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AfricaInteract: Enabling research-to-policy dialogue for adaptation to climate change in Africa

Review of research and policies for climate change adaptation in the agriculture sector in West Africa

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About *AfricaInteract*

AfricaInteract (http://africainteract.coraf.org/en/) is a platform enabling research-to-policy dialogue for adaptation to climate change among a broad range of African stakeholders in sub-Saharan Africa. These include civil society, researchers, policy-makers, donors, and the private sector working on adaptation to climate change in the agriculture and health sectors as well as urban areas with water and gender as cross cutting issues. The overall objective of AfricaInteract is to develop a platform for the effective and efficient transfer of information to policy makers, with the ultimate aim of enhancing the resilience of vulnerable populations.

AfricaInteract is funded by the International Development Research Centre (IDRC) and coordinated by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD) under the auspices of the Forum for Agricultural Research in Africa (FARA). The regional focus of *AfricaInteract* is based on the Regional Economic Communities in the four sub regions of sub-Saharan Africa. Focal organizations coordinating regional activities are as follows: The Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) – East Africa; Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) – Southern Africa; Commission des Forets d'Afrique Centrale (COMIFAC) – Central Africa; and Energie-Environnement et Developpment (Enda) – West Africa.

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Acronyms and Abbreviations

ACMAD	African Centre of Meteorological Application for Development
AGRHYMET	Agro-Hydro-Meteorology
APSIM	Agricultural Production System Simulator
CA	Conservation Agriculture
CBO	Community Based Organisation
CILSS	Comité permanent Inter-État de Lutte contre la Sécheresse au Sahel
CIMMYT	International Maize and Wheat Improvement Center
CORAF/WECARD	Council for Agricultural Research and Development in West and Central Africa
CSRP	Subregional Commission for West Africa
DFID	Department for International Development
ECOWAP	Regional Agricultural Policy for West Africa
ECOWAS	Economic Community of West African States
ENDA-TM	Environnement et Développement du Tiers-Monde
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
FASDEC	Food and Agricultural Development Policy
GDP	Gross Domestic Product
GIZ	Gesellschaft für Internationale Zusammenarbeit
GEF	Global Environment Facility
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
ISFM	Integrated Soil Fertility Management
IWMI	International Water Management Institute
LGP	Length of Growing Period

NAPA	National Adaptation Programme of Action
NARES	National Agricultural Research and Extension System
NGO	Non-Governmental Organisation
ROPPA	Network of Farmers and Agricultural Producers Organizations of West Africa
SSA	Sub-Saharan Africa
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WAEMU	West African Economic and Monetary Union

Executive Summary

The agricultural sector in Africa is very vulnerable to climate change and there is need for strong support to research on adaptation to climate change. A desk study on the synthesis of research and policy on climate change in the agricultural sector in West Africa was undertaken as part of the activities of a platform for exchange between researchers and policymakers for adaptation to climate change (AfricaInteract), a project funded by the International Development Research Centre (IDRC) and coordinated by the Council for Agricultural Research and Development in West and Central Africa (CORAF/WECARD). The objective of the review is to enhance the knowledge base and support research-based policy formulation for climate change adaptation in the smallholder agricultural sector (crops, livestock, pastoral systems and fisheries) in West Africa. Peer reviewed journal papers, peer reviewed reports of CGIAR centres and international organisations, papers published in conference proceedings and consultancy reports were studied. Materials published from 1995 to 2013 were used for the report.

Even though recent research indicates that global increases in surface temperature may not be as severe as previously predicted, there is scientific evidence of climate change and impacts on agriculture. Furthermore, farmers in the region are increasingly becoming aware of the negative effects of climate change and variability as well as the associated extreme events on their production systems and livelihoods. The impact of climate change is moderated by factors such as access to land, inputs, credit and markets. General Circulation Models are being used to describe scenarios in the future that could result from climate change. While there is consistency between the models in predicting increases in temperatures of about 2^{0}C between 2000 and 2050, predictions for rainfall are less consistent.

Detrimental effects in all sectors, as measured by several parameters, are indicated if adaptation measures are not adopted. Decline in yields of 5-25 percent between 2000 and 2050 for rainfed crops can occur. Crop revenues are projected to drop by 17-32 percent by 2100. For livestock, climate change is likely to have serious impacts in terms of changes in land use; reduced availability of water; changes in productivity of forage, plant species composition and quality; and severity and distribution of animal diseases. Concerning fisheries, the likely impacts – especially in the coastal zone of West Africa where marine fisheries is a major economic activity – are increased floods, death of fish and salinisation of fresh waters. A decline of 21 percent in annual landed value, a 50 percent drop in fisheries related jobs and annual losses of $311 million by 2050 is predicted for West Africa. However, rising sea level also creates opportunities for aquaculture, for which production is under greater human control.

The length of growing period (LGP) for most crops is expected to drop below 90 days in some parts of West Africa. Declining LGP will negatively impact even drought-tolerant crops such as millet as well as water resources, forages and pastures, and therefore the productivity and livelihoods of smallholders in the crops, livestock, pastoral and fisheries sectors of agriculture. Without adaptation, gross domestic product (GDP) in West Africa is projected to decline by two to four percent by 2100.

Several forms of adaptation by smallholders have been documented including adoption of technological practices, on- and off-farm diversification, mobility of pastoralists and use of weather forecasts. Barriers to adaptation include low economic capacity, poor infrastructure and institutions, socio-cultural perspectives, conflicts between interested parties and poor knowledge dissemination pathways. Gender sensitivity is increasingly being incorporated into technology development, implementation and policy.

Several gaps or deficiencies in research approach, research output and policy formulation are outlined, such as inadequate decision support tools, limited use of participatory approaches and inadequate knowledge on adaptation strategies, including poorly developed index based insurance and weather forecasting. There is little knowledge on the link between climate change and trade or on adaptation to future climates. There is also poor understanding of policy processes and political factors influencing priorities and affecting adaptation.

At the regional and national levels, agricultural development policy documents indicate that considerations of climate change issues (no matter how brief) are most of the time mentioned in the plans, while the impact of climate change on the agricultural sector and adaptation are given consideration in climate adaptation policy documents. There is little to no mainstreaming of climate change policy into agricultural development policies. Key barriers to the uptake of research for policy formulation are limited or no involvement of policymakers in the research process, delays in reports reaching policymakers, ineffective forms of communicating research results, short term perspectives of politicians and linear research-policy linkage. Barriers to implementation of policy include weak institutions, lack of political will and inadequate funding.

A wide range of stakeholders are operating in the region. The Economic Community of West African States (ECOWAS) is providing leadership in formulating policy, aligned to the Comprehensive Africa Agriculture Development Programme (CAADP), at the regional level on adaptation to climate change. CORAF/WECARD, the African Centre of Meteorological Application for Development (ACMAD) and the Agro-Hydro-Meteorology

(AGRHYMET) Regional Centre work in concert with ECOWAS. The Basin Authorities have crucial roles in the mangement of transboundary waters. National governments and national agricultural research and extension systems (NARES) in each of the 15 ECOWAS states are key players. The NARES work in partnership with the CGIAR Centres, which are better capacitated to lead strategic research on climate smart agriculture. Non-governmental organisations (NGOs) such as Environnement et Développement du Tiers-Monde (ENDA-TM), World Vision and CARE are well placed to do important work at the grassroots level. IDRC, the UK Department for International Development (DFID), UN Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP) and Germany's Gesellschaft für Internationale Zusammenarbeit (GIZ) all play important roles as determined by their mandates, missions and strengths.

Good governance, sound macroeconomic policies and access to credit and markets are required for successful adaptation to climate change, as well as training and provision of extension services to farmers. Learning from success stories and on-farm testing of best bets to fit well into the biophysical and socioeconomic circumstances of smallholders is required. Climate-smart agriculture involving complementary adaptation and mitigation practices should be promoted. Stakeholders becoming familiar with participatory approaches in research and development and mainstreaming of adaptation to climate change into new projects on food security are opportunities worth embracing. Research findings should be made use of in developing agricultural sector policies through better use of informal dialogue; early involvement of policymakers, journalists and farmer associations; and joint stakeholder monitoring and evaluation of adaptation projects. Policies on climate adaptation should be gender sensitive and flexible to allow for continuing adjustments and improvements with a focus on strengthening adaptive capacity of farmers. There is need for substantial funding by governments and donors of adaptation projects in the agricultural sector and institutions dealing with adaptation to climate change.

1. Introduction

Background and motivation

Climate has been a source of threat to agriculture for decades in Africa. With climate change, the continent's vulnerability is increasing, making Africa one of the most exposed region in the world to climate change (Boko et al. 2007). There is evidence globally of changing climate, but there is uncertainty regarding the pace, extent, and impacts on sub-regions, nations, communities and sectors as well as adaptation to climate change. This uncertainty renders policymaking difficult and underscores the need for Africa to build its knowledge base to strengthen the capacity of regional and national institutions in developing the evidence base for addressing climate change adaptation issues. The International Development Research Centre (IDRC) provided the West and Central African Council for Agricultural Research and Development (CORAF/ WECARD) a grant for the establishment of a platform, AfricaInteract, for exchange between researchers and policymakers for adaptation to climate change in Africa. The project is being coordinated by CORAF/ WECARD in collaboration with partner organisations Forum for Agricultural Research in Africa (FARA), Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Food, Agriculture and Natural Resources Policy Network (FANRPAN), Commission des Forets d'Afrique Centrale (COMIFAC) and Enda Energie-Environnement-Développement. As part of the activities of AfricaInteract, CORAF/ WECARD commissioned a desk study for synthesis of research and policies related to climate change adaptation in the agricultural sector of West Africa. The overall objective of the review is to enhance the knowledge base and to support research-based policy formulation for climate change adaptation in the agricultural sector in West Africa. The Scope of Work is shown in Annex 1. The expected outputs are (1) a synthesis of research related to climate change in the agricultural sector accomplished, (2) research and policy gaps related to climate change adaptation in the agricultural sector identified and (3) key stakeholders and opportunities in climate change adaptation in the agricultural sector identified.

The key questions that guided the review were:

1. What is the role of climate change challenges in the context of the multiple challenges and opportunities facing the agriculture sector in West Africa?

2. What is the current state of knowledge on adaptation to climate change in the agricultural sector in West Africa?

3. What is the current state of knowledge on whether and how research findings are integrated in agriculture sector policies in West Africa?

4. What are the major gaps in research on adaptation to climate change in the agricultural sector?

5. What is needed to ensure that research findings are better integrated into agricultural sector policies in West Africa?

6. What is the current state of knowledge on the stakeholders involved with research and policy on adaptation to climate change in the agricultural sector in West Africa, and how stakeholder involvement could be improved?

The key crosscutting considerations were social differentiation and gender implications, implications for water resources, and focus on smallholders.

The remainder of the report is structured as follows. Section 2 sets out the methodology for the review and defines key concepts; section 3 is an overview of agriculture in West Africa; section 4 synthesises climate change adaptation research in the agricultural sector; section 5 deals with the state of knowledge of agricultural development policies and climate change adaptation policies and whether there is any integration; section 6 draws out the gaps in climate change adaptation research and policy in the agricultural sector; section 7 is on analysis of stakeholders and opportunities for collaboration; while section 8 outlines the conclusions and recommendations.

2. Concepts and Methodology

2.1 Methodology

A desktop study was carried out with access to information from a number of sources: Science Direct, OARE, AGORA, Google, IDRC Library and websites of organisations whose work is strongly related to climate change adaptation. The materials accessed were in the form of peer reviewed journal papers, peer reviewed reports of CGIAR centres and international organisations, papers published in conference proceedings and consultancy reports. Documents were also received from colleagues. Materials spanning the period 1995 to 2013 were used for the report. The review covered agriculture (crop farming, livestock, fisheries and agroforestry as related to climate change adaptation) for the whole of West Africa, but the sections on policy focused on Nigeria, Ghana and Senegal as case studies. Limitations were (1) the unavailability of 'grey literature' and adequate quantitative data and (2) the use of different methodologies by researchers. Together these prevented rigorous comparisons between countries.

2.2 Key concepts

Vulnerability

Vulnerability is the degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC 2007a).

Adaptation to climate change

According to IPCC (2007a), adaptation comprises initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaption exist, for example anticipatory and reactive; private and public; autonomous and planned. Adaptation is an iterative, dynamic, multiscale and multifactor process.

Coping strategies

Coping strategies are a set of actions that are used ex-post as reactions to the occurrence of a risk event. They are therefore used to survive the impacts of a disaster (CGIAR 2009). They are typically immediate short term responses which may break down under extreme stresses. The distinction between coping and adaptation may not always be clear-cut, as coping strategies can lead to adaptation, and thus the understanding of local coping strategies is an important element of planning for adaptation.

Resilience

Resilience is defined as the ability of a social or ecological system to absorb disturbance while retaining the same basic structure and ways of functioning, the capacity for self-organisation and the capacity to adapt to stress and change (IPCC 2007a). It also includes elements of transformation to better states.

Climate smart agriculture

Climate Smart Agriculture has been defined as agriculture that sustainably increases productivity, resilience (adaptation), reduces /removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals (FAO 2010). The concept encompasses improved practices along agricultural value chains, appropriate institutions and policy, adequate financing and investment. Coordination across agricultural subsectors such as crops, livestock, pastoralism, forestry as well as other sectors such as water and energy is required so as to capitalise on potential synergies, reduce trade-offs and optimise the use of natural resources and ecosystem services (FAO 2013).

3. Overview of Agriculture in West Africa

3.1 Key facts on the agricultural sector

3.1.1 Types of agricultural systems

The CORAF/WECARD member states in West Africa are broadly grouped geographically as Sahelian and Gulf of Guinea or Coastal countries. The former comprise Burkina Faso, Chad, Cape Verde, Gambia, Guinea Bissau, Mali, Niger and Senegal. Benin, Côte d'Ivoire, Ghana, Guinea, Liberia, Nigeria, Sierra Leone and Togo make up the Gulf of Guinea countries. However, more than one agroecological zone occurs within each country. Climate change may lead to changes in agroecological zonation, and options for adaptation to climate change vary by zone (Adebayo et al. 2011); hence the need for an understanding of their characteristics. Jalloh et al. (2011a) provide an overview of the agricultural zones in West Africa in terms of annual rainfall, length of growing season and soil types. The dominant farming systems are smallholder rainfed annual and perennial crop farming, livestock rearing and fisheries. The livestock systems are agro-pastoral, pastoral and crop-livestock (Thornton et al. 2007). Nomadic pastoralists and semi-nomadic pastoralists are referred to as transhumance pastoralists (Bare 2011). The fisheries sector is made up of marine fisheries, inland freshwater fisheries and inland aquaculture.

3.1.2 Key development indicators and trends

As a region, West Africa has a low human development status but the situation is improving, although there are significant differences between countries. According to the World Bank (2011a), the population of the region in 2009 was 306m and is growing at an average of 2.65 percent, with a range of 1.4 percent (Cape Verde) to 4.2 percent (Liberia). Population density is highly variable from a low 9 persons/km2 in Chad to a high 171 persons/km2 in Gambia. Life expectancy is low, averaging 55 years, while infant mortality is high at 133 per 1,000 births. Male literacy ranges from 51 percent in Guinea to 90 percent in Cape Verde, averaging 63 percent. Female literacy is lower, ranging from 23 percent in Chad to 80 percent in Cape Verde, with an average of 43 percent. Trade balance is negative for nearly all countries, implying that there is opportunity for improving regional trade. Average growth of GDP for West Africa was negative in 1980 and 1990, but since 2003 it has been positive, having ranged from three percent to 5.9 percent but dropped back to three percent in 2009. Between 2000 and 2009 it averaged 4.6 percent. Total real GDP rose from US$54bn in 1980 to US$131bn in 2009; average real GDP also rose from US$3.9bn in 1980 to $8.2bn in 2009, indicating an improving economic situation. The improvement has however not been good enough, and the first Millennium Development Goal is predicted to be met only after 2020 (IFPRI 2006). Agriculture's contribution to GDP, though declining in some countries, is very significant. It averaged 37 percent in 1980 and 25 percent in 2009. In 1980, it ranged from 20 percent in Senegal to 60 percent in Ghana; in 2009, it ranged from nine percent in Cape Verde to 51 percent in Sierra Leone. Food production in West Africa increased by 46 percent between 1983 and 2006 (Wiggins and Leturque 2010). Coastal zone countries have shown a higher agricultural productivity compared to the Sahelian countries (IFPRI 2006).

3.2 Climate change challenges

3.2.1 Key characteristics of the climate

Jalloh et al. (2013; 2011a; 2011b) summarised key characteristics of climate in West Africa: average annual rainfall of 250-550mm, length of growing period (LGP) of 60-90 days in the semi arid zone (Sahel); 550-900mm, LGP of 90-165 days in the Sudan savannah (dry subhumid); 900–1,500mm, LGP of 165-270 days in the Guinea savannah (subhumid); and 1,500–4,000mm, LGP of 270-365 days in the coastal zone (humid). Rainfall is subject to a high degree of spatial and seasonal variability because of the modulation of the seasonal cycle linked to position of and intensity of the Intertropical Convergence Zone (ITCZ) plus the magnitude of rainfall due to squall lines. As a result, seasonal characteristics of monsoon rainfall (onset, length and cessation of the rainy season), seasonal rainfall amount and the intra-seasonal distribution show high inter-annual variability. Sunshine is uniformly high, especially in the semi arid and arid zones (2,500- 3,000 hours per annum). Temperatures are high across the region, with mean annual temperature above 18°C; within ten degrees north and south of the equator mean annual temperature is about 26°C with a range of 1.7-2.8°C, the diurnal range being 5.5-8.5°C. Between latitude 10°N and the southern parts of the Sahara, mean monthly temperature can rise up to 30°C. Maximum temperatures range from 30-33°C in countries along the coast to 36-39°C in the Sahel.

3.2.2 Climate change projections for west africa

Climate change scenarios are uncertain for West Africa, especially when it comes to rainfall. Namara et al. (2011) reported that Global Circulation Models (GCMs) predict the start of the rainy season 1-2 months earlier than what is observed and that the observed Sahelian climate between 1961 and 1970 is at variance with the climates simulated by six GCMs of the Intergovernmental Panel on Climate Change (IPCC). The models show a marked rainy season almost throughout the year, along with a considerable bias (140-215mm/year) in annual aggregate rainfall estimates as compared to the observed data. There are also discrepancies between models; in the coastal zone, for example Sierra Leone, ECHAM4 and HADCM2 give rainfall values similar to observed values while CSIRO-TR and UKTR give lower values than observed (Jalloh et al. 2011b). The average rise in temperature between 1980-1999 and 2080-2099 is predicted to be +3°C in the coastal zone of West Africa, rising to +4°C in the western Saharan region (IPCC 2007b) – that is, 1.5 times the global average.[1] For the period 2000 to 2050, Nelson et al. (2010) reported lower temperature increases for West Africa (Table 1). Increase in intensity in rainfall per rainfall event is predicted across Niger, Mali and Burkina Faso, while Senegal and Southern Nigeria may see decreases in rainfall per rainy day (Ericksen et al. 2011).

3.2.3 Overview of the range of possible impacts of climate change in the agricultural sector

There are several likely effects of climate change on agriculture in the region. Details on impacts on a country basis are provided in chapter 4. Land suitable for cropping and length of growing period could change, withthe Sahelian zone potentially the hardest hit. The effects of rise in temperature and extreme rainfall events on crop yields will generally be negative and crops least tolerant to drought will suffer most. Farming calendars will change. Climate change will negatively affect livestock keeping and pastoralists through animal health, water resources and pasture. Cattle are likely to be affected more than small ruminants (goats and sheep) which are hardier and can forage better. Rise in sea level, more frequent storms and floods would degrade marine fisheries

Table 1: Temperature and precipitation scenarios for West Africa from General Circulation Models

GCM	Change in precipitation (%)	Change in precipitation (%)	Change in average minimum temperature (%)	Change in average maximum temperature (%)
CNRM-CM3	8.2	51.3	2.75	2.03
CSIRO MK30	1.9	11.7	2.05	1.73
ECHAM 5	1.3	7.9	2.21	1.98
MIROC 3.2	-1.7	-10.9	2.26	1.57

Source: Nelson et al. (2010)

resources; fish would die because of high temperatures and low oxygen concentration of waters. Climate change may entrain deforestation as more lands are brought under cultivation. Mangrove forest in coastal areas, some used for rice cultivation, may be damaged and breeding grounds for fisheries threatened. Flows of major rivers would fall, in a situation of increasing demand for irrigation water and population growth. Rise in sea level will lead to entry of salty water into agricultural lands and cause degradation. By 2100, farm sector losses due to climate change and variability could reduce regional GDP by two to four percent (Namara et al. 2011). These impacts would be moderated by local conditions and factors such as availability and accessibility of adaptation options, markets, migration of fishes, settlement patterns, institutions and policies.

3.2.4 Overview of key causes of vulnerability in the agricultural sector

Three major components/causes of vulnerability of agriculture in relation to climate change have been identified (Adebo and Ayelari 2011; Brooks et al. 2005): these are social, economic and environmental. Factors contributing to social vulnerability include rapid population growth, poverty, hunger, poor health, low levels of education, gender inequity, fragile and hazardous locations, frequent natural disasters, conflicts, poor national and local governance (including marginalisation of certain groups in decision making) and lack of access to resources and services including knowledge and technology. Economic vulnerability refers to the importance of agriculture in the national economy, trade and foreign exchange, aid and investments, international prices of agricultural commodities and inputs and production and consumption patterns. Regarding environmental vulnerability the concerns are for management of natural resources, such as land degradation, water scarcity, deforestation and the threat to biodiversity.

3.3 Implications of climate change for other key challenges (and opportunities) for the agricultural sector

3.3.1 Population growth and urbanisation

Although little is known about how climate change interacts with other drivers of change in agricultural systems and broad development trends (Thornton 2006), some generalisations about the implications of climate change can be made. Africa has the highest rate of urban growth in the world at four percent, compared to the global average of 2.5 percent. The urban population of Africa is projected to increase from 15 percent in 1950 to 62 percent of the total population in 2050 (UNDESA 2008; UNOWA 2007), and in West Africa from 132m in 1980 to 344m in 2020 (UNEP 2006). Even without climate change, a steady movement of people from rural to urban areas, many of them cities located in coastal areas, has been reported; about 50 percent of the population of West Africa now live in urban areas (UNOWA 2007). There is wide variability between countries in the rate of urbanisation; it ranges from 16 percent in Niger to 46 percent in Senegal. Coastal countries (where marine fisheries, urban agriculture and tourism are major economic activities), for example Senegal and The Gambia, tend to have higher urbanisation rates compared to landlocked countries (Hitimana et al. 2011). High population growth combined with low economic opportunities would increase vulnerability to climate change.

For example, Jallow et al. (1996) predicted that unless adaptive capacity is built and sustained, Banjul, the capital city of The Gambia, will be lost through erosion and inundation by 2046-2056, with a total of 42,000 persons displaced. Proactive adaptation to climate change would be an opportunity for citizens to benefit from the construction and maintenance of appropriate infrastructure by the government and municipal councils in coastal cities.

3.3.2 Water resources supply, demand and governance challenges

Detailed, up-to-date information on surface and underground water resources in sub-Saharan Africa (SSA) is scarce, but it is known that between 1971 and 1989 there was about a 30 percent reduction in the flow of the River Niger and a 60 percent reduction in that of the River Senegal and River Gambia (Namara et al. 2011; IUCN 2004). Water resources are much greater in the coastal compared to the Sahelian zone, but the former can still have problems of scarcity. Molden et al. (2007) distinguished between physical scarcity of water and economic scarcity and classified countries in the coastal zone as experiencing economic scarcity, that is, investments needed to keep up with growing water demand are constrained by financial, human or institutional capacity, although water is physically available.

Rainfed production (highly susceptible to climate change) accounts for about 75 percent or more of agricultural production across West Africa (Molden et al. 2007). However, only 15-30 percent of the rainfall is used as productive 'green water', that is water stored in the soil; in arid areas it may even be below ten percent (Shah et al. 2007). The substantial irrigation potentials of four major international water basins in West Africa, each providing water to four or more countries, are shown in Table 2.

Conflicting needs (dams for irrigation, energy and fishing) have contributed to the decline of the water resources of Lake Chad, illustrating that governance of the international river basins cannot be done unilaterally and requires cooperation of the countries sharing the waters.

Table 2: Major international water basins and irrigation potentials in West Africa

Basin	Countries	Area (km2)	Irrigation potential (ha)
Lake Chad	Cameroon, Chad, Niger, Nigeria	2,381,635	1,163,200
Niger	Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria	2,273,946	2,816,510
Senegal	Mali, Senegal, Guinea, Mauritania	483,181	420,000
Volta	Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Togo	394,196	1.487,000

Source: FAO (2005)

West African countries have varied challenges and opportunities in managing the impacts of climate change on water resources. In general, there are negative implications for the following: water quality (salinity in coastal areas); surface and groundwater systems (drop in level of lakes such as Lake Chad); precipitation; sea level rise; and the dynamics of oceans (Urama and Ozor 2010). A good example is Nigeria, which has an 800km low lying coastal belt running from Lagos to Calabar. Lagos, Africa's most populous city, is seriously affected by sea level rise. Flooding has resulted in the removal of beach fronts and sometimes adjacent roads, leading to acute traffic disruption and destruction of property, social conflicts and migration. In the semi arid areas such as Niger, pastoralists migrate in search of water and seasonal grazing, leading sometimes to conflicts with settled agrarian communities.

3.3.3 *Land resources*

Climate change can result in increased temperatures, reduced rainfall or excessive rainfall events leading to reduction in soil vegetative cover and serious water and wind erosion, and therefore soil crusting and land degradation. Lands in coastal areas are being degraded from the intrusion of salt water resulting from rise in sea levels. A reduction in agricultural production is the overall consequence.

Studies of the Niger Basin (NBA 2007, cited in Namara et al 2011) showed that threats to livelihoods and ecosystems through deterioration in the natural resource base have been posed by a combination of population growth, unsustainable resource use and deteriorating climatic conditions. A generalised nexus between climate change, desertification and biodiversity loss is illustrated in Figure 1. It is however often difficult to separate the effects of climate change from other stresses on land resources. Le et al. (2012) used response of green biomass to rainfall to separate areas of 'human induced declining biomass' from 'climate driven dynamics' in the Volta Basin. Their study, based on data sets covering 1982 to 2003, showed that land degradation occurred in eight percent of the Volta Basin (83 percent of which is Ghana and Burkina Faso), but that when atmospheric fertilisation (caused by CO_2 and NO_x in the atmosphere) is considered, up to 65 percent of land is degrading in terms of soil quality and vegetation productivity. The degradation was most severe in woodland (12,200 km^2), agricultural land (8,300 km^2), shrubland (7,300 km^2) and dense woodland (1600 km^2).

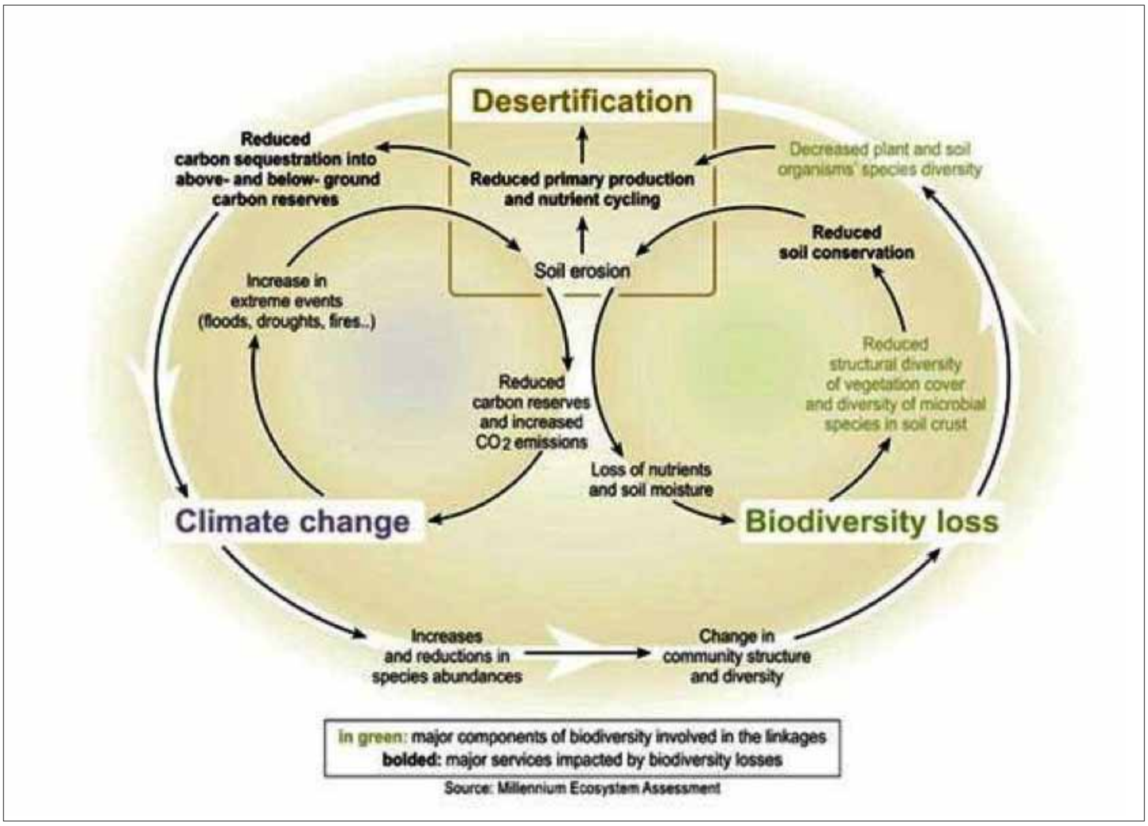
Soil nutrient depletion (soil mining) contributes to poor soil quality. Crasswell et al.(2004) reported moderate to high nutrient ($N+P_2O_5+K_2O$) losses in several countries in West Africa for the period 1996 to 1999 as follows: Mauritania, 58kg/ha; Burkina Faso, 54 kg/ha; Ghana, 53kg/ha; Nigeria, 50kg/ha; Mali, 45 kg/ha; and Senegal, Benin and Niger, about 38kg/ha each. Country level soil mining data, however, may hide hotspots requiring urgent attention (Dreschel and Gyiele 1999).

Using land for growing non-food crops such as biofuels, sometimes in the context of land grabbing by multinational companies from small scale farmers, presents opportunities for diversification in response to climate change and increased incomes of rural communities and increased national GDPs (Brittaine and Lutaladio 2010; Ngigi 2009), but caution is required because these crops may compete with food crops for land, nutrients and water, resulting in landless people and social unrest. Biofuel plants such as Jatropha are becoming popular in Mali and Ghana.

3.3.4 *Gender and agriculture*

Knowledge of the different opportunities and responsibilities of men and women in West African agriculture is relevant for a good understanding of climate change impacts and adaptation. The gender issues affect land and water management by smallholders and consequently adaptation to climate change in agriculture as follows: unequal access to land because traditional land tenure systems are generally male dominated even though women spend much time working on the land; gender inequity in decision-making concerning water resources management; low economic status of women and inadequate access to credit; high illiteracy levels; and inadequate access to information and technology (Ngigi 2009). Of concern in conservation agriculture involving

Figure 1. Generalised nexus between climate change, desertification and biodiversity loss



minimum tillage (an option for adapting to climate change) is the shift in labour use from land clearing and tillage (usual tasks of men) to weed control (normally done by women) (Giller et al. 2009).

Like other sectors of agriculture, there is gender disparity in marine fisheries. NEST (2011) reported marked gender differences in fishing communities in Nigeria, with women occupying lower-margin economic activities and excluded from decision-making.

However, increasing attention is being given to address gender needs in adaptation projects. Research in Burkina Faso suggests that adaptation options targeting women, such as diversification into income generating activities involving vegetable production, poultry raising and small plot agro-pastoral farming, have addressed women's practical needs but not their strategic interests, such as access to and control over capital, income earned and decision making power (Gonzalez et al. 2011). Also, Weeratunge and Snyder (2009) observed that while gender is taken into consideration in some analysis of employment in fisheries and aquaculture in Africa, the treatment is usually descriptive of gender division of labour and does not go far enough. The development of a tool kit in Nigeria on gender and climate change adaptation (NEST 2011) and a training guide by FAO (2012) are other examples of the importance being given to gender implications of climate change in agriculture.

3.3.5 Youth and future farmers

Although in West Africa youth aged 30 or below make up 60 percent of the total population (UNOWA 2007), they are among the marginalised segments with regards to access to resources necessary for adaptation to climate change. In a study of fish farmers in Ondo and Ekiti states of Nigeria, Adebo and Ayelari (2011) reported that most of the fish farmers are young literate males, relying mainly on personal savings and money borrowed from friends and relatives. They find it difficult to cope with the unprecedented change in weather manifested as heavy downpours and flooding which reduce productivity. The migration of youth from rural to urban and mining areas is leading to labour shortage for agriculture in rural areas. Continued degradation of the environment and low productivity of enterprises due to climate change and other stresses will make all sectors of farming unattractive to prospective farmers. The lack of knowledge on how to adapt to future climates also increases the risks associated with farming for future farmers.

3.3.6 Use of local and indigenous knowledge and its combination with scientific knowledge

The term indigenous knowledge refers to knowledge systems developed by a community in a particular place over time, as opposed to scientific knowledge (Ajibade and Shokemi 2003). West African crop farmers, agro-pastoralists and pastoralists have coped with changing environments, sometimes due to climate variability. Despite some successes of indigenous coping strategies, there is evidence of breakdown because of a rapidly changing environment in terms of land use, socio-political and cultural stresses (IPCC 2007b). Dieye and Roy (2012) reported from a case study in the semi arid north of Senegal that although crop farmers and pastoralists have a clear appreciation of changes in natural resources, few new adaptive/coping strategies to climate change beyond traditional ones were envisaged. Traditional responses may not be adequate at present and especially in the future to climate change stresses, and may even lead to unsustainable responses in the longer term (DFID 2004). Rather than utilising indigenous knowledge on its own, or discarding it completely, its incorporation into climate change policies can lead to the development of effective adaptation strategies that are cost effective and sustainable. Indigenous knowledge provides suitable entry points for research and development on climate change adaptation practices (FAO 2008). Examples of use of indigenous knowledge as options for adaptation in pastoralism and fisheries are provided in sections 4.33 and 4.43.

3.3.7 Climate change and conflicts

The underlying causes of conflicts are complex and may be political and social, but climate change may contribute to conflicts between states and within states because of competition for water use if increased supply to meet growing demand cannot be assured (Urama and Ozor 2010; Niasse 2005). When water supply is short, pastoralists come into conflict with crop farmers. Such conflicts can be so serious that they result in deaths on both sides, as happened in Nigeria between the Fulani cattle herders and sedentary crop farmers over grazing land and water bodies. These kinds of conflicts amongst smallholders are frequent in other parts of the semi arid zone of West Africa. The drying up of Lake Chad, to which climate change has contributed strongly, has led to confrontations between fishermen, farmers, cattle herders, indigene Chadians and Chadians from elsewhere (Urama and Ozor 2010; Associated Press 2006). Land degradation through salinisation and consequent shortage of land might also encourage conflicts. Sayne (2011) however observed that attributing conflicts to climate change in Nigeria calls for caution because the scientific, social, economic and political implications of changing climate in the country are poorly understood. Unsolved conflicts would certainly increase vulnerability to climate change.

4. Vulnerability and Adaptation of Agricultural Systems

4.1 Vulnerability and adaptation of crop farming systems

4.1.1 Scientific evidence for implications of climate change for crop farming in a multi stressor context

Vulnerability to climate change is a state that is governed not only by climate change itself but by multiple processes and stressors (CGIAR 2009). Poverty, access to land, soil nutrient mining, use of low yielding crop varieties susceptible to pests and diseases, high post harvest losses and poor access to credit and markets are all challenges facing the smallholder. The relative contribution of climate change to low agricultural productivity, taking all the other challenges into consideration, is difficult to quantitatively assess.

Several GCMs including CSIRO-MK 3.0, MIROC 3.2, CNRM-CM 3 and ECHAM 5 have been used to outline scenarios of climate change by region, broad agroecology and country. While increasing temperatures in the Sahel are clearly indicated by the GCMs, there is some uncertainty in rainfall related projections for West Africa (Mertz et al. 2009; SWAC/OECD 2007). This uncertainty carries over when crop simulation models are integrated into GCM scenarios.

The results of modelling studies have been reported for millet, sorghum, maize, rice, groundnut, beans, cassava, cocoyam and cotton in West Africa (for example, Jalloh et al. 2013; Nelson et al. 2010; Sarr et al. 2007; Sagoe 2006; Huq and Reid 2005). Roudier et al. (2011), from an analysis of 16 modelling studies, showed a wide spread of yield changes ranging from -50 percent to +90 percent, with a median of -11 percent for West Africa. The predicted impact is larger in the northern Sudano-Sahelian countries (-18 percent) than in the southern Guinea countries (-13 percent) and the negative impacts on crop productivity increase in severity as warming intensifies. The negative impact on yield was attributed mainly to projected temperature increases, although rainfall (uncertain to predict) has the potential to reduce or increase this impact. Apart from temperature and rainfall, increases in the concentration of carbon

Table 3: Changes in area, yield and production for maize in West Africa under A1B Scenario

Country	2010			2050					
	Yield (t/ha)	Area (thousands of ha)	Production (t)	Yield (t/ha)		Area (thousands of ha)		Production (t)	
				Min	Max	Min	Max	Min	Max
Benin	1.08	748	810	1.87	2.08	886	929	1,660	1,911
Burkina Faso	1.41	458	646	2.20	2.61	408	424	900	1,105
Côte d'Ivoire	1.11	745	824	1.98	2.09	787	825	1,601	1,661
Gambia	1.93	16	31	2.55	2.73	17	18	43	48
Ghana	1.52	825	1,255	2.44	2.59	945	990	2,311	2,538
Guinea	1.15	138	159	2.14	2.29	161	168	344	386
Guinea Bissau	1.90	16	31	2.03	2.15	18	19	37	41
Mali	1.39	381	531	2.31	2.61	304	313	703	803
Niger	0.78	4	3	1.57	1.69	1	2	2	3
Nigeria	1.29	4,696	6,070	1.74	1.90	4,405	4,829	7,664	9,181
Senegal	1.98	132	263	2.76	2.90	144	151	398	439
Sierra Leone	1.92	10	20	2.98	3.10	10	11	30	33
Togo	1.11	477	531	1.78	2.01	318	334	567	661

Source: Based on analysis conducted for Nelson et al. (2010) and Jalloh et al. (2013)
NOTE: A1B scenario assumes fast economic growth, a population that peaks in mid-century and the development of new and efficient technologies, along with the balanced use of energy resources.

dioxide in the atmosphere as a result of climate change may directly impact upon yield levels of certain crops. Ongoing impacts on the ground are reflected in the adaptation strategies being promoted by stakeholders and adopted by farmers (sections 4.13. 4.23, 4.33 and 4.43 of this report).

There can be problems when comparisons are made between results of modelling studies involving GCMs of impacts of climate change on crop yields because of different time horizons, methodological approaches, climate projections and crop parameters.

The recent study by Jalloh et al. (2013) where the same models and parameters are employed for all 11 countries studied in West Africa is therefore important. The models predict significant decline in crop yields between 2000 and 2050 if no adaptation measures are undertaken. CSIRO and MIROC models predict a general decrease in maize yields of 5-25 percent over baseline in most parts of countries which lie on the southern coast of West Africa and a yield increase of 5-25 percent in the Sahel zone. Both models indicate a yield decline in the northernmost parts of Mali, Burkina Faso and Nigeria. Table 3 shows predicted production changes by country, assuming increased use of inputs (including improved varieties) and improved management practices. The models predict 5-25 percent drop in yields of sorghum across most parts of West Africa, with yield losses greater than 25 percent in some parts of Togo, Benin and adjacent areas of Ghana and Nigeria. Yields of rainfed rice are predicted to decline by 5-25 percent in most parts of Côte d'Ivoire, Ghana and Togo based on CSIRO and MIROC and in Nigeria based on CSIRO. For groundnut, the two models predict decreases in yields of 5-25 percent across most parts of West Africa but lower yield changes in Sierra Leone, Liberia and Guinea. Yield increases of 5-25 percent are predicted for some parts of northern Côte d'Ivoire, Ghana, Burkina Faso and Nigeria.

Apart from crop yields, impacts of climate change have been assessed in terms of crop revenues and length of growing period. Kurukulasuriya and Mendelsohn (2008) estimated a multinomial logit to predict the probability of agroecological zones. A model was then used to calculate baseline values of cropland and revenues and estimates of impacts of climate change on them made. They reported reduction in crop revenue in West Africa of between US$9.2 bn (-17 percent) and US$17.4 bn (-32 percent) for the Parallel Climate model (PCM) and the Canadian Climate Centre model (CCC) respectively by 2100. Jones and Thornton (2009) studied arid and semi arid zones of sub-Saharan Africa including West Africa and found that under scenarios in which the emission of carbon is high the number of reliable growing days (RGD) would drop below 90 days for several hectares of marginalised land. For a low emission scenario the acreage would reduce by 50 percent. The significance of the finding is that if RGD drops below 90, rainfall may be so inadequate that maize cultivation, with the common varieties, will not be possible and even the cultivation of millet will be difficult.

4.1.2 *Options for strengthening adaptive capacity and supporting crop farming*

Research approach and options

The International Development Research Centre (IDRC) and the UK Department for International Development (DFID) through their shared programme Climate Change Adaptation in Africa (CCAA) have reported success stories in the use in West Africa of Participatory Action Research as a tool for strengthening smallholders' indigenous adaptive capacity to climate change. The approach favours joint identification of climate change related problems and probable solutions, practical action and shared learning among researchers and many of those most affected – farmers, village elders, meteorologists, agronomists, academics, local leaders, government officials and civil society organisations (Gologo 2012). Another example of a participatory approach being used in adaptation to climate change in West Africa is the testing, with UN Food and Agriculture Organisation (FAO) support, of climate change best practices and technologies in Farmers Field Schools in Burkina Faso (GEF 2012,) and in Liberia (Government of Liberia 2013). Nevertheless, the largest part of the knowledge obtained on best bet technological options has been through conventional research methods.

A number of research and development practitioners have advocated the use of one or more of the available adaptation options which are in accord with the aspirations of the National Adaptation Programmes of Action (NAPAs) and national documents, to improve the response of farmers to climate change and variability and support crop farming (Farauta et al. 2012; Adesina and Odekunle 2011; World Bank 2011b; Below et al 2010; Ngigi 2009; Woodfine 2009; Harrington et al. 2008; Howden et al. 2007; Sagoe 2006). Strengthening capacity of farmers involves making adaptation options available to them (through research and development) and accessible by them as well as providing training and extension services and access to credit (Zorom et al. 2013) and markets. They include use of stress tolerant varieties; adjustment of cropping calendars and cropping systems; crop residue management; integrated soil fertility management; conservation agriculture; soil and water management; agroforestry; biotechnology; reduction of post harvest losses; value addition; weather forecasting and early warning systems; insurance for producers; and diversification and migration. Examples of research findings related to climate change adaptation in West Africa on some of these options are presented in the following sub-sections.

Improved varieties tolerant to climate change stresses

Plant breeders at AfricaRice, the Africa Rice Centre, have identified several traits that contribute to drought tolerance and rice breeding materials, including some found in the indigenous African rice *Oryzae glaberrima*. Molecular markers are being identified that tag genes that contribute to drought tolerance so as to speed up development of drought tolerant lines. Gene pools of wild or weedy rice species O. *barthii* and O. *longistamata* are also being exploited (Manneh et al. 2007). Africa Rice has combined the useful traits of O. *sativa* and O. *glaberrima* and developed interspecific lines (NERICAs). Many are weed competitive, tolerant to major pests and diseases, early maturing and high yielding. Rice varieties with some tolerance to salinity are available (Rhodes 2005). The International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA) have developed and released in West Africa several new maize hybrids and open pollinated varieties which are drought tolerant and produce 20-50 percent higher yields than other maize varieties under drought conditions (CGIAR 2010; CIMMYT 2008). To improve adoption rate by local communities, research institutions throughout West Africa where IITA and AfricaRice operate now engage in participatory varietal selection, wherein farmers are actively involved in the development of improved crop varieties.

Adjustment of planting date and cropping systems

Kra and Ofosu-Anim (2010) did mathematical modelling of daily maximum and minimum temperatures for selecting the best planting date so as to minimise the total irrigation water requirements for maize in a situation of water shortage and competing uses. They showed that up to 96 percent more irrigated area could be brought under irrigation without additional irrigation water through optimum planting date selection in the coastal savannah zone of Ghana. In another modelling study involving Ghana, Burkina Faso, Niger and Senegal, date of planting in combination with crop sequence was found to be an adaptation strategy worthy of further study. However, the implications of shift in date of planting and change of cropping systems for labour use have to be considered (Waha et al. 2013).

Crop residue management

Smallholder farmers in West Africa usually dispose of crop residues by burning, thereby releasing CO_2 into the atmosphere. Numerous reviews (for example Schlecht et al. 2006; Bationo and Buerkert 2001; Bationo et al. 1996) have pointed out the benefits of crop residue restitution to soil organic matter content, water holding capacity and agricultural productivity in West Africa. The practice is therefore considered climate smart. Rhodes (1995) used a nitrogen (N) balance model and predicted a relative loss in labile soil organic nitrogen over 10 years of 158kg/N/ha for a system of fertiliser N plus maize crop residue restitution compared to 225 kg N/ha for fertiliser N alone in the semi deciduous forest zone of Ghana. Gonzales-Estrada et al. (2008) showed that a crop simulation model and a household-level multiple criteria optimisation model could be used to identify a set of best practices that can sequester carbon (increase soil organic matter) and increase farm income in the Upper West Region (Guinea/Sudan savannah transition zone) of Ghana. There is spatial variability in soil organic matter content around homesteads and farms, especially in the Sahel, and field dispersion is an effective strategy to manage agro-climatic risk of crop failure (Akponikpe et al. 2011; Rhodes et al. 1996). In a study conducted in the Upper East Region (Guinea/Sudan savannah transition zone) of Ghana (MacCarthy et al. 2009), the Agricultural Production Systems Simulator model (APSIM) predicted that the amount of fertiliser N needed for sorghum in homesteads fields (where crop residues are returned to the soil) would be half of that required in bush farms. Rate of residue application seems to affect the performance of APSIM; Akponikpe et al. (2010) concluded that the model performs satisfactorily for simulating millet response to fertiliser and manure in Niger when P is not limiting, but only for low rates of crop residue application (≤900kg/ha crop residue).

Integrated soil fertility management

in its basic form, Integrated Soil Fertility Management (ISFM) stipulates the judicious combination of organic materials (animal manures, crop residues, green manures or composts) with mineral fertilisers and use of N-fixing legumes to improve fertiliser use efficiency and soil and crop productivity (Vanlauwe 2004). For swamp rice cultivation, improving fertiliser efficiency by reducing losses of N_2O gas to the atmosphere is climate smart. The International Center for Soil Fertility and Agricultural Development (IFDC) has in this context demonstrated improved N fertiliser efficiency and increased rice yields from deep placement of urea in West Africa (IFDC pers. comm. 2012). Participatory Action Research (PAR) was successfully used in Ghana's forest/savannah transition zone as an entry point, empowering communities to self-mobilise and self-organise to co-learn and experiment with ISFM technologies as an adaptation option to climate change (Mapfumo et al. 2013).Using participatory action research, ISFM was found to work in Ghana, Mali and Burkina Faso, but it was concluded that best fit options based on detailed analysis of the specific farming context including goals, resources and biophysical environment were required instead of relying on blanket recommendations (CCAA 2012). Kato et al. (2011) also cautioned that adequate attention should be paid to biophysical conditions of the plots and the household access to labour endowments, livestock equipment and land tenure for ISFM to be scaled up and widely used in West Africa.

Conservation agriculture and carbon sequestration

The key principles of conservation agriculture (CA) are (1) minimising mechanical soil disturbance (involving use of herbicides to control weeds), (2) maintaining permanent soil cover with organic mulch and (3) diversification of crop rotations. CA resulted in increase in soil organic matter and carbon sequestration in Mali (Doraiswamy et al. 2007). Bayala et al. (2012) did a synthesis of reports on the effects of components of CA on yield of maize, millet and sorghum in Burkina Faso, Mali, Niger and Senegal. The practices compared were (1) parkland trees associated with crops, (2) coppicing trees, (3) green manure, (4) mulching, (5) crop rotation and (6) traditional soil/water conservation. They found significant variability in cereal response with all practices, but the average effects of CA on crop yields were more positive than negative. Response to green manure and mulching were the best. The findings underscore the need of avoiding a 'one size fits all' mentality. Despite being widely promoted as climate smart, its uncritical use by smallholders should be avoided (Giller et al. 2011; 2009) because of the implications of additional labour for weeding for women and the need for further fine tuning to the conditions of smallholders.

Soil and water management

It is well known that good soil and water management are prerequisites for efficient use of water, especially in situations of declining rainfall in the Sahel and semi arid zones (Ngigi 2009), and thus these are invaluable in combating the effects of climate change. Technologies of soil and water management including provision of soil cover, minimum or no tillage, rainwater harvesting and irrigation are available. However, very little information is available on the economics of soil and water management on farmers' fields. Reij and Smaling (2008) estimated the costs of establishment and maintenance of zaï pits for soil water and fertility management at US$250/ha/yr and US$65/ha/yr respectively. Fox et al. (2005) found that the combination of rainwater harvesting and surface irrigation yielded a net profit of US$151 to US$622/ha for smallholder irrigation in Burkina Faso.

Agroforestry

The use of trees and shrubs in agroforestry systems helps to tackle the triple challenge of achieving food security, mitigating climate change and increasing the adaptability of agricultural systems (Torquebiau 2013; FAO 2010). Recovery from extreme weather events or market failures is an attribute of agroforestry systems because of the diversified temporal and spatial management options. For these reasons agroforestry is said to be climate smart. Research on agroforestry in West Africa as related to climate change has focused on its carbon sequestration potential and effect on soil fertility (Asare et al. 2008; Takimoto et al. 2008; Woomer et al. 2004). Thus carbon sequestration by traditional agricultural parklands in Senegal was estimated at only 0.4t/ha/yr with a potential of 20t/ha in 50 years (Tschakert 2004); this finding led to the conclusion that in the West African Sahel, agroforestry seems more valuable for adaptation than for mitigation (Torquebiau 2013). In Mali, Takimoto et al. (2008) reported that the potential to sequester carbon in traditional agricultural parkland was greater than in live fences and fodder banks. Concerning the coastal zone countries, it was shown in Ghana that traditional shaded cocoa stored 155t/ha compared to 72t/ha for unshaded intensive cocoa (Asare et al. 2008). The productivity of the cocoa was higher in unshaded farms than shaded farms, indicating a trade-off between cocoa productivity and carbon stocks. The fertility of the soil under shaded cocoa was greater than under unshaded cocoa.

Biotechnology

Genetically modified organisms (GMOs) constitute a technological option for adaptation to climate change for developing countries, for example through improved effectiveness of insect pest management (Howden et al. 2007). The Economic Community of West African States (ECOWAS), West African Economic and Monetary Union (WAEMU) and Comité permanent inter-État de lutte contre la sécheresse au Sahel (CILSS) are harmonising their regional biosafety regulations (Knight and Sylla 2011) and Burkina Faso, Mali, Ghana and Nigeria have legislation allowing field trials of GM products. Burkina Faso is at the front in West Africa in the application of biotechnology for improving crop productivity. A survey conducted in 2009 in Burkina Faso showed that insect protected biotech cotton increased yields by 18 percent over conventional cotton and resulted in increased income of US$62/ha over conventional cotton (Vitale et al. 2010). By 2010/2011 yields had increased by 66 percent (Knight and Sylla 2011). In addition, biotech cotton made farmers less dependent on fertilisers and better able to adapt to rainfall shortage in Burkina Faso (Samari 2011). Biotech cowpea has recently been approved for confined field trials in Burkina Faso and Nigeria (Knight and Sylla 2011).

Reducing post harvest losses, improving marketing and value addition

Agricultural productivity can be improved not only by increasing yields but by reducing post harvest losses, which are considerable in West Africa. In Sierra Leone in the hot humid coastal zone, research (Government of Sierra Leone 2004) has shown a range of losses depending upon the produce: 20 percent for rice and 40-50 percent for fruits and vegetables. Recovery rate is 40-50 percent of oil from palm bunches and 40 percent for green coffee beans by traditional methods. Technology is available to reduce substantially these losses, for example rapid drying after harvest to moisture content of 14 percent or less, use of mechanical rice and coffee hullers and oil palm mills. Value addition through processing by available improved methods (for example mechanical cassava graters for gari production) and improved infrastructure to access markets also reduces losses. The predicted temperature rise from climate change will increase post harvest losses of annual crops, and thereby vulnerability of farmers to climate change, if corrective measures are not undertaken.

Assessment of 'best practice' technologies

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) researchers (Cooper et al. 2009) tested the hypothesis that in the medium term (2010-2050), ICRISAT is well placed to assist farmers in mitigating the challenges and exploiting the opportunities that are posed by climate change, through application of existing knowledge on crop, soil and water and the redeployment and retargeting of the existing germplasm of its mandate crops. The ex-ante analysis involving the GCMs, APSIM and the Decision Support System for Agrotechnology Transfer (DSSAT) showed that adoption by farmers of existing recommendations even under climate change will result in substantially higher yields than farmers are currently obtaining. Other CGIAR centres covering West Africa – IITA, AfricaRice, CIMMYT and the International Water Management Institute (IWMI) – have also developed improved technologies for their mandate commodities and published Best Practices (CGIAR 2008). CORAF/WECARD in collaboration with CTA has also published Best Practices developed by the National Agricultural Research Systems (CORAF/WECARD 2011). According to Lybbert and Sumner (2010), best practices should be regarded as providing a source of tactical responses (short term) to a changing climate as opposed to an acceptance of untested strategic responses (long term).

Weather forecasting and early warning systems

Modelling studies have been done to get a better understanding of the utility of weather forecasts to smallholders. Sultan et al. (2010) reported on the ex-ante economic value of seasonal forecasts in the Nioro Rip semi arid zone of Senegal, using a bio-economic model to simulate the decisions of farmers with access to a priori information on the quality of the next rainy season. They showed that predicting a wetter than average rainy season would expose farmers to a high risk of failure by favouring cash crops such as maize and groundnut that are very vulnerable to drought. On the other hand, for a drier than average rainy season forecast, farmers respond to minimise the climate risk by choosing crops such as millet and sorghum, which can tolerate higher rainfall in case of the forecast being wrong. Roudier et al. (2012) showed for the Niamey Region of Niger that in response to forecasts, farmers were able to choose between millet cultivars, between levels of fertilisation and between sowing dates. Seasonal forecasts improved farmers' situation in bad years and farmers benefited from improved incomes even when the forecast was not perfect. They concluded that improving forecasting systems by including the prediction of onset and cessation of rainfall would be of great value. In a case study in the savannah zone of Ghana, both men and women farmers reported that their use of weather forecasts over the radio is only occasional and they trust and rely on traditional methods (Naab and Koranteng 2012). The IDRC/DFID programme showed through PAR how weather forecasting taking into consideration indigenous knowledge can be successfully used to strengthen farmers' adaptive capacity to climate change (CCAA 2012).

Insurance

Ngigi (2009) reported very little provision of formal insurance for smallholders in West Africa, but the situation seems to be improving. In Senegal, for example, the government has set up a national fund for agricultural insurance supporting 50 percent of the premium (M. Diop, pers. comm. 2013).

Index based insurance (which correlates strongly with farmers' production outcomes) can serve as a buffer against climate extremes (Ngigi 2009). Muamba and Ulimwengu (2010) studied the viability of rainfall insurance in 12 districts in the northern region of Ghana for maize producers through a mathematical programming approach. They concluded that rainfall insurance may not work in all districts but may be satisfactory in districts that exhibit a positive correlation coefficient between maize yield loss and indemnity payments; and that rainfall may not be an ideal index for losses, and indexes such as area yield or remote-sensed vegetation may perform better in the design of optimal crop insurance. Although there is need for further studies to find the most appropriate index based insurance at community levels, an index based insurance scheme is up and running. Some smallholder farmers in Ghana have been able to insure their crops against climatic risk through the Ghana Agricultural Insurance Programme (GAIP). At the start of the growing season, farmers pay GAIP a tenth of their cultivation expenses. A period of 12 consecutive days without rain triggers compensation payments to farmers. This insurance scheme is based on data collected daily by 19 automatic weather stations on wind, rainfall, humidity and temperature. During the first year of implementation 136 farmers were compensated (Spore 2013b).

In summary, there is evidence of the availability, through research and development, in West Africa of several options for strengthening elements of the adaptive capacity and supporting crop farming, at least in the short to medium term, of smallholder farmers. These options are components of a climate smart agriculture. How well they will work in the long term as climate change continues is uncertain. The research agenda and products of the national agricultural research and extension systems (NARES), CGIAR centres in West Africa and other research organisations, although initially not intended to respond to climate change adaptation per se, are relevant to some of the short to medium term needs expressed in the NAPAs and National Communications.

4.1.3 Documented adaptation by crop farmers

Research has been conducted in West Africa which provides evidence of adaptation to climate change and/or adoption of recommended adaptation options by farmers. This adoption is a reflection of the realities of climate change and variability on the ground and the ability of farmers to make informed choices from a range of available options. Surveys/case studies of countries in West Africa have documented the following: shallow and hand dug wells to supplement the shortfall in water in the dry season (Ngigi 2009); soil moisture improvement technologies like zaï, half-moons and mulching (Nkonya et al. 2011; Ngigi 2009); irrigation, drainage and lowland cultivation (Zorom et al. 2013; Adebayo et al. 2011; Nkonya et al. 2011; Ngigi 2009); adjustment of planting dates (Adebayo et al. 2011; Nkonya et al. 2011); agroforestry and crop rotation (Adebayo et al. 2011; Ngigi 2009); rainwater harvesting, collection of rainwater from zinc roofs for storage in tanks, and local earthen wares, bunds, contour bunds, dugouts and small reservoirs (Zorom et al. 2013; Panyan et al. 2011; Ngigi 2009); fertiliser and manure use (Zorom et al. 2013; Nkonya et al. 2011); diversification in the form of introducing new crops and livelihood changes (Nkonya et al. 2011); integration of livestock with crops and engagement in off-farm activities, for example gold mining (Ngigi 2009); protection and planting of trees (Nkonya et al. 2011); migration of farmers into wetter areas (Ngigi 2009); and use of weather forecasts and early and/or drought tolerant crop varieties (Roudier et al. 2012; Nkonya et al. 2011; Ngigi 2009). Concerning weather forecasts, Roudier et al. (2012) cited examples of adaptation to weather forecasts reported by farmers (Table 4).

Gender-disaggregated research data is scarce, but Naab and Koranteng (2012) found that in the same village in the Upper West Region, in the savannah of Ghana, men reported that they used planting of trees, intercropping, crop rotation and cultivation of lowlands to adapt to climate change and women reported tree planting, dry season vegetable gardening, compost and farmyard manure use, not burning bush and crop residues and application of crop residues as adaptation/coping strategies.

The relationship of adoption to agroecologies and the determinants of adoption have been studied: thus, Adebayo et al. (2011) grouped technologies adopted by farmers in southwestern Nigeria in response to climate change in terms of agroecologies. They found that for swamps, the order of adoption was first construction of drainages, being much greater than channelisation of beds, which was in turn greater than adjustment of planting date. For the forest zone, adoption of irrigation was much greater than afforestation, which was greater than use of fadamas (valley bottoms/lowlands). In the savannah zone 'no adoption' was much greater than irrigation, which was greater than adjustment of planting date.

Table 4: Some adaptation strategies to seasonal forecasts reported by farmers

Country	Adaptation Strategy
Niger	Change crop types; reduce herd size; change grazing methods, change planting time; relocate
Burkina Faso	Plant short duration crops/varieties; plant drought tolerant crops/varieties; use or do not use fertilisers; store/sell grain stocks; orient furrows across slope; acquire capital to purchase inputs; ration food

Source: Adapted from Roudier et al. (2012).

Key determinants of adoption of drought tolerant maize in Bono State of north-eastern Nigeria, in the northern Guinea savannah zone of West Africa, were shown to be access to technology, complementary inputs, extension services and climate change information (Tambo and Abdoulaye 2012). They also found that off-farm income and wealth status of a household were important in adoption, implying that it would be difficult for resource-poor farmers to adopt adaptation technologies. Farmers identified costs of the technology package, in particular fertiliser inputs, as major constraints to adoption. Nkonya et al. (2011) reported that in the semi arid zone of Niger, female headed households were less likely to respond to climate change than male headed, whereas in the same zone in Nigeria gender did not have a significant effect. Both in Niger and Nigeria having non-farm activities reduced the likelihood to respond to climate change and there was a positive association between distance to markets and response to climate change. This suggests that marketing opportunities provide stimulus for maintaining or increasing productivity.

A word of caution was raised by Mertz et al. (2009), who in a study of the Eastern Saloum, Senegal, concluded that communities are highly aware of climate issues but climate narratives are likely to influence responses when questions mention climate change. Changes in land use and livelihoods in the study area are driven by adaptation to a wide range of risk factors of which climate, though important, appeared not to be the most important. The wider applicability of this conclusion to savannah and forest communities in West Africa is untested.

4.1.4 Lessons from adaptation projects and interventions in crop farming

A consistent lesson reported from climate adaptation research is that although climate change is a source of significant stress (and perhaps opportunities), it is only one factor among many that smallholders have to contend with. Several adaptation projects have been conducted or are ongoing in West Africa. Lessons reported by a selection of projects and successful interventions (Mapfumo et al. 2013; BNRCC 2012; CCAA 2012; Jobbins 2011; Nkem et al. 2011; Bonkoungou et al. 2010; Hounkponou et al. 2010; Ziervogel and Opere 2010; CCAA 2009; Ngigi 2009) are grouped in Table 5 in terms of implementation, gender, weather, local knowledge and participation, partnerships and institutions and policymakers.

4.1.5 Key documented barriers to adaptation by crop farmers

Adoption and assimilation of adaptation strategies and options into national development plans has been slow. The documented barriers include economic capacity, information systems, technology development and dissemination, infrastructure/institutions, socio-cultural perspectives, gender issues, environmental issues, extension services, incentives and conflicts among different interest groups and inadequate policies or lack thereof (Nkem et al. 2011; Nzeadibe et al. 2011; Ngigi 2009).

Economic capacity, information systems, technology and technology dissemination

Farmers need to have money to adopt new technology but smallholders in West Africa are poor, and therefore lack capacity to adapt. Cost of adaptation packages (including good quality seeds and fertilisers) has been documented as a constraint to adaptation (Adebayo et al. 2011). Farmers can therefore be locked into a vicious cycle of poverty, little use of nutrient inputs, soil mining and therefore degradation of the environment and increasing vulnerability to climate change.

At the regional level, the African Centre of Meteorological Application for Development (ACMAD) and the Agro-Hydro-Meteorology (AGRHYMET) Regional Centre provide broad information to national partners, but their work is based on inadequate data. The density of meteorological stations in SSA is one-eighth of the minimum recommended by the World Meteorological Organization (Tall 2010). Poor information systems both at local and national levels to collect, process and disseminate climate change information and weather forecasts hinder uptake. Poor availability and access to technology and a community's inability to modify technology adversely affect uptake. It was shown in an earlier section that availability of crop technology for adaptation, at least in the short term, is not a problem; the issue is with regards to accessibility. National extension services are generally weak due to funding and skills constraints.

Infrastructure, institutions and land tenure

Poor physical infrastructure (irrigation water supply, water management structures, transport and marketing systems, storage and processing structure and communication) and inadequate social infrastructure/ institutions such as inadequately funded research institutions and unempowered farmers' organisations, cooperatives and water users associations are widespread. For example, the Sierra Leone Agricultural Research Institute, with five operating research centres, was allocated just Le 2.6bn (US$600,000) in 2013 for non-salary recurrent expenses, which is 10.6 percent of the non-salary recurrent allocation to the Ministry of Agriculture, Forestry and Food Security (Government of Sierra Leone 2012).

Furthermore, funds actually disbursed are sometimes less than funds allocated (earmarked). With increasing population all over West Africa, access to land in the context of current land tenure systems is becoming very difficult. Poor access to credit for investments and inputs is also linked to the fact that land under the traditional system cannot be used as collateral for loans. Ngigi (2009) drew attention to how ensuring land tenure for farmers increased water management and irrigated rice production in the Office du Niger, Mali.

Table 5: Lessons from adaptation projects and interventions in crop farming	
Groups	**Lessons**
Implementation	• Sufficient time is needed to promote learning and action with full community participation, to enhance local adaptive capacities and strengthen the resilience of communities, and to learn from these actions.
Gender	• Women and children are usually the most vulnerable groups and the most affected by climate change impacts. • In ensuring awareness and sensitisation to the issues, it is important that all community members, both women and men, agree on and are clear about the process. • More work needs to be done to overcome the social and cultural barriers for communities to fully embrace gender equality.
Weather, Local Knowledge and Participation	• Farmers are better able to adapt to climate change and variability when they engage with and apply climate information. • Scientific seasonal climate forecasts information is mostly supply driven at the national level and does not reflect understanding of user needs. • Integrating indigenous knowledge forecasts and scientific seasonal climate forecasts has worked well in many instances but could benefit from further analysis and policy support. • Participatory Action Research is necessary to take into account local knowledge to adjust advice and frequency of forecasts to the specific realities of an area or community. Messages in the local languages greatly facilitate uptake. • Choosing influential farmers as experimenters can increase uptake of tested soil and water management practices. • Participatory technology testing is most effective when farmers are respected and their knowledge considered. In addition, farmers should have ownership of the process of reflection-action-evaluation-planning and its integration into ways of addressing their constraints. • Participatory action research provides an entry point for building adaptive capacity of farmers.
Partnerships	• Vulnerability assessments, identification of adaptation options and the implementation of those options often depend on different areas of experience and expertise in order to minimise the risk of failure. • Partnerships among relevant institutions including non-governmental organisations (NGOs) and local communities can strengthen capacity and increase use of seasonal and indigenous forecasts. • Project achievements derive largely from the strength and dedication of the entire project team, including the partner organisations and the participating community members with the support of their village heads.
Institutions and Policymakers	• Institutional barriers to adaptation are more important limitations compared to issues with scientific uncertainties surrounding adaptation options. • Involving policymakers at the early stage of a project permits them to appreciate the benefits themselves and help identify resources to sustain useful practices identified through research.

Socio-cultural perspectives and governance structure

Two case studies conducted in Burkina Faso provide examples of how socio-cultural factors can influence adaptation. It was shown that weather information necessary for adaptation sometimes circulates selectively; in a village in Burkina Faso, women were excluded and in two villages 'lower caste families' and families opposed to the village leader and herders residing at the edges of the villages did not receive forecast information (Roncoli et al. 2001). Nielsen and Reenberg (2010) studied two ethnic groups, the Fulbe and Rimaiibe, in the village of Bidi 2, northern Burkina Faso. They found that although the Fulbe were aware of the potential benefits of livelihood diversification – labour migration, development work, women's work and gardens – as they daily observed how these strategies of adaptation to climate change benefited the Rimaiibe by providing them with cash for household survival, they were unwilling to fully embrace them because they entail attributes deemed 'non Fulbe'. It is unknown how widespread this behaviour is in Burkina Faso or in West Africa but it underscores the need for taking local factors into consideration in technology development and policy formulation.

There are vulnerable groups of both genders in rural communities in West Africa; but it is widely recognised that, in general, women are the most disadvantaged. Unequal access to land and water resources, limited involvement of women in water resources management systems, inadequate contribution to decision making processes, higher illiteracy rates than men and poor access to credit are all mitigating against innovation and adoption of climate adaptation practices and other agricultural technologies. Weak governance hinders the content of policies, policy formulation process and implementation at the regional, national and local levels with regards to climate change and adaptation (Ngigi 2009).

Table 6: Country-by-system breakdown of LGP change class to 2050, Scenario A1

Country	COAST	LGA	LGH	MIA	MIH	MRA	MRH	OTHER	TREEC	URBAN
Benin	2	2	2		2	2	2	2		
Burkina Faso		2	2			2		2		
Chad		2		2		2		2		
Côte d'Ivoire	2	2	2			2	2	2	1	
Gambia		2				2		1		
Ghana	1	2	2			2	2	1	1	2
Guinea Bissau		1		1		1		1		
Guinea	1	1	1	1		1	1	1	1	
Liberia	1						1	1	1	
Mali		2		2		2		2		
Niger		2		2		2		2		
Nigeria		2	1	2	1	2	1	1		
Senegal	1	2		1		2		1		
Sierra Leone			1				1	1	1	
Togo		2				2	2	2	1	

Source: adapted from Thornton et al. (2006)

NOTES: The A1 scenario represents a future of very rapid economic growth, global population peaks in mid century and declines thereafter and the rapid introduction of new and efficient technologies.

Rating '2' indicates substantial losses (>20%) in at least 50% of the system in that country; '1' indicates moderate losses (5-20%) in at least 50% of the system.

Land Use Systems Codes:

COAST	Coastal artisanal fishing-based systems
LGA	Livestock only systems, arid-semi arid
LGH	Livestock only systems, humid-subhumid
MIA	Irrigated mixed crop/livestock systems, arid-semi arid
MIH	Irrigated mixed crop/livestock systems, humid-subhumid
MRA	Rainfed mixed crop/livestock systems, arid-semi arid
MRH	Rainfed mixed crop/livestock systems, humid-subhumid
OTHER	Other systems, including root-based and root-based mixed
TREEC	Tree crop systems
URBAN	Built-up areas as defined by GLC 2000

4.2 *Vulnerability and adaptation of livestock systems*

4.2.1 Scientific evidence for implications of climate change for livestock raising in a multi-stressor context

Apart from climate change, existing threats to livestock keepers include population pressure from both internal growth and external encroachers and migrants; insecure land tenure; weakened customary governance; loss of land; reduced land carrying capacity; conflicts between pastoral groups and with crop farmers; market failures and entry barriers; inequity in global livestock trade (subsidies and concessions) undercutting local markets; and poor access to foreign markets (IUCN 2010). Climate change is likely to have major impacts on poor livestock keepers in SSA and on the natural resources on which they depend. The impact on LGP, a key land quality factor affecting both the livestock and crop sectors, on a country basis for different farming systems/livelihoods is shown in Table 6. Impacts on the arid-semi arid livestock system (LGA) for all but two countries are predicted to be strong. In general, impacts of climate change for livestock raising will include changes in the productivity of forage, reduced water availability, land use, species composition, quality of plant material, changing severity and distribution of livestock diseases and changes in the marketing and prices of livestock products (IUCN 2010; Thornton et al. 2007).

Water and feeds, changes in primary productivity and species composition and quality of plant material

Climate change models predict increases in temperature of about 2^{0}C for West Africa. Demand by livestock for water increases as temperature increases. For *Bos indicus* water intake increases from about 3kg per kg dry matter intake at 10^{0}C ambient temperature to 5kg at 30^{0}C and to about 10kg at 35^{0}C (NRC 1981, cited in Thornton et al. 2007). The effect of climate change on livestock production is generally expressed partly through changes in feed resources, which could influence feeding options, grazing management, prices of stover and grain, trade in feed and overall livestock productivity. The localised impact on water and feeds is not well known.

In C4 plant species increase in temperature up to 30-35^{0}C will increase the productivity of fodder and pastures, so long as the ratio of evaporation to potential evapotranspiration and nutrient availability do not significantly limit growth. In the semi arid rangelands of the Sahel, where the ratio of actual to potential evapotranspiration limits plant growth (Le Houerou et al. 1988, cited in Thornton et al 2007) and LGP may decline significantly (Jones and Thornton 2009; Kurukulasuriya and Mendelsohn 2008), rangeland productivity is likely to decrease.

The proportion of browsing in rangelands would increase as a result of increased growth and competition of browsing species due to increased CO2 levels (Morgan et al. 2007, cited in Thornton et al. 2007). This would affect the types of livestock species grazing the lands. Also, the mix between legumes and grasses could be changed thus altering the nutritional value.

Since lignification of plant materials increases with temperature, the rates of degradation of plant materials would be affected (Minson 1990, cited in Thornton et al. 2007). This may lead to reduced nutrient availability for livestock and reduction in livestock production.

Livestock health

Climate change would impact vector borne diseases. Tsetse flies are very sensitive to environmental change resulting from the activity of man or climate change. Species inhabiting the forest and riverine ecologies are more sensitive to climatic factors than those in savannah areas. Predictions of climate and population change on tsetse fly density indicates that tsetse populations and animal trypanosomiasis will decrease most in the semi arid and subhumid zones of West Africa. In addition to vector borne diseases, helminth infections of small ruminants will be influenced by changes in temperatures and humidity.

4.2.2 Options for strengthening adaptive capacity and supporting livestock raising

There is a range of available options from technological types for increasing or maintaining productivity, to investment in specific sectors and risk reduction options which may increase the adaptive capacity of livestock keepers and are climate smart. They include (Thornton 2011; Howden et al. 2007; Thornton et al. 2007): breeding heat tolerant animals, matching stocking rate to pasture production capacity, modified rotations of pasture, altered times of grazing, altered timing of reproduction, changing the mix of animals, changing animal feeds, forage and concentrates, local food banks, modified fertiliser recommendations, diversification, weather forecasting and livestock insurance. However, concrete research evidence in West Africa on many of these topics is lacking or limited.

Genetic improvement and tolerance to stress

Genetic improvement of livestock, as for crops, is an important technological option for adaptation to climate change and other stresses. It was difficult in the past to quantitatively access the socioeconomic performance of different breed types within village settings. New genomic techniques now allow the breed composition of individual animals to be determined from DNA information. By combining genomic-based information the most appropriate breed/cross type for a particular production environment can be determined.

This approach is being used in an International Livestock Research Institute (ILRI) project in Senegal (ILRI 2012). The West African Dwarf sheep is robust and has strong sexual vigour that enables it to withstand the stress of climate, disease and irregular feeding and has different coat colours. Fadare et al. (2012) studied in Nigeria the effect of coat colour on heat stress, using physiologic indicators and blood parameters and showed that selection of white coloured sheep to control heat stress is desirable.

4.2.3 *Documented adaptation by livestock raisers and lessons from adaptation projects and interventions*

The documented adaptations include controlled livestock and rangeland management (Nkonya et al. 2011). Zorom et al. (2013) reported for the Tougou community in the Yatenga province, northern Burkina Faso (Sahelian zone) that adoption of sheep fattening, cattle fattening, animal breeding, transhumance, altering the numbers of animals, animal traction and hay harvesting for feed as adaptation options to climate change varied between farmers in the same community. Other documented adaptation strategies used by livestock raisers are similar to those of pastoralists as outlined in 4.3.

The broad lessons reported are similar to those outlined in the previous section. One of the factors that may lead to fodder scarcity is drought resulting from climate change. A lesson learned from an action research project in Niger on enhancing livelihoods of poor livestock keepers through increasing use of fodder (ILRI 2006) is that addressing fodder scarcity is much more complex than simply providing technologies such as improved germplasm. Socioeconomic factors are equally important and so too is the need to appreciate different types of partnerships and that new partners may be necessary to address evolving constraints within the system.

4.2.4 *Key documented barriers to adaptation by livestock raisers*

The documented structural barriers are similar to those in the crops subsector. Much of the socioeconomic research on adaptation to climate change emphasises the need for supportive institutions and policies at local, national and international levels. Producers' choices are often limited by institutions such as markets and land tenure and policies that encourage production that may not be compatible with climate change.

4.3 Vulnerability and adaptation of pastoral systems

4.3.1 *Scientific evidence for implications of climate change on pastoralism in a multi-stressor context*

In addition to the vulnerabilities listed in section 4.2, restriction of transhumance, loss of access to key resources and sedentarisation policies leading to land degradation are the stresses pastoralists have had to contend with apart from climate change.

There is inconsistency between the GCMs and uncertainty concerning even the broad impacts of climate change on the pastoral systems of West Africa, in particular the direction of rainfall shifts and the extent to which climate variability is likely to increase in the future (Ericksen et al. 2011; CGIAR 2009). Some climate change scenarios have indicated an intensification of the African monsoon and even a greening of the Sahel (Brooks 2006). CGIAR, (2009) reported that even for a low greenhouse gas emission scenario, pastoral systems in West Africa are likely to undergo considerable shortening of the length of growing season and the total area affected by drought is likely to increase.

Impacts of climate change and variability on agro-pastoral and pastoral systems in Niger, assessed through farm surveys, reveal that increased labour emigration, increased dependence of households on remittance from labour migrants, increased ownership of livestock by non-livestock specialists, increased need to supplement livestock feed and reduced livestock mobility were the major effects over the past two decades (CGIAR 2009).

4.3.2 *Options for strengthening adaptive capacity and supporting pastoralism*

Pastoralism is itself an adaptation to climate change and variability (Brooks 2006). The broad options to strengthen adaptive capacity and support pastoralism include (CGIAR 2009) managing herd composition with regards to age and sex both to meet household needs and preserve the viability of the herd; splitting up herds to avoid overgrazing; changing species composition; fodder conservation; diversification into crop and off-farm activities; migration (as response to spatial and temporal variation in rainfall and vegetation); mobility; ex-ante risk management involving self insurance by building up assets (bigger herds) in good years to permit 'acceptable' levels of depletion in bad years. However, there are some issues worth mentioning: the utility to pastoralists of managing production risks at the farm level using seasonal forecasts and early warning was questioned by Jost (2002) because pastoralists often react to rain that has fallen rather than waiting for rain to fall on areas that they manage. Adaptation options in pastoralism can be negated by options in other sectors in agriculture. Thus in most states of Nigeria with fadamas, fadama water, ponds and rivulets formerly used as watering points for livestock when converted to sources of irrigation for crops became a disadvantage to pastoralists.

4.3.3 *Documented adaptation by pastoralists*

Many strategies have been documented for West Africa. These include (GabreMichael 2011): keeping animals that can endure seasonal feed shortage and long intervals between drinking water; keeping large herds in the hope that some can survive a period of feed shortage; following the rains within the semi arid areas;

seasonal movements between the dry areas that cannot be cropped and better-endowed areas that may offer more forage, for example in the form of crop residues; acquisition of land in better endowed areas that can be used for cropping; diversification into cropping and trade; changing herd composition; and replacing cattle with sheep, goats and camels, for example in Niger. Many of these strategies were designed to handle climate variability but at times of extreme drought lasting several years they sometimes do not work and high mortality of livestock and famine occurs amongst pastoralists.

There is also an increase in the numbers of donkeys kept because they can draw water from deep wells and transport water and materials to and from farms. Older women in Niger have started to donate donkeys to young women as marriage gifts to reduce the drudgery of household and farm work. Many pastoralists in Niger are making hay (some of which is sold to livestock keepers in town) and purchasing crop residues from crop farmers and agro-pastoralists to complement the grazing of natural pastures.

4.3.4 *Lessons from adaptation projects and interventions in pastoralism*

Many lessons have been reported (CCAA 2012; GabreMichael 2011) including:

1. Innovations by local people in adaptation to climate change need to be assessed together with other environmental, socioeconomic and policy changes. This helps avoid the trap of concluding that locally developed practices are evidence of deliberate adaptation to climate change alone.

2. Vulnerability is a complex issue; it is determined by a combination of factors including demographic changes, macroeconomic policies and market changes. Impacts of climate change cannot be clearly separated from other impacts on the livelihoods of rural people.

3. Due attention should be given to local innovations regardless of whether they are in response to climate change or other stresses, because they are sources of valuable new technology based on rooted experience of pastoralists.

4. Pastoralists live in areas full of uncertainties and risks to their livelihoods and have therefore always had to experiment and adapt. Their innovations can provide insights into unexpected possibilities of adapting to climate change.

5. Multi stakeholder platforms that gather, interpret and disseminate climate information can strengthen understanding and uptake of climate information among crop farmers and pastoralists.

4.3.5 *Key documented barriers to adaptation by pastoralists*

The documented structural barriers reported are similar to those outlined earlier; barriers specific to pastoralism include (CGIAR 2009; Cavanna 2007):

1. Mobility being constrained by the expansion of crop farming, shifting livestock ownership and allocation of household labour from herding to sedentary farming.

2. Perception of governments that pastoralism is backwards, uneconomic and destructive to the environment. Governments have therefore tried to convert pastoralists into modern livestock keepers.

3. Government policies have failed to protect vital pastoral resources including wetlands, dry season reserves and livestock corridors from encroachment by crop farmers, investors and national parks.

4.4 *Vulnerability and adaptation of fisheries systems*

4.4.1 *Scientific evidence for the implications of climate change on fisheries*

Fish stocks in West African waters have been declining for decades.[2] Over-exploitation both by small-scale artisanal and foreign trawlers has been a major cause of the decline. Projected climate change, population and market changes acting together could make the situation worse in terms of very negative impacts on local fish supply and human nutrition in West Africa, if adaptation measures are not undertaken (Warren et al. 2006, cited in IPCC 2s007; Allison et al. 2005; ECF/PIK 2004). Increase in the temperature of the Atlantic Ocean may affect upwelling along the Gulf of Guinea which could result in ocean water becoming unsuitable to fisheries, causing serious reduction in the marine fisheries enterprise. Rise in temperature could also lead to death of fish, loss of species diversity and adverse changes in fish habitats in the Guinea coastal zone (Omitoyin and Tosan 2012). Increased runoff bringing in nutrients from sewage could result in algal blooms also leading to death of fish. Sea level rise is already causing salinisation of water and soils. Lam et al. (2012) used models to estimate that total landings of 14 West African countries will drop by about eight percent and 26 percent from 2000-2050 for a low and high greenhouse gas emission scenario respectively. In addition, the study indicated that the Exclusive Economic Zones (EEZs) of Ghana, Côte d'Ivoire, Liberia, Togo, Nigeria and Sierra Leone will experience up to and above 50 percent reductions in landings under a high emission scenario (Table 7). The total landed value was estimated to drop from US$732m to US$577m between 2000 and 2050 for the high emission scenario.

Table 7: Current landings, projected landings and percentage change in landings over current levels in West Africa

Exclusive Economic Zone (EEZ)Country	Current landings in the 2000s (t)[a]	Low-range greenhouse gas emission scenario (constant 2000)		High-range greenhouse gas emission scenario (SRES A1B)	
		Projected landings in the 2050s (t)[b]	Potential percentage change in catch over current level (2000s)	Projected landings in the 2050s (t)[b]	Potential percentage change in catch over current level (2000s)
Ghana	264,796	154,806	-41.5	119,243	-55.0
Côte d'Ivoire	58,268	35,752	-38.6	25,434	-56.4
Liberia	22,848	14,599	-36.1	11,318	-50.5
Togo	14,907	10,520	-29.4	5,959	-60.0
Nigeria	288,140	220,682	-23.4	136,456	-52.6
Sierra Leone	59,307	51,000	-14.0	27,723	-53.3
Guinea	107,380	97,331	-9.4	79,924	-25.6
Benin	8,148	7,456	-8.5	6,172	-24.2
Cape Verde	17,007	15,996	-5.9	13,328	-21.6
Guinea Bissau	13,351	12,940	-3.1	10,331	-22.6
Gambia	32,147	34,471	7.2	29,637	-7.8
Western Sahara	821,642	890,892	8.4	691,230	-15.9
Mauritania	293,861	327,211	11.3	251,541	-14.4
Senegal	608,982	717,029	17.7	527,598	-13.4
West Africa	2,610,786	2,590,686	-8	1,935,895	-25.9

Source: Adapted from Lam et al. (2012)

NOTES:

[a] Average annual landing data from1990 to 2003 obtained from the Sea Around Us Project catch database (www.seaaroundus.org).

[b] Annual landings in the 2050s projected by using the SRES model A1B Scenario (Nakicenovic and Swart 2000).

Negative impacts have also been recorded for inland fisheries in West Africa. As reported by the Associated Press (2006), fish stocks in Lake Chad have diminished markedly. One fisherman is quoted as saying, 'they used to risk having their oar-propelled canoes tipped over as the fishes were giants; now they are lucky to take home small fishes the size of a hand; a catch that included 20 types of fish has diminished to half a dozen or less; two thirds of fish have just disappeared.' According to Chadian government officials, as reported by the Associate Press, Lake Chad is disappearing solely because of global warming, with severe droughts since the 1970s and temperature rising up to 50^{o}C causing large quantities of water to evaporate. In contrast, international observers attribute the reduced water level of Lake Chad to a combination of stresses, among which are climate change, population pressure in the surrounding countries resulting in heavy irrigation of farmlands and the demand for electricity which has seen the construction of dams on many rivers in the catchment for hydroelectricity schemes (Urama and Ozor 2010). In Côte d'Ivoire, major fish species are being affected by changes in fresh water flows and greater intrusion of salt water into lagoons and lakes (Government of Côte d'Ivoire 2000). For aquaculture, increasing seasonal and annual variability in rainfall and resulting flood and drought extremes are likely to be the most significant drivers of change. The impacts are likely to be felt most by the poorest farmers, who use ponds that retain small quantities of water and dry up quickly. Adebo and Ayelari (2011) reported on how flooding washes away fish from small fish farms in Nigeria.

4.4.2 Options for strengthening adaptive capacity and supporting fisheries

Current fisheries stocks in West Africa are over-exploited mainly because of dominance of foreign trawlers in the EEZs, and this may limit adaptation to changes in resource and environmental conditions. In this situation, policy formulation and enforcement of regulations have major roles in regional and national adaptation to climate change. The general options for adaptation in the sector, especially for artisanal fisheries (the most important form of fishing for local needs), include early warning/weather forecasting; insurance; strengthening capacity for careful stock management and harvesting; reducing post harvest losses; reducing pollution and habitat destruction; diversification; migration; switching fishing gear, species and marketing chains to accommodate different available species; and aquaculture (Morand et al. 2012; Omitoyin and Tosan 2012; Williams and Rota 2010; Bene et al. 2009; WorldFish 2009; Allison et al. 2007; Jallow et al. 1996).

Technology for reducing post harvest losses through improvement of local preservation methods (smoking) as well as use of cold storage are available but the latter may not be accessible outside cities. Improved sanitation in processing, packaging and certification of marine fisheries produce in countries such as Senegal and Sierra Leone where marine fisheries are a major economic activity facilitates regional and international trade. Examples of research findings on some options are outlined below.

Diversification and migration

Diversification and migration are well known adaptation options in artisanal fisheries. The case study of Omitoyin and Tosan (2012) showed successful diversification of a study group of artisanal fisherfolk (62 percent marine fisheries, 26 percent aquaculture and 12 percent combination of marine and aquaculture) in Lagos State, Nigeria into crop production, trading, livestock production, tailoring, fish processing, artisanal work, civil service and hunting. There are however exceptions to diversification as a strategy. Morand et al. (2012) presented findings that contradict conventional wisdom on diversification and migration. A case study on fishing communities in the Inner Niger Delta of Mali (the largest inland fisheries in the Sahelian region of West Africa) was conducted to test the hypothesis that adoption of diversified and spatially discrete patterns of livelihood activities confers greater coping and adaptation advantages. The results showed that the traditional livelihood strategies associated with hydro-climatic conditions, although diversified and well suited to past conditions, offer a limited set of options to adapt. For fish-dependent households that have adopted a mixed set of activities through rainfed/flooded rice farming, the high seasonality and constraints characterising both of the two main activities did not allow for switching of activities. For households that do seasonal fishing migration, there was little opportunity to modify migration routes or find new settlements inside the delta because of the high population density in the area.

It is worth highlighting the fact that diversification into the agricultural sector may break down under increasing climate stress while diversification outside of agriculture may not be feasible because of lack of credit, markets and other factors.

Aquaculture

Marine fisheries normally constitute the major component of commercial fisheries in West Africa. Although Omitoyin and Tosan (2012) found that the proportion of artisanal fisherfolk involved in aquaculture in Lagos State is increasing as a form of adaptation (diversification), probably because of the dwindling size and diversity of fish catch from open waters resulting from climate change, as well as flooding, which creates opportunities for aquaculture, production from aquaculture in the region is unlikely to fill the gap between fish supply and demand soon. Their study showed that the standard and productivity of fish farming by fisherfolk in Ondo and Ekiti States is low with the use of earthen ponds and only kitchen waste, poultry dung and other locally available feed because of the poor financial status of fish farmers.

Production (choice of species, feeding and stocking) is under greater control by smallholders in aquaculture compared to marine fisheries. Studies on the breeding of Tilapia (Eknath et. 2007) and the stocking density of Tilapia and the African catfish in Côte d'Ivoire (Coulibaly et al. 2007; Ouattara et al. 2003) suggested that aquaculture fish improvement and management can serve as adaptation strategies to climate change and variability as for crops and livestock. WorldFish has developed an improved variety (Akosombo) of the Nile Tilapia that grows 30 percent faster than non-improved varieties and is now boosting productivity in West Africa (Spore 2013a). WorldFish is also working with partners in SSA to refine integrated aquaculture-agriculture technologies and cycling of nutrients on farms; this work has relevance to West Africa and is climate smart.

Insurance

Formal insurance in the aquaculture sector in West Africa is generally poorly developed. As noted in section 4.12, insurance in one form or the other is being advocated as a risk management strategy to combat climate change. A case study conducted in the Ondo and Ekitii states of southern Nigeria found that only 8.3 percent of fish farmers were insured by private companies; out of the few insured, only 33.5 percent were compensated by insurance companies after the incidence of floods, and the compensations were delayed. Only 12.8 percent received financial aid from the government after a flood (Adebo and Ayelari 2011).

4.4.3 Documented adaptation by fisherfolk

Omotoyin and Tosan (2012) reported diversification as a key adaptation strategy among marine artisanal fisherfolk in Lagos State, Nigeria. A case study in the Oue'me' valley of the Oue'me' river in southern Benin (the most important basin in Benin) illustrates the dynamic nature of adaptation (Kpadonou et al. 2012). Local adaptation to climate change and flooding moved from fishing in ponds to crop farming through agro-fishing practices. Ponds dug mainly in flood plains served as refuge for wild fish migrating during flooding, thereby enabling farmers to take advantage of the succession and regularity of the flooding. Over time, the decline of fishes in the river led to a decline in the income from this activity and there was risk of floods to croplands. From simple holes the finger ponds became part of an agro-fishing practice, where the holes retained their traditional use as fish ponds but broad dykes formed on high strips of land became areas for dry season cropping. As climate variability increased, farmers concentrated on crop production on the dykes. An improvement in the productivity of the finger pods is still possible through artificial feeding and culture of adapted fish species.

4.4.4 *Lessons from adaptation projects and interventions in fisheries and key documented barriers to adaptation by fisherfolk*

Participatory action research in the Volta Basin of Ghana has shown that biophysical manipulation of fisheries ecosystems (man-made reservoirs) to improve productivity is feasible, but to realise the full potential, adaptive research needs to work closely with users to make sure that the rationale of the intervention and the technical details are fully appreciated by stakeholders and beneficiaries and that research and extension staff understand the real opportunities and constraints facing farmers (Bene et al. 2009). The Fishing Policy to Climate Change in West Africa Project led by the Dakar-based Environnement et Développement du Tiers-Monde (ENDA-TM) found, through PAR, that regulations to protect fish stocks and reinforcement of port infrastructure are best enforced at the local level, but require direction and funding from the national level. Also, agreements on fisheries quotas are best done at regional level but should be translated into regulations at the national level (CCAA 2010).

The documented structural barriers are similar to those outlined for the other agricultural sectors. Poor sanitation and quality of marine products poses serious hindrance to trade with European countries. The importance of international and regional trade as an adaptation strategy to climate change in all sectors has been emphasised.

5. Agricultural Development and Climate Change Adaptation Policies

5.1 *Climate change considerations in continental agriculture sector policies*

The African Union/New Partnership for Africa's Development (NEPAD) Comprehensive Africa Agriculture Development Programme (CAADP) sets the overall framework and principles on agricultural development in SSA, intended to be cascaded to the regional and national levels. CAADP contains broad themes of opportunities for investment to reverse the crisis facing African agriculture which has made the continent import-dependent, 'vulnerable to even small vagaries of climate' and largely reliant on food aid (AU/NEPAD 2003). The 'vagaries of climate and consequent risks' that determine investment is also listed as one of six challenges to achieving a productive agriculture. 'Land and water management', which is very important for adapting to climate change, is a Pillar of CAADP. In addition, the environmental initiative of NEPAD prioritises climate change as one of its ten programmatic areas.

Africa Union's concern for climate change is also seen in its policy framework for pastoralism in Africa (AU 2010). The overarching objectives of the framework are to (1) secure and protect the lives, livelihoods and rights of pastoral people and ensure continent-wide commitment to political, social and economic development of communities and pastoral areas; and (2) reinforce the contribution of pastoral livestock to national, regional and continent-wide economics. Defining practical approaches to managing risks and thereby reducing the vulnerability of pastoral people to climate events, particularly droughts and floods, and to conflicts is one of the specific objectives. The framework stipulates that policy development should be initiated at the national level with the establishment of national steering committees. These continental initiatives are therefore broadly in tune with climate change.

5.2 *Climate change considerations in regional agricultural sector policies*

The ECOWAS Regional Agricultural Policy for West Africa (ECOWAP) and the Offensive for Food Production and Against Hunger (ECOWAS 2005) is the framework of reference that provides the principles and objectives assigned to the agricultural sector and to guide interventions in agricultural development in the region. The ECOWAP themes on Improving Water Management and on Improved Management of Shared Resources (sustainable fisheries resource management) are in line with the CAADP Pillars on Sustainable Land Development and Water Control and on Sustainable Development of Livestock, Fisheries and Forestry respectively. ECOWAP recognises that deterioration of climatic conditions, characterised by reduced rainfall and high temperatures and flooding, is an important challenge to be faced for West Africa's agriculture to increase work and land productivity while protecting the natural resources and boosting production systems resilient to climate change. In 2005, an Action Plan was adopted in which climate change was not one of the key points but areas relevant to climate change and adaptation are outlined such as: promotion of water management to include development of small scale irrigation; integrated management of water resources; integrated soil fertility management; delivery of appropriate services to farmers, including increased advisory services and access to research results; decision and development of disaster insurance mechanisms; and organisation of transhumance pastures.

5.3 Agriculture considerations in regional climate change policies or strategies

ECOWAS developed an Environmental Policy (ECOWAS 2008) whose overall objectives are to reverse environmental degradation and depletion of natural resources, ameliorate the quality of the living environment and conserve biological diversity to ensure a healthy and productive environment. The strategic actions include promoting monitoring of environmental change and the prevention of risks by setting up a Regional Center Observatory, combating land degradation, drought and desertification and sustainable management of coastal, inland and marine ecosystems. Response to climate change was not one of the actions.

Thus in 2010 a Regional Action Program to Reduce Vulnerability to Climate Change in West Africa (ECOWAS 2009a; 2009b) was adopted. It was agreed at the International Conference for Reduction of Vulnerability to Climate Change of Natural, Economic and Social Systems in West Africa of 2007 in Burkina Faso and the Ministerial Meeting on Climate Change of 2008 in Benin to develop and implement a programme of action to reduce vulnerability of West Africa and Chad to climate change. CILSS, the Economic Commission for Africa (ECA) and ACMAD were mandated to develop the programme.

The regional programme document noted that while urgent priority measures in the NAPAs are worthy of continuation and support, it is also important to complement them with concerted adaptation options at the regional level. The goal of the ECOWAS programme is, at the regional level, to develop the required mechanism, actors and capacity to provide support to governments and communities as they adapt to climate change. The objectives are: (1) regional institutions are politically, technically and financially supporting the states in their process to adapt to climate change; (2) national stakeholders in each country are adopting harmonised and coordinated approaches to adapting to climate change; and (3) climate change is mainstreamed into priority regional and multi-country investments, programmes and projects. The coverage of ten development sectors including agriculture (crops, livestock, fisheries and agroforestry) is envisaged but the extent to which adaptation to climate change in the agricultural sector will be dealt with is not given and presumably will depend on national priorities.

Contribution to policy by other regional bodies

In addition to ECOWAS, there are smaller regional bodies such as ENDA-TM's West African Fisheries Policy Network (REPAO) and the Subregional Commission for West Africa (CSRP) working on policy related issues that are pertinent to climate change in the region. CSRP, with a mandate to harmonise fisheries policy in the region, works with National Fisheries Directors from Cape Verde, Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal and Sierra Leone. CSRP incorporates a regional advisory body with membership from professional organisations and NGOs involved in fisheries in West Africa (CCAA 2010).

5.4 National policies on agriculture and climate change

The low income developing countries in West Africa developed NAPAs under the guidance of UNFCCC while Nigeria, Ghana and Côte d'Ivoire developed their own national adaptation documents separately. Gender was given due consideration in the development of some NAPAs, for example that of Burkina Faso, as follows: views of men and women on previous and current measures were sought in workshops and surveys; and gender was taken into account in terms of the composition of the group of experts that guided the development of the NAPA. Nevertheless 67 percent of the projects identified were potentially more beneficial to men and 33 percent to women (Gonzales et al. 2011). Policy documents of Nigeria, Ghana and Senegal are reviewed in more detail in this section. Key elements and questions of the analysis are links of national policies to ECOWAP; whether considerations of climate change are given in agricultural sector policies and vice versa; outlines of guiding principles, goals, objectives and strategies; whether policy development and implementation are participatory; whether research informed policy; and whether monitoring and evaluation is given due consideration.

5.4.1 Considerations in agricultural sector and climate change policies of Nigeria

Nigeria's Vision 20:2020, the Federal Government's current economic growth plan, recognises the changing climate as a threat to sustainable growth in the next decade, which is an important step towards a climate change adaptation strategy and action plan. Water, Aquaculture and Environment Resource Management, one of the Government of Nigeria's five major agricultural programmes to 2020, is in line with ECOWAP's Improved Water Management and Improved Management of Shared Natural Resources themes (Government of Nigeria 2009). Other major policy documents without specifically mentioning climate change imply response to climate change: thus the National Policy on Environment supports the prevention and management of natural disasters such as flood, drought and desertification; and one of the objectives of the National Agricultural Policy is to protect agricultural land resources from drought, desert encroachment, soil erosion and floods. There are also other important policy documents related to climate change such as Nigeria's Drought Preparedness Plan, National Policy on Erosion and Flood Control and National Water Policy, but these policies, strategies and plans are not being used to support climate change adaptation in Nigeria (Government of Nigeria 2011).

The Government of Nigeria and civil society organisations developed a National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN). The document was developed through multi-stakeholder consultations led by four partners: the Climate Change Department of the Federal Ministry of Environment; the Nigerian Environmental Study/Action Team (NEST) through its Building Nigeria's Response to Climate Change (BNRCC) Project; NigeriaCAN; and the Heinrich Böll Foundation. Other participants in the preparation of the document included persons from grassroot communities, sector specialists and researchers. Many studies and reports were consulted and new research commissioned when deemed necessary. However, the document lists only a few research papers and reports in its bibliography. The adaptation strategy is characterised by certain imperatives such as being based on knowledge and research, incorporation of local knowledge, gender mainstreaming and integration into the national agenda so as to command wide acceptance and ensure production of the desired results.

The agricultural sector (crop and livestock) is one of thirteen for which adaptation policies, programmes and measures are described. Related sectors for which there are policies are freshwater resources, coastal water resources and fisheries. The goal of adaptation in the agricultural sector is to ensure that vulnerable communities and groups alter their agricultural practices to adapt to the changing climate, including predicted temperature and rainfall changes and extreme weather events. The strategies are as follows: (1) adopt improved agricultural systems for both crops and livestock; (2) implement strategies for improved resource management; and (3) focus on agricultural impacts in the drier areas that are likely to be most affected by the impacts of climate change.

The range of technological options for adaptation is well covered and implementation is participatory by a range of actors – the Federal Government, state and local governments, civil society and the organised private sector. The Federal Government has the overall responsibility for evaluation and reporting to the President of Nigeria and the public on progress made in the adaptation indicators outlined in the document.

5.4.2 *Considerations in agricultural sector and climate change policies of Ghana*

Ghana's Food and Agriculture Development Policy (FASDEC II 2007-2012) objectives are aligned to ECOWAP themes and CAADP Pillars (Kolavalii et al. 2010). The objectives are food security and emergency preparedness; improved growth in incomes; increased competitiveness and enhanced integration into domestic and international markets; sustainable management of land and environment; science and technology applied in food and agriculture development; and improved institutional coordination. While it considers areas that will be impacted by climate change such as food security, emergency preparedness and sustainable management of land and environment, it does not highlight climate change itself or its consequences. The Sustainable Management of Land and Environment Strategy also does not specify climate change while addressing environmental issues in food and agriculture.

Ghana's National Climate Change Adaptation Strategy (NCCAS) was prepared in a participatory fashion with the key ministry being the Ministry of Environment, Science and Technology (CCDARE 2008). It involved using outputs of sectoral vulnerability and adaptation assessments done by national experts and a network of stakeholders at the national, sectoral and district levels. This implies that research informed policy development but the extent is not clear because only a few research publications are listed in its references. The key guiding principles are: adaptation policies must be addressed as part of a broader context of national development policy framework; smallholder participation is central to formulation and implementation to ensure ownership; attention to sustainable development and poverty reduction; and adaptation should focus on long term impacts of climate change and gender sensitivity. The need for policy to maintain capacity to make continuing adjustments is somehow reflected in the guiding principles in that there is mention of flexibility and iteration. The goal of the Strategy is to enhance Ghana's current and future development to climate change impacts by strengthening its adaptive capacity and building resilience of the society and ecosystems.

Agriculture and fisheries are two of the eight areas for which strategies are developed. The strategies are to (1) build and strengthen capacity of local farmers to increase agricultural productivity and awareness of climate issues; (2) build and strengthen capacity of extension officers in new farming technologies in order to enhance their support for farmers; (3) enhance the living standard of vulnerable groups through acquisition of alternative livelihoods skills; (4) protect the environment through the promotion of agricultural biodiversity; (5) promote cultivation of crops and rearing of animals adapted to harsh climatic conditions; (6) document existing indigenous knowledge and best practices; and (7) train trainers to promote post-harvest technologies to minimise losses of farm produce. Ghana's Shared Growth and Development Agenda, as indicated in 'Ghana Goes for Green Growth' (Government of Ghana 2010), also recognises agriculture and food security as key adaptation issues.

The implementation of 10 prioritised options in the NACCS is through the existing decentralised planning and implementation system. Ministries, departments and agencies at the national level are responsible for policy, planning, monitoring and evaluation, while execution of programmes and projects is at the district level involving NGOs, community based organisations (CBOs), traditional authorities and the private sector. Monitoring and evaluation is part of the regional system for development of programmes and projects in districts and communities in which NGOs, CBOs and the private sector will participate.

5.4.3 *Considerations in agricultural sector and climate adaptation policies of Senegal*

There are several policy documents in the agricultural sector; pertinent ones are the New Orientation of Agricultural Policy: Return to Agriculture (Government of Senegal 2006a), New Sectoral Initiative for the Development of Livestock (Government of Senegal 2004a) and the Agro-Sylvo-Pastoral Orientation Law (Government of Senegal 2004b). The objectives of one or more of these policies and regulations include improvement of food security, reduction of malnutrition and poverty, efficient and sustainable management of water, protection of farmlands and the environment and encouraging women and youths to have productive livelihoods on their farms. One of the articles in the Agro-Sylvo-Pastoral Law, linked to the ECOWAS and CAADP protocols, refers to the need for reduction of the impact of climate, economic and environmental risks through proper management of water and diversification of production.

The NAPA (Government of Senegal 2006b) was developed in the context of CAADP and the Millennium Development Goals. The process involved sectoral studies on impacts, strategies of adaptation taking into account regional and international experience; public consultations to identify potential activities; participatory evaluation of actual and potential vulnerability; and prioritisation of responses to climate change. Only a few research publications are listed under references in the document as evidence of research informing policy.

Agriculture (crops and livestock) was one of five vulnerable sectors considered, the others being Coastal zone, Water resources, Tourism and Fisheries. For the short term, indentified options include agroforestry; crop diversification; use of short duration crop varieties; use of varieties tolerant to salinity; water harvesting; efficient use of water and control of water erosion; early warning systems in rural areas; appropriate fertiliser use; and institutional support and training of policymakers on the challenges of climate change and strengthening their capacity for analysis and the consequences of their actions. Some of these measures may have mainly short term responses in mind, but they have merit. According to Hansen et al. (2007), the most promising opportunities to adapt to climate change involve action on shorter time scales that also contribute to immediate development challenges. Rehabilitation of degraded lands involving carbon sequestration is considered a longer term option of the NAPA. Prioritisation in all sectors was done and programmes developed.

The overall strategy of intervention is participatory and caters for actors at all levels to have a common perception of problems and accord with proposed interventions, and in all cases responding to the expressed demand of beneficiaries. Oversight is provided by a National Committee of Evaluation in the Ministry of Environment and including Ministers from other relevant ministries, cooperatives and NGOs. At the regional and community levels, within the decentralised structure, NGOs, CBOs and various farmer organisations are involved.

5.5 *Trade-offs and barriers to mainstreaming climate change adaptation into agricultural policy*

ECOWAS's regional policy guidelines, the NAPAs (prepared under guidance from UNFCCC) and the policy documents prepared by Nigeria and Ghana all indicate that policy documents on climate change are separate from the agricultural development policies and other plans/strategies. However, in general, the agricultural development policies/plans recognise directly or indirectly the need for responding to climate change without tying productivity targets to the projections of how climate change could impact agriculture.

There are benefits and disadvantages to mainstreaming adaptation to climate change into agricultural policies (Bockel and Smit 2009). The benefits are: additional policies and their associated bureaucracy to be added to already stretched government institutions are not required; it does not increase duplication, potential incompatibilities or conflicts among policies and agencies; adaptation initiatives fall within policies that are already established in agencies with expertise, experience and stakeholder connections in policymaking; it focuses more directly on practical adaptation and mitigation initiatives than on climate monitoring, models and predictions. The disadvantages are that many programmes and agencies have to be engaged; and it is difficult to distinguish accomplishments in climate change adaptation from other development activities responding to various stresses.

The United Nations Environment and Development Programmes (UNEP and UNDP) Climate Change and Development Project – Adapting by Reducing Vulnerability (CC DARE) in Senegal, Togo, Benin and Ghana reported inadequate knowledge on climate change risks, level of vulnerability and adaptation options at the local level; inadequate institutional capacity to address the challenges posed by climate change at the local level; weak partnership between central and local government; and lack of proactive, targeted and cost effective strategy that increases the long term resilience of the population as barriers to mainstreaming adaptation into national development frameworks (Nkem et al. 2011).

5.6 Key arguments for policy on adaptation to climate change

The general argument for policy will first be outlined and then examples from West Africa on how policy has influenced adoption of climate change adaptation options will be cited. Technical interventions cannot be effective and sustainable without supportive governance measures concerning policy and legal issues (Ngigi 2009). Incentives and flexibility are enhanced by good governance, policy and institutional responses. The benefits of adaptation to climate change are more local compared to mitigation whose benefits are more global, hence the need for national and local policies dealing with adaptation is crucial.

In Mali, a comprehensive macro-economic policy and institutional reforms (including provision of short and medium term credit to farmers and access to land) have turned irrigated agriculture into a profitable enterprise, sustaining livelihoods of farmers and improving the national economy (Aw and Diemer 2005, cited in Ngigi 2009). Also, a case study in the semi arid zone of Nigeria and Niger concluded that the support by the Nigerian government over several years for irrigation development and more recently small scale irrigation has increased agricultural production and reduced production risks in the drier northern states (Nkonya et al. 2011). Although the irrigation programmes were not implemented as part of an adaptation to climate change programme, they helped farmers adapt to climate change. Furthermore, the adoption rate by farmers of fertilisers was relatively high because of the government's substantial fertiliser subsidy and promotion of fertilisers for a long time. For Niger, the granting to users of the right to own and benefit from trees on their farms, through the Rural Code, contributed to the greening of the Sahel.

5.7 Funding streams for adaptation projects

The World Bank estimates that the total costs of Africa's adaptation to climate change will be US$18bn a year by 2050 and will not be covered if the current level of disbursement continues. Nineteen funds are dedicated to climate mitigation and/or adaptation in SSA, including the multilateral Adaptation Fund, the Global Environment Facility (GEF) Trust Fund, the Global Climate Change Alliance, the Green Climate Fund and the Least Developed Countries Fund, all of which involve funding of adaptation projects (www.climatefundsupdate.org 2012). The total amount approved for adaptation in SSA was US$958m, out of which US$137m was disbursed. Adaptation projects have received 28 percent of climate funding approved since 2003 although they have received 40 percent of funds disbursed. The top ten recipients in terms of number of approved projects included Niger, Nigeria and Ghana, and on the basis of amount disbursed it was Ghana, Senegal and Nigeria.

Fifty-six percent of climate finance in SSA is directed to mitigation even though SSA accounts for only four percent of greenhouse gas emissions; this is because it is the most vulnerable region to the effects of climate change (Schalatek et al. 2012). Information on funding streams specifically for adaptation in agriculture in West Africa is scarce. UNFCCC (2007) estimated that for 2030 funding required for agriculture, forestry and fisheries in developing countries would be less than one percent of the total for all sectors. The budget for the ECOWAS Action Program to Reduce Vulnerability to Climate Change is US$150m, which is more than the total funds for adaptation in SSA disbursed. Schalatek et al. (2012) suggest that high transaction costs of small projects for the poorest countries and the difficulty of implementing such projects in financially viable ways account for the small amounts of global climate finance reaching SSA. This argument strengthens the case for preparing regional projects.

5.8 Key barriers to uptake of research and successful policy implementation

The linkage between research and policy is weak, and research therefore does not adequately inform policy. The reasons for this are many: very conscious of maintaining their objectivity, researchers traditionally get uncomfortable about close contacts with policymakers. Decision-makers on their side may think of researchers as too academic and impractical or their findings not useable for decision-making. Other obstacles are the perceived uncertainties surrounding climate change and modelling (for example, there is some inconsistency in the predictions made by GCMs) and the short term perspectives of politicians related to their tenure in office. The time lag between the time the research is conducted and the findings are made known is very long and the presentation often too technical; sometimes outputs of research do not even reach national policymakers, natural resource managers or farmers (Huq and Reid 2005). What approach in research-policy dialogue works best and under which situation is unknown.

Structural barriers to implementation include weak public services, weak institutions and inadequate decentralisation of governance and lack of political will. For example, in the livestock sector, while regional conventions permit free movement of people, pastoralists could face problems in moving their animals across borders because of a fear of infiltration of pastoralists by terrorists across borders. States in Nigeria in which fadamas (bottomlands) are prominent agroecologies did not comply with a World Bank recommendation of setting aside 20 percent of fadamas to pastoral use (Bare 2011). In the marine fisheries subsector, technical capacity for surveillance and control and monitoring of marine fisheries resources limit its governance. For all sectors, there is lack of legislation to back up policy and poor enforcement of laws.

Policymaking in West Africa, even when evidence based, is generally linear. IDS (2011) and Venot and Dare (2011) argue that the policy process is not linear where researchers' roles are limited to providing scientific evidence at the end of the research process. The policy process is a disputed space, a complex mesh of competing interests and negotiations, in which power and politics are central.

6 Gaps in Climate Change Adaptation Research and Policy in the Agricultural Sector

Several studies undertaken in West Africa on adaptation research and policy reveal incomplete detailed technical knowledge of how to adapt sustainably to climate change in agriculture and weakness in policy formulation and implementation (CGIAR 2011; Sultan et al. 2010; FAO 2010; 2008; Ngigi 2009; Thornton et al. 2007; Huq and Reid 2005). Gaps in knowledge and deficiencies in research and policy from a regional perspective are outlined in this section.

6.1 Key research gaps and challenges

Crops

Across the region there is limited or inadequate knowledge in several thematic areas such as how in response to climate change, farmers will shift to different crops, affecting feeding habits, nutrition and cultural norms; on conservation agriculture; on adaptation at the watershed level; and on the productivity of biofuel crops in water stressed conditions. There are no improved varieties of Jatropha that are being promoted in Mali and Ghana as a biofuel crop. There has been little research on climate change and tree crops/agroforestry.

Livestock/pastoral systems

The work of Thornton and associates at ILRI provides very useful insights on detailed technical research gaps in adaptation research in the livestock/pastoral sectors at the regional level. The gaps include limited knowledge of the following: vegetative composition and biodiversity of rangeland ecosystem under changes in grazing pressure; rangeland restoration, seeding and water retention techniques; appropriate livestock species mix under changing climate based on different physiological and nutritional characteristics; changing phenotypic variation in herds and their resilience to climate change; genetic characterisation of indigenous animals; animal breeding systems for meeting the challenges of improving productive traits while maintaining adaptive traits; preservation of animal genetic diversity as a global insurance against unanticipated change; and limited tools (models) and methods to determine which adaptation option may be appropriate for various situations.

Fisheries

The key gaps identified for marine fisheries include limited knowledge on fishing stocks in the EEZs, value of the stocks and decline and change in habitats. There is also inadequate quantification of scenarios and combining them with climate to fish models and lack of knowledge on species that could adapt to new environments (Badjeck and Diop 2010). For aquaculture, inadequate knowledge relates to new strains of aquaculture species tolerant of lower quality water and higher levels of salinity induced by climate change and management for high productivity.

Cross cutting gaps

The incomplete understanding of the wide-ranging processes underlying the performance of markets, ecosystems and human behaviour contributes to the uncertainties associated with modelling the impacts of climate change on the agricultural sector (Nelson et al. 2013). There is little or no routinely reliable method on the predictability of the onset of the rainy season and intra-seasonal variability and how to make weather forecast work best for smallholders. There is also limited knowledge on the applicability of index based insurance to smallholder situations. Other areas of limited or inadequate knowledge are: adaptation through control of plant and livestock diseases; thresholds in natural systems beyond which adaptation may be very difficult or impossible; assessment of the effectiveness of adaptation options and understanding likely adoption rates, trade-offs, costs and returns of adaptation strategies; effective ways of communicating climate change information and its consequences on livelihoods and the environment; women's strategic interests (access to land and credit, decision making power, etc.) in responding to climate change and variability; and relative benefits of promoting regional versus global trade for crops, livestock and fisheries products.

Furthermore, many of the adaptation strategies and options identified in this review are rather of a short to medium term nature. There is limited knowledge on how short term response tactics/strategies link to long term options to make sure that management and policy implemented over the next 10-30 years do not undermine the ability to adapt to the potentially larger impacts in the long term. In this context, CGIAR (2011) and Thornton and Cramer (2012) have identified gaps in knowledge for developing countries in Africa for the crops, livestock and fisheries sectors which need to be filled or narrowed for adequate technological and policy responses to climate scenarios with emphasis on the medium to long term. This includes gaps in decision support tools – i.e., uncertainties in the science of modelling impacts on the agricultural sector.

6.2 Key policy gaps and challenges

The national policies in place in West Africa (specifically Nigeria, Ghana and Senegal) are generally more robust for technological practices compared to non-technical risk management, for example trade. International trade is expected to play a critical role in adaptation and would itself be affected by climate change but there is little understanding of how all of these will play out and what the appropriate policies should look like.

That climate change and adaptation are not always mentioned in Agricultural Development Policies and Strategies is an important weakness. Also, some policies to the benefit of one sector have been to the detriment of another; for example policies to adapt economies to climate change by the construction of dams in catchment areas including neighbouring countries have led to decline of flood strength and therefore fisheries resources in flood plains (Morand et al. 2012) and contributed to the drying up of Lake Chad and its fisheries resources.

There are inadequate policies or lack of policies in several areas; for example, protection of key pastoral resources such as wetlands, dry season reserves and livestock corridors from encroachment by crop farmers, investors and national parks; on the integration of the Sahelian and coastal zone livestock markets; transboundary control of water resources; management of marine fisheries resources in the shared Atlantic Ocean; strengthening climate communication and information networks to improve timely delivery of weather information; built-in capacity for flexible policies that continuously respond to changes; collaborative learning processes and understanding of the context in which decisions are made and the capacity of decision-makers to change; gender imbalance in access to factors of production; mainstreaming gender into all climate adaptation policies and strategies; and weak institutional capacity to generate and utilise adaptation technologies.

6.3 Options, spaces and opportunities for improved uptake of research

Policy spaces are places, areas, locations and gaps where policy can be influenced. Examples of policy spaces and tools for policy engagement are informal expert consultations through national consultative groups used effectively to widen debate and common understanding on topics such as food insecurity and climate change and climate smart agriculture, and creating informal spaces within otherwise formal processes (IDS 2011). An example of exploitation of spaces and joint scenario building would be the participation of policymakers in workshops such as 'Envisioning 2050: Aquaculture and Fisheries in West Africa' (Badjeck et al. 2011). Through its interaction with the Sectorial Permanent du Plan d'Action Pour la Gestion Intégrée des Ressources en Eau (SP/PAGIRE) in Burkina Faso and the Water Research Commission (WRC) in Ghana, the CGIAR Challenge Program on Water and Food (CPWF) is promoting a 'visionary team' (mediators) to guide project activities and ensure uptake of the programme (Aduna 2011). The fact that researchers, trained in the conventional way of investigation and reporting, are becoming familiar with participatory action research and donors are keen to fund PAR are all opportunities for bridging the gap.

7. Analysis of Stakeholders And Opportunities for Collaboration

The successful strengthening of adaptive capacity of smallholder farmers depends on how well the different stakeholders play their various roles. There is indeed a diversity of stakeholder organisations in the region ranging from political and economic institutions through scientific/technical/development organisations to farmers' associations. Their roles and interactions as relevant to climate change are outlined in this section.

7.1 Political and economic organisations

ECOWAS is the main political body responsible for regional integration in terms of agricultural development; its policies are aligned to the Africa Union's NEPAD and CAADP. Its decision-making process involves a parliament of 115 members, with representatives from the parliaments of each member state, a council of ministers and Heads of State. CILSS, an intergovernmental organisation with a membership of 13 West African states, is mandated to promote research on food security and desertification. CILSS is administering a regional programme on sustainable land management and adaptation to climate change, the expected outputs of which include: (1) knowledge about the impacts of climate change and best experiences on sustainable land management and climate change adaptation capitalised and disseminated for upscaling; and (2) capacity of CILSS/ECOWAS countries to integrate sustainable land management and adaptation into strategies, policies and regulatory frameworks improved. The website outlines technologies for food security and climate adaptation and provides a portal on climate change. At the country level, policymaking is largely in the domain of government ministries which report to cabinets chaired by the Heads of State.

7.2 River basin authorities

These include the Niger Basin Authority, the Lake Chad Basin Authority, the Gambia Basin Authority, the Organization of Senegal River and the Mano River Union. Their roles include the promotion of inter-state cooperation for development of the national resources of the river basins; harmonisation of national development policies relating to these resources; development of projects and programmes; reducing the vulnerability of member states to climate risk; and promoting sub-regional security.

7.3 Scientific, technical and development organisations, civil society and farmers' organisations

In the scientific/technical/development group, the NARES in all 15 ECOWAS states are major players for developing options to respond to climate and other stresses. They work in partnership with CGIAR centres such as AfricaRice and IITA, which have headquarters in Benin and Nigeria respectively, and ICRISAT with a large Sahelian Centre in Niger. ILRI, the World Agroforestry Centre, IWMI and the International Food Policy Research Institute (IFPRI) do not have headquarters in West Africa but have a strong presence in the region through their projects. Until comparatively recently, interventions by NARES and CGIAR centres were designed to respond to stresses other than climate change per se. Major efforts were on developing improved plant materials or livestock and associated crop/livestock and soil management practices for increasing agricultural productivity and protecting natural resources. These technologies have now turned out to be best bets in adapting to climate change (first line of defence). The CGIAR centres are better staffed, equipped and funded compared to NARES and are better placed to conduct strategic research on climate change. The comparative advantage of NARES lies in their knowledge and experience of the biophysical and socioeconomic circumstances of smallholders at the local level.

A number of regional climate monitoring initiatives and early warning systems exist, including those of ACMAD and AGRHYMET Regional Centre. A survey done by Niang (2007) revealed that ACMAD and AGRHYMET Regional Centre were perceived by respondents as centres of excellence in climate change related research in the West African region. The main areas in which they are deemed to contribute to climate change work were (1) gathering and providing climate relevant data; (2) conducting research in climate change and adaptation in different sectors; (3) production of scientific reports on climate related matters; and (4) capacity building through sharing of experience, training on forecasting and natural resources monitoring (AGRHYMET 2012; 2004). Their weakness is inadequate human and physical resources which could be ameliorated through training, acquisition of modern equipment and partnership with advanced institutions outside Africa. AGRHYMET Regional Centre is a specialised institution of CILSS.

The development partners include FAO, UNEP, UNDP, USAID, DFID, IDRC, the International Fund for Agricultural Development (IFAD), Gesellschaft für Internationale Zusammenarbeit (GIZ) and the NGOs. Some have produced useful guides on mainstreaming gender into policies and tools for guiding developing countries in policy development on climate change adaptation (FAO 2012) and adaptation tool kits (Enda 2013). IDRC in partnership with DFID has funded an important programme on Climate Change Adaptation in Africa (CCAA). GEF has been a source of funds for the development of NAPAs and implementation of some adaptation projects. GIZ is establishing a West African Science Service Center on Climate Change and Adapted Land Use (WASCAL), focusing on the Guinea savannah zone.

Several NGOs especially in the semi arid and subhumid zones have been working with smallholders on improving agricultural water management, a topic very relevant to adaptation to climate change. International NGOs are well funded and their operation at the grassroots levels is a big advantage. Sustainability of recommended technologies would be improved if activities are well coordinated with government efforts. SciDev.Net (2013) reported on how civil society successfully campaigned for adoption of rules and regulations in Burkina Faso for 'safe innovation' while not discouraging the use of genetically modified cotton for improving farmers' productivity and incomes. The Network of Farmers' and Agricultural Producers' Organizations in West Africa (ROPPA), with membership in francophone and anglophone countries, is in touch with the vulnerable farming groups and advocates for the needs of their members.

7.4 Opportunities

Niang's (2007) review of the institutional framework in relation to climate change in West Africa showed that opportunities for influencing policy are a function of the type of organisations. Thus although many sub-regional organisations have links with political decision-makers the nature of the link depends on whether they are (1) political organisations such as CILSS and WAEMU where Heads of State are the ultimate decision-makers; (2) organisations with structures in which political decision-makers are represented at the highest levels, for example the river basin authorities; (3) organisations with government supervision such as AGRHYMET Regional Centre; and (4) independent organisations such as the NGOs.

A number of cost sharing opportunities in the region have been identified (Niasse 2007) in which the national, basin and regional organisations can find roles. These are: (1) collaboration in the establishment and use of decision support knowledge bases; (2) collaboration in the development and sustainable exploitation of transboundary natural resources and ecosystems; (3) identifying, promoting and disseminating appropriate climate change adaptation technologies; and (4) establishing a regional framework for consultation on climate change and impacts.

There is a marked absence of the formal private sector (creditors, input suppliers, marketers) on climate change issues, probably because of the perceived uncertainties and risks involved. These are missing voices worth drawing in. The space between researchers and technocrats (civil servants), for example through their membership on boards of national research institutes, also does not seem to have been well exploited. CORAF/WECARD's current policy of promoting competitive grants, in which a major criterion for successful application is that proposals should be jointly developed by about three West African countries, and also that proposals should show evidence of partnership between a range of stakeholders within countries (innovation platforms) is an opportunity for improved collaboration between stakeholder organisations.

8. Conclusions and Recommendations

8.1 Conclusions

Smallholders in West Africa are highly vulnerable to climate change because of a combination of social, economic and environmental factors. Climate change adaptation challenges for the agricultural sector are considerable, bearing in mind that smallholders operate in multi-stressor environments where productivity is determined by several interacting factors and the farmers' capacity to adapt to climate change is limited by poor access to technology, credit, markets, poor institutional factors and infrastructure. Climate change also has implications for population growth, water resources and demand, land resources and gender issues.

Concerning the current state of knowledge on climate change and adaptation, there is clear evidence that temperature will increase as a result of climate change with negative consequences for the crops, livestock, pastoral and fisheries subsectors in the region. The prediction for rainfall is less certain but whatever way it goes there will be harmful consequences for agriculture in terms of extreme events. Technological options designed initially to achieve food security and conserve natural resources now serve as best bets in adaptation. There is documented evidence of coping and adaptation to climate change by smallholders but the extent could not be determined in a review of this nature.

There are many gaps and deficiencies regarding research approach and knowledge of how to adapt. Emphasis so far has been on development of technological options, for example drought tolerant crop varieties and soil and water management. Serious gaps relate to modelling scenarios dealing with the agricultural sector, risk management that deals with weather forecasting and communication, index based insurance, marketing and trade. Adaptation strategies are mainly short to medium term so as to attend to the immediate needs of poor farmers. A big challenge is developing technologies that cannot be fully assessed or validated now because the situations for which they are developed do not now exist. There is little evidence of deliberate attempt for agricultural development policies to directly cater to predicted climate change scenarios. The research-policy linkage is weak.

There are elements of alignment of continental, regional and national policies for Nigeria, Ghana and Senegal which have been used as case studies in this review; this is good for the efficient use of donor and government resources for the benefit of farmers. Substantial information is available on the activities of key stakeholders. Their diversity and their interest in adaptation to climate change are strengths to meet the challenges of adaptation. Membership of innovation platforms, participation in scenario building workshops and multi donor funded regional projects are examples of how stakeholder involvement could be improved. A number of recommendations in line with the questions that guided the review are made below.

8.2 Recommendations

8.2.1 Tackling climate change in the context of multisector challenges

A comprehensive approach involving coordination of activities in the crops, livestock, fisheries and forestry sectors is recommended, taking cognizance of the cross-cutting issues of water, energy and gender. Interdisciplinary research, as appropriate, is therefore required. Fundamental to success in adaptation is good governance in the form of rule of law, decentralisation and participation of citizens in decision-making that creates the environment for social cohesion, rapid agricultural growth rates and GDP growth that translate into improved human development.

8.2.2 Improving adaptation to climate change by smallholders

Improved access by smallholders to best bets, through diagnosis of problems and on-farm demonstrations/ adaptive trials and improved dissemination systems, improved credit systems by way of strengthened rural banks and microcredit schemes and improved access to markets through better infrastructure (storage, feeder and major road networks) are required. Training on the options for adaptation to climate change, for example reduction of post harvest losses and value addition to agricultural produce, and provision of extension services to farmers is required. Periodic assessments of adaptation strategies should be done so as not to perpetuate any one form of adaptation; rather, emphasis should be on strengthening adaptive capacity to assess changing socioeconomic circumstances and adjust accordingly. For sustainability, local communities should have ownership of interventions in adaptation.

8.2.3 Filling gaps in research on adaptation to climate change

Both conventional scientific research and participatory action research should be employed as appropriate as they complement each other. PAR is strongly demand driven and identifies problems as perceived by end users at the community level, but some problems may have underlying causes that require in-depth investigation beyond the capabilities of PAR. Conventional research is more proactive and can therefore forestall disasters. The right balance between research for developing short term and long term strategies should be kept. New research, especially of a strategic nature, should be done as best as possible in the context of existing initiatives at the national, regional and international levels (CGIAR centres).

This review has focused on adaptation to climate change in agriculture, but there is need for research at various levels on both the mitigation and adaptation aspects of climate smart agriculture, their interactions and trade-offs. For a deeper understanding of the effects of climate change on the agricultural sector and the science of adaptation the following tentative themes and topics are recommended; however, they do not preclude themes and topics meant to respond to community-level demand that may emerge from consultation with crop famers, livestock keepers, pastoralists and fisherfolk in PAR. The complementary roles of indigenous knowledge and scientific knowledge should be recognised at all levels of adaptation. The themes and topics would need to be prioritised by sub-regions (Sahelian and Coastal zones) and on a country by country basis.

8.2.3.1 Technical research on crops, livestock and fisheries

The tentative research themes and topics include: crop and animal improvement for yield and tolerance to biotic and abiotic stresses; effects of climate change on incidence of crop and animal pests and diseases; fine tuning conservation agriculture to diverse biophysical and socioeconomic conditions for improved smallholder uptake; livestock conservation of genetic diversity through genebanks; pasture improvement based on controlled grazing, mobility, fluctuating herd size and different livestock species; animal manure management; increasing quality and adding value to crops, livestock and fisheries products; nutritional value of processed products; improving efficiency of agricultural water use in the crops and livestock sectors; reclamation of land degraded by salty water; prolonging the growing season; climate change and tree crops; screening and matching agroforestry species and plant populations with ecological zones and agricultural practices; and agroforestry and use of biochar as technologies for soil improvement and climate smart agriculture. Work on climate resilient sustainable intensification of aquaculture, including identification of suitable stocks and increasing feed efficiency, should also be encouraged.

8.2.3.2 Socioeconomics and policy research

Research is recommended on the policy process and political factors influencing priorities and affecting adaptation; land use patterns and adaptation; land use regulations and mobility of pastoralists; costs and returns of adaptation options, quantity and value of fish stocks; ex ante evaluation of adaptation options, effectiveness of adaptation options, adoption rates and determinants of adoption; analysis of existing marketing structures to improve efficiency and determine how regional integration of markets and access to global markets will be important in responding to climate change; gender considerations in adaptation to climate change and variability; and effect of knowledge of climate change and variability on achievement of national development goals including poverty reduction, food security at national and regional levels. Improved modelling capability would facilitate technical and socioeconomic research.

8.2.3.3 Risk management dealing with stocks, weather forecasting and insurance

Risk management should involve feasibility study of buffer stocks (grain reserves), improvement in the quality of meteorological data collection and weather forecasting tools and techniques and therefore early warning systems to reflect the needs of farmers; and innovative insurance schemes for smallholder crop farmers, livestock keepers and fisherfolk. The latter should include rainfall index for crops or greenness of rangelands index (based on remote sensing) for livestock and pastoral systems.

8.2.4 Improving policy formulation and how research findings can be better integrated into agricultural policies

At the regional level, opportunities for policy planning and cooperation through ECOWAS, CILSS, the river basin authorities and ROPPA should be exploited. For example, the strengthening of basin-level cooperation in hydro-climatic data collection, analysis and sharing is needed. ECOWAS should intensify efforts in harmonising trade policies in the region. There is a very strong case for regional and sub-regional cooperation in the fisheries sector because of the commonly shared Atlantic Ocean and transboundary waters. Coherent marine fishing policies in the region and flexible arrangements should be put in place to prevent overfishing, cope with the changing and dwindling stocks and arrest poaching by foreign trawlers. This may go beyond controlling levels of catches to the designation of protected areas.

National policies on agricultural development and climate change adaptation should be evidence based and provide an enabling environment for maintaining or improving the productivity of land, water and labour under changing climate. This will involve policies to facilitate access by smallholders to credit and markets; policies to improve institutional capacity and infrastructure; smart subsidies; insurance schemes for smallholders in the crops, livestock and fisheries sectors; and crisis management. Sustainable food security must be made the central concern. In the context of multi-sectoral policymaking, policies must be flexible. They must be gender sensitive and address gender imbalance in access to land and credit. Farmers should be provided with financial incentives to adopt climate-smart agricultural practices. Integrating climate adaptation into new agricultural development projects is feasible and highly recommended. Allocation of funds to various development sectors on the basis of prioritised needs and creation of functional, inter-ministerial working committees will mitigate power struggles.

The linear 'research to policy model' should give way to more participatory approaches. To be useful in supporting policy formulation, strategies for adapting food systems to climate change and variability must be elaborated in the context of the policy processes. Better still, policymakers must be brought into the research loop very early. A range of decision support approaches and tools from sensitisation to more concrete joint scenario building and analysis for examining consequences and trade-offs of policy options should be explored. Out of these sessions, the best tools that facilitate dialogue for different audiences and circumstances can be found and exploited. For successful adaptation it is necessary to go beyond policy formulation to enacting legislation and enforcing laws.

8.2.5 Improving stakeholder involvement in research and policy on adaptation

Guides and toolkits developed by the international partners, for example on mainstreaming gender into agricultural policies and on how climate adaptation strategies can be developed at community levels, should be made use of by researchers and practitioners of adaptation. It is recommended that financial and technical support be given to ACMAD and AGRHYMET Regional Centre for them to become genuine centres of excellence on climate change matters for crop farming, livestock keeping, pastoralism and fisheries and to provide evidence on which policy can be based. This would involve increasing the density of meteorological stations in West Africa. For excellence in research, at the national level the NARES should be adequately funded and their links with advanced laboratories in developed countries and CGIAR centres strengthened. Collaboration between stakeholders within countries should be strengthened through innovation platforms and participatory action research. Scientists in the range of disciplines dealing with climate change and adaptation should work together in regional projects. Ways in which the private business sector can be effectively brought into the dialogue on climate adaptation should be explored. Civil society, farmers' associations and journalists should be considered important stakeholders in linking researchers with policymakers and be encouraged to participate with the other stakeholders in training and scenario building workshops. Donors should give agriculture a higher level of priority in climate change financing negotiations, bearing in mind the low proportion of adaptation funding currently allocated to the agricultural sector.

End Notes

[1] According to the most recent IPCC assessment, global mean surface change for 2016-2035 relative to 1986-2005 will likely be in the range of +0.3°C to +0.7°C.

[2] See the Sea Around Us Project catch database (www.seaaroundus.org).

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