# Overview of the Scientific, Political and Financial Landscape of Climate-Smart Agriculture in West Africa

Working Paper No 118

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Robert Zougmoré, Alain Sy Traoré, Yamar Mbodj (Eds.)

Working Paper

CGIAR

RESEARCH PROGRAM ON
Climate Change,
Agriculture and
Food Security

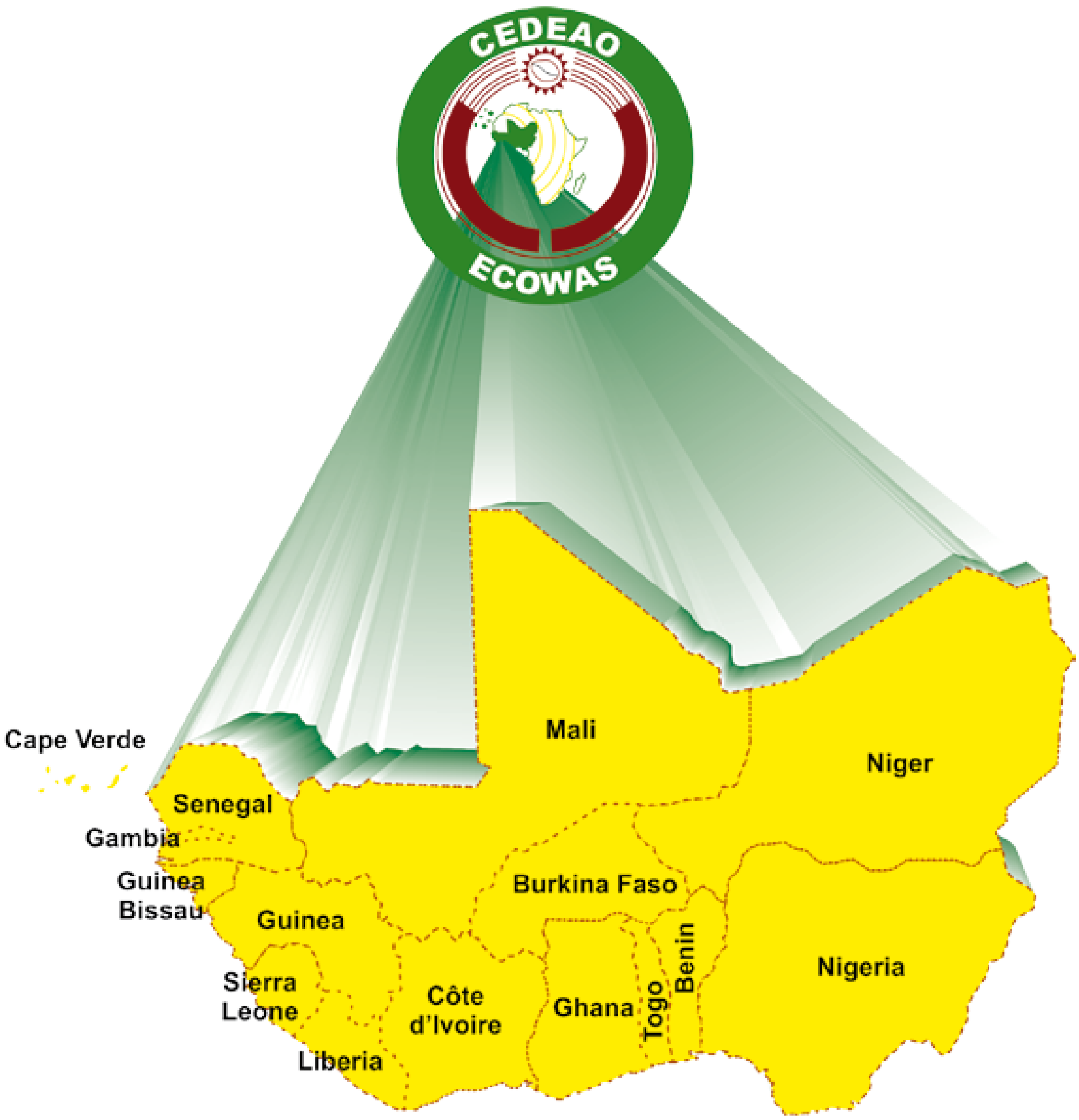
CCAFS

# Overview of the Scientific, Political and Financial Landscape of Climate-Smart Agriculture in West Africa

Working Paper No 118

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Robert Zougmoré, Alain Sy Traoré, Yamar Mbodj (Eds.)



**Correct Citation:**
Robert Zougmoré, Alain Sy Traoré and Yamar Mbodj (Eds.), 2015. Overview of the Scientific, Political and Financial Landscape of Climate-Smart Agriculture in West Africa. Working Paper No. 118. CGIAR Research Program on Climate Change, Agriculture and Food Security.
**Available online at: www.ccafs.cgiar.org**

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices, and stimulate feedback from the scientific community.

This working paper is published by the Research Program of the Consultative Group for International Agricultural Research (CGIAR) on climate change, agriculture and food security (CCAFS). CCAFS is a strategic partnership of CGIAR and Future Earth. The CCAFS Program is supported by the CGIAR Fund, the Danish International Development Agency (DANIDA), the Government of Australia (ACIAR), the Irish Aid Agency, the Government of Canada through the Federal Ministry of the Environment, the Netherlands Ministry of Foreign Affairs, the Swiss Agency for Development and Cooperation (DDC), the Instituto de Investigação Científica Tropical (IICT), the UK Aid Agency, and the European Union (EU). The program is implemented with technical support from the International Fund for Agricultural Development (IFAD).

**Contact:**
CCAFS Coordination Unit – Faculty of Science, Department of Plant and Environmental Sciences, University of Copenhagen, Rolighedsvej 21, DK-1958 Frederiksberg C, Denmark. Tel: +45 35331046; Email: ccafs@cgiar.org


CCAFS Working Paper No 118

Photos: CCAFS, ILRI, IWMI, WorldFish, CIFOR, ICRAF
Maps: ECOWAS

Proofreading and graphics design: CCAFS and PAO Bougou
Printing: PAO Bougou

# Abstract

The agricultural sector plays a key role in the Economic Community of West African States (ECOWAS). As the backbone of the economy, it affects society at many levels since national economies and people's jobs, incomes and food security depend upon it. Climate change and variability pose a major threat to farmers in the region, which is already experiencing rising temperatures, shifting precipitation patterns, and increasing extreme events. The ECOWAS has put in place various policy instruments such as the Economic Community of West Africa States Agricultural Policy (ECOWAP) and its derived Regional Agricultural Investment Plan (RAIP) in order to promote a modern and sustainable agriculture based on effective and efficient family farms and the promotion of agricultural enterprises through the involvement of the private sector. Taking stock on member States' expressed needs, ECOWAS would like to integrate a new type of public policy instruments into the RAIP: instruments for adapting the West-African agriculture to climate change, towards a Climate-Smart Agriculture (CSA) focusing on adaptation, mitigation and food & nutrition security joint objectives. This book documents and analyses specific features of the scientific, institutional, policy and funding CSA landscape in West Africa. It provides relevant information that could guide the definition of the ECOWAS Framework for CSA Intervention, Funding, Monitoring and Evaluation. Five major agricultural sectors have been covered: crop production, livestock, fisheries, forestry/agroforestry, and water. For each sector, a particular emphasis was given to the current status, the climate projections and likely socio-economic and environmental impacts expected, the bottlenecks to action and suggested next steps for adaptation and mitigation. Actionable messages and recommendations have been directed to ECOWAS stakeholders so as to incentivise CSA in West Africa.


**Key words:** Climate change ; Climate-smart agriculture ; Crop production ; Livestock ; Water resources ; Fisheries ; Forestry ; Agroforestry ; West Africa

# Authors

**Dr Robert Zougmoré** is an agronomist and soil scientist with a PhD in Production Ecology & Resources Conservation, University of Wageningen. He is based at ICRISAT Bamako where he currently leads the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) for West Africa region. With more than 20 years research experience, his major research covered soil and water management, runoff and soil erosion, land rehabilitation and integrated soil, water and nutrient management options and their economic benefits at plot and watershed levels. His current work focuses on the development of climate-smart agriculture technologies, practices, institutions and policies for better climate risk management in West Africa. Email: r.zougmore@cgiar.org

**Mr Alain Sy Traoré** is Director of Agriculture & Rural Development at the ECOWAS Commission. He obtained a "DEUG" in Biology-Geology from the Faculty of Science and Technology (University of Ouagadougou) in 1992, a Master degree in Sciences & Technology of Rural Development with specialization in Agronomy in 1995, and a degree of Engineer in Rural Development with specialisation in Agronomy from the Institute of Rural Development (University of Ouagadougou) in 1996. Alain Sy Traoré has nearly achieved 20 years of experience as Head of Marketing/Development in a seed company, Project Manager and Agribusiness Advisor and Development in West Africa. He progressively accumulated knowledge and experiences in areas such as Climate-Smart Agriculture, Agricultural Project Monitoring and Evaluation, or Agri-food Marketing and Development. Email: satraore@ecowas.int or syalaintraore@yahoo.fr

**Dr Yamar Mbodj** is the Executive Director of Rural Hub. He has over 30 years experience in agriculture, particularly in the coordination and facilitation of multidisciplinary teams, driving process and operational strategic thinking involving several countries, support for political dialogue between actors and the support for the formulation of regional strategies, etc. He worked as Advisor Agriculture/NEPAD at the ECOWAS' Commission in Abuja from 2004 to 2010 and served as Advisor and Coordinator of food security activities strategic thinking to the Executive Secretary of the Permanent Interstates Committee for Drought Control in the Sahel (CILSS) from 1994 to 2004. From 1974 to 1994 he worked as lecturer and researcher, respectively as Expert trainer at AGRHYMET and as Coordinator of research programs at ISRA in Senegal. Yamar Mbodj is a Doctor of Agricultural Sciences, Faculty of Agricultural Sciences at the Catholic University of Louvain (Belgium). Email: yamarm@hubrural.org

**Dr Marloes Mul** is a Senior Researcher in Hydrology and Water Management at the International Water Management Institute, based in Ghana. She has a PhD in Hydrology from Delft University of Technology. Her current work focusses on planning and management of natural and built infrastructure, focusing on increasing resilience to climate change through water storage in the West African region. Email: M.Mul@cgiar.org

**Dr T. Olalekan Williams** is Director for Africa at the International Water Management Institute (IWMI). He is based at the West Africa and Africa Regional Office of IWMI in Accra, Ghana. He holds a Doctorate degree in Agricultural Economics from Oxford University, UK. He is currently conducting research to examine the food security, livelihoods and ecosystems impacts of large-scale agricultural land investments in Africa. Williams is an Honorary Fellow of the Association of African Agricultural Economists. Email: T.O.Williams@cgiar.org

**Dr Olufunke Cofie** is a Soil Scientist and head of the International Water Management Institute (IWMI) in West Africa. She also coordinates the CGIAR Research Program on Water Land and Ecosystems (WLE) in Volta-Niger Basin region. She is posted in Accra, Ghana. Her main research interests are: (i) recovering nutrients, organic matter and water from municipal wastes for urban and peri-urban agriculture; and (ii) improving smallholder agricultural water management. Email: o.cofie@cgiar.org

**Dr Abdulai Jalloh** has more than 25 years of agricultural research for development experience in Africa. He served as an Agronomist and led research teams of the Sierra Leone Agricultural Research System from 1987-2009. He is managing the Natural Resources Management Program of the West and Central African Council for Agricultural Research and Development (CORAF/WECARD) addressing issues that involve soils, water, biodiversity as well as climate change. He is also coordinating the continent wide AfricaInteract project that is enabling research-to-policy dialogue for adaptation to climate change. Email: abdulai.jalloh@coraf.org

**Dr Bamidele Omitoyin** is an aquaculture and fisheries management expert with a PhD in Fisheries Management from the University of Ibadan, Ibadan, Nigeria. He is Professor of Aquaculture and Aquatic pollution/Toxicology and the current Head of Department of Aquaculture and Fisheries Management, University of Ibadan. His current research focus is developing Aquaculture Smart technologies in mitigating climate change impacts on Fisheries and Aquaculture particularly among smallholder farmers. Email: bo.omitoyin@mail.ui.edu.ng or bam_omitoyin@yahoo.co.uk

**Dr Patrice Savadogo** serves as Agroforestry Systems Scientist simultaneously for the World Agroforestry Centre (ICRAF) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). He holds a PhD in Forest Management, especially Tropical Silviculture from the Swedish University of Agricultural Sciences. His current research interests are in the areas of dryland agroforestry, tree domestication, disturbance ecology in dry forest (fire, grazing and wood biomass removal) and how to streamline restoration of degraded rural landscapes based on disturbance legacies both for climate mitigation and livelihood improvement. Email: P.Savadogo@cgiar.org

**Dr Timothy S. Thomas** has been serving as a research fellow at IFPRI in the Environment and Production Technology Division since March 2010. His work at IFPRI involves using a variety of models to assess the impact of climate change on agriculture, with the goal of identifying policies that will help farmers adapt to the change. He is also working to assess policies designed to mitigate climate change by modifying greenhouse gas emissions from the AFOLU (agriculture, forestry, and land use change) sector. Email: Tim.Thomas@cgiar.org

**Dr Augustine Ayantunde** is a Senior Livestock Scientist, with more than twenty years of experience in ruminant nutrition and evaluation of feed resources in West African Sahel, evaluation and monitoring of natural resource use in pastoral and agro-pastoral systems, assessment of vulnerability of pastoral and agro-pastoral systems to climate change, conflict management, indigenous ecological knowledge and participatory assessment of strategies for sustainable intensification of crop-livestock systems in West Africa. He holds a PhD in Ruminant Nutrition from University of Wageningen, The Netherlands. Email: A.Ayantunde@cgiar.org

**Dr Polly Ericksen** holds a PhD in Soil Science from University of Wisconsin. She is the Programme Leader for Livestock Systems and Environment at ILRI, based in Nairobi. Her areas of focus include adaptation to climate change in livestock systems. Email: p.ericksen@cgiar.org

**Dr Mohammed Said** holds a PhD in Ecology from Wageningen University. He is a Senior Scientist at ILRI, based in Nairobi, with expertise in remote sensing and other spatial analysis. He has over 20 years experience working on the rangelands of East Africa, particularly on livestock and wildlife interactions. Email: m.said@cgiar.org

# Acknowledgement

The authors wish to acknowledge with thanks the support of ECOWAS and its partners for the West Africa stakeholders' forum for Climate-Smart Agriculture framework and alliance development. They also thank all organisations members of the technical support and monitoring team of the forum.

# Preface

The population of West Africa has quadrupled over 50 years, from 90 million in 1960 to 342 million in 2011, and is expected to double by 2050. This rapid population growth will result in increased demand for food, which will be more challenging than the current food insecurity in the region. In a bid to mitigate this situation, ECOWAS has developed the regional agricultural policy (ECOWAP) which assessed the agricultural and food security issues and challenges facing the region.

As the reference framework for intervention in agricultural development across West Africa, ECOWAP also evaluated the development potential across countries, the aim being to contribute in a sustainable way to meeting the food needs of the population, to economic and social development, to the reduction of poverty in Member States. It is in this perspective that ECOWAS has put in place various incentives policy instruments in order to accelerate the implementation of the Regional Agricultural Investment Plans (RAIPs) and the countries' Agricultural Investment Plans (NAIPs).

It is however unfortunate that the additional threats posed by climate change may limit or slow down the attainment of these goals. Indeed, climate change shocks and stresses caused by higher temperatures and changing rainfall patterns, will worsen the productive asset of smallholder farmers who are already weakened by various constraints in their activities for crops, livestock, fisheries, forestry production.

Adapting to climate change is a must for West Africa region, especially for the agricultural sector which employs 60 percent of the active labour force and contributes 35 percent of Gross Domestic Products. It is in this endeavour to promote the regional agricultural growth that ECOWAS has engaged a process to integrate Climate-Smart Agriculture (CSA) into the RAIPs and NAIPs. We believe that CSA is a new approach that will soundly enable agricultural producers from our regional community to achieve the triple wins of increased food security and income, increased resilience of ecosystems and livelihoods to climate change, and wherever possible, reduced greenhouse gas emissions.

This book produced under the coordination of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and in collaboration with Hub Rural, has documented and analysed the current and future perspectives of Climate-Smart Agriculture for five majors sectors in West Africa. We see this synthesis as an important initial step that sets the scene of the scientific, political and financial landscape of CSA in our region. This book represents a substantial source of knowledge and information that will certainly guide further analyses for actionable recommendations aiming to promote CSA in West Africa. More importantly, we hope that CSA will help and complement other ECOWAS-led initiatives in mainstreaming climate change in order to sustainably improve the livelihoods of West Africa's population, now and in the future.

**Dr Lapodini ATOUGA**
Commissioner for Agriculture, Environment and
Water Resources, ECOWAS

# Foreword

The changing climate that is affecting our planet requires that we have the knowledge and information to cope and adapt. Although the short- and long-term changes and impacts of climate change are difficult to disentangle from other drivers of change, it is now well-known that increases in greenhouse gasses affect temperature, seasonality, rainfall and sea level, with knock-on effects to other facets of the global system (e.g. glacier processes, biodiversity, ocean acidity) in complex interactions.

Agriculture is probably the sector that will be hit hardest by climate change, because farmers are generally at the whim of the weather. In addition, agriculture is also crucial for climate change mitigation, through sequestering carbon in the soil and above-ground biomass, contributing to low-carbon development by substituting conventional high-carbon products with agricultural or forestry products, by intensifying so as to not result in deforestation, and by cutting emissions from agricultural practices (in particular livestock and rice production, poor fertiliser practices). Agriculture today and tomorrow must become low-carbon agriculture if we are to continue producing enough food while contributing to GHG reductions.

Generating the scientific knowledge to inform agricultural development strategies is crucial, from global to regional to local levels, thus informing decision makers who are engaging in policy development to promote climate-smart agriculture for improved food systems.

This book is produced by CGIAR scientists and their partners in West Africa. It provides state-of-the art knowledge on the current status of CSA development in the ECOWAS region. It documents the technical, political and financial landscape of CSA in the region, covering all sectors: crop production, livestock, fisheries, forestry/agroforestry, and water. For each of these sectors, the authors analyse the current status, the climate projections and likely socio-economic and environmental impacts expected. It identifies the bottlenecks to action and suggests some next steps for adaptation and mitigation. Actionable messages and recommendations have been directed to ECOWAS stakeholders so as to incentivise CSA in West Africa.

This work benefited from the interactions and contributions of various key stakeholders from West Africa, allowing for cross-agency learning, a crucial need for climate change adaptation. The recommendations will help fine tune a promising future for CSA in West Africa and help ECOWAS stakeholders build a regional food system that is resilient to climate variability and change.

**Dr Bruce CAMPBELL**
Director of the CGIAR Research Program on
Climate Change, Agriculture and Food Security (CCAFS)

# Contents

## Abbreviations and Acronyms

| | |
|---|---|
| ACMAD | African Centre of Meteorological Application for Development |
| AfDB | African Development Bank |
| AGRHYMET | *Centre Régional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle* (Regional training and application center for agrometeorology and hydrology) |
| ASFF | Africa Sustainable Forestry Fund |
| BMPs | Better management practices |
| BNRCC | Building Nigeria's Response to Climate Change |
| CAADP | Comprehensive African Agricultural Development Programme |
| CBD | Convention on Biological Diversity |
| CC | Climate Change |
| CCAFS | Climate Change, Agriculture and Food Security |
| CEC | Cation exchange capacity |
| CGIAR | Consultative Group for International Agricultural Research |
| CILSS | *Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel* (Permanent Interstates Committee for Drought Control in the Sahel) |
| CLE | *Comité Local de l'Eau* (Local water committees) |
| CNRM | *Centre National de Recherches Météorologiques* |
| CORAF/ WECARD | *Conseil Ouest et Centre africain pour la recherche et le développement agricoles*/West and Central African Council for Agricultural Research and Development |
| CSA | Climate-Smart Agriculture |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| EAA | Ecosystem Approach to Aquaculture |
| ECA | Economic Commission for Africa |
| ECOWAP | Economic Community of West Africa States Agricultural Policy |
| ECOWAS | Economic Community of West African States |
| EEZs | Exclusive Economic Zones |
| EPTD | Environment and Production Technology Division |
| FAO | Food and Agriculture Organization |
| FASDEC | Food and Agriculture Development Policy |
| FDI | Foreign Direct Investments |
| FIP | Forest Investment Programme |
| FMNR | Farmer Managed Natural Regeneration |
| GCM | General Circulation Model |
| GDP | Gross domestic product |
| GEF | Global Environment Facility |
| GHG | Greenhouse gas |
| ICRAF | World Agroforestry Centre |
| ICRISAT-WCA | International Crops Research Institute for the Semi-Arid Tropics – West and Central Africa |

| | |
|---|---|
| IFPRI | International Food Policy Research Institute |
| ILRI | International Livestock Research Institute |
| IPCC | Intergovernmental Panel on Climate Change |
| ISRA | *Institut Sénégalais de Recherches Agricoles* |
| ITTO | Timber Trading Organization |
| IWMI | International Water Management Institute |
| IWRM | Integrated Water Resource Management |
| MSE | Management strategy evaluation |
| NAIP | National Agricultural Investment Programme |
| NAMAs | Nationally Appropriate Mitigation Actions |
| NAPAs | National Adaptation Programmes of Action |
| NAPs | National Adaptation Plans |
| NARS | National Agricultural Research Systems |
| NASPA-CCN | National Adaptation Strategy and Plan of Action on Climate Change for Nigeria |
| NDVI | Normalized Difference Vegetation Index |
| NEPAD | New Partnership for Africa's Development |
| NEST | Nigerian Environmental Study/Action Team |
| NFP | National Forest Programme |
| NGOs | Non-governmental Organizations |
| NTFPs | Non-timber forest products |
| ODA | Official Development Assistance |
| PRSPs | Poverty Reduction Strategy Papers |
| R&D | Research and Development |
| RAIP | Regional Agricultural Investment Plan |
| RAIP | Regional agricultural investment programme |
| REDD | Reducing Emissions from Deforestation and Forest Degradation in Developing Countries |
| SOM | Soil organic matter |
| SWAC-OECD/ ECOWAS | Sahel and West Africa Club - Organisation for Economic Co-operation and Development/ECOWAS |
| UN | United Nations |
| UNCCD | UN Convention to Combat Desertification |
| UNFCCC | UN Framework Convention on Climate Change |
| USAID | United States Agency for International Development |
| WA | West Africa |
| WISP/IUCN | World Initiative for Sustainable Pastoralism/International Union for Conservation of Nature |
| WLE | Water Land and Ecosystems |

# Chapter 1
## Overview of the scientific, political and financial landscapes of Climate-Smart Agriculture in West Africa: sector of crop production

**Timothy S. Thomas[1] & Robert Zougmoré[2]**

[1]Environment and Production Technology Division (EPTD), International Food Policy Research Institute (IFPRI), Washington DC, USA

[2]CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), West Africa Region, ICRISAT-West and Central Africa, Bamako, Mali

## Executive summary

This chapter reviews some recent studies on the impact of climate change on agriculture in West Africa between 2000 and 2050, with a focus on the crop sector. We note that without adaptation or technological advancement, climate change will adversely impact major crops between 5 and 22 percent. But with technological advancement, together with population growth and GDP growth, it is likely that yields will grow between 40 and 160 percent for major crops. In order for such growth to be realized, however, investment in agricultural research will need to increase, along with the ability of institutes to produce new varieties that will help farmers deal with rising temperatures, changing rainfall patterns, and higher weather variability.

Some adaptation strategies also appear to be good mitigation strategies, creating win-win scenarios. Yet, in cases in which mitigation and adaptation may work against each other (such as increasing fertilizer use which may result in higher nitrous oxide emissions), it is a better strategy to pursue adaptation, particularly when it involves small family farms.

Best ideas include trying to increase soil organic matter, increase soil nutrients, increase investment in results-oriented agricultural research, and develop separate strategies for each farming system.

## 1. Current status for crop production in West Africa

The Economic Community of West Africa States Agricultural Policy (ECOWAP) was adopted in 2005. This is a common agricultural policy that shares a vision and objectives. It is meant to strengthen production on family farms, reduce food insecurity, and assure fair incomes to agricultural workers. One of the specific objectives is to achieve sustainable intensification. Under this program, individual governments retain their own planning with the support of the ECOWAS commission, and develop their own National Agricultural Investment Programs.

However, the affirmation of a joint strategy makes a great deal of sense in terms of the climate of the region, which creates distinct ecozones, which, for the majority of the region, run east-west in bands that span multiple countries. Distinct farming systems have developed as a result of the ecozones, which create economies of scale for regional agricultural policy, planning, and research. The cropping systems include the agro-pastoral / millet / sorghum system in the arid to semi-arid regions; irrigated systems; cereal / root crop systems; pure root crop systems; coastal fishing; and tree crop systems. Each one of these will be impacted differently by climate change. In this chapter, the focus will be on annual crops.

The five leading crops by harvested area in West Africa are (in millions of hectares) millet, 16.0; sorghum, 14.3; cowpea, 10.3; maize, 7.8; and rice, 5.7. Yields tend to be low, because of low and erratic rainfall, generally low levels of soil nutrients, and low fertilizer use (FAOSTAT data averaged over the 2006 to 2008 period).

# 2. Climate projections and socio-economic and environmental impacts expected by 2050

## 2.1. Modelling of the expected impacts

The four climate models used in Jalloh *et al.* (2013a) all projected a rise in temperature, though there was great geographical variation between models, and the average rise ranged across the four GCMs from 1.5$^{O}$ C to 2.3$^{O}$ C between 2000 and 2050. Mean annual rainfall changes across the four climate models differed more modestly, ranging from a drop of 23 millimetres per year to a rise of 22 millimetres per year.

Table 1 shows the weighted tabulations of productivity change for important crops grown in West Africa, based on DSSAT crop model analysis together with the four climate models (Nelson *et al.*, 2010; Jalloh *et al.*, 2013a; Thomas and Rosegrant forthcoming). In the table, only rain-fed rice shows positive response, and that a very modest gain. Losses to wheat and irrigated rice are projected to be around 20 percent; sorghum, 14 percent; and maize, soybeans, and groundnuts, between 5 and 7 percent.

Figure 1 shows the detailed geographic results for one of the crop model analyses for the CSIRO A1B GCM, for rain-fed sorghum. We note something that is true for all of the crops and GCMs analysed: there is a band in the northern boundary of currently cultivable areas which will likely not be able to be cultivated in the future due to temperature increases[1]. Some productivity reductions along southern portions of coastal countries are due to rainfall reductions in those areas in some of the climate models.

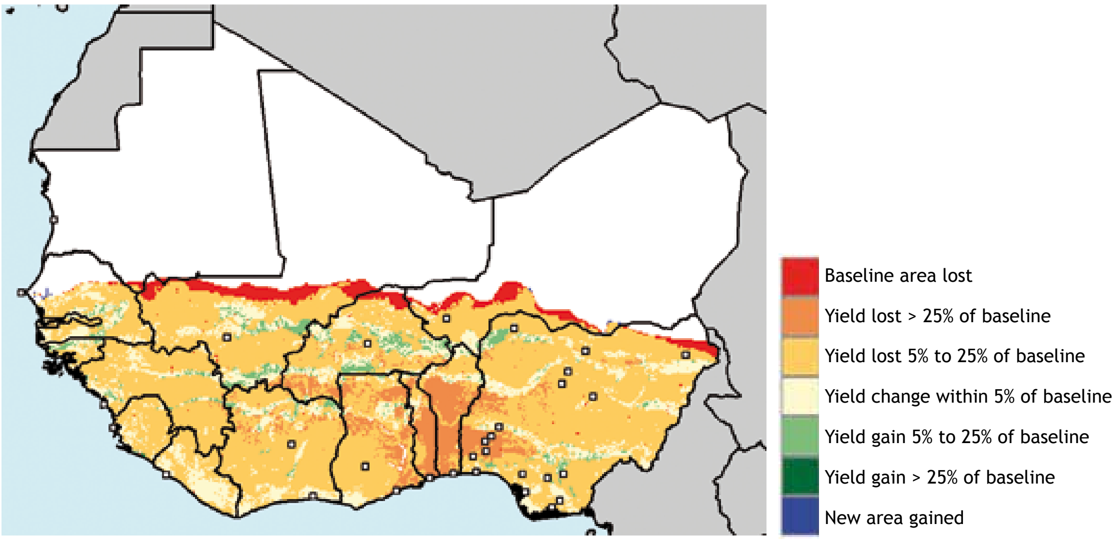
### Table 1. Yield changes (%) for various crops in West Africa as a result of climate change, 2000-2050

| Water | Crop | Median | CNRM | CSIRO | ECHAM | MIROC |
|---|---|---|---|---|---|---|
| Rain-fed | Groundnuts | -6.8 | -5.8 | -7.7 | -9.2 | 0.3 |
| Rain-fed | Maize | -5.5 | -2.3 | -8.1 | -6.0 | -4.9 |
| Irrigated | Rice | -19.0 | -19.9 | -12.4 | -20.0 | -18.2 |
| Rain-fed | Rice | 0.9 | 4.4 | 0.5 | 0.9 | 1.0 |
| Rain-fed | Sorghum | -13.9 | -15.9 | -9.5 | -14.8 | -13.0 |
| Rain-fed | Soybeans | -5.0 | -1.5 | -8.4 | -1.6 | -14.2 |
| Irrigated | Wheat | -21.4 | -37.8 | -10.9 | -28.5 | -14.3 |

Source: Based on analysis in Jalloh *et al.* (2013a) and presented in Thomas and Rosegrant (forthcoming).

Notes: All GCMs are from the AR4, and represent the A1B scenario.

[1] However, in recent analysis of AR5 GCMs under the AgMIP project (see more on this later in this report), it is possible that the stress caused by higher temperatures might be compensated by increases in precipitation, resulting in this band actually increasing in productivity for sorghum as well as millet.




## Figure 1. Yield changes for rain-fed sorghum, CSIRO A1B GCM, 2000-2050

Source: Jalloh *et al.* (2013a)

Table 2 shows the results of a different analysis which used a global partial equilibrium model of food and agriculture, called IMPACT. This model takes into account productivity changes from the crop model analyses, but includes projected technological growth. As a result, there are large yield increases projected, even under climate change. Additionally, the model takes into consideration global demand for food, based on higher GDP projected for the future, and a large population. When equilibrium prices rise sufficiently, farmers intensify production, sometimes enough to increase yields under climate change above the yields of the no climate change scenario.

The table should not be read as suggesting that climate change will be positive for agriculture generally. Table 1 already showed that the direct effects of climate change on agriculture will be mostly negative. The large productivity increases in Table 2 emphasize the importance of continuing technological improvement, and should suggest the value of continued and increased investment in agricultural research and extension, along with productivity-enhancing investments in irrigation, mechanization, fertilizer supply, and climate-smart agriculture.

## Table 2. Change (%) in productivity, West Africa, 2010-2050, IMPACT Model

| Crop | No Climate Change | Median of 4 GCMs | MIROC A1B | MIROC B1 | CSIRO A1B | CSIRO B1 |
|---|---|---|---|---|---|---|
| Cassava | 49.5 | 46.3 | 37.2 | 62.5 | 35.5 | 55.5 |
| Cotton | 90.9 | 80.8 | 76.5 | 85.2 | 71.4 | 89.1 |
| Groundnuts | 42.0 | 42.5 | 43.9 | 47.3 | 35.4 | 41.1 |
| Maize | 57.4 | 57.3 | 59.8 | 58.7 | 53.0 | 55.9 |
| Millet | 147.2 | 154.0 | 176.2 | 156.2 | 151.9 | 147.5 |
| Rice | 89.3 | 89.1 | 89.1 | 89.7 | 87.5 | 89.1 |
| Sorghum | 94.1 | 97.4 | 106.3 | 99.4 | 95.5 | 95.2 |
| Soybeans | 81.5 | 79.2 | 77.7 | 78.5 | 80.0 | 84.6 |
| Sweet potatoes and yams | 73.5 | 60.7 | 49.1 | 84.0 | 48.1 | 72.3 |

Source: Based on analysis conducted for Nelson *et al.* (2010).

Note: Values are for the baseline economic-demographic scenario

Table 3 shows projections from the IMPACT model for prices. With climate change, we see prices will rise more than if there were not climate change. Median wheat price under climate change will more than triple, while apart from climate change, it would only increase by two-thirds of the price in 2010.

### Table 3. World price changes (%), 2010-2050

| Crop | No climate change | Median of 4 GCMs | MIROC A1B | MIROC B1 | CSIRO A1B | CSIRO B1 |
|---|---|---|---|---|---|---|
| Rice | 54 | 84 | 83 | 87 | 85 | 82 |
| Wheat | 66 | 202 | 121 | 106 | 99 | 93 |
| Maize | 103 | 160 | 209 | 165 | 156 | 145 |
| Sweet potatoes & yams | 60 | 130 | 141 | 96 | 156 | 120 |
| Cassava | 18 | 57 | 78 | 50 | 64 | 42 |
| Sugarcane | 77 | 110 | 125 | 113 | 108 | 103 |
| Sorghum | 82 | 107 | 115 | 104 | 110 | 104 |
| Millet | 8 | 10 | 8 | 8 | 14 | 13 |
| Groundnuts | 13 | 34 | 35 | 33 | 37 | 33 |

Source: Based on analysis conducted for Nelson *et al.* (2010).

Note: The price changes are from the baseline economic-demographic scenario.

Table 4 shows changes in malnutrition. While the reductions of numbers appear to be modest by 2050, with a growing population, the percent of malnourished might be reduced by almost half, even with climate change, due to projections in GDP per capita growth outpacing the food price growth, especially under the optimistic economic-demographic scenario.

### Table 4. Number and percent of malnourished children under 5 in West Africa, 2010 and 2050, IMPACT Model

| Scenario | 2010 | | 2050 | | | |
|---|---|---|---|---|---|---|
| | | | No climate change | | Average of max and min of 4 GCM-SRES scenarios | |
| | Number | Percent | Number | Percent | Number | Percent |
| Baseline | 15,157 | 31.0 | 12,415 | 20.9 | 13,913 | 23.4 |
| Optimistic | 14,733 | 30.2 | 7,615 | 15.1 | 8,949 | 17.1 |

Source: Based on analysis conducted for Nelson *et al.* (2010).

## 2.2. Which behaviour and actions towards uncertainties?

In light of the recent comparisons under CMIP (the Coupled Model Intercomparison Project[2]) and AgMIP (the Agricultural Model Intercomparison Project[3], see Rosenzweig *et al.* 2014), we have noted that there is much variation between climate models, between crop models (Rosenzweig *et al.*, 2014), and between economic models. Scientists, unfortunately, have not been able to come to general agreement on future projections. With so many diverse potential outcomes, it is unwise to put all investment into overcoming a single outcome. Rather, the approach should be multi-pronged, and should be focused on giving farmers many options. Some of these will be outlined in the next section.

[2] This has been an ongoing modeling exercise under the IPCC that generates climate models that are evaluated for their ability to be able to predict recent past and that can be used in the IPCC assessment reports for evaluating the impact of climate change in the future. The current set of general circulation models (GCMs), developed for the Fifth Assessment Report (AR5) is designated CMIP5.

[3] This is an international collaborative effort which include comparing results from different crop modeling systems and endeavoring to apply the models to climate models, so that the impact of climate change on agriculture and food security might be better known. For more information, see, http://www.agmip.org/crop-modeling-team/.

# 3. Next steps to cross for adaptation and mitigation

## 3.1. At the scientific and technical level

Much has been written recently on climate smart agriculture. Important references include the FAO's *Climate-Smart Agriculture Sourcebook* (2013), and their earlier *Save and Grow* (2011) and *"Climate-Smart" Agriculture* (2010):

**Cultivar development.** In the realm of cultivar development, this would include developing varieties that withstand higher temperatures. But it would also include varieties that are resilient to at least one other threat, whether it be drought, pest, weeds, salinity, flooding, etc. The best new varieties would be ones resilient to more than one threat. Since it takes many years to develop and test new cultivars, investment should start now.

**Water.** Along with cultivar development, supporting farming techniques should be developed. These might include irrigation and water harvesting. There may be benefits from shifting the focus from large-scale public irrigation to small-scale private irrigation, which may include more efficient management and distribution of water, related to the user actually bearing the costs of the water use, bypassing issues related to equitability and funding in large-scale schemes. Furthermore, one of the critical issues surrounding climate change is the variability in weather, with floods and droughts both becoming more frequent. Water conservation and supplementation are both important to develop when feasible, especially in marginal areas.

**Agroforestry.** Integrating trees with crops can have several advantages when done properly. Trees can sometimes serve as "nutrient pumps", bringing nutrients that are too deep for crops. They can be used to enhance soil nitrogen, when nitrogen-fixing trees are planted. Their leaves can serve as a mulch which might suppress some weed growth but would also help cool the soil, overcoming some of the impacts of temperature rise on crop growth. Furthermore, the litter would eventually be converted to soil organic matter (SOM), which has important properties that we will address next.

**Soil carbon sequestration.** Soil organic matter has been known for years to be beneficial to cultivation, due to its abilities to improve soil structure and enhance water and nutrient retention. The challenge is to leave enough (or place enough) vegetation for the SOM to increase. Agroforestry is one option, but other possibilities include no-till agriculture, off-season cover crops, use of animal manure, and biochar[4].

In addition to giving the farmer direct benefits, if carbon is sequestered in the soil, the mitigation benefits are likely to be realized. Not all of the science on this latter point is settled. Since nitrous oxide, a greenhouse gas approximately 300 times more powerful than carbon dioxide, can be emitted during nitrification and denitrification, increasing SOM under some conditions may also increase GHG emissions (see Duxbury, 2012, which cites Duxbury, 2005; Duxbury *et al.*, 1999; Smith *et al.*, 1982; Kramer *et al.*, 2002; and West and Marland, 2002. See also Corsi *et al.*, 2012; and Holland, 2004). More research can be done for "smart soil carbon sequestration".

**Seasonal weather forecasting.** Farmers would benefit greatly with good projections that helped them determine before planting whether the rainfall will be high or low in the season, and whether the temperatures will be high or low. Additionally, they need help on determining the

[4] Biochar is the conversion of crop residues into a substance similar to charcoal, but much smaller in size. When integrated into the soil, it can enhance many soil properties, thus enhancing soil fertility at a low cost and potentially increasing yields while sequestering carbon in the soil. There have been promising results in some studies in some countries, while in other countries the potential is less clear. Much of the analysis hinges on the valuation of household labor, and whether there are labor constraints that limit labor available for biochar production and incorporation in the fields.

likely onset of the rains, so they know when to plant. AGRHYMET, which is responsible for weather monitoring in the Sahelian countries, should be supported in extending its activities to the remaining countries in the West African region to ensure reliable weather data collection for the region.

**Fertilizer efficiency.** Too much fertilizer, or fertilizer applied at less than optimal times, can be wasted, going beyond the reach of the crop. Not only is this economically inefficient, but the fertilizer can be converted to the greenhouse gas nitrous oxide and emitted to the atmosphere. However, fertilizer, applied in proper times and amounts can be used efficiently by the crops while minimizing emissions. This may involve promoting integrated soil fertility management that seeks, among other things, to enhance the soil organic matter content of the soils, which improves nutrient retention.

**Rice water management.** With optimal management of water in a rice system, such as alternate wet and dry (AWD), methane emissions can be reduced without adversely impacting yield and potentially increasing yields. It may also prove to be a more efficient use of water in many locales. The danger of such a system is that if done incorrectly, the nitrous oxide emissions will increase so much that they will negate any gains in methane emission reduction.

**Perennial crops.** These crops can increase carbon stocks and can be a good alternative to annual crops. They also can sometimes be used for non-food purposes such as firewood.

**Alternative crops.** With the climate changing, it may not always be possible to continue cultivating the traditional crop, even with improving the cultivars. Furthermore, with weather variability increasing, it may be a good strategy to diversify to a crop that can perform well in anticipated adversity. For example, cassava can do well under dry conditions, and in some areas may be a good crop to introduce to provide the farmer an alternative food source.

**Increase cropping intensity.** One way to improve cultivated areas without actually expanding into forests or other higher carbon areas is to increase cropping intensity. This would involve reducing fallow cycles in lands that are currently held in fallow, and would involve growing crops in multiple seasons in other areas. This could be done through irrigation, or in some cases with shorter-duration varieties planted in wet seasons. While limiting expansion of area into forests saves carbon in that way, carbon would be lost, generally, when a fallow system cycle is shortened.

## 3.2. At the policy and institutional level

The FAO's *Save and Grow* (2011) has a very good chapter on policies and institutions. They observe that "greater protection of intellectual property in plant innovations, rapid progress in molecular biology and the global integration of agricultural input and output markets have generated strong incentives for the private sector to invest in agricultural research and development." This suggests carefully evaluating incentives and laws necessary to better integrate the private sector into the realm or developing inputs for climate-smart agriculture.

Other suggested policies include:

- "Market smart" subsidies, aimed at supporting the development of demand and participation in input markets using vouchers and grants;
- Stabilization of agricultural output prices;
- Ensure farmers' access to quality seeds of varieties that meet their production, consumption and marketing conditions;

- Adequate public infrastructure and services to ensure low transaction costs for input acquisition, produce marketing, and access to natural resources, information, training, education and social services;
- Continue developing land tenure programmes, taking into consideration customary and collective systems of tenure, since they can also provide effective incentives for investments;
- Shift focus of agricultural research systems to be more development-oriented, considering the needs of the poorer farmers;
- Link research with extension;
- Help farmers obtain adequate credit;
- Develop social safety net programmes which will become more important with weather variability. These might include cash transfers and distribution of food, seeds and tools;
- Improve access to markets by small farmers through better organization and greater cooperation.

**Overlap with forests.** This chapter has endeavoured to stay focused on crops. However, it would be important for one of the authors to point out that whenever there are productivity improvements in the cropping sector, to make agriculture more profitable, there will be pressure placed on the forests and uncultivated savannahs. Therefore, these improvements would need to be coupled with thoughtful measures to protect forests.

### 3.3. At the financial level

Benin and Yu (2013) report that "there is a strong correlation between agricultural output growth rate and agricultural R&D expenditure growth rate, with larger correlation coefficients and greater statistical significance for longer time frames (from investment to outcome)." They also report that "for agricultural research and development (R&D), most African countries spend far less than the NEPAD target of 1 percent of agricultural GDP." Making a concerted effort to meet this target would be a valuable step toward adapting to climate change.

In the same report, we also see that ECOWAS countries regressed slightly in percent of national budget devoted to agriculture from the five years preceding CAADP adoption to the 7 years following CAADP adoption. Admittedly, there was a global recession late in that period that may have influenced the ability to follow through on the commitment to some extent, but there needs to be a refocusing of efforts.

## 4. Messages and recommendations for the sub-sector

### Focus on improving soil fertility

#### Increase soil organic matter

Unless currently managed well, it is likely that West African soils that are being cultivated are low in soil fertility. In particular, they are likely to be low in essential plant nutrients, and this is largely due to low soil organic matter (SOM). SOM increases the cation exchange capacity (CEC) of soils, thus increasing nutrient retention, and generally increasing water retention and improving soil structure. Furthermore, increasing SOM is the main way to sequester carbon in the soil, reducing GHG emissions, at least from carbon.

While this appears to be win-win for adaptation vs. mitigation, there is some concern that increasing SOM will also, at least in the short-run and possibly in the long-run, increase total GHG emissions, since nitrous oxide (N2O) can be released through denitrification in wet soils or through nitrification with oxygen. Farmers can be taught how to minimize conditions for releasing large amounts of N2O.

### Increase nutrients through organic or synthetic fertilizer

One of the keys to productivity is to make more nitrogen available to crops. This could be through chemical fertilizer or organic means such as manure or leguminous crops and trees. Nonetheless, any increase in nitrogen is likely to involve an increase in emissions, particularly if chemical fertilizers are used. Nonetheless, even if total emissions increase, it is possible that additional fertilizers will still result in lower emissions per unit of output (one of the definitions of "smart mitigation").

### Increase investment in research that results in varieties that farmers desire

Increased weather variability (temperature and rainfall) require crops that can handle a wider range of shocks. Furthermore, with temperature increases, new varieties will need to be developed that can flourish under hotter conditions. Careful consideration should be made into whether the private sector can be incentivized to develop varieties.

### Develop strategies for each ecozone/farming system

A one-size-fits-all solution cannot work for all of the varied climates in the region. Use gridded analyses to help in planning strategies, and ensure research institutes are focused on each farming system.

## References

Benin, Samuel and Bingxin Yu, 2013. *Complying the Maputo Declaration Target: Trends in public agricultural expenditures and implications for pursuit of optimal allocation of public agricultural spending*. ReSAKSS Annual Trends and Outlook Report 2012. Washington: International Food Policy Research Institute (IFPRI).

Corsi, Sandra, Theodor Friedrich, Amir Kassam, Michele Pisante, and João de Moraes Sà, 2012. *Soil Organic Carbon Accumulation and Greenhouse Gas Emission Reductions from Conservation Agriculture: A Literature Review*. Integrated Crop Management, Vol. 16. Plant Production and Protection Division. Rome: FAO.

Duxbury, John M., 2012. "Soil Carbon Sequestration and Nitrogen Management for Greenhouse Gas Mitigation", in The Natural Farmer Archives. Downloaded March 12, 2014 from http://tnfarchives.nofa.org/?q=article/soil-carbon-sequestration-and-nitrogen-management-greenhouse-gas-mitigation.

Duxbury, J.M., 2005. Reducing greenhouse warming potential by carbon sequestration in soils: opportunities, limits and tradeoffs. In R. Lal *et al.*, Climate Change and Global Food Security, p. 435-450, Taylor and Francis, Boca Raton.

Duxbury, J.M., D.R. Bouldin, R. Terry and R.L. Tate, 1982. Emissions of nitrous oxide from soils. Nature, 298:462-464.

FAO (Food and Agriculture Organization of the United Nations), 2010. *FAOSTAT Database on Agriculture*. Rome.

Holland, J. M., 2004. “The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence”, *Agriculture, Ecosystems and Environment* **103**:1-25.

Jalloh, Abdulai, Mbène Dièye Faye, Harold Roy-Macauley, Paco Sérémé, Robert Zougmoré, Timothy S. Thomas, and Gerald C. Nelson, 2013. “Overview,” Ch. 1 in *West African Agriculture and Climate Change: A Comprehensive Analysis*, ed. by Abdulai Jalloh *et al.* Washington: IFPRI. Available at http://www.ifpri.org/sites/default/files/publications/rr178ch01.pdf.

Jalloh, Abdulai, Mbène Dièye Faye, Harold Roy-Macauley, Paco Sérémé, Robert Zougmoré, Timothy S. Thomas, and Gerald C. Nelson, 2013. “Summary and Conclusions,” Ch. 14 in *West African Agriculture and Climate Change: A Comprehensive Analysis*, ed. by Abdulai Jalloh *et al.* Washington: IFPRI. Available at http://www.ifpri.org/sites/default/files/publications/rr178ch14.pdf.

Kramer, K.J., H.C. Moll and S. Nonhebel, 1999. Total greenhouse gas emissions related to the Dutch cropping system. Agric., Ecosyst. and Environ. 72:9-16.

Nelson, G. C., M. W. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, *et al.*, 2010*. Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options*. Washington, DC: International Food Policy Research Institute. http://www.ifpri.org/sites/default/files/publications/rr172.pdf.

Rosenzweig, Cynthia, Joshua Elliott, Delphine Deryng, Alex C. Ruane, Christoph Müller, Almut Arneth, Kenneth J. Boote, Christian Folberth, Michael Glotter, Nikolay Khabarov, Kathleen Neumann, Franziska Piontek, Thomas A. M. Pugh, Erwin Schmid, Elke Stehfest, Hong Yang, and James W. Jones, 2013. “Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison”, *PNAS*, published ahead of print December 16, 2013, doi:10.1073/pnas.1222463110.

Smith, K.A., F. Conen, B.C. Ball, A. Leip, and S. Russo, 2002. Emissions of non-CO2 greenhouse gases from agricultural land, and the implications for carbon trading. In J. van-Ham *et al.* (eds) Non-CO2 greenhouse gases: scientific understanding, control options and policy aspects. Proc. 3rd International Symposium, Maastricht, Netherlands 21-23 Jan 2002. Millpress Science Publishers, Rotterdam, Netherlands.

Thomas, Timothy S. and Mark C. Rosegrant. Forthcoming. “Climate Change Impact on Key Crops in Africa: Using Crop and Economic Models to Bound the Predictions”, chapter in the proceeding of the “FAO Expert Consultation on Global Food Production under Changing Climate and Increased Variability: Implications for Trade and Food Policy”, November 5-6, Rome.

West, T.O. and G. Marland, 2002. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: comparing tillage practices in the United States. Agric. Ecosyst. and Environ. 91:217-232.

# Chapter 2
# Overview of the scientific, political and financial landscapes of Climate-Smart Agriculture in West Africa: sector of livestock production

**Augustine Ayantunde[1], Polly Ericksen[2] & Mohammed Said[2]**

[1]International Livestock Research Institute, Ouagadougou, Burkina Faso

[2]International Livestock Research Institute, Nairobi, Kenya

## Summary

Livestock contribute significantly to livelihoods of rural populations in West Africa. At least 100 million poor people in West Africa rely on livestock as part of their livelihood strategy. Climate change and variability is a major challenge to livestock production in the region. Drought is particularly a major constraint to livestock production in West Africa Sahelian countries. Adapting livestock production systems to climate change and variability is not only necessary to preserve purely livestock-based livelihood but also essential for agro-pastoral and mixed crop-livestock livelihoods. Adaptation strategies at community level are diverse, context-specific, dynamic and non-linear. For livestock-based livelihood, adaptation options depend on the climatic risks, agro-ecological zones, the livestock production systems and the socio-economic profiles of the household. The overall objective of this chapter is to provide an overview of the scientific, political and financial landscape of Climate-Smart Agriculture (CSA) for the livestock sub-sector. The specific objectives are to enumerate the impacts of climate change and variability on livestock production systems in West Africa, place these impacts within the policy and socio-economic context, and to highlight the adaptation strategies at community level for livelihoods that include a significant livestock component.

## 1. Current status for livestock production in West Africa

Livestock contribute significantly to livelihoods of rural populations in West Africa. At least 100 million poor people in West Africa rely on livestock as part of their livelihood strategy (Williams and Okike, 2007). Livestock contribute significantly to the economies of the region, especially the Sahelian countries (SWAC-OECD/ECOWAS, 2008). Livestock sector accounts for about 35% of the GDP in the region and, in the Sahelian countries, it supplies on average 30% of the

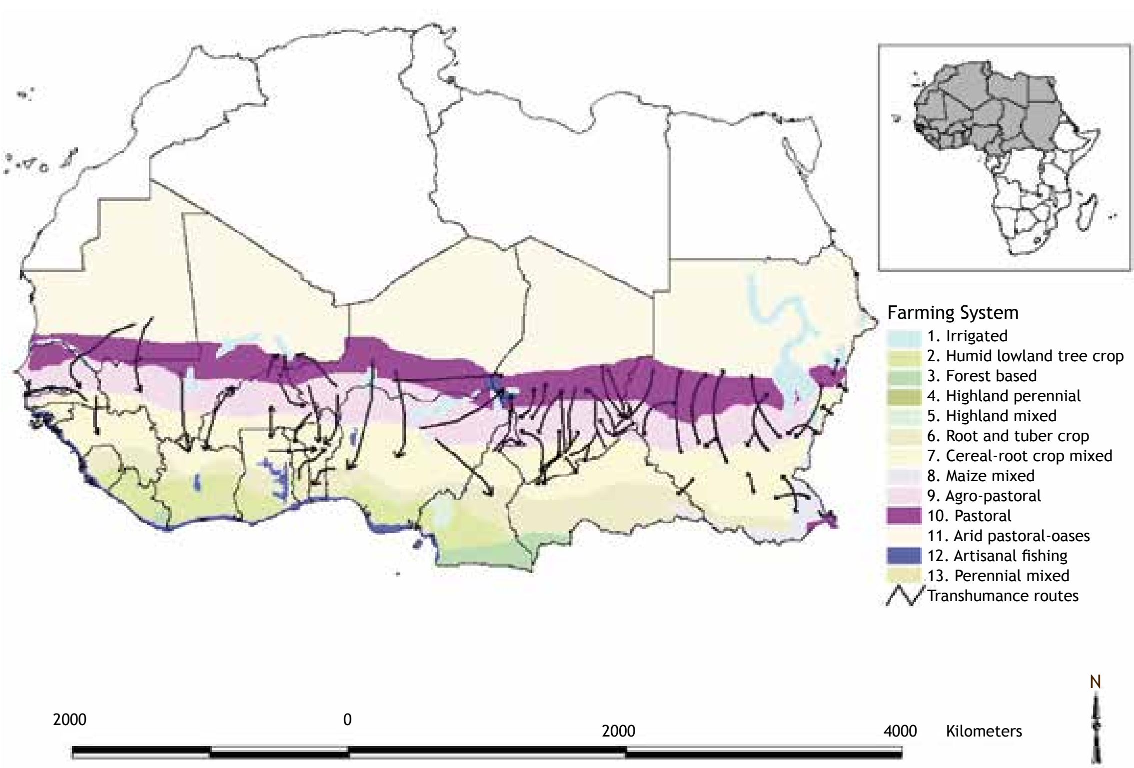



**Figure 1. Distribution of livestock movement across different farming systems in West Africa**

revenue in the agriculture sector (SWAC-OECD/ECOWAS, 2008). In the arid and semi-arid agro-ecological zones of the region, livestock husbandry provides the main source of employment for the majority of the people and is by far the most important source of revenue. For both crop farmers and pastoralists, livestock serve as a productive asset to generate income, reduce risks and mitigate the effects of climate change and variability. Apart from income generation, livestock form a key element in food security strategies in many countries of West Africa. In addition, livestock provide draught power, skins, transport and manure, and fulfil various socio-cultural functions such as payment of dowry, establishment and reinforcement of relationships and source of prestige within the pastoral society.

Livestock production in West Africa is largely associated with exploitation of natural rangelands (i.e. pastoral and agro-pastoral systems) (Breman and de Ridder, 1991). However, livestock area also found in mixed smallholder systems in which crop residues are increasingly becoming important as animal feed with the expansion of crop fields into marginal (grazing) lands (Fernandez-Rivera *et al.*, 2004). Technical challenges facing livestock production in the region include low and variable forage availability, poor feed quality, access to water, low productivity of the indigenous breeds, and degradation of rangelands. Low available forage due to low biomass production from the rangelands is a major problem in arid and semi-arid zones in the region. Livestock production in the region often follows the perennial cycle of live weight gain in the wet season followed by weight loss in the late dry season. Climate change and variability is another challenge to livestock production in the region. Drought is particularly a major constraint to livestock production in West Africa Sahelian countries (Turner, 2000; Hiernaux *et al.*, 2009). Drought affects livestock production through reduced herbage production and water scarcity which often leads to high herd mortality. All the above challenges pose a major threat to livestock-based livelihood in the region as in other parts of sub-Saharan Africa. Adapting livestock production systems to climate change and variability is essential to preserve smallholder livestock production systems across the range of agroecologies found in West Africa.

Of course, adaptation to climate change happens in political, social and economic contexts. Some of the policies and institutional challenges that West African livestock producers face include constrained market access to rural producers; poor infrastructures for transportation, processing and marketing; and weakly enforced institutional mechanisms. For example, pastoral and agro-pastoral producers in the north, who supply 60% of cattle meat, 40% of small ruminant meat and 70% of milk (SWAC-OECD/ECOWAS, 2009) rely on moving their cattle in search of grazing area and water every year during the Sahelian dry season to gain access to the more humid farming areas of the south. Protection of the key transhumant corridors from north to south is key for their animals to survive (SWAC-OECD/ECOWAS, 2009) (see Figure 1), but increasing conflicts due to more livestock competing for resources is a concern (Turner *et al.*, 2011). In terms of economic competitiveness, West Africa still imports animal products, and commodity chains need better infrastructure support, linking of producers and traders across value chains, and attention to harmonizing actors to foster regional trade (SWAC-OECD/ECOWAS). Livestock production systems are in a transition to both a more sedentarized but possibly more intensified mode that needs proper policy support, in order to sustain the economic contributions but to adapt to changing climate conditions.

# 2. Impacts of climate change on livestock production

There is still a fair amount of uncertainty as regards rainfall-related climate projections for West Africa (Thornton *et al.*, 2009). If a simple average of all the model scenarios is taken, slight humidification in the Sahelian region, with no real changes along the Guinean coast can be inferred (IPCC, 2007), but the fourth assessment report found that the GCMs are inconsistent in their projections for West Africa (Ericksen *et al.*, 2013). The impacts of climate change on livestock and agriculture in general in West Africa will vary depending on agro-ecological zones, and the interactions among demographic change, economic development and the environment. Ericksen *et al.* (2013) attempted to map areas of West Africa where frequency of droughts or floods might increase, along with changes in LGP. These results illustrate the tremendous heterogeneity in expected changes across the region, and the difficulty of planning for the impacts of climate change at national or regional levels. The changing frequency of extreme climate conditions such as droughts and floods will have greater impacts on livestock and the associated livelihoods than average trends from climate change (that is, average change in precipitation and temperature; Thornton *et al.*, 2009). For example, repeated occurrence of droughts in the Sahel has led to adoption of agro-pastoralism (combination of crop farming and livestock rearing within the same farm) among the pastoralists who were once solely depending on livestock for their livelihood (Turner, 2000; SWAC-OECD, 2008). Besides, crop farmers have also diversified in the past two decades into rearing livestock due to repeated crop failure associated with droughts (Mortimore and Adams, 2001). According to these authors, many farmers own or aspire to own livestock even in many predominantly agricultural areas in West Africa.

The general impacts of climate change and variability on livestock and livestock-based livelihoods are likely to be changes in feed and grazing availability, greater heat stress leading to a decline in productivity and overall a decline in GDP from livestock especially for the Sahelian countries, and changes in available land and water resources (Thornton *et al.*, 2009). Climate determines the type of livestock most adapted to different agro-ecological zones and therefore the animals that are able to sustain rural communities. Climate change is expected to affect livestock at both the species and breed level, although this is a research gap and we know little about indigenous breeds in particular. Specific impacts of climate change on livestock include changes in availability and quality of forage resources, access to water, species and breeds of livestock that can be kept, livestock mobility, and animal diseases (emerging and re-emerging diseases). A hotter and drier climate in the arid and semi-arid zones of the region will favour livestock species and breeds that thrive well under heat stress and those with less water requirements such as small ruminants (sheep and goats) and camels. This is already the case in West African Sahel with the shift in livestock species from cattle before the droughts of early 1970s and 1980s to sheep and goats (Turner, 2000) as the latter (small ruminants) are less costly, hardier, require lower feed and reproduce faster than cattle. A hotter and drier climate in sub-humid and humid zones will modify the habitat of the endemic livestock breeds which are resistant to trypanosomiasis, the major animal disease in the zones and will consequently alter the breeds that can be kept. Climate change impacts on forage availability and quality, including changes in herbage growth, changes in floristic composition of vegetation, changes in herbage quality and changes in importance of crop residues as animal feed (Thornton *et al.*, 2009). Generally, the impacts of climate change on herbage growth will depend on the plant species as increase in future CO2 levels may favour different grass species than currently, while the opposite is expected under associated temperature increases (IPCC, 2007).

The consequences of these impacts for livestock producing households depend on the development pathway taken, such as population growth, changes in income levels, growth in regional trade, and degree of technological development (Thornton *et al.*, 2009). The current low adaptive capacity is expected to make the region particularly vulnerable, as other parts of sub-Saharan Africa, to climatic shocks such as drought and flood. In general, the impacts of climate change on the poor livestock keepers will be context-specific, reflecting factors such as geographic location, socio-economic profiles, prioritization and concerns of individual households as well as institutional and political constraints (FAO, 2007). However, livestock will remain an important asset to help households manage climate risks.

## 3. Climate change adaptation at community level for livestock-based livelihood

In addressing climate change adaptation for livestock-based livelihoods, key questions to consider include: (1) Which types of livestock management are suited to climate change and where? (2) Which animal species and breeds should be kept in which areas and what are the trade-offs? (3) Which animal diseases should we focus on? (4) Are there current livestock-based livelihood systems in the region that are best suited to climate change adaptation? (5) How can we add value to the existing livestock-based adaptation strategies? (6) Are there policy and institutional mechanisms to enhance adaptation of livestock production systems to climate change and variability? (7) How could the capacity of rural institutions be strengthened to use appropriate tools and strategies to cope better with consequences of climate change? (8) How could we balance the need for short-term adaptation, which is often reactive, with long-term climate change adaptation planning? At community level, climate change adaptation should be considered in the context of other significant drivers of change (demographic change, economic development, market opportunities). Livestock production systems should be "climate-smart" by contributing to increasing food security, adaptation and mitigation in a sustainable way. Any livestock management practice that improves productivity or the efficient use of scarce resources can be considered climate-smart because of the potential benefits with regard to food security, even if no direct measures are taken to counter detrimental climate effects.

Adaptation strategies at community level are diverse, context-specific, dynamic and non-linear. They are often an integral part of current livelihood systems and the benefits are highly localized (FAO, 2007). These adaptation strategies are largely based on indigenous knowledge and are often reactive, that is, the focus is on short-term adaptation. For livestock-based livelihood, adaptation options depend on the climatic risks, agro-ecological zones, the livestock production systems and the socio-economic profiles of the household (Table 1). A community's capacity to adapt to climate change and the associated risks depends on its economic resources, geographic location, available technologies and information, infrastructures, institutions and networks (FAO, 2007). Generally, poor infrastructures and weak institutions inhibit adaptive capacity and planning of a community. For most livestock keepers in West Africa, adaptation options are often not limited to livestock but a mixture of livelihood options including crop agriculture, non-agricultural activities and migration (Turner, 2000). Efficient livestock feeding systems, balanced feed rations and efficient manure management will contribute to the reduction of greenhouse gas emissions. Combination of climate-smart livestock-related technologies like efficient feeding practices, fodder production, crop residue management, and manure management with effective climate information services which build on local knowledge and institutions, and community development plans will not only enhance the adaptive capacity of the smallholder farmers but will also improve food security and livelihood of the smallholder farmers.

## Table 1. Adaptation options for livestock-based livelihood to major climatic risks according to agro-ecological zones in West Africa

| Agro-ecological zone | Dominant livestock system | Climatic risk | Adaptation option |
|---|---|---|---|
| Arid | - Pastoral<br>- Agro-pastoral | - Drought | - Shift to small ruminants and camels<br>- Livestock mobility to semi-arid/sub-humid zones<br>- Commercial activities<br>- Growing of adapted crop varieties in the "oasis"<br>- Migration (local and regional) |
| Semi-arid | - Pastoral<br>- Agro-pastoral<br>- Peri-urban livestock | - Drought<br>- Flood<br>- Bush fire | - Shift to small ruminants<br>- Livestock mobility to sub-humid zone<br>- Better integration of crop and livestock<br>- Commercial activities<br>- Growing of adapted crop varieties e.g. drought tolerant millet/sorghum<br>- Fodder conservation<br>- Migration (local and regional) |
| Sub-humid/ Humid | - Mixed crop-livestock<br>- Peri-urban livestock | - Flood<br>- Bush fire<br>- Vector borne diseases e.g. ticks, trypanosomiasis | - Intensification of crop-livestock production<br>- Growing of cash crops e.g. cotton<br>- Fodder production and conservation<br>- Use and conservation of endemic livestock breeds<br>- Commercial activities<br>- Moving out of agriculture to service industry |
| Coastal | - Peri-urban livestock | - Flood<br>- Water erosion<br>- Vector-borne diseases | - Use and conservation of endemic livestock breeds<br>- Commercial activities<br>- Moving out of agriculture to service industry |

Climate-smart agriculture also includes mitigation, and the livestock sector is one of the major contributors in agriculture, by some estimates contributing up to 18% of the global GHG emissions. Of this, about 1/3 is due to land use change associated with livestock production, another 1/3 is nitrous oxide from manure and slurry management, and roughly 25% is methane emissions from ruminant digestion (Thornton and Herrero, 2010). However, the contribution of livestock to GHG emissions varies tremendously by type of system, and there is scarce data for Africa. Recent analysis by Herrero *et al.* (2013) suggests that developing world regions contribute about 2/3 of the global emissions from ruminants, with sub-Saharan Africa a global hotspot for emissions intensities, largely due to low animal productivity and low quality feeds. These numbers suggest, therefore, that there are easy gains to be made in terms of mitigation in the livestock sector, as improving feed resource use efficiencies would improve livestock productivity as well as reduce emissions per unit of product. The challenge then becomes finding the right behavioural incentives to encourage greater feed resource use efficiency, taking advantage of a win-win opportunity.

It is now well understood that while many communities are highly adaptive and community-based approaches are critical, many governments and donors worry that a more concerted effort at higher levels of action and governance are needed, to move beyond so-called incremental adaptation and bring about the transformations that will allow for systemic adaptation. This is even more necessary if synergies between adaptation and mitigation are to be found and taken advantage of to promote gains on both fronts. One challenge to this is the need for better integration between agriculture and livestock ministry staff and climate change units, so that climate change issues can be integrated into ongoing development planning. In the particular case of the livestock sector, another issue is the lack of support for pastoral production systems, and the failure to recognize that these are highly adaptive systems which resist conformation to the standard "intensification" model (WISP/IUCN, 2014). Third is failure in many policy dialogues to recognize that food security improvements will not always be compatible with seeking reductions in emissions from the livestock sector, and there are not "one-size-fits-all" models (Scoping report). In West Africa, livestock make tremendously important contributions to economies and food security.

In terms of financing flows available, agriculture in general, and livestock in particular, suffer from inherent biases in the current mitigation financing mechanism. The Clean Development Mechanism excludes agriculture by and large; there are a few voluntary carbon markets with interest in agriculture, particularly agroforestry and livestock production. Within these schemes, however, there is a bias towards "high potential" systems such as intensive dairy, where gains could be made from improving feeding practices. More extensive grazing-based systems are considered to be too difficult institutionally to manage. In terms of adaptation financing, many countries now have National Adaptation Programmes of Action (NAPAs) but often agriculture is given short attention, and often the funds get "stuck" at the national level, failing to reach the local communities (CSA FAO report).

# 4. Conclusions and recommendations for climate change adaptation in relation to livestock

In West Africa, as in other parts of sub-Saharan Africa, livestock represent the major stores of wealth that are mobilized in response to climatic shocks, e.g. drought. Adaptation strategies in response to climate change at community level involve a mixture of livelihood options – livestock husbandry, crop agriculture and off-farm activities. These strategies are often location-specific, dynamic and reactive (short-term adaptation). Based on what we know on likely impacts of climate change and variability on agriculture in general and livestock production in West Africa region, the following recommendations can be made regarding adaptation strategies at community level.

- Regional framework for the adaptation of West African agriculture to climate change cannot be dissociated from the political, economic and social dynamics in the region, as these dynamics drive adaptation pathways.
- Adaptation strategies in response to climate change at community level involve a mixture of livelihood options. Therefore, priorities should be given to activities that can enhance adaptive capacity of rural communities within the context of sustainable development.
- Adaptation to climate change needs to be considered in the context of other significant drivers of change (competition for land and water, population growth and changing demographic distribution, increasingly globalized food systems which transmit price shocks). It is therefore essential to mainstream adaptation and resilience in the development process.
- Adaptation strategies at community level are often location-specific and the recommendation domains are often of limited scale. Adaptation planning should therefore avoid "one-size-fits-all" approach.
- Growth in livestock sector and the improvement of production competitiveness, processing or trade in animal require additional investments in rural infrastructure, particularly roads, storage, processing and markets.
- Building capacity of rural institutions to put climate and adaptation information into active use and implement appropriate adaptation strategies is essential to climate-smart agriculture.
- Adaptation activities need to value existing local knowledge and be flexible to accommodate new information.

- For livestock-based livelihood, adaptation options depend on the climatic risks, agro-ecological zones, the livestock production systems and the socio-economic profiles of the household.
- In terms of mitigation, a principle challenge is developing the databases and accounting mechanisms that will allow the West African livestock sector to be realistically evaluated. There is little appetite for mitigation solutions in the livestock sector at the moment.

## References

Breman, H., de Ridder, N., 1991. Manuel sur les pâturages des pays Sahéliens. Paris/Wageningen: Karthala/ACCT/CTA.

De Leeuw, J., Said, M., Neely, C., Ericksen, P., Ayantunde and Vrieling, A., 2014. Pastoral farming systems and food security in Sub-Saharan Africa: Priorities for science and policy. In: Dixon, J., Garrity D. and Lynam, J. (Eds.) African Farming systems, in press.

Ericksen, P.J., J. de Leeuw, P. Thornton, M. Said, M. Herrero and A. Notenbaert, 2013. Climate change in Sub-Saharan Africa: what consequences for pastoralism? In Catley, A., J. Lind and I. Scoones (eds). Pastoralism and development in Africa: dynamic change at the margins. Earthscan/Routledge, UK. Pp. 71 – 82

FAO, 2007. Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities. Rome: FAO, Interdepartmental Working Group on Climate Change.

FAO, 2010. "Climate Smart" Agriculture. Report for the Hague Conference on Agriculture, Food Security and Climate Change.

Fernandez-Rivera, S., Okike, I., Manyong, V., Williams, T.O., Kruska, R.L., Tarawali, S.A., 2004. Classification and description of the major farming systems incorporating ruminant livestock in West Africa. In T.O. Williams, S.A. Tarawali, P. Hiernaux, S. Fernandez-Rivera (Eds.). Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa (pp. 89 – 122). Nairobi/Wageningen: ILRI/CTA.

Herrero, M. *et al.*, 2013. Global livestock systems: biomass use, production, feed efficiencies and greenhouse gas emissions. *PNAS* 110 (52): 20888-20893.

Hiernaux, P., Ayantunde, A., Kalilou, A., Mougin, E., Gerard, B., Baup, F., Grippa, M., Djaby, B., 2009. Trends in productivity of crops, fallow and rangelands in Southwest Niger: Impact of land use, management and variable rainfall. Journal of Hydrology 375 (1-2), 65-77.

IPCC, 2007. Climate change 2007: The Fourth Assessment synthesis report. Summary for policymakers. Geneva: IPCC. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Mortimore, M.J., Adams, W.M., 2001. Farmer adaptation, change and "crisis" in the Sahel. Global Environmental Change 11, 49-57.

SWAC-OECD/ECOWAS, 2008. Livestock and regional market in the Sahel and West Africa – Potentials and challenges. Sahel and West Africa Club/OECD, Paris, France. 151 pages.

Thornton, P.K., van de Steeg, J., Notenbaert, A., Herrero, M., 2009. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. Agricultural Systems 101, 113-127.

Thornton, P.K and M. Herrero, 2010. Potential for reduced methane and carbon dioxide emissions from livestock and pasture management in the tropics. *PNAS* 107 (46): 19667-19672. DOI 10.1073/pnas.0912890107.

Turner, M.D., 2000. Drought, domestic budgeting, and changing wealth distribution within Sahelian households. Development and Change 31, 1009-1035.

# Chapter 3
# Overview of the scientific, political and financial landscapes of Climate-Smart Agriculture in West Africa: sector of fisheries

**Bamidele O. Omitoyin[1], Robert Zougmoré[2], Abdulai Jalloh[3]**

[1]Department of Aquaculture and Fisheries Management, University of Ibadan, Nigeria

[2]CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), ICRISAT Bamako, Mali

[3]West and Central African Council for Agricultural Research and Development (CORAF/WECARD), Dakar, Senegal

## Executive summary

In West Africa, fish is a food and nutritional security issue and vital to livelihoods. Total fish production in West Africa is 2,484,777 MT and the number of jobs created in the sector is over 5,600,000. This crucial economic activity is however, endangered by climate change. Climate change is already modifying the distribution of fish species thus affecting habitat size, species diversity and productivity and livelihoods. Models used to predict climate change can be one-, two- or three-dimensional domains, however, top-down and bottom-up assessment models are particularly relevant to Africa. Modeling of the expected impact that was agreed on is Open-source models and Ecosystem indicator. Modeling of the expected impact where there was no agreement are: Management strategy evaluation (MSE) models and Fully coupled end-to-end models. The task of assessing various impacts and the feedbacks among them is enormously complex and requires a number of simplifying assumptions. The complex, integrated nature of the climate change problem in West Africa fishery sub-sector have led to advocacy for integrated assessments that incorporate many aspects of fisheries in the region. Adaptation at scientific and technical level options includes relevant research to reduce GHGs emissions from fishing activities and search for new and better adapted aquaculture species. At policy and institutional level, application of better management practices (BMPs) into small-scale farming practices need to be integrated into EAA strategies. At the financial level, an adaptive measure that will help limit bankruptcies is advocated. The impacts of climate change on fisheries and aquaculture is complex, uncertain, but it is already evident with some winning and others losing. Adaptation to climate change should however address both the threats and opportunities and be tailored to local conditions and needs. Promoting aquaculture can help to increase fish production and lower carbon footprint in human diet. Capacity building on sustainable fisheries techniques with respect to climate change vulnerability and mitigation must include Gender Mainstreaming, with greater capacitation of women and youth, strengthening of National Agricultural Research Systems (NARS), private sectors, NGOs in decision making for CSA in West Africa is recommended.

## 1. Current status of fisheries sub-sector in West Africa

Agriculture is vital to livelihoods in West Africa. It is the main source of employment for the 290 million people who live in the region, employing 60 percent of the workforce, and accounting for 35 percent of the region's gross domestic product (GDP). This crucial economic activity is endangered by climate change (Jalloh *et al.,* 2013).

African fisheries encompass a wide range of ecological and socio-economic components. Africa has huge potential for fish farming in terms of land availability with 31 percent of its surface area suitable for small-scale fish farming and 13 percent suitable for commercial fish production. African fisheries contribute significantly to food and nutritional security of an estimated 200 million people and provide a source of income for over 10 million who are engaged in production, processing and trade (Aguilar-Manjarrez and Nath, 1998).

West African population is estimated to increase to 430 million by 2025 and more than half of the region's population consumes fish products on a daily basis which accounts for up to 3-5% of total GDP (FAO/SFLP, 2007). Total fish production in West Africa is 2,484,777 MT with percentage contributions from Nigeria (23), Ghana and Senegal (16 each), Mauritania (10), Cameroon and Sierra Leone (6 each), Guinea and Mali (4 each) and other countries (15). In 2005, total seafood export value was however evaluated to US$711,600,000 (2005). The artisanal fishery sector dominates employment in the fishing industry. The fishermen that operate the artisanal fishing industry use traditional wooden boats, sometimes motorized, with a variety of gear types, including nets, lines, and seines. The industrial fishing is however operated by non-African trawlers and fleets with less direct economic and employment benefits.

Total number of jobs created in the sector is over 5,600,000 while total number of direct jobs is over 1,800,000 million (USAID West Africa, 2008). Women are responsible for artisanal processing and distribution of fish to urban centers and inland. Traditional processing methods include smoking, drying, salting, and curing. Industrial processing exists in some countries. In many countries, inaccessibility of cold storage facilities inhibits the growth of a value-added industry (USAID West Africa, 2008). Aquaculture, which is the world's fastest growing food production system, growing at 7% annually is still at developing stage in West Africa. It has however, recently received higher levels of governmental and private support.

## 2. Climate projections and socio-economic and environmental impacts expected by 2050

Climate change is projected to impact broadly across ecosystems, societies and economies, increasing pressures on all livelihoods and food supplies, including those in the fisheries and aquaculture sector (FAO, 2008). FAO (2010) reported that the projected changes due to climate impact in West Africa coastal fisheries include changes in the composition, production, and seasonality of plankton and fish populations. These projected impacts of climate change on fisheries will affect both social and economic for fishing fleets and fishing communities. It also projected that the West Africa Inland fishery zones will be impacted by potential reduction in floodplain zones for seasonal inland fishing areas as a result of lowered precipitation as projected by many climate models. Increased demand for dam infrastructure for access to water or energy exacerbates the reduction in fish landings for seasonal inland fishing. Allison *et al*. (2009) projected that in addition to precipitation and temperature changes, changes in sea level rise, land-based runoff and increasing frequency of storms and storm surges threaten coastal infrastructure, aquaculture located in riparian and coastal zones, and loss of harbours or homes.

Omitoyin (2009) reported that climate change is already modifying the distribution of fish species thus affecting habitat size, species diversity and productivity of Lagos Lagoon in Nigeria. The total landings of 14 West African countries were estimated to fall by about eight percent and 26 percent from 2000-2050 due to low and high greenhouse gas emission scenario respectively (Lam *et al.* (2012) as cited by Rhodes *et al.* (2014). 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. The total landed value was estimated to drop from US$732 million to US$577 million between 2000 and 2050 for the high emission scenario. Associated Press (2006) reported low fish catch in Lake Chad; while field observation on Lake Chad in 2012 shows that there is not only reduction of fish catch but also of total area covered by water. Rhodes *et al.* (2014) reported that 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. Impact on aquaculture will include increasing seasonal and annual variability in rainfall leading to flooding and drought extremes. In Nigeria, Adebo and Ayelari (2011) reported on how flood washes away fish from small fish farms in Nigeria.

Modelling of the expected impact that was agreed on is Open-source models and Ecosystem indicator. This addresses the challenges of assessing the impact of multi-sector, multi-species and management strategies relative to the goals of fisheries under changing climate conditions. Modelling of the expected impact where there is no agreement are: Management strategy evaluation (MSE) models and fully coupled end-to-end models. MSE endeavours to develop projection models that would allow managers to evaluate the implications of their actions within an ecosystem context. However, these models do not address multi-species, multi-sector and multi-objectives fisheries management within the eco-context. On the other hand, fully-coupled end-to-end models addresses the challenges of multi-species, multi-sector and multi-objectives fisheries but required a rich database which is not available in most of the climate change vulnerable countries, especially Sub-Saharan Africa. The behaviour and actions towards uncertainties include: the biological characteristic of fish, multi-sector and multi-objectives nature of managing the resources and poor database for most fisheries activities. This limits the application of most of the existing models to adequately assess forecast and manage the effect of climate change on fisheries resources.

## 3. Progress, bottlenecks and steps to adaptation and mitigation of climate change in West Africa

Small-scale fisheries and aquaculture have contributed little to the causes of climate change but will be amongst the first sectors to feel its impacts. For instance, surface water resources in West Africa are concentrated in a few watershed areas in the Congo, Niger, Lake Chad, Senegal, the Gambia and the Volta. Following the decrease in rainfall since the 1970s, the main rivers have witnessed a drop in their stream flows. The Niger River's (Onitsha) stream flow fell by 30% between 1971 and 1989; those of the Senegal and Gambia Rivers fell by almost 60% IUCN (2004).

According to studies by McCartney *et al.* (2012), water resources development is vital for the well-being and livelihoods of the people living in the Volta River Basin and central to the economic development of the riparian countries. There remains great uncertainty about how Climate Change (CC) will affect water resources of the basin. However, the results of this study have shown that anticipated reductions in rainfall, and increases in temperature and potential evapotranspiration, would affect both river flow and groundwater recharge, which in turn will impact the performance of existing and planned reservoirs and hence irrigation and hydropower schemes. Climate Change as anticipated in the mentioned study will mean that, overall; system performance will be significantly curtailed. If it is given the highest priority, domestic water supply is largely safeguarded but, even with greatly increased surface water storage (i.e., full development scenario), the performance of existing and planned irrigation and hydropower schemes is likely to be severely compromised. By 2050, on average, only 75% of annual irrigation water demand will be supplied and just 52% of potential hydroelectricity will be generated. The rise in sea levels has had a direct impact on submergence and coastal erosion, an increase in flood-prone areas and in salinity in estuaries and coastal water tables. Mangrove swamps, which occupy large surface areas in Nigeria, Guinea, Guinea Bissau, Cameroon and Senegal, are particularly sensitive (ECOWAS-SWAC/OECD, 2008). The submergence of these mangrove swamps or coastal lagoons could lead to a loss in biodiversity. The cost adaptation could amount to at least 5-10% of Gross Domestic Product (GDP). Changes in coastal ecosystems will have a direct bearing on settlements; productivity, fish stocks and coastal dwellers will have no alternative but migrate. The resultant shortage of labour in source areas and pressure on limited natural resources in destination areas could result in many undesired outcomes. In the fisheries sector, $CO_2$ emissions from harvesting and shipping of fish and fish products are estimated at 0.05 Gt per year with Africa producing 3.6% of the world's $CO_2$ emissions. About three fourths of total emissions from agriculture and land use originate in developing countries (IPCC, 2007).

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 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, Nigeria CAN, and the Heinrich Böll Foundation. Other participants in the preparation of the document included persons from grassroot communities, sector specialists and researchers. 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 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.

Adaptation at Scientific and Technical Level Options includes relevant research to enable fisheries and aquaculture to adapt to climate change with countries and regions streamlining on:

- reduction of GHGs emissions from fishing activities by improving fuel efficiency through switching to more efficient gear types or vessels, switching to sails or changing fishing practices;
- use of bulk sea freight rather than air freight or non-bulk sea freight, or increasing consumption closer to the source (reducing travel distance) would reduce fuel use which is a major problem in product transport;
- removal and storage of atmospheric carbon through coastal ecosystems management of mangroves, sea grass beds, salt marshes (McLeod *et al*., 2011);
- use of more stable fishing vessels of all sizes to allow for fishing further away from the coastal area to follow targeted species and resist inclement weather;
- use of fish aggregating devices to lure fish back within the traditional fishing grounds;
- new diseases and preventive treatments;
- search for new and better adapted aquaculture species to confront sea level rise;
- better feeds and feeding practices that are more ecosystem friendly;
- strengthening of technology transfer mechanisms to share weather as well as market information with farmers.

During the WorldFish/ZMT meeting to envision climate change and its effect on aquaculture and fisheries up to the year 2050 as reported by Badjek *et al.* (2011), it was agreed that for research and development in the fisheries and aquaculture sector, a regional or sub-regional effort is needed to better integrate scientific knowledge and to put into place coherent fisheries policies. Additionally, a better understanding of the impacts of climate change on the sector is needed, with for instance, the development of coupled climate-fisheries models for major commercial fisheries in the region. Participants unanimously agreed that strategic planning and foresight studies methodologies should be widely disseminated. Indeed, the opportunity for reflective and creative thinking was recognised as an important part of planning – especially adaptation planning – to climate change. Chaos induced by climate variability and change is pervasive: climatic disruptions such as droughts, floods, increase in temperature and sea level rise are worsening and will be rife over a long period of time. Additionally, the ability to predict these changes is limited, creating further chaos. Inland areas are receiving even less rain, resulting in a massive population exodus to coastal zones: the coast is considered a refuge, a zone of ultimate "resort" and there is exponential pressure on all aquatic resources. In the ocean, trophic levels are changing, with the lowest trophic species with low or no commercial value dominating the fishery. Small pelagic fisheries will be greatly affected as they are extremely sensitive to environmental fluctuations. These species are the most affordable for the poorest of the population who will resort to fishing, increasing the fishing pressure. Despite this turmoil caused by climate change, society still tries to respond to these extreme environmental changes through adaptive management.

According to De Silva and Soto (2009), in terms of institutional and policy measures, the following are priority areas for the development of the fisheries sub-sector:

- to implement an ecosystem approach to aquaculture as a regional strategy;
- to prioritize and enhance mariculture and specifically non-fed aquaculture (filter feeders, algae);
- to enhance the use of suitable inland water bodies through culture-based fisheries and appropriate stock enhancement practices;
- at the regional level, regional agreements among countries sharing trans-boundary stocks will also need to be adjusted as shifts in stock distributions and changes in productivity occur;
- the use of risk spreading or reduction tactics, such as livelihood diversification, disease and disaster risk management, and creative combinations of public and private insurance tools;
- Governments should work with the private sector, both nationally and internationally to build appropriate regulatory environments conducive to private investment;
- facilitate the development of profitable and resilient value chains of significant benefit to small-scale fisherfolks and fish farmers, particularly women and youth;
- Governments should also provide an enabling environment to ensure access to markets of fisheries and aqua-products which depends, in part, on appropriate rural infrastructure;
- awareness is increasing in West Africa and efforts are being made to promulgate existing policies and establish the relevant existing ones in the wake of the results from more recent studies. Plans to educate and create awareness of the implication of climate change to fisheries stakeholders through workshops, seminars and media are underway.

At the financial level, an adaptive measure that will help limit bankruptcies in aquaculture businesses as a result of losses caused by climatic events is to encourage aquaculturists to take insurance against damage to stock and property from extreme climatic events. Adebo and Ayelari (2011) reported how flooding washes away fish from many fish farms in Nigeria. Appropriate insurance cover will at least ensure that finance is available for businesses to recommence operations (De Silva and Soto, 2009). Practical financial incentive programmes for fisherfolks and fish farmers who engage in production system that mitigate climate change should be supported.

# 4. Messages and recommendations for the fisheries sector in West Africa

**Messages:** Fisheries and aquaculture contribute significantly to food security and livelihoods and depend on healthy aquatic ecosystems but these facts are often unrecognized and undervalued. The impacts of Climate Change on fisheries and aquaculture is complex, uncertain but it is already evident with some winning and other losing. Adaptation to Climate Change should however address both the threats and opportunities which should be tailored to local conditions and needs, since the nature of risks and the affected livelihood groups varies. Promoting aquaculture can therefore help to increase fish production and lower carbon footprint in human diet. To build resilience to the effects of climate change and derive sustainable benefits, fisheries and aquaculture managers need to adopt and adhere to best practices such as Conduct for Responsible Fisheries.

**Recommendations:** Research for CSA should be based on IAR4D with strong innovation platform to ensure sustainability. Climate information is an important part of Climate-Smart Agriculture, therefore fisherfolks and fish farmers should be provided with reliable climate information to guide management of scarce resources and to safeguard their investment. For sustainable CSA in West Africa, regional and national Centre for Agriculture, hydrology and meteorology responsible for weather monitoring and prediction should be mandated to regularly make available climate and allied data and information to researchers, development practitioners, farmers and all other stakeholders. Governments should ensure increased capacity in the areas of information technology and modelling in the fisheries sub-sectors of the economy to better address vulnerability and build resilience for CSA in West Africa. Suitable adaptation and mitigation measures should be site-specific to respond to anticipated changes in rainfall and temperature in West Africa for CSA. Policies in capacity building on sustainable fisheries techniques with respect to climate change vulnerability and mitigation must include Gender Mainstreaming, with greater involvement of women and youth, strengthening of National Agricultural Research Systems (NARS), private sectors, NGOs in decision making for CSA in West Africa. There should be increased capacity of countries in West Africa to develop the aquaculture sector through capacity building and technological transfer and “climate proof”, this sector with appropriate water efficiency techniques promoted and used for inland aquaculture. As a major outcome of the present study, it is recommended that a climate-risk insurance system for the fisheries sector is needed and should be considered. Regional participation should be broadening to identify potential of coordinated CC action beyond the national level. A participatory backcasting exercise for all drivers in each CC scenario in each country in West Africa should be conducted. Continue to integrate youth in fisheries sector development plans, formulation of adaptation strategies and more broadly strategic planning for the sector. Develop local scenarios in each country and compare them with national level ones to understand cross-scale interactions

## References

Adebo, G.M. and Ayelari, T.A., 2011. Climate Change and Vulnerability of Fish Farmers in South Western Nigeria, *African Journal of Agricultural Research,* 6(18): 4230-4238

Aguilar-Manjarrez, J. and. Nath, S.S., 1998. A strategic reassessment of fish farming potential in Africa. CIFA Technical Paper 32, FAO, Rome. 172 p.

Allison, E.H., Perry, A.L., Badjeck, M.C., 2009. Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries* 10(2), 173–196.

Associated Press, 2006. *Shrinking of Lake Chad,* 14 December/ http:// www.globalpolicy. org/component/ content/article/198/40377.html

Badjeck Marie-Caroline; Katikiro, Robert E.; Flitner, Michael; Diop, Ndiaga; Schwerdtner Máñez, Kathleen, 2011. Envisioning 2050: Climate Change, Aquaculture and Fisheries in West Africa. The WorldFish Center Workshop Report No. 2011-09. The WorldFish Center, Penang, Malaysia. 28 pp

De Silva, S.S. and Soto, D., 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto and T. Bahri

ECOWAS, 2009a. *Sub-Regional Action Program to Reduce Vulnerability to Climate Change in West Africa. Part1: Overview of West Africa Vulnerability to Climate Change and of Response Strategies*, Abuja, Nigeria: Economic Community of West African States

ECOWAS, 2009b. *Sub-Regional Action Program to Reduce Vulnerability to Climate Change in West Africa. Part 2: The Strategic Action Plan,* Abuja, Nigeria: Economic Community of West African States

ECOWAS-SWAC/OECD, 2008. Atlas on Regional Integration in West Africa. www.atls.westafrica.org

FAO, 2008. Climate change implications for fisheries and aquaculture. In: *The State of Fisheries and Aquaculture 2008*. FAO, Rome, Italy, pp. 87–91.

FAO, 2010. *Climate Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation*, Rome, Italy: Food and Agriculture Organization

FAO/SFLP, 2007. Building adaptive capacity to climate change. Policies to sustain livelihoods and Fisheries. *New Directions in Fisheries – A Series of Policy Briefs on Development Issues*. No. 8. Sustainable Fisheries Livelihoods Programme, FAO, Rome.

IPCC, 2007. *Climate Change 2007: Synthesis Report – Contribution of Working Groups I, II, and III to the Fourth Intergovernmental Panel on Climate Change*. Core Writing Team: R.K. Pauchauri and A. Reisinger, eds. IPCC, Geneva, Switzerland, 8 pp.

IUCN, 2004. Réduire la vulnérabilité de l'Afrique de l'Ouest aux impacts du climat sur les ressources en eau, les zones humides et la désertification

Jalloh, A., Nelson, G.C., Thomas, T.S, Zougmoré, R. and Roy-Macauley, H. (eds), 2013. *West African Agriculture and Climate Change,* Washington DC: International Food Policy Research Institute

Kolavalli, S., Flaherty, K., Al-Hassan, R. and Baah, K.O., 2010. *Do Comprehensive Africa Agriculture Development Program (CAADP) Processes Make a Difference to Country Commitments to Develop Agriculture? The Case of Ghana.* IFPRI Discussion Paper 01006, Washington DC: International Food Policy Research Institute

McCartney, M., Forkuor, G., Sood, A., Amisigo, B., Hattermann, F., Muthuwatta, L., 2012. The water resource implications of changing climate in the Volta River Basin. Colombo, Sri Lanka: International Water Management Institute (IWMI). 40p. (IWMI Research Report 146). doi:10.5337/2012.219

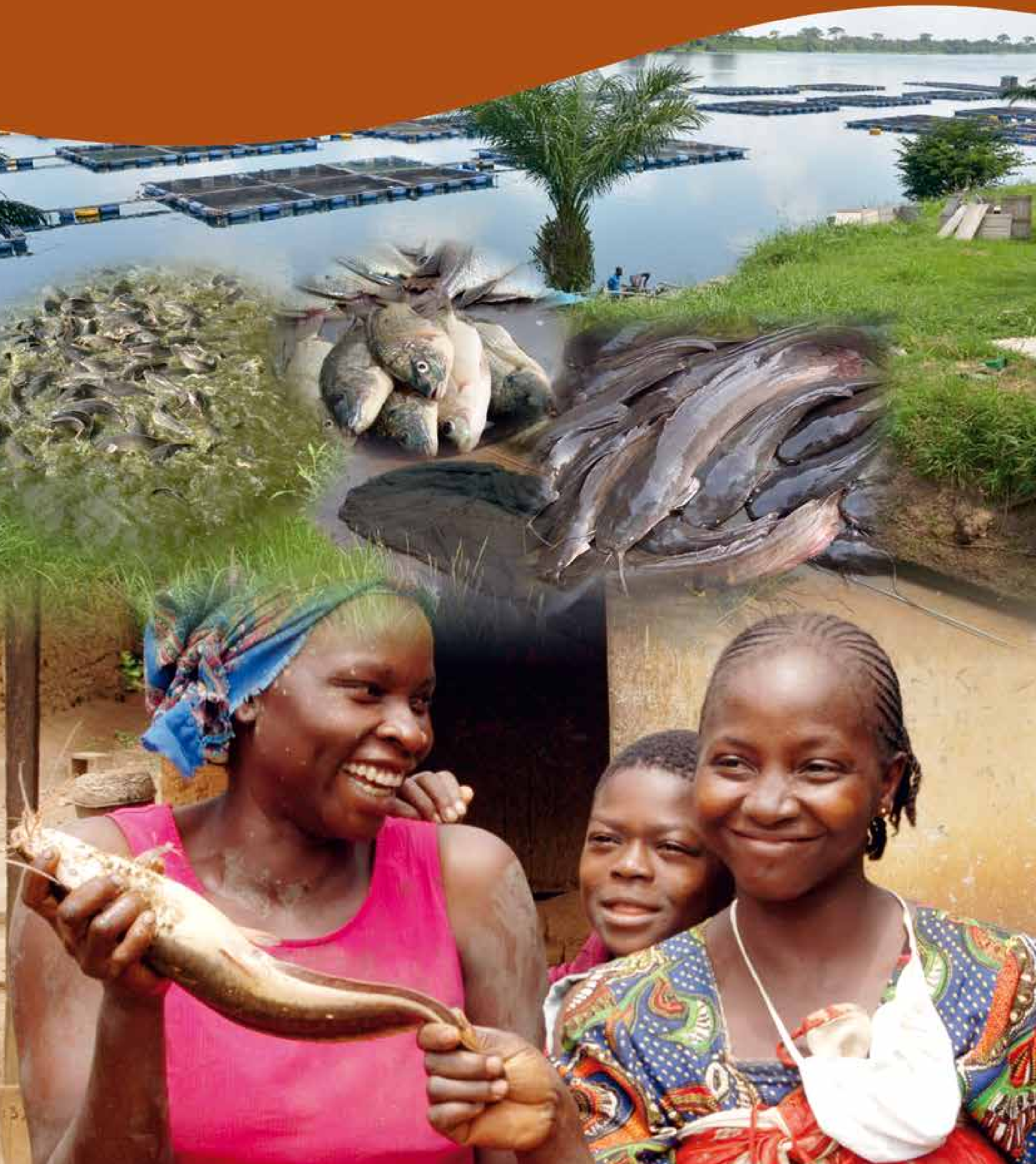
Mcleod, E., Chmura, G.L., Bouillon, S., Salm, R., Björk, M., Duarte, C.M., Lovelock, C., Schlesinger, W. & Silliman, B., 2011. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. *Frontiers in Ecology and the Environment*, 9: 552–560

Omitoyin, S.A., 2009. Impact of Climate Change on Livelihood and Food Security of Artisanal Fisherfolks in Lagos State, Nigeria. Paper Presented at Copenhagen Conference on Climate Change, Denmark, December 12-15, 2009

Rhodes, E. R., Jalloh, A. and Diouf A., 2014. *Africa Interact: 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. Working paper 090; 52p

Soto, D., Aguilar-Manjarrez, J., Brugère, C., Angel, D., Bailey, C., Black, K., Edwards, P., Costa Pierce, B., Chopin, T., Deudero, S., Freeman, S., Hambrey, J., Hishamunda, N., Knowler, D., Silver, W., Marba, N., Mathe, S., Norambuena, R., Simard, F., Tett, P., Troell, M. and Wainberg, A., 2008. Applying an ecosystem-based approach to aquaculture: principles, scales and some management measures. In D. Soto, J. Aguilar-Manjarrez & N. Hishamunda, (eds). Building an ecosystem approach to aquaculture. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Spain, Mallorca. FAO Fisheries Proceedings. No. 14. Rome, FAO. pp. 15–35.

USAID, 2008. West African Fisheries Profile 2pp.



# Chapter 4
# Overview of the scientific, political and financial landscapes of Climate-Smart Agriculture in West Africa: sector of water resources

**Marloes L. Mul, Timothy O. Williams & Olufunke Cofie**

International Water Management Institute, Accra, Ghana

## Executive summary

The climate in West Africa is highly variable and although the climate change projections are not in agreement on all aspects, it is generally accepted that the climate variability will increase combined with increasing temperatures and both increasing and decreasing trends in rainfall. These projected changes in climate will have a strong impact on the water availability in the region, which will lead to: 1) Overall less water; 2) Very large rainstorms leading to flooding and increased soil erosion; 3) More frequent and severe droughts (ODI & CDKN, 2014). Amongst other things, Climate-Smart Agriculture (CSA) will have to deal with this variability through increasing the storage capacity from farm to river basin level as an adaptation measure to reduce the effects of water shocks and build climate resilience. Various agricultural water management (AWM) solutions have been proven to improve agricultural productivity and can significantly reduce the problems posed by variability in rainfall, runoff and recharge; however they have not been scaled-up partly due to lack of policy and institutional support and partly due to incomplete knowledge of large scale impacts (including GHG reduction as adaptation co-benefits). Additional challenges for the smallholder farmers are to raise the required investment costs, in particular for the poorest in the communities. Investments in large scale water infrastructure in Africa are also lagging behind, although it has been proven to contribute substantially to economic and human development in the region. As investments in water infrastructure are perceived as a public responsibility, raising the required funds is often challenging. New financing mechanisms are being explored such as public-private partnerships. Decisions on investments in water resources, at various levels, should concentrate on easing the factors limiting adoption and enhancing system productivity while maintaining ecosystem services. New investments in multi-objective water storage infrastructure should take into account the potential effects of climate change. Given the various transboundary river basins in West Africa, cooperative management of water resources is necessary to maximize the region's yield of food, power and economic development, while reducing the effects of floods and droughts and strengthening environmental sustainability. Coherence and coordination of various adaptation measures in different national initiatives (e.g. National Adaptation Programmes of Action (NAPA) and National Agricultural Investment Programmes (NAIP)) will ensure joined-up effort for effective adaptation to climate change.

## 1. Current status of water resources in West Africa

Water resources comprise of rainfall, surface water and groundwater resources, whereby the main driver is rainfall, which directly affects the surface and groundwater resources availability. Only a small part of the rainfall (examples from the Volta and Niger basin show this is less than 10%) ends up as surface water, which is the easiest to manage. In addition, groundwater recharge is estimated to be less than 5% of the total rainfall (Martin and van der Giesen, 2005). Surface water and groundwater resources are highly influenced by changes in rainfall, whereby Mahe *et al.* (2013) estimated that a reduction in rainfall of 20% results in a reduction of runoff by 60%, this is due to a threshold behaviour (Andreini *et al.*, 2000). Rainfall in West Africa is highly variable, both on an inter- and intra-annual basis. In general, total annual rainfall decreases and variability increases from South to North, with the population in the northern regions therefore being much more vulnerable to the climate variability.

Water resources are not only affected by climate, the region has also experienced rapid population growth and economic development. Urbanization and land use change are among the major drivers that affect water resources. Urbanization directly increases the demand for domestic water, but also the demand for energy which is reflected in water resources through the construction of hydropower dams (e.g. Akosombo and Bui dams in Ghana), and for food production (e.g. the office du Niger in Mali). Land use change, on the other hand, mainly increases agricultural lands and decreases natural landscapes such as forest cover. These changes will impact water resources availability in the region.

In general, West Africa has, compared to the rest of Africa, ample water resources, but both surface and groundwater resources vary across the region. Two countries are currently facing water scarcity (<1,000 $m^3$/cap/yr, Burkina Faso and Cape Verde) whereas others have abundant water resources (>10,000 $m^3$/cap/yr, Guinea, Guinea-Bissau, Liberia and Sierra Leone), (FAO, 2005). Due to expected population growth, three countries are expected to experience water stress in the near future (<1,700 $m^3$/cap/yr, Ghana, Niger and Nigeria). In addition, water resources availability is highly seasonal, with a large number of rivers in the northern part drying up during the dry season. The region has several transboundary rivers that flow throughout the year, even through some of the driest areas of the region (e.g. Niger, Senegal and Volta rivers), and is therefore an important source of water in those areas. Long term variations have been experienced in the region with multi-annual periods of above or below average rainfall. For the last four decades the region has experienced below average rainfall, although the rainfall in the more recent decades is higher compared to the drought years of the 1980s, it remains below the long term average (Oguntunde *et al.*, 2006; l'Hôte *et al.*, 2002; 2003; Ozer *et al.*, 2003). In addition, in the last 10-20 years, projected climate change impacts have slowly become apparent in the region. The start of the rainy seasons has become erratic, total annual rainfall amounts are more variable and intra-seasonal variability is increasing with longer dry spells and more high intensity rainfall events (Lacombe *et al.*, 2013). This also has its influence on surface and groundwater resources, whereby flow during the dry season are reduced and floods have increased.

FAO (2005) estimates that only a fraction (<5%) of the 1,300 $Bm^3$/yr of total annual renewable water resources in West Africa is currently utilized. In addition, less than 10% of the potential irrigated areas are exploited (FAO, 2005). The existing schemes are very important for food production for example the Office du Niger in Mali produces an estimated 40-50% of the rice production in Mali (Beliérès *et al.*, 2011). The FAO figures are for public irrigation schemes, however a large part of the irrigation development in these countries is privately managed. For example, the privately managed smallholder irrigation area in Ghana is 25 times the area under public sector irrigation (Giordano *et al.*, 2012). Currently the main source of water for irrigation is surface water. Villholth (2013) indicated that approximately 37% of the irrigation in West African countries is based on groundwater, which is higher than the average percentage in Sub-Saharan Africa (20%). Ghana and Nigeria are the countries with largest areas under groundwater irrigation being 81 and 54%, respectively (Namara *et al.*, 2013 and Abric *et al.*, 2011). Nevertheless, this is a small amount compared to the renewable groundwater resources. Obuobie *et al.* (2012) estimated for the Volta basin only approximately 5% of the renewable groundwater resources is currently being used. Foreign direct investments in agricultural land in the region are also on the increase and potentially have a large impact on the water resources in the region (Williams *et al.*, 2012; Kizito *et al.*, 2012).

A large part of the food production in the region is produced by smallholder farmers. Rain-fed agricultural systems are highly susceptible to rainfall variability. The inter-annual variability leads to significant fluctuations in yields and income of farmers from one year to another. During years with high rainfall, yields can be good, but at the same time prices are low, and vice versa. In addition, intra annual variability (i.e. dry spell occurrences or local flooding during the planting season) can affect crop yields significantly and even cause complete crop failure. AWM solutions, including small-scale privately or communally managed irrigation, have been proven to have potential to improve the livelihood of smallholder farmers, through increased productivity and increased income derived from dry season farming, thereby increasing their household resilience (Douxchamps *et al.*, 2012). Other adaptive co-benefits of these AWM, such as reducing GHG emissions through carbon sequestration are less reported, but can be inferred.

# 2. Climate projections and the expected socio-economic and environmental impacts for water resources

This section focusses on projections and expected impacts in the medium to long term. Climate change projections reveal that water resources in the West Africa region will be affected by climate, with rainfall projections being the most important one. Changes in temperature can also affect the water resources by influencing the water use by crops, in general the projections agree in an increase in temperature from 2-6°C by 2100. However, the climate projections for annual rainfall amounts do not show consistent responses (results show increasing and decreasing trends) for the West Africa region with a low confidence range (IPCC, 2014; Sultan *et al.*, 2013). A meta-analysis on the impact of climate change on the water resources in West Africa show very high uncertainties for mean annual discharge, with a median showing no trend (close to zero) (Roudier *et al.*, 2014). Results for individual river basins show similar inconclusive results, which are dependent on the CC scenario selected (Roudier *et al.*, 2014). Further investigation towards inter seasonal variability, such as floods and drought has been studied less and relies on the climate projection and downscaling techniques used. This is, however, very important for flood protection and dam design (Roudier and Mahe, 2010). Studies on the impact of climate change on groundwater resources are even more limited, but some studies show there is a strong link to groundwater recharge (Obuobie, 2008). What is clear is that the inter- and intra-annual variability will remain a major challenge, which might be further aggravated by reduction of total rainfall.

Water resources availability in the future is also dependent on the socio-economic developments in the region. For example, population in West Africa is expected to double by the year 2050 (WRI, 2013), and agricultural water use for Sub-Saharan Africa is expected to more than triple compared to 2000 (Hilderink *et al.*, 2012), similar values are expected for West Africa, but not available. Villholth (2013) assessed that water use from groundwater is increasing more quickly than surface water use. For the Volta basin, McCartney *et al.* (2012) predicted that increasing water resources development of large infrastructure will have a substantial impact on the performance of existing and planned reservoirs, and resultant development outcomes. On the other hand, Leemhuis *et al.* (2009) showed that the development of small reservoirs will have a limited impact. Climate change is predicted to aggravate the situation.

Population growth is also linked to changes in land use, which is known to be linked to water resources availability. For example forest cover conversion to agricultural land in arid and semi-arid areas can increase the flow variability, through a decrease in base flow and increase in peak flow. These changes aggravate the challenges faced due to climate change, less water is available during the dry season and more devastating floods are expected during the rainy season. Because of these projected changes in the temporal water resources availability, adaptation measures are required, focusing on harvesting and storing water when it is in abundance to be used during times of drought. Before such CSA interventions are promoted, it should be clear what the implications are on downstream water availability.

# 3. Proven approaches, barriers and next steps towards CC adaptation and mitigation in relation to water resources in West Africa

## 3.1. Scientific and technical aspect

Various scientific and technical solutions to improve agricultural water management have been studied, promoted and funded in the region over the last 50 years (Douxchamps *et al.*, 2012). These solutions range from on-farm *in-situ* solutions, small-scale water harvesting structures to small reservoirs and large dams. Most of these interventions focus on boosting the resilience of the system against climate variability, through increasing water storage at different spatial scales. The water storage interventions range from increasing the storage on agricultural field, to small storage structures and small, medium and large dams (McCartney and Smakhtin, 2010).

*In-situ* on-farm strategies aim at enhancing rainfall infiltration in the soil, improve soil water storage and limit top soil losses through wind and water erosion. At the field level, water storage is enhanced through improved soil and water management practices, such as deep tillage that improve soil structure and depth, increasing root depth and increasing infiltration into the unsaturated zone. Water can also be harvested from rainfall and runoff in small individually-owned storage structures, such as rooftop harvesting tanks and underground storage tanks. Small reservoirs are structures capturing and storing run-off at macro-catchment level. They have multiple uses: supplementary irrigation during dry spells, dry season irrigation, fishing, livestock and household watering, and groundwater recharge through decreasing run-off. These structures are often communally-managed; this is well developed especially in Burkina Faso and northern Ghana where there are approximately 1,053 and 500 of the so-called small reservoirs (Leemhuis *et al.*, 2009; Johnston and McCartney, 2010). These storage mediums store water for bridging dry spells but also increase dry season agricultural production, especially for vegetables. With increasing variability, new ideas have evolved around harvesting floods to be made available for drier periods through flood recession farming, an intervention that is gaining attention in recent years. In this case, water stored in the floodplains after a flood event is lifted with small pumps during dry spells to grow crops.

As these innovations focus on increasing overall agricultural productivity and enhancing resilience, they contribute to improving the livelihoods of farmers especially for those who earn additional income during the dry season cultivation when food prices are relatively higher, leading to higher income. Appropriate water storage facilities and water lifting and distribution equipment allow farmers to produce and sell when market prices are high. Though this is only relevant where farmers have access to land for cultivation as well as access to inputs and markets for the products, especially for fresh agricultural produce such as fruits and vegetables with very short shelf life. Studies in Asia indicated that the largest share of GHG emission in agricultural systems is related to the production and transportation of agro-chemicals, followed by the use of diesel to pump water into the fields (Maraseni *et al.*, 2009). Appropriate CSA interventions should minimize the use of fossil fuel to lift and transport water to the field, either through distributed storage interventions, minimizing the distance from source to the field or through alternative energy sources such as solar and wind powered pumps (Burney *et al.*, 2010).

Climate change projections for rainfall in West Africa show varying responses with limited confidence (IPCC, 2014). Rainfall is the main driver for water resources availability and therefore uncertainty in rainfall projections will be amplified in the water (both surface and groundwater) resources projections (de Wit and Stankiewicz, 2006). Additional work has to be done on improving the climate change projections for the region and in particular towards downscaling, both spatially as well as temporally. In addition, improved hydrological modelling of the impact of the climate change projection needs to take into account both land use as well as increased water utilization, as these developments have major implication for the water resources. In addition, increased understanding of uptake of CSA interventions on water resources availability from catchment to river basin is needed to guide policies for supporting CSA interventions that have the required impact at field scale (increased production) as well as at larger scale, reducing GHG emission, increasing basin wide benefits and sustaining the environment.

## 3.2. Policy and institutional aspect

At the regional level, ECOWAS developed a regional agricultural policy for West Africa (ECOWAP), which specifically mentions the following priority areas: improving water management by i) promoting irrigation and ii) integrated water resources management and sustainable agricultural development at farm level through a) integrated soil fertility management b) better support services for producers and c) dissemination of improved technologies (ECOWAS, 2006) – with no specific reference to AWM solutions. The regional agricultural investment programme (RAIP) and national agricultural investment programmes (NAIP) of ECOWAS countries specifically mention improving water management, including the improvement of irrigation. However, except in the case of Burkina Faso where an explicit reference to climate change adaptation was mentioned, all the other countries failed to mainstream climate change adaptation into their NAIPs. On the other hand, strategies towards increasing climate resilience are captured in the National Adaptation Programmes of Action (NAPA). Several countries in West Africa have identified priority adaptation activities and projects through these NAPAs, of which most identified areas related to improving availability of water resources. For example, water harvesting is mentioned in the Malian NAPA, exploitation of surface water resources by Senegal, Benin and Niger and increasing groundwater usage by Niger. A key issue to address going forward is better harmonization and coordination of adaptation measures envisaged under various national programmes such as NAIP and NAPA in order to increase the effectiveness and returns to investment in climate change adaptation.

Although at national level, policies and programmes are in place and at the grassroot level AWM solutions are tested and implemented, there is a disconnect between these two levels. This is affecting the adoption level of potentially successful AWM. While farmers perceive the positive effects of AWM strategies on their natural capital and on agricultural production in particular, there are still a number of factors limiting sustainable adoption. These factors range from material scarcity, work load and costs, land tenure constraints, maintenance and use of communal infrastructure, traditional customs and ways of thinking, to lack of institutional support and project design (Douxchamps *et al.*, 2012). They also identified a lack of supportive institutional structures for smallholder agricultural water management practices as a key challenge. Knowledge of AWM is not reaching the target audience through official channels and institutions due to the lack of financial and human capacity. Innovative ways to support farmers and disseminate required information is needed. In addition, construction and maintenance of communal projects such as small reservoirs require communal efforts and management, which in turn requires farmers' or village organizations to be in place (Schweigman, 2003). In some countries such organizations exist. For instance in Burkina Faso, the government initiated in 2003, local water committees (*Comité Local de l'Eau* (CLE)). CLEs are meant to serve as platforms for consultation, mobilization and promotion of ideas for communal management of water resources rather than a decision-making body with enforcement powers. Due to a limited mandate and lack of resources, the CLEs have not risen to become active change agents that can address and solve water management issues. These types of institutions need clear mandates and rules and appropriate financial support in order to improve their effectiveness.

There are many existing opportunities to address constraints and unlock the sector's potential. With food security on the international agricultural agenda, and climate change increasing the uncertainty of rainfall, it is an opportune time to reconsider investments related to water for CSA. Technically a lot is already known on best AWM solutions and their impact at farm level; however, little is known about what this impact is on a systems level. Douxchamps *et al.* (2012) proposed the following to improve uptake and institutional support for suitable AWM solutions: adopting an integrated management and systems approach; landscape approach and ecosystem services; economic aspects; climate change and risk management; governance and adoption; development aid and impact assessment. The adoption of small-scale irrigation technologies by many individual farmers is a new dynamic, which presents opportunities and challenges that differ from conventional irrigation development. Smallholder AWM requires new organizational models because existing governing bodies concerned with water management are often not adapted to handle the challenges posed by this alternative, dispersed mode of supplying water. Irrigation departments tend to oversee large-scale canal irrigation, while agricultural departments are more concerned with rain-fed farming and pays only limited attention to small-scale irrigation. As a result, small-scale private irrigation falls between the two and, therefore, lacks an institutional 'home'. The end effect is that opportunities for improving small-scale private irrigation are often lost. But the situation is gradually changing and the momentum created towards providing support for smallholder small-scale irrigation needs to be sustained as a means of ramping up adaptation to climate change at the grassroots level.

Additional challenges arise with the quest for greater economic development, with increasing demand for irrigation and power generating infrastructure, in particular when these are planned in transboundary river basins. Several existing institutions coordinate development in the Niger, Senegal and Volta basins. However, these agencies as well as the riparian countries face challenges in allocating water resources among competing multiple uses as climate change results in less stable water supplies and urbanization and increased agricultural production increase demand for water. Effective decision making and regional coordination is required to incorporate basin wide benefits while considering large scale investments such as dam construction to avoid conflict (Jalloh *et al.*, 2013). In addition, local communities who are affected by the construction of the infrastructure should get a share in the benefits (Bazin *et al.*, 2011; Skinner *et al.*, 2009).

## 3.3. Financial aspect

Increasing the climate resilience of agriculture requires investments in infrastructure at different scales, from farm to river basin scale. For investments on farm level, few investors are on the market to offer loans, as a result NGOs and government institutions are subsidizing these investments, but few AWM have shown scope for achieving full cost recovery. This is particularly an issue with the smaller individual investments, which often do not attract attention and support from donors. Studying AWM solutions therefore need to have a clear business component, to show the possible return on investments in order to attract loans. An example of such research was done on comparing the financial costs of low-head pumps for shallow aquifers in northern Ghana. For a small head difference (<5m), it is possible to get a reasonable return on the investment of a small petrol pump (Namara *et al.*, 2011). Energy powered pumps are also increasingly being used, with solar pumps in combination with drip irrigation providing an interesting option (Burney *et al.*, 2010), but need a thorough financial analyses on their investment returns. Larger investments that provide support to a community are more easily financed by donor or governmental agencies, through subsidies. However, because it is a subsidy, the projects do not recover their cost, as it is not part of the design. In addition, lack of local ownership manifest itself in governance problems and lack of maintenance, as expectations are that the donors will return to fix the investments when they break down. When investing in these community projects, sufficient attention should be given to improve local ownership and invest in human capacity building on governance and management of the system.

Smallholder farmers demonstrate a genuine interest by financing and installing irrigation technologies and investing their own resources in their agricultural businesses. Small-scale AWM could expand significantly if farmers were able to overcome key constraints, such as high upfront investment costs; poorly developed supply chains; high taxes and transaction costs; difficulty accessing information and knowledge on irrigation, seeds, marketing, equipment and other inputs; and imbalances of power that leave farmers at a disadvantage when selling their produce. Poor farmers (often women and young people) in particular face difficulties generating the investment costs for AWM technologies and the associated agricultural investments needed to generate higher profits (Giordano *et al.*, 2013). While all farmers face agricultural risks, poorer farmers are often less able to access resources and assume proportionally larger financial risks. Providing access to loans is key to enable smallholders to invest in small-scale irrigation technologies; through: i) increasing awareness and consideration of the banking sector on the profitability of irrigated agriculture; ii) develop subsidies or financial incentives for irrigation equipment; iii) develop loan guaranties from either the States or donors to reduce the risk for the banking sector to invest in this field.

At the same time, large scale infrastructure investments in Africa are lagging behind, although "Infrastructure contributes to half of the economic growth in Africa" (Foster and Briceño-Garmendia, 2010). In addition, water infrastructure contributes to human development through providing water supply, reducing water borne diseases and improving nutrition. As water infrastructure is commonly regarded as a public commodity, new financing mechanisms are being promoted, such as public-private partnerships (Foster and Briceño-Garmendia, 2010).

Currently, the World Bank is initiating an investment programme aimed to more than double the area under irrigation in six Sahelian countries (Burkina Faso, Chad, Mali, Mauritania, Niger and Senegal) from the current level of approximately 400,000 ha to 1 million ha by 2020 at an estimated cost of US$ 7 billion. It is important that this initiative takes into consideration lessons learnt from past investments in large-scale irrigation and more importantly put in place programmes to support smallholder small-scale irrigation and promote climate-smart agriculture across all irrigation scales.

# 4. Key messages and recommendations for the water resources sub-sector

## 4.1. Regarding ECOWAS framework on CSA

- **Expand water storage capacity from basin to watershed and farm-scale levels and improve the management of existing water storage and distribution infrastructure**

New investments are needed at various scales to improve water storage and reduce the effects of water shocks (droughts and floods) that are likely to arise from climate change and thereby build climate resilience. Basin-, community- and on-farm-level water storage should be built. Investments in multi-purpose water storage systems should take into account the potential effects of climate change. Appropriately designed climate proof water storage infrastructure can help to reduce the danger of rainfall variability and capture floodwater for productive use in agriculture. Appropriate financing mechanisms should be promoted and supported by ECOWAS.

- **New investments in infrastructure need to be combined with investment in institutional reforms**

As urbanization and industrial development increase and climate change leads to less stable water supplies, river basin organizations will face challenges in allocating water resources among multiple uses at the basin level. Adaptive, multilevel collaborative governance arrangements to manage water and resolve conflicts will need additional financial and human resources for improving their effectiveness in decision making.

AWM as a climate adaptation strategy is not adequately reflected in existing policy documents (West Africa Resources Policy and Action Plan; Regional Agricultural Investment Policy) and NAIPs. On the other hand, Integrated Water Resource Management (IWRM) regional action plan considers AWM but it is not being implemented. Revised policies and investment plans that emphasize coherence, harmonization and coordination of AWM measures included in various regional and national initiatives are needed for effective adaptation to climate change.

- **Improve access of smallholder farmers to water by removing technical and institutional barriers**

Promotion of CSA interventions is necessary but insufficient to improve smallholder farmers' adaptation to climate change. Improved land and water rights, especially for women, and removal of economic and institutional impediments that prevent smallholder famers from gainfully using water are urgently needed. Giordano *et al.* (2012) developed pathways towards improving the livelihood of smallholder farmers, which can also assist them in adapting to the effects of climate change. These pathways focus on leveraging the factors that limit adoption (catalyze smallholder value chains through innovative financing mechanisms and helping farmers buy equipment and become profitable and creating policy synergies between sectors), enhance productivity (increasing access to water through rainwater harvesting, shallow groundwater and small reservoirs) while maintaining healthy ecosystem services (taking a watershed perspective). The ECOWAS framework should take a systems perspective, taking into consideration water-crop-livestock interactions and improved access to markets. Equal access to financing structures for investments should include the more vulnerable in the society.

Finally, as CC is potentially bringing various risks to the water resources section, actions towards reducing this risk fit into the global process of disaster risk reduction, which started in 2005 and is moving towards its second phase (UN, 2005). It shows there is a need for a long-term perspective, to foresee the best strategies for CSA and manage risk in this variable environment.

## 4.2. Regarding the Alliance for the convergence and coordination of initiatives on CSA in West Africa

There are numerous projects and programs currently working on aspects of CSA in the region, in particular there is a wealth of knowledge on agricultural water management practices in the region (Douxchamps *et al.*, 2012). The current project portfolio predominantly focusses on increasing productivity and only few investigate risk reduction, GHG emissions and other aspects of climate-smart systems. This includes a coordinated approach of identifying the cumulative social and environmental impacts of implementation of these CSA interventions. There is a clear need to sensitize and raise awareness of stakeholders on the need for climate-smart water resources (both surface and groundwater) management. There is a need for a multi-scale, landscape perspective, to understand ecological landscape processes and trade-offs between ecosystem services derived from and affected by CSA adoption across different scales. We suggest adopting a watershed perspective to address potential social and environmental issues.

## References


Abric, S., Sonou, M., Augeard, B., Onimus, F., Durlin, D., Soumaila, A., and Gadelle, F., 2011. Lessons learned in the development of smallholder private irrigation for high-value crops in West Africa. Washington, DC, World Bank.

Andreini, M. N. van de Giesen, A. van Edig, M. Fosu, and W. Andah, 2000. "Volta Basin Water Balance." ZEF – Discussion Papers on Development Policy, No. 21. Bonn: ZEF.

Bazin, F., Skinner, J., Koundouno, J. (eds), 2011. Sharing the water, sharing the benefits. Lessons from six large dams in West Africa. International Institute for Environment and Development, London, UK. 118 pages.

Bélières, J.-F., Hilhorst, T., Kébé, D., Keïta, M. S., Keïta, S., Sanogo, O., 2011. Irrigation et pauvreté : le cas de l'Office du Niger au Mali. Cahiers Agricultures 20, 144–149.

Burney, J., Woltering, L., Burke, M., Naylor, R., Pasternak, D., 2010. Solar-powered drip irrigation enhances food security in the Sudano-Sahel. Proceedings of the National Academy of Sciences 107 (5), 1848-1853.

Douxchamps, S., Ayantunde, A., Barron, J., 2012. Evolution of Agricultural Water Management in Rainfed Crop-Livestock Systems of the Volta Basin. Colombo, Sri Lanka: CGIAR Challenge Program for Water and Food (CPWF). 74p. (CPWF R4D Working Paper Series 04)

ECOWAS Commission, 2006. Regional Agricultural Policy for West Africa: ECOWAP. Make agriculture the lever of regional integration. p. 12.

FAO, 2005. Irrigation in Africa in figures – AQUASTAT survey 2005. FAO-Water report 29, FAO, Rome, Italy.

Foster, V., Briceño-Garmendia, C., 2010. Africa's Infrastructure; A Time for Transformation. African development forum series, World Bank.

Giordano, M., de Fraiture, C., Weight, E., van der Bliek, J. (Eds.), 2012. Water for wealth and food security: supporting farmer-driven investments in agricultural water management. Synthesis report of the AgWater Solutions Project. Colombo, Sri Lanka: International Water Management Institute (IWMI). 48p. doi:10.5337/2012.207

Hilderink, H., Brons, J., Ordoñez, J., Akinyoade, A., Leliveld, A., Lucas, P., Kok, M., 2012. Food security in sub-Saharan Africa: An explorative study, The Hague/Bilthoven: PBL Netherlands Environmental Assessment Agency.

l'Hôte, Y., Mahé, G., Some, B., 2003. The 1990s rainfall in the Sahel: the third driest decade since the beginning of the century, Hydrological Sciences Journal, 48:3, 493-496.

l'Hôte, Y., Mahé, G., Some, B., Triboulet, J.P., 2002. Analysis of a Sahelian annual rainfall index from 1896 to 2000; the drought continues, Hydrological Sciences Journal 47(4), 563-572,

Jalloh, A., Nelson, G.C., Thomas, T.S., Zougmoré, R., Roy-Macauley, H., 2013. West African Agriculture and Climate Change; A Comprehensive Analysis. IFPRI

Johnston, R., McCartney, M., 2010. Inventory of water storage types in the Blue Nile and Volta river basins. IWMI Working Papers 140, pp 48. Colombo: International Water Management Institute (IWMI).

Kizito, F., Williams, T.O., McCartney, M., Erkossa, T., 2012. Green and blue water dimensions of foreign direct investment in biofuel and food production in West Africa: The case of Ghana and Mali: In: T. Allan, M. Keulertz, S. Sojamo and J. Warner (eds.). Handbook of Land and Water Grabs in Africa: Foreign Direct Investment and Food and Water Security. Routledge, London. pp. 337-358.

Lacombe, G., McCartney, M., Forkuor, G., 2012. Drying climate in Ghana over the period 1960–2005: evidence from the resampling-based Mann-Kendall test at local and regional levels, Hydrological Sciences Journal 57 (8), 1–16.

Leemhuis, C., Jung, G., Kasei R., Liebe, J., 2009. The Volta Basin Water Allocation System: assessing the impact of small-scale reservoir development on the water resources of the Volta basin, West Africa. Advances in Geosciences 21, 57-62.

Mahe, G., Lienou, G., Descroix, L., Bamba, F., Paturel, J.E., Laraque, A., Meddi, M., Habaieb, H., Adeaga, O., Dieulin, C., Chahnez Kotti, F., and Khomsi, K., 2013. The rivers of Africa: witness of climate change and human impact on the environment. Hydrological Processes 27(25), 2105–2114, doi:10.1002/hyp.9813.

Maraseni, T. N., Mushtaq S., Maroulis, J., 2009. Greenhouse gas emissions from rice farming inputs: a cross-country assessment. Journal of Agricultural Science 147, 117–126

Martin, N., van de Giesen, N.C., 2005. Spatial Distribution of Groundwater Production and Development Potential in the Volta River basin of Ghana and Burkina Faso. Water International 30(2), 239-249

McCartney, M., Forkuor, G., Sood, A., Amisigo, B., Hattermann, F., Muthuwatta, L., 2012. The water resource implications of changing climate in the Volta River Basin [Africa]. Colombo, Sri Lanka: International Water Management Institute (IWMI). 33p. (IWMI Research Report 146)

McCartney, M.P., Smakhtin, V., 2010. Water storage in an era of climate change: Addressing the challenge of increasing rainfall variability. Blue Paper. Colombo, Sri Lanka: International Water Management Institute (IWMI). 20p.

Namara, R. E., Awuni, J. A., Barry, B., Giordano, M., Hope, L., Owusu, E. S. and Forkuor, G., 2011. Smallholder shallow groundwater irrigation development in the upper east region of Ghana. IWMI Research Report 143. Colombo, Sri Lanka: International Water Management Institute. 35p.

Namara, R.E., Gebregziabher, G., Giordano, M.A., de Fraiture, C., 2013. Small pumps and poor farmers in Sub Saharan Africa: An assessment of current extent of use and the poverty outreach. Water International 38(6), 827-839.

Obuobie, E., Diekkrueger, B., Agyekuma, W., Agodzoc, S., 2012. Groundwater level monitoring and recharge estimation in the White Volta River basin of Ghana. Journal of African Earth Sciences 71–72, 80–86.

Obuobie, E., 2008. Estimation of groundwater recharge in the context of future climate change in the White Volta River Basin, West Africa. Ecology and Development Series No. 62, University of Bonn, Germany.

Oguntunde, P.G., Friesen, J., van de Giesen, N., Savenije, H.H.G., 2006. Hydroclimatology of the Volta River Basin in West Africa: Trends and variability from 1901 to 2002. Physics and Chemistry of the Earth 31, 1180–1188.

Overseas Development Institute (ODI) and Climate and Development Knowledge Network (CDKN), 2014. The IPPC's Fifth Assessment Report. What is in it for Africa? London.

Ozer, P., Erpicum, M., Demarée, G., Vandiepenbeeck, M., 2003. The Sahelian drought may have ended during the 1990s, Hydrological Sciences Journal 48(3), 489-492.

Roudier, P., Mahé, G., 2010. Calculation of design rainfall and runoff on the Bani basin (Mali): a study of the vulnerability of hydraulic structures and of the population since the drought, Hydrological Science Journal 55, 351–363.

Roudier, P., Ducharne, A., Feyen, L., 2014. Climate change impacts on river discharge in West Africa: a review. Hydrology and Earth System Sciences 18, 2789-2801.

Schweigman, C., 2003. Food security: opportunities and responsibilities, or: the illusion of the exclusive actor. CDS Research report No. 19 Groningen: University of Groningen, Centre for Development Studies.

Skinner, J., Niasse, M. and Haas, L. (eds.), 2009. Sharing the benefits of large dams in West Africa. Natural Resource Issues No. 19. International Institute for Environment and Development, London, UK. 70 pages.

Sultan, B., Roudier, P., Quirion, P., Alhassane, A., Muller, B., Dingkuhn, M., Ciais, P., Guimberteau, M., Traore, S., Baron, C., 2013. Assessing climate change impacts on sorghum and millet yields in the Sudanian and Sahelian savannas of West Africa, Environmental Research Letters 8, 014040, doi:10.1088/1748-9326/8/1/014040.

UN, 2005. Report of the World Conference on Disaster Reduction, Kobe, Hyogo, Japan, 18-22 January 2005.

Villholth, K., 2013. Groundwater irrigation for smallholders in Sub-Saharan Africa – a synthesis of current knowledge to guide sustainable outcomes. Water International 38 (4), 369-391.

Williams, T.O., Gyampoh, B., Kizito, F., Namara, R., 2012. Water implications of large-scale land acquisitions in Ghana. Water Alternatives 5(2), 243-265

De Wit, M., Stankiewicz, J., 2006. Changes in surface water supply across Africa with predicted climate change. Science 311, 1917-1921.

World Resources Institute (WRI), 2013. Creating a Sustainable Food Future: A menu of solutions to sustainably feed more than 9 billion people by 2050. World Resources Report 2013–14: Interim Findings.

# Chapter 5

# Overview of the scientific, political and financial landscapes of Climate-Smart Agriculture in West Africa: sector of forestry and agroforestry

**Patrice Savadogo[1], Robert Zougmoré[2]**

[1]ICRISAT-ICRAF, Niamey, Niger

[2]CCAFS West Africa Program, ICRISAT-WCA, Bamako, Mali

## Executive summary

West Africa (WA) lies squarely in the path of the devastating impact of climate change, which is predicted to affect this region more heavily than any other part of Africa. Extreme weather events such as droughts and floods have historically plagued the region, and climate change is expected to increase both the frequency and magnitude of such events. Indeed, there is evidence that this increase is already happening. In this environment, forests and trees-outside-forests are reported to strengthen the buffering capacity of ecosystems and their ability to support local livelihoods, especially in years when hazards arise. The central roles of trees and forests in the lives of rural West African people are demonstrated by the extensive use of tree products for nutrition and food security, livestock fodder, shelter, energy, and health as well as by the social, cultural and spiritual uses of forests. However, the region's forests and tree resources are facing increasing pressure, translating to rapid deforestation and degradation that are undermining the sustainable production of goods and services. Climate change and land use change will not only alter entire ecosystems, vegetation cover and biodiversity patterns, but also the supply of ecosystem services. Coping with this situation will require action on many fronts including watershed conservation, biodiversity conservation, and capacity building at various levels, all of which will require adequate resources as well as policy and institutional changes, regional cooperation and developments in science and technology. The challenges of climate change make it very important to develop resilient farming systems. Trees on farms can contribute in many ways to this endeavour because they increase ecosystem resilience in a number of ways. Among other things, trees have moderating micro-climatic effects and also increase structural and functional diversity within a farm ecosystem, helping to diversify the production system and thereby minimize risk due to climate variability. It is well documented that small-scale farmers can achieve impressive local successes despite their poverty and acute vulnerability to climate change by adopting proven climate-smart agriculture (CSA) technologies that take advantage of trees on their farms. These agroforestry options can greatly increase farm production, enhance crops' resilience to climate change, and also help mitigate global climate change – the so-called triple-win of CSA. As a leading economic and political institution in West Africa, ECOWAS needs to foster and take active measures to curb or halt deforestation while addressing the barriers to scaling up forestry and agroforestry successes that restore tree cover and improve the livelihoods of populations.

## 1. Current status (2014) for the sub-sector in the region

The West Africa (WA) sub-region constitutes about 17 percent of Africa's total land area. The agro-ecological zones of WA are closely related to the region's agro-climatic zones, with rainfall decreasing from the forested southern coastal region to the sub-humid and semi-arid Sahelian region in the north (Jalloh *et al.*, 2012). The total forest cover in the WA sub-region is estimated at 72.1 million ha, accounting for about 14 percent of the region's land. It comprises 4.2 million hectares of primary forests, 66.2 million hectares of secondary forests, and 1.7 million hectares of forest plantation and important agroforestry parklands. There is considerable variation between countries in the extent of forest cover. Guinea-Bissau, with about 60 percent of its land area under forests, is the most forested country in the sub-region, while Niger, with about 1 percent of its area under forests, is the least forested country (FAO, 2010). A large portion of the sub-region's land is covered with shrubs and sparse trees, and is classified as "other wooded lands". Although not included in the forest area figures, these lands have substantial tree and shrub diversity and growth, which can have important effects on ecosystem services, agricultural production, and adaptation to climate change. A wide variety of products are collected from forests, woodlands, and trees outside forests; many of them are consumed by households or sold locally while some find export markets (Whiteman and Lebedys, 2006), thereby contributing to wealth generation and national economic growth.

The current situation with regard to forestry and agroforestry in WA can be summarized as follows:

- **Rapid deforestation and widespread degradation of forest resources**: WA has a low forest cover because it is mostly dominated by Sahel and was also the major source of raw material for the European market until recently. According to the FAO's statistical data, forests in West Africa are receding at an alarming rate of 19% per decade. The Global Forest Assessment of 2010 revealed that 870,000 ha of forests were lost in the sub-region each year between 2000 and 2010 (FAO, 2010). These losses were primarily due to illegal cutting, bush fires, extensive agriculture (farming over large areas of land with low productivity) and transhumance (moving livestock from one grazing area to another), as well as legal, political, technical and economic limitations. The overall rate of deforestation in West Africa is much higher than the continental average (FAO, 2010) and accounts for approximately 24% of Africa's annual forest loss. WA is undoubtedly among the world's most vulnerable sub-regions to the adverse effects of the destruction of vegetation cover and land degradation, which have negative impacts on human health, food security, economic activity, and efforts to reduce poverty in countries that are dependent on agriculture. Lack of cooperation between various stakeholders, as well as the negative consequences of various conflicts in the area, have had a negative impact on forest conservation. Currently there are multiple transboundary resource conflicts in the ECOWAS region, some of which relate to forest and tree resource rights and transhumance. In Senegal, for example, forest resources are illegally harvested and taken across the border into neighbouring states. In addition to causing reductions in cover, these problems create degradation and fragmentation, particularly in the humid-zone forest. For instance of Ghana's 6 million hectares of forest land, only 1.6 million ha is considered to be "intact closed forest"; the rest is mostly degraded forest.
- **Inadequate conservation**: West Africa has a network of protected areas that covers 27.7 million hectares and provides a wide range of goods and services including wood and non-wood products for household and commercial needs (FAO, 2010). However, the management of these protected areas is far from satisfactory. Insufficient investment and a growing demand for wood and non-wood products are resulting in 'paper parks' with ineffective or insufficient management, and the progressive degradation of the resources that the parks and reserves were established to protect. Large-scale mining for iron ore, diamonds, gold and bauxite, and small-scale mining for gold and diamonds also pose a major threat to the forests. At current annual growth rates, the populations of the West African countries are expected to double by 2025. The demand for forested land will therefore increase dramatically, and the pressure on existing protected areas will become more severe. Growing urban populations and infrastructure development (e. g. improved road networks) will also affect protected reserves, as will the increasing occurrence of illegal activities such as bush meat hunting and logging in the region. For example, Ghana can sustainably produce about one million cubic meters of timber from its forest reserves and agricultural lands. However, in 2002, around 3.7 million cubic meters' worth of logs were extracted from the country's forests, almost four times the maximum sustainable harvest. The expansion of extensive lower yield and intensive higher yield agricultural systems (cultivating plants such as oil palms or rubber trees) poses threats to conservation because farmers generally eliminate wild species from their lands in order to reduce the negative effects of trees. To eliminate these problems, agricultural landscapes will need to be designed and managed so that they can accommodate wild biodiversity without adversely affecting (or ideally, with beneficial effects on) agricultural production and livelihoods. Innovative practitioners, scientists and indigenous land managers are adapting, designing and managing diverse types of 'ecoagriculture' landscapes to generate positive co-benefits for production, biodiversity and local people.

- **Plantation experience:** The establishment and management of plantations and community woodlots can contribute to availability of wood and non-wood products as well as rehabilitation of degraded areas. Vast areas of land offer opportunities for restoration – there are almost 450 million hectares of degraded forest landscape in Africa (Laestadius *et al.*, 2011). West Africa is one of the most degraded and fragmented tropical ecosystems in the world, having only around 20% of its original forest cover (IUCN, 2005). This extensive forest degradation is largely due to land clearance and the large-scale expansion and intensification of commodity crop cultivation. The conversion of degraded land into well managed forest or agroforestry plantations represents a way of bridging the gap between wood supply and demand while preserving the environment. The restoration of the degraded landscape can be configured to accommodate diverse land uses including, for example, the creation of protected reserves and ecological corridors, forest regeneration, agroforestry, planting along waterways and well-managed plantation. Several countries in WA have considerable experience with plantation forestry (Chamshama *et al.*, 2010) and have been able to take advantage of emerging trade opportunities, especially for valuable tree species such as teak. Available data indicate that among West African countries, Nigeria, Côte d'Ivoire and Ghana have significant areas of plantations. The plantations in Nigeria are mostly composed of *Gmelina arborea* for pulpwood production, which is estimated to be planted on 112,000 ha. Teak is widely grown in industrial plantations and small-scale community woodlots in Nigeria (30,000 ha), Côte d'Ivoire (29,000 ha), Ghana (10,000 ha), Togo (10,000 ha), and Benin (8,000 ha). Owners of plantation forests in Africa range from large groups such as governments and large industrial corporations to individual farmers, and their management also varies considerably – some owners use relatively simple and low-input management techniques while others apply highly sophisticated and intensive systems. However, given the region's extreme population pressure and the limited availability of land, the scope for significant expansion of plantations is limited.
- **Shift to natural resource management as timber declines**: Several countries have begun actively managing their natural forests and woodlands, shifting from simple conservation to a natural resource management approach that aims to support sustainable resource usage. Both the public and private sectors face many constraints arising from inadequate land and tree tenure, inadequate incentives to adopt sustainable forest management, and more particularly the absence of an appropriate legal and institutional framework that will ensure compliance with sustainable forest management principles. Although West Africa accounts for just over 1% of the global growing stock (FAO, 2010), commercial timber production is an extensive and lucrative occupation, contributing significant proportions of national income and foreign exchange. For example, in 1998, Côte d'Ivoire exported US$228 million worth of wood products (mostly sawn wood), and Ghana exported US$140 million worth (Sebukeera *et al.*, 2006). Trade is largely dominated by unprocessed products, primarily round wood and sawn planks. Comprehensive statistics on wood and timber production are generally lacking for most West African countries but the general trend is one of decline. Ghana's timber harvest fell by 9.4% and 4.4% in volume and value, respectively, between 2010 and 2011 (ITTO, 2011).
- **Increase in tree cultivation on private lands**: In the semi-arid and sub-humid zones of West Africa, farmers have for many generations maintained a traditional land use system, referred to as "agroforestry parklands", characterized by the deliberate retention and regeneration of trees on cultivated or recently fallowed land. While forests are valued for their timber, fruits and medicinal utility, little is known about agroforestry's impact on communities in the region or the benefits it can offer them. Agroforestry technologies that can be readily adopted include regeneration of nitrogen-fixing and fodder-producing trees (e.g. *Faidherbia albida*), the domestication of indigenous fruit trees and medicinal trees, live fencing, and the creation of woodlots for timber and fuel-wood. Farmers in the semi-arid WA region are embracing

innovative climate-smart agroforestry practices by combining conservation agriculture with "fertilizer trees." These trees outside forests have emerged as a major source of wood and non-wood products. There is also widespread recognition of their ecological service functions – they are known to help break the vicious circles of deforestation and soil erosion, and to help address other environmental problems (Sinare and Gordon, 2015) facing the ECOWAS region. These positive contributions disprove the conventional wisdom of "more people, fewer trees."

- **Unrealized potential of non-wood forest products:** Non-timber forest products (NTFPs) play a major role in meeting people's basic needs, including income-generation. NTFPs are derived from large variety of plants and animals and may be used as food and medication by forest dwellers or processed into various products. The quantity and types of NTFPs that are available in different parts of WA naturally depend on the ecosystems that are present: mangroves, rainforests, dry forests, and savannahs, all provide different ranges of NTFPs. However, efforts to exploit these resources to date have been limited. Few studies have attempted to calculate the value of NTFPs at the national level (Agrawal *et al.*, 2013). Mali represents an exception: Faye *et al.* (2010) reported that NTFPs account for as much as 40% of its national annual income. In 2012, an estimated 350,000 MT of unprocessed shea kernels were exported from Africa, with a market value of approximately US$120 million (http://www.globalshea.com).

# 2. Climate projections and socio-economic and environmental impacts expected by 2050 for the forestry/agroforestry sector

## 2.1. Modelling of the expected impacts / what models do agree on

Climate-change projections for Africa in general are highly variable. However, most models for temperature and precipitation changes over Africa (including both MMD models incorporating known forcings and MMD-A1B simulations extending through the 21st century archived at the Program for Climate Model Diagnosis) project an increase in temperature by the end of the 21st century, with a multimodel average of 2.5–3°C in West Africa (Baptista *et al.*, 2013). The Sahel and Sahara regions are likely to see the greatest temperature increase, with projected rises in excess of 5°C. Despite the variation among models, there is a general consensus that there will be changes in precipitation patterns with reduced precipitation in heavy rainfall areas, particularly those along the Guinean coastal region, and a more humid climate in the Sahel and parts of the Sahara (Jalloh *et al.*, 2013). West Africa is especially vulnerable to climate change and variability on account of its socio-economic and physical characteristics, which render it disproportionately susceptible to adverse effects arising from climatic variations (Baptista *et al.*, 2013). There is a significant risk that the adaptive capacity of many African forest ecosystems that provide vital goods and services will be exceeded. Climate change is also likely to threaten food security, as sudden changes of temperature are likely to increase rates of desertification, which will be exacerbated by changing migration patterns and the overuse of agricultural land. By the early 1980s, Niger's rural population had suffered a decade of drought that had killed more than 100,000 people across the Sahel, and made hundreds of thousands dependent on food aid (Anderson *et al.*, 2013). It was feared that this "desertification" trend would continue southwards into the grasslands and wooded savannahs of WA.

Climate change has already affected many aspects of forest ecosystems in WA, including tree growth and dieback, the distribution of species, seasonal patterns in ecosystem processes, and the population dynamics of forest species (Baptista *et al.*, 2013). In some cases it has been implicated in the extinction of forest species. In Burkina Faso for example, the local extinction of several species valued for their non-wood forest products (e.g. *Adansonia digitata*, *Diospyros mespiliformis* and *Anogeissus leiocarpa*) has been attributed to a combination of recent recurrent drought and the unsustainable harvesting of these species. In Ghana and other West African countries, the tree species *Khaya senegalensis* is in decline. An increase in disease associated with climate change is likely to increase pressure on this species because of the over-harvesting of its bark, which is used as a cure for several ailments.

Climate change is projected to alter fire regimes in forest and savannah-woodlands, with the incidence of fire likely to increase in the Sahel belt (Baptista *et al.*, 2013). Elevated $CO_2$ levels can affect tree growth through increased photosynthetic rates and improved water-use efficiency. Some dynamic vegetation models indicate vegetation shifts attributable to factors associated with climatic and atmospheric changes, particularly $CO_2$ fertilization and the increased abundance of C3-vegetation over C4-vegetation at elevated $CO_2$ levels (Scheiter and P., 2015). This 'fertilizer effect' may encourage the spread of forest at the expense of grasslands because it will enable trees to recover from fire more quickly and to reach fireproof levels more rapidly. When considering climate change alone, the results of a recent predictive vegetation modelling exercise suggest biome shifts toward a greening trend in West Africa by 2050, with increasing tree cover in inland areas of Benin, Burkina Faso, Côte d'Ivoire, Ghana, and Togo. However, when human impacts are incorporated, the models used in this study suggest future forest degradation and potential desertification (Heubes *et al.*, 2011). Increasing temperature and decreasing precipitation were found to have resulted in a significant decline in tree density from 1954 to 2002 in the western Sahel at two sites in Senegal as well as a significant decline in tree species in the Sahel (Mauritania, Mali, Burkina Faso, Niger, and Chad) from 1960 to 2000 (Gonzalez *et al.*, 2012).

## 2.2. Modelling of the expected impacts / what models do not agree on

The analysis of climate patterns reveals that there are still major gaps in knowledge about the impacts of climate change on forests and people in Africa and about how adaptation measures can best be tailored to local conditions. Specifically, there are some uncertainties in understanding future climate changes and their impact on key development sectors such as agriculture, food security, and forests, as the impacts vary widely over space and time (Müller *et al.*, 2014). The development of a General Circulation Model (GCM) representation of the West African monsoon remains a challenge for climate modelling groups; existing models do not reliably reproduce the main features of the current climate in West Africa and their results for this region are often contradictory (Biasutti *et al.*, 2008; Biasutti and Sobel, 2009). Therefore, there is still considerable uncertainty concerning the climate change scenarios confronting the WA region (ECOWAS-SWAC/OECD, 2008). The complicated and uncertain measurement of the climate's future impacts on the region thus necessitates a degree of caution when analysing models' predictions. In addition, there is still disagreement about West African vegetation dynamics (AMCEN, 2011). Local studies in West Africa have revealed a 'drying out' that has caused plant species and vegetation zones to shift southwards (Heubes *et al.*, 2011). In contrast, no southern spread of the Sahara was observed for the 1980-1997 period in a study based on long-term satellite data. Some findings suggest a trend of increasing vegetative greenness (NDVI index) in certain parts of West Africa (Ezeife, 2014), including 5 million hectares from the Zinder and Maradi regions of Niger. Because of farmer-managed natural regeneration and increased rainfall, both of these areas had more tree cover in 2005 than 20 years earlier despite their population growth (Reij *et al.*, 2009). The contrast between localized increases in greenness and a general decrease in greenness may be due to the small-scale spatial heterogeneity of different trends (Giannini *et al.*, 2008).

### 2.3. What behaviours and actions can mitigate against uncertainties?

Despite their uncertainties, modelling studies have provided useful insights that should be accounted for when drawing-up climate-smart development strategies. In particular, strategies should be adopted that allow plans to be adapted in response to unforeseen changes and provide a range of sound options for increasing resilience. Likely, impacts of climate change such as a greater decline in rainfall within the Guinean coastal region and a more humid climate in the Sahel clearly necessitate the development of new coping strategies, even though it is not currently clear how intense these changes will be. Given that many rural communities are directly dependent on forest and trees on farmland for basic needs (food, fuel, fodder and fibber), climate change poses real threats to their livelihoods. Changes in phenology, threats to species biodiversity, and fauna and flora migration are all likely to have adverse effects on production systems, particularly given that crop failures and livestock deaths are already causing heavy economic losses in West Africa that undermine food security. Feeding a sub-region with one of the highest rates of population growth in the world will require a radical transformation of a largely underdeveloped agriculture over the coming decades. A major challenge is to increase the agricultural production of resource-poor farmers without exacerbating environmental problems while coping with climate change.

## 3. Progress observed, bottlenecks and next steps to facilitate adaptation and mitigation related to the sub-sector in the region

Farmers are probably the group facing the greatest threats from climate change in WA, but they could also play a major role in addressing it through effective climate-smart practices. Climate-smart agriculture technologies are capable of delivering multiple benefits – specifically food security and development benefits together with climate change adaptation and mitigation co-benefits. This section describes some key technical and scientific developments relating to climate-smart practices within the forestry and agroforestry sector as well as policy and institutional arrangements and financial mechanisms required for a smooth transition to production systems that can generate significant mitigation benefits by increasing carbon sinks and reducing emissions. It also highlights the main barriers to the adoption of climate-smart practices, and lays out a way forward for adaptation and mitigation in the forestry and agroforestry sector.

### 3.1. At the scientific and technical level

**Agroforestry:** There is a fair amount of scientific evidence that ecological and agricultural resilience to climate change is created by maintaining a diverse range of integrated production systems combining crops, livestock and trees (Scherr and McNeely, 2008; Sinare and Gordon, 2015). These farming systems known as agroforestry (or agro-silvo-pastoral) systems, have the potential to improve food security, reduce the magnitude of climate change, and increase resilience (Bayala *et al.*, 2012). According to the World Agroforestry Centre, "agroforestry is uniquely suited to address both the need for improved food security and increased resources for energy, as well as the need to sustainably manage agricultural landscapes for the critical ecosystem services they provide". Research in this area has focused on four main themes: (1) developing the concepts and principles of agroforestry, (2) development of databases relevant to agroforestry, (3) development of agroforestry methodologies, and (4) development and performance evaluation of prototype technologies. Some agroforestry technologies that have been widely tested in West Africa are: • Alley cropping, i.e. growing annual crops between rows of trees; • Boundary plantings/living fences, in which trees are planted along boundaries or property lines; • Multi-strata agriculture, which is based on home gardens and agroforests that combine multiple species; • Scattered farm trees, i.e. the inclusion of trees, shrubs or shaded perennial crops such as coffee and cocoa scattered among crops or pastures and along farm boundaries; and perhaps most importantly, • Farmer Managed Natural Regeneration (FMNR), which may have contributed not only to a remarkable rise in vegetation greenness or "re-greening" on a large scale (Herrmann *et al.*, 2005), but also to improvements in agricultural and environmental conditions (Reij *et al.*, 2009). It is a promising climate-smart agricultural method that provides an inexpensive means of enhancing rural livelihoods (Weston *et al.*, 2014) and may contribute to climate change mitigation by sequestering large amounts of carbon in tree biomass and soil in addition to conserving biodiversity. Much of the new understanding of CSA has come from various research partners and development agencies, which have built up a body of research on issues such as the use of particular tree varieties and how they can improve soil quality, complement specific field crops, and generate new income streams for smallholders.

Past and present research on agroforestry production systems has focused on improving the systems themselves, primarily in terms of adaptability; social and cultural acceptance; the incorporation of local knowledge, practices, and capacities; equity and gender issues; characterization of crops with respect to minimum space requirements, water and fertilizer needs, and shade tolerance; selection of trees and shrubs; and evaluation of generated ecosystem services. Further research is needed to address various issues in the ECOWAS region and to enable the exploitation of opportunities arising from the integration of trees in croplands. Issues on which new studies are required include:

1. Biophysical tree-crop and tree-crop-livestock interactions, and their effects on the technical performance of agroforestry systems. Key variables and phenomena to examine will include soil and water properties, carbon sequestration, illumination, temperature, and microclimate buffering. In addition, it will be necessary to study the establishment and management of systems, with particular emphasis on (i) identifying tree/crop germplasm (including local species, shade tolerant species, fodder species, fruit trees, and medicinal plants) that is ecologically adapted to the target environment and can thus enhance agro-ecosystem resilience for enhanced agro-ecosystem resilience, and (ii) determining how trees and crops share above- and below-ground resources in a changing climate context.

2. Social innovation in institutions, governance and markets, including the policy environment, particularly relating to tree and land tenure. Important objectives are (i) identifying ways to improve the legal framework so as to clarify the status of trees in the field and empower farmers to manage them, (ii) finding ways to involve all key stakeholders in the development and management of agroforestry systems, (Iii) determining how best to recognize the value of local innovations and indigenous knowledge that can contribute to the development of tree-crop integration, and (iv) investigating what can be done to ensure secure land tenure for individuals and communities, mainstream and integrate policy and institutional support for agroforestry, and enhance women's participation in household and community decision making.

3. Livelihoods and the economic performance of agroforestry, including how it can support food and nutrition security while simultaneously providing important ecosystem services.

4. Scaling up best practices in agroforestry and harnessing opportunities arising from partnership and digital technologies.

Key barriers to the practice of agroforestry are:

- poor access to agroforestry inputs and resources including water, seeds and germplasm, and credit;
- lack of land tenure and tree tenure that does not provide a long-term guarantee of benefit from up-front investments;
- agroforestry production or management issues relating to a lack of knowledge about agroforestry systems, quality control, storage, processing of products, access to technical outreach services, and up-front costs versus long-term gain;
- the main benefits of agroforestry are perceived in the medium term at least five to ten years after establishment; this means that farmers must be prepared to invest in their establishment and management for several years before the main benefits are generated;
- marketing of agroforestry products and services: lack of access to transport, handling, processing, and marketing infrastructure, bans/restrictions on timber products, over-production, and lack of demand for products.

**Forestry:** forested areas in West Africa are home to enormous species diversity including thousands of tree and shrub species that are valuable sources of medicinally relevant compounds, gums and resins, spices and condiments, dyes and tanning materials, edible vegetables, fruits, stimulants and fodder. In addition, many of these plant species are capable of increasing soil fertility through nitrogen fixation. Products from forest and woodland resources are likewise known to provide local communities with needed resources and incomes, especially during droughts and other climatic disasters. Improving tree-based systems can thus simultaneously contribute towards the major UN environmental conventions, the Framework Convention on Climate Change (UNFCCC), the Convention to Combat Desertification (UNCCD), and the Convention on Biological Diversity (CBD). Current usage is almost entirely extractive with minimal management of these huge resources for sustainable production and utilization.

Research efforts in the WA region have mainly concentrated on descriptive studies in natural forest ecosystems and plantation silviculture with exotic species (Evans and Turnball, 2004). Consequently, some important knowledge gaps remain. First of all, there is a need for accurate baseline information in the form of national forest inventories for the region. These inventories would provide a basic framework for planning, implementing and monitoring forest management and conservation activities. Also lacking are effective methods for devolving forest management responsibility to local communities and the private sector while safeguarding access to and use of forest resources. Moreover, a systematic research effort is needed to improve understanding of the dynamics of the natural forest and woodland as well as their responses to common disturbances (fire, grazing, logging) and climate change. Finally, it is necessary to identify silvicultural approaches that might appeal to smallholders and farmers such as reforestation and restoration techniques that use indigenous species, and systems of payment for ecosystem services.

## 3.2. At the policy and institutional level

To meet the multiple challenges posed by climate change to the forestry and agroforestry sector, there is an urgent need for better alignment of policy approaches across agricultural, environmental and financial boundaries at the regional level, and innovative institutional arrangements to support the transition to climate-smart technologies and practices. To date, within the ECOWAS zone, some progress has been made towards establishing the needed international coordination and cooperation.

An enabling policy environment: significant efforts have been made to increase coherence in national policy-making and to establish coordinated international policies. At the national level, almost all states from the ECOWAS zone have drawn up climate change policies that are embodied in National Adaptation Plans (NAPs) and Nationally Appropriate Mitigation Actions (NAMAs) as well as national or regional climate change strategies. Agricultural development and food security plans are expressed in National Agriculture Investment Plans (NAIPs) and Poverty Reduction Strategy Papers (PRSPs). Particularly for the forestry sector, ECOWAS has begun the process of implementing the Convergence Plan for the Sustainable Management and Utilization of the Forest Ecosystems in West Africa. The plan was adopted during a Meeting of Ministers responsible for Forestry and the Environment held on 9-12 September 2013. The plan's potential in terms of agroforestry is well documented, although structural challenges remain. Issues of land and tree tenure, for instance, continue to discourage smallholder investment in trees, particularly in rural areas. There is also great concern about conservation and environmental issues. Most West African countries are moving towards the implementation of agrarian reforms to ensure that farmers integrate trees into land-use systems.

**Institutions and governance**: to ensure an efficient and coherent policy approach to forests and climate change, national policy-makers are integrating climate change strategies and plans with national forest policy frameworks and other sectors that affect forests. Equally importantly, forest-based adaptation and mitigation priorities are being reflected in national climate change strategies. Several countries have identified the need for legal reform to implement national strategies on REDD+, and a move is underway to strengthen forestry institutions' structures, operations and capacities. Other major processes with implications for the management and governance of forests, such as those related to forest law enforcement, governance and trade, should also be taken into account.

The emergence of REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries): the debate on climate change has clearly identified the forestry sector as having an essential role in mitigation. REDD is opening up new possibilities for the forestry sector and the environment. The challenges and opportunities arising from climate change, and the increased value placed on carbon, are creating a new paradigm in which the rural poor can play an important role in the regional development of West Africa, and where communities and nations that align their agricultural and forestry goals can reap great rewards. The sustainable management of agroforestry systems (including tree crop systems) and forests is vital to the success of community mitigation efforts since the loss of tree cover is a major contributor to GHG emissions in the sub-region. Fortunately, both governments and regional organizations are showing increasing interest in and demand for learning and development in this area (Mbow *et al.*, 2012). Consequently, a growing number of initiatives have been launched with the aim of meeting the REDD criteria, including National Adaptation Plans (NAPs), sustainable agriculture land management initiatives, plantation and re-greening initiatives (e.g. the Great Green Wall) and sustainable wood energy systems that are more carbon neutral. A broad-based landscape-level carbon enrichment strategy will also increase the availability of biomass for energy, reducing pressure on forests that are critical for environmental services while also enriching soils so they become more productive and can support greater agricultural production and incomes. The main technical barriers to the implementation of REDD (Mbow *et al.*, 2012) in West Africa are the lack of appropriate emissions accounting, transfer incentives, and the lack of an effective system for monitoring, reporting and verifying actions, particularly in relation to deforestation, degradation and carbon stocks.

Despite the establishment of some policy and institutional frameworks and strategies for the forestry and agroforestry sector through national and international channels in the West African sub-region, the implementation of climate-smart smallholder farming system transformations is hindered by many barriers including:

***Lack of technical and institutional capacities:*** many states or local governments and their agencies in the sub-region are understaffed or over-burdened, especially with respect to technical staff. Most state governments do not have adequate financial and human resources to implement climate change adaptation programs in the forestry sector.

***Dysfunctional institutional structures:*** tedious and complicated bureaucratic processes in some state agencies are known to hamper proper implementation of climate-smart smallholder agricultural transformations. For instance, in most countries, the land tenure system does not allow for proper land use planning and integration of forestry activities (plantation and natural regeneration) due to the persistence of conflicting traditional and modern land rights. Also, there is still a need to improve the quality of forest governance to ensure the success of forest-based climate change adaptation and mitigation. For instance, systems for forest governance assessment and monitoring need to be tailored for each country, taking into account a range of other forest-related governance issues including forest law enforcement.

## 3.3. At the financial level

Climate change creates new financing requirements to support vital investments, which will require innovative institutional solutions. A recent review of forest financing in Africa (Gondo, 2010) indicated that domestic public financing is the major source of financing for forestry activities in most parts of the continent including the ECOWAS region. Domestic public funding generally comes from government budgetary allocations to official forestry institutions/bodies and revenues generated from state-owned forests, but some is derived through investments made by the domestic private sector, commercial banks and microfinance institutions. The most common sources of revenue include user fees/harvesting or use licenses, taxes, fines, confiscation and damages for infringements of the law, and direct sale of plants, plant material and other forest products.

The second source of forest finance flows through two main channels: public Official Development Assistance (ODA) and private Foreign Direct Investments (FDI). The public Global Environment Facility (GEF) finances “new and additional grant and concessional funding to meet the agreed incremental costs of measures to achieve agreed global environmental benefits”. The GEF is the only multi-convention financing facility in existence and is now the major source of funding specifically supporting the Convention on Biological Diversity (CBD) and the UNFCCC. Further, the GEF also provides support for the implementation of the UN Convention to Combat Desertification (UNCCD). The African Development Bank (AfDB) forestry portfolio currently stands at around USD 352 million. The ECOWAS Forestry programme is increasing its financial resource mobilization through stronger partnerships with AfDB. The International Timber Trading Organization (ITTO) is also contributing to forestry ODA, with Ghana as its major recipient of funds in the ECOWAS region. Other contributors include the National Forest Programme (NFP) Facility, which is housed in FAO; the Africa Sustainable Forestry Fund (ASFF), which also focuses on Ghana; and the Forest Investment Programme (FIP). While the latter has not yet disbursed any funds, the FIP sub-committee has approved programs in eight countries worldwide, including two from the ECOWAS region (Burkina Faso and Ghana). In countries like Mali, the Green Climate Fund is also currently being put in place to promote the green economy.

Despite the diversity of contributors, sustainable forest management in the ECOWAS region requires substantially increased financial resources to overcome the level of degradation. Some key issues and gaps include the low profile and priority of forestry sector (budgets at the state level are generally meagre); inefficient revenue collection systems; forest revenue leakage; weak law enforcement resulting in high incidences of illegal activity and low revenue collection; limited access to finance and credit lines for the private sector; limited financial support to smallholders and community forestry efforts; and a failure to adequately capture NTFPs' contribution to forest revenues. To date, the uptake of agroforestry has been supported by public Official Development Assistance (ODA) and Foreign Direct Investments (FDI) through NGOs. There is also some private sector investment into agroforestry management practices, focusing on the reintroduction of shade trees to cocoa plantations to enhance biophysical conditions in the fields while enhancing biodiversity and enabling product diversification for smallholder producers (Obiri *et al.*, 2007).

Great opportunities exist but there is a need to strengthen the institutional and financial support available to enable smallholders to exploit them. More specifically, there is:

- a growing demand for forestry products (especially construction materials) in the region. This provides a strong ready market for forestry products;
- growing domestic and international markets for non-timber forest products, which provide markets and investment opportunities, especially in low forest cover countries;
- carbon finance – there is a growing range of financing mechanisms that the region could take advantage of, provided that issues of capacity are addressed and an enabling investment climate is created.

## 3.4. Next steps

To enable effective climate-smart practices within the West African forestry and agroforestry sector, the following issues must be addressed in the region:

- Enhancement of property rights, including tree and land tenure: this should be the starting point for promoting investment in the forestry and agroforestry sector.
- Forest policy and legislative reform: in many African countries, the existing policy environment encourages inappropriate forest use by undervaluing and underpricing forest resources. Therefore there is a need for promulgation and enforcement of existing laws with respect to forest exploitation and environmental protection.
- Governance: the mandates of African governments should be to improve governance, with an emphasis on transparency and accountability, the rule of law, and improved financial management and budgetary process. More rights and responsibilities should be given to farmers, local communities, and the private sector, as appropriate.
- Involvement of farmers and communities in forestry activities through policy and legal change: training in participatory planning will also enable forestry agencies to develop partnerships for forest management and reforestation with local communities and NGOs. In addition, governments should facilitate dialogue among various stakeholders to facilitate sustainable forest management by local people and help resolve local conflicts.
- Enhancement of private sector involvement in planning and policy making in the forestry and agroforestry industries.
- Improvement and dissemination of forest-related knowledge and technology: more research should be conducted on best silvicultural practices and strategies to improve export markets, with closer cooperation between researchers and the potential users of their results. Also lessons learned from pilot field activities need to be disseminated more widely.

- Institutional changes and empowerment: reform policy and regulatory responsibilities for public sector institutions; community participation in forest resource management, more involvement of the private sector, especially in plantation management; involvement of civil society, improve transparency and accountability in forest activities; decentralization of administration; capacity building in resource management at the local level.

# 4. Messages and recommendations for the sub-sectors

## 4.1. Regarding ECOWAS framework on CSA

In view of the foregoing, ECOWAS, as well as relevant regional organizations that have a stake in the development of the region, particularly with regard to agricultural development related to climate change adaptation in the region, need to consider the following suggestions:

- Pursue efforts in economic integration, particularly the adoption of a common currency and harmonization of the multiple trade policies of member states to encourage trade of agroforestry and tree products within the region. Effective implementation of the revised ECOWAS Agricultural Policy will be a step in the right direction.
- Pursue efforts in deepening inter- and multi-sectoral approaches to forestry and agroforestry research and development. For instance, provision of a platform for scientists and practitioners to access accurate baseline data on forest resource in the respective countries, better understand and design effective agroforestry strategies, programs and activities for up-scaling success stories such as forest protection and regeneration, Farmer Managed Natural Regeneration in additional countries.
- Ensure long-term sustainability of efforts to scale up and out agroforestry as a science and a practice in integrated natural resource management through a knowledge-to-action framework. This could be done though communication and dissemination for uptake of best practices with regards to tree and forest management.
- Work to establish an updated forest database by developing a common inventories protocol that will provide harmonized information on the current state of forest ecosystems and their biological resources, as well as trends in deforestation. Monitoring systems should be established to provide regular updates for ongoing forest resource assessment.
- Increase education provision: this is a crucial aspect of forestry and agroforestry development in the region. The professional and technical capabilities to support forestry and agroforestry development are in short supply, so a large expansion of forestry training in terms of both numbers of students and quality of education will be essential for future forestry and agroforestry development. Priorities requiring local, regional and international attention include supporting a better planned regime of capacity development and mobilization in forestry; re-orienting forestry education in the context of new regional and global realities; a higher level of responsiveness to changing business, landscape and environmental needs, with particular emphasis on cross-sectoral needs; retooling educators and forestry schools with contextually relevant learning resources, with a special focus on technician training; coupling research with academic programs, and stimulating regional and international collaboration and exchange.
- Promote policy and institutional changes at different scales (global to local) as appropriate to embrace the agroforestry and forestry sectors.
- Facilitate cross-site and cross-regional analyses, syntheses and exchange of knowledge.

- Work on harmonization of forestry policies and legislation, facilitate the decentralized management of forest resources and improved governance approaches while involving women and youth.
- Facilitate access to existing opportunities related to adaptation, mitigation and vulnerability to climate change.
- Ensure better knowledge of current forest ecosystem dynamics to create a baseline for future action.
- Provide guidance, harmonized approaches, and decision-support tools to address desertification and soil degradation through rehabilitation of fragile and degraded ecosystems (mangrove, humid and arid zones), control of bush fires, and the anarchical exploitation of shared and transboundary pastoral resources.
- Support forestry research and development.

### 4.2. Regarding the Alliance for the convergence and coordination of initiatives on CSA in West Africa

- The Alliance should focus on the following priority intervention areas:
  - policy harmonization and analysis
  - knowledge of the dynamics of forest ecosystems
  - management of forest ecosystems and reforestation
  - preservation of biodiversity
  - promotion of the socioeconomic benefits of forest ecosystems, to increase capacity development in institutions and among local communities in support of full sustainable use of resources
  - forest research
  - Information, education and communication, including encouraging local communities to take responsibility for forestry resources.
- The Alliance should prioritize the public and private investments needed to meet different objectives relating to conservation and industrial needs while ensuring that there is synergy in their objectives. There is a need for product and market diversification: local demand for NWFPs from plantations is often limited, so there is a need to diversify markets and target niche export markets in order to access a volume of demand that is sufficient to make the enterprise economically sustainable. Also, more effort should be put into the transformation of raw products locally before exportation.

## Conclusion

In most regions of West Africa, livelihoods depend heavily on forest ecosystems and tree resources. However, numerous drivers of change are creating a range of fundamental economic, ecological, social and political challenges for their governance. Climate change and its impacts on countries and the entire sub-region add a new dimension to an already challenging situation. Although great progress has been made in the study and implementation of climate-smart practices, forested landscapes and trees outside forests are undergoing rapid transformations presenting numerous challenges that must be addressed. Key problems that must be overcome in this process include a lack of expertise and knowledge gaps. In addition, the contribution of forests to wealth creation and the wider economy of the countries in the sub-region is currently relatively small, poorly accounted for, and generally under-valued. Other important problems include dwindling human and financial resources; the limited extent to which the agenda of international forestry forums has been exploited; failures to consistently enforce legislation, apply control processes, and rigorously assess the impacts of major works (e.g. road or dam construction) on forest ecosystems; and land tenure systems that provide little or no security to small farmers. Governance systems must establish a framework for formulating, financing and implementing adaptation strategies at multiple levels, often in a context of ongoing institutional changes such as decentralization. Forest policies need to be better coordinated, international and regional agreements on forest conservation and use must be better implemented, and the impacts of interventions in forest environments should be better assessed. A regional framework for collaboration on climate-smart agriculture that will deal with the forest and agroforestry sector issues needs to be put in place to catalyse movement towards lasting solutions.

## References

Agrawal, A., Cashore, B., Hardin, R., Shepherd, G., Benson, C., Miller, D., 2013. Background Paper 1: Economic contributions of forests. Background paper prepared for the United Nations Forum on Forests. 132 p.

AMCEN, 2011. Addressing Climate Change Challenges in Africa; A Practical Guide Towards Sustainable Development.

Anderson, J., Colby, M., McGaheuey, M., Mehta, S., 2013. Nature, Wealth, and Power 2.0: Leveraging Natural and Sociall Capital for Resilient Development. Annex 3.2, Landscape level improvements in the Sahel, USAID pp. 103-112.

Baptista, S., Brottem, L., de Sherbinin, A., Edquist, M., Fischer, A., Levy, M., Schnarr, E., Simon, C., Sundareshwar, P.V., Trzaska, S., 2013. Background paper for the ARCC west Africa regional climate change vulnerability assessment. USAID African and Latin American Resilience to Climate Change (ARCC).

Bayala, J., Sileshi, G.W., Coe, R., Kalinganire, A., Tchoundjeu, Z., Sinclair, F., Garrity, D., 2012. Cereal yield response to conservation agriculture practices in drylands of West Africa: a quantitative synthesis. Journal of Arid Environment 78: 13-25.

Calabrese, J.M., Vazquez, F., Lopez, C., San Miguel, M., Grimm, V., 2010. The Independent and Interactive Effects of Tree-Tree Establishment Competition and Fire on Savanna Structure and Dynamics. American Naturalist 175, E44-E65.

Chamshama, S.A.O., Savadogo, P., Marunda, C., 2010. Chapter 9: Plantations and woodlots in dry forests regions of Africa. In: Chidumayo, E. & Gumbo D. A. (Editors). The dry forests and woodlands of Africa: Managing for products and services. The Earthscan Forestry Library. pp 205-230.

ECOWAS-SWAC/OECD, 2008. Atlas on regional integration in West Africa. Environment series: Climate and climate change. www.atlas-westafrica.org

Evans, J., Turnball, J.W., 2004. Plantation forestry in the tropics. The role, silviculture and use of planted forests for industrial, social, environmental  and agroforestry purposes (third edition), Oxford University Press, Oxford.

Ezeife, N.D., 2014. Projected Impact of Global Warming on West Africa: Case for Regional and Transnational Adaptive Measures. Annual survey of International and comparative law. Vol. 20, issue 1. Article 9.

FAO, 2010. State of the World's Forests 2010. Food and Agriculture Organization of the United Nations, Rome. ftp://ftp.fao.org/docrep/fao/007/y5574e/y5574e00.pdf.

Giannini, A., Biasutti, M., Verstraete, M.M., 2008. A climate model-based review of drought in the Sahel: Desertification, the re-greening and climate change. Global and Planetary Change 64, 119–128.

Gondo, P.C., 2010. A review of forest financing in Africa. A study prepared for the United Nations Forum on Forests (UNFF).

Gonzalez, P., Tucker, C.J., Sy, H., 2012. Tree density and species decline in the African Sahel attributable to climate. Journal of Arid Environments, 78, 55–64.

Herrmann, M.S., Anyamba, A., Tucker, C.J., 2005. Recent trends in vegetation dynamics in the African Sahel and their relationship to climate, Global Environmental Change 15: 394–404.

Heubes, J., Kühn, I., König, K., Wittig, R., Zizka, G., Hahn, K., 2011. Modelling biome shifts and tree cover change for 2050 in West Africa. Journal of Biogeography 38, 2248–2258.

ITTO, 2011. Tropical Timber Market Report. Volume 16 Number 4, 16th – 28th February 2011.

IUCN, 2005. Forest Landscape Restoration Broadening the Vision of West African Forests. IUCN Forest Conservation Programme. IUCN, Gland, Switzerland and Cambridge, UK.

Jalloh, A., Nelson, G.C., Thomas, T.S., Zougmoré, R., Roy-Macauley, H. (Eds.), 2013. West African agriculture and climate change: a comprehensive analysis. IFPRI books and research monographs, ISBN 978-0-89629-204-8; DOI: http://dx.doi.org/10.2499/9780896292048, 408p.

Jalloh, A., Roy-Macauley, H., Sereme, P., 2012. Major agro-ecosystems of West and Central Africa: Brief description, species richness, management, environmental limitations and concerns. Agriculture, Ecosystems and Environment 157, 5– 16.

Laestadius, L., Maginnis, S., Minnemeyer, S., Potapov, P., Saint-Laurent, C., Sizer, N., 2011. Carte des opportunités de restauration du paysage forestier. Unasylva 62 (2) : 47- 48.

Mbow, C., Skole, D., Dieng, M., Justice, C., Kwesha, D., Mane, L., Eel Gamri, M., von Vordzogbe, V., Virji, H., 2012. Challenges and prospects for REDD+ in Africa: Desk review of REDD+ implementation in Africa. GLP Report No 5, GLP-IPO, Copenhagen

Müller, C., Waha, K., Bondeau, A., Heinke, J., 2014. Hotspots of climate change impacts in sub-Saharan Africa and implications for adaptation and development. Global Change Biology, 2014; DOI: 10.1111/gcb.12586.

Obiri, B.D., Bright, G.A., McDonald, M.A., Anglaaere, L.C.N., Cobbina, J., 2007. Financial analysis of shaded cocoa in Ghana. Agroforest Systems 71:139–149.

Reij, C., Tappan, G., Smale, M., 2009. Agroenvironmental Transformation in the Sahel: Another Kind of "Green Revolution." Discussion Paper 00914 (November), International Food Policy Research Institute, Washington DC.

Scheiter, S., P., S., 2015. Ecosystem management can mitigate vegetation shifts induced by climate change in West Africa. Global Ecology and Biogeography, in press.

Scherr, S.J., McNeely, J.A., 2008. Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. Philosophical Transaction of the Royal Society 363, 477–494.

Sebukeera, C., Muramira, E., Momokama, C., Elkholei, A., Elbagouri, I., Masumbuko, B., Rabesahala, V., 2006. Chapter 6 forests and woodlands. In Africa Environment Outlook 2: Our Environment, Our Wealth. United Nations Environment Programme Pp 196-222. ISBN: 92-807-2691-9.

Sinare, H., Gordon, L.J., 2015. Ecosystem services from woody vegetation on agricultural lands in Sudano-Sahelian West Africa. Agriculture, Ecosystems and Environment 200 (2015) 186–199.

Weston, P., Hong, R., Kaboré, C., Kull, A.C., 2014. Farmer-Managed Natural Regeneration Enhances Rural Livelihoods in Dryland West Africa. Environmental Management. DOI: 10.1007/s00267-015-0469-1.

Whiteman, A., Lebedys, A., 2006. The Contribution of the Forestry Sector to African Economies. International Forestry Review, 8(1):31-43.

# Conclusion

Achieving sustainable food security in a world of growing population and changing diets is a major challenge under climate change. In West Africa, climate change will have far-reaching consequences for agriculture that will disproportionately affect poor and marginalized groups who depend on agriculture for their livelihoods and have a lower capacity to adapt. Climate-related crop failures, fishery collapses and livestock deaths already cause economic losses and undermine food security, and these are likely to become more severe as global warming continues.

The Economic Community of West African States (ECOWAS) has engaged a process to integrate climate-smart agriculture (CSA) into the Regional Agricultural Investment Plan and the member countries' National Agricultural Investment Plans. CSA is an approach to achieve short and long term agricultural development priorities in the face of climate change and it serves as an integrator to other development priorities. It seeks to support countries and other actors in securing the necessary policy, technical and financial conditions to enable them to sustainably increase productivity, enhances resilience, reduces/removes greenhouse gas emissions, and enhances the achievement of national food security and development goals.

Decisions makers, researchers and practitioners will find in this book, relevant information on the scientific, political and financial landscape of CSA for crop production, livestock, fisheries, water resources and forestry/agroforestry sectors in West Africa. It analysed the current status, climate projections and likely expected socio-economic and environmental impacts, and identified the bottlenecks to action for climate change adaptation and mitigation.  These information are vital for shaping regional and national policies that will allow the rapid scaling of climate-smart agriculture across the sub-region.

RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

CGIAR CCAFS

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic initiative of the Consultative Group on International Agricultural Research (CGIAR) and Future Earth, led by the International Center for Tropical Agriculture (CIAT). CCAFS is the world's most comprehensive global research program to examine and address the critical interactions between climate change, agriculture and food security.

**For more information, visit www.ccafs.cgiar.org**

Titles in this Working Papers series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

CCAFS is led by: CIAT

Strategic partner: futurearth

Research supported by:

Fund CGIAR, Australian Government Australian Centre for International Agricultural Research, España, Irish Aid, European Commission, Ministry of Foreign Affairs of the Netherlands, IFAD, Swiss Agency for Development and Cooperation SDC, Government of Canada / Gouvernement du Canada, IICT, UKaid, New Zealand Ministry of Foreign Affairs & Trade