutions (Agwu , Madukwe & Dimelu, 2008). According to Tugrul and Ajit (2002) it is not a simple aggregation of organizations as portrayed by some views, but a group of agents who operate like an invisible orchestra characterized by coherence, harmony and synergy. It is an interactive learning process in which enterprises/agents in interactions with each other, supported by organizations and institutions play key roles in bringing new products, new processes and new forms of organizations into social and economic use (Francis, 2006). The above definitions point to the three essential elements of innovation system namely:

1. The organizations and individuals involved in generating, diffusing, adapting and using knowledge.
2. The interactive learning that occurs when organizations engage in generating, diffusing, adapting and using new knowledge and the way in which this leads to innovation (new products, processes or services).
3. The institutions (rules, norms, conventions, regulations, traditions) that govern how these interactions and processes occur.

The concept of innovation system is built on several assumptions and integrates current trends in development in the analytical framework. They include the followings:

- a. Innovation takes place everywhere in the society and therefore bringing the diffuse element of a knowledge system and connecting them around common goals should promote economic development.
- b. Innovation is an interactive process and is embedded in the prevailing economic structure and this determines what is to be learnt and where innovation is going to take place.
- c. Innovation includes development, adaptation, imitation and the subsequent adoption of technology or application of new knowledge.
- d. Innovation takes place where there is continuous learning and opportunity to learn is a function of the intensity of interactions among agents.

- e. Heterogeneous agents are involved in innovation process, and formal research is a part of the whole innovation processes.
- f. Linkages and/or interaction among components of the system (knowledge generating, transfer and using agents) are as important as direct investment in R and D.
- g. Institutional context rather than technological change drives socio-economic development.
- h. In addition to technical change and novelty, innovation includes institutional, organizational and managerial knowledge.

Speilmen (2005) reported that analysis of innovation system may focus on the study of the system at different spatial (local, regional, national) at different sectoral levels (agriculture, environment) in relation to a given technological set (biotechnology, Information and Communications Technologies (ICTs)), focus on the material (particular goods or services) and temporary dimension that studies how relationships among agents change over time as result of knowledge flow.

Empirically, the application of the innovation system approach at different analytical dimensions such as local, national, regional, sectoral and others have been advanced in literature. For instance, its early application started with introducing the concepts such as institutional learning and change, and the relationships between innovation and institutional context in which innovations occur. According to Speilmen (2005), studies by Johnson and Segura Bonilla (2001), Clark, Sulaiman % Naik (2003) and Hall and Yoganand, (2001, 2002) introduced innovation system to the study of developing countries agriculture and agricultural research systems.

At the national and regional level the concept was adopted in sub-Saharan Africa by Samberg (2005), Roseboom (2004), Chema, Gilbert and Roseboom (2003), Peterson, Gijsbera and Wilks (2003), and Hall and Yoganand (2004), in Latin America by Vieira and Hartwich (2002) and in India by Hall et al (1998). Generally, most of its application across countries focused on institutional arrangements in research and innovation. For example Hall et al. (2002) emphasized on public-private interactions in agricultural research in India; and in south Asia and sub-Saharan Africa. Kangasmemi (2002) focused on producers organizations. Other scholarly studies focused on technologies opportunities, for example zero tillage

cultivation survey in Argentina conducted by Ekboir and Parallada (2002) which revealed social, and economic change that encouraged the diffusion of zero-tillage cultivation.

2.4 Application of Innovation System Concept to Agriculture and its Relevance

In the last decade, economic and technology strategies have shifted from national agricultural research system (NARS) to agricultural knowledge, and information system, (AKIS) and more recently to agricultural innovation system (AIS). The national agricultural research system perspective emerged in the late 1980s and tends towards linearity in movement of knowledge from known source (formal research) and flowing to some end users (the farmers). It further recognizes the public good nature of agricultural research, the role of the state in fostering technology change, and assumed that the social and economic context of technological change is exogenous and unchanging. By 1990s agricultural knowledge and information system (AKIS) evolved as a more sophisticated and less linear approach. Contrary to the focus of the NARS, it emphasizes linkages between research, education and extension in generating and fostering technological change. AKIS, however, is limited in its ability to conduct analysis beyond the nexus of the public sector and to consider the heterogeneity among agents, the institutional context that conditions their behaviours and the learning processes that determine their capacity to change (Speilman, 2005). In general, the system projects agricultural research system as the epicenter of innovation as opposed to the multiple knowledge bases put forward in innovation system perspective. The agricultural innovation system (AIS) comprises a far broader set of actors than the traditional agricultural research, extension and education agencies. Innovation takes place throughout the whole economy, and not all innovations have their origin in formal S & T nor are they all exclusively technical. This new perspective places more emphasis on the role of farmers, input suppliers, transporters, processors and markets in the innovation process. While each of the three system concepts has its own strengths and weaknesses, they can be seen as interlinked and cumulative: NARS focuses on the generation of knowledge, AKIS on the generation and diffusion of knowledge, and AIS on the generation, diffusion, and application of knowledge.

Agricultural innovation system evolved directly from the concept of national innovation system with the sectoral level as the unit of analysis. Adapting the

various definitions of innovation system, agricultural innovation system is defined as a set of agents that jointly and/or individually contribute to the development, diffusion and use of agriculture-related new technologies and that directly and/or indirectly influence the process of technological change in agriculture (Tugrul and Ajit, 2002). The organizations include research institutes, training and education institutions, credit institutions, policy and regulatory bodies, private consultants / NGOs, farmers, farmers' associations and public services delivery organizations. It emphasizes agricultural innovations and goes beyond previous knowledge system concepts by incorporating the goals of current reform measures, such as political decentralization, public sector alliances with the private sector, enabling private sector participation in advancing consensus approach to development and promoting demand-driven services. Besides, it captures the intricate relationships between diverse actors, processes of institutional learning and change, market and non-market institutions, public policy, poverty reduction and socioeconomic development. Figure 3 shows the possible linkages and relationships among diverse actors in an agricultural innovation system.

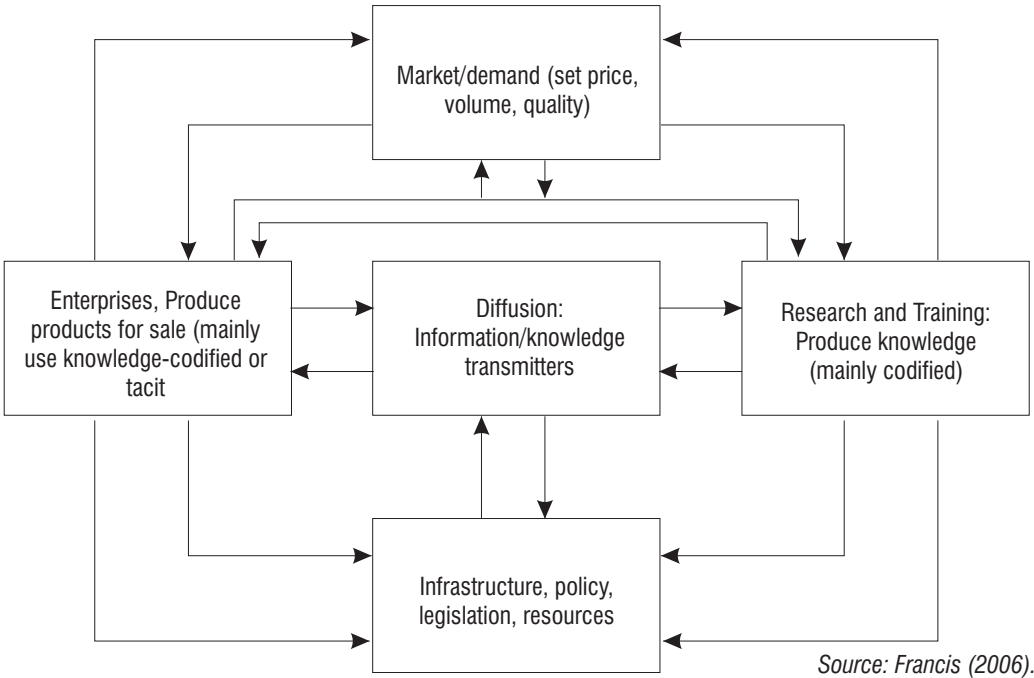


Figure 1: Elements of Agricultural Science Technology and Innovation (ASTI).

By adopting an AIS perspective, bigger issues come into focus than when adopting a more limited NARS or AKIS concept. By starting at the knowledge-application end, the question of why farmers innovate or why they don't becomes a major issue for debate and research. What are the constraints that hold them back? Is it the prices in the market, for example, or the lack of (or lack of access to) technology? Are farmers passive recipients of technology or do they actively search for innovations? What are the roles of input suppliers, cooperatives, traders, processors, NGOs, and government-extension services in technology diffusion? What are the relative strengths and weaknesses of each diffusion channel? How can they be improved and what can be done to reach more farmers? In answering these questions, we may learn that the most critical bottleneck is not the lack of available technology, but whatever prevents other factors from playing their often-far-more-crucial role. Hall and Yoganand (2002) highlighted that applying innovation system to agriculture in developing countries may provide the following features:

- a) It focuses on innovation as its organizing principles. Here the concept of innovation is used in its broad sense as the activities and processes associated with the generation, production, distribution, adaptation and use of new technical, institutional, organizational and managerial knowledge.
- b) Conceptualizes research as part of the wider process of innovation and extends its tentacle to identify actors and their scope, and the wide set of relationships in which research is embedded.
- c) Recognize the importance of both technology producers and technology users and acknowledge that their roles are both context specific and dynamic.
- d) It recognizes that the institutional context of the organizations involved (and particularly the wider environment that governs the nature of relationships) promotes dominant interests and determines the outcome of the system as a whole.
- e) It recognizes that innovation systems are social systems. It therefore focuses not only on the degree of connectivity between different elements but also on the learning and adaptive process that make systems dynamic and evolutionary.
- f) Matches better with the non-linear interactive concept of innovation.
- g) It is more holistic including the final step (application) in the innovation process and incorporates ideas from various disciplines.

- h) It stresses the importance of linkages among different actors.
- i) It is only a framework for analysis and planning and can draw on a large body of existing tools

Nonetheless, scholars have expressed concern as to the relevance of national innovation system concept for agriculture in developing countries. Issues raised include the fact that transplanting the insight from innovation studies in developed countries is against the evolutionary character of the national innovation system, which argues that innovation process and systems are context specific and historically determined. In contrast however, Johnson and Segura-Bonilla (2001) reporting from their experience in Central America favourably argues for the suitability of national innovation system for agriculture in developing countries buttressing the following points:

- 1) The national innovation system concept help to concentrate on what we believe is important in development as it takes departure in learning capabilities and focuses on innovation processes and their role in development.
- 2) It has a broad explanation of innovation as based on both research and in every day routine economic activities and in both high-tech and low-tech sectors.
- 3) Its growth factors are interacting and feeding upon each other. An interaction between firms, organizations and the public sector is the essence of the concept.
- 4) Institutions and production structures matter.
- 5) It is a flexible approach, which for example can direct emphasis on local, national, regional systems and their mutual interdependence.
- 6) Finally, it is an inherently comparative approach and compares the anatomy and changes of different innovation systems.

In addition, Spielman (2005) argued that innovation system perspective on agriculture is critical to shifting socio-economic research beyond technological change “induced” by the relative prices of land, labour and other production factors in agriculture; beyond the concept of linear technology transfers from industrialized to developing countries, from advanced and international research centres to national systems as engine of change. Spielman (2005) thus concluded that the application of innovation system analytical framework to

agriculture is embedded within the wider context of institutional change, change process, and answers certain questions that the linear, conventional research and systems are unable to address.

In other words, the innovation system approach offers a more holistic, multidisciplinary and comprehensive framework for analyzing innovation processes for climate change adaptation and food security, as well as the roles of science and technology actors and their interactions because of its emphasis on wider stakeholder participation, linkages and institutional context of innovation and processes. Whilst climate change is presenting specific additional challenges to development, it cannot be addressed in isolation. Unless concrete and urgent steps are undertaken to reduce vulnerability and enhance adaptive capacity of poor people, and unless these actions are integrated in national strategies for poverty eradication and sustainable development, it may be difficult to meet some MDGs by 2015.

3. Methodology

3.1 Area of Study

The study was carried out in three west African countries, namely: Nigeria, Sierra Leone and Liberia.

Nigeria is a federal constitutional republic comprising thirty-six states and one Federal Capital Territory. The country is located on the Gulf of Guinea, and has a total area of 923,768 km² (356,669 sqmi) and shares land borders with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north (Wikipedia, 2009). Nigeria is an important centre for biodiversity. It is widely believed that the areas surrounding Calabar, Cross River State, contain the world's largest diversity of butterflies. Nigeria's Delta region, home of the large oil industry, experiences serious oil spills and other environmental problems.

When dividing Nigeria by climatic regions, three regions, the far south, the far north, and the rest of the country emerge. The far south is defined by its tropical rainforest climate, where annual rainfall is 60 to 80 inches (1,524 to 2,032 mm) a year (). The far north is defined by its almost desert-like climate, where rain is less than 20 inches (508 mm) per year. The rest of the country, everything in between the far south and the far north, is savannah, and rainfall is between 20 and 60 inches (508 and 1,524 mm) per year (<http://www.uni.edu/gai/Nigeria/Background/Standard5.html>).

However, according to Federal Government of Nigeria report on drought management (FGN,1999), the Nigeria landmass of 923,766 km² is divided into seven ecological zones. This classification is based on the similarity of climatic elements and the type of vegetation that can be supported. These ecological

zones are the mangrove swamp, rainforest, montane forest /grassland, derived savannah, guinea savannah, Sudan savannah and the Sahel savannah. The mangrove swamp and rainforest zones, and part of derived savannah zone are found in the southern part of the country. These zones are characterized by high rainfall intensity, long wet season, dense vegetation, rugged topography and temperature range of 26 – 28°C and small farm holdings. Flood and water erosion are the major problem of crop production in these zones. A sizeable hectare of agricultural land and farmer's properties are lost yearly to water erosion in the eastern part of the country. Maize, cassava, yam and vegetables are the major crops grown in these zones.

The Republic of Sierra Leone is a country bordered by Guinea in the north, Liberia in the southeast, and the Atlantic Ocean in the southwest. Sierra Leone covers a total area of 71,740 km² (http://encarta.msn.com/encyclopedia_761563681/Sierra_Leone.html).

The national capital Freetown sits on a coastal peninsula, situated next to the Sierra Leone Harbor, the world's third largest natural harbour. The climate is tropical, with two seasons determining the agricultural cycle: the rainy season from May to November, and a dry season from December to May, which includes harmattan, when cool, dry winds blow in off the Sahara Desert and the night-time temperature can be as low as 16 °C (60.8 °F) (Blinker, 2006). Logging, mining, slash and burn, and deforestation for land conversion have dramatically diminished forested land in Sierra Leone since the 1980s. Until 2002, Sierra Leone lacked a forest management system due to a brutal civil war that caused tens of thousands of deaths. Deforestation rates have increased 7.3% since the end of the civil war. The Republic of Sierra Leone is composed of three provinces: the Northern Province, Southern province and the Eastern province and one other region called the Western Area. The provinces are further divided into 12 districts, and the districts are further divided into chiefdoms, except for the Western Area. The country is divided into four agro –climatic regions, namely, Coastal Plains, Rainforest, Savannah Woodland and Transitional Rainforest/Savannah Woodland.

Liberia has a tropical climate with two wet seasons in the southeast and one wet season from May to October for the rest of the country. The climate is

characterized by constant high temperatures and abundant rainfall. Annual mean temperature is 77,5 degree (22.5 degree). Annual mean temperature is 77,5 degree (22.5 degree). High humidity is common during the wet season and the prevailing winds are the NE and SW Monsoons as well as the Harmattan which is a dust laden wind from the Sahara Desert. Tornadoes are also common during the wet season. Average annual precipitation in Monrovia is 4,150 mm (163 inches) and average temperature ranges are from 22 degrees Celsius (72 degrees Fahrenheit) to 27 degrees Celsius (81 degrees Fahrenheit) all year. According to USAID Report (1999) Liberia has four distinct agro-ecological zones (AEZ), each having its unique and vegetation determined by rainfall pattern, altitude/topography, and temperature. The four major AETs are: (a) Coastal Plains; (b) Upper Highland Tropical Forest; (c) Lower Tropical Forest; and (d) Northern Savannah.

3.2 Data Collection Technique

Tools of participatory research namely: semi structured interview schedule, key informant interviews and focus group discussions (FGDs) were used in data collection. These instruments contained both open ended and semi structured questions.

Section A of the interview schedule elicited the farmers' profile; information concerning the respondents was collected. Section B identified the manpower and training needs of the farmers. Section C determined the respondent's awareness and knowledge of climate change phenomenon. Section D of the interview schedule sought for information on various innovative climate change adaptation measures used by respondents. Section E looked at the food security issues as it affects the respondents. Section F sought to elicit information on the intensity and trend of collaborations and networks with other stakeholders in the last five years. Section G sought to ascertain the performance of the farmers as regards climate change adaptation; while section H sought information on perception of respondents on domestic environments efforts to support climate change adaptation and food security issues.

3.3 Population and Sample Size

The population for this study included all types of farmers and major stakeholders in the field of agriculture/ food security and climate change issues in the three countries.

Respondents for this study were selected through a multistage sampling technique. In the first stage, thirteen states (namely: Abia, Adamawa, Borno, Cross Rivers, Delta, Enugu, Imo, Kogi, Ondo, Oyo, and Plateau states), were selected from the seven agro-ecological zones in Nigeria; In Sierra Leone, six districts (namely: Freetown Peninsula, Kailahun, Bo, Koinadugu, Moyamba and Free Town Coastal Plain districts) were selected from the four agro-climatic regions, while seven counties (namely: Nimba, Bong, Lofa, Grand Bassa, Margibi, Grand Cape Mount and Grand Gedeh) were selected from the four agro-climatic regions, in Liberia.

In the second stage, using the delineation by the different states' Agricultural Development Programmes (ADPs), two agricultural zones were randomly selected from each state giving a total of 26 agricultural zones in Nigeria. From each of the selected zones, 25 farming households were randomly selected for interview. This gave a total of 650 farming households from Nigeria. In Sierra Leone, a sample size of 70 farming households were randomly selected from each of the six districts giving a total of 420 households; while in Liberia 60 farming households were randomly selected from each of the counties surveyed, giving a total of 420 farming households.

The sample of farming households for this study was selected through a combination of strategies that recognized the social component of indigenous knowledge and practices. Criteria used for selection included age (for historical insight on indigenous knowledge), farming experience and interest. In all, a total of 1,490 farming households were interviewed. However, 1,424 (624 from Nigeria); (400 from Sierra Leone) and (400 from Liberia) completely filled interview schedules were used for analysis.

3.4 Measurement of Variables

Section A of the instruments elicited information on characteristics of the farming households. Variables measured under this section were: age (in years); years of farming experience (in years); sex; marital status; household size; ownership structure of farm and organization; main areas of focus in farming; available extension activities on climate change.

Section B of the interview schedule identified the available manpower and areas of specialization of respondents. Respondents were asked to name their highest

academic qualification and areas of interest. Respondents were asked if they have had any specialized training on climate change and/or whether their organizations provided opportunities for staff training on climate change adaptation by ticking against a response option of “Yes” or “No”. Respondents were also asked to indicate by ticking the appropriate response to show if their manpower strength was “Decreasing=1”, “Remained the same=2” or “Increased=3” over the last five years.

Section C farmers' instrument, sought to elicit the availability of overseas and / or local collaborators and whether these collaborations covered the issues of food security/climate change. Respondents were asked to indicate the existence of collaborations by ticking “Yes” or “No”, they were also asked to indicate the main areas of available collaborations. The intensity of collaboration was measured on a five point Likert-type scale of “None”, “Weak”, “Average”, “Strong” and “Very strong”, with nominal values of 1, 2, 3, 4 and 5, respectively. These values were added to obtain 15, which was further divided by 5 to get a value of 3.0, which was regarded as the mean. Collaborations with mean scores of less than 3.0 were regarded as showing weak intensity while those with mean scores of greater or equal to 3.0 were regarded as showing strong intensities. Respondents were also asked to indicate how collaborations with the various organizations have changed over the past five years. To measure this trend, each respondent was required to indicate his/her responses by ticking any of the options namely “Decreasing”, “Remained the same” and “Increasing”. Values assigned to these options were 1, 2 and 3; these values were summed to obtain 6.0 and was divided by 3 to obtain 2.0 which was regarded as the mean. Collaborations with mean scores of less than 2.0 were regarded as showing decreasing intensities over the past five years with, while those with mean scores of above 2.0 were regarded as showing increasing intensities over the past five years.

Section D looked at performance of the systems on the basis of innovation generations. Respondents' were asked to indicate by tick in if they had introduced any innovation into their farms in the past ten years. A list of innovation options was provided.

Section E elicited information on how the respondents' perceived the domestic environment support for climate change adaptation and food security. Respondents' were required to tick where appropriate, the available support in

favour of climate change adaptation and food security.

3.5 Data analysis

Data relating to farmers' profile, manpower and specialization were summarized using percentages and mean scores. Also, mean scores and trend analysis were used to summarize information on manpower trend, financing trend, budgetary trend climate change trend and intensity of collaborations among key stakeholders in the climate change /food security innovation system in the last five years.

4. Results & Discussion

The findings of the study are presented under the following headings:

1. Manpower and Specialization (Training, experience and skills) of surveyed Enterprises;
2. Intensity and Trends of Collaboration among key actors in the Climate Change and Food Security Innovation System;
3. Respondents' perception of household food security situations in their various countries;
4. Performance of the System on the basis of Innovation Generation and5. Respondents' Perception of Domestic Environment support for Climate Change Adaptation and Food Security

4.1 Manpower and Specialization (Training, Experience and Skills) of Surveyed Enterprises in Nigeria, Sierra Leone and Liberia

4.1.1 Enterprise manpower and specialization in Nigeria, Sierra Leone and Liberia

Educational qualification

Entries on Table 1 show that about 59% of the respondents in Sierra Leone, 38% of Liberian respondents and 14% of respondents from Nigeria had no formal education. The table further shows that 27.5%, 22.8% and 31.6% of the respondents from Nigeria, Sierra Leone and Liberia respectively completed secondary school while, 17.5% of the Nigerian respondents, 0.2% and 0.7% of respondents from Sierra Leone and Liberia had university education. On a general note, the data show that respondents from Nigeria were more literate than respondents from the other two countries.

Possession of Specialized Training on Climate Change Adaptation and/or Food Security Issues

From Table 2, it is evident that only 1.8% of respondents from Nigeria, 2.5% of respondents from Sierra Leone and 0.7% of respondents from Liberia possessed special training on climate change adaptation and food security issues. It can be inferred from the above findings that majority of the respondents across the three countries possessed no special training on climate change adaptation and on food security issues.

The Table further reveals that only about 2% of family members or farm workers from Nigeria, 1% from Sierra Leone and 0.2% from Liberia possessed a specialized training on climate change adaptation and food security issues. On provision of opportunities for training for staff or family members on climate change adaptation, 3.0% of respondents in Nigeria noted to have provided such opportunities, while 0.2% of respondents from both Sierra Leone and Liberia agreed to have also provided such opportunities for training. The implication for this is that there is so much work to be done by all stakeholders involved in climate change adaptation measures, if the issue of food security is to be achieved for the teeming population across Africa and the world at large. Capacity building at local, national and regional levels is vital to enable developing countries to adapt to climate change. It is important for stakeholders and fund raisers to recognise the role of universities, tertiary centres and centres of excellence (UNFCCC, 2007) in the training and retraining of farmers especially to boost their capacities or resilience in adapting to the changing climate.

Table 2: Distribution of rural households by training, experience and skills possessed

Training, experience and skills	Nigeria	Sierra Leone	Liberia
Highest academic qualification			
No formal education	14.3	59.0	37.5
Primary school	17.3	14.8	20.5
Secondary school	27.5	22.8	31.6
Certificate Course / Diploma	23.5	3.2	9.6
University education	17.5	0.2	0.7
Years of farming experience			
1-10	26.2	30.1	46.7
11-20	33.7	38.5	28.8
21-30	18.7	23.0	15.1
Above 31	21.4	8.7	9.4
Mean farming experience	21.55	17.62	15.04
Do you have specialized training in Climate Change adaptation and /or food Security issues			
Yes	1.8	2.5	0.7
No	98.2	97.5	99.3
Do any members of your family or farm workers have specialized training in Climate Change adaptation and /or food Security issues			
Yes	2.2	1.0	0.2
No	98.8	99.0	99.8
Does your farm provide opportunities for training staff / family members			
Yes	3.0	0.2	0.2
No	97.0	99.8	99.8

4.1.2 Trend in manpower structure within the farms over the past five years

Data in Table 3 and Figure 1 show a positive growth in the manpower strength of farms in Nigeria over the past five years, while Liberia had a positive growth up till 2008 and a downward trend in the 2009. However, Sierra Leone has had an unstable manpower trend (both upward and downward trend) over the past five years. The data on the Table further show that the manpower structure in the farms are dominated by farm labourers followed by management staff, with technical staff being the least in most cases.

Table 3: Trend in manpower structure within the farms over the past five years

Manpower Trend	2005			2006			2007		
	A	B	C	A	B	C	A	B	C
Management	1.32	2.13	1.12	1.37	2.05	1.16	1.39	2.05	1.21
No. of	0.85	0.00	1.21	0.84	0.00	1.21	0.96	0.00	1.25
Technical staff									
No. of labourers	1.89	2.19	1.36	1.92	2.01	1.40	1.80	2.17	1.58
/ family									
members									
Overall mean	1.35	1.44	1.23	1.38	1.35	1.26	1.38	1.41	1.35
Manpower Trend	2008			2009					
	A	B	C	A	B	C			
Management	1.43	1.98	1.24	1.46	1.99	1.25			
No. of	0.98	0.00	1.36	1.01	0.00	1.28			
Technical staff									
No. of labourers	1.86	2.15	1.71	1.91	2.27	1.72			
/ family									
members									
Overall mean	1.42	1.38	1.44	1.46	1.42	1.42			

A = Nigeria; B = Sierra Leone; C = Liberia

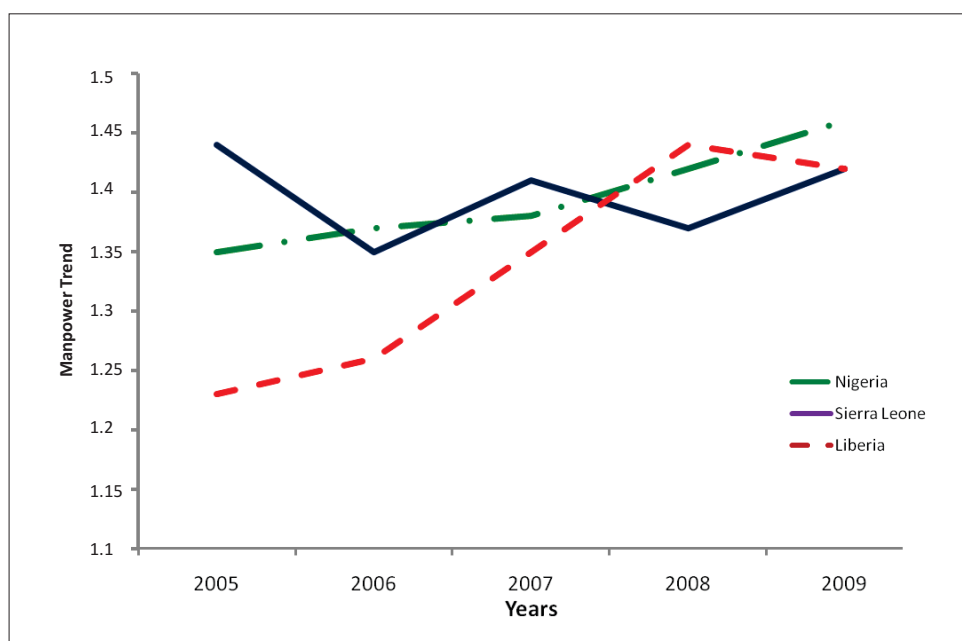


Figure 2: Trends in manpower structure of farms in Nigeria, Sierra Leone and Liberia over the past 5 years.

4.2 Intensity and Trends of Linkages / Collaboration among Key Actors in the Climate Change and Food Security Innovation System

4.2.1 Existence of local and overseas collaborations in the climate change and food security innovation system in Nigeria, Sierra Leone and Liberia

Data in Figure 2 indicated the non – existence of overseas linkages / collaboration in the area of climate change and food security among majority of the rural households across the three countries. The need for the existence of international collaborations cannot be under emphasized as effective international collaboration helps to enable training on, and structured dissemination of international and national activities on adaptation with a view to retaining experts working in their region and promoting the exchange of information between experts from key sensitive sectors (UNFCCC, 2007). The presence of local collaboration was higher in Nigeria (11.0 percent) than in Sierra Leone (2.0 percent) and Liberia (3.2 percent). Collaboration among actors in the climate change and food security innovation system is essential for relevance, capacity

building and increase innovative performance of the actors and the system in general. The extent of collaboration also suggests the level of involvement in climate change and food security activities.

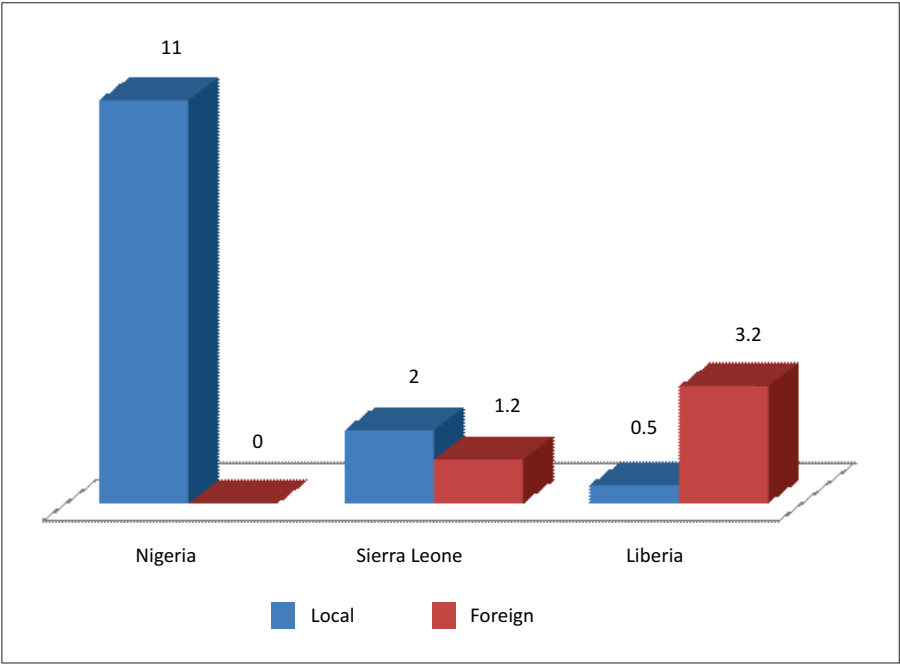


Figure 3: Farmers' reported existence of local and overseas collaborations on climate change and food security in Nigeria, Sierra Leone and Liberia

4.2.2 Intensity of linkages / collaborations between farmers and other actors in the climate change and food security innovation system in Nigeria, Sierra Leone and Liberia

Data on Table 4 reveal that the intensity of linkages / collaborations existing among actors in the enterprise domain, in the three countries, outweighs that with other domains, with higher collaborations existing among the small-scale farmers and farmers' associations. Nigeria tends to have higher linkages / collaborations among the actors in all the domains followed by Liberia in three out of the four major domains, while Sierra Leone only showed a higher intensity than Liberia in the area of linkage with policy makers. Collaboration among actors in the climate change and food security innovation system is essential for relevance, capacity building and increase innovative performance of the actors and the system in

general. The extent of collaboration also suggests the level of cohesion and/or involvement of the different actors in climate change and food security activities.

Table 4: Mean scores of intensity of linkages/collaborations between farmers and other actors in the climate change and food security innovation system

Collaborating Actors	Nigeria		Sierra Leone		Liberia	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
R & D Agencies Domain						
National agricultural research organization (e. g. NIHORT, FIRO, NRCRI, IAR, etc.)	2.14	1.17	1.07	0.25	1.09	0.34
Regional agricultural research organization / network	1.36	0.66	1.07	0.25	1.13	0.44
International agricultural research organization / network (e.g. IITA)	2.21	1.46	1.05	0.22	1.05	0.22
Universities	1.89	1.29	1.09	0.34	1.21	0.42
Overall mean	1.90	1.15	1.07	0.27	1.12	0.36
Policy Makers Domain						
National agricultural research council	1.42	0.62	1.14	0.35	1.06	0.30
Policy makers	1.66	1.13	1.19	0.39	1.21	0.41
Standard setting body (e. g. NAFDAC, SON, etc.)	2.06	1.06	1.03	0.18	1.01	0.09
Overall mean	1.71	0.94	1.12	0.31	1.09	0.27
Enterprise Domain						
Small – scale Farmers	2.93	1.08	1.19	0.38	1.42	0.70
Medium – large scale farmers	2.69	1.40	1.17	0.39	1.14	0.44
Farmers Association	2.88	1.35	1.22	0.44	1.25	0.70
Agricultural cooperatives	2.37	1.09	1.22	0.44	1.19	0.49
Financing/ credit/ venture capital	2.44	1.38	1.03	0.17	1.02	0.15
Input suppliers e.g. Seed companies	2.00	1.09	1.03	0.18	1.03	0.17
Agricultural machinery suppliers	1.41	0.69	1.05	0.23	1.04	0.30
Agricultural produce marketers	2.39	1.21	1.09	0.25	1.18	0.48
Consumers of agricultural products	2.81	1.32	1.08	0.21	1.18	0.54
Overall mean	2.44	1.18	1.13	0.30	1.16	0.44
Extension Agencies Domain						
Extension agencies (e. g. ADPs including private extension services)	1.98	1.17	1.12	0.37	1.25	0.46
Federal / State Ministries of Agriculture	1.84	0.91	1.11	0.39	1.33	0.47
Federal / State Ministries of Environment	2.10	1.12	1.05	0.22	1.28	0.45
Overall mean	1.97	1.07	1.09	0.33	1.29	0.46

4.2.3 Linkage trends between farmers and r & d institutions in the climate change and food security innovation system in Nigeria, Sierra Leone and Liberia

Figure 3 shows the perceived linkages existing between farmers and research and development institutions between 2005 and 2009 in the three countries. The data reveal a perceived increase in the trend of linkage between the farmers and

the R & D institutions in Nigeria between 2007 and 2009, with a linkage index of more than 2. On the other hand, data from Sierra Leone and Liberia show a stabilized trend in their linkage with R & D institutions over the past five years (with linkage index of less than 2 each), with Sierra Leone showing a higher intensity of linkage than Liberia. According to UNFCCC 2007, collaborations between educational, training and research institution would help to enable the formal exchange of experience and lessons learnt among different institutions of the different regions.

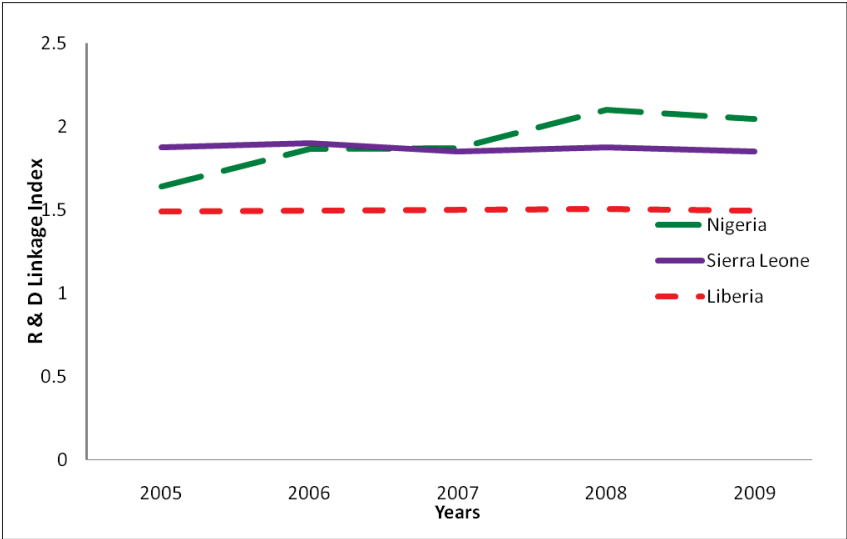


Figure 4: Percieved trend of linkage between farmers and R &D institutions in Nigeria, Sierra Leone and Liberia

4.2.4 Linkage trends between farmers and policy making bodies in the climate change and food security innovation system in Nigeria, Sierra Leone and Liberia

Data in Figure 4 show the linkage trend between farmers and policy making bodies in the different countries. The Figure shows a low linkage index of less than 2 for all the countries. However, data from Nigeria show an unstable trend between 2005 and 2008, with an upward trend since 2008. On the other hand, data from Sierra Leone and Liberia reveal a more stable linkage between the farmers and policy making bodies, with Sierra leone having a higher collaboration intersity than Liberia.

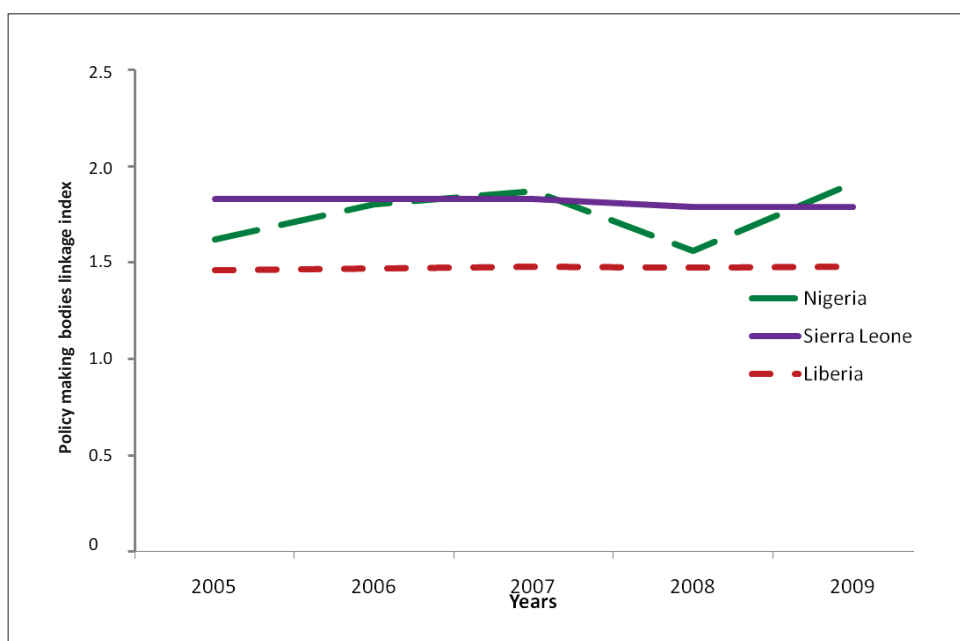


Figure 5: Percieved trend of linkage between farmers and policy making bodies in Nigeria, Sierra Leone and Liberia

4.2.5 Linkage trends among actors within the enterprise domain in the climate change and food security innovation system in Nigeria, Sierra Leone and Liberia

Data in Figure 5 show the linkage trend among key actors (which include Small – scale farmers, medium – large scale farmers, farmers association, agricultural cooperatives, financing/ credit/ venture capital, Input suppliers, agricultural machinery suppliers, agricultural produce marketers and consumers of agricultural products) within the enterprise domain. The data reveal a higher linkage index among these actors than with other actors in the climate change and food security innovation system across the three countries. The data also show an increasing linkage trend among these actors in Nigeria than in Sierra Leone and Liberia, with Sierra Leone showing a higher linkage intersity trend than Liberia.

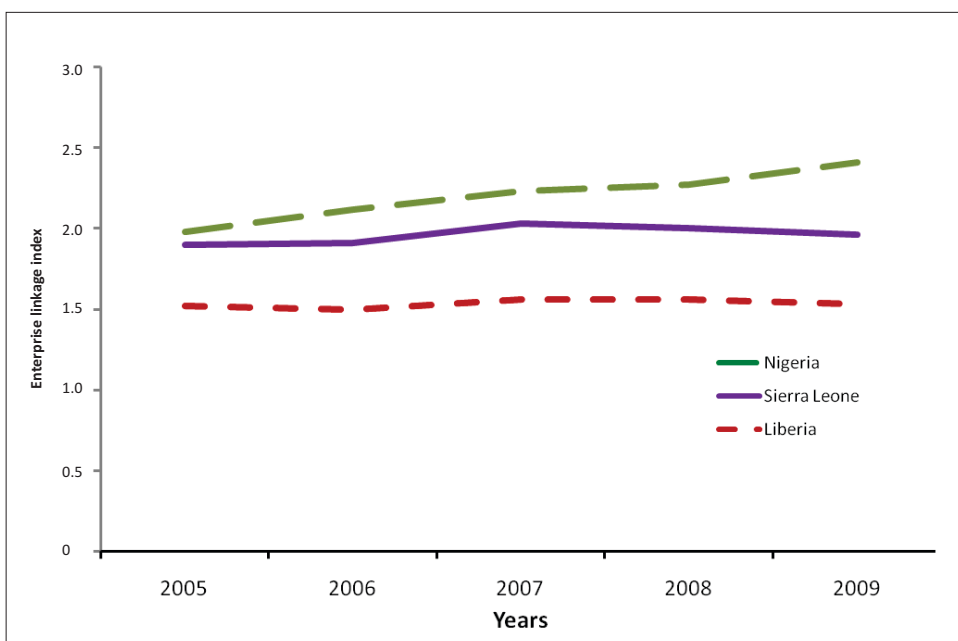


Figure 6: Percieved trend of linkage among actors in the enterprise domain in Nigeria, Sierra Leone and Liberia

4.2.6 Linkage trends between farmers and technology delivery institutions in the climate change and food security innovation system in Nigeria, Sierra Leone and Liberia

Figure 6 shows the linkage trends between farmers and the technology delivery institutions across the three countries. The data reveal an increasing higher linkage index (of more than 2) between farmers and the technology delivery institutions in Nigeria than in Sierra Leone and Liberia. On the other hand, data from Sierra Leone also shows an uneven increasing linkage trend over the past five years, with Liberia showing a more stable linkage trend between the farmers and technology delivery insitutions. The linkage index between farmers and the technology delivery insitutions in Sierra Leone and Liberia was less than 2.

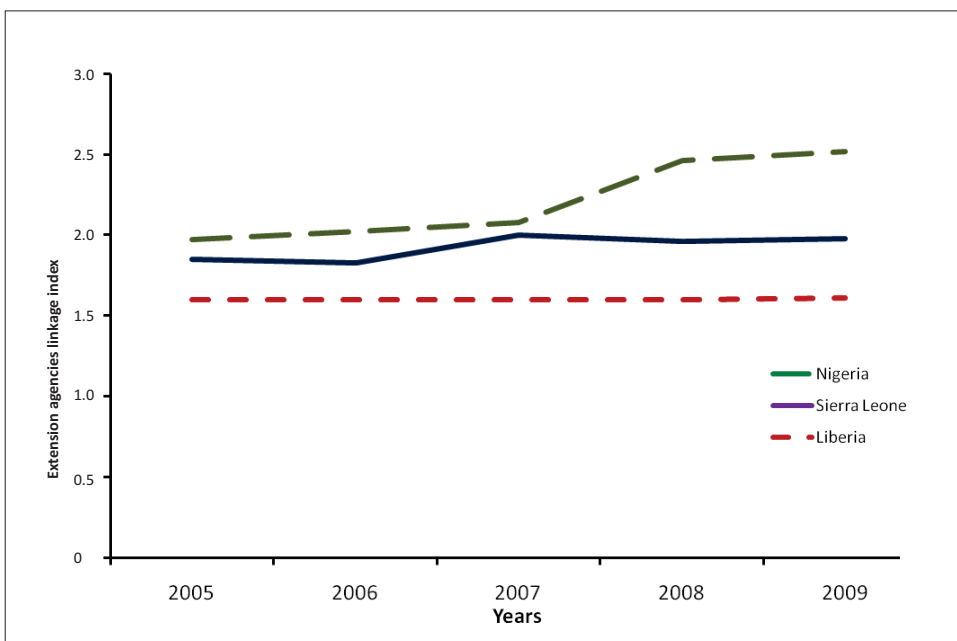


Figure 7: Linkage trends between farmers and technology delivery services in Nigeria, Sierra Leone and Liberia

4.3 Respondents' Perception of Household Current Food Situations

From Figure 7, it is evident that majority of the respondents from Nigeria (21.4%), Sierra Leone (24.5%) and Liberia (25.9%) perceived the current household food situations as a little worse than what it was previously. About 23% of respondents from Nigeria noted that the situation has remained the same, while 34% of rural households from Sierra Leone and 21% from Liberia noted also that the situation has not changed. Only 23.5% of rural households from Nigeria perceived their current situation to have improved a little better than it was previously. Respondents from Sierra Leone and Liberia respectively (33.8% and 21.2%), noted that there has also been a little improvement on their current food situation over time. This means that on an average note in the three countries under study, there have not been many changes in their current food situations. In order to beef up food security issues and self sufficiency in terms of food production in these countries, there is need to invest more in agricultural production so that the teeming populations food needs can be met appropriately.

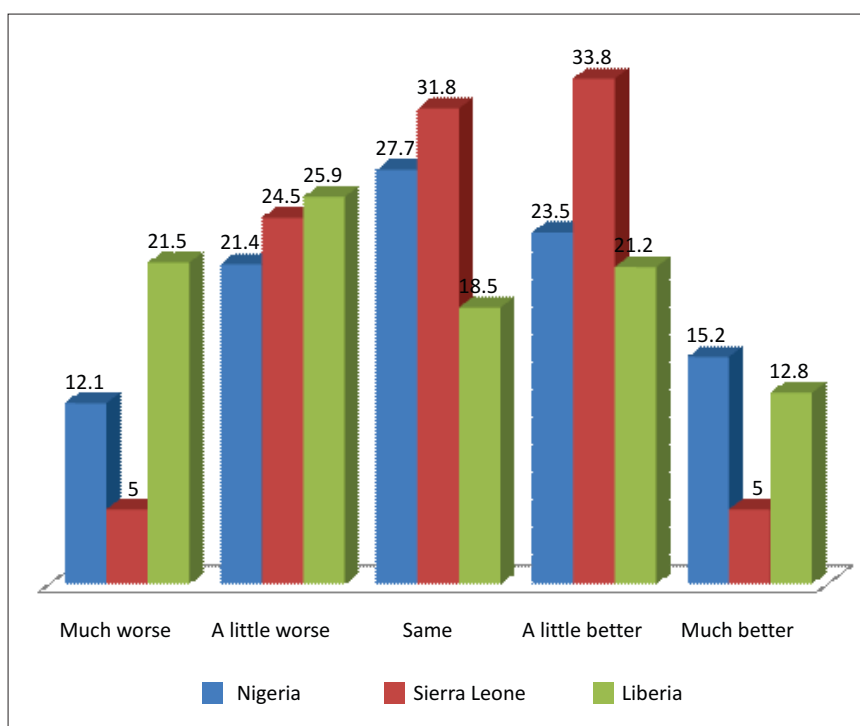


Figure 8: Distribution of respondents by perceived household current food situation in Nigeria, Sierra Leone and Liberia

4.4 Performance of the System on the Basis of Innovation Generation

Figure 8 reveals the types of innovation generated by enterprises over the past ten years in Nigeria, Sierra Leone and Liberia. In Nigeria, it is evident that new improved crop varieties / livestock breeds (38.5%), new information (25.2%), new markets for products (16.1%) and upgrading of machinery were the innovation generated over the past ten years. In Sierra Leone, the innovations generated included new markets for products (16.1%) and upgrading of machinery (13.3%). For Liberia, it is evident that over the past ten years, virtually nothing has been done in the area of generating innovations by the enterprises. From this findings, it is clear that innovations are been very poorly generated across the countries under study. Efforts should be channelled by the relevant government bodies e.g. Ministries of Agriculture, Research organizations etc to ensure that innovations are generated always so that the gap between the use of primitive methods in agricultural production and use of improved methods as found in other developed parts of the world can be bridged.

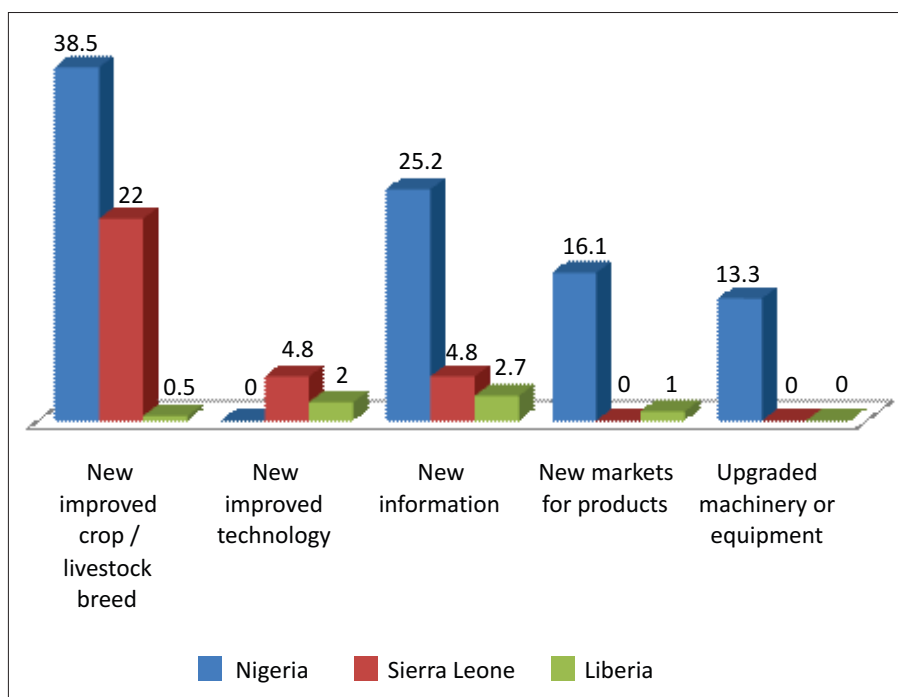


Figure 9: Types of innovations generated by enterprises over the last ten years in Nigeria, Sierra Leone and Liberia

4.5 Respondents' Perception of Domestic Environment Support for Climate Change Adaptation and Food Security

4.5.1 Respondents' perception of farms ability to adapt to changes in the local or international environment

Figure 9 reveals the respondents' perception on their farms ability to adapt to changes in their environment. Respondents from the three countries (Nigeria, Sierra Leone and Liberia respectively) noted that the ability of their farms to adapt to climate changes was not good (28.8%, 67.5% and 46.7%). On the average, 40.2%, 32.2% and 0.5% of the farmers from Nigeria, Sierra Leone and Liberia respectively agreed that their farms can adapt to these changes. This findings show that farms in these countries have very limited capacities to adapt to changes in the environment. This could probably be done to absence of policies on climate change or limited adaptive measures to the changing climate. There is need therefore to strengthen if any, existing policies on climate change adaptation and mitigation and to also reposition research institutes in the search for innovative adaptive measures to climate change effects.

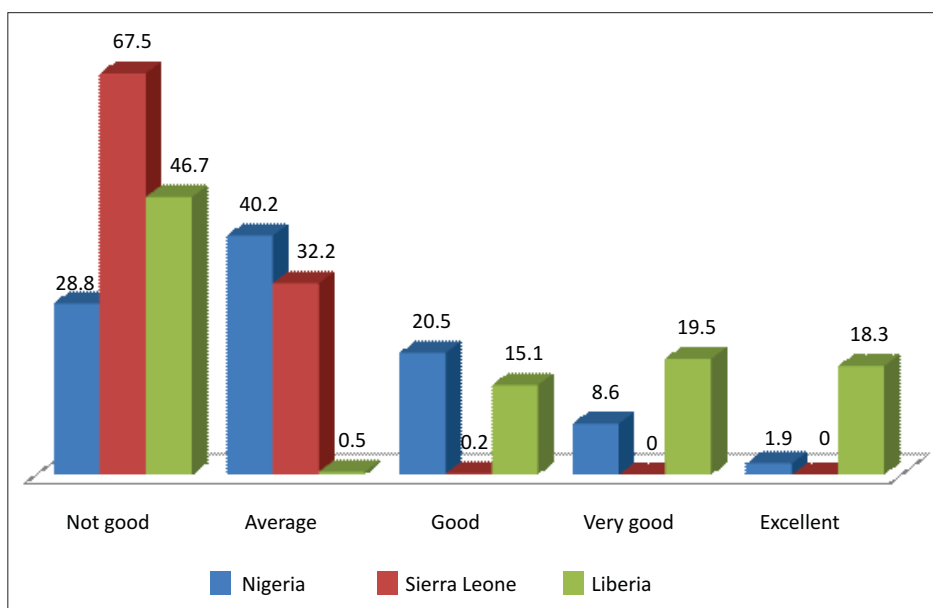


Figure 10: Percentage distribution of respondents by perceived ability of farms to adapt to change environment

4.5.2 Farmers perception on domestic support for climate change adaptation and food security in Nigeria, Sierra Leone and Liberia

It is evident from Table 5 that the respondents from the countries under study perceived domestic environments support for climate change adaptation and food security to be poor. The reason for this may be due to absence of mitigation measures and policies on climate change that cater for the rural poor in the fight against the dangerous consequences of climate change. Table 5: Farmers' perception of domestic environment support for climate change adaptation and food security in West Africa.

Table 5: Farmers' perception of domestic environment support for climate change adaptation and food security in West Africa

Statements	Nigeria		Sierra Leone		Liberia	
	Mean	SD	Mean	SD	Mean	SD
Government incentives for innovation	1.73	1.06	1.16	0.44	1.18	0.41
Availability of trained and experienced scientists	1.76	1.07	1.18	0.48	1.34	0.53
Local universities responsiveness to needs of the sector	1.60	1.23	1.15	0.65	1.19	0.39
National R & D organizations responsiveness to needs of the sector	1.39	0.78	1.07	0.26	1.06	0.27
Standard setting bodies and laboratory infrastructure	1.44	0.90	1.10	0.37	1.02	0.14
Intellectual property protection to support innovation	1.50	0.99	1.14	0.43	1.01	0.11
Availability of financing / venture capital	1.51	0.90	1.23	0.57	1.02	0.20
Information and telecommunication infrastructure	1.79	1.07	1.34	0.73	1.10	0.35
State of power supply	1.49	0.74	1.26	0.61	1.01	0.10
State of water supply	1.72	1.01	1.30	0.60	1.04	0.11
Road, rail, air and sea communication infrastructure	1.63	0.92	1.24	0.55	1.34	0.30
Supportive policies for science and technology and agriculture	1.61	0.98	1.16	0.48	1.07	0.68
Marketing infrastructure and supportive policy	1.59	0.94	1.12	0.37	1.24	0.35

5. Conclusion & Recommendations

5.1 Conclusion

The positive growth in manpower strength in Nigeria and Liberia should not be taken as the presence of special programmes or training in climate change adaptation in the countries under study. The absence of specific trainings on climate change adaptation and food security issues highlight the non – existence of foreign linkages/collaborations in the three countries. The world presently is advancing in the fight against the changing climate; the developing countries on the other hand need key into the fight now, else, they will be left behind to determine their own fate after the world must have gone ahead.

At the local level, there existed collaborations between farmers research and development, technology delivery institutions; but this collaboration did not reflect increase in innovations generated over a period of five years nor did it indicate a positive/increased perception of domestic environment support for climate change adaptation and food security by respondents. The weak domestic environment support for climate change adaptation and food security could possibly be a reason for poor ability of farms in the three countries studied to adapt to the changing climate.

5.2 Recommendation

Based on the major findings of this research work, the following recommendations were made:

1. There is need for a comprehensive information flow from research institutions to farmers and vice versa so that agricultural information developed or generated over time can be transferred to the end users. This

portrays the need to maintain good contact among the stakeholders (extension service delivery, research institutes and farmers).

2. Farmers should be exposed to specialized training on climate change adaptation and food security. This will prepare them adequately for coping with these varying changes in the climate.
3. There is need for improved technical and managerial strengths/skills of farmers to enhance their ability to manage effects of climate change.
4. There is need to strengthen collaborations between research, extension and farmers so that new and sustainable adaptive climate changes measures can be developed.
5. With increase in collaborations among research, extension and farmers, there will be improved agricultural production systems which will enhance the food security status of the countries.
6. Collaborations in the area of food security and climate change issues should be encourages between countries and overseas/foreign partners.
7. Domestic environment should be more proactive and also concretize their efforts in the support for climate change adaptation and food security issues by enacting policies aimed at mitigating climate change, encouraging the various stakeholders involved in agricultural production systems.
8. Systems/stakeholders involved in innovations generation should intensify efforts in order to ensure that there is continuous generation of innovations so that farmers do not experience any gap in the use of new information.

References

Archer, E.M. (2003). Identifying Undeserved End-User Groups in the Provision of Climate Information. Bull. Am. Meteorol. Soc. Vol.84. Pp. 1525-1532.

ADB (African Development Bank). (2002). Achieving the millennium development goals in Africa: Progress, prospects, and policy implications.

<http://www.afdb.org/knowledge/publications/pdf/global_poverty_report_jun_2002.pdf>.

Adejuwon, S. A. (2004). Impacts of Climate Variability and Climate Change on Crop Yields in Nigeria. Climate Change Unit, Department of Environmental Assessment; Federal Ministry of Environment, Abuja.

Agbam J.U. (2000). Agricultural research extension systems: An international perspective. Agricultural Research and Extension Network Paper No. 106. ODI London, UK: 7.

Agwu, A. E., Madukwe, M. C and Dimelu, M. U. (2008): Innovation system approach to agricultural development: Policy implications for agricultural extension delivery in Nigeria African Journal of Biotechnology. Vol. 7 (11), pp. 1604 - 1611.

Asenso-Okyere, K. and Davis, K. (2009). Knowledge and Innovation for Agricultural Development. IFPRI Policy Brief N0. 11

Babatunde, R.O. Omotesho, O. and Sholotan, O.S. (2007). Socio-Economic Characteristics and Food Security Status of Farming Households in Kwara State, North-Central Nigeria. Pakistan Journal of Nutrition, Vol. 6., Pp.49-58.

Babatunde, R.O, Olorusanya, E.O and Adejola, A.D. (2008) Assessment of Rural Household Poverty: Evidence from Southwestern Nigeria. American – Euroasia Journal of Agriculture and Environment Science, Vol. 3 (6). pp. 900-905.

Blinker, L. (2006), Country Environment Profile (Cep) Sierra Leone, Freetown, Sierra Leone: Consortium Parsons Brinckerhoff, P. 12.

Chema, S., Gilbert E., and J. Roseboom. (2003). A Review of Key Issues and Recent Experiences in Reforming Agricultural Research in Africa. Research Report 24. The Hague: ISNAR.

Clark N., Hall A., Sulaimain R., Naik G. (2003). Research as capacity building: The case of an NGO facilitated post-harvest innovation system for the Himalayan Hills. *World Development* 31(11): 1845- 1863.

Edquist C. (ed.) (1997). *System of Innovation Approaches: Technologies, Institutions and Organizations*. London: Pinter.

Egyir, I. S. (2009). The Plantain ASTI System in Ghana. Paper presented at the CTA Training of Trainers (ToT) Regional Workshop on Agricultural Science, Technology and Innovation (ASTI) Systems held at Sheraton Hotel and Towers, Abuja, Nigeria 24 – 28th August 2009.

Ekboir J., Parallada G. (2002). Public-private interactions and technology policy in innovation processes for zero tillage in Argentina. In Byerlee D, Echeverria R (eds.), *Agricultural Research policy in an Era of Privatization*. Oxon UK: CABI.

Federal Government of Nigeria (1999). *Combating Desertification and Mitigating the Effects of Drought in Nigeria. National Report on the Implementation of the United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification particularly in Africa (CCD)*, Federal Republic of Nigeria.

Freeman C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.

Freeman C (1995). The national innovation systems in historical perspective. *Cambr. J. Econ.* 19(1): 5-24.

Food and Agricultural Organization of the United Nations (FAO), (2000). *The State of Food and Agriculture*, Rome, Italy.

FAO (2001). *Global Forest Resources Assessment. Summary Report*. (www.fao.org/forest/fo/fra/index.jsp)

Francis, J. (2006). National Innovation System – Relevance for Development. Training of Trainers (TOT) Workshop for ACP Experts on Agricultural Science, Technology and Innovation (ASTI) Systems. 2nd – 6th October 2006 Accra, Ghana.

Hall, A., and Yoganand B. (2002). New institutional arrangements in agricultural R&D in Africa: Concepts and case studies. Paper presented at the Workshop on Targeting Agricultural Research for Development in the Semi- Arid Tropics of Sub-Saharan Africa held at Nairobi, Kenya, 1-3 July 2002.

Intergovernmental Panel on Climate Change (IPCC) (2007), Climate Change 2007, Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Annex I., M.L.

IPCC (2007). Adaptation and mitigation options. In (book section): Summary for Policymakers. In: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)). Print version: IPCC, Geneva, Switzerland. This version: IPCC website. ISBN 9291691224. Retrieved 2010 04-26.

Johnson B., Segura-Bonilla O. (2001). Innovation Systems and Developing Countries: Experiences from the SUDESCA Project. DRUID Working Paper No. 01-12. Aalborg: Danish Research Unit for Industrial Dynamics, University of Aalborg.

Lundvall B. (1985). Product Innovation and User-Producer Interaction. Aalborg, Denmark: Aalborg University Press.

McMichael, A.J et al (2004), “Climate Change: Comparative Quantification of Health Risks”, WHO, Geneva

Metcalfe JF (1995). The economic foundations of technology policy. In P. Stoneman (Ed.), Handbook of the Economics of Innovation and Technological Change :409-512. Oxford: Blackwell.

Morlai, T. A., Mansaray, P. and Vandy, G. (2010) Enhancing Agricultural Yields by Small-holder Farmers through Integrated Climate Change Adaptation Programme in Sierra Leone. Grant No.: ATPS CP0109/13.

National Bureau of Statistics (2006). Socio–Economic Survey on Nigeria, Abuja.

Partz, J.A et al (2005), “Impacts of Regional Climate Change on Human Health”, Nature 438:310-17.

Philips, D.R and Verhasselt, Y. (1994): 'Health and Development', Routledge.

Roseboom J. (2004). Adopting an Agricultural Innovation system perspective: Implication for ASARECA'S strategy ASARECA strategic planning paper No. 7:14.

Roling, N. (2007). Conceptual and methodological developments in innovation

Samberg, J. (2005). Systems of innovation theory and the changing architecture of agricultural research in Africa. Food Pol. 30: 21-41.

Schneider, S.H., S. Semenov, A. Patwardhan, I. Burton, C.H.D. Magadza, M. Oppenheimer, A.B. Pittock, A. Rahman, J.B. Smith, A. Suarez and F. Yamin (2007). Executive summary. In (book chapter): Chapter 19: Assessing Key Vulnerabilities and the Risk from Climate Change. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.). Print version: Cambridge University Press, Cambridge, UK. This version: IPCC website. ISBN 9780521880107. Retrieved 2010-04-06.

Smit, B., Burton, I., Klein, R. T. J. and Wandel, J. (2000). An anatomy of adaptation to climate change and variability. Climate Change 45:223–251.

Speilman, D. J. (2005). Innovation Systems Perspectives on Developing Country Agriculture: A Critical Review. ISNAR Discussion Paper 1: 10-40.

Todd, B. (2004). Africa's Food and Nutrition Survey Situation, where are we and how did we get here? IFPRI 2020 discussion paper 37. New York.

Tugrul T., Ajit M. (2002). The cotton supply chain in Azerbaijan. ISNAR. The Hague, Netherlands.

United Nations Agency for International Development (USAID) (1999). USAID Report on agricultural activities in Liberia.

United Nations Environmental Programme (UNEP) (2004). Desk study on the Environment in Liberia.

UNFCCC (2007). Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. Retrieved from , 2010.

Warren, R. et al (2006): 'Understanding the Regional Impacts of Climate Change'. Available at: http://www.tyndall.ac.uk/publications/working_papers/twp90.pdf

Ziervogel, G., Nyong, A., Osman, B., Conde, C., Cortes, S. and Downing, T. (2006). Climatic Variability and Change Implications for Household Food Security. AIACC working paper. No 20. An electronic publication of the AIACC project. Retrieved from: www.aiaccproject.org.

http://www.fao.org/docs/up/easypol/forum/31//31_REVIEW_OF_PAST_AGRICULTURAL_POLICIES_IN_SIERRA_LEONE-FINAL

http://en.wikipedia.org/wiki/Adaptation_to_global_warming



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