CHAPTER 12: Socio-economic and gender related aspects of climate change in Africa

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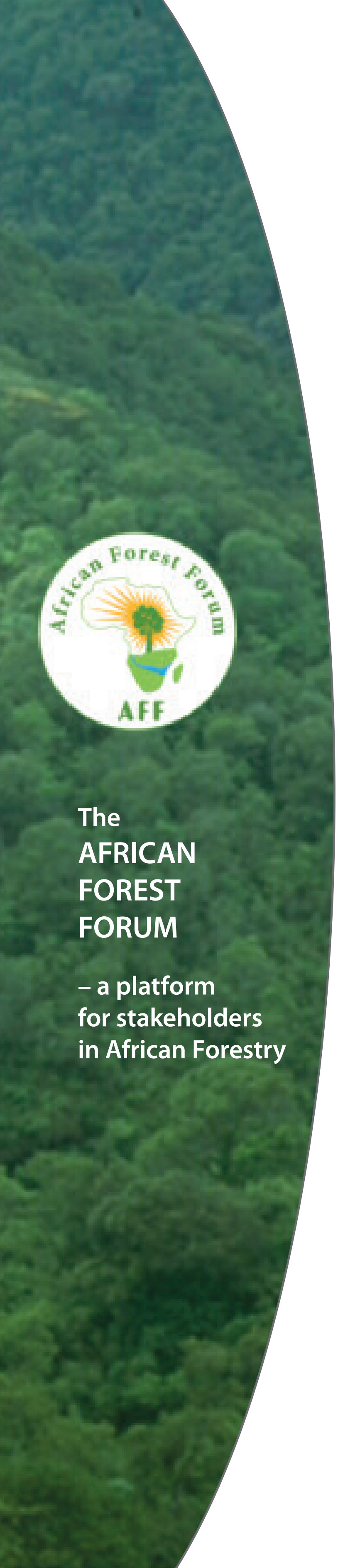
Balgis Osman-Elasha
African Development Bank Group



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CLIMATE CHANGE AND AFRICAN FOREST AND WILDLIFE RESOURCES

Emmanuel Chidumayo, David Okali,
Godwin Kowero, Mahamane Larwanou
Editors

African Forest Forum
P.O. Box 30677-00100, Nairobi, KENYA
Tel: +254 20 722 4203
Fax: +254 20 722 4001
www.afforum.org

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Editors

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The opinions expressed in this book are the sole responsibility of the authors and do not necessarily reflect those of Sida, FAO, KSLA and the African Forest Forum.

CONTRIBUTORS

Alfred Opere. Senior Lecturer, University of Nairobi,
P.O. Box 30197, G.P.O, Nairobi. Kenya.
Balgis Osman-Elasha. Climate Change Adaptation Expert, African Development Bank,
P.O.Box 323-1002, Tunis-Belvedere, Tunisia.
Brent Swallow. University of Alberta,
632 Central Academic Building, Edmonton, Alberta T6G 2G1, Canada
Daniel Olago. Senior Lecturer, University of Nairobi,
P.O. Box 30197, G.P.O, Nairobi. Kenya.
David Okali. Emeritus Professor, University of Ibadan,
Ibadan, Nigeria.
Emmanuel Chidumayo. Ecologist/Manager, Makeni Savanna Research Project,
P.O. Box 50323, Ridgeway, Zambia.
Godwin Kowero. Executive Secretary, African Forest Forum,
United Nations Avenue, P.O. Box 30677-00100, Nairobi, Kenya.
Jaffer Wakhayanga. Chairperson, Kenya Alliance for Rural Empowerment,
P.O. Box 3394, Kisumu, Kenya.
Macarthy Oyebo. Chairperson, Governing Council of African Forest Forum,
No. 3 Daniel Arap Moi Close, Off Maitama Sule Street, Asokoro, Abuja, Nigeria.
Mahamane Larwanou. Senior Program Officer, African Forest Forum,
United Nations Avenue, P.O. Box 30677-00100, Nairobi, Kenya.
Oluyede Ajayi. Senior Scientist, World Agroforestry Centre,
P.O. Box 30798, Lilongwe 3, Malawi.
Paul Donfack. Coordinator, Nature Information Tracks,
BP 31 205 Yaoundé, Cameroon.
Peter Minang. Global Coordinator ASB, World Agroforestry Centre,
United Nations Avenue, P.O. Box 30677-00100, Nairobi, Kenya.
Willy Makundi. Environmental Management Consultant,
P.O. Box 974, Moshi, Tanzania.
Yatich Thomas. Environment and Community Development, Social Affairs and Environment Section,
Delegation of the European Union to Kenya,
P.O. Box 45119-00100, Nairobi, Kenya.
Yonas Yemshaw. Senior Program Officer, African Forest Forum,
United Nations Avenue. P.O. Box 30677-00100, Nairobi, Kenya.

PREFACE

Climate and ecosystems are mutually impacting on each other and this has been recognized in various African eco-zones. And more recently climate change has become the topical issue in forestry and other circles. Climate change and forests are related in functional and structural ways. Carbon sequestration increases in growing forests, a process that positively influences the level of green house gases in the atmosphere, which, in turn, may reduce global warming. In other words, the forests, by regulating the carbon cycle, play vital roles in climatic change and variability. Climate, on the other hand, affects the function and structure of forests. Understanding this vital relation is critical in developing appropriate policies and technology options that can contain the adverse effects of climate change and variability.

In Africa, much as the forestry sector joined the debate on climate change fairly late, significant achievements for the sector have been made. These debates have succeeded in profiling the sector at all levels and also in mobilizing attention and resources for the sector to address the climate change important issues, and more specifically those related to reducing deforestation and degradation, enhancing carbon stocks, improving the protection of forests, and enhancing sustainable management of forest resources. All these are in line with the REDD+ approach that was adopted at the COP16 of the UNFCCC negotiations. Still another window for enhancing reforestation and afforestation activities of the sector arises through the CDM.

The great diversity of forest types and conditions in Africa is at the same time the strength and the weakness of the continent in devising optimal forest-based responses to climate change. Current and proposed mechanisms (CDM and REDD+, and possibly REDD++ or AFOLU in the future) will fare differently under different forest types and conditions. For example, high deforestation rates are likely to be associated with forests close to densely populated communities; forest regrowth from abandoned farmland will likely exhibit higher carbon dioxide sequestration rates than old forests in protected areas, while a subsistence practice of agro-forestry can readily facilitate the adoption of intensification as an adaptation measure. The forest types and conditions will have to be ascertained for each situation to provide the appropriate fit to either CDM or REDD+ arrangements.

Interventions that hold significant potential in terms of REDD+ in African forests include improvements in crop and livestock agriculture, enhancement of bio-energy efficiency, better wood and non-wood forest products harvesting and processing techniques, diversification of rural livelihood options, better planning and management of other land uses like communication infrastructure (like dams, roads, railways and power lines), large scale crop and forest plantations, and urbanization; all of which are land based. Emphasis should also be given to support existing initiatives or programmes. Existing national forest programmes (nfps) in many African countries and programmes/projects/activities that implement various international agreements, initiatives and conventions (like CBD, UNCCD, and UNFF-NLBI) all target the key components of REDD+. Support to these initiatives will considerably facilitate the attainment of the REDD+ objectives.

This book is therefore timely in that it highlights to all stakeholders, and in a systematic manner, the climate change issues relevant to the African forestry and wildlife sectors, with the view of increasing these sectors' contribution, at various levels and fora, to addressing the vagaries of climate change. The book also outlines the opportunities that climate change brings to the sectors.

Mr. Macarthy Oyebo
Chairman, Governing Council of the African Forest Forum

CLIMATE CHANGE AND AFRICAN FOREST AND WILDLIFE RESOURCES

INTRODUCTION

Chapter 1
CLIMATE CHANGE AND AFRICAN FORESTS AND TREE RESOURCES: THE STAKES ARE ENORMOUS

Godwin Kowero

1.1 The significance of African forests and trees

Africa has vast areas under forests and tree resources. More than anything else, these resources are at the centre of the socio-economic development and environmental protection of the continent. Life on the continent is largely shaped by these resources; their availability and quality. African forests and trees are renowned for their habitats for wildlife, beekeeping, unique natural ecosystems and genetic resources. They are catchment to many rivers and harbour many river basins that are cornerstones of economic development on the continent. The overwhelming majority of Africans obtain their energy needs from forests and trees, mostly as woodfuel. Furthermore, the natural forest resources are increasingly receiving global attention because of their share in biological diversity, potential for industrial timber exports, capacity for mitigating global climate change, livelihood 'safety nets', and as levers for rural development. African forests and trees also offer some unique opportunities for rural communities to adapt to the adverse effects of climatic change. In short, African forests and trees underpin key sectors of the economies of many African countries, providing the bulk of the energy needs, supporting crop and livestock agriculture, wildlife and tourism, water resources and livelihoods.

Of particular significance is agriculture, which is the mainstay of practically all African national economies. Forests and trees in Africa offer considerable support to agriculture. In fact much of the agricultural belt lies within the dry forest zone. The forests continue to serve as a reservoir of land onto which agriculture expands. Most of the agriculture in Africa is rain-fed and therefore very vulnerable to climate variability that is characterized by frequent droughts and occasional floods (a sign post for global climate change), which at times destroy crops and livestock. At such times the rural communities increase their reliance on the forests and trees for wild foods including fruits, tubers, fish and bush meat, edible insects, beeswax and honey, as well as traditional medicines.

In addition, the forests are central to maintaining the quality of the environment throughout the continent, while providing international public goods and services.

Climate change is argued to have the potential to adversely affect these resources in many countries. This will no doubt seriously disrupt the socio-economic fabric of the continent. Little is understood about these resources and how climate change will impact them; and this underlines the enormity of the problem of containing climate change in Africa.

Forests and woodlands cover an area of about 675 million hectares, or 23% of Africa's land area and about 17% of global forest area (FAO, 2011). Tropical moist forests in Central and parts of West Africa and woodlands in southern Africa are the dominant formations. Africa has extensive areas classified as 'other wooded land', with an area of 350 million hectares. The five countries with the largest forest area are the Democratic Republic of Congo, Sudan, Angola, Zambia and Mozambique; together they contain 55% of the forest area on the continent (*ibid*.). The proportion of the land area covered by forests in the various subregions is: Central Africa (43.6%), Southern Africa (31%), East Africa (20.8%), West Africa (14.3%) and North Africa (7.2%) (FAO 2003). Planted forest area is 14.8 million hectares, and this represents 5% of the global total (FAO, 2009).

The productivity of tropical rain and moist forests in Africa is high. Though the forests are largely under government ownership, very little forest management is practiced. The forests are mainly exploited, through concessions, mostly by the private sector, with minimal benefits going to the local communities that live by the forests. Dry forests, woodlands and savannas which sandwich the major agricultural belt are fairly open and have low productivity. They are, however, the dominant vegetation in 63% of the sub-Saharan African countries (Chidumayo, 2004) and are under immense human pressure for various needs. Major African towns and cities are found in their proximity, and they harbour many of the river basins in Africa. They are also home to much of the wildlife of Africa, supporting many important game reserves and parks. There is increasing effort to involve local communities in ownership and management of these forests and their wildlife (Kowero *et al*., 2006). Problems of African forests are complex and are very much related to the support of livelihoods of the many people who depend on them. Africa's population is projected to increase from 943 million in 2006 to 1.2 billion people by 2020, with the rural population expected to increase by 94 million people between 2005 and 2020 (FAO, 2009).

African forests and woodlands supply the bulk of the domestic energy needs, housing construction materials, wild foods and local medicines that serve the majority of the people on the continent. They ameliorate the climate and support local industries that produce wood and non-wood products. Goods and services from African forests contribute immensely to the quality and standard of living of the African people. They underpin the economies of many African countries, while enhancing the quality of the environment. Over 70% of the continent's population depends on forest resources for their survival (AfDB, 2003); yet, many African countries continue to give low priority to forestry in their planning. In 2005 agriculture accounted for about 70% of the rural employment (FAO, 2009).

Added to the above, significant tree based products obtained from trees on farms, especially in agroforestry and out-grower systems, and parklands, augment supplies from forests.

African forests and trees are seriously threatened by agricultural expansion, commercial harvesting, increased exploitation for fuelwood and other products and increasing urbanization and industrialization. All these are happening under conditions of inadequate land use planning, inappropriate land and tree tenure regimes, inappropriate agricultural systems, drought and, sometimes, armed conflicts. All these contribute to the high rates of deforestation and forest degradation in Africa.

1.2 Relationship between the forestry sector and other key national economic sectors

The interrelationships between food, agriculture, energy use and sources, natural resources (including forests and woodlands) and people in Africa, in addition to the macro-economic policies and political systems that define the environment in which they operate are extremely complex. Yet, understanding of these interrelationships is paramount in influencing the process, pace, magnitude and direction of development necessary for enhancing people's welfare and the environment in which they live.

The agricultural sector is the major contributor to the economies of many African countries, averaging 21%, and ranging from 10% to 70% of the gross domestic product (GDP) of the sub-Saharan countries (Mendelsohn *et al.*, 2000). However, agriculture is critically dependent on environmental resources such as land, water, forest and air. The use of any one of these resources can affect, directly or indirectly, the other natural resources, through dynamic and complex interrelationships existing in the natural systems. This implies that wrong use of land, water or forests in the production of crops and livestock can have far-reaching effects on environmental integrity. To avoid any adverse consequences, agricultural sector policies must fit in the overall environmental policy. This is critical in guiding proper and balanced use of natural resources and in defining sectoral responsibilities for environmental management. Agricultural policies, besides being internally consistent, must provide for a mechanism to link the sector with other sectors in protecting and enhancing the environment.

The agricultural sector, which is composed of livestock and crop components, hinges on the exploitation of land resources (soil and vegetation). In this context, it has direct and indirect influences on the indigenous forest resources in terms of their exploitation and conservation. The direct effects result from the competition for land between forests and agriculture, while the indirect effects result from the exploitation of the forest resources either for subsistence (food, energy, building material) and/or for income. Wanton deforestation and land degradation are a reflection of unsustainable land use emanating from poor policies on agriculture and poverty alleviation in most sub-Saharan African countries. Many studies have demonstrated the potential effects of agricultural policies on the forest condition.

To the extent that many in Africa rely on wood from forests and trees for domestic energy and home-building, energy and housing policies must be formulated to be in harmony with forest policy.

1.3 African forests and trees in climate change

There is growing evidence that climate change is impacting on forests and forest ecosystems in Africa, and therefore on the livelihoods of forest dependent communities as well as on national economic activities that depend on forest and tree products and services. Africa is one of the most vulnerable regions in the world to climate change. This vulnerability is expected to have considerable negative impacts on the agricultural sector and could render useless significant regions of marginal agricultural land. With basic farming technology and low incomes, many African farmers will have few options to adapt, much as they have in the past adapted to varying intensities of climate variability. This will inevitably increase the pace of reliance on natural resources for survival, and especially natural forests and trees. Vulnerability to climate change is thus a serious threat to poverty eradication programmes and the environment in Africa.

Globally, the climate change problem is manifesting through, amongst others, unusually high temperatures, floods, droughts, unreliable water supplies, enhanced migration of flora and fauna, melting glaciers and decreasing mountain snow caps. For example, the mosquito belt has considerably expanded to higher elevations due to the temperature incline. The frequency and intensity of forest fires has increased due to abundance of fuel and droughts. The scenario is that the interaction between climate change and national socio-economic policies will drastically reduce crop yields in the foreseeable future in most African countries. River flows and water stocks in reservoirs may decline considerably under a warmer climate while forest ecosystems are predicted to shift their ranges and lose some of their biodiversity with consequential impoverishment in the natural heritage of the countries and a decline in tourism. The impacts of climate change, whether biophysical, social or economic, are therefore a source of great concern to practically all African countries.

In the forestry sector, this concern has given rise to the urgent need to develop and implement national and regional forest-based strategies for responding to climate change on the continent. However, the existing knowledge base and capacity in Africa to respond to climate change through the forest sector is weak (Chidumayo, 2004).

Climate affects forests but forests also affect climate. It is important to understand adequately the dynamics of this interaction to be able to design and implement appropriate mitigation and adaptation strategies for the forest sector. This could also facilitate the management of forests to contribute to mitigation of climate change, for example through reduction in greenhouse gas (GHG) emissions, especially carbon dioxide, from avoided deforestation and enhancement of carbon sequestration. Africa has 14% of the world's population and a low level of industrial activity; thus, there are relatively few consumers of fossil fuels in the continent. Africa's emission of climate-change inducing GHGs is low, estimated at 3.5% of world's total (IPCC WGII Fourth Assessment Report, 2007), while the vast African forests are potentially a significant sink for carbon dioxide.

Currently little is known about the potential of African forests and trees to adapt to climate change. Models suggest that climate change will cause shifts in the ranges of many vegetation communities, but different species respond differently to climate factors. As such, understanding the responses to climate change of individual species, especially the dominant and ecosystem critical species, is of paramount importance to the development of forest-based adaptation strategies and measures, as well as to the assessment of the ability of forests and trees in Africa to mitigate climate change. Thus both climate response and mitigation by forests and trees need to be carefully assessed so that informed strategies and measures (taking on socio-economic, ecological, gender, tenure and rights aspects) can be put in place to promote the role of forests and trees in climate change programmes.

With respect to vulnerability and adaptation in Africa, there is insufficient knowledge on resilience of forests and trees to the impacts of climate change. However, agroforestry systems hold considerable potential for human and domestic animal adaptation to climate change. Such systems supplement food supplies and also serve as a buffer during periods of crop failure and droughts, among other roles.

The forestry sector is a late comer to the global climate change debate. This has led to there being no coherent African response to climate change from the forestry sector. Apart from determining the emission profile of different African forest conditions, consideration should also be given to smallholder agriculture, bio-energy plantations, pasture lands, parklands and other landscapes that hold potential for climate change mitigation and adaptation.

This book systematically presents climate change in the context of African forests, trees and wildlife resources. It is written for various audiences. Section 1 will be more appealing to those interested in the broader aspects of climate change and variability, while those interested in only climate change in African forests and trees will find Section 2 more appealing. Section 3 presents an overview of climate change on African wildlife resources. Socio-economic and policy considerations are part of Section 4, while Section 5 presents some key observations from all the sections. The lay reader will also find most of the text easy to follow.

1.4 Organization of the book

The book is organized into five sections. Section 1 presents climate change in the global and African context by looking at a few key areas, including the physical processes of climate change, a review on adaptation to and mitigation of climate change in the African forestry and wildlife sectors, and a review of the international debate on climate change and how Africa features in it.

Climate change in African forests is the subject of Section 2. This includes climate change issues related to moist forests, woodlands and savannas, and those specific to the Sahel. In addition institutional and governance arrangements that would be necessary for identified interventions in these eco-zones are discussed.

Section 3 presents an overview of climate change on African wildlife resources as found in moist forests, woodlands and savannas and the Sahel. Again institutional and governance arrangements that would be necessary for identified interventions in these eco-zones are discussed.

Socio-economic and policy considerations are presented in Section 4. They include aspects of community based adaptation to climate change, how climate change features in the socio-economic life of the African people, including specific issues related to gender, carbon trade and markets, policy and other approaches to climate change in African forests, trees, and wildlife resources. Section 5 summarizes some key observations from the various sections. This could be a good section for those who have no time to read the whole book or just want to have a quick overview of the issues in the book before delving into details in the various chapters.

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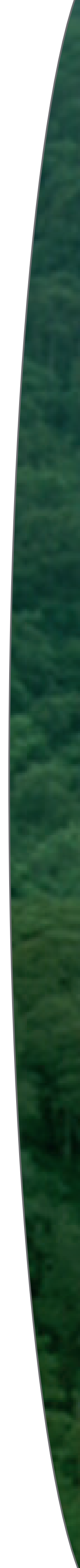
SECTION 1

CLIMATE CHANGE: GLOBAL AND AFRICAN CONTEXT



INTRODUCTION

This section examines the issues and the environment that is shaping climate change in forestry. Chapter 2 describes, albeit briefly, the processes that contribute to climate change, and discusses trends in climate change and its impacts in sub-Saharan Africa. This includes projections of future climatology that are based on IPCC models and scenarios. It also examines briefly perspectives from palaeoclimatic observations, theory and modeling. Further it describes impacts on natural resources and livelihoods in Africa, including impacts on water resources, biodiversity and agriculture.

Chapter 3 is about climate change adaptation and mitigation as it relates to forestry. It examines briefly the various types of adaptation that include anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation. It briefly looks at the National Adaptation Plans of Action (NAPAs), as well as the Nationally Appropriate Mitigation Actions (NAMAs), and other experiences related to forests. It also gives a brief account of forest mitigation related actions in Africa. The chapter ends with a brief on the status of climate change negotiations.

Chapter 4 describes how climate change talks and negotiations have evolved, the place of forestry in it, and African forestry perspectives and experiences in these negotiations.

Chapter 2
CLIMATE CHANGE PROCESSES AND IMPACTS

Alfred Opere, Daniel Olago, Emmanuel Chidumayo and Balgis Osman-Elasha

2.1 Introduction

Climate change is expressed as deviations from a regional climatology determined by analysis of long-term measurements, usually over a period of at least 30 years, or the normally experienced climate conditions and a different, but recurrent, set of climate conditions over a given region of the world (IPCC, 1998). Climate change may also refer to a shift in climate, occurring as a result of human activities (Wigley, 1999). Changing climate is expected to continue in the 21st century in response to the continued increasing trend in global green house gas (GHG) emissions (IPCC, 2007a), stimulating three main responses: technical and livelihood adaptations by affected communities, mitigation actions that sequester GHGs or reduce fossil fuels dependence, and formal international dialogue on the scope and correction of this now rapidly emerging threat to human existence. Climate change scenarios for Africa include higher temperatures across the continent estimated to be increasing by 0.2°C per decade (Elagib and Mansell, 2000) and more erratic precipitation with slight increase in ecozones of eastern Africa and moist forest ecozones of West Africa and sustainable declines in the productivity in the Sahel and the ecozones of southern, Central and North Africa (Stige *et al.*, 2006). This projection is in part reinforced by changes in rainfall over the last 60 years that has declined by up to 30% (Sivakumar *et al.*, 2005), with the greatest negative impacts felt in the Sahel of West Africa (Nicholson *et al.*, 2000; Hulme *et al.*, 2001).

Although climate change is affecting all countries of the world, a major impact of climate change in sub-Saharan Africa is its adverse effects upon the natural resource base (Kurukulasuriya and Mendelson, 2006) and countries in this region of Africa are expected to be hit earliest and hardest (IPCC, 2007b) because their environments are closely linked with climate, and the livelihoods of its inhabitants are largely dependent on the utilization of land-based resources (soils and forests) as well as on freshwater, lacustrine and riverine systems as sources of potable water, fish and transport. As a result of this dependency and widespread poverty, the communities in sub-Saharan Africa are particularly vulnerable to the effects and impacts of climate change and are likely to be adversely affected in terms of food security, sustainable water supply and by extreme climate and severe weather phenomena such as floods, droughts and threats of desertification. In addition, these impacts are likely to be exacerbated by the lack of financial and technical means with which to reduce their vulnerability to global climate change. The Third Assessment Report, 2001 (TAR) concluded that Africa is very vulnerable to climate change given its low capacity to respond and adapt.

This chapter describes, albeit briefly, the processes that contribute to climate change and discusses trends in climate change and its impacts in sub-Saharan Africa.

2.2 Processes that contribute to climate change

2.2.1 Emission of greenhouse gases

The Earth has a natural temperature control system. Certain atmospheric gases are critical to the stability of this system and are known as greenhouse gases (GHGs). On average, about one third of the solar radiation that reaches the earth is reflected back to space. Of the remainder, the atmosphere absorbs some but the land and oceans absorb most. With reduced forests and vegetal cover in sub-Saharan Africa, the cordon sinks on land are reduced. The Earth's surface becomes warmer and as a result emits infrared radiation. The greenhouse gases trap the infrared radiation, thus warming the atmosphere (the greenhouse gas effect). Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO_2), ozone, methane (CH_4) and nitrous oxide (N_2O), and together create a natural greenhouse effect. However, human activities are causing greenhouse gas levels in the atmosphere to increase. Overall, agriculture (cropping and livestock) contributes 13.5% of global greenhouse gas emissions mostly through emissions of methane and nitrous oxide (about 47% and 58% of total anthropogenic emissions of CH_4 and N_2O, respectively). The largest producer is power generation at 25.9% followed by industry with 19.4%. However, Africa's contribution to climate warming through greenhouse gas emissions is insignificant (e.g. Figure 2.1). Analysis shows that per capita greenhouse gas emissions in a typical European country and the USA is roughly 50–100 times and 100–200 times more, respectively, than a typical African country.

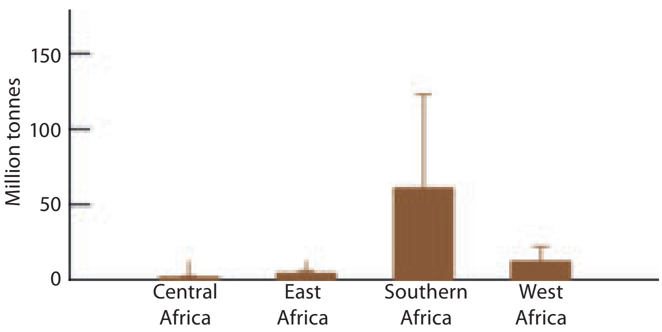


Figure 2.1 Average carbon dioxide emissions, excluding emissions from land use change, biomass fuels and cement manufacturing, per country in different regions of sub-Saharan Africa in 2001. Based on International Energy Agency (IEA) (2004).

2.2.2 Deforestation

Forests can play a significant role in climate change through their influence on rainfall. For example, 95% of the rainfall in the Congo Basin derives from water recycling (Biodiversity Support Program, 1992). Logging of large areas can thus affect rainfall in surrounding forest areas (Baidya *et al.*, 2005). Studies have indicated that deforestation has a strong effect on rainfall and that the desertification in Africa is an example of declining mean rainfall during the last half of the 20th century that has caused a 25–30 km south-west shift in the Sahel while the Sudan and Guinea vegetation zones in West Africa have shifted at an average rate of 500–600 m per annum (Zhao *et al.*, 2005). Several studies also have highlighted the importance of terrestrial vegetation cover and resultant dynamic feedbacks on the physical climate (IPCC, 2007a). An increase in vegetation density, for example, has been noted to result in a year-round cooling of 0.8°C in the tropics, including tropical areas of Africa. Models show that deforestation would cause a general drying trend over Africa with rainfall increasing in some areas but decreasing by up to 40% with increased heat waves in other areas (Paeth and Thamm, 2007). Complex feedback mechanisms – mainly due to deforestation/land cover change and dust – also play a role in climate variability, particularly for the drought persistence in the Sahel and its surrounding areas (Nicholson, 2001; Semazzi and Song, 2001).

2.2.3 Assessments of climate change

Studies of climate change involve analyses of *1)* historical climate data, *2)* projections into the future using scenarios based on future changes in concentrations of greenhouse gases, *3)* palaeo-climatogical observations, and *4)* tree-ring chronology.

2.2.3.1 Analysis of historical climate data

The main sources of climate data are meteorological stations. In sub-Saharan Africa some stations started recording data as early as 1857 in southern Africa and 1888 in West Africa but the majority of stations have records only dating back to early 20th century (Hansen, 1987). These data are used to analyze trends in temperature and precipitation and are often presented as anomalies that are deviations from the normal or mean calculated for a specific reference period of at least 30 years. For example, World Meteorological Organization (WMO) published the 1961–1990 climatological normals (WMO, 1996) against which anomalies can be compared.

As elsewhere in the world, an increasing trend in surface mean temperature has been observed for the African region using historic climate data (Figure 2.2). Although these trends seem to be consistent over the continent, the changes are not always uniform. For instance, decadal warming rates of 0.29°C in the African moist forests (Malhi and Wright, 2004) and 0.1°C to 0.3°C in South Africa have been observed. In South Africa and Ethiopia minimum temperatures have increased slightly faster than maximum or mean temperatures. Between 1961 and 2000, there was an increase in the number of warm spells over southern and West Africa, and a decrease in the number of extremely cold days. In eastern Africa, decreasing trends in temperature from weather stations located close to the coast or to major inland lakes have been noted. This trend is expected to continue and even to increase significantly and according to the Intergovernmental Panel on Climate Change (IPCC, 2007b), a medium-high emission scenario would see an increase in global annual mean surface air temperatures of between 3°C and 4°C by 2080.

The trend in annual precipitation indicates a small but statistically significant decline in rainfall over Africa (Figure 2.3). The IPCC (2007a)

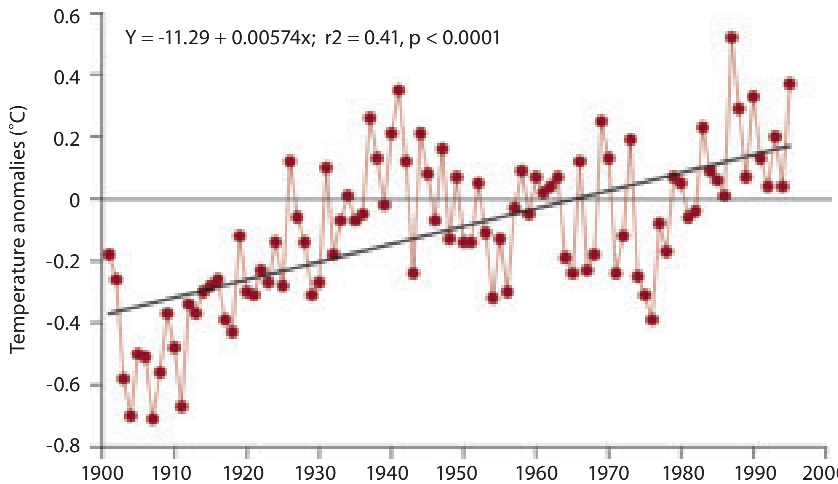


Figure 2.2 Trend in mean surface temperature anomalies over Africa from 1900. Based on IPCC (2001).

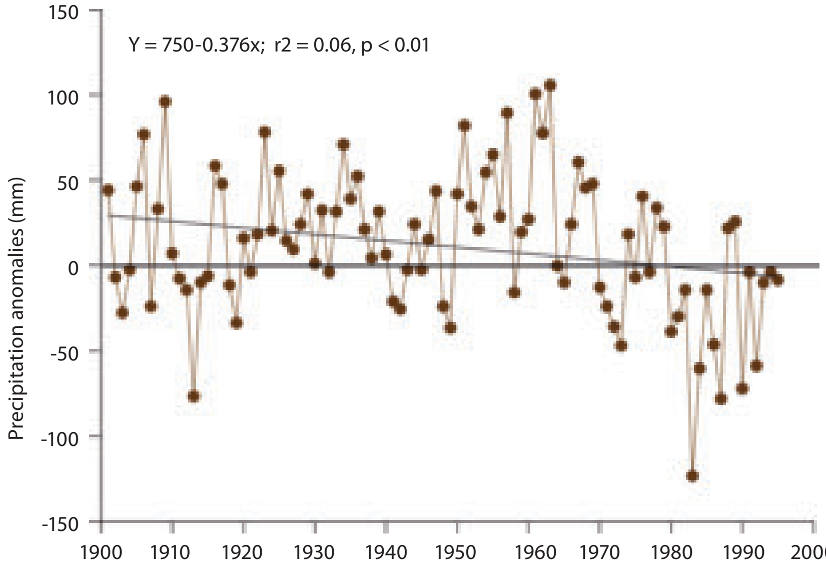


Figure 2.3 Trend in precipitation anomalies over Africa from 1900. Based on IPCC (2001).

indicated a decrease in precipitation occurring over the 1900s particularly after the 1960s over the subtropics and the tropics from Africa to Indonesia. This is further emphasized by Hume *et al.* (2001), who observed a decline in precipitation by about 2.4±1.3% per decade in the moist forest zone of Africa since the mid-1970s; a rate which has been stronger in West Africa (-4.2±1.2% per decade) and in North Congo (-3.2±2.2% per decade) (Nicholson *et al.*, 2000) . In this ecozone, a decline in mean annual precipitation of around 4% in West Africa, 3% in North Congo and 2% in South Congo for the period 1960–1998 has also been noted. The drying peaked in the 1980s, when most of West Africa and the Congo basin were anomalously dry and where the rate was 10% lower in the period 1968–1997 than in the period 1931–1960 (Nicholson *et al.*, 2000; Mahli and Wright, 2004). A 10% increase in annual rainfall along the Guinean coast for the last 30 years has, however, also been noted (Nicholson *et al.*, 2000). In other regions, such as southern Africa, no long-term trend has been noted, however, a significant increase in heavy rainfall events has been observed, including evidence for changes in seasonality and extremes (Parry *et al.*, 2007). Based on the IPCC projections both North African and parts of southern Africa regions are very likely to experience reductions in rainfall and in some parts it may exceed 30% for the A1B scenario (Christensen *et al.*, 2007), with the greatest reductions in rainfall projected over the south-western Africa in the coastal Namib Desert region. Coupled with an increase in average global temperature (above 2°C) might result in the complete collapse of the ecological systems and enhanced mobilization of sand dunes throughout the greater Kalahari region (Thomas *et al.*, 2005). With regard to the African Sahel, the observed increase in rainfall since the early 1990s is projected to continue, as climate model projections indicate a strengthening of the monsoon across the central and eastern Sahel. This is expected to result in a consistent band of projected higher rainfall extending from Mali in the west to northern Sudan in the east which could lead to the occurrence of more intense rainfall events and associated flash flood risks. Moreover, there is a general consensus among regional models on the 'greening' of the Sahel and southern Sahara although these projections are associated with high level of uncertainty (Brooks, 2004).

2.2.3.2 Climate change projections

Projections of future climatology are based on IPCC models and scenarios. A climate projection refers to model-derived estimates of future climate while climate scenarios are plausible future climates that have been constructed to determine impacts of climate change on resources and the environment. General Circulation Models or GCMs are based on equations of physical laws that describe the earth's radiation budget and the dynamics of the atmosphere and ocean and these models are described in the 2007 IPCC Fourth Assessment Report. Future climate scenarios for impacts modeling are either 'idealized' scenarios or simulations derived from climate models that incorporate assumptions about future greenhouse gas (GHG) concentrations. Idealized scenarios consist of specifying *a priori* the change in climatic variables across the region of interest, e.g. temperature increases of 1°, 2°, 3°C and precipitation changes of ± 5%, 10%, 20% (Beaumont *et al.*, 2008). Such scenarios do not enable a temporal scale of species responses to be estimated and imply a uniform change in the climate variable across the region of interest and assume linear relationships between climate variables. Climate-based model scenarios integrate models with projections of greenhouse gas concentrations and there are a number of computer codes that are described as climate models (e.g. Table 2.1).

On the basis of some of these models the global mean surface temperature is projected to increase between 1.5°C and 5.8°C by 2100. The IPCC in its 2007 report stated that warming in Africa is very likely to be larger than the global annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics. The future warming rate is likely to range from 0.2°C per decade (for the low scenario) to more than 0.5°C per decade (for the high scenario). This warming will be greatest over the interior of semiarid margins of the Sahara and central southern Africa. The observed annual rainfall anomalies of the climate change models indicate that there are possible increases in precipitation in East Africa, contrasted with reduced precipitation for southern Africa in the next 100 years. While for East Africa an increase in rainfall

Table 2.1 Examples of codes of general circulation models and their emission scenario combinations.

Model	Code	Emissions scenario
Geophysical Fluid Dynamics Laboratory Coupled Model	GFDL-A2	Strong increase in fossil fuel consumption and related global CO_2 emissions
Geophysical Fluid Dynamics Laboratory Coupled Model	GFDL-A1B	Balanced use of fossil fuel consumption
Geophysical Fluid Dynamics Laboratory Coupled Model	GFDL-B1	Lower levels of fossil fuel consumption and related global CO_2 emissions
Max Planck Institute for Meteorology Model	ECHAM-A2	Strong increase in fossil fuel consumption and related global CO_2 emissions
Max Planck Institute for Meteorology Model	ECHAM-A1B	Balanced use of fossil fuel consumption
Max Planck Institute for Meteorology Model	ECHAM-B1	Lower levels of fossil fuel consumption and related global CO_2 emissions
Hadley Center Coupled Model	HadCM3-A2	Strong increase in fossil fuel consumption and related global CO_2 emissions
Hadley Center Coupled Model	HadCM3-A1B	Balanced use of fossil fuel consumption
Hadley Center Coupled Model	HadCM3-B1	Lower levels of fossil fuel consumption and related global CO_2 emissions

as projected would be welcome, it will be accompanied by an increase of extremely wet events, from the current 5% to about 20%, which could seriously impact on forest resources, biodiversity, food production systems, water resources and supply and infrastructure.

2.2.3.2 Palaeoclimatological observations

Palaeoclimate science has made significant advances since the 1970s, when a primary focus was on the origin of the ice ages, the possibility of an imminent future ice age and the first explorations of the so-called Little Ice Age and Medieval Warm Period. Even in the first IPCC assessment of 1990, many climatic variations prior to the instrumental record were not that well known or understood. Palaeoclimatic record is examined in a chronological order, from oldest to youngest. This approach was selected because the climate system varies and changes over all time scales, and it is instructive to understand the contributions that lower-frequency patterns of climate change might make in influencing higher-frequency patterns of variability and change. In addition, an examination of how the climate system has responded to large changes in climate forcing in the past is useful in assessing how the same climate system might respond to the large anticipated forcing changes in the future. Cutting across this chronologically based presentation are assessments of climate forcing and response, and of the ability of state-of-the-art climate models to simulate the responses.

Perspectives from palaeoclimatic observations, theory and modeling are integrated wherever possible to reduce uncertainty in the assessment. Several sections also assess the latest developments in the rapidly advancing area of abrupt climate change, that is, forced or unforced climatic change that involves crossing a threshold to a new climate regime (e.g. new mean state or character of variability), often where the transition time to the new regime is short relative to the duration of the regime (Alley *et al.*, 2003).

One of the most important aspects of modern palaeoclimatology is that it is possible to derive time series of atmospheric trace gases and aerosols for the period from about 650 thousand years (kyr) to the present from air trapped in polar ice and from the ice. As is common in palaeoclimatic studies of the Late Quaternary, the quality of forcing and response series are verified against recent (i.e. post 1950) measurements made by direct instrumental sampling. Atmospheric CO_2 concentrations can be inferred back millions of years, with much lower precision than the ice core estimates.

The Earth's climate repeatedly has gone through significant variations. Recurrently strong worldwide climate changes have been reported since the Mesozoic (Corfield, 1994; Li and Keller, 1999). Especially the period between ~100 Ma and ~50 Ma is characterized by a significant global cooling, commonly referred to as the greenhouse to icehouse transition (Sellwood and Valdes, 2006).

During the past 800,000 years, the late Pleistocene and subsequent Holocene, the Earth's climate has swung between cool and warm and back again many times. Variations in incoming solar radiation, modulated by Earth's orbital parameters, along with recurring ups and downs in atmospheric carbon dioxide concentrations, are among the prominent features associated with these climate swings. At first glance, then, it looks like climate is intimately coupled with solar radiation and CO_2. But on closer inspection, differences become apparent between the amplitudes of climate changes and CO_2 variations in particular that raise the question of how tight that coupling is.

Pre-Quaternary climates prior to 2.6 Ma were mostly warmer than today and associated with higher CO_2 levels. In that sense, they have certain similarities with the anticipated future climate change (although the global biology and geography were increasingly different further back in time). In general warmer climates are to be expected with increased greenhouse gas concentrations. There are ongoing efforts to obtain quantitative reconstructions of the warm climates over the past 65 Myr.

The Mid-Pliocene (about 3.3 to 3.0 Ma) is the most recent time in Earth's history when mean global temperatures were substantially warmer for a sustained period (estimated by GCMs to be about 2˚C to 3˚C above pre-industrial temperatures [Sloan *et al.*, 1996; Haywood *et al.*, 2000; Jiang *et al.*, 2005]), providing an accessible example of a world that is similar in many respects to what models estimate could be the Earth of the late 21st century. The Pliocene is also recent enough that the continents and ocean basins had nearly reached their present geographic configuration. Taken together, the average of the warmest times during the middle Pliocene presents a view of the equilibrium state of a globally warmer world in which atmospheric CO_2 concentrations (estimated to be between 360 to 400 ppm) were likely higher than pre-industrial values (Raymo and Rau, 1992; Raymo *et al.*, 1996)

Climate models indicate that the Last Glacial Maximum (about 21 ka) was 3˚C to 5˚C cooler than the present due to changes in greenhouse gas forcing and ice sheet conditions. The inclusion of the effects of atmospheric dust content and vegetation changes gives an additional 1˚C to 2˚C global cooling, although scientific understanding of these effects is very low. It is very likely that the global warming of 4˚C to 7˚C since the Last Glacial Maximum occurred at an average rate about 10 times slower than the warming of the 20th century.

Global sea level was between 4 and 6 m higher during the last interglacial period, about 125 ka, than in the 20th century. In agreement with palaeoclimatic evidence, climate models simulate arctic summer warming of up to 5˚C during the last interglacial. The inferred warming was largest over Eurasia and northern Greenland, whereas the summit of Greenland was simulated to be 2˚C to 5˚C higher than present. This is consistent with ice sheet modeling suggestions that large-scale retreat of the south Greenland Ice Sheet and other arctic ice fields contributed a maximum of 2 to 4 m of sea level rise during the last interglacial, with most of the remainder coming from the Antarctic Ice Sheet.

A recent study has reconstructed the lake surface temperature of Lake Tanganyika in East Africa from analysis of lake-sediment cores and has confirmed the warming of the surface water of this second largest and second deepest lake in the world (Tierney *et al.*, 2010) (Figure 2.4).

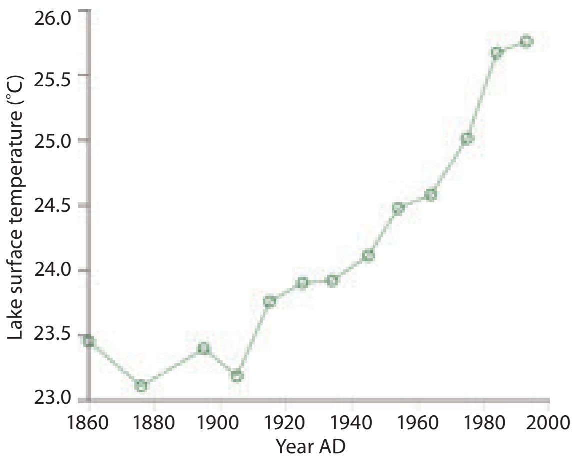


Figure 2.4 Lake surface temperature in Lake Tanganyika from results of analysis of multicore samples. Based on Tierney et al. *(2010).*

2.2.3.3 Tree-ring chronologies

Some studies have used tree-ring chronologies to reconstruct past climate characteristics in sub-Saharan Africa. For example, Schöngart *et al.* (2006) used climate-growth relationships of tropical tree species in West Africa to demonstrate its potential for climate reconstruction. Their study revealed a significant relationship between tree growth, local precipitation and surface sea temperature anomalies in the Gulf of Guinea while a master chronology enabled the reconstruction of the annual precipitation in the central-western part of Benin to the year 1840. The mean ring-width chronologies of *Pterocarpus angolensis* were significantly correlated with regional rainfall totals during the wet season from 1901 to 1990 in western Zimbabwe (Stahle *et al.*, 1999). In Ethiopia, high positive correlations were found between the tree-ring width chronologies and precipitation data and all the studied tree species showed similar response to external climate forcing and declines in tree-ring width correlated remarkably well with past El Niño Southern Oscillation (ENSO) events and drought/ famine periods (Gebrekirstos *et al.*, 2008).

2.3 Impacts on natural resources and livelihoods in Africa

The IPCC 2007 Fourth Assessment Report (AR4) indicates that Africa's climates, ecosystems and economies have already been affected by global warming and are likely to experience further change. The adverse effects of climate change will lead to secondary effects in African countries, and in particular the poorest of these countries, resulting in diminishing subsistence capacities of natural systems and/or the durability of human settlements. These effects include the use of water resources of poor quality, abandonment of the rural economy, displacement of populations and infrastructures, and the spread of epidemics. Therefore, adaptation is not an option for Africa, but a necessity. The challenge lies in the fact that Africa's adaptive capacity is low due to the extreme poverty of many of its people, compounded by frequent natural disasters such as droughts and floods, and poor institutional and infrastructural support.

2.3.1 Impacts on water resources

Several large lakes registered abrupt transgressions and recessions of magnitudes far larger than any witnessed in recent times; there is a large body of evidence on lacustrine extensions in the Sahelian and Saharan subtropical latitudes, as well as in equatorial Africa in the early Holocene (Lézine 1989; Street-Perrott *et al.*, 1989; Gasse, 2001; Thorweihe and Heinl, 2002; Edmunds *et al.*, 2005; Odada and Olago, 2005; Dühnforth *et al.*, 2006; Olago *et al.*, 2007), suggesting that large areas, now arid, and also humid areas, were regularly receiving substantial tropical rainfall. This was followed by abrupt desiccation events in some African lakes such as in the Ziway Shala basin of Ethiopia in East Africa, where a lake lowering of 50 m is recorded between 8,000 to 6,500 yr BP (Gasse and Street, 1978; Levine, 1982, Gillespie *et al.*, 1983), with lowest levels between 7,800 and 7,000 yr BP. The Holocene wet phase lasted until about 4,000 yr BP when drier conditions set in (Gasse and Street, 1978; Hoelzmann, 2002; Barker *et al.*, 2004, Hoelzmann *et al.*, 2005). The end of the humid phase occurred when gradually declining boreal summer insolation crossed a threshold value of 4.2% greater than present; a similar insolation threshold that coincided with abrupt tropical lake level rises during the early deglacial warming (deMenocal *et al.*, 2000).

The lagged response of northern hemisphere sea surface temperatures, relative to the southern hemisphere, is postulated as a possible reason why lake levels and precipitation were still high in the mid-Holocene when summer insolation was already declining (Mulitza and Ruhlemann, 2000). As recently as several hundred years ago, Lake Malawi is believed to have been 50 m shallower than it has been during the last 150 years (Owen *et al.*, 1990), and a high resolution record of hydrological change from Lake Naivasha indicates that there were three decadal to inter-decadal scale droughts in the East Africa region that matched oral historical records of famine, political unrest and large-scale migration of indigenous peoples (Verschuren, 2002). Thus, these changes over long timescales have been attributed in part to precessional driven variability at ca. 23,000 yr cycles in the tropical regions, and half precessional cycles (11,5000 yr) in the equatorial region (Olago *et al.*, 2000; Verschuren *et al.*, 2009), as well as to shorter solar variability episodes that account for sub-millennial scale hydrological changes (Verschuren *et al.*, 2002).

Some regions of Africa are particularly vulnerable to reduced precipitation, especially given that the climate trend indicates longer periods of drought and shorter periods of heavy rain. Most vulnerable are the arid, semiarid, and dry sub-humid areas where the ratio of precipitation to potential evaporation (PET) ranges from 0.05 to 0.65. These areas cover 13 million km^2 or 43% of the continent's land area, where 270 million people or 40% of the continent's population live (UNDP, 1997).

The major effects of climate change on African water systems will be through changes in the hydrological cycle, the balance of temperature, and rainfall (IPCC, 2001). River flow rates are predicted to decrease. The Nile region for example, most scenarios estimate a decrease in river flow of up to 75% by 2100. The rise in global surface temperatures has been accompanied by an accelerated hydrological cycle, evidenced by, for example, increases in extreme precipitation, reductions in snow cover and mountain ice and changes in the frequency and intensity of ENSO events. In eastern Africa, the last strong ENSO in 1997/98 caused widespread destruction and losses in the agricultural sector, destroyed critical infrastructure such as roads, railways and power supply systems by extensive flooding and localized landslides. It also led to the outbreak of climate and water related diseases and caused significant loss of human and other life. The impact on the national economies and food security of the affected countries was extremely severe. In Ethiopia, so sensitive is economic growth to hydrological variability that even a single drought event within a 12-year period (the historical average is every 3–5 years) will diminish average growth rates across the entire 12-year period by 10% (World Bank, 2006).

Water plays a central role in society by providing the basic resource for maintenance of ecosystems, irrigation, hydroelectric power, fisheries and aquaculture, and livestock production. Its availability is thus one of the most critical factors in the development of Africa. Africa's renewable water resources average 4,050 km^3 per year, providing in the year 2000 an average of about 5,000 m^3 per capita per year which is significantly less than the world average of 7,000 m^3 per capita per year and water availability per capita is projected to decrease by 53% in southern Africa, 54% in East Africa and 60% in West Africa from 1990 to 2025 (Figure 2.5).

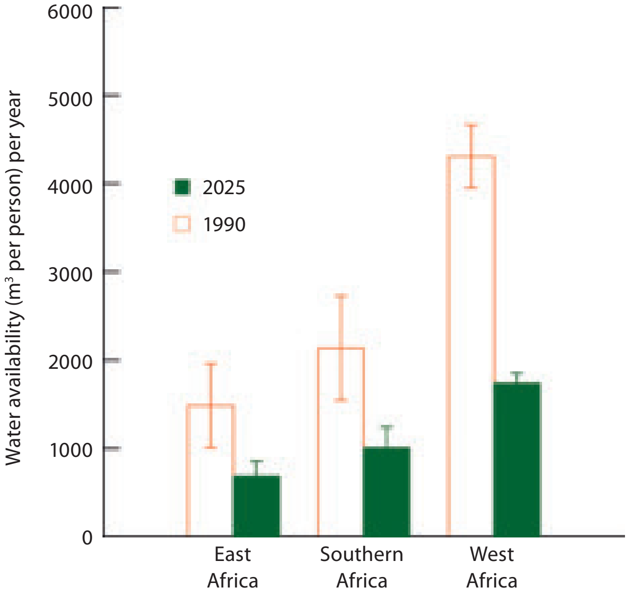


Figure 2.5 Water availability in different regions of Africa. Based on United Nations Environment Programme (UNEP) (1999).

Many African countries are today experiencing water stress, and it is projected that many more will shift from a water surplus state to a water deficit state by 2025 due to changes in population alone (IPCC, 2001). In addition to this, non-climatic changes such as water policy and management practice may have significant effects. Thus, water has emerged as one of the highest priorities on the global development agenda as evidenced by major international efforts to assess the condition of the resource and to create a dialogue on its wise use (WSSD Johannesburg 2002, World Water Forum 3 Kyoto 2003, World Water Assessment Programme). Twenty-five countries in Africa are expected to experience water stress over the next 20 to 30 years and it is projected that about 480 million people will be affected. Problems with freshwater availability are further complicated by highly variable levels of rainfall hence large numbers of people are dependent on groundwater as their primary source of freshwater, yet little is known about the quantity and quality of the groundwater resource and the ecosystem requirement for water.

Many of the forests in Africa are situated in high altitude mountain regions and, alongside the expansive lowland moist forests, are important sources of water. They act as storage and distribution sources of water to the lowlands, providing the greater part of the river flows downstream. They also sustain many natural habitats, both in the mountains and the lowlands, thus contributing to the conservation of biodiversity. The glacial melt-water from the tropical glaciers of eastern Africa contributes significantly to the hydrological budget of rivers originating from the slopes of the mountains. The rivers on Mount Kenya currently meet 50% of the country's freshwater requirements and supply the national grid with about 70% of its hydroelectric power. Major reductions in snow and glaciers on Mt. Kenya, Kilimanjaro and Ruwenzori have been observed over the past century, and scientists have estimated that the ice cap on Kilimanjaro, which has decreased by about 80% from the year 1912 to 2000, is likely to disappear between 2015 and 2020 if the climatological conditions of the past 88 years persist. Today, the changes in land use around the water towers, deforestation, water abstraction for farm irrigation and the gradual melting of the mountain-glaciers are thought to be responsible for depleting waters in streams and rivers. Tourism in the region is potentially threatened as the visual appeal of the ice caps disappears and ecosystems of high economic value, such as the Mara River ecosystem complex that is dependent on water supply from the Mau Forest complex in Kenya, are degraded and altered as a consequence of insufficient water.

As rainfall declines, the quality of water deteriorates because sewage and industrial effluents become more concentrated, thereby exacerbating water-borne diseases and reducing the quality and quantity of fresh water available for domestic use. River flow rates are predicted to decrease. The time consuming task of gathering and transporting water is also usually the responsibility of the women, as water becomes scarce the work overload increases drastically as they have to walk longer distances in search of water. It has been estimated that women in developing countries spend an average of 134 minutes a day collecting water for their households (Rosen and Vincent, 1999). This increases the rate of school dropouts for young women as they take on extra work-loads, reducing the opportunities for women to participate in nontraditional activities that would empower them.

2.3.2 Impacts on biodiversity

The Convention on Biological Diversity (CBD) defines biodiversity as the variation between ecosystems and habitats; the variation between different species; and the genetic variation within individual species. Biodiversity can therefore be described in terms of the diversity of ecosystems, species and genes. In this book sub-Saharan Africa is divided into three major ecozones or ecosystems (Table 2.2).

Table 2.2 Major ecosystems or ecozones in sub-Saharan Africa.

Major Ecozone	Phytoregion based on White (1983)
Moist forests	Guineo-Congolian in West and Central Africa
	Lake Victoria in East Africa
	Afromontane in East and southern Africa
Woodlands (including dry forests) and savannas	Guinea-Congolia/Zambezian Regional Transition Zone in Southern Africa
	Guinea-Congolia/Sudania Regional Transition Zone in West Africa
	Zambezian Region in East and southern Africa
	Sudanian Region in West Africa
	Kalahari-Highveld Regional Transition Zone in southern Africa
	Somali-Masai Region in East Africa
Sahel	Sahel in West Africa

Global biodiversity is changing at an unprecedented rate (Pimm *et al.*, 1995), the most important drivers of this change being land conversion, climate change, pollution, unsustainable harvesting of natural resources and the introduction of exotic species (Sala *et al.*, 2001). Africa occupies about one-fifth of the global land surface and contains about one-fifth of all known species of plants, mammals and birds in the world, as well as one sixth of amphibians and reptiles (Siegfried, 1989). Biodiversity is an important resource for African people. Uses are consumptive (food, fiber, fuel, shelter, medicine) and non-consumptive (ecosystem services and the economically important tourism industry). Given the heavy dependence on natural resources in Africa, many communities are vulnerable to the biodiversity loss that could result from climate change.

Novel climates are projected to develop primarily in the tropics and subtropics, including some parts of Africa such as the Western Sahara and lowlying portions of East Africa, whereas disappearing climates are concentrated in tropical montane regions. Specific areas likely to be affected in Africa include African Rift Mountains, the Zambian and Angolan Highlands, and the Cape Province of South Africa. Because climate is a primary determinant of species distributions and ecosystem processes, novel 21st-century climates may promote formation of novel species associations and other ecological surprises, whereas the disappearance of some extant climates increases the risk of extinction of species with narrow geographic or climatic distributions and disruption of existing communities. Under the high-end A2 scenario, 12–39% and 10–48% of the Earth's terrestrial surface may respectively experience novel and disappearing climates by 2100 AD. Corresponding projections for the low-end B1 scenario are 4–20% and 4–20%.

Terrestrial fauna biodiversity in Africa is concentrated in the moist forests, woodlands and savannas. Loss or alterations of terrestrial habitats by climate change will likely impact these species as they struggle to adapt to changing conditions (Lovett *et al.*, 2005). For example, climate change of the magnitude predicted for the 21st century could alter the range of African antelope species (Hulme, 1996) and other herbivores due to changes in food (vegetation) availability, migratory routes (and timings) of species that use seasonal wetlands (e.g. migratory birds). It may also increase conflicts between people and large mammals such as elephants, particularly in areas where rainfall is low (Thirgood *et al.*, 2004), or where migratory routes are blocked by park fence boundaries which have been demonstrated to disrupt migration, leading to a population decline in wildebeest (Whyte and Joubert, 1988). In addition, weather extremes can also affect biodiversity in more complex ways. For example, in African elephants (*Loxodonta africana*), breeding is year-round, but dominant males mate in the wet season and subordinate males breed in the dry season. Subsequently, a change in the intensity or duration of the rainy versus drought seasons could change relative breeding rates and, hence, genetic structures in these populations (Poole, 1989; Rubenstein, 1992).

Global change processes on land, and climate change impacts on aquatic ecosystems is also affecting the biodiversity of aquatic species. The coasts of many African countries have rich ecosystems such as coral reefs, seagrass meadows, mangrove forests, estuaries and floodplain swamps, while inland rivers, lakes (freshwater and soda) and riverine edge swamps, valley swamps, seasonal floodplains, ponds and high altitude peatforming wetlands all contribute to a wide variety of aquatic ecosystems that support an extensive range of resident as well as migratory species.

Differential responses to climate change by species in ecosystems may lead to disruption of important functional interactions, with potentially highly serious consequences for the provision of ecosystem services such as pest control, pollination, seed dispersal, decomposition and soil nutrient cycling. In addition to the effects on natural ecosystems, these could have socio-economic consequences for agriculture. Certain ecosystem types will be particularly vulnerable: ecotones (transition areas between different ecosystems, with high species and genetic diversity), which are important for adapting to climate change are highly threatened by climate change especially in semi-arid drylands prone to desertification. These are amongst the so-called biodiversity 'hotspots'. Hotspots are areas where species diversity and endemism are particularly high and where there is an extraordinary threat of loss of species or habitat, the most vulnerable are the woodlands and savannas. There are 25 internationally recognized hotspots; six of them are in Africa (Mittermeier *et al.*, 1999).

The current system of protected habitats under the Ramsar Convention is based on the present distribution of climate, raising the possibility of vastly changed habitat type and quality under climate change. The designation of some areas as 'biodiversity hotspots' is a useful concept developed in recent years as a means of prioritizing habitats for conservation (Myers, 1990).

2.3.3 Impacts on agriculture

Agriculture represents 30% of Africa's Gross Domestic Product (GDP) and climate change threatens this economy because agriculture in Africa is climate-dependent (Mendelsohn, 2000). The African agricultural sector relies heavily on direct rainfall, and patterns in economic growth closely follow precipitation patterns. For example, maize, sorghum, millet and groundnut yields have a strong association with the year to year variability of ENSO (El Niño/Southern Oscillation) in Africa. If global climate change moves more towards El Niño-like conditions, crop production will decline and in southern Africa productivity is expected to drop by 20–50% in extreme El Niño years (UN, 2008). Staple crops such as wheat and corn that are associated with subtropical latitudes may suffer a drop in yield as a result of increased temperature, and rice may disappear because of higher temperatures in the tropics (Odingo, 1990). In addition to climate change effects, food production in sub-Saharan Africa has not kept pace with the growing population.

Climate change will lead to changes in cropping and livestock systems through shifting of agricultural and pasture zones and increased incidence of pests and diseases. Drought and land degradation are also major obstacles to agricultural production as 46% of the land is vulnerable to desertification. Pastoralism is a major livelihood system in many African countries, with livestock and livestock products contributing about 19% to the total production value from agriculture in sub-Saharan Africa while rangelands represent up to 83% of the agro-ecosystem area. Fifty percent of Africa's livestock production is confined to drier regions and between 1970 and 2000 the per capita livestock production has generally decreased or remained stable. Pastoral communities have used mobility to take advantage of annual and seasonal rainfall variations. But the prolonged drying trend in the Sahel since the 1970s has demonstrated the vulnerability of such communities to climate change. They cannot simply move their axis of migration when wetter zones are already densely occupied and permanent water points disappear at the drier end. The problem of droughts appears to be most severe in sub-Saharan Africa, particularly in the Sahel and the Horn of Africa. The result has been widespread loss of human life and livestock, and substantial changes to social systems. It is estimated that about 60 million people will eventually move from the desertified areas of sub-Saharan Africa towards northern Africa and Europe by the year 2020 (UNCCD, 2006).

There are five main climate change related drivers in the agriculture sector: temperature, precipitation, sea level rise, atmospheric carbon dioxid content and incidence of extreme events. These may affect the agriculture sector in the following ways:

- *Reduction in crop yields and agriculture productivity:* There is growing evidence that in the tropics and subtropics, where crops have reached their maximum tolerance, crop yields are likely to decrease due to an increase in the temperature.
- *Increased incidence of pest attacks:* An increase in temperature is also likely to be conducive for

a proliferation of pests that are detrimental to crop production.

- *Limit the availability of water:* It is expected that the availability of water in most parts of Africa would decrease as a result of climate change. In particular, there will be a severe down trend in the rainfall in southern African countries.
- *Exacerbation of drought periods:* An increase in temperature and a change in the climate throughout the continent are predicted to cause recurrent droughts in most of the regions.
- *Reduction in soil fertility:* An increase in temperature is likely to reduce soil moisture, moisture storage capacity and the quality of the soil, which are vital nutrient sources for agricultural crops.
- *Low livestock productivity and high production cost:* Climate change will affect livestock productivity directly by influencing the balance between heat dissipation and heat production and indirectly through its effect on the availability of feed and fodder.
- *Availability of human resource:* Climate change is likely to cause the manifestation of vector and vector born diseases, where an increase in temperature and humidity will create ideal conditions for malaria, sleeping sickness and other infectious diseases that will directly affect the availability of human labour in the agriculture sector.

Major impacts on food production will come from changes in temperature, moisture levels, ultraviolet (UV) radiation, CO_2 levels, and temperatures may cause expansion of production into higher elevations. The grain filling period may be reduced as higher temperatures accelerate development, but high temperatures may have detrimental effects on sensitive development stages such as flowering, thereby reducing grain yield and quality. Crop water balances may be affected through changes in precipitation and other climatic elements, increased evapotranspiration, and increased water use efficiency (WUE) resulting from elevated CO_2. It is suggested that major changes in farming systems can compensate for some yield decreases under climate change, but additional fertilizer, seed supplies and irrigation will involve extra costs.

2.4 Conclusions

Climate change refers to a shift in climate, occurring as a result of human activities. Changing climate is expected to continue in the 21st century in response to the continued increasing trend in global greenhouse gases (GHGs) emissions. Although climate change is affecting all countries of the world, a major impact of climate change in sub-Saharan Africa is its adverse effects upon the natural resource base and countries in this region of Africa are expected to be hit earliest and hardest because their environments are closely linked with climate, and the livelihoods of its inhabitants are largely dependent on the utilization of land-based resources.

As elsewhere in the world, an increasing trend in surface mean temperature has been observed for the African region using historic climate data. The trend in annual precipitation indicates a small but statistically significant decline in rainfall over Africa. Many of the forests in Africa are situated in high altitude mountain regions and are important sources of water. They act as storage and distribution sources of water to the lowlands, providing the greater part of the river flows downstream. Careful management of mountain water resources must therefore become a global priority in a world moving towards a water crisis in the 21st century. Reduced water availability will have adverse health effects. The water supply situation in Africa is already precarious and the water stress will be exacerbated with climate change. Less water will result in increasing gastrointestinal problems. As water resource stresses become acute in future water-deficit areas of Africa as a result of a combination of climate impacts and escalating human demand, the conflict between human and environmental demands on water resources will intensify. In addition, because maintenance of healthy ecosystems is an underpinning to economic sustainability, there is need in each water basin management unit to identify and factor into development projects the need for environmental flows. Africa's vulnerability to climate change and its inability to adapt to these changes may be devastating to the agriculture sector, the main source for livelihood to the majority of the population. The vulnerability is due to lack of adapting strategies, which are increasingly limited due to the lack of institutional, economic and financial capacity to support such actions. The utmost concern should therefore be a better understanding of the potential impact of the current and projected climate changes on African agriculture and to identify ways and means to adapt and mitigate its detrimental impact.

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Chapter 3
ADAPTATION TO AND MITIGATION OF CLIMATE CHANGE IN FORESTRY

Mahamane Larwanou, Balgis Osman-Elasha and Godwin Kowero

3.1 Introduction

The world's forests, oceans and other water bodies are the main life-supporting mechanisms for planet Earth. The forests are key to sustaining the biodiversity of natural ecosystems and in regulating the world's climate system. Sustainable management of the vast and diverse African natural forest resource is proving to be extremely challenging. There is scanty information on the biophysical aspects of the natural forest estate, and even less on the properties and end use of the various tree species. There is much less information on socio-economic and policy aspects related to the forest condition and responses to the same by users of such resources. In short there is scanty information, and of questionable quality and quantity, to guide rational decision making in planning and managing the resources, and in particular on how to use the resources in ways that alleviate rural poverty and promote environmental protection. Further, large tracts of natural forests in Africa are being treated as open access resources.

Africa's forest and woodland constitute about 20% of the world's total. While in Africa, the population density relative to forest area is close to the world's average, the deforestation rate is four times the world's average. Low government priority assigned to the forestry sector, as seen from the low budgetary allocation to the sector, poor enforcement of regulations; lack of incentives, in particular to local communities and the private sector; ill-defined property rights and the treatment of forest resources as public goods, among others, have been identified as factors inhibiting the implementation of sustainable forest management practices in Africa.

Globally, forest ecosystems have also experienced various threats due to the impacts of climate change. These threats vary with regions, but are generally reflected through changes in growth rates, species composition and density and shifting of ecosystems. Expected impacts for Africa include the loss of biodiversity and vegetation cover as well as the degradation of soil productive capacity. The various manifestations of the impacts have been attributed to factors like recurrent droughts and climate variability. Human factors such as deforestation have for long been identified as catalytic factors to climate change in contributing to accelerating the impacts of climate change on forest ecosystems.

Many changes have already been observed in Africa's forests and other tree-based ecosystems that can largely be attributed to climate variability and change, particularly drought. Recent FAO (2010) statistics show that about 3.4 million ha of forests are lost every year due to various factors among which are climate change and variability and human intervention. The loss of forest resources is seriously impacting peoples' livelihoods and well-being in Africa, as well as on the incomes of various nations and on the environment. Various adaptation and mitigation measures have been developed and in some cases adopted in response to these impacts in Africa. Sustainable forest development in Africa requires integrating livelihood, climate adaptation and mitigation initiatives with forestry, agriculture and other land based activities.

Louman *et al.* (2009) noted that adaptation involves changes in how services are being affected by climate change, as well as in the way that services relate to human well-being. Generally, when climate conditions change, as they have often done in the past, and depending on the severity of the change, species must adapt (genetically or behaviorally), or migrate to follow and find suitable conditions (Fischlin *et al.*, 2007). Forest ecosystems can tolerate some change (Fischlin *et al.*, 2007), but if the coping capacity of the system exceeds a tolerable threshold level as a result of the external stimuli, the ecosystem will be severely impacted; including the supporting services it provides at the local level, and in some cases also at the regional and global levels (Eastaugh, 2008).

3.2 Forest-related adaptation to climate change

While Africa is the region most vulnerable to the negative impacts of climate change, it also has low adaptive capacity. Adaptive capacity is defined as the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2001).

Forests can play a key role in improving adaptive capacity of human societies; this is especially true for rural populations in Africa. The diversity of functions and services provided by forests such as the provision of wood and non wood forest products, soil fertility, water regulation and biodiversity conservation, give the forests a potentially significant role on adaptation approaches undertaken through different natural resources and land based sectors including agriculture, water, energy, and rangeland management. Moreover, trees and shrubs in farming systems, including agroforestry, have always played an important role in protecting agricultural soil from erosion and sand storms, thus contributing to sustainable agricultural production and food security.

Adaptation to climate change is defined by the IPCC as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2001).

3.2.1 Autonomous adaptation

Autonomous adaptation is defined as those measures that take place – invariably in reactive response to climatic stimuli – without the direct intervention of a public agency (IPCC, 2001). However, in the context of this chapter, it is used to describe local community measures that include traditional knowledge and practices. These have been spontaneously developed and used by African communities in their attempts to cope with past and current climate viability and change. A number of studies have shown that African communities, particularly at the local level, have historically developed coping strategies to adverse climatic conditions and are currently making efforts to adjust to observed environmental changes. Trees and forest products have always been part of their coping strategies e.g. in agroforestry systems, and use of various non timber forest products (NTFPs), particularly during drought. However, and despite the intimate understanding of the forests by these local communities, the unprecedented rates of climate change are expected to jeopardize their ability to adapt to present and future changed conditions.

A multidisciplinary review of adaptation of forests to climate change by Eastaugh (2008) found that climate change is expected to impact heavily forest-dwelling communities with no other sources of sustenance. FAO (2005a) also points out that smallholder and subsistence farmers, pastoralists and fisherfolk in developing countries may not be able to cope with climate change effectively due to their reduced adaptive capacity and higher climate vulnerability. In such cases planned adaptation will be needed, as examples in Table 3.1 demonstrate.

A recent study in Ghana that assessed the role of traditional knowledge to cope with climate change in the rural areas indicated that the traditional and local authorities identified clearing of riparian vegetation as a major factor for increasing soil erosion and siltation of rivers which eventually reduces stream flow; and that measures to remedy the situation are being undertaken (Gyampoh *et al.*, 2009). Among the remedial measures adopted are: awareness raising as to the effects of deforestation, particularly around water bodies; sensitizing the communities about prevention of bush fires; promoting community-based management of forests; and imposing fines on those who indiscriminately set fire to the forests, clear riparian vegetation, or violate other measures to protect the environment. The study also revealed a variety of coping strategies that have been applied, but with mixed success. This suggests that local traditional knowledge could provide the basis for the development of more effective strategies.

The collection and commercialisation of non-timber forest products (NTFPs) by local people has the potential to provide an increased source of income for people living in or near forests. Non timber forest products also have important subsistence uses, for example, they are a 'free' source of food, medicines, fuel and construction materials. If properly managed, NTFPs can be an incentive for forest communities to protect existing forests and restore degraded areas, and this ensures that their source of income is sustainable. For example, Michael (2006) and Brown and Crawford (2007) observed that one coping strategy in Africa involves the harvesting of NTFPs only in times of crop failures; in this case the use of NTFPs can be considered as an ex-post gap filling utilization. In other cases, forest products are extracted for households' consumption in case of low crop returns.

On the other hand, forests are being cleared as the global demand for timber rises and as ranching and large-scale agricultural activities expand. Many forest species fundamental to supporting livelihoods are vulnerable; and with forest resources declining this increases the vulnerability of local people and communities to climate change.

Marketing NTFPs could be planned in ways that enhance conservation and development of forests, and therefore sustain the supply of goods and

Table 3.1 Examples of adaptation to local climate conditions and variability. Adapted from Roberts (2009).

Country	Adaptive strategy
Botswana	Planting drought-resistant fruit trees around villages. The fruits are vitamin-rich and the trees are able to produce even during drought years and provide an additional income when traditional crops fail due to poor weather (Boven and Morohashi, 2002).
Burkina Faso	Afforesting areas with *Acacia* to protect against drought and aridity and to provide firewood, fodder, tannin, pulpwood, shelterbelts and for soil improvement (UNFCCC, 2008).
Mali	Growing *Jatropha* for fuel and protection from damage by wind and water (Henning, 2002).
Senegal	Cultivating *Moringa* trees that are very drought-resistant and tolerate a wide variety of soil types. They can be used to combat malnutrition by providing enriched food, and are also used for treating drinking water (Boven and Morohashi, 2002).
Tanzania	Promoting vegetation regeneration and tree planting, that is traditionally known as 'ngitili', has helped protect the environment, particularly against drought and aridity, and also improved the livelihoods of communities in the Shinyanga region (Barrow, 2002).
Zimbabwe	Practicing agroforestry with deep-rooted trees to tap moisture from lower depths during the dry season and also return large amounts of nutrients to the soil, as well as provide shelter against wind erosion (Agobia, 1999).

services from them. This can add economic value to forested areas, while at the same time providing local people with a sustainable and productive activity. However, for this to happen, researchers and policymakers must collaborate to make community-based forest management initiatives socially and economically viable, and inclusive of all forest products and services.

3.2.2 Planned adaptation

Planned adaptation is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state. Planning adaptation is essential in order to realize the full potential of forests and trees in sustainable development in Africa, both to meet the immediate and future needs of increasing populations and to provide the continuity of the natural resource base. Achievement of this goal requires a comprehensive approach in which a wide range of contributions of forest resources to society is fully appreciated and supported. Planned adaptation measures in forestry, more than any other sector, ought to be considered holistically, and in coordination with other sectors. It is equally important to create synergies with interventions aiming at controlling desertification, land degradation, conserving biodiversity, among others.

The synergy between adaptation to climate change and biodiversity conservation requires a unifying strategy in order to enhance the sustainability of the forest resource pools on which poor communities directly depend for their livelihoods. Therefore, ecosystem-based adaptation, which integrates biodiversity and provision of ecosystem services into an overall climate change adaptation strategy, can be cost-effective, generate social, economic and cultural co-benefits, and can help maintain resilient ecosystems (Mortimore, 2000). FAO (2005b) highlights a number of adaptation options related to forestry including *1)* forest fire management, promotion of agroforestry, adaptive management with suitable species and silvicultural practices; *2)* increased training and education; *3)* identification and promotion of (micro-) climatic benefits and environmental services of trees and forests.

In many African countries, the value of for-ests and trees to local livelihoods is not fully captured in national development plans. The potential contribution of forests and trees outside forests in climate change adaptation is also not well understood and therefore not reflected in official national documents, such as the national communication reports to the UNFCCC. Only a few National Adaptation Programmes of Action (NAPAs) developed by the Least Developed Countries (LDCs) in Africa identify forest-based adaptation as a priority area for intervention (Osman and Downing, 2007). However, some National Communication Reports (e.g. the one for Ethiopia), identify the establishment of seed banks that maintain a variety of seed types to preserve biological diversity and provide farmers with an opportunity to diversify their products and tree cover, among the adaptation options. Soil conservation and well-managed tree plantations are also emphasized (UNFCCC, 2006).

Some forest-related adaptation strategies adopted in Africa include *1)* reliance on forest products as a buffer to climate-induced crop failure in climatically marginal areas for agriculture (Dube *et al.*, 2001); *2)* decentralization of local governance of resources, for example through the Community Based Natural Resource Management (CBNRM) approach, to promote use of ecosystems goods and services, as opposed to exclusive reliance on agriculture (in climatically marginal areas for agriculture), and *3)* transformation of land use leading to land use shifts, e.g. from livestock farming to game farming as in the case in southern Africa (UNFCCC, 2006). Tribal and individual movements and migration are identified as adaptation options (as found in western Africa), since they provide employment and income diversification away from farms and reduce vulnerability to drought (UNDP, 2008; DFID, 2004).

3.2.3 Adaptation gaps and barriers

Results from the Global Forest Assessment (FAO, 2010) demonstrate a general global decline in deforestation, except for Africa which experienced an increase in deforestation, and also accounting for more than 50% of the global damage to forest areas by wild fires. This presents an added burden and extra responsibility for forest planners in addressing the many challenges caused or influenced by climatic and non-climatic factors. One of the biggest challenges for forest planners in the future will be to increase the general awareness about the role of forests and trees in adaptation to climate change impacts, and to develop livelihood adaptation strategies that ensure the continuity in the provisioning of forest ecosystem goods and services that continue to contribute to food security and poverty alleviation on the continent. Use of indigenous knowledge and local coping strategies should be promoted as a starting point for planning adaptation. Some of the barriers identified by FAO (2005b) for dealing with forest adaptation include limited economic resources and infrastructure, low levels of technology, poor access to information and knowledge, inefficient institutions and limited empowerment and access to resources. The range of measures that can be used to adapt to climate change is diverse, and includes changes in behavior, structural changes, policy based responses, technological responses or managerial responses (FAO, 2008).

The multidisciplinary review of adaptation of forests to climate change (Eastaugh, 2008), highlighted socio-economic effects of climate-change impacts on subsistence lifestyles of forest-dependent communities and the role of forests in adaptation responses within different sectors and regions, as areas requiring further research. Other important research gaps identified by IPCC (2007) include the integrated assessment of climate-change impacts on ecosystem services, including food, fibre, forestry and fisheries; and the relationship between biodiversity and the resilience of ecosystem services at a scale relevant to human well-being (Parry *et al.*, 2007).

3.2.4 Some examples of the forestry adaptation efforts in Africa

3.2.4.1 Tropical forests and climate change adaptation

The Centre for International Forestry Research (CIFOR), together with the Tropical Agriculture Centre for Research and Higher Education (CATIE), developed a 4-year project on Tropical Forests and Climate Change Adaptation (TroFCCA) funded by the European Commission. This project launched the Africa component in Ghana, Mali and Burkina Faso, focusing on dry tropical forests. The project noted that the implementation of any adaptation measures in drylands, and in particular the NAPAs, to adverse impact of climate change, as well as the National Action Plans to fight against desertification, provide a tremendous opportunity to create a real and effective synergy between climate change and desertification (*http://www.cifor.cgiar.org*).

3.2.4.2 Sustainable land use and forestry programs

The Central African Regional Program for the Environment (CARPE) is an initiative supported by the United States Agency for International Development (USAID) that seeks to promote sustainable natural resource management in the Congo Basin. This basin contains massive expanses of closed-canopy tropical moist forest. One of the aims of this initiative is to facilitate to mitigate climate change by absorbing and storing carbon dioxide from the atmosphere, promoting biodiversity conservation, as well as improving forest management and sustainable agriculture in West Africa, and by so doing also helps reduce the vulnerability of ecosystems. The region is threatened by unsustainable timber exploitation, shifting cultivation, urban expansion and decades of human conflict. In addition to providing other valuable ecosystem services, the large forested area of the Congo Basin serves as a globally important carbon stock. The principal goal of CARPE is to reduce the rate of forest degradation and biodiversity loss through increased local, national and international co-operation, as a means to conserve the forests and other biological resources that are essential for economic development in the region. It is also expected to contribute to slowing global climate change, as well as conserving species and genetic resources of the Congo Basin (*http://carpe.umd.edu/*). This in return is expected to contribute to the protection of the resource base on which local communities depend on for their livelihoods.

3.2.4.3 The Congo Basin Forest Partnership

The Congo Basin Forest Partnership (CBFP) was established at the World Summit on Sustainable Development in Johannesburg, South Africa, in 2002, and involves 29 governmental and international organizations. The USAID contributed USD 15 million to the partnership through the Agency's Central African Regional Program for the Environment (CARPE). The CBFP activities aim to improve the management of the region's forests and protected areas, and develop sustainable livelihoods for the 60 million people who live in the Basin (*http://carpe.umd.edu/links/congo-basin-forest-partnership-cbfp*).

3.2.5 National Adaptation Programmes of Action (NAPAs)

The National Adaptation Programmes of Action (NAPAs) are provided for through Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC) which requires Non-Annex I parties to formulate national and regional programmes to facilitate measures for adequate adaptation to climate change (UN, 1992; FAO, 2007; Yohe and Tol, 2002). The Intergovernmental Panel on Climate Change's Third Assessment Report (IPCC, 2001) established the severity of climate change impacts on developing countries, their vulnerability to the impacts, and drew attention to the need for international support for adaptation actions in LDCs. This led to the establishment of the Least Developed Countries Fund (LDCF), through the decision of the Sixth Conference of Parties (COP6) of the UNFCCC to support LDCs in identifying their most urgent needs for adaptation through the preparation of NAPAs (Mace, 2005; UNFCCC Secretariat, 2007; IIED, 2008). The significance of public participation in designing and implementing measures for climate change adaptation is enshrined in Article 6 (a) (iii) of the UNFCCC, which calls for public participation in addressing climate change and its effects and developing adequate responses (UN, 1992). Decision 28 of COP6 also calls upon developing countries to use a multidisciplinary approach when preparing their NAPAs. The NAPAs are prepared through bottom-up participatory approaches.

The concept of using participatory approaches is of paramount importance in identifying policy interventions for climate change adaptation (Few *et al.*, 2007). This being a relatively new area also requires adaptive research. The benefits of using participatory tools for project design are many and include enhancing trust between communities and researchers (Hellin and Dixon, 2008), enabling co-generation of knowledge thereby increasing communities' capacity to use such knowledge to sustain their livelihoods (Nemeroff, 2008; Reed, 2008), and enabling researchers to understand micro-realities within the community (Bar-On and Prinsen, 1999).

There have been several warnings that increased global warming is expected to undermine agriculture (Simonsson, 2005) and forest ecosystem productivity (Delire *et al.*, 2008) and to reduce water supplies and quality (Harvey 2007), with devastating socio-economic impacts on communities whose survival is anchored to forest ecosystem goods and services (FEGS) (Brown *et al.*, 2007). Forest ecosystems provide goods and services that create opportunities for development, contribute to human well-being and represent a common heritage with livelihood portfolios shared by the great majority of people, especially in developing countries (Daily, 1997; Nkem *et al.*, 2007). The ecosystem-based adaptation refers to the use of ecosystem goods and services for planning adaptation and the ecosystem approach is intended to manage human activities in ecosystems (Bunch *et al.*, 2008), which in this case are crucial for the provision of ecosystem goods and services while also safeguarding the integrity of the ecosystem.

The role of FEGS is well understood and has been clearly recognized in the NAPA documents of some countries. However, there are still knowledge gaps in the understanding of direct and indirect benefits that communities obtain from forest ecosystems. This lack of a common understanding distorts policy and programme design, and at times hinders the development of cross-sectoral institutional alliances. Most stakeholders outside the forestry sector have little knowledge of the benefits they get from FEGS (Lange, 2003). Subsequently, the lack of knowledge can influence programming and implementation of climate change adaptation interventions that directly impact the sources of well-being for rural communities.

In many African countries, adaptation strategies were developed either from the NAPAs or were related to other individual governments' efforts in undertaking activities to cope with the effects of climate change. Some adaptations strategies and actions implemented in African countries have involved many stakeholders (local communities, local government, civil servants, government, etc.) with variable results. There are examples of failed adaptation strategies and actions as well as successful experiences.

3.2.5.1 Funding

The long time it takes for the funding agencies to approve projects for funding constrains the perceived urgent implementation of NAPAs, and therefore undermines the urgency that should characterize responses to climate change. The NAPAs are intended to enable LDCs to identify and prioritize activities that require urgent and immediate action for adaptation to climate change (UNFCCC, 2009); but this scheme is rendered redundant when the identified 'urgent and immediate' activities remain unimplemented, in some cases for more than three years because of lack of funding.

3.2.5.2 Stakeholder participation

In many African countries, stakeholders like the ministries in charge of decentralization, economy and development, and relevant NGOs often do not participate in the implementation of identified NAPA projects, mainly because they had not been involved in the initial planning stage or because they are unaware of what they are expected to do. Public participation in implementation of NAPA priority projects will therefore be determined by the level of awareness and clearly defined stakeholder roles. For example, in Burkina Faso stakeholders participating in the implementation of NAPA projects include, among others, the ministries responsible for environment, transport (in charge of meteorological information), livestock, agriculture, and water resources.

Some stakeholders, however, may not participate even if they are aware mainly because there are no clearly defined roles for the stakeholders or because climate change is not part of their programme portfolios.

3.2.5.3 Political will

Political will is an important factor in the realization of NAPAs, and its lack impedes the implementation of various activities. This is because on one hand, parliamentarians are responsible for approving bills and annual budgets allocated to ministries, and if climate change adaptation is not of budgetary priority, it may not receive adequate government financing.

On the other hand, representatives of donor countries emphasize that governments negotiate bilateral agreements with donor governments. It is at this stage in the negotiations that the recipient government presents its priority projects for funding. So if climate change adaptation is not included as a priority, it may never be funded through bilateral arrangements. Donor countries give recipient governments what they ask for.

National forest programmes are the core instruments of new forest governance arrangements at the national level; they can promote the adaptation of forests to climate change by reinforcing the use of sustainable forest management as a mechanism for reducing deforestation and forest degradation.

The following are some recommendations for enhancing effective implementation of NAPA priority projects in Africa:

- The use of an ecosystem approach for NAPA projects should be encouraged since all priority sectors relate to ecosystem goods and services. This approach will improve the adaptive capacity of poor communities and promote co-benefits, thereby increasing the cost effectiveness and efficiency of implemented actions.
- NAPA implementation should be integrated with other national strategy plans, for example national biodiversity strategy, national water resources strategy, and Poverty Reduction Strategies (PRSPs). This would ensure that NAPA priority projects are tailored into other existing initiatives that are being implemented by various government ministries and/or NGOs. This is also crucial in cost-saving and efficient resource utilization.
- Stakeholder participation in implementing NAPA priority projects depends on their level of awareness and resources available to them. There is great need for raising awareness at both national and community levels. While print (copies of NAPA documents and newspapers) may be a suitable dissemination tool at the national level (ministries, NGOs, funding partners, research institutions), the same may not be the case with local communities, especially to populations whose capabilities to understand climate change issues are limited by high illiteracy levels and/or the complexity of the issue. Tools such as community meetings and workshops, national radio and television broadcasts should be used to reach out to a large number and a variety of audiences.
- In implementing NAPAs there will be need for monitoring and evaluation to enable countries to revise their priorities and to improve current adaptation priorities. This will also be important for reporting, reviewing and up-scaling of successful cases.

3.3 Nationally Appropriate Mitigation Actions (NAMAs) and other experiences related to forests

Mitigation of climate change is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases. NAMAs are voluntary emission reduction measures undertaken by developing countries and are reported by national governments to the UNFCCC. They are expected to be the main vehicle for mitigation action in developing countries, and can be policies, programs or projects implemented at national, regional, or local levels. The NAMAs are a relatively new concept, and consequently opportunities for developing countries to develop NAMAs to support low carbon development and mobility have not been fully realized.

Many countries have developed and submitted their NAMA reports to the UNFCCC Secretariat. They have developed actions and budgets for mitigating the effects of climate change, and therefore seek funding support for their implementation. NAMA submissions that seek international support must contain sufficient information for them to be evaluated and appraised, although it is important that the concept remains open and flexible. The process for accessing support for the NAMAs should also be relatively unbureaucratic, in order to help ensure that the necessary financial, technology transfer, and capacity building support is provided in a timely manner; and that momentum is not lost. This should apply both to support for implementation of plans and also to wider enabling factors, such as capacity building and to fulfill the Measurable, Reportable and Verifiable (MRV) requirement (Holger and Anne, 2010).

Financial support is presently provided on an ad-hoc basis to support these actions. Following Article 4, paragraph 3, of the UNFCCC, developed country Parties are obliged to provide enhanced financial support, among other things, to developing country Parties to support the preparation and implementation of the NAMAs.

3.3.1 Forest mitigation related actions in Africa

3.3.1.1 Initiatives on mitigation of climate change

The Kyoto Protocol to the UN Climate Change Convention that was adopted in 1997 and entered into force in 2005 has established innovative mechanisms to assist developed countries to meet their emissions commitments. The Protocol created a framework for the implementation of national climate policies, and stimulated the creation of the carbon market and new institutional mechanisms that could provide the foundation for future mitigation efforts (Geoff, 2009). The first commitment period of the Kyoto Protocol within which developed countries included in Annex I to the Protocol are to achieve their emission reduction and limitation commitments ends in 2012. The Protocol has an accounting and compliance system for this period, with a set of rules and regulations. Developed countries are under an obligation to demonstrate that they are meeting their commitments.

APF (2009) noted that in addition to stipulating the domestic actions that should be undertaken by developed country Parties, the Protocol has flexible mechanisms through which developed countries can achieve their emissions reduction commitments. These include Emissions Trading, Joint Implementation (JI), and the Clean Development Mechanism (CDM). Of interest to African forestry is the CDM which allows developed countries to invest in green projects that reduce carbon emissions in Africa and other developing countries. The credits earned from CDM projects can be purchased and used by industrialized countries to meet part of their emission reduction commitments under the Kyoto Protocol. However, CDM has so far largely bypassed the African forestry sector – partly because of reasons specific to the CDM and partly because of the policy framework and investment conditions in many African countries. While the CDM was initially praised as an opportunity for Africa to achieve sustainable development, it has not worked well for African forestry. The potential for CDM growth in Africa seems to be further impeded by the continent's low greenhouse gas emissions and the sectoral bias in favour of highly emitting industrial sectors, consequently the development of large-scale CDM projects is constrained. Furthermore, while the Kyoto Protocol allows for the registration of afforestation and reforestation projects under the CDM framework, this can only be done as defined under the Kyoto protocol. These conditions seriously limit African participation in CDM. Also, current regulations within the European Emissions Trading Scheme (EU-ETS), the world's largest carbon emission credit market, does not allow for the use of emission credits from African forest-based projects. More information on this subject is provided in chapter 13.

3.3.1.2 Status of negotiations on mitigation for Africa

Chapter 4 discusses in more detail how negotiations on climate change have progressed over the years. However, only a few highlights will be given in this section and in relation to NAMAs, NAPAs and REDD/REDD+.

The 13th Conference of Parties to the Climate Change Convention (COP13) in June 2007 resolved to urgently enhance implementation of the Convention. To achieve this objective, COP13 launched the Bali Action Plan, which identifies seven specific issues relating to mitigation that should be addressed, and they include:

- Mitigation commitments or actions by all developed country Parties taking into account differences in their national circumstances;
- Nationally appropriate mitigation actions by developing country Parties in the context of sustainable development;
- Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation (REDD)

and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries;

- Cooperative sectoral approaches and sector-specific actions, in order to enhance implementation commitments by all countries so as to reduce greenhouse gas emissions;
- Various approaches, including opportunities for using markets, to enhance the cost-effectiveness of, and to promote, mitigation actions, bearing in mind different circumstances of developed and developing countries;
- Economic and social consequences of response measures on climate change; and
- Ways to encourage multilateral bodies, the public and private sectors and civil society as a means to support mitigation in a coherent and integrated manner. (APF, 2009.)

At the negotiating meeting in June 2009, countries expressed divergent views on enhanced action on mitigation. Several developing countries, including the African Group, and developed countries highlighted the need for legally binding emission reduction targets by all developed countries. A number of developed countries stressed the need for mitigation commitments from advanced developing countries. The following is a summary of the then contentious issues in the negotiations on enhanced action on mitigation:

- Whether or not to have legally binding emission reduction targets for all developed countries or only those listed in Annex I to the Kyoto Protocol;
- Whether or not to have legally binding emission reduction targets for advanced developing countries;
- The sufficiency of nationally appropriate mitigation actions (NAMAs) and whether or not NAMAs should be legally binding;
- Links between developing country mitigation action and developed country financial support;
- Whether or not monitoring, reporting and verification of mitigation actions (MRV) should be voluntary or mandatory; and
- The relative importance of public finances and sourcing from carbon markets to support mitigation actions in developing countries. (APF, 2009.)

During COP16 in December 2010, considerable progress was made on this through *"Decision 1/CP.16, The Cancún Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention"*.

The Cancún Agreements took a step further and came up with several decisions including the following:

"48. *Agrees* that developing country Parties will take nationally appropriate mitigation actions in the context of sustainable development, supported and enabled by technology, financing and capacity-building, aimed at achieving a deviation in emissions relative to business as usual emissions in 2020;

50. *Invites* developing countries that wish to voluntarily inform the Conference of the Parties of their intention to implement nationally appropriate mitigation actions in association with this decision to submit information on those actions to the secretariat;

51. *Requests* the secretariat to organize workshops, to understand the diversity of mitigation actions submitted, underlying assumptions, and any support needed for implementation of these actions, noting different national circumstances and respective capabilities of developing country Parties;

52. *Decides* that, in accordance with Article 4, paragraph 3, of the Convention, developed country Parties shall provide enhanced financial, technological and capacity-building support for the preparation and implementation of nationally appropriate mitigation actions of developing country Parties and for enhanced reporting by these Parties;

53. *Also decides* to set up a registry to record nationally appropriate mitigation actions seeking international support and to facilitate matching of finance, technology and capacity-building support to these actions;

54. *Invites* developing country Parties to submit to the secretariat information on nationally appropriate mitigation actions for which they are seeking support, along with estimated costs and emission reductions, and the anticipated time frame for implementation;

61. *Also decides* that internationally supported mitigation actions will be measured, reported and verified domestically and will be subject to international measurement, reporting and verification in accordance with guidelines to be developed under the Convention;

62. *Further decides* that domestically supported mitigation actions will be measured, reported and verified domestically in accordance with general guidelines to be developed under the Convention;

63. *Decides* to conduct a process for international consultations and analysis of biennial reports in the Subsidiary Body on Implementation, in a manner that is non-intrusive, non-punitive and respectful of national sovereignty; the international consultations and analysis aim to increase transparency of mitigation actions and their effects, through analysis by technical experts in consultation with the Party concerned, and through a facilitative sharing of views, and will result in a summary report;

64. *Also decides* that information considered should include information on mitigation actions, the national greenhouse gas inventory report, including a description, analysis of the impacts and associated methodologies and assumptions, progress in implementation and information on domestic measurement, reporting and verification and support received; discussion about the appropriateness of such domestic policies and measures are not part of the process. Discussions should be intended to provide transparency on information related to unsupported actions;

65. *Encourages* developing countries to develop low-carbon development strategies or plans in the context of sustainable development;

66. *Agrees* on a work programme for the development of modalities and guidelines for: facilitation of support to nationally appropriate mitigation actions through a registry; measurement, reporting and verification of supported actions and corresponding support; biennial reports as part of national communications from non-Annex I parties; domestic verification of mitigation actions undertaken with domestic resources; and international consultations and analysis;

67. *Invites* Parties to submit views on the items in paragraph 66, including with respect to the initial scheduling of the processes described in this section, by 28 March 2011." (*http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2*.)

In relation to REDD+ the decision is described in paragraph 70 of the AWG/LCA outcome:

"Encourages developing country Parties to contribute to mitigation actions in the forest sector by undertaking the following activities, as deemed appropriate by each Party and in accordance with their respective capabilities and national circumstances:

a) Reducing emissions from deforestation;
b) Reducing emissions from forest degradation;
c) Conservation of forest carbon stocks;
d) Sustainable management of forest;
e) Enhancement of forest carbon stocks." (*ibid*).

Further, financing mechanisms are provided for, including the establishment of a Green Climate Fund to be operated by the Convention. Measures for capacity building and technology development and transfer are provided for in the Cancún Agreements. Also the Cancún Agreements provide "Guidance and safeguards for policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries".

It is expected that COP17 in Durban, South Africa, will take this further in December 2011.

3.4 Conclusion

In Africa, various initiatives have been developed in terms of adapting people and forests to cope with climate change, either by the local communities themselves and out of their own volition, or through initiatives promoted by governments, the international community and other stakeholders. These initiatives started in the early 1980s in many countries. They have since been incorporated in the national adaptation and mitigation programmes within the framework of the United Nations Framework Convention on Climate Change. The emphasis in these approaches is the necessity to integrate all key sectors related to climate change so that holistic programmes are developed and implemented by all relevant stakeholders for the benefit of all people, their governments and the environment.

However, the international negotiations on climate will continue to shape our thinking on climate change, how relevant plans are made, resources for their implementation secured, and modalities for their implementation defined.

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Chapter 4
FORESTS IN INTERNATIONAL ARRANGEMENTS ON CLIMATE CHANGE: THE AFRICAN EXPERIENCE AND PERSPECTIVE

Macarthy A. Oyebo

4.1 Introduction

4.1.1 Background

The report of the World Commission on Environment and Development (WCED), also known as the 'Brundtland Report' drew world attention to "the accelerating deterioration of human environment and natural resources, and the consequences of that deterioration for economic and social development" (WCED, 1987). The report, aptly titled 'Our Common Future', dealt with sustainable development and the changes in politics needed for achieving that. Sustainable development was defined as "the development that meets the needs of the present without compromising the ability of the future generations to meet their own needs". The report advanced understanding of global interdependence and the relationship between economics and the environment.

The United Nations Conference on Environment and Development (UNCED), in Rio de Janeiro in 1992, provided a forum for governments to build on the Brundtland Report by agreeing on common actions, in the context of the famous Agenda 21, to ensure development into the 21st century. Among other outcomes of the Conference was the adoption of three conventions (commonly referred to as the Rio conventions), namely the United Nations Convention on Biological Diversity (CBD), the United Nations Convention on Combating Drought and Desertification (UNCDD) and the United Nations Framework Convention on Climate Change (UNFCCC) .

The UNFCCC is an environmental treaty with a focus on climate change, which is now considered to be the most serious threat to sustainable development, with adverse effects on health, food security and economic activity. Scientists agree that rising concentrations of anthropogenically-produced greenhouse gases (GHGs) in the earth's atmosphere are leading to changes in climate. Scientists have now agreed that global warming is causing the greatest and most rapid climatic change in the history of humankind. It will also have enormous consequences for all life on earth. The international political response to climate change was, therefore, strengthened with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The UNFCCC sets out the framework for actions aimed at stabilizing atmospheric concentrations of greenhouse gases to avoid dangerous anthropogenic interference with the climate system. The UNFCCC entered into force on March 21 1994 and as of December 2009 it had 192 parties.

Given its enormity and seriousness, and the urgency to contain climate change, international action on climate change began with the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The mandate of IPCC is to assess the scientific, technical and socio-economic information relevant to understanding the risks associated with human-induced climate change, its potential impacts and options for adaptation and mitigation. Since its inception, the IPCC has published four Assessment Reports (ARs), in 1990, 1995, 2001 and 2007 that provide scientific information on climate change to the international community, including policy makers and the public. The Assessment Reports have played an important role in framing national and international policies including advancing climate change negotiations under the UNFCCC.

4.1.2 Conferences of Parties (COP) to the UNFCCC

Parties to the UNFCCC hold a meeting annually referred to as the 'Conference of Parties' (COP). The first COP was held in Berlin in 1995. One of the roles of the COP is to promote and review the implementation of the UNFCCC. It also reviews existing commitments in the light of the Convention's objectives, new scientific findings and the effectiveness of national climate change programmes.

4.1.3 The Kyoto Protocol (KP)

At the third COP, held in Kyoto, Japan, in 1997 the parties established the Kyoto Protocol, which set out emission reduction targets for industrialized countries and countries with economies in transition (identified as Annex I parties). The parties agreed that Annex I parties should reduce their overall emissions of six greenhouse gases by an average of 5.2% below their levels in 1990 in the period 2008–2012, with a specific target for each country. The period 2008–2012 is known as the first commitment period. The Kyoto Protocol (KP) entered into force on February 16, 2005, and has now been signed and ratified by 187 countries. (*http://en.wikipedia.org/wiki/Kyoto_Protocol*).

In order to assist the industrialized countries meet their emission targets, the Kyoto Protocol created three flexible mechanisms: Emission Trading (ET), Joint Implementation (JI) and the Clean Development Mechanism (CDM). Emission Trading and Joint Implementation take place among Annex I countries within the framework of emission reduction commitments, while with CDM, Certified Emission Reductions (CERs) generated by projects in developing countries could be traded and used by Annex I countries to meet their commitments under the Protocol. CDM provides developing countries the incentive to participate in emission reduction, through trade in carbon, while pursuing sustainable development; JI and CDM are 'projects based' mechanisms, because they fund actual projects. CDM is the only part of the Kyoto Protocol which directly involves developing countries in reducing greenhouse gas emission.

4.2 Highlights of relevant Conferences of Parties

4.2.1 The 'Forest COPs'

Forest issues first surfaced prominently in COP6, COP6bis (that is unfinished COP6), COP7 and COP9, all dubbed the 'Forest COPs'. COP6, held in The Hague in 2000, debated, but failed to reach agreement, over several issues relevant to Land Use and Land Use Change and Forestry (LULUCF). COP6bis, held in Bonn in 2001, produced a draft agreement (the Bonn Agreement) which the parties added to and adopted at COP7 in Marrakesh, Morocco in November 2001, to yield what is commonly referred to as the Marrakesh Accords. These included a decision on modalities and procedures for operating the CDM, covering the composition and functioning of the CDM Executive Board, requirements for participation of Annex I and non-Annex I parties; procedures for accreditation of Designated Operational Entities (DOEs), validation and registration of projects, monitoring, verification and certification of emission reductions, leading to the issuance of Certified Emission Reduction (CER) credits.

Delegates agreed that each country participating in the CDM must establish a Designated National Authority (DNA) tasked, among other things, with approving projects. They also decided that small scale projects may benefit from simplified modalities and procedures.

In effect the Marrakesh Accords set out the rules for CDM projects with the exception of those involving forestry projects. However they determined that forestry projects be restricted to afforestation and reforestation (A/R) projects, and set a limit on their use. This meant that the assigned amount resulting from eligible Land Use and Land Use Change and Forestry (LULUCF) project activities under the Clean Development Mechanism should not exceed one percent of base year emissions of the party times five.

4.2.2 Other COPs and meetings on the Kyoto Protocol

4.2.2.1 COP9 and COP10

COP9, held in Milan, Italy, in December 2003, reached agreement on modalities and procedures for afforestation and reforestation projects (sink projects) under the CDM first commitment period. COP9 also initiated work on simplified modalities and procedures for small scale sink projects under the CDM. These were finalized by COP10, held in Buenos Aires, Argentina, in December 2004.

For technical guidance, especially for the monitoring methodology, the Parties agreed that the Good Practice Guidance for Land Use, Land Use Change and Forestry (GPG-LULUCF) of IPCC should be consulted. The document is the response to the invitation by UNFCCC to develop good practice guidance for estimating, measuring, monitoring and reporting on carbon stock changes for greenhouse gas emissions from LULUCF activities under Article 3, paragraphs 3 and 4 and Articles 6 and 12 of the Kyoto Protocol (*http://unfccc.int/resource/docs/convkp/kpeng.pdf*).

4.2.2.2 COP/MOP1

The first conference of parties serving as the meeting of the parties to the Kyoto Protocol (COP/MOP1) took place in Montreal Canada from 28 November to 10 December 2005. The meeting formally adopted the Marrakesh Accords; and established a Subsidiary Body – the Ad Hoc Working Group on Further Commitments – for industrialized countries beyond the first commitment period. On CDM, the meeting adopted a decision addressing issues related to governance, methodologies and additionality, and COP/MOP requested submission from parties on systematic barriers to equitable distribution of CDM projects in response to concerns raised over regional distribution of projects and lack of projects in Africa.

4.2.2.3 COP/MOP2

This took place in Nairobi, Kenya, in November 2006 and, among other activities, carried out the first review of the Kyoto Protocol. The meeting addressed several issues relevant to developing countries, including CDM and equitable distribution of CDM projects and establishment of the 'Nairobi Framework' to catalyze CDM in Africa. The objective of the Nairobi Framework is to help developing countries, especially those in sub-Saharan Africa, to improve their level of participation in CDM.

4.2.2.4 COP13 and COP/MOP3

This took place on 3–15 December 2007, in Bali, Indonesia, with the main focus on long term international cooperation on climate change. But the negotiators spent much of their time seeking to agree on a two-year process, or 'Bali road map' to finalize a post-2012 regime by COP15 in

December 2009, in Copenhagen. COP13 established the Ad Hoc Working Group on Long-term Cooperative Action (AWP-LCA). COP/MOP3 considered preparations for the second review of the Kyoto Protocol. The meeting also decided to abolish the registration fee and adaptation levy from CDM projects implemented in least developed countries. The COP/MOP encouraged the Nairobi Framework partners to accelerate their activities to catalyze the CDM in Africa.

The UNFCCC announced plans to establish the African Carbon Forum in collaboration with the International Emissions Trading Association (IETA) and the Nairobi Framework partner organizations, including UNEP, World Bank and the African Development Bank. In 2007, parties also concluded a decision entitled Reducing Emission from Deforestation and Forest Degradation (REDD).

4.2.2.5 COP14 and COP/MOP4

COP14 and the 4th Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol (COP/MOP4) were held in Poznan, Poland, on 1–12 December 2008. The outcomes of the meeting covered a wide range of topics, including the Adaptation Fund under the Kyoto Protocol, the 2009 programmes for the Ad Hoc Working Group on Long-term Cooperation Action (AWG-LCA) and Ad Hoc Working Group-Kyoto Protocol (AWG-KP), and outcomes on technology transfer, the Clean Development Mechanism (CDM), capacity building, national communication, finance and administration matters and various methodological issues.

The main focus in Poznan was on long-term cooperation and the post-2012 period, at the expiry of the Kyoto Protocol's first commitment period, in December 2012. The Bali meeting had already approved the Bali Action Plan and roadmap that set COP15 (in December 2009) as the deadline for agreeing on a framework for action after 2012. The Poznan meeting, therefore, marked the half way work towards the December 2009 deadline. While the Poznan negotiations resulted in some progress, there were no significant breakthroughs. The subsequent 12 months were to be hectic for negotiators in order to meet the critical deadline of December 2009 in Copenhagen, Denmark, for COP15.

4.2.2.6 COP15 and COP/MOP5

COP15 and COP/MOP5, held in Copenhagen, Denmark, 7–18 December 2009, were expected to deliver a legally binding outcome in the form of amendment to the Kyoto Protocol for the second commitment period for Annex I parties. Developed countries were expected to honour their legally binding commitment for a second commitment period and also honour their other commitments under the convention relating to *adaptation, finance and technology*. The international community was to ensure that the global architecture that was to be put in place by the UNFCCC should take cognizance of the opportunities for developing countries to implement REDD in ways that deliver benefits related to poverty reduction, human rights protection, as well as promotion of livelihoods. Benefits were likely to be greatest and risk minimized, if REDD financial flows and national level implementations were harmonized with other pre-existing international commitments and national development strategies.

A key challenge was to design appropriate procedural standards including assessment, monitoring and verification mechanisms. This was to ensure that risks and opportunities were recognized without imposing excessive transaction costs that work to the detriment of achieving REDD objectives and benefits.

The main accomplishment of COP15, however, was to 'take note' of the *Copenhagen Accord*, which was a three-page non legally-binding document that was negotiated by what several developing countries regarded as a non-transparent and non-inclusive process. Only a selected group of 26 countries produced the document.

The Accord requested Annex I parties to commit to implement individually or jointly the quantified economy-wide emission targets for 2020 to be submitted in a format given as Appendix I to the UNFCCC Secretariat by 31 January 2010, while non-Annex I parties to the Convention were to implement mitigation actions, reporting same to the UNFCCC Secretariat by 31 January 2010 in a format given as Appendix II. Most relevant to forestry was the recognition of the crucial role of REDD, and agreement on the need to provide positive incentives to such actions, including REDD plus, through the immediate establishment of a mechanism to enable the mobilization of financial resources from developed countries.

It is noteworthy that the Executive Secretary of the UNFCCC, on 25 January 2010, clarified that since the COP neither adopted nor endorsed the Accord, but merely took note of it, its provisions do not have any legal standing within the UNFCCC, even if some parties associate with the Accord. Secondly, the Secretariat clarified that since the Accord is a political agreement rather than a treaty instrument subject to signature, a single letter or *note verbale* to the Secretariat from the appropriate authority of Government is sufficient to communicate the intention of a party to associate with the Accord.

4.2.2.7 COP16 and COP/MOP6

UNFCCC COP16 and COP/MOP6 were held in Cancún, Mexico, from 29 November to 11 December 2010, and ended with the adoption of a balanced package of decisions that set all governments more firmly on the path towards a low-emissions future, and support for enhanced action on climate change in the developing world. The package, dubbed the 'Cancún Agreements', provided, among other things for curbing emissions from the forestry sector in developing countries, with technological and financial support, through:

a) Reducing emissions from deforestation.
b) Reducing emissions from forest degradation.
c) Conservation of forest carbon stocks.
d) Sustainable forest management.
e) Enhancement of forest carbon stocks.

Countries undertaking the above are required, among other things,

a) to develop:
- a national strategy or action plan,
- a national forest reference emission level and/or forest reference level,
- a robust and transparent national forest monitoring and reporting system, and

b) to address, *inter alia*, drivers of deforestation and forest degradation, land tenure issues, forest governance issues, gender considerations and safeguards ensuring full and effective participation of relevant stakeholders, including indigenous people and local communities.

At Cancún, countries agreed also to the formation of a *Green Climate Fund* that will be governed by a board of 24 members comprising an equal number of members from developing and developed country parties. The Fund is to be managed under the auspices of the UN rather than the World Bank, although the World Bank is to be involved as the interim trustee of the Fund, subject to a review three years after its launch.

The formation of the *Green Climate Fund* is expected to serve to simplify the present complicated network of funding mechanisms and bilateral agreements that currently provide low carbon and climate adaptation investment for developing countries with the final agreement stating that a significant share of climate adaptation spending will flow through the new fund.

The agreement, however, did not state clearly how the funding will be raised. This only points to the fact that parties remained committed to providing USD 100 billion a year of climate funding from 2020 that will be generated from a wide variety of sources, namely public and private, bilateral and multilateral, including other alternative sources.

4.3 The role of forests in climate change

4.3.1 Forests as CO_2 sinks

Forests are important carbon pools which continuously exchange CO_2 with the atmosphere, due to both natural processes and human action. That climate change was eventually to affect forestry had become obvious by 1989 when ministers responsible for environment from 68 nations proposed afforestation of 12 million hectares annually in the Noordwijk Ministerial Declaration on Climate Change (IUCC, 1993). Today it is acknowledged that forests can help mitigate climate change, need to be adapted to it and may help humanity in coping with its effects.

At the global level, 19% of the carbon in the earth's biosphere is stored in plants, and 81% in the soil. In all forests, tropical, temperate and boreal together, approximately 31% of the carbon is stored in biomass and 69% in the soil. In tropical forests approximately 50% of the carbon is stored in the biomass and 50% in the soil (IPCC 2007). Wood products derived from harvested timber are also significant carbon pools. Their longevity depends upon their use – lifetimes may range from less than one year for wood fuel to several decades or centuries for lumber. Oxidation of carbon in organic matter and the subsequent emission of CO_2 result from the following processes:

- Respiration of living biomass.
- Decomposition of organic matter by other living organisms.
- Combustion.

Removing CO_2 from the atmosphere for the process of photosynthesis explains why forests function as CO_2 sinks.

4.3.2 UNFCCC, the Kyoto Protocol and forestry

UNFCCC stipulates that all countries have a commitment to promote sustainable management of sinks and reservoirs of all greenhouse gases, including biomass, forests and other ecosystems. The Kyoto Protocol of the UNFCCC sets commitments to developed countries (Annex I parties) to stabilize their greenhouse gas emissions in the period 2008–2012. A major part of the greenhouse gas emission limitations is expected to take place in energy, industry, transport, agriculture and waste sectors. According to the Protocol developing countries (non-Annex I parties) are also accountable for emissions resulting from land use change since 1990 due to afforestation, reforestation and deforestation. This implies that developing countries have a clear incentive to reduce deforestation and greenhouse gas emissions resulting from deforestation.

Discussion concerning forest degradation started in the run-up to the agreement on additional land use activities under the Kyoto Protocol. The concern was that some emissions from forest degradation would be omitted from the accounting system. The Intergovernmental Panel on Climate Change (IPCC) was invited to explore the methodological issues related to forest degradation and devegetation. In 2003, IPCC prepared a report on *Definitions and Methodological Options to Inventory Emissions from Direct Human Induced Degradation of Forests and Devegetation of other Vegetation Types*. The report discusses, *a)* alternative definitions and provides possible framework definitions for countries to consider; *b)* methodological options to inventory emissions from degradation and devegetation activities, *c)* approaches to reporting and documentation, and *d)* implications of methodological and definitional options for accounting under the Kyoto Protocol.

Land use, land-use change and forestry (LULUCF) are major sources of carbon emissions. Land-use change is estimated to release 1.6 billion tonnes of carbon a year, most of it through tropical deforestation. Yet avoidance of deforestation was rejected in CDM in the Marrakesh Accords, partly because of unresolved issues regarding disproving spurious threats to forests, and especially leakage, non-permanence and additionality.

From a climate change policy perspective, deforestation results in immediate release of the carbon originally stored in trees as CO_2 emission (along with small amounts of CO and CH_4), particularly if the trees are burned, and slower release of emissions from the decay of organic matter. IPCC (2007) estimated that the rate of emission from deforestation in the 1990s was 5.8 $GtCO_2$/yr, representing nearly 20% of global CO_2 emissions. IPCC also noted that reducing and/or preventing deforestation is the mitigation option with globally the largest and most immediate carbon stock impact in the short term, as release of carbon as emission into the atmosphere is prevented.

4.3.3 Introduction of REDD into UNFCCC Agenda

Reducing emissions from deforestation in developing countries and approaches to stimulate action (REDD) was first introduced into UNFCCC agenda at COP11 in December 2005, at the request of the governments of Papua New Guinea and Costa Rica, supported by eight other countries. There was general agreement on the importance of the contribution of emissions from deforestation in developing countries to global greenhouse gas emissions. At the instance of COP11, therefore, two workshops were organized on the subject by the UNFCCC Secretariat. These were held at FAO (Rome) in 2006 and 2007, and discussed scientific, socio-economic, technical and methodological issues and policy approaches and incentives for REDD, while in December 2007 the Subsidiary Body on Scientific and Technological Advice (SBSTA), at its 26th Session, followed by drafting texts on REDD, which were finalized in the light of discussions on Long Term Cooperative Action at COP13. In 2008 and 2009, policy approaches and positive incentives relating to REDD and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries were considered under the UNFCCC process as part of the Bali Action Plan.

4.3.4 REDD+ adopted in principle

The 28th session of SBSTA was held in Bonn, Germany, in June 2008 and was followed by the third REDD workshop in Tokyo, Japan, to share views on methodological issues. In December 2008 SBSTA29 and COP14 in Poznan, Poland, invited Parties to submit their views on needs for technical and institutional capacity – building and cooperation, and on issues relating to indigenous peoples and local communities. Between March and April 2009, the Ad-hoc Working Group on Long-term Cooperative Action (AWG-LCA), considered several aspects of REDD and endorsed REDD+ in principle, and by June 2009, the 30th session of SBSTA drafted negotiation texts for COP15 in Copenhagen, Denmark.

4.3.5 How the international climate change agreements address forests

From the foregoing, it is clear that both the UNFCCC and the Kyoto Protocol recognize the importance of forestry in addressing climate change. They, in fact, list general obligations regarding forests that apply to all member countries, who should:

- Promote sustainable forest management.
- Promote and cooperate in the conservation and enhancement of forests as sinks and reservoirs of greenhouse gases.
- Promote afforestation and reforestation as well as renewable energy.
- Consider forests as part of national inventories of greenhouse gas emissions and renewals, in technology transfer and in national programmes of adaptation to climate change.

Despite this, however, forestry, and in particular African forestry, has not featured significantly in arrangements such as the CDM for addressing climate change. Some reasons for this are presented below.

4.3.6 Why African forestry has not featured significantly in CDM

Reasons advanced by Desanker (2005) for the low participation of African forestry in CDM include:

1. Prohibitive costs and lack of investment capital to develop forest projects over the many years before income from emission trading starts to accrue.

2. Lack of private investors for afforestation and reforestation, since these activities have typically been carried out through government or donor supported development projects in most of Africa.

3. Uncertain markets for emission reductions, especially the reluctance by many buyers in developed countries to consider credits from forestry activities.

4. The complexity of the processes for developing projects to completion especially the preparation of methodologies and the lack of national technical capacity to develop methodologies without reliance on expensive international technical support.

5. Lack of adequate international institutional capacity for the various steps in a CDM project from mobilization of resources to certification and validation for the diversity of situations in the many African countries.

6. Lack of institutional capacity in Africa for implementing all the requirements of CDM participation, such as the establishment of a Designated National Authority (DNA) whose role is to define sustainable development criteria and facilitate private investment in CDM activities.

7. Difficulties in identifying eligible projects. Eligible sink projects ought to be on land that had no forest as at December 1989. Data sources for demonstrating this may be limited. Although aerial photocopy of satellite imagery may be available, their scale is often inadequate to authenticate small scale projects; land use records are usually not available in most African countries.

8. Projects are also required to demonstrate additionality and the absence of leakage (emissions shifted elsewhere as a result of the project). Since in most instances, many African countries rely heavily on wood fuel for domestic energy needs, it becomes difficult to fund eligible forestry activities that can be regarded as truly additional and not displace existing land use practices important to people's livelihoods like grazing and fuel wood harvesting or shift related emissions elsewhere.

Another challenge to African forestry was the acceptance into CDM of only small scale bio-energy projects that could replace fossil fuels. This excluded most innovative projects aimed at replacing unsustainable fuel-wood use with solar energy, sustainable biomass or biogas. It also excluded projects aimed at reducing unsustainable fuel-wood use through more efficient cooking stoves.

Since the African forestry sector has not benefited much from the CDM or the voluntary carbon market, vigorous efforts are needed to address the inadequate technical capacity and policy and institutional constraints of the region in order to be able to take advantage of REDD.

4.4 Africa in climate change negotiations

4.4.1 Challenges to Africa in the negotiations

Although the African continent remains the most vulnerable region in the world to climate change, especially because it lacks the capacity to adapt to the adverse effects of climate change, African voices are scarcely heard at climate change negotiations. Main reasons for this include *1)* inadequate representation because of limited funds; often only the national focal point whose sponsorship is financed by the UNFCCC Secretariat attends international meetings, leaving many negotiating sessions or committees that run in parallel and where critical decisions are made without adequate African representation, *2)* lack of continuity in following debates because of frequent changes in delegates, *3)* inadequate preparatory meetings at both regional and country levels because of funding constraints, *4)* difficulties of negotiating under the umbrella of G77 plus China because of conflicting climate change profiles of such members as China, India and Brazil in the group, and *5)* language barriers to accessing and exchanging information among anglophone, francophone and lusophone African delegates, despite the operation of such facilities as the websites of the Intergovernmental Agency for the French-speaking World (*http://www.francophonie.org/*), the Climate Convention Secretariat (*http://unfccc.int/portal_francophone/items/3072.php)*, the French Inter-Ministerial Mission for the greenhouse effect, and of the Senegal-based NGO, ENDA.

4.4.2 Developing a common negotiating position for Africa

The African Ministerial Conference on Environment (AMCEN) at its twelfth session held in Johannesburg in June 2008 took landmark decisions on:

1. Africa's preparations for developing a common negotiating position on a comprehensive international climate regime beyond 2012, and

2. developing a comprehensive framework of African climate change programmes.

Subsequently, meetings of the African Group of negotiators, held in Accra, Algiers, Poznan and Bonn between August 2008 and April 2009, agreed on the African common climate platform to Copenhagen, called the Algiers Platform, which, among other things, provided that:

a) There should be a shared vision, based on scientific evidence and broad political consensus, accommodating the priorities for Africa of sustainable development, poverty reduction and attainment of the MDGs, in any future climate change regime. Such a regime should also provide increased support for capacity building, financing, and technology development and transfer, for adaptation and mitigation in Africa, and the stabilization of emissions in the atmosphere.

b) Africa seeks a future global emissions reduction regime with targets for all developed countries to reduce their emissions by 2020 towards the upper end of the 25–40% range for emissions reduction below 1990 levels, and by 2050 by between 80 and 95% below those levels, to achieve the concentration of 450 ppm CO_2e of greenhouse gases in the atmosphere.

c) Adaptation in Africa must be given higher priority in order to balance it with mitigation on the international negotiating agenda.

d) There is a need for a significantly upscaled adaptation financing that is new and additional, which would not divert existing Overseas Development Assistance away from poverty eradication and other development priorities, to be channeled through the Kyoto Protocol's Adaptation Fund.

e) There is a need for simplification of procedures and the removal of conditionalities to provide access to international climate funds.

f) There is the necessity for all developed countries to engage in ambitious multilateral, legally binding, absolute emission reduction as this is critical in securing carbon markets.

g) There is a need to negotiate improvements to the Clean Development Mechanism rules to enable Africa to take advantage of funds from the carbon market to support sustainable development and the transfer of climate friendly technologies to Africa.

h) National growth and poverty reduction aspirations remained key imperatives and could be supported through increased investment and incentives for technological innovations, including incentives to support home grown technology.

i) There is the necessity for regional preparations for the Copenhagen meeting in 2009 and for the recognition of the importance of regional strategies for implementation, and the involvement of women and youth in climate strategies at all levels, particularly in the areas of education, awareness raising and capacity building.

j) Africa should renew partnerships on an equitable basis with, among others, the Group of Eight, China, India, Japan, South America and European Union, through concrete projects in Africa, to deal with the global problem of climate change at the continental and sub-regional levels.

To give effect to the call for regional preparations towards the Copenhagen meeting, four related ministerial meetings were subsequently held in Bangui, Central African Republic (for the Economic Community of Central African States – ECCAS – in September 2008); Cotonou, Benin (for the Economic Community of West African States – ECOWAS – in October 2008); Nairobi, Kenya (for Common Market for Eastern and Southern Africa – COMESA – in November 2008), and in Algiers (November 2008). The first phase of AMCEN deliberations on climate change in Africa ended with the African High Level Expert Panel on Climate Change, held in Nairobi, Kenya, from 25 to 26 May 2009. The meeting served as the preparatory meeting of African experts for the special session of AMCEN on climate change also held in Nairobi on 29th May 2009. The African High Level Expert Panel included senior officials and African focal points for the UNFCCC, working in collaboration with UNEP, NEPAD and the Commission of the African Union. The expert panel was mandated to develop the common position, including a plan of action for building consensus in the region in support of a focused and coordinated approach to climate change negotiations.

4.4.3 Comprehensive framework of African climate change programme

The development of the Framework of Sub-regional Climate Change Programmes (FSCCPs) was with the goal of finalizing a Comprehensive Framework of African Climate Change Programme. This initiative was to ensure that the negotiation process informed the programmatic work being carried out on the continent and vice versa. In this regard, this part of the work was aimed at:

a) Developing FSCCPs in each of the following sub-regions: central African, west African, eastern African, southern African and north African.

b) Raising the capacities of the Regional Economic Communities, the African Union Commission and NEPAD Secretariat, to facilitate and/or prepare as well as implement FSCCPs.

c) Strengthening the capacity of AMCEN Secretariat to facilitate the development of the FSCCPs as well as other subsequent implementation activities.

4.5 Funding and mobilization of resources to accommodate the forestry sector in the climate change regime

4.5.1 Existing financing mechanisms

Existing financial mechanisms in climate change arrangements fall into two categories, namely:

1. Existing international public financing initiatives for both mitigation and adaption including both multilateral and bilateral initiatives, and
2. The Clean Development Mechanism.

Recently, there has been a proliferation of new international climate funds, which the forestry sector can take advantage of for mitigation or adaptation purposes. Taking the latter into account, existing financing mechanisms for forestry include the following:

4.5.1.1 The Global Environment Facility (GEF)

The Global Environment Facility (GEF) is at the centre of the existing system of financing programmes and projects to protect the global environment. Article 11 of the UNFCCC established a financial mechanism for the provision of financial resources on a grant or concessional basis including for the transfer of technology. At COP2, GEF was assigned the role and responsibility of operating the financial mechanism. The mechanism is accountable to the COP, which decides on its climate change policies, programmes, priorities and eligibility criteria for funding. The projects selected for GEF funding are implemented by multilateral agencies such as the World Bank, UNDP, UNEP, IFAD, FAO, UNIDO and four regional development banks – Inter-American Development Bank (IADB), African Development bank (AfDB), Asian Development Bank (ADB) and European Bank for Reconstruction and Development (EBRD).

Funding available under GEF are for *a)* The Climate Change Focal Area, covering enabling activities, mitigation and adaptation, and *b)* GEF Multi-focal Area, which includes integrated ecosystem management, under which activities relevant to forestry and climate change fall.

4.5.1.3 The Special Climate Change Fund (SCCF)

This was established to finance the special needs of developing countries, including Africa, in adaptation, technology transfer, energy, transport, industry, agriculture, forestry and waste management, and economic diversification for countries whose economies depend on the fossil fuel sector.

4.5.1.4 The Least Developed Countries Fund (LDCF)

This fund was established to cover the work on least developed countries' National Adaptation Programmes of Action (NAPA). It is to assist least developed countries to formulate funding demands to the GEF. Land use and forestry can benefit from this fund.

4.5.1.5 The Kyoto Protocol Adaptation Fund

This fund is established to finance adaptation of developing country parties to the Kyoto Protocol. The projects that could be eligible under this fund include capacity building for adaptation, conservation of tropical forests in vulnerable zones where forests contribute to adaptation, rehabilitation of degraded lands and combating desertification in Africa. This fund is operated by the GEF, and like other GEF funding, demands should originate from a host country and there is a requirement to meet certain criteria. The Adaptation Fund can potentially serve as a model for future international financial mechanisms.

4.5.1.6 Opportunities in the Clean Development Mechanism

The Clean Development Mechanism (CDM) was earlier introduced as an instrument of the Kyoto Protocol assisting Annex I countries to fulfill their emission reduction targets, while enabling non-Annex I developing countries to use clean technologies for sustainable development. In this section, the potential of the instrument as a financing mechanism for forestry is examined. Relevant to forestry is the admission of the following actions as eligible CDM projects:

- Projects inducing a reduction of greenhouse gases emissions by sources, excluding emissions from biomass combustion.
- Projects inducing an increase in removals of CO_2 by sinks through afforestation and reforestation.

Thus forestry in developing countries can benefit from CDM directly and indirectly. Forestry projects which correspond to the definitions for 'afforestation' and 'reforestation' can be certified directly as CDM projects. Indirectly, the use of biomass as a substitute for fossil energy in the form of oil, coal or natural gas, is eligible for CDM certification. The restrictions for forestry activities, embodied especially in the definitions for afforestation and reforestation, coupled with the rules that govern the CDM, account for the very low participation of the African forestry sector in this mechanism. Reasons for the low participation of African forestry in CDM and measures to remedy this are further treated in chapter 13.

4.5.1.7 The French Global Environment Facility (FFEM)

This is a bilateral fund financed by the French Government, over and above French Government's development assistance. The fund has complemented GEF activities since 1994, with the aim of financing the additional costs incurred in protecting the global environment. The eligibility criteria for FFEM are the same as for the focal areas of GEF. Of particular relevance to African forestry is the inclusion of the following activity areas as eligible for support by the Facility:

- Combating climate change, which includes carbon sequestration by forests and soils.
- Mixed biodiversity climate change projects, which facilitate the application of global environmental concepts particularly to African forestry, especially the inclusion in this area of *1)* development of appropriate tools, method-

ologies and criteria for dealing with biodiversity and climate change mitigation in forestry development projects, and *2)* creating tools and methodologies for facilitating FFEM projects that focus on combating desertification, and improving their integration into development projects.

4.5.1.8 Summary of economic instruments available to developing countries

The economic instruments that can be utilized by developing countries and their potential for forestry development are shown in Table 4.1.

4.5.2 Multilateral initiatives

Table 4.2 gives the summary of some multilateral climate change funding initiatives and the disbursement that was made to Africa under each initiative.

4.5.2.1 African Development Bank (AfDB)

The AfDB is now engaged in climate funding for the region through its Clean Energy Investment Framework (CEIF). The fund was approved in 2008 and is financed through non-concessional resources from the AfDB to provide public sponsored projects and programmes in the 15 middle-income and 'blend' countries. The 'blend' category is used to classify countries that are eligible for

Table 4.1 Economic instruments towards developing countries and their potential for forestry. Source: FAO (2003), Forest and Climate Change.

Type	Instrument	Potential for Forestry
Funds prioritized by the Convention or the Protocol	GEF climate change focal area	Biomass production and use Carbon sequestration
	GEF Multifocal area OP 12 Integrated ecosystem Management	Projects addressing climate, biodiversity and land degradation issues, e.g. rehabilitation and improved management of forested watersheds (sustainable forest management)
	Special climate change fund of the convention	Adaptation, technology transfer, forestry
	Least developed countries fund of the convention	Capacity building and adaptation priorities identification
	Adaptation Fund of the Kyoto Protocol	Conservation projects in vulnerable zones where forests constitute an adaptation measure
Mechanisms to foster North/South private and public investment flows	French fund for the global environment	Carbon sequestration in forests and soils
	CDM for GHG sinks	Afforestation and reforestation projects, as defined by COP9
	CDM for GHG sources	Substitution projects of fossil fuels by biomass
	All pilot phase	All forestry activities, as a learning experience for the CDM

Table 4.2 Summary of multilateral climate change funding initiatives. Source: http://www.climatefundsupdate.org/ *(adapted).*

Name of fund	Administered by	Funding instrument	Disbursed to Africa as at September, 2009 (million USD)
Adaptation Fund	Adaptation Fund Record UNFCCC	Grants	0
Clean Energy Investment Framework	AfDB	Part non-concessional resources, part non-guaranteed financing	0
Congo Basin Forest Fund	AfDB	Unknown	Unknown
Strategic Priority on Adaptation	GEF	Grants	9
Special Climate Change Fund	GEF	Grants	15
Least Developed Countries Fund	GEF	Grants	42
Climate Change Focal Area	GEF	Grants	407
UN-REDD Programme	UNDP	Grants	0
Strategic Climate Fund	The World Bank	Grants, Loans, Guarantees, Credits	0
Forest Carbon Partnership Facility	The World Bank	Grants	0
Clean Technology Fund	The World Bank	Grants, Concessional Loans, guarantees	0

IDA resources on the basis of per capita income but also have limited credit worthiness to borrow from IBRD. They are given access to both sources of funds, but are expected to limit IDA funding to social sector projects and use IBRD resources for projects in the 'harder' sectors.

The AfDB is also hosting the Congo Basin Forest Fund (CBFF) launched in 2008 with initial contribution of USD 200 million from the United Kingdom and Norway. Other parties are expected to contribute to the fund, which will be used to curb deforestation through local capacity building efforts in the Congo basin countries.

4.5.2.2 United Nations Development Programme (UNDP)

The UNDP runs the UN Collaborative Programme on Reducing Emissions from Deforestation and forest Degradation in Developing Countries (The UN-REDD Programme), which is a collaborative project between FAO, UNDP, and UNEP. It aims to generate the requisite flow of resources to significantly reduce global emissions from deforestation and forest degradation.

4.5.2.3 The World Bank

The World Bank, along with other multilateral development banks, developed a Climate Investment Fund (CIF) in 2008. The Fund is an interim measure to scale up assistance to developing countries and to strengthen the knowledge base in the development community. As at September 2009, about USD 6 billion had been pledged for the CIF, comprising both grants and concessional loans, to address urgent climate challenges in developing countries. CIF has been criticized for creating parallel structures for financing climate change adaptation and mitigation outside the ongoing multilateral framework for climate change negotiations and within a process dominated by G8 countries.

Table 4.3 Summary of bilateral climate change funding initiatives. Source: http://www.climatefundsupdate.org/ *(adapted).*

Name of fund	Administered by	Funding instrument	Disbursed to Africa as at September, 2009 (million USD)
Cool Earth Partnership	Japan	2,000 in grants 8,000 in ODA loans	Unknown
Environmental Transformation Fund – International Window	UK	Part grants, part concessional loans	0 (GBP)
International Climate Initiative	Germany	Part grants, part concessional loans	61 (EUR)
Global Climate Change Alliance	European Commission	Grants	Unknown
International Forest Carbon Initiative	Australia	Unknown	Unknown

4.5.3 Bilateral initiatives

Table 4.3 gives a summary of bilateral climate change finding initiatives and funds disbursed to Africa under each initiative.

4.5.3.1 The Japanese Cool Earth Partnership (CEP)

The Japanese CEP has three priorities:

1. Establishing a post-Kyoto framework that will ensure the participation of all emitters, aiming at fair and equitable emission targets.
2. Strengthening international environmental cooperation, under which Japan will provide assistance to help developing countries achieve emissions reductions and to support adaptation in countries suffering from severe climate change impacts.
3. Supporting activities focused on the development of innovative technology and a shift to a low carbon society.

4.5.3.2 The UK Environmental Transformation Fund – International Window (ETF-IW)

The international window of the UK ETF aims to support poverty reduction, provide environmental protection and tackle climate change in developing countries by addressing unsustainable deforestation, access to clean energy, and activities that support adaptation. Most of the finance available under this initiative will be channeled through the World Bank's Climate Investment Fund, although early support to the Congo Basin Conservation Fund has been provided.

4.5.3.3 The European Commission's Global Climate Change Alliance (GCCA)

GCCA will address mitigation, adaptation and poverty reduction via a proposed partnership with developing countries that will include the provision of both technical and financial assistance. In addition, it aims to provide an informal forum that will facilitate negotiations for a post-2012 climate agreement. GCCA also plans to add value by acting as a clearing house mechanism to coordinate the international adaption initiatives of EU member states. GCCA is the only scheme that can be considered to fall under the EU-Africa Partnership, a political partnership focused on establishing a shared Africa-EU vision for climate change.

4.5.3.4 The German International Climate Initiative (ICI)

The German ICI has three objectives:

1. Supporting sustainable energy systems, adaptation and biodiversity projects related to climate change.

2. Ensuring that investments will trigger private investments at a greater magnitude.

3. Ensuring that financed projects will strategically support the post-2012 climate change negotiations.

The German ICI is unique in terms of how funds are generated. The German Federal Environmental Ministry (BMU) raises funds by auctioning 9% of its nationally allocated carbon allowances for the second phase (2008–2012) of the EU Emissions Trading Scheme (ETS), rather than giving the permits away free. Of the EUR 800 million expected annually, half will be used for both domestic and international climate initiatives. One hundred and twenty (120) million Euros of the money will be allocated to developing countries, half of which will be allocated to adaptation and forest protection. Germany's ICI is in addition to a much larger sum of money already spent bilaterally by the German Government on adaptation.

4.5.3.5 The Australian International Forest Carbon Initiative (IFCI)

Australia's IFCI aims at facilitating global action to address emissions from deforestation by providing incentives to developing countries to reduce deforestation.

4.5.4 Reducing Emissions from Deforestation and Forest Degradation (REDD)

Recent initiatives from REDD open up new funding opportunities. Reduction in emissions from deforestation and forest degradation is generally recognized as a relatively low cost greenhouse gas mitigation option. The Stern Report (2006) and its sobering forecast of the economic cost associated with climate change was compelling in reminding policy makers of the important linkages between forests and climate change: one-fifth of total annual carbon emissions now come from land-use change, most of which involves tropical deforestation.

The Collaborative Partnership on Forest (CPF) in 1999, reported that about 65% of the total mitigation potential of forest related activities is located in the tropics, and about 50% of the total could be achieved by reducing emissions from deforestation (IPCC, 2007). COP13 of UNFCCC in December 2007 adopted a decision on reducing emissions from deforestation in developing countries.

The success of REDD in reducing emission will depend on tackling profound market and governance failures. REDD policies will have to strengthen the alignment of economic actors and the public interest, a challenge made more difficult by the complexity of the issues behind deforestation and the fact that many of the drivers of deforestation are external to the forestry sector.

Policies need to be tailored to address diverse local situations and other factors that encourage forest conversion, unsustainable extraction, developing rights and responsibilities to local forest users and promoting the other concepts and ecosystem services of forests besides carbon storage and sequestration. Several governments have already announced their willingness to support such actions and to provide funds to address methodological issues.

The first proposals for a mechanism for REDD did not consider emission from terrestrial carbon stores outside the core of standing forest. It also did not address the drivers of deforestation adequately. A more recent proposal (the REDD-plus) addresses the range of forest types more fully, taking into account forest conservation, sustainable forest management and enhancement of forest carbon stocks, in addition to avoided deforestation and degradation.

4.6 Some observations on the current climate change financial instruments as of 2010

4.6.1 Problems with GEF funding

Many developing countries, particularly in Africa, have felt very little impact of Global Environment Facility in the forestry sector. GEF has not prioritized the adaptation needs of the most vulnerable countries and has disproportionately funded projects in countries that have relatively low levels of poverty. Other criticisms of GEF governance include:

1. The governance structures are seen by developing countries as complex and weighted in favour of donor countries.

2. The rules and structures make accessing of funds difficult and time consuming.

3. There appears to be a lack of transparency in decision making that is the prerogative of powerful individuals.

4. There is an emphasis on supporting projects rather than programmatic approaches.

5. The focus on securing environmental projects over development projects results in fewer global benefits.

If GEF is to continue as a financing mechanism, Africa should push for governance reforms within the Facility.

4.6.2 The CDM

Even though the CDM has proved successful in generating emission reduction projects in many developing countries, Africa accounted for only about 5% of CDM transactions in 2007 and roughly 2% of CDM activities overall. It was reported that as at October 2008, only 17 out of 1,186 CDM projects were located in sub-Saharan Africa and most of these (14 out of 17) were located in South Africa. The CDM as currently constituted is inadequate as a tool to support the needs of Africa in its quest for sustainable development and its fight against global warming. The distribution of CDM investments is not geographically equitable as far as the African continent is concerned. The governance framework of CDM excludes non-Annex I countries even though the primary objective is to provide an offset mechanism for Annex I countries.

4.6.3 The Adaptation Fund

The Adaptation Fund is unique in being exclusively dedicated to the funding of concrete adaptation activities as opposed to research or knowledge building. The fund also operates on the principles of accountability in management, operation and use of funds, short and efficient project development and approval cycles, and expedited processing of eligible activities. It also stresses the need for projects to be country driven, taking into account existing national planning exercises and development activities. The Adaptation Fund can potentially serve as a model for future international financial mechanisms.

4.6.4 The Climate Investment Funds (CIF) of the World Bank

The Climate Investment Fund (CIF) under the aegis of the World Bank was not, as at September 2009, fully operational and funding had not yet been disbursed even though some projects had been approved.

The World Bank's track record of lending with its conditionalities is well known. There is the feeling that the World Bank's attempt to control climate change funding could undermine the UNFCCC process. The language of the fund recognizes the UNFCCC principles merely as a guide for the fund's policies rather than as binding and internationally negotiated commitments of State Parties, which must be respected. As such, the principles negotiated under the Convention and the legal status of commitments under the UNFCCC are not well reflected in CIF.

4.6.5 Emerging Green Climate Fund

Not included in the above analyses is the emerging Green Climate Fund, the establishment of which was agreed at COP16 in Cancún, Mexico (December, 2010). The Green Climate Fund is established to support projects, programmes, policies and other activities in developing country parties. Besides providing for equal representation of developed and developing country members on the governing board of the fund, another notable feature is that the Fund is expected to simplify the present complicated network of funding mechanisms and bilateral agreements that currently provide low carbon and climate adaptation investment for developing countries, with the final agreement stating that a significant share of climate adaptation spending will flow through the new Fund.

4.7 The way forward

4.7.1 General

Climate change and the international instruments dealing with it have created a gamut of new challenges, opportunities and tasks for the forest sector. Meeting them successfully requires fresh perspectives, modified priorities, new knowledge, skills and creativity. In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) emphasizes the likelihood that climate change and variability will negatively impact Africa's economic activities and exacerbate its current development challenges. With this warning in mind, Africa should make effort to reduce greenhouse gas emissions, plan for immediate and future adaptation, and integrate climate change considerations into development programmes and strategies.

The projected estimates that will be required to meet the cost of alleviating and adapting to climate change in Africa are in tens of billions of dollars per annum. Unfortunately, the investment in carbon market in Africa is low and the support from multilateral and bilateral funding mechanisms, including ODA, are not enough to meet the needs of Africa. The financial support for mitigation and adaptation, as well as for addressing the shortcomings in the current financing mechanisms, must be very clear in the minds of the African negotiators and policy makers as well as the regional African institutions. This will help in shaping Africa's negotiating position from an informed base.

The way forward will be for African negotiators to get familiar with key principles of both the UNFCCC and the Kyoto Protocol, as various articles in the treaties are very explicit on the commitments of both developed and developing countries in reducing emission and financing. These facts will be used to buttress their negotiations. Some of the areas to work on are in the following sections.

4.7.2 The development agenda of UNFCCC and the Kyoto Protocol

Development and poverty eradication are the first and overriding priorities of African countries. Following a sustainable development path will help to identify inter-linkages and promote synergies between meeting development goals and delivering climate benefits. Therefore, efforts aimed at meeting development imperatives can at the same time be geared towards reducing greenhouse gas emissions. This will enable Africa to play a meaningful role in global environment and development governance. Understanding of this fact will be the basis for Africa to negotiate for increased financial assistance, sound investments, and transfer of environmentally sound technologies.

4.7.3 The CDM and Africa

The impact of the CDM to provide adequate financial support for mitigation activities in Africa is very limited. It is therefore necessary for Africa to take cognizance of the existing carbon market opportunities and come out with a clear position for post-2012 negotiations in order to increase the flows of carbon finance needed for Africa to meet the challenges of climate change and sustainable development. The African negotiating position should focus on actions that can broaden the CDM approach and coverage in a post-2012 framework, so that Africa can have a fair share of CDM transactions. Some of the actions that are desirable to take include: *a)* expansion of types of projects eligible for CDM and support for a REDD agreement, *b)* simplification of methodologies, and *c)* supporting the concept of sectoral CDM.

a) *Expansion of types of projects eligible for CDM and support for a REDD agreement.*

A major inhibiting factor to the growth of CDM in Africa is the limitation of the types of projects currently eligible for CDM. The land use sector holds the greatest potential for carbon finance in Africa. Realizing the full potential for mitigation in Africa requires considerable new investments in measures to prevent deforestation and to adopt land use practices that sequester high carbon.

Reducing emission from agricultural landscapes has both local and global benefits. The IPCC report (2007) puts the emission from deforestation at about 20% of global GHGs in the atmosphere, while emission from agriculture accounts for about 14%. Together, this represents more emissions (34%) than the global transport sector (13.1%) or emissions from industry (19.1%).

Reducing greenhouse gas emissions from Agriculture, Forestry and other Land Uses (AFOLU) offers a great opportunity for Africa to contribute to climate change mitigation and help millions of small holder farmers adapt to climate change impact. In view of the foregoing, African negotiators should push for an agreement on a work plan for reducing emissions from AFOLU under a post-2012 climate change agreement. They should also push for a position that international greenhouse gas offset markets should accept bicarbon credits from emission reductions and carbon stock increases from AFOLU from developing countries. The role of Africa in global carbon markets will be greatly enhanced if the AFOLU sector is taken on board.

b) *Simplification of methodologies.*

Negotiators should work on how to simplify the rules for determining baselines, monitoring carbon emissions and enforcing offsets.

c) *Support the concept of sectoral CDM.*

This involves establishing sectoral baselines and granting carbon credits for emission reductions relative to these sectoral baselines. By reducing the transaction costs for individual companies, this sectoral approach provides financing opportunities for sectors that are currently under-represented under the CDM in Africa, such as transport.

4.7.4 Negotiation on basis of the key principles of the Convention related to finance

The key financial burden-sharing principle is that of common but differentiated responsibilities and respective capabilities, enshrined in Article 3.1 and Article 4.3 of the Convention, maintaining that developed countries are obliged to transfer finance to developing countries. Annex I countries have an obligation to provide new additional, adequate and predictable resources to developing countries to fund the agreed incremental costs of mitigating and adapting to climate change. Article 4.4 states that developed country parties and other developed parties included in Annex II shall also assist the developing country parties that are particularly vulnerable to the adverse effect of climate change in meeting costs of adaptation to those adverse effects. Article 11 makes it clear that the financial mechanism of the Convention shall be accountable to the Conference of the Parties and shall have an equitable and balanced representation of all Parties within a transparent system of governance.

The African negotiators should use these principles to agree on the financial architecture for post-2012.

4.7.5 African preparatory meeting

A preparatory meeting for African delegations to meetings of the Conference of Parties should be a priority so that a common negotiating position could be reached. The present dispensation of adding political weight to the negotiation through African Ministers of Environment and Finance, and African Heads of States, is a welcome development and should be sustained.

4.7.6 Capacity building

The African Group should be persistent in restating the inadequacy of the commitment to capacity building and urging the Annex I parties to honour their commitments. This is because many countries in Africa face capacity constraints on the implementation of the Convention and the Protocol.

4.7.7 Adaptation Fund

Even though mitigation is very important given the vulnerability of Africa to the impacts of climate variability and change, adaptation should be the main concern of African negotiators. Issues relating to the operationalization of the Adaptation Fund should be voiced. Negotiators should continue to push for increased support for adaptation and technology transfer, basing the argument on the principle of common but differentiated responsibilities.

4.7.8 Technology development and transfer

Low technological capacities and capabilities are major impediments to development in Africa. The African Group should maintain its position on the importance of technology development and transfer to meeting the development needs and climate change concerns in Africa.

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SECTION 2

CLIMATE CHANGE AND AFRICAN FORESTS

INTRODUCTION

The biomes – moist forests, woodlands and Sahel – form the framework for the discussion of climate change and African forest and wildlife resources in this book. At issue is that these biomes, which are intricately linked to and form the main support for livelihoods and the productive systems of people in Africa, are now threatened by the impact of climate change, over and above the pressures on them from increasing human use driven, in most cases, by burgeoning populations. By describing the key features of these biomes, such as their location, distribution, biomass and carbon stocking, the vulnerabilities and adaptation of the natural systems and of the people who depend on them, conservation and management status as well as the institutional and governance arrangements for their management and use, the chapters in this section provide the background for appreciating issues discussed in the rest of the book.

In more specific terms, the biome descriptions help in the evaluation of the extent to which moist forests, woodlands and the Sahel in sub-Saharan Africa can withstand the temperature and rainfall variability, as well as the extreme weather events, associated with climate change. They enable the appreciation of the contribution of the biomes to global carbon cycling, which is the starting point for understanding how the biomes may be involved in forest-based efforts to combat climate change. Descriptions of current uses and adaptation practices of the communities that depend on the biomes pave the way for designing effective and timely response measures to climate change that do not compromise the support to livelihoods.

It is hoped that readers of other chapters in this book will use this section as a reference base.

Chapter 5
CLIMATE CHANGE AND AFRICAN MOIST FORESTS

David Okali

5.1 Introduction

This chapter focuses on the interrelations among African moist forests, the people who depend on them for their livelihoods, climate change and climate variability. Emphasis is placed on the extensive moist deciduous forests, at low altitudes under rainfall regimes of 1,000–2,500 mm per annum, and the true rain forests, also at low altitudes but at higher rainfall regimes (over 2,500 mm per annum). Commonly referred to, collectively, as rain forests, both types of forest cover an extensive area on the continent, but are concentrated in West and Central Africa, where they are the principal base for industrial wood production (Okali and Eyog-Matig, 2004). Although the chapter dwells on these lowland moist forests, the forest-people-climate change issues treated apply equally to moist forests at higher altitudes (especially the Afromontane broadleaf forests at >900 m elevation), which, though widely scattered in distribution, cover less area. Significant departures of the high altitude forests from lowland forest characteristics are specifically pointed out.

Like other forests on the continent, moist forests are intricately linked to the socio-economic and productive systems of people in Africa; they underpin the economies of many countries that have them, supporting, besides industrial wood production, livelihoods that are based on agriculture, extraction of wood for energy and housing, and collection of non-wood products for food, medicine and various other uses. African forests, in fact, serve as 'livelihood safety nets', helping communities that live by them to overcome shocks from natural disasters and economic or climatic vagaries. They also function to maintain the quality of the environment, and command international attention because of their rich biodiversity and the unique products this provides, as well as their high productivity and potential to influence climate.

Tropical moist forests, as a whole, are among ecosystems expected to be most affected by climate change (IPCC 2007). Impacts that diminish the capacity of the forests to provide goods and services, including maintenance of the quality of the environment, will have far reaching, mostly adverse, consequences for the livelihoods of forest-dependent communities, particularly in Africa, where the capacity to adapt is low. It is important, therefore, that the vulnerabilities and resilience of African moist forests, and their peoples, to climate change be better understood than at present, in order to facilitate the design of effective and timely response measures. Furthermore, since tropical forests are increasingly being considered as critical components of strategies for addressing climate change, it is important that the status of African moist forests, in terms of their size, productivity and resilience to climatic and non-climatic pressures, among other characteristics, be well understood, for effective use of the forests in addressing climate change. In doing this, it is important also to understand the responses to change in forest status by the forest-dependent peoples themselves, from whom much can also be learned of age-old traditional approaches that have been used in responding to natural climate variability. Insights based on natural climate variability can help in dealing with climate change.

This chapter reviews the status of African moist forests, with particular emphasis on the lowland forests that are extensive, together with the reactions of the forest-dependent people to changes in the status of the forests, in terms of:

a) Stocking, including areal cover, biomass content, carbon pools and productivity potentials.

b) Conditions, vulnerability and resilience of the forests in response to utilization and climate change impacts.

c) Adaptation and coping practices of the forest-dependent communities in response to changes in forest status.

d) How climate change and variability, and change in forest status, are monitored and reported in the moist forest regions.

e) Existing institutional and governance arrangements for addressing and sharing information on climate change in the moist forest regions.

The chapter also treats the following issues that are considered to be important for effective inclusion of African moist forests in strategies for addressing climate change:

a) Relevant global and Africa-specific adaptation and mitigation initiatives on climate change and variability.

b) Relevant policy actions and incentives for addressing climate change adaptation and mitigation in African moist forests.

c) Summary of experiences in adaptation and mitigation in African moist forest regions.

d) Ways of improving forestry sector linkages with other sectors of the economy to address climate change.

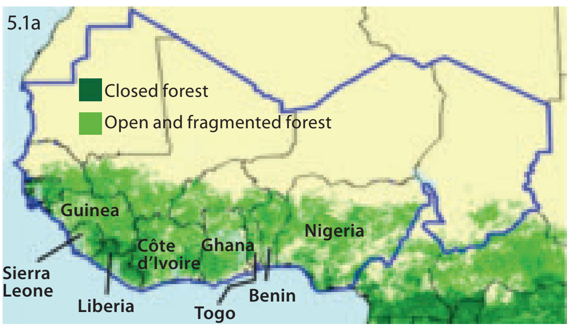
e) Domestication and mainstreaming of global processes on climate change within the forestry sector in the moist forest regions.

f) Institutional issues (tenure, rights, ownership, administration, governance, gender dimensions) for addressing climate change adaptation and mitigation in the moist forest regions.

5.2 African moist forests

5.2.1 Location and areal cover of lowland moist forests

African lowland moist forests occur mainly in Sierra Leone, Guinea, Liberia, Côte d'Ivoire, Ghana, Togo, Benin and Nigeria in the West African sub-region; and in Cameroon, Equatorial Guinea, Central African Republic, Gabon, Congo and the Democratic Republic of Congo in the Central African sub-region (Figure 5.1). True rain forest covers only 6% of Africa's land area, representing about one third of the total rain forest remaining in the world (Table 5.1, IPCC Special Report 1997).



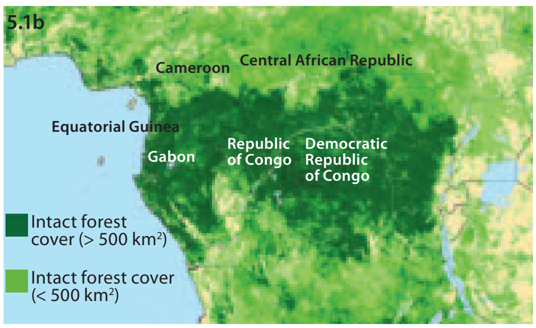


*Figure 5.1 African moist forests. **5.1a**: West Africa. Forest cover according to FRA 2000 Map of the World's Forests 2000. **5.1b**: Central Africa. Adapted from South Dakota State University, Maryland, and USAID CARPE Project.*

Table 5.1 *Rain forest cover by biogeographical regions. Source: Butler (2006).*

Realm	Area (million ha)	% share of world rain forest cover
Afrotropical	187.5	30
Australasian	56.3	9
Indo-Malayan	100.0	16
Neotropical	281.2	45

Lowland moist forests as described above approximate to the closed forests of FAO (2001), and together with woodlands cover about 650 million hectares or 21.8% of Africa's total land area (Cutler, 2008).

Areal cover of lowland moist forest in the countries listed above, together with the percentage of total land area covered, and an indication of the population pressure on the forest in terms of area of forest per thousand of population is summarized in Table 5.2.

The bulk of the lowland moist forest in Africa is clearly located in the Central African sub-region, and is dominated by the forest of the Congo Basin, where, on the average, close to 60% of the land area is recorded as being under forest cover. The Congo Basin moist forest is, in fact, the second largest contiguous block of forest in the world after the forest of the Amazon Basin. The area of forest available per thousand people is also much greater in Central Africa than in West Africa, signifying the greater population pressure on the forests of West Africa. In general, the Central African forests exist in sparsely populated areas such that, on the average, close to 6,000 ha of forest (over 16,000 ha in Gabon) is available per thousand people. By contrast, the average area per thousand of population is barely 400 ha in West Africa.

Table 5.2 Areal cover of lowland moist forest in West and Central Africa. Source: FAO (2009).

Country	Extent of forest, 2005		
	Forest area (1,000 ha)	Forest area as percent land area (%)	Forest area per 1,000 people (ha)
West Africa			
Benin	2,351	21.3	268
Côte d'Ivoire	10,405	32.7	550
Ghana	5,517	24.2	240
Guinea	6,724	27.4	732
Liberia	3,154	32.7	881
Nigeria	11,089	12.2	77
Sierra Leone	2,754	38.5	480
Togo	386	7.1	60
Total/average West Africa	**42,380**	**24.5**	**411**
Central Africa			
Cameroon	21,205	45.6	1,169
Central African Republic	22,755	36.5	5,337
Congo	22,471	65.8	6,091
Democratic Republic of Congo	133,610	58.9	2,203
Equatorial Guinea	1,632	58.2	3,297
Gabon	21,775	84.5	16,662
Total/average Central Africa	**223,448**	**58.3**	**5,793**

5.2.2 Location of Afromontane broadleaf forests

High altitude forests in Africa are discontinuous in distribution, occurring on highlands separated by lowland regions, scattered from West Africa and the Sudan in the north, through to southern Africa. By analogy with the distribution of islands in the sea, they are sometimes referred to as the Afromontane archipelago. Countries of occurrence of broadleaf high altitude forests are listed in Table 5.3.

5.2.3 Growing stock, biomass and carbon content

Growing stock, biomass and carbon contents corresponding to the lowland forest areas listed above are summarized in Table

Table 5.3 Location of Afromontane broadleaf forests.
Source: http://en.wikipedia.org/wiki/Afromontane.

Forest	Country
Albertine Rift montane forests	Democratic Republic of the Congo, Burundi, Rwanda, Tanzania, Uganda
Cameroonian Highlands forests	Cameroon, Nigeria
East African montane forests	Kenya, Sudan, Tanzania
Eastern Arc forests	Kenya, Tanzania
Ethiopian montane forests	Eritrea, Ethiopia, Somalia, Sudan
Guinean montane forests	Guinea, Côte d'Ivoire, Liberia, Sierra Leone
Knysna-Amatole montane forests	South Africa
Mount Cameroon and Bioko montane forests	Cameroon, Equatorial Guinea
Mount Mabu	Mozambique

5.4. These features are treated only for the dominant, extensive lowland forests. The country data in Table 5.4 are quite incomplete for West Africa. To enhance the comparability of the data, the total figures for West Africa were adjusted to compensate for the missing values. Figures in brackets in the main body of Table 5.4 are thus totals derived by applying the average per hectare values in Table 5.4 to total forest area for West Africa given in Table 5.2.

Both the unadjusted and adjusted figures show clearly the greater stocking of the forests in the Central African sub-region, in terms of volume, biomass and carbon content. The total stocking values correspond with the greater forest cover of the Central African sub-region, while the per hectare values imply a greater density of the forests in

Table 5.4 Growing stock, biomass and carbon content of lowland moist forest in West and Central Africa. Source: FAO (2009). [In brackets in the main table are entries adjusted for missing data.]

Country	Growing stock		Biomass		Carbon content	
	Per hectare (m^3/ha)	Total (million m^3)	Per hectare (tonnes/ha)	Total (million tonnes)	Per hectare (tonnes/ha)	Total (million tonnes)
West Africa						
Benin	–	–	–	–	–	–
Côte d'Ivoire	258	2,683	386	4,014	179	1,864
Ghana	58	321	180	993	90	496
Guinea	77	520	189	1,272	95	636
Liberia	158	498	287	908	144	453
Nigeria	125	1,386	253	2,803	126	1,402
Sierra Leone	–	–	–	–	–	–
Togo	–	–	–	–	–	–
Total/average West Africa	135.2	5,408 [5,729]	259	9,990 [10,976]	126.8	4,851 [5,373]
Central Africa						
Cameroon	62	1,313	179	3,804	90	1,902
Central African Republic	167	3,801	246	5,604	123	2,801
Congo	203	4,551	461	10,361	231	6,181
Democratic Republic of Congo	231	30,833	347	46,346	173	23,173
Equatorial Guinea	66	107	142	231	70	115
Gabon	223	4,845	335	7,285	167	3,643
Total/average Central Africa	158.7	45,450	285	73,631	142.3	37,815

Table 5.5 African lowland moist forest stock data in relation to total Africa and world forest stocks. Source: FAO (2009).

Forest stock	African lowland moist forest	All Africa forest	Total world forest	African lowland moist forest as %	
				All Africa	Total world
Wood volume (million m^3)	51,179	63,858	384,007	80.1	13.3
Biomass (million tonnes)	97,607	120,137	436,360	81.2	22.4
Carbon content (million tonnes)	43,188	59,927	240,441	72.1	17.9

Central Africa. Lowland moist forests contain over 80% of the wood volume and biomass and more than 70% of the carbon stock in forests in Africa, representing 13, 22 and nearly 18 per cent of the world's forest stock of wood by volume, biomass and carbon, respectively (Table 5.5).

In the context of climate change, current interest in African moist forests derives mainly from the potential influence of these forests on the global carbon balance. In this regard, the data in Table 5.4 confirm the often quoted reference to the carbon stocking of the Congo Basin as being equivalent to 4 years' global carbon emission (WWF, 2007; IPCC, 2007). The contribution of African moist forests to global carbon cycling depends on *a)* the extent of the forests, *b)* their stocking per unit area, and *c)* the rate and direction of change of this stocking, all of which must be accurately known for precise determination of the contribution. But the data in Tables 5.2 and 5.4 are derived from national forest statistics that, in Africa, are based on infrequently conducted national inventories, with uncertainties about the included errors and the representativeness of the samples used. As discussed, for example, by Justice *et al*. (2001) and Houghton (2005), such data lack sufficient detail for quantification of errors; they are also inadequate for assessment of the stock of carbon in the various pools of the forest ecosystem, e.g. living vegetation above and below ground, dead organic matter, litter and soil, or for tying stock estimates to the actual sites where changes in stocking may be taking place. Appropriate sampling designs, combined with techniques such as allometry (Lewis *et al*. 2009), modeling and remote sensing by satellite imagery (Laporte *et al*., 1995; Mayaux *et al*., 1998) have been used to enhance the quality of tropical forest stocking data.

Lewis *et al*. (2009), for example, applied allometric equations to measurements on trees in 79 forest plots, spread through 10 African countries, and estimated the average carbon stock in above ground live trees at 202 tC/ha, with a 95% Confidence Interval of 174–244 tC/ha. An inventory by Adams (2006) illustrates the major pools of the forest ecosystem for which determination of stocking is sought. For tropical moist forest, Adams (2006) differentiated the carbon stock into storage in *a)* above and below ground vegetation (210 tC/ha), *b)* dead standing trees, coarse woody litter, leaf litter, other debris (necromass) (10 tC/ha), and *c)* soil organic matter (100 tC/ha), yielding a total carbon stocking density of 320 tC/ha for tropical moist forest.

While volume and biomass stock data directly give an indication of how much material is available for exploitation or for support of the rich biodiversity of the forests, the carbon stocking indicates how much carbon will be emitted into the atmosphere, thereby exacerbating climate change, in the event of destruction of the forests. Current concern about deforestation in Africa and other tropical regions arises mainly from this latter factor. Of paramount interest in evaluating the role of African moist forests in climate change is whether the forests function as a source or a sink for carbon dioxide. Repeated measurement of stocking allows the change in stocks to be determined. Increase in stocking signifies net fixation of carbon, and the forests acting as a sink, while decrease suggests loss and contribution of carbon to the atmosphere. Lewis *et al*. (2009) concluded from repeated measurements that African moist forests fixed carbon at the rate of 0.63 tC/ha/yr between 1968 and 2007, a rate comparable to that earlier determined for the Amazon moist forest (Baker *et al*., 2004), with the forests serving as a sink in both cases (see also Luyssaert *et al*., 2008). On the other hand, Feeley *et al*. (2007), monitoring up to three million trees of 6,000 species in 18 sites around the world found that tree growth rates decreased significantly in the tropical moist forests of Panama and Malaysia, implying that, over the period of monitoring, moist forest in those two locations served as a source of carbon to the atmosphere. Determination of the true role of African moist forests in the carbon cycle is essential for guiding decisions on investment on the forests in carbon trading and the emerging mechanism of REDD being designed for combating climate change.

Moist forests are the most productive terrestrial ecosystems in the world and the African examples are no exception. Covering only about 6% of the total land area of the Earth, moist forests account for more than 30–50% of total primary productivity in terrestrial ecosystems. The high productivity supports the rich biodiversity, which functions to maintain the goods and services provided by moist forests. There is concern that climate change and climate variability may impact adversely on the productivity of African moist forests, thereby diminishing their capacity to support a rich biodiversity and the livelihoods of the people who depend on them. The latter could severely curtail the options for adaptation of the forest dependent people to climate change. In addition, biodiversity loss will be more consequential for the Afromontane forests where a high proportion of the species are endemic.

5.2.4 Status, vulnerability and resilience of African moist forests

Moist forests in Africa are heavily depleted by commercial logging, conversion for agriculture, exploitation of non-timber forest products (NTFPs), expansion of settlements and their associated infrastructure and, in some places, activities associated with mining or civil strife. Afromontane moist forests are additionally degraded by invasion of alien species escaping from extensive plantation of exotics.

Anthropogenic pressure is much higher in West Africa, leading to the loss of more than 90% of the original forest, because of the greater density of the human population than in Central Africa. In both sub-regions the moist forest zone is a mosaic of forest reserves within which most of the industrial wood production is concentrated, set in a matrix of forests outside reserves which contribute also to industrial wood production, farms and forests at various stages of re-growth from farming or disturbance (Okali and Eyog-Matig, 2004). Especially in West Africa the forests are very fragmented, with logging tracks pioneering access to the forests. Central Africa still has large blocks of contiguous forest, with over two-thirds of the forests being classifiable as 'low-access forest, i.e. contiguous forest areas of at least 1,000 km^2, unbroken by public roads (Minnemeyer, 2002). In West Africa industrial wood production is dominated in numbers by indigenous entrepreneurs operating small scale businesses, while in Central Africa, exploitation is dominated by a few, mostly foreign-connected, concerns operating large concessions, around which most of the forestry development in the sub-region is centered (Okali and Eyog-Matig, 2004). Very little of the moist forest is managed sustainably at an operational level in both sub-regions, although West Africa has a long history of attempts to achieve sustained wood yield by use of management plans incorporating trials of various silvicultural systems. Economic, political and social imperatives appear to have overwhelmed the efforts in West Africa and remain the main obstacles to sustainable forest management in both sub-regions (Okali and Eyog-Matig, 2004; Justice *et al.*, 2001), so that deforestation and forest degradation remain serious threats to African moist forests, especially in West Africa. According to FAO (2009) (Table 5.6), the moist forest countries in West Africa collectively lost 710,000 ha, or about 1.9% of their forest cover, between 2000 and 2005. The corresponding figures for the Central African countries, with a much larger expanse of forest, are 611,000 ha and 0.38%. Forest loss from African moist forest countries as a whole was as much as 18% of the total world forest loss between 2000 and 2005, even though moist forest area in Africa represents only 6.8% of world forest cover.

Deforestation is occurring mainly because of the pressure of disturbance by human activities. The apparent luxuriance and high productivity of moist forests are maintained by a balance set through complex interactions among the very diverse species in the ecosystems and between the species and the physical environment. This balance is readily upset by disturbance which exceeds levels of change to which the forests are exposed in the gap-phase dynamics by which the forests are naturally maintained. This happens because many species in the high diversity moist forests exist within narrow niches that can readily be transgressed (IUFRO, 2009). Deforestation and degradation occur when the impacts of logging, slash and burn agriculture (which is the predominant farming practice) and overexploitation of NTFPs cross the threshold of resilience of the forests. For African moist forests to participate in the emerging mechanism of REDD for addressing climate change, the drivers of deforestation and forest degradation must be understood and effectively checked.

African moist forests are clearly vulnerable and have a low resilience to human disturbance, accounting for the deforestation discussed above. It is recalled that the tropical moist forest was once described as a non-renewable resource (Gomez-Pompa *et al.*, 1972) on account of the rapid rate at which the ecosystem is depleted. It is noteworthy that IPCC (1997), in discussing vulnerability, noted that moist forests are under threat from population pressure and systems of land use, and that the effects of these threats include loss of biodiversity, rapid deterioration in land cover and depletion of water availability through destruction of catchments and aquifers. The panel noted further that the effects of climate change will interact with these underlying changes in the environment, and add further stresses to an already deteriorating situation.

Table 5.6 Forest area loss (deforestation) for African lowland moist forest countries 2000–2005. Source: FAO (2009).

Country	Annual change rate	
	Area (1,000 ha)	%
West Africa		
Benin	-65	-2.5
Côte d'Ivoire	15	0.1
Ghana	-115	-2.0
Guinea	-36	-0.5
Liberia	-60	-1.8
Nigeria	-410	-3.3
Sierra Leone	-19	-0.5
Togo	-20	-4.5
Total/mean West Africa	**-710**	**-1.87**
Central Africa		
Cameroon	-220	-1.0
Central African Republic	-30	-0.1
Congo	-17	-0.1
Democratic Republic of Congo	-319	-0.2
Equatorial Guinea	-15	-0.9
Gabon	-10	0
Total/mean Central Africa	**-611**	**0.38**
World total	**7,317**	

Actual studies on the vulnerability and resilience of moist forests to the impacts of climate change and climate variability are few. Some of such studies (e.g. Lewis *et al.*, 2009) suggest that African moist forests may be responding positively to the increased CO_2, increased nutrient addition or increased rainfall, all associated with climate change, by increase in growth rate. Others (e.g. Feeley *et al.*, 2007) find the contrary – tree growth rates decreasing significantly in tropical moist forests in recent years. IPCC (2007) prediction is that with climate change productivity gains in forest ecosystems may result from three mechanisms – CO_2 fertilization, warming in cold climates with concomitant increase in precipitation or through precipitation increase where water limits growth. In the warm humid conditions of African moist forests, only CO_2 fertilization may be important, but gains in productivity from this mechanism are likely to be countered by the higher respiration rate induced by global warming. Whether there is a net gain or a net loss in primary production depends on the balance between the enhancement of photosynthesis by CO_2 fertilization and the increased respiration induced by the higher temperatures. Reduced growth rate coupled with deforestation could leave more CO_2 in the atmosphere and, through a positive feed-back, exacerbate rather than mitigate climate change. Friedlingstein *et al*. (2008), from modeling and simulation studies, concluded that warming over African ecosystems induced reduction of net ecosystem productivity, making a 20% contribution to the global climate-carbon positive feed-back. However, African moist forests alone made only a negligible contribution to the overall feed-back, being much smaller than the Amazon forest.

The response of African moist forests to climate change could also be mediated through enhanced evapotranspiration from the forest, induced by the warmer temperatures (Schochet, undated). The low clouds formed by the massive transfer of moisture to the atmosphere could reflect radiation helping to maintain lower temperatures around the forests. Without temperature enhanced respiration, gains in primary production resulting from CO_2 fertilization could be retained, making African moist forests to serve as a sink for CO_2 and an important factor in climate change mitigation. Deforestation, which is rapidly depleting the forests, would have to be checked to realize any benefits from African moist forests as a sink.

It is worth noting that IPCC (2007) concluded that with climate change, forests are likely to undergo species range shift and changes in tree productivity, and that a large proportion of species may be threatened or endangered in the future. Studies are urgently needed to ascertain the true response and the stability of African moist forests to climate change and climate variability. In such studies, since different species respond differently to climatic factors, attention should focus on the dominant and ecosystem critical species (Okali and Eyog-Matig, 2004; AFF, 2009)

5.3 Adaptation, monitoring and governance

5.3.1 Adaptation and coping practices of the forest-dependent communities

As indicated earlier, moist forest communities engage mainly in farming, for which the forests provide fertile land, ameliorate the microclimate in the farming landscape and, through catchment protection, conserve soil water. The communities gain employment and livelihood support from participating in the logging industry where this takes place. They rely on the forests for the supply of wood to meet energy and house-building needs, and for the supply of a wide range of non-wood products to meet various other needs, especially food and medicines. The practices used by the communities in these engagements with the forest are themselves adaptations to prevailing conditions. To sustain their livelihoods the communities adjust these practices in various ways in response to changes in the environment, including changes in the economic environment, but especially changes in the capacity of the forest to provide continued support. For farming, for example, which is entirely weather-dependent, they already have practices for managing weather-related risks, such as dislocation in the pattern of rainfall, relying on their knowledge of the links between meteorological phenomena and animal behaviour or plant phenology. Aware of inter-annual variability in factors such as onset of the rainy reason, farmers in African moist forest communities insure against total crop failure by staggering crop-sowing dates.

What follows is a review of adaptation practices by moist forest communities, organized around livelihood choices, land use, farming and forest management practices. The review draws largely from on-going practices in Cross River State of Nigeria, which contains the largest expanse of moist forest in the country, and focuses on adaptation practices at the lowest level of social organization – communities and households (CERCOPAN, private communication). Enhancement and security of livelihood, as well as conservation of the natural resource base for livelihood pursuits, are the overall goals of adaptation choices.

People in African moist forest communities combine a number of activities for livelihood support. Farming appears to be the base occupation to which other activities like hunting for bush-meat and collection of NTFPs are added. Farming, hunting and NTFP collection may be carried through to the point of engaging in selling of products to which value has been added by processing. The balance in the effort devoted to these activities or to a combination of activities is determined by the perceived profitability of the choice made. Adaptation consists essentially of adjusting this balance, to the point that some activities may be reduced, phased out or enhanced in relation to others, or the entire search of livelihood support in the rural setting, may be dropped. The latter leads to migration as an adaptation response, and this could be temporary and seasonal to sell labour, or more prolonged for temporary settlement in an urban setting. The cue for adjustment, or for an adaptation response, is usually failing returns for effort made or perceived opportunity in a new line of action. Dwindling returns from farming could be caused by weather-related factors, such as shortening of the growing season because of delayed onset or early cessation of rains or a combination of both factors. Extreme weather events such as drought, excessive heat or flooding could also lead to poor returns from farming. Flooding from excessive rainfall is frequently experienced in parts of the moist forest zone of Cross River State. With collection of NTFPs, returns for effort may fall because of increasing scarcity of the products and the need to travel longer distances as the habitats from which the products are obtained recede with deforestation and forest degradation. Scarcity may also arise from overexploitation of the products. In Cross River State, both factors are operating causing collectors to travel longer distances for the collection of the highly valued bush-mango (*Irvingia gabonensis*) and leafy vegetable (*Gnetum* sp.) Migration, change in livelihood occupation or alteration in the balance of activities undertaken to support livelihoods are clearly options that moist forest people may adopt to adapt to the impacts of climate change.

Land use practice is being reformed in the moist forest zone of Cross River State in the effort to increase the conservation of land to accommodate the rising population pressure. Encouraged by NGOs, communities in the area are now instituting Community Land Use Plans (CERCOPAN, private communication) to control wasteful use of land, adopting essentially the Biosphere Reserve concepts of the Man and the Biosphere Programme of UNESCO (UNESCO). Community forest land is now mapped and demarcated into various use zones, including a core zone that is totally protected, areas for collection of NTFPs, recuperation areas and farmland. Adherence to the prescribed uses is controlled by regulations and bye-laws endorsed at the local government level of administration. This effort at controlled land use is only a few years old. Its potential for contributing to reduce deforestation is evident, but the practice would need to be tested over a longer period to accept it as a viable adaptation option for climate change.

With farming, the cue for adaptation is usually first given by declining soil fertility. Adaptation response commonly involves 'shifting' to a new site or changing the crops grown. In the moist forests of Cross River State and other parts of Nigeria, 'shifting' means cutting new forest in the absence of fallow vegetation old enough to provide the required level of soil fertility. When old forest area is exhausted as has happened with some communities, fallows are repeatedly cropped after short periods of fallowing, leading to further degradation of the soil. In the heavy rainfall zone of Cross River State, the end point of such degradation is gulley erosion. This process can be exacerbated by climate change-induced increase in rainfall amount and intensity. In the moist forest zone of Cross River State the choice crops when soil fertility is high are bananas and plantains (*Musa* spp.) followed by yams (*Dioscorea* spp.). Depleted soils are put on cassava (*Manihot* sp.) which is grown repeatedly on shortened fallows until the soil is completely exhausted and abandoned when badly degraded by erosion. The range of crop species used could widen in an effort to adapt to climate change. The main effort to reduce further depletion of forests, and at the same time respond to the exhaustion of farmland soil fertility, is the adoption of agro-forestry practices. This serves also to keep the land continuously under vegetation cover, which protects the land against soil erosion, and could be a potent adaptation option for climate change. The economic benefits of agro-forestry could also help to reduce poverty which is a major driver of deforestation.

At present, farmers rely on indigenous knowledge of the relationships between plant (phenology) or animal (commonly birds) behaviour to forecast the weather, or detect inter-annual climate variability for agricultural decisions and operations. This traditional approach is becoming increasingly unreliable partly because of the lag in adaptation of the biological phenomena used to the changing climate (IUFRO, 2009). Efforts are only now being made to introduce farmers to the use of weather data from meteorological services (Saleem *et al*., 2003). But much remains to be done in developing reliable short-term forecasts from meteorological data and propagating the use of these among farmers as an adaptation option for climate change.

Cultivation of land for planting also reflects adaptation to the environment. Planting in the moist forest zone of Nigeria is usually on mounds/heaps or ridges. Land prone to inundation is traditionally prepared for cropping by making high mounds or ridges with hoes adapted for the purpose. This practice could spread as an adaptation response if flooding increased with climate change. Similarly the practice of mulching could become more widely used to conserve moisture and protect crops as an adaptation against climate-change induced drought.

For forest conservation, in addition to the benefits of planned land use pointed out earlier, key practices that can be adapted to respond to climate change in the moist forest region include sustainable forest management (SFM) now being vigorously pursued in Cross River State through Community Based Forest Management (Okali, 2002; Odera, 2004), and organized production, outside forests, of many of the products for which forests were ravaged – woodlots for fuel wood and building materials, plantations or agro-forests of wild fruit trees (notably the wild mango, *Irvingia* spp.), domestication of wildlife, including bush-meat yielding animals (e.g. grass-cutter, *Thryonomis swinderianus*), snails in snaileries and bees in apiaries for honey. Attempts are also being made to scale-up the cultivation of the very popular leafy vegetable, afang (*Gnetum* sp.), hitherto only lightly cultivated in home-gardens, as a major livelihood option. Medicinal plants, hitherto collected from the wild, and now made scarce by forest destruction, are also being grown in specialized gardens as livelihood options. Most of the forest management practices are designed to cut back on forest exploitation thereby conserving forest resources. To this end, improved efficiency in utilizing forest products, e.g. use of improved stoves for efficient burning of wood, are also part of the practices being developed, and to the extent that these forest practices increase incomes of the forest-dependent people, they also serve to reduce poverty and deforestation.

Similar adaptation practices as reviewed above are reflected in the extensive discussions of adaptation to climate change globally (IUFRO, 2009) and in Africa (IPCC, 2007). Both sources stress the importance of good governance for realizing the goals of adaptation. The practices described above are taking place in the context of improving environmental governance at least up to the local government level of administration which provides the cover for enforcement. Note should be taken, however, of the alert by IPCC (2007) that the traditional adaptation practices developed by African farmers to cope with current climate variability may not be sufficient for future changes of climate. Despite this, traditional climate risk management practices remain a valid take-off point in the development of optimal climate change adaptation practices.

5.3.2 Monitoring and reporting on climate change and change in forest status

Monitoring and reporting on climate change in the moist forest countries of Africa can only be a relatively recent development. Climate records kept for decades by national meteorological services are only now being analyzed and interpreted in the context of climate change, by the meteorological services themselves, or by researchers in the field. Such treatment, for instance, recently enabled the Nigerian meteorological service (NIMET, 2008) to produce maps showing evidence of climate change in the country, based on 1940–2000 data. At present, there is little capacity to use meteorological data for climate monitoring at the rural community level. Any monitoring that occurs at this level most likely relies on indigenous knowledge. Monitoring of climate change is now facilitated by satellite technology and African countries are taking advantage of this (e.g. INFORMS, see below). Of interest is the increasing development of partnerships with industrialized countries to share their satellite facilities for climate change monitoring in Africa. This international collaboration is engendered by the widespread concern for the high vulnerability of the African continent to climate change. Notable among such initiatives is the recent launching, by the African Union, of the Africa Climate Change Monitoring Station in partnership with the European satellite agency EUMETSAT (AFP, 2009). The aim of the initiative is to track the effects of climate change on the continent, and achieve better dissemination of environment information for improved decision-making processes, and to develop coherent and sound policies across a wide spectrum in the field of the environment (Ping, 2009).

There is a longer experience with monitoring of forest cover, than with monitoring of climate change, in the moist forest countries of West and Central Africa. Periodic inventories are made of the forest estate and the data are fed into FAO forest statistics for world-wide dissemination. The inventories are, however, infrequent and sometimes only partial. According to Okali and Eyog-Matig (2004), in West Africa, only Benin and Nigeria carried out an inventory of their forest resources in the 90s; Sierra Leone, Liberia and Togo made their last inventories in 1986, 1980 and 1975, respectively, while only partial inventories existed for Ghana and Côte d'Ivoire at the time of reporting. Okali and Eyog-Matig (2004) also reported that in Central Africa, the inventories at that time covered only part of the productive forested domain in Cameroon, the Congo, Gabon and the Central African Republic; national level inventories existing for the Democratic Republic of Congo and Equatorial Guinea were dated, 1982 and 1992, respectively. Most of the data in the Global Forest Resources Assessment 2000 Main Report were based on national expert estimates (FAO, 2001).

As with monitoring of climate change, the use of satellite remote sensing technology and international collaboration now greatly aid monitoring of change in forest status. In this regard, notable initiatives focused on the Congo Basin include the Central Africa Regional Project for the Environment (CARPE) of USAID *(http://carpe.umd.edu)*, and the Integrated Forest Monitoring System for Central Africa (INFORMS) project of Woods Hole Research Center (*http://www.whrc.org/mapping/index.html*).

At the community level, change in forest status is readily noticed from the changed appearance, structure and species composition of the forest.

The disappearance of forest species of hunted animals, reduction in abundance of exploitable plants and the invasion of weedy species must be some of the earliest signs of changing forest status. Except with the emerging introduction of land use planning and mapping, change in forest status was traditionally not recorded. Information on forest status was simply disseminated by oral tradition.

5.3.3 Institutional and governance arrangements for climate change

Institutional and governance arrangements for addressing climate begin, for each country, with the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) and ratification of instruments deriving from the Convention, such as the Kyoto Protocol. Setting up the structures necessary for participating in UNFCCC activities, such as the Conferences of Parties and its relevant committees, would then follow, along with measures to domesticate the provisions of the Convention and the submission of necessary reports. Full address of climate change would entail having the appropriate policies and programmes systematically coordinated at the national level but reaching to the grassroots, with climate change considerations embedded in all relevant development programmes.

The 14 countries in the two sub-regions of concentration of lowland moist forests are parties to the UNFCCC and subscribe to the Kyoto Protocol, having ratified both instruments, the last country doing so by March 2008 (Table 5.7). Ratification of the Kyoto Protocol is significant, as this is the instrument through which engagement of the forestry sector with climate change action occurs.

Benin, Central African Republic, Democratic Republic of Congo, Equatorial Guinea, Liberia and Togo are additionally among 50 parties to the UNFCCC listed as Least Developed Countries (LDCs), which receive special support for addressing climate change. For example, Least Developed Countries were funded under UNFCCC to prepare National Adaptation Programmes of Action (NAPA). Among the African moist forest LDCs only Equatorial Guinea and Togo are yet to submit their NAPA report. All the countries have named appropriate government ministries, departments or agencies, mostly related to the Environment, as the focal point for the Convention, with Ghana and Nigeria also appointing Designated National Authority (DNA) for the Clean Development Mechanism (CDM) of the Kyoto Protocol. Except for Equatorial Guinea and Liberia, all have also submitted their First National Communication, required by the Convention to indicate the circumstances of each country, the status of information on the inventory of

Table 5.7 Status of African lowland moist forest countries in relation to UNFCC and the Kyoto Protocol. Source: UNFCCC website.

Country	Date ratified		Reports	
	UNFCCC	Kyoto Protocol	FNC	NAPA
West Africa				
Benin	30 Jun 1994	25 Feb 2002	X	X
Côte d'Ivoire	29 Nov 1994	23 Apr 2007	X	
Ghana	6 Sep 1995	30 May 2003	X	
Guinea	7 May 1993	7 Sep 2000	X	
Liberia	5 Nov 1995	5 Nov 2002		X
Nigeria	29 Aug 1994	10 Dec 2004	X	
Sierra Leone	22 Jun 1995	10 Nov 2006	X	X
Togo	8 Mar 1995	2 Jul 2004	X	
Central Africa				
Cameroon	19 Oct 1994	28 Aug 2002	X	
Central African Republic	10 Mar 1995	18 Mar 2008	X	X
Congo	14 Oct 1996	12 Feb 2007	X	
Democratic Republic of Congo	8 Jan 1995	23 Mar 2005	X	X
Equatorial Guinea	16 Aug 2000	16 Aug 2000		
Gabon	21 Jan 1998	12 Dec 2006	X	

the greenhouse gases, mitigation and adaptation efforts, and areas where the countries might need support to fully participate in pursuing the objectives of the Convention.

The countries are mostly all engaged with capacity building, training and public awareness raising on climate change. Mostly with external agencies' support, activities relevant for forest-based response to climate change are also taking place (see Okali and Eyog-Matig, 2004, for a list of externally supported initiatives working on Central African forests). These include research, updating inventories on the greenhouse gases, monitoring land cover status, clarifying vulnerabilities to scenarios of climate change and seeking to identify optimal adaptation options (e.g. the Building Nigeria's Response to Climate Change Project, supported by the Canadian International Development Agency (CIDA) in Nigeria (BNRCC, 2008), the Central Africa Regional Project for the Environment (CARPE) supported by USAID (Justice *et al*., 2001), and the Congo Basin Forest Partnership project in which the German government is helping the six countries that share the Congo Basin to develop a common forest policy (Barbara and Cramer, 2008). Initiatives such as CIFOR's Congo Basin Forests and Climate Change Adaptation Project are, among other things, researching to harness the safety net role of forests into profitable household strategies for adapting to climate change (Nkem *et al*., 2008). The external interventions aim to enhance the capacities of the countries to respond to climate change.

In the African moist forest countries, climate change is mostly governed by existing environmental policies, acts, laws and regulations. Nigeria is in the process of articulating a specific policy on climate change, which will be followed by appropriate regulations and legislation. In some countries (e.g. Ghana, Guinea and Nigeria) special units have been set up to coordinate climate change activities, within the environment sector and across sectors. In Nigeria, for example, coordination within the Federal Ministry of Environment, which is the focal point, is the responsibility of a Special Climate Change Unit (SCCU) of the ministry, while an Inter-Ministerial Committee on Climate Change coordinates activities across sectors. National coordination is effected through a National Climate Change Coordinating Committee, comprising, in addition to government ministries, representatives of civil society organizations and the private sector. In Guinea, coordination is effected by a National Climate Change Coordinating Committee comprising 13 public and private institutions. The elaborate arrangement made for coordination to achieve an effective response to climate change is illustrated by the case of Ghana (see Box 5.1).

5.4 Issues in forest-based climate change response

5.4.1 Barriers to expanding the role of African moist forests in climate change response

The challenge of climate change has been the focus of several Africa regional and sub-regional summits (IISD 2009), from which have emerged such general initiatives as the ClimDev Africa programme, aimed at improving climate-related data management and dissemination towards building climate-resilient capacity in all aspects of the continent's development (E/ECA/COE/23/8). The Africa Union partnership with EUMESTAT to create the African Climate Change Monitoring Station also has a similar objective. This section, however, focuses on forest-based climate change initiatives.

Interest in an expanded role for African moist forests in climate change response strategies arises, primarily, because of the concern for the rapid rate of loss of tropical forests (see Table 5.5), which accounts for about 20% of global emission of CO_2 (IPCC, 2007). Forest loss at the same time diminishes the capacity of forests to sequester, and serve as a sink for, CO_2, while, mainly through the loss of biodiversity, it also curtails the opportunities for, and capacities of, forest-dependent local people to

Co-ordination of Climate Change and UNFCCC activities in Ghana

A National Committee on Climate Change is hosted by the Ministry of Environment, Science & Technology. This committee (made up of representatives from Ministries, Universities, Research Institutions, the private sector and Non-Governmental Organizations) has been mandated to review policies and programs that can complement the national development priorities while at the same time contributing to reduction of greenhouse gas emissions and increase in carbon sinks. The Ministry is the focal point for the UNFCCC activities in the country. The main Country Implementing Institution (CII) for the technical coordination of activities on Climate Change, the UNFCCC and other environmental conventions ratified by Ghana, is the Environmental Protection Agency. Since 1997, a special Conventions and Projects Implementation Department has been established within the Agency to perform, *inter alia*, the following functions:

a) Serve as the focal point for National, Regional and International Projects and Conventions implemented by the Agency.

b) Liaise with other departments to generally facilitate the coordination of Ghana's involvement in the preparation, ratification and implementation of Conventions and Protocols on the environment.

c) Act as the 'desk' for the implementation of climate change related issues.

Experts selected from the Universities, NGOs, Research institutions and Ministries, Departments and Agencies have also been organized into Working Groups and Climate Change Study Teams to assist with the implementation of the Climate Change Project. They form a core of experts who execute various activities in identified areas within the national economy that affect greenhouse gas emissions and sinks and also provide technical support to projects under the national climate change activities. This initial National Communication is based on the results obtained from the working groups and study teams.

Box 5.1 Source: Ghana's First National Communication to UNFCCC.

adjust and adapt to the adverse effects of climate change. Thus, African moist forests, as indeed all tropical forests, are particularly central to the issue of responding to climate change, through the two major approaches articulated by UNFCCC for addressing the problem globally – mitigation (by reducing emissions and/or sequestering carbon) and adaptation (by adjusting to the anticipated or existing effects of climate change).

Under the UNFCCC, the key global initiative of relevance, from the forest point of view, is the Kyoto Protocol, which, is the main instrument for regulating emission up to 2012, and is mandatory to countries that have ratified the protocol (Robledo *et al*., 2008). It is noteworthy that all the 14 African moist forest countries discussed in this chapter have ratified the Kyoto Protocol (Table 5.6), and significant that not one of the countries has a forest project under the protocol addressing climate change. Understanding why this is so, despite the acknowledged importance of forests, provides a clue to the thrust of most Africa-specific, forest-related positions or initiatives on climate change. It leads also to the understanding of the relevance of issues considered, in this chapter, to be important for effective engagement of African forests in climate change response strategies.

Under the Kyoto Protocol, the existing instrument through which forestry activities can be conducted as a response to climate change is the Clean Development Mechanism (CDM). African moist forest countries have not been able to access this facility mainly because they lack the expertise and financial resources to meet the project preparation standard and heavy financial cost involved. The high transaction and plantation establishment costs, the requirement for clear property rights and the difficulty of meeting the sustainability criterion are further obstacles that have made it difficult for local communities to participate even in the simplified afforestation and reforestation (A/R) projects under the CDM (Robledo *et al*., 2008).

These obstacles are among the issues of concern to Africa in the emerging mechanism of REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing countries), by which it is sought to expand the engagement of tropical forest countries in quantified emission reduction action. Africa's position in responding to this emerging mechanism is well articulated, for example, in the submission made by the Common Market for Eastern and Southern Africa (COMESA) to the UNFCCC Ad-hoc Working Group for Long-Term Cooperative Action recently (COMESA, 2009), and in the recently issued African Forest Forum position paper on present and emerging climate change arrangements (AFF, 2009). The primary concern is that the design of REDD or, indeed, of any climate change response mechanism affecting forests, in the post-2012 arrangements, must take account of the full range of the Agriculture, Forestry and Other Land Use (AFOLU) activities that are key drivers of deforestation in Africa. Since these activities support the livelihoods of forest-dependent local communities the mechanism must lead to enhancement of these livelihoods in addition to its environmental benefits. The compensation for avoiding deforestation must cover the cost of enhanced alternative livelihoods. At the same time, the transactions for putting such mechanisms into place must also be so simplified and involve realistic criteria for assessing emission reduction credits as to be readily operated and accepted by local people. The financial and other benefits accruing from the mechanism must in addition be equitably distributed to reach both men and women in the affected communities.

5.4.2 Providing the enabling environment

Global agreements and processes, as might result from current negotiations on REDD, must first be domesticated by African moist forest countries, and accompanied by the necessary policies, laws, regulations and guidelines, as well as administrative structures to facilitate their implementation. Domestication implies embedding the essential elements of the global agreements and processes into local instruments of governance, taking local realities into account. For example, successful implementation of an instrument like REDD, or other forest-based climate change mitigation or adaptation measures, would require policy reforms that *1)* settle the issues of forest land and trees ownership and rights, *2)* provide for the equitable distribution of benefits and incentives, taking gender considerations into account, *3)* provide for the institution of financial and technical incentives, to overcome transaction and early establishment difficulties, and *4)* create the necessary conditions for enhancement of the knowledge base in support of the transaction and implementation of projects. It would be necessary also for the moist forest countries to maintain a regular update of the status of their forest resources, through frequently repeated inventories that specify at least ownership, cover and stocking of the forests.

Linkage of the forestry sector with other sectors like agriculture, energy, housing and settlements, water resources, tourism and finance must be taken fully into account in designing forest-based responses to climate change. While forestry impacts on these sectors, activities that drive deforestation often come mostly from them. There will be need to co-ordinate effectively policies in these sectors in support of forest-based mitigation and adaptation measures. In addition to doing this at the highest policy-making level, devices such as inter-ministerial committees comprising relevant ministries, departments and agencies, and national coordinating committees comprising civil society and private sector representatives, added to government representatives, can help to enhance coordination in policy implementation. Cross-sectoral coordination can further be strengthened by designating and maintaining forestry/climate change desks and focal points in relevant ministries, departments and agencies. It is emphasized that the critical factor is the commitment to cross sectoral coordination at the highest level of policy-making. This ensures that the necessary support is provided to make inter-ministerial or coordinating committees, as well as designated focal points or desks effective.

5.5 Conclusion

African lowland moist forests are located mainly in West and Central Africa, with the forest in the Congo basin being the second largest continuous block of forest in the world after the Amazon forest. An archipelago of high altitude moist forests occurs mainly in the eastern and southern African countries. Together with woodlands, African moist forests occupy about 22% of Africa's land area, contain more than 80% of the wood biomass of forests in Africa, and are intimately linked to the socio-economic and productive systems of the people. Besides being the base for industrial wood production, they support livelihoods that are organized around agriculture and collection of forest products for food, energy, medicine and house-building, and serve as livelihood safety nets that help the people to overcome livelihood-threatening shocks.

African moist forests are currently under considerable pressure from human use and are also impacted by climate change, at the same time that interest is increasing in their potential to contribute to climate change mitigation and adaptation strategies. Pressure from human use is leading to degradation, fragmentation and outright loss of forest cover such that African moist forests, which represent less than 7% of the world's forest cover, contribute nearly 20% of total world deforestation. The impact of climate change is reflected mainly in the increasing rate of species loss, but the effects on forest productivity, which is critical for knowing the extent to which African moist forests serve as a sink for, or a source of, carbon dioxide are not yet well understood.

However, since tropical deforestation is known to contribute about 20% of annual global emission of CO_2, any reduction in loss of African moist forests will contribute to mitigating climate change. The challenge is how to achieve reduction in forest loss and at the same time meet the livelihood needs of the majority of Africans who depend on forests. The debate on the emerging mechanism of reducing emission from deforestation and degradation of tropical forests, REDD, centres largely on how to meet this challenge. Inclusion of African moist forests in global arrangements to respond to climate change requires mechanisms and procedures that are so simplified as to be readily accessible to African people, in terms of definitions, criteria for emission reduction assessment, transaction time and cost. The mechanism(s) must also take into account, and provide resources and technologies to develop the full range of activities in Agriculture, Forestry and Other Land Uses (AFOLU), that avoided deforestation will forego.

To engage effectively in such mechanisms, African countries must themselves take steps to develop the expertise and knowledge base (especially of the status of forest resources and of issues in the transaction process), and establish the necessary institutional, legislative and administrative framework, domesticating as necessary international laws and processes in ways that fully take local realities into account. Policies must be reformed to clarify and secure forest land and trees ownership, tenure and rights, taking equity and gender considerations fully into account, so that benefits from the engagement reach the grassroots. Policy reforms must also provide for incentives and financial assistance for transaction and initial implementation costs, and install management regimes that ensure full accountability in the transactions and regular monitoring of the resource base. And since the drivers of deforestation often come from many sectors outside the forestry sector, mechanisms for cross-sectoral coordination of policies and their implementation must be in place.

Engaging African moist forests in climate change mitigation and adaptation strategies could provide the impetus for the development of efficient and sustainable ways of using the forests. However, much methodological and policy reform, as well as capacity building, remains to be accomplished before the improved and sustainable ways of using the forests, to combat climate change and variability while enhancing livelihoods, can be realized.

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Chapter 6

CLIMATE CHANGE AND THE WOODLANDS OF AFRICA

Emmanuel Chidumayo

6.1 Introduction

Woodlands in Africa contain a high diversity of plant species with a high degree of endemism and are therefore important for biodiversity conservation. Woodlands in sub-Saharan Africa are also of crucial importance to water resources management because all the major river basins in sub-Saharan Africa are either located or have most of their headwaters in woodland zones where this vegetation plays a crucial role in sustaining river flows and water supplies. Agriculture is a significant local economic activity in many countries of sub-Saharan Africa because the majority of the people – who live in rural areas – depends on both subsistence production and local trade in agricultural produce. Large areas of African woodlands have been subjected to clearing for agriculture which has greatly affected their extent and condition. Much of the cropland is rain-fed and is therefore vulnerable to climate variability that is characterized by periodic droughts and occasional floods that frequently cause crop failure. During such times the majority of coping strategies for woodland inhabitants involves gathering of wild foods in the forest. Threats to African woodlands can be attributed to a number of factors and processes including policies that fail to take into account impacts on forests, conversion of forest to cropland arising from both population growth and structural adjustment policies, urbanization, over-dependence on wood-based energy sources, unsustainable harvesting of wood products, fire and climate change and variability. In respect of climate change, emerging evidence also suggests that climate warming might reduce overall plant production in woodlands of East and southern Africa. At larger geographical scale shifts in ranges of individual plant species are likely impacts of climate change on African woodland species.

This chapter describes the distribution of woodlands in sub-Saharan Africa and discusses the state of woodland biomass and carbon stocks, utilization, threats to woodlands and opportunities for improved management, vulnerability of the woodlands to climate change and impacts on trees and forests, and climate change adaptation and mitigation issues in the woodlands. The chapter ends with recommendations for managing woodlands for climate change adaptation and mitigation.

6.2 Distribution of woodlands in sub-Saharan Africa

The term woodland is here used in its broadest sense and includes a variety of wooded vegetation formations in which the woody canopy covers more than 10% of the ground surface, under climatic conditions with a dry season of three months or more. This definition incorporates vegetation types commonly termed woodland, shrubland, thicket, savanna, wooded grassland, as well as dry forest in its strict sense but does not include moist forest and the Sahel. Woodlands are found in 34 countries (excluding island states) in sub-Saharan Africa and dominate the vegetation in the majority

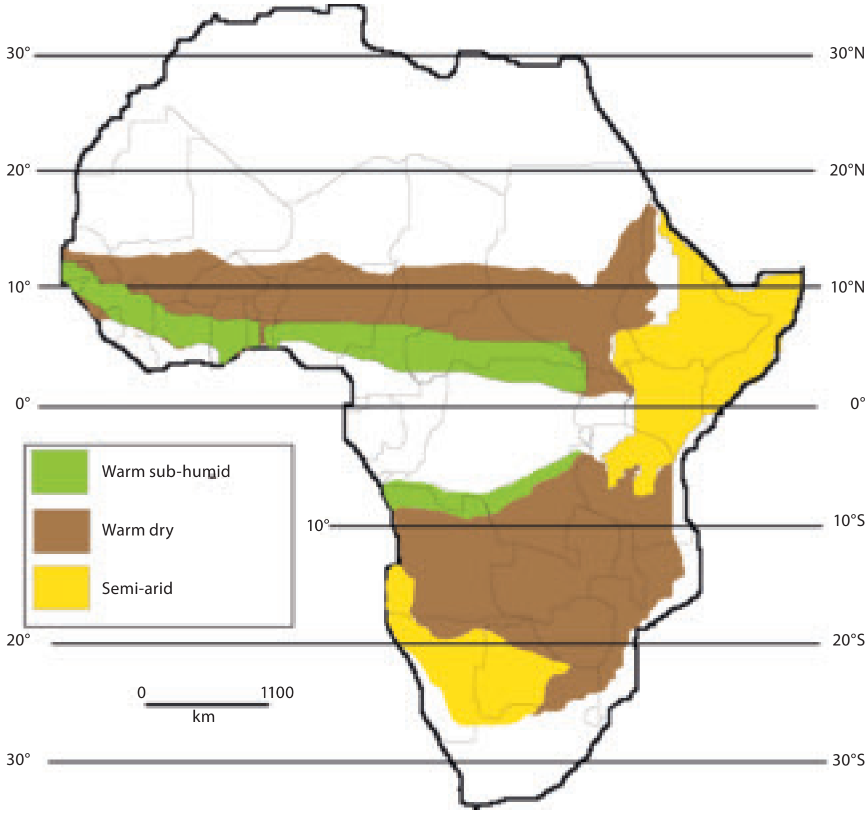


Figure 6.1 Distribution of woodlands in sub-Saharan Africa. Based on White (1983).

of these countries. On the basis of climate these woodlands can be divided into three main types: warm sub-humid, warm dry and semi-arid (Figure 6.1). The warm sub-humid woodlands are actually dry forests with a typical forest structure and occur in two of White's (1983) floristic regions – the Guinea-Congolia/Zambezian regional transition zone in southern Africa and the Guinea-Congolia/Sudanian regional transition zone in West Africa. Warm dry woodlands occur in the Zambezian and the Sudanian regional centres of endemism, while the semi-arid woodlands cover most of the Somali-Masai regional centre of endemism in northeast Africa and the Kalahari-Highveld regional transition zone in southern Africa.

6.3 Woodland stocks and condition

The level of vegetation cover in sub-Saharan woodlands depends on their structure and phenology, but generally tree cover is highest in sub-humid woodlands (over 70%) and lowest in semi-arid woodlands (10–40%) although Mayaux *et al*. (2004) give a range of 15–40% for the latter. Because of the deciduous nature of the woodlands, vegetation cover also varies seasonally. The increase in greenness during the late dry season is due to the woody component, while that in the early wet season is due to the grass component (Chidumayo, 2001). Degradation of the tree component, by fire, timber and wood harvesting, drought or browsing/grazing by wildlife or livestock, tends to reduce dominance of the woody component in favour of the grass component. This grass dominance can then be maintained by fire or grazing.

The analysis of data for 164 woodland sample plots in sub-Saharan Africa revealed that stem density does not vary significantly: stem density ranged from 300 to 900 per ha with a tendency for higher stem densities (800–900 per ha) in semi-arid woodlands and lower densities (700–800 per ha) in warm dry woodlands. However, data for 92 sample plots indicated that basal area varies significantly among woodlands - the highest basal area (at breast height) is found in sub-humid woodlands (24–28 m^2 per ha) and this declined to a range of 11.5–14.1 m^2 per ha in warm dry woodlands in southern Africa and 8.4–11.0 m^2 per ha in Kalahari-Highveld semi-arid woodlands. The basal area in the Sudanian warm dry woodlands of West Africa ranges from 3.6 to 10.1 m^2 per ha.

Large areas of African woodlands have been subjected to clearing for agriculture which has greatly affected their extent and condition. In addition, woodland fragmentation has occurred due to logging and wood harvesting for fuel. The greatest impact of agriculture has been in West and East Africa, where more than 50% of woodlands has been converted to agricultural use. Because of the nature of shifting cultivation that is widely practiced in Africa, land under agriculture represents a number of cover types, including cropland, abandoned fields and fallows at various stages of recovery. For example, Lanly and Clement (1982) estimated that 20% of open woodland in Africa is made up of fallows and land use conversion to agriculture is continuing as population pressure on woodlands grows resulting in a decline in woodland area per person: land per person in the Zambezian woodlands in southern Africa decreased from 1.45 ha in 1975 to 1.05 ha in 2000, and corresponding values for the Sudanian woodlands of West Africa are 1.58 ha in 1975 and 1.28 ha in 2000 (Eva *et al*., 2006).

Estimates based on the Food and Agriculture Organization (FAO) (2005) indicate that tropical woodlands in sub-Saharan Africa covered a total of 2.9 million km^2 in 2000 and represented nearly 23.4% of the total land area in the 34 countries in which these vegetation types occur. The broad distribution of woodland cover in the different subregions in sub-Saharan Africa is shown in Table 6.1.

6.4 Uses of woodlands

Woodland ecosystems in Africa contain a high diversity of plant species with a high degree of endemism and are therefore important for biodiversity conservation. Floristic diversity in African

Table 6.1 Distribution of woodland vegetation types in sub-Saharan Africa in 2000.

Woodland category	Phytoregion[1]	Subregion	Total land area (km^2)[1]	Woodland area[2]	
				km^2	% of woodland
Warm sub-humid	Guinea-Congolia/Sudanian transition zone	West Africa	1,165,000	94,365	8.1
	Guinea-Congolia/Zambezian transition zone	Southern Africa	705,000	129,015	18.3
Warm dry	Sudanian	West Africa	3,731,000	790,972	21.2
	Zambezian	Southern Africa	3,770,000	1,474,070	39.1
Semi-arid	Kalahari-Highveld	Southern Africa	1,223,000	50,143	4.1
	Somali-Masai	Northeast Africa	1,873,000	376,400	9.0
All			**12,467,000**	**2,914,965**	**23.4**

1) Based on White (1983).
2) Based on FAO (2005).

woodlands was assessed by White (1983) and has recently been re-evaluated by Linder *et al*. (2005). Plant species diversity in the different woodlands in sub-Saharan Africa are presented in Table 6.2. The large differences in species diversity between White (1983) and Linder *et al*. (2005) (Table 6.2) are probably due to *1)* taxonomic classifications and revisions, especially following the work of White, *2)* variable sampling effort, and *3)* differences in delineating phytoregions. The latter source of difference is particularly acute in the case of woodlands and savannas of Africa that are diverse and their delineation vary considerably among workers. However, both the assessments by White (1983) and Linder *et al*. (2005) indicate that the Zambezian woodlands of southern Africa have the highest floristic diversity while the Kalahari-Highveld semi-arid woodlands, also in southern Africa, have the poorest. According to White (1983), phytoregions with high levels of endemism (30–55%) include the Somali-Masai, Sudanian and Zambezian centers of endemism and this is supported by the assessment by Linder *et al*. (2005), except for the Sudanian phytoregion that was given a very low level of endemism of one percent (Table 6.2).

Woodlands in sub-Saharan Africa are of crucial importance to water resources management. In fact, all the major river basins in sub-Saharan Africa are either located or have most of their headwaters in woodland zones where this vegetation plays a crucial role in sustaining river flows and water supplies. Agriculture is a significant local economic activity in many countries of sub-Saharan Africa because the majority of the people – who live in rural areas – depends on both subsistence production and local trade in agricultural produce. Agriculture is therefore a major land use in African woodlands. In fact, the major zone of crop agriculture in sub-Saharan Africa is located in woodland areas (Mayaux *et al*., 2003, 2004). Much of the cropland is rain-fed and is therefore vulnerable to climate variability that is characterized by periodic droughts and occasional floods that frequently cause crop failure. During such times the majority of coping strategies for woodland inhabitants involves gathering of wild foods in the forest. This reliance on woodland resources is actually greater considering that forests also support local industries that produce wood products. And most important is the diverse range of other products, including fruits, fish and bush meat, edible insects, bees wax and honey and traditional medicines, that come from woodlands and are indispensable to the lives of woodland-dwelling communities. Most of these non-timber forest products are produced, traded and consumed outside the cash economy and therefore are not adequately captured in national economic statistics. Nevertheless, the FAO (1999a) estimated that the export of timber, nuts, gum and other forest products generates about 6% of the economic product of African countries.

Table 6.2. Plant species richness and endemism in woodlands of sub-Saharan Africa.

Woodland category	Subregion	Plant species richness		% of endemic species	
		White (1983)	Linder *et al*. (2005)	White (1983)	Linder *et al*. (2005)
Warm sub-humid	West Africa	2,000	711	3	1
	Southern Africa	2,000	571	3	5
Warm dry	West Africa	2,750	684	35	1
	Southern Africa	8,500	1,725	54	22
Semi-arid	Northeast Africa	4,000	931	31	11
	Southern Africa	3,000	583	2	2

6.5 Carbon pools in wood biomass and soils in the woodlands

Woodland trees through photosynthesis capture carbon dioxide (CO_2) to produce carbon compounds that constitute much of the woody biomass. However, few studies have assessed wood biomass in African woodlands. The determination of aboveground wood biomass in trees is generally achieved using the relationship between tree diameter and/or height and biomass derived from felled sample trees. A combination of tree- and stand-based basal area (derived from diameter measurements) was used to develop a common equation for estimating wood biomass from basal area data (Figure 6.2). This approach is particularly useful because most forest standing stocks are reported as basal area per ha and an equation based on basal area could have a wider application in estimating aboveground wood biomass in woodlands of Africa. The equation in Figure 6.2 was applied to basal area data from different woodland sample plots in Africa to compute aboveground wood biomass. Data for a total of 92 sample plots in sub-Saharan Africa, including Benin (Schreckenberg, 1999), Burkina Faso (Nikiema, 2005; Sawadogo *et al*., 2002; Zida *et al*., 2007), the Democratic Republic of Congo (Freson, unpublished; Malaisse, 1978; Malaisse, 1984; Malaisse *et al*., 1970; Malaisse *et al*., 1975), Mali (Picard *et al*., 2006), Mozambique (Musanhane *et al*., 2000; Sambane, 2005; Williams *et al*., 2008), South Africa (Shackleton *et al*., 1994; Scholes, 1990), Tanzania (Banda *et al*., 2006; Gausala, 1989; Isango, 2007), Zambia (Araki, 1992; Chidumayo, 1987, 1997, unpublished; Endean, 1968) and Zimbabwe (Ward and Cleghorn, 1964) were used in the analysis.

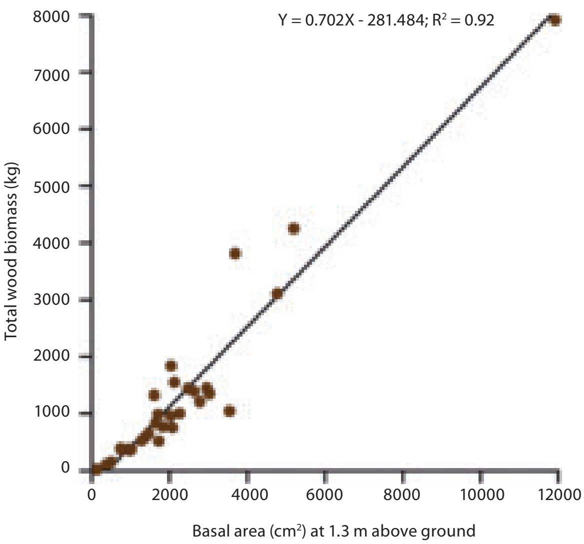


Figure 6.2 Linear equation for estimating total aboveground wood biomass (oven-dry basis) from basal area of individual and stand trees in African woodlands. Source: Chapter author.

The basal area data that were originally based on stump height (between 15 and 30 cm aboveground) measurements were converted to basal area at breast height using the following equation (Chidumayo, unpublished):

Basal area = - 0.0019 + 0.71*stump height basal area, $r^2 = 0.999$, $P < 0.0001$.

In addition data on wood biomass were obtained directly from literature for 73 sample plots in Benin (Orthmann, 2005), Ivory Coast (Lamotte, 1970; Menaut and Cesar, 1979), Kenya (Okello *et al*., 2001; Western and Ssemakula, 1981), Mozambique (Sambane, 2005), Nigeria (Fatubarin, 1984), South Africa (Higgins *et al*., 1990) and Zimbabwe (Kelly and Walker, 1976).

The results of the analysis indicate that aboveground wood biomass (mean ±1se) is highest in Congo-Guinea and Congo-Zambezian subhumid woodlands (179 ± 24 t per ha) followed by the Zambezian warm dry woodlands (93 ± 4 t per ha), then the Sudanian woodlands (57 ± 6 t per ha), Kalahari-Highveld (28 ± 6 t per ha) and lastly Somali-Masai (16 ± 3 t per ha).

There have been even fewer studies on belowground wood biomass in African woodlands but Frost (1996) estimated that belowground wood biomass represented about 40% of the aboveground biomass. This is most likely an underestimation of belowground wood biomass given that the depth of roots of woodland trees may exceed 5 m (Savory, 1962) while most root samples have been obtained at depths of less than 2 m (Chidumayo, 1993a). Estimates of belowground wood biomass were therefore derived from multiplying aboveground biomass by 0.4 as suggested by Frost (1996). Carbon content in wood biomass was estimated by multiplying wood biomass by a factor of 0.47 (Chidumayo, 1993b; Williams *et al.*, 2008; Woomer *et al.*, 2004).

Woodland soils also contain considerable amounts of organic matter. Total organic matter content ranges from 1 to 2% that is concentrated in the top 30 cm (Brookman-Ammissah *et al.*, 1980; Chidumayo, 1993a; Lugo and Sanchez, 1986; Orthmann, 2005; Trapnell *et al.*, 1976; Williams *et al.*, 2008). Soil bulk density ranges from 1.2 to 1.4 (Brookman-Ammissah *et al.*, 1980; Chidumayo and Kwibisa, 2003; Williams *et al.*, 2008). To estimate soil organic carbon in the top 30 cm the product of organic matter content of 1% and a bulk density of 1.2 was multiplied by a factor of 0.58 which is the proportion of carbon in soil organic matter (McVay and Rice, 2002).

The estimated carbon density in African woodlands is shown in Figure 6.3 and total carbon stocks are summarized in Table 6.3. The major carbon stocks are found in warm subhumid and warm dry woodlands of southern Africa (70% of the carbon in wood biomass and 55% of the carbon in soil).

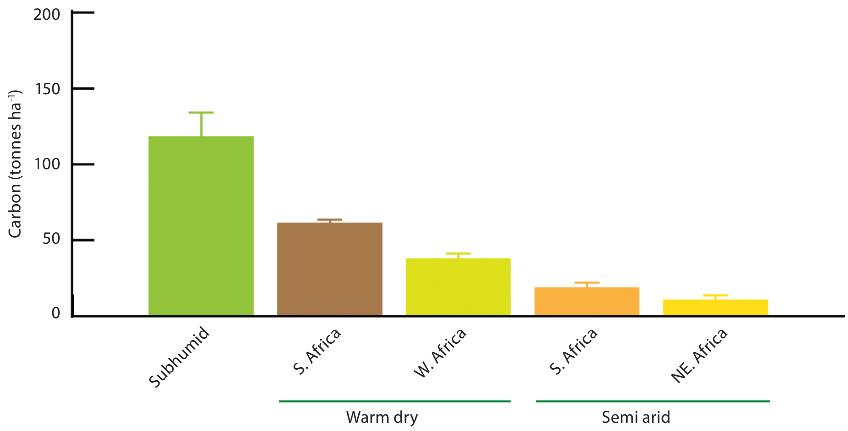


Figure 6.3 Average carbon stocks per ha in woodlands of sub-Saharan Africa. Vertical line above each bar is standard error of mean value.

Table 6.3 Distribution of carbon stocks in woodlands of sub-Saharan Africa in 2000. Based on FAO (2005).

Woodland category	Subregion	Woodland area	Carbon stocks in million tonnes		
		km^2	Wood	Soil	Total
Warm sub-humid	West Africa	94,365	1,112	200	1,312
	Southern Africa	129,015	1,520	274	1,793
Warm dry	West Africa	790,972	2,967	1,677	4,644
	Southern Africa	1,474,070	9,020	3,126	12,146
Semi-arid	Southern Africa	50,143	92	106	199
	Northeast Africa	376,400	396	798	1,194
All		**2,914,965**	**15,107**	**6,181**	**21,288**

6.6 Threats to the woodlands

Given the difficulties of modeling deforestation and degradation of tropical open woodlands (Grainger, 1999), estimates of woodland cover loss in Africa tend to vary greatly depending on the methodology used to estimate deforestation and degradation. Estimates of woodland loss therefore can only be indicative of the extent of the problem of deforestation in woodland areas. During 1990 to 2000 it was estimated that woodland countries in sub-Saharan Africa lost nearly 5 million ha of forest cover annually or nearly 1.7% of the forest cover in 2000 (FAO, 2005). Much of this loss occurred in West Africa (2.5 million ha) and southern Africa (2.3 million ha). According to Kigomo (2003) the causes of woodland cover degradation and loss in semi-arid Africa are overgrazing, agricultural expansion and overexploitation of forest resources. He indicated that 48% of woodland degradation was due to overgrazing which is concentrated in semi-arid areas, 32% was due to agricultural activities, 12% was due to deforestation and 9% was due to resource overexploitation. Mayaux *et al*. (2004) estimated that nearly 15% of the Zambezian woodlands has been converted to agriculture while similar values for the Sudanian and Somali-Masai woodlands are 60% and 80%, respectively.

Threats to African woodlands can be attributed to a number of factors and processes, including *1)* policies that fail to take into account impacts on forests, *2)* conversion of forest to cropland arising from both population growth and structural adjustment policies, *3)* urbanization, *4)* over-dependence on wood-based energy sources, *5)* unsustainable harvesting of wood products, *6)* fire, and *7)* climate change and variability.

The influences of macroeconomic policies on forestry in southern Africa have been reviewed in Kowero *et al*. (2003) who observed that macroeconomic policies affect factors that make forest conversion, wood processing and trade attractive while increased growth as a result of macroeconomic policies can also result in extensive deforestation. Because charcoal requires more wood to produce, due to wastage during conversion, the use of charcoal in urban areas of sub-Saharan Africa has also serious implications on woodland condition and land cover loss.

In tropical woodlands, fire is a common threat to the vegetation. Although some fires originate from lightning around the start of the rainy season, most are caused by humans. Some originate accidentally from burning undertaken during land preparation, from making charcoal or from honey collecting, but others are set deliberately to flush out mammals or birds for hunting or to stimulate new grass growth for livestock and wild herbivores (Frost, 1996). However, it must be recognised that fire is a natural feature of woodlands in Africa, although its frequency is probably now much higher than historically. Fire has a composite nature (Frost and Robertson, 1987), its behaviour, timing, intensity, frequency all vary independently, and all affect vegetation structure and composition differently. Fire can kill trees, but it can also change the competitive status, allowing vegetation to change over time through differential recruitment and survival of seedlings and saplings. Seedlings and sprouts face frequent and severe fire damage that can retard their recruitment into the tree layer. Between fires, seeds have to germinate and seedlings must build enough root reserves to survive the next fire. However, given that fires usually occur once in every 2–4 years (Chidumayo, 2004; Sankaran *et al*. 2007), sprouts would need to grow rapidly to escape damage.

There will undoubtedly be some marked changes in distribution and extent of African vegetation types during the 21st century, probably resulting from an increased tendency in many areas to lower mean annual precipitation (see chapter 2). But such effects have also got to be seen in the context of equally – or more – rapid changes in land use resulting from intensification and increased population pressures. However, climate change and increased human impacts on vegetation are likely to be intertwined, and it is difficult to predict what the consequences will be in detail.

Woodlands in sub-Saharan Africa occur in a climate that is seasonal with rainfall during the wet season(s) but almost no rain during the dry season(s). The climate also exhibits high interannual and interdecadal variability. These woodlands will be increasingly subjected to drying in the 21st century, as well as increasing land-use intensity. In the last 10 to 20 years woodlands in Africa have experienced erratic weather patterns, including short-term climatic cycles, that have adversely affected productivity of these forests (Gonzalez, 2001), with serious implications for human well-being in woodland communities.

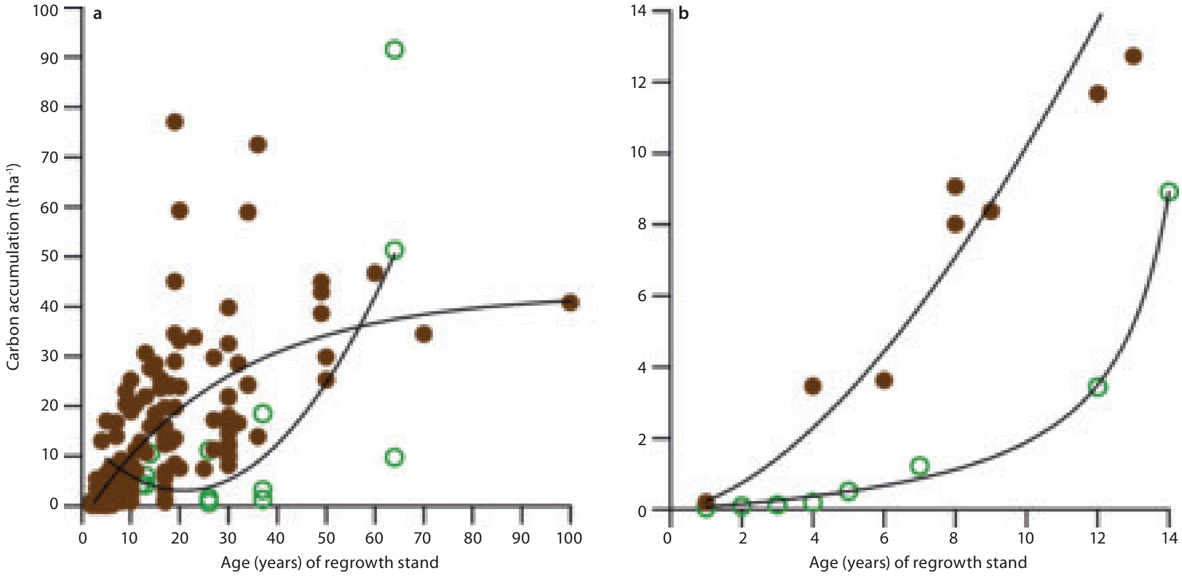
6.7 Opportunities for sustainable management of the woodlands

In spite of the above threats, a number of opportunities exist in support of sustainable management of African woodlands. Woodlands in sub-Saharan Africa are thinly populated with an overall density of 1.7 ha of woodland per person in 2000 (FAO, 2005). The lowest density of 2.9 ha per person is found in southern Africa and the highest density of 0.5 ha per person occurs in northeast Africa. A total of 5.2 million ha have been designated as forest protected areas in woodland countries in Africa which represents only 1.8% of the forest area in 2000. Thus potential exists to increase the proportion of woodland under forest protection.

Woodlands in sub-Saharan Africa regenerate easily following wood harvesting and clearing for shifting cultivation, a major land use in Africa. Once the woodland has been cleared and the land abandoned, regeneration often takes place but the speed of woodland recovery depends on the methods used in clearing, the sources available for regeneration, and site history (i.e. type, frequency and intensity of stress and/or disturbance). Regeneration occurs through either sexual or vegetative means. Sexual regeneration is achieved through seed germination and establishment of seedlings and their recruitment into the sapling and tree phases. Vegetative regeneration occurs through the recruitment of sprouts or resprouts from pre-existing trees that get cut or damaged, sometimes termed coppice. Sprouting is the production of secondary trunks as an induced response to injury or to profound changes in growing conditions. Seed dispersal, predation, desiccation and seedling mortality can act as strong constraints that impede woodland recovery after disturbance. The ability to sprout after severe injury from disturbances such as herbivory, fire, floods, logging or drought, overcomes these barriers, as these individuals bypass the seed stage and tend to have more vigorous shoots than seedlings presumably because vegetative shoots take advantage of the extensive root system and the substantial food storage in the remaining parts of the parent plant. However, sprouting ability varies with the age or size of a plant and also with the type and severity of injury.

Aboveground wood carbon accumulation in regrowth woodland stands was assessed based on the model given in Figure 6.2 using data in the literature from Ghana (Swaine *et al*., 1987), Ivory Coast (Louppe *et al*., 1995), Kenya (Johansson and Kaarakka, 1992; Okello *et al*., 2001), Mozambique (Sambane, 2005), South Africa (Scholes, 1990), Tanzania (Boaler and Sciwale, 1966), Zambia (Chidumayo, 1987, 1988a, 1988b, 1997, unpublished) and Zimbabwe (Strang, 1974). This gave a total of 123 sample plots representing a variety of forest management regimes. In addition, direct estimates of wood biomass were obtained for 62 sample plots in Burkina Faso (Nygård *et al*., 2004), Ivory Coast (Menaut and Cesar, 1979), Kenya (Okello *et al*., 2001), Mozambique (Sambane, 2005) and Zambia (Chidumayo, 1990; Oyama, 1996).

In most woodlands carbon accumulation with increasing age was best explained by a steep rise in carbon stocks with increasing age of regrowth, although accumulation in early stages of regrowth is depressed (Figure 6.4). The only asymptotic carbon accumulation was observed in Zambezian miombo woodland of southern Africa in which the bulk of the carbon is accumulated within 50–60 years with very little change afterwards (Figure 6.4). A high



a) Zambezian miombo (●, $y = 42.71 - 45.70x^{0.97}$, $r^2 = 0.42$) and Sudanian woodlands (o, $y = 14.19 - 1.06x + 0.03x2$, $r^2 = 0.56$).

b) Kalahari-Highveld woodlands (●, $y = 0.24x^{1.63}$, $r^2 = 0.97$) and Somali-Masai woodlands (o, $y = -1.08x/(-15.7 + x)$, $r^2 = 0.99$).

Figure 6.4 Models describing the pattern of carbon accumulation in aboveground wood biomass in regrowth. Based on data from literature (see text).

potential therefore exists for carbon assimilation in African regrowth woodlands that can contribute to mitigation measures against climate change.

As the regrowth woodland reaches maturity, the carbon stocks also approach a steady state (e.g. Figure 6.4 for a miombo woodland). However, even though mature woodlands are considered to be in a steady state with respect to the carbon balance, many of these woodlands have been disturbed in the past by biotic factors, especially human factors such as selective harvesting and burning. It is therefore probable that under good forest management, such relatively mature woodlands have the potential to accumulate additional carbon in woody biomass and soil while maintaining existing stocks and therefore can contribute to climate change mitigation and stabilization. For example, Endean (1968) observed that under good forest management, relatively mature miombo woodland in Zambia had a mean annual increment of 1.2% until it reached a basal area of about 16.2 m^2 per ha.

6.8 Vulnerability of the woodlands to climate change and impacts on trees and forests

Woodland vulnerability to climate change refers to the degree to which the woodland system is susceptible to or unable to cope with adverse effects of climate change, its variability and extreme events. Vulnerability therefore includes the system's sensitivity once exposed to climate change and its adaptive capacity. Sensitivity is the degree to which a system is affected either adversely or beneficially by climate change stimuli, such as change in rainfall or temperature. Currently evidence suggests that the climate in eastern and southern Africa is warming at a faster rate than has been predicted from global models. For example, temperature rises of 0.25–0.5°C per decade have been recorded in Zambia (Chidumayo, 2008), Kenya (Altmann *et al.*, 2002), Kenya and Tanzania (Ogutu *et al.*, 2007) and Uganda (Chapman *et al.*, 2005). However, no clear trend in rainfall patterns has been observed although extreme events, such as droughts and floods, appear to have increased in frequency. The significant climate change stimuli, which African woodlands are likely to be subjected to in the near future in East and southern Africa, are most likely related to climate warming due to rising temperatures and extreme events such as droughts and floods. Plant responses to such changes will occur via altered ecophysiological processes.

Plant reproductive processes that might be affected by climate factors include flowering, pollination, seed production and seed germination. The effect of climate change on seed production will depend on flowering phenology, behaviour of pollination agents and fruit/seed development periods. The few observations that have been made in East and southern Africa suggest that fruiting levels will be negatively affected by climate warming. For example, a negative correlation between the proportion of fruiting trees in Kibale National Park, Uganda, and minimum temperature has been observed (Chapman *et al*., 2005; Figure 6.5a). Similar observations have been made concerning fruit production in *Strychnos spinosa* in Lusaka, Zambia, (Chidumayo, unpublished data; Figure 6.5b). It appears therefore that climate warming is likely to reduce fruit/seed production in African woodland trees with negative consequences for sexual regeneration and therefore plant genetic diversity.

Chidumayo (2008) studied seedling emergence and mortality in relation to climate factors in five savanna woodland trees at a field site in central Zambia and assessed their likely responses to a 1°C warmer climate. In four of the species, temperature significantly affected seedling emergence and this was predicted to decline in three of the species but an increase was predicted in one of the species. Temperature also significantly affected seedling mortality in all the five species such that under a warmer climate, mortality was predicted to increase in two of the species but a decrease was predicted in three other species. The conclusion

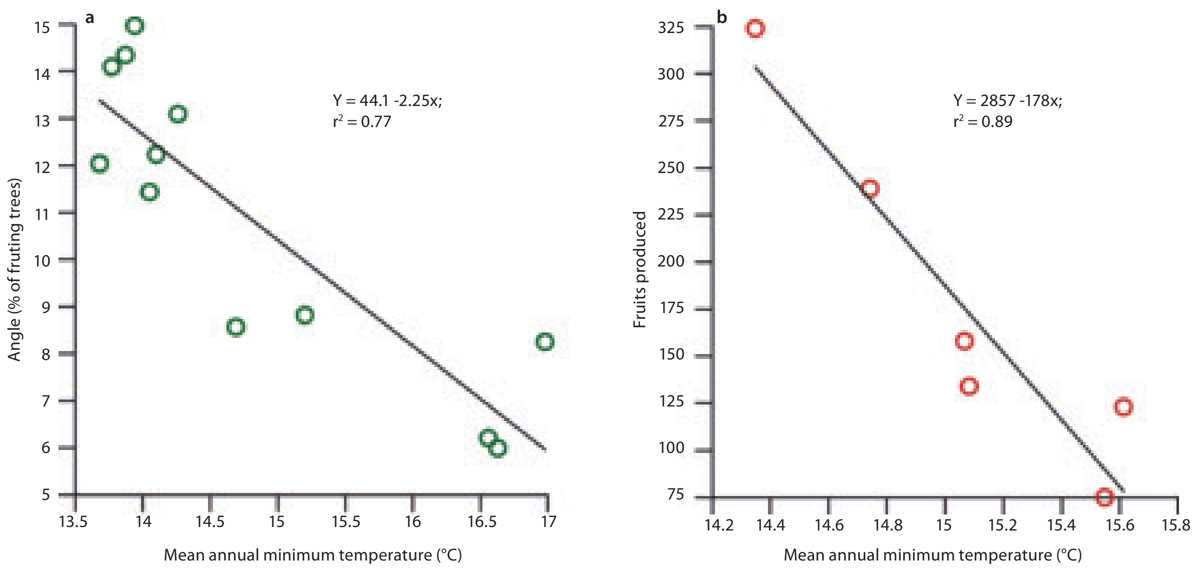


Figure 6.5 Relationship between a) *proportion of fruiting trees (angular transformed data) and minimum temperature in Kibale National Park, Uganda (based on Chapman* et al.*, 2005) and* b) *fruits produced by* Strychnos spinosa *tree and minimum temperature at Lusaka, Zambia (Chidumayo, unpublished data).*

was that African woodland trees would respond to climate warming in different but predictable ways.

Leaf phenology of most woodland trees in East and southern Africa is correlated with minimum temperature (Jeffers and Boaler, 1966) and Woodward (1988) proposed that minimum temperature could be an important determinant of the distribution of a number of plant species in the tropics. Ernst (1988) also observed that photosynthesis in seedlings of *Brachystegia spiciformis*, an important miombo woodland tree, ceased when temperatures dropped below 16°C while it has been suggested that tropical trees remain dormant below temperatures of 12–15°C (Larcher, 1995). All these observations indicate the significance of temperature in determining leaf phenology and productivity in African woodland trees.

Emerging evidence also suggests that climate warming might reduce overall plant production in woodlands of East and southern Africa. Chidumayo (2001) observed that minimum and maximum temperature had a significant additive effect on woodland leaf phenology (based on the Normalized Difference Vegetation Index [NDVI]), which is a measure of vegetation greenness and therefore productivity. Indeed recent declines in NDVI in the Mara-Serengeti ecosystem in eastern Africa have also been attributed to the rise in minimum temperature (Ogutu *et al.*, 2007; Figure 6.6). A mean series of 38 years for *Isoberlinia tomentosa* trees in Tanzania revealed significant correlation of tree ring widths and *1)* monthly precipitation, *2)* monthly maximum air temperature and *3)* monthly Southern Oscillation Index (SOI) value (Trouet *et al.*, 2001). Observations made at a Makeni savanna site in central Zambia also show that the radial growth of the majority of trees declined due to additive effects of temperature factors which explained a significant proportion of the variation in tree annual growth (Chaidumayo, unpublished data; Table 6.4). However, productivity of the dominant C_4 grasses at the same savanna site increased apparently in response to rising temperatures that was in sharp contrast to the growth pattern in the majority of C_3 trees. This difference in the growth responses of C_3 trees and C_4 grasses may be due to the fact that C_4 photosynthetic pathway is characterized by high water-use efficiency and high optimum temperatures for photosynthesis compared to the C_3 photosynthetic pathway. Most trees in African woodlands are C_3 plants while most grasses are C_4 plants and climate warming is likely to have different effects on these two plant functional groups.

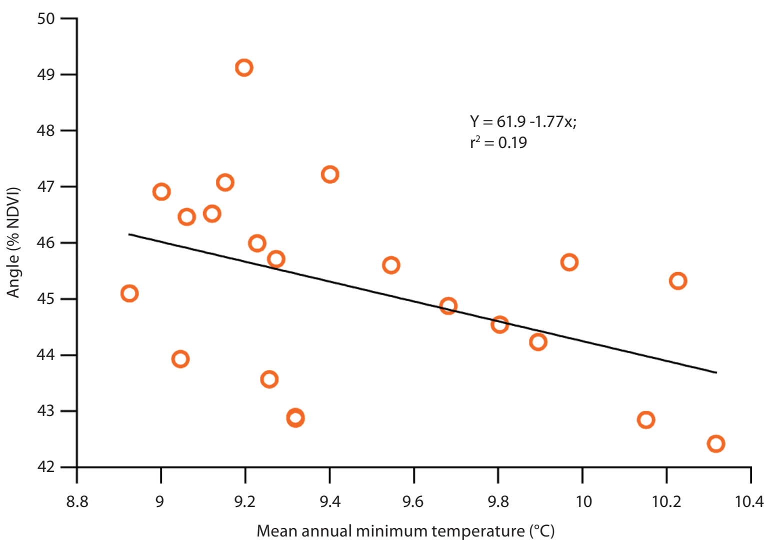


Figure 6.6 Relationship between NDVI (angular transformed data) and minimum temperature in the Mara-Serengeti ecosystem in east Africa. Based on Ogutu et al. *(2007).*

Table 6.4 Regression models for predicting the radial growth (y) of trees at a Makeni savanna site in central Zambia during 1998 to 2008. Predictor variables are annual rainfall (R, mm), mean annual daily average temperature (T_{avg}, °C), minimum temperature (T_{min}, °C) and maximum temperature (T_{max}, °C). Based on Chidumayo (unpublished data).

Species	Model for predicting y (cm year^{-1})	r^2	P	Predicted annual growth rate under a 1°C warmer climate
Indigenous trees				
Acacia polyacantha	21.6 – 0.4R	0.16	0.0001	No change
Acacia sieberiana	24.6 – 1.1T_{avg}	0.20	0.0001	Decrease
Combretum molle	41.5 – 0.001R – 1.02T_{min} – 1.1T_{avg}	0.39	0.0001	Increase
Piliostigma (Bauhinia) thonningii	32.4 – 0.001R – 2.1T_{avg} + 0.52T_{max}	0.30	0.001	Decrease
Exotic trees				
Eucalyptus grandis	19.1 – 0.8T_{avg}	0.08	0.04	Decrease
Gmelina arborea	16.2 – 1.0T_{min}.	0.17	0.001	No change
Senna siamea	5.7 – 0.002R – 2.1T_{avg} + 0.52T_{max}	0.38	0.001	Decrease

Increased variability in rainfall and changes in temperature, as predicted under climate change scenarios, will likely disrupt woodland leaf phenology and such ecosystem services as evapo-transpiration. This may occur in a number of ways. A changed warmer climate might shorten 'winter' dormancy in African woodlands and advance the onset of spring leaf flush. If this was to happen without a corresponding advance in the onset of the rainy season, then a prolonged period of pre-rains water stress may trigger premature leaf loss and/or tree mortality. In fact, in most of Africa, soil water availability is projected to have the greatest impact on plant processes (IPCC, 2001) because woodland species are adapted to a particular water regime, such that these may perform poorly and possibly die out under a changed warmer climate. For example, in spite of the impacts of elephant and fire damage on trees in a Tanzanian woodland over a 25-year period, a dramatic decline in density of small trees was caused by a severe drought in 1993 (van de Vijver *et al*., 1999). This indicates that extreme climatic events may in some cases have more dramatic effects on tropical woodlands in Africa, especially in semi-arid zones.

At larger geographical scale shifts in ranges of individual species are likely impacts of climate change on African woodland species (McClean *et al*., 2005). These authors through modeling have predicted that 25–75% of the plant species in African woodlands might lose all their currently climatically suitable ranges under a future warmer and drier climate. Indeed, retraction of mesic species to areas of higher rainfall and lower temperature as a result of desertification in the last half of the 20th century has been documented in Senegal (Gonzalez, 2001) while modelling of the distribution of forest species has projected changes from mesic vegetation to xeric vegetation in Tanzania and The Gambia (Jallow and Danso, 1997) and a shift from arid to moist vegetation in Mozambique (Bila, 1999).

Increasing temperatures in southern Africa are predicted to either extend the growing season in some ecosystems or shorten it in some others (Rutherford *et al*., 1999). Climate change is also likely to alter the frequency, intensity, seasonality and extent of vegetation fires that are characteristic of African woodlands. Such changes in the fire regime are likely to change the structure and composition of these woodlands. Climate-induced fires have also been cited as being responsible for the downward shift of cloud forests on Kilimanjaro Mountain in Tanzania in the last three decades

(Hemp, 2009). It is most likely, however, that under these predicted changes in climate and disturbance factors, species will respond individualistically, perhaps with substantial time lags and periods of re-organization, rather than wholesome shifts in vegetation formations.

6.9 Climate change adaptation and mitigation issues in the woodlands

Adaptation is primarily aimed at tackling localized impacts of climate change while mitigation addresses the impacts on the climate system. Adaptation is therefore perceived to have the potential to reduce adverse effects of climate change but not necessarily prevent all the damage caused by climate change (Hulme, 2005). Given that African woodlands and the resources they contain will undoubtedly be impacted upon as a result of climate change, adaptive strategies should aim at managing species and habitats to reduce the negative impacts of climate change.

African woodlands are commonly used for wood harvesting, livestock grazing and wildlife management, including tourism. Biodiversity contributes to livelihoods in African woodlands but also to the well-being of others that live outside the woodlands, for example people who visit as tourists or use medicinal or horticultural products derived from woodlands. Often it is during times when there is crop failure that local communities appreciate the values of woodland resources as sources of food. This gives the impression that wild food resources will always be available in times of natural disasters and therefore reliance on wild food sources is considered an adaptation to climate change. However, this may not be the case for future climate impacts. For example, fruit production in many woodlands trees is likely to decline (see Figure 6.4) and this will lower the woodland capacity to supply edible fruits to meet local consumption needs and for sale. Women and children who are currently the main consumers of wild foods are most likely going to be worse off under a warmer future climate. One adaptive strategy for dealing with such a future reduction in wild food production is to plant more indigenous fruit trees in order to increase tree populations and reduce the impact of low fruit production in the wild that is likely to be caused by climate change.

According to Desanker and Magadza (2001) the most promising adaptation strategies to declining tree resources in sub-Saharan African countries include natural regeneration of local species, sustainable forest management and community-based natural resources management. However, the success of such strategies generally depends on the ability of local people to exercise power to inventory and manage local resources in systems of community-based natural resources management. For example, decentralization of decision-making and revenue allocation authority has promoted efficient forest management in some areas in Niger, Madagascar and Zimbabwe (FAO, 1999b). Nevertheless, if forest and tree productivity decline, as is predicted, under a future warmer climate, yields will also decline, as will revenue generation from forest resources. Adaptive strategies therefore will have to include changes in harvesting regimes to reduce overexploitation, including imposition of longer cutting cycles for timber and possibly allocation of larger areas dedicated to forest management in order to ensure adequate yields to meet local expectations under community-based forest management models.

Hundreds of potentially valuable tree species are often not used but simply burnt in forest clearing operations like logging, agricultural conversions and dam building. Little is known at the present about their possible end-uses or even their physical and mechanical properties. Nevertheless, utilization of such lesser known species may help to alleviate the pressure on the diminishing high-value species while contributing to increasing yields under a warmer climate and by so doing, increasing the economic opportunities for communities responsible for sustainable forest management (Vlosky and Aguire, 2001). In addition, the use of lesser known species is desirable because *1)* the logging intensity in African woodlands is low and can presumably be increased if more species are used, without jeopardizing the functioning of the ecosystem, and *2)* an increase in yield per hectare reduces costs of logging and silvicultural operations per unit product.

6.10 Conclusions

Climate affects forest condition but forests also affect climate. The forest sector in Africa therefore needs to be adequately equipped to respond to climate change. It is important to understand how climate change is likely to impact on forests in order to implement adaptation strategies for the sector. In the same vein, the forest sector needs to improve the management of forests to mitigate climate change, especially through the reduction in CO_2 emissions from deforestation and forest degradation and carbon sequestration from the atmosphere. Improved management of forests, e.g. through the protection of forested watersheds, will also contribute to sustainable water supplies for human use, agriculture, fisheries, wildlife and hydropower generation and ultimately improve livelihoods, food security, poverty reduction and a healthy environment.

Currently little is known about the potential of woodlands in Africa to adapt to climate change. Models suggest that climate change will cause shifts in the ranges of many vegetation communities but it is also possible that different species respond differently to climate factors and therefore may respond differentially to climate change. If this is true, then understanding the responses of individual species, especially the dominant species, is of paramount importance to the development of forest-based adaptation strategies. If climate warming reduces the productivity of woodland trees, then their role in mitigation against climate change through carbon sequestration may be reduced. Climate change may also affect forest regeneration and afforestation. Thus both climate response and mitigation by forests need to be assessed so that informed strategies and measures can be made to address the role of forests in climate change.

Harvesting strategies need to be adapted to changed climate. Given the predicted decline in tree growth, current sustainable wood and timber harvesting rates may represent overestimations for the future climate scenarios. Clear trade offs will have to be worked out between maximizing average harvest and minimizing the risk of population collapse. Indirect consequences of species harvest on non-target species may require special attention where a common resource base is likely to alter under climate change. Under certain circumstances, current harvesting regimes may no longer be sustainable and will require reformulation or redesigning, as parts of the adaptation process.

Establishing effective climate adaptation strategies requires that scientists, managers and policymakers work together to *1)* identify climate-sensitive species and systems, *2)* assess the likelihood and consequences of impacts, and *3)* identify and select options for adaptation (Hulme, 2005). It is also important to recognize that although climate plays a significant role in determining species' distribution, other variables such as human population density, land use and soils can have similar, if not more, important roles. Issues of population growth and land use change therefore should be considered in developing adaptive strategies to climate change.

Climate envelope models suggest that for some species predicted changes in climate may significantly reduce the suitability of currently occupied habitats. Such threats are likely to be most keenly felt by species with limited dispersal ability. For such situations, adaptive management may involve either improving connectivity of habitats to facilitate natural dispersal or human-aided dispersal to appropriate habitats. Under the latter, success can be improved by ensuring that the size of the introduction is sufficiently large to overcome the risk of Allee effects that can drive small populations towards extinction.

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Chapter 7
CLIMATE CHANGE IN THE WEST AFRICAN SAHEL AND SAVANNAS: IMPACTS ON WOODLANDS AND TREE RESOURCES

Mahamane Larwanou

7.1 Introduction

The climate of the West African Sahel has shown various changes, especially in terms of rainfall, of which inter-annual variability has been very high in the last 30 years (Ben *et al*., 2002). The West African Sahel is already known as an area characterized by important interaction between climate variability and key socio-economic sectors such as agriculture and water resources. Local to regional interaction between vegetation and rainfall was also shown to be linked to the variability of Sahel rainfall (Zeng *et al*., 1999).

In the 1970s and 1980s many publications were made on energy crisis in Sahelian countries and elsewhere in arid and semi-arid zones (Eckholm, 1975; Winterbottom, 1980). The recurring theme was that there is an important gap between the energy needs of the people that was exclusively wood-based and the annual growth of tree resources. It was then assumed that in the near future, areas near big towns in the Sahel could be seriously denuded due to increasing needs of fuel wood by the growing urban population.

The Sahel also experienced a period of crisis because of serious and recurrent droughts. These droughts have had significant consequences for the poorly resourced farmers, whose incomes depend mainly on rain-fed agriculture. However, the long period of rainfall insufficiency and the gradual but persistent drying up of streams spurred people to adjust by expanding cultivation to hill slopes and giving more preference to farming in lowland areas (Salibo and Joseph, 2001). Many inhabitants in search of water sources migrated and settled closer to streams. These pressing climate changes lead to disastrous floods during the short rainy season while water scarcity continues to worsen year after year during the dry season.

Research has for several decades focused on the causes of the dryness in the Sahel. Earlier studies identified desertification and land degradation as possible causes for the persistent drought in the Sahel. Other studies suggest that the build up in dust as a result of changes in land surface, exacerbated by anthropogenic factors, may have contributed to large-scale climate change (Nicholson, 2000). This tendency, it is argued, ignites large scale climate fluctuations, which ultimately could impact on rainfall (Biasutti and Gianini, 2006), and consequently on ecosystems of the Sahel. However, the regional atmospheric response to these crises is not very clear. Will it be a very wet or a very dry Sahel, or just a Sahel with more frequent dry years as Cook and Vizy (2006) suggested? Proper understanding of the influence of modes of variability at all time scales on Sahel rainfall, and the ability of the climate models to accurately represent these modes of variability, will help improve seasonal to inter-annual climate predictions (Thiaw and Bell, 2004) that will help society to cope with these climate conditions. Olsson *et al*. (2005) have noted that more recent studies in the Sahel suggested secular trends of change, many related to vegetation and land use, in selected case studies (Mortimore and Adams, 2001; Reij and Thiombiano, 2003), at a national scale (Niemeijer and Mazzucato, 2002) and even at the regional to sub-continental scale (Eklundh and Olsson, 2003). Although it is evident that the observed vegetation trend is the result of a complex combination of social and environmental factors, most of which are yet to be understood better, there are already some important policy implications.

In response to climate change, the recent global debate has focused on two broad levels. The first, known as mitigation, involves reducing greenhouse gas (GHG) emissions to slow or stop climate change. The second, adaptation, is learning to cope with the impacts of climate change. Adaptation is important for two reasons: first, some climate change impacts are now inevitable and, indeed, are already being observed. Second, even if all GHG emissions were to stop immediately, average temperatures would continue to rise for some time because of lags in the earth's natural processes. Hence, adaptation will be of great importance in dealing with the inevitable impacts of climate change over the next 30 years, while the benefits gained from mitigation will only start to be felt in 30+ years time (IIED, 2008). This could also be true in forest and tree resources especially in arid zones like the Sahel.

The aim of this paper is to present the state of the resources and impacts of climate change on forests and trees as well as efforts made in the Sahel region to contain them.

7.2 The Sahel and West African savannas: characteristics and forest resources status

7.2.1 Characteristics of the Sahel

The term 'Sahel' was first coined by the botanist Chevalier (1900), which he used primarily as a phytogeographical unit. The origin of the term is variously translated from the Arabic 'Sahel', meaning coast or shore and 's'hel', meaning plain or flat land (White, 1983; Le Houérou, 1989). This is where ecology and climate make life possible after traveling thousands of kilometers through the Sahara desert on a southern direction from the Maghreb countries. It is a transition zone between the arid north and the green tropical forest along the maritime coast. The vegetation cover is composed of shrub, herbs and trees that increasingly become dense towards south. Agriculture is only viable with crop varieties resistant to drought. The Niger and Senegal rivers crossing the Sahel increase dry season cropping. Livestock rearing is an important activity, but the long dry seasons make herders to move towards the south for pastures. Therefore, the term Sahel applies to an agro-climatic zone than a geopolitical entity as shown in Figure 7.1.

Some of the factors characterizing the Sahel include:

- High climatic variations ranging from 200 to 800 mm of rainfall per annum.
- Predominance of agriculture and livestock rearing: more than half of the active population is employed in these sectors which contribute almost 40% of GDP.
- High population growth (more than 3.1% per year) and a rapid urbanization with a growth rate of 7% per year.

The Sahelian region is also characterized by the degradation of various ecosystems, especially land, due mainly to overexploitation of natural resources by local communities, especially wood for energy. Further, land degradation has been largely due to extensive agricultural production. These evolutions

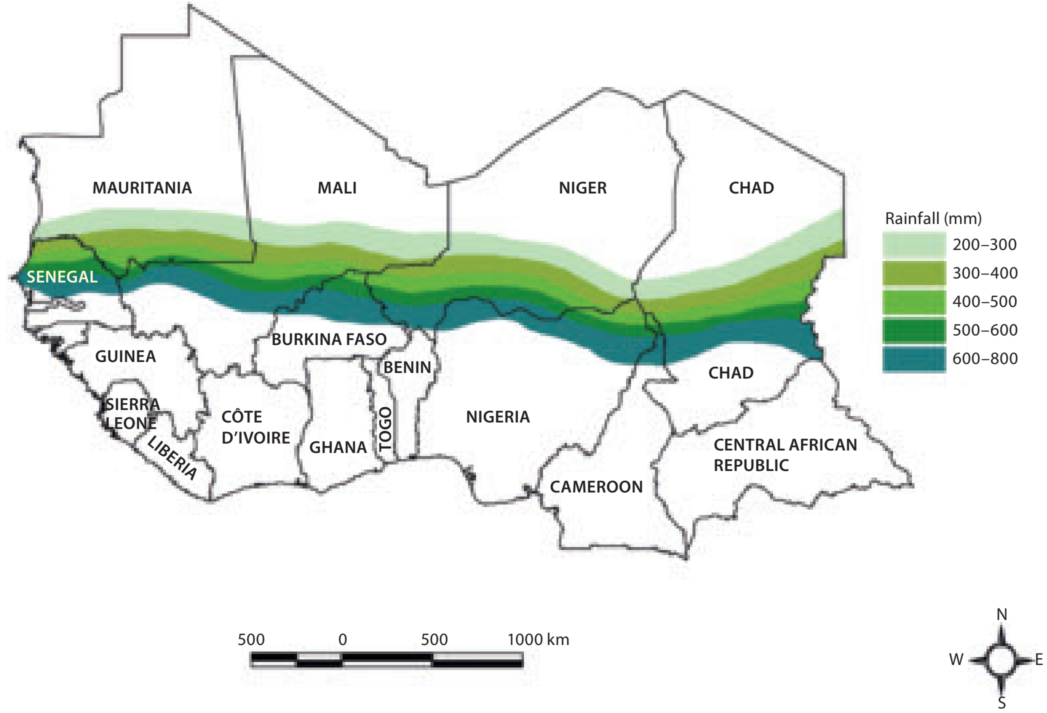

Figure 7.1 The Sudano-Sahelian region showing the area with annual rainfall ranging from 200 to 800 mm. Adopted from Mamby Fofana (2007).

bring serious concerns on soil fertility management, in the sense that fallow systems enter into crisis.

The Sahel vegetation is semi-desert grassland, thorn scrub and wooded grassland dominated by *Acacia* spp. (Wickens and White, 1979; White, 1983; Wickens, 1984).

The Sahelo-Saharian zone in the northern fringe has relatively few trees including *Acacia ehrenbergiana*, *Acacia tortillis* and *Balanites aegyptiaca*. Sparse grass such as *Panicum turgidum* is found on sand dunes. South of the Sahelo-Saharian zone is more vegetated with characteristic species like: *Acacia ehrenbergiana*, *A. nilotica*, *A. Senegal*, *A. tortillis*, *Balanites aegyptiaca*, *Maerua crassifolia*, *Salvadora persica*, *Ziizphus mauritiana*, etc. Annuals such as *Aristida asdscensionis*, *A. funiculata*, *Panicum laetum* and *Schoenefeldia gracilis* are found on silty soils. *Aristida mutabilis*, *Cenchrus bifloris* and *Tribulus terrestris* are found on sandy soils. The vegetation cover increases in the Sudano-Sahelian zone, reaching 10–12 percent on sandy soils and over 60% on silty soils. *Andropogon gayanus* and *Zornia glochidiata* are representative grasses of the Sudano-Sahelian zone; representative trees include *Faidherbia albida*, *Acacia seyal*, *Adansonia digitata* and *Combretum glutinosum*.

Generally, the flora is made up of about 1,200 species, 40 of which being strictly endemic (Kigomo, 1998a).

Sahel trees are multi-usage. The 114 woody species listed by von Maydell (1986) have all multiple uses. In the Sahel, it appears that nearly all trees are used, either for fruit (*Balanites aegyptiaca*, *Phoenix dactylifera*) or for forage (*Acacia* spp.) (Okigbo, 1986).

Since the initiation of the international efforts to combat the effects of drought in the arid and semi-arid zones of West Africa in the 1970s, the term 'Sahel' has been more broadly applied to non-Sahelian regions of the member states of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS). The states include Cape Verde, Senegal, The Gambia, Mauritania, Mali, Burkina Faso, Niger and Chad. In these states the Sahel covers approximately 2 million square kilometers comprising 27% of Senegal, 39% of Mauritania, 40% of Mali, 7% of Burkina Faso, 50% of Niger and 32% of Chad (Leonard *et al*., 1983).

7.2.2 West African savannas

Savannas lie between the equatorial rainforests and the deserts of the subtropics. Worldwide, they cover about one-quarter of the earth's surface (Andrew, 1995). The term 'savannas' is generally used to describe landscapes characterized by vegetation types ranging from pure grassland to dense woodland with the presence of a more or less continuous ground layer of grasses beneath or between the trees as common denominator. As defined by geographers, the term mainly corresponds to the African part of the geographical entity sometimes described as the Intermediate Tropical or Savanna Zone, which is defined as the part of the tropical world experiencing a dry season of 2.5–7.5 months duration (Harris, 1980).

However, some authors include semi-arid areas with dry seasons lasting up to 10 months as part of the African savannas (Phillips, 1959). Although it is difficult to define the boundaries of the African savannas precisely it has been estimated to nearly 60% of tropical Africa (Okigbo, 1986) including the Sahel.

In view of the overriding importance of climate, and particularly the length of the crop growing season, the corresponding dry season in determining the types of natural vegetation and the possibilities for rain fed agriculture, a classification mainly based on bioclimatic zones is used (Phillips, 1959) in tropical Africa. The essential feature of the bioclimatic classification is that the natural vegetation closely reflects the integration of rainfall, temperature and soil. Therefore, areas with the same or very similar types of natural vegetation have similar agricultural potentials (Table 7.1).

Table 7.1 Bioclimatic zones of the West African savannas.

Bioclimatic zone	West Africa	Mean annual rainfall (mm)	Length of growing season (days)
Arid savannas	Southern Sahelian	300–600	60–90
Sub-arid savanna	Sudanian	600–900	90–140
Sub-humid savanna	Northern Guinean	900–1,200	140–190
Humid savanna	Southern Guinean	1,200–1,500	190–230

The arid savanna zone covers most of northern Senegal from Dakar to just south of the Senegal River, and extends eastward across Africa, including large parts of central Mali, northern Burkina Faso, southern Niger, northern Nigeria, Chad, Sudan, and Ethiopia (Andrew, 1995). It extends into southern Ethiopia and as a narrow strip through Kenya into Somalia and central Tanzania. It is also widespread in southern Mozambique, Zimbabwe and eastern and northern Botswana, extending into eastern Zambia and southwest Angola.

The vegetation in this zone consists mainly of *Acacia* spp., with *Acacia senegal* (gum arabic), *Acacia raddiana*, *Leptadenia pyrotechnica*, *Salvadora* spp., *Grewia* spp., *Acacia seyal* in low areas liable to flooding, and grasses such as *Aristida* and *Chloris* spp., common in the Sahel. In eastern Africa, *Commiphora* spp. is also important.

7.2.3 Resources stocks in the Sahel and West African savanna

In the Sahelian zone, the woody biomass of forests is as low as 4 tonnes per hectare (FAO, 2003).

The biomass productivity is extremely low and extraction often far exceeds natural productivity. Substantial investment is therefore needed to increase productivity.

In West Africa, the total land area is 505.3 million hectares with a forest land area of 72.2 million hectares. This is 14.3% of total land area in this region with an annual change of -1.26% as deforestation rate (FAO, 2001a).

Resource use conflicts are severe in the Sahel and savanna zones as a result of the combination of low natural productivity and intense demands. Management plans are available for a negligible fraction of the area. While these woodlands are important for local communities, their low commercial value makes them less attractive for investment, and the ability of local communities to invest in them is limited. They are thus largely characterized by low investment and high resource exploitation by many users (FAO, 2003).

Trees outside forests are therefore important suppliers of wood and non-wood forest products due to natural forests decline and are becoming a major source of these products. The area covered by agroforestry parklands (trees in farm lands) in the Sahel is variable depending on rainfall, type of soils and farmers' practices and management. For instance it was estimated that Niger has more than 10 million hectares of agroforestry parklands with a mean density of 40 trees/hectare (Larwanou *et al.*, 2006).

Plantation forests are not well developed in the Sahel and savanna zones because of the arid conditions. Where they exist, they are intended to play an environmental role mainly for desertification control. Windbreaks and shelterbelts have been used to stabilize shifting sand dunes and reduce the effects of dry winds on agricultural crops. Private woodlots are also used to produce woods for commercial purposes.

Land rehabilitation is therefore very important and constitutes a greater part of land based activities in the Sahel region. According to CNEDD (2003) from 1984 to 2002, nearly 120 millions trees were planted in Niger. A total of 378,000 ha of degraded lands have been restored in that country.

7.3. Climate impacts

7.3.1 Climate variability in the Sahel: brief overview

Sahelian climate is seen as "the most dramatic example of climatic variability that has quantitatively been measured anywhere in the world". Hulme (1998) showed that, in global terms, the droughts of 1970s and 1980s were unique in their severity. He indicated that natural climatic variability, coupled with the known effects of changes in land cover and land uses, explains more variability than global climatic changes and global warming effects alone.

These droughts have varying impacts because the Sahel is a region with a great diversity of soils, climate, livelihood systems and ethnic groups. For many, the droughts were grim historical markers, because of their disturbing effects on food supply and human welfare in a semi-arid region so dependent on rainfall.

The social actors of the Sahel are its people, who are not only responding to social and environmental change, but creating this change through their own actions. It is true, however, that environmental, economic and political constraints continue to structure many aspects of social life. Much can be gained by promoting an 'enabling environment' to support these local responses, buttressed by policies provided by national governments, aid agencies, and by organizations like CILSS.

Faced with an inability to accurately predict the onset of a future drought or its impacts, and given the varied capacities to adapt as described by Raynaut (1998), scientific understanding appears limited in the Sahel region. There is therefore need for a better scientific understanding of the conditions and building up of better adaptive mechanisms in these complex systems.

7.3.2 Impacts on ecosystems

Ecosystems degradation is caused by the complex interactions between physical, biological, political, social, cultural and economic factors. This is more or less similar to desertification.

According to the United Nations Convention on Desertification, the term 'desertification' means "degradation of lands in arid, semi-arid and dry sub-humid zones following various factors among which climatic variations and human activities".

Land degradation causes reduction or loss of soil productivity, vegetation, cultivated lands, pasture lands and forests. In extreme cases, these conditions precipitate famine and poverty and therefore become causes and consequences of land degradation at the same time.

The two main factors that come into play in terms of desertification are climatic variations and human activities. When temperatures are high for many months and rainfall is scarce and irregular, plant/vegetation growth become difficult. This makes agricultural production difficult especially in the Sahelian countries where major economic resources come from agriculture and little or no other extra alternative revenues. The soils are over-exploited with fallowing of land becoming difficult or shortened because of the need to produce more to feed the ever growing population. The consequences of this are that the soils lose the organic matter and this constrains or even stops the vegetation growth and reduces the plant cover. The soils are thus exposed to erosion by violent winds, water runoff and flooding. All these combine to reduce crop harvests, constrain livestock husbandry and consequently the incomes of rural people diminish. Further more is biodiversity change, through loss of species in addition to constraining agriculture and other livelihoods supporting systems.

As a response to this situation there has been an increase in human and animal migration, as well as an increase in conflicts over resources and changes in the forest resources.

Some other problems which are frequent in the Sahel are:

- Lowering of water table and reduction in river flow.
- Erratic rainfall patterns which increase over the years.
- Increase in evapo-transpiration.
- Increase in water percolation and water infiltration due to sandy nature of the soil.
- Decline in humidity (both air and soil).
- Increase of invasion of pests and diseases (e.g. locust).
- Increase in wind erosion because of reduced vegetation cover.
- Increase in dust storm.
- Degradation of land resources (physical degradation and loss of soil fertility).
- Reduction of plant and animal biodiversity.
- Disturbance of hydrological regimes.
- Sand invasion and saline intrusion in some areas.
- Reduction of livestock numbers due to the shrinking of grazing areas.
- Reduction of fauna and fishing resources.
- Expansion of cultivated areas to compensate for low yields with encroachment in low potential areas.

All these have contributed in changing the forest conditions as demonstrated in Table 7.2.

These impacts have not only affected the forest conditions in terms of area covered, but also the species diversity. For instance, a study conducted by the Famine Early Warning System Network (FEWSNet) in 13 villages in Burkina Faso, Chad, Mali, Mauritania and Niger through forest inventory between 1960 and 2000, revealed serious loss of forest species diversity (Figure 7.2).

The climatic factors also affected the physiological features of forest plant species from the cell to the ecosystem level (Table 7.3). With respect to the Sahel, increase of temperature affects tree species up to ecosystem level. Also, decrease in rainfall results in tree/species/ecosystem levels effects. The net effect has been the observed changes of forest ecosystems (in Table 7.2) and species loss (Figure 7.2).

Table 7.2 Forest resources trend from 1947 to 2000 in some Sahelian countries (adopted from Serge and Ozer, 2005).

Country	Site	Landscape unit	BZ	Author(s)	Period	S (%)
Burkina Faso	Kodel	Dense and continuous savanna	SA	Lindqvist and Tengberg (1994)	1955–1990	-2.9
Burkina Faso	Oursy	Dense and continuous savanna	SA	Lindqvist and Tengberg (1994)	1955–1990	-1.1
Mali	Sorobasso	Woodland savanna	SA	Cuny and Sorg (2003)	1952–1998	-2.2
Mauritania	Tekane	Forests	SA	Niang *et al.* (2006)	1954–2003	-2.0
Niger	Diffa	Forests	A	CNEDD (200a)	1947–2000	-1.7
Niger	Zinder	Forests	SA	CNEDD (200b)	1947–2000	-1.5
Niger	Maradi	Forests	SA	CNEDD (200b)	1947–2000	-1.2
Niger	Dabaga	Forests	A	CNEDD (200b	1954–1990	-2.7
Niger	Bangui	Forests	SA	CNEDD (200b)	1954–1992	-2.6
Niger	Karofan	Forests	SA	CNEDD (200b)	1955–1992	-1.4
Niger	Tapkin Zaki	Forests	SA	CNEDD (200b)	1955–1992	-2.4
Niger	Makaortchin Gayi	Forests	A	Karimoune (2004)	1958–1987	-2.7
Niger	Baban Rafi	Forests	SA	CNEDD (200b)	1962–1992	-1.8
Nigeria	Kaska	Forests	SA	Mortimore and Turner (2005)	1950–1990	-1.0
Nigeria	Futchimiran	Forests	SA	Mortimore and Turner (2005)	1954–1990	-2.1
Senegal	Tendouk	Forests	SHD	Gueye and Ozer (2000)	1954–1990	-1.6
Senegal	Suel	Forests	SHD	Gueye and Ozer (2000)	1954–1990	-2.0
Senegal	Kourouk	Forests	SHD	Gueye and Ozer (2000)	1954–1990	-1.8
Senegal	Bambey and Diourbel	Wooded valley	SA	Ba *et al.* (2000)	1954–1999	-1.7
Senegal	Boulel	Woodland savanna	SA	Ba *et al.* (2004)	1965–2000	-2.9

BZ = Bioclimatic zone
A = Arid (100–300 mm)
SA = Semi-arid (300–600 mm)
SHD = Semi humid dry (600–1,000 mm)
S = Speed of changes

Table 7.3 Impact of climate change on forest ecosystems. Source: Modified from Benoit (2007).

Climatic factors	Cell level	Organ level	Tree/species level	Ecosystem level
Increase of CO_2	Increase in photosynthesis rate Decrease in stomatic conductance	Increase in growth rate Increase in the water use efficiency Increase in grain/seed production	Reduction of grain/seed mortality Changes in growth cycle Changes in tree density	Increase in biomass production Changes in species competition and composition
Increase of temperature	Increase/decrease of photosynthesis Increase/decrease of periodic photosynthetic activity Increase in transpiration	Increase/decrease of primary production Changes in seed production	Changes in regeneration rate Possible increase in mortality rate Negative effect on sensible species to the temperature variations	Changes in species competition and composition Increase in soil mineralization
Rainfall regime changes	Reduction of growth rate	Increase in mortality rate of grains/seeds	Increase in mortality rate of adult trees	Changes in species competition and composition

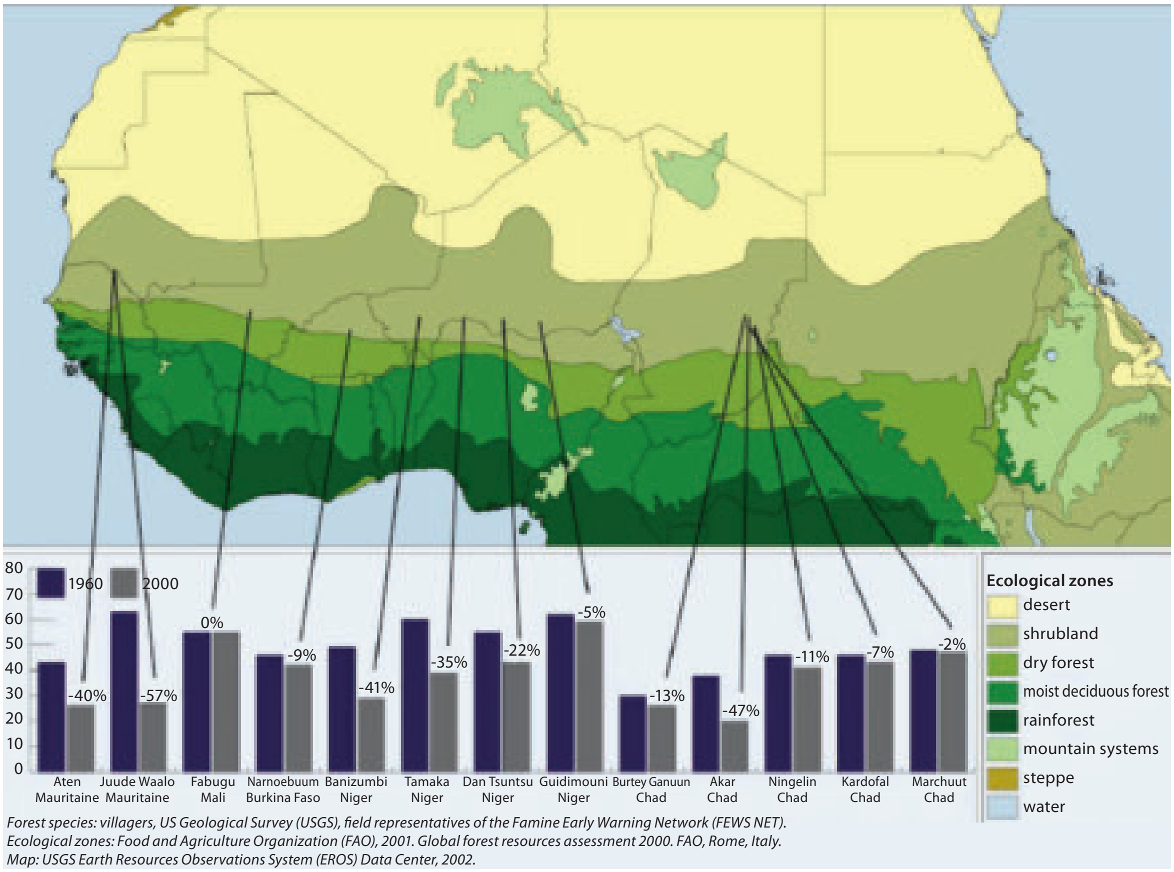

Figure 7.2 Forest species loss in the Sahel (1960–2000). Total number of forest species on village lands and percent decline.

The Sahel populations depend much on forest products and services through the following:

- Products – timber, poles, fuel, non timber forest products (NTFPs), wood biomass, forage.
- Services – shading, soil fertility, protection of water catchment's areas.
- People are shifting from using forest products to other resources (e.g. animal dung for fuel).

But, climate change is seriously affecting the availability of these products and services through:

- Forest fires which are associated with drought.
- Changes in patterns of pests and diseases infestations.
- Reduction in the availability of forest products and services.
- Low agricultural productivity.

The current demand by the rural and urban populations for fuelwood and charcoal already exceeds supply and often has to be transported for considerable distances (Larwanou *et al*., 2006). Agricultural production does not meet the needs of the ever increasing population.

To respond and cope to the situation, various actions have been undertaken by local communities in collaboration with the governments and aid agencies. Some of the actions were tended to solve the problem of wood for fuel and construction through assisting natural regeneration of trees in private lands to develop and provide useful products. Also, simple water conservation techniques were adopted and used to protect soil against erosion and rehabilitate land for increased agricultural production.

These various actions have resulted in the improvement of agroforestry parklands in Sahelian countries.

7.4 Responses to climate impacts in the Sahel

7.4.1 Internationally developed approaches

Sahelian droughts and their effects have been studied intensively since the 1970s, as part of the international response to 'environmental problems'. It is only in the decade of 1990–2000, however, that the long-term impacts of the famines of the 1970s become evident. Those events provoked a re-thinking of the links between population growth, drought, and socio-political change, and also helped to refocus development policy away from expensive and unsuccessful 'interventions' towards more considerate schemes targeted at boosting local capacities (Sabio, 2001). The international community has acquired an increasing capability to prevent the onset of drought-induced food shortages through: *1)* Early warning systems. These provide the data necessary to predict or assess potential crop loss and animal shortfalls, based partly on remotely-sensed data of vegetation cover and rainfall patterns and partly on food market surveys. The Famine Early Warning System Network (FEWSNet), developed by the American aid programme (USAID) for example, alerts policymakers and governments to rapid price hikes for the staple foods at local markets, and unusual land cover changes that may signal an impending food shortage. *2)* This is done on working with the human and drought-induced stress on natural ecosystems, by supporting only modest increases in the production of foodstuffs and livestock numbers but, at the same time, improving the resilience of these systems to 'bad years' of drought or other hazards. *3)* Improved production technologies that include high yielding drought-resistant crops, irrigation, or improved ranching and grazing schemes.

7.4.2 Specific Sahelian approaches

The drought of the 1970s and 1980s shifted down the water table seriously affecting vegetation cover. Many trees and forest stands died. Desertification became a serious threat to livelihoods and environment. As a response to this, most of the Sahelian countries changed their forest policies encouraging more active participation of the population in development projects. Interventions developed under such projects promoted growing of trees outside forests, establishment of woodlots, green belts around big towns, dune fixation using trees, water and soil conservation and soil restoration using trees. This drought period coincided also with the establishment of various sub regional organizations such as the Inter-States Committee for Drought Control in the Sahel (CILSS), Sahel Institute, United Nations Office for the Sahel and the Club du Sahel. These are all established to help contain the adverse effects of the droughts. There were also debates at regional and national levels where important decisions were taken in terms of fight against desertification using integrated and participatory approaches. Key outcomes from these debates were emphasizes placed on food security, satisfying energy needs, restoration and protection of the environment and national action plans to combat desertification. These outcomes helped to shape a clear vision on natural resources management in the Sahel in improving the productive capacity at village level. Concrete actions carried out in response to the vision include the development of:

- forest management and energy projects;
- natural forest management plans;
- land rehabilitation plans and projects.

Various activities were developed and promoted around these three broad areas and were intended to sustainably manage natural resources and at the same time facilitate the fight against desertification.

7.4.3 Ecosystems changes in the Sahel

Ecosystem changes definitely impact on climate change and variability, not only in the Sahel but also globally. Some of the impacts of these changes include:

- Increased emission of green house gases (GHGs).
- Increased temperature.
- Increased albedo.
- Less radiation.
- Low precipitation.
- Low interception and retention of rain water.

According to Le Houérou (1989) and Le Houérou *et al.* (1993), attempts at establishing browse species in areas receiving less than 400 mm annual rainfall have not met with any long-term success, even with indigenous species, apart from a plantation of *Acacia senegal* (L.)Willd. and *A. tortilis* (Forssk.) Hayne at M'Bidi in Senegal. However, some encouraging results have been obtained with *Bauhinia rufescens* Lam., *Combretum aculeatum* Vent., *Piliostigma reticulatum* (DC.) Hochst. and *Ziziphus mauritiana* Lam. This is not intended to mean that reforestation of the Sahel is impossible, rather that it is extremely difficult and long-term.

For example, Olsson *et al.*, 2005, have shown, through Normalized Difference Vegetation Index (NDVI) derived from satellite images NOAA-AVHRR over 1982–1999 periods, a trend to good rainfall conditions and regreening of the Sahel in

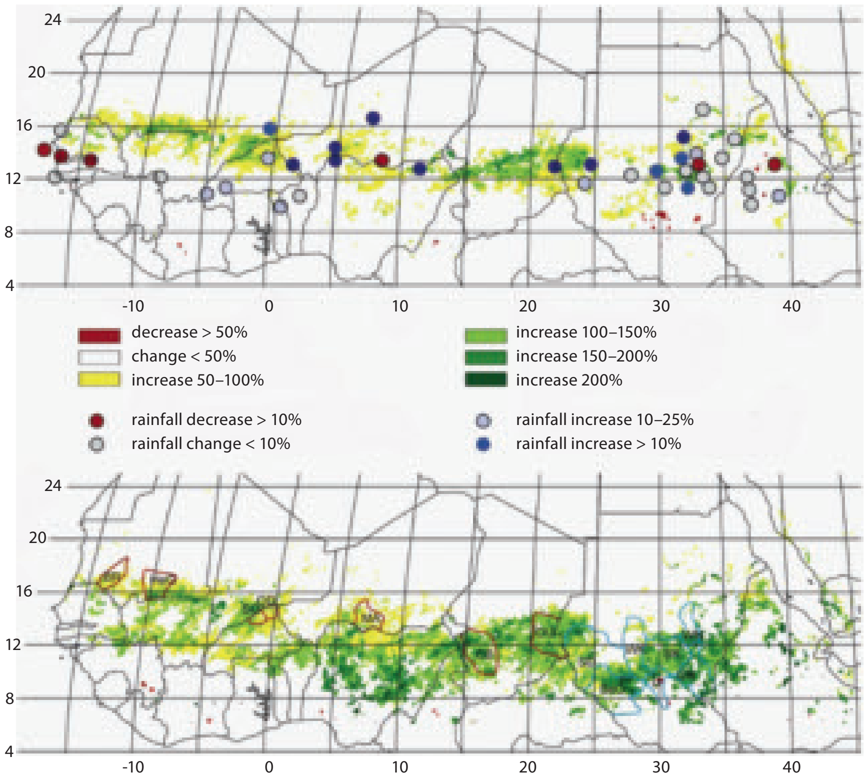

Figure 7.3 Results of trend analyses of time series of NDVI amplitude (top) and NDVI seasonal integral (bottom) of NOAA-AVHRR NDVI-data from 1982 to 1999. Areas with trends of <95% probability in white.

Data from 40 climate observation stations, showing percent change between the periods 1982–1990 and 1991–1999, have been superimposed on the top figure (adopted from Olsson et al.*, 2005).*

some areas as shown in Figure 7.3. However, recent findings suggest a consistent trend of increasing vegetation greenness in much of the region. Increasing rainfall over the last few years is certainly one reason, but does not fully explain the change. Other factors, such as land use change and migration, may also contribute (Olsson *et al*., 2005).

There is an increase of Normalized Difference Vegetation Index during the period 1990–1999 (Figure 7.3) compared to 1980–1989 which could be explained by:

- An increase in rainfall in some areas.
- Reforestation actions (farmer managed natural regeneration, tree planting).
- People's migration from rural areas to towns (Olsson *et al*., 2005).

7.4.3.1 The parkland dynamics

The parkland system is an agroforestry system in which trees are scattered in agricultural lands. It is found all over the Sahel and savanna regions of West Africa and functional for centuries (Figure 7.4). Trees provide farmers high value goods and services. In addition to reducing wind erosion during the nine months of dry season yearly, trees stop water erosion during the rainy season.

Trees from the parkland system also provide food and nutritional security through their fruits, leaves, oil, spices, of which are the principal elements of the regions' food regime. They also provide fuelwood for domestic uses and fodder for animals. They constitute supplementary sources of revenues. Some high value trees in parkland systems like *Vitellaria paradoxa* (karité in French or sheanut in English), *Parkia biglobosa* and *Adansonia*

Figure 7.4 Agroforestry traditional parklands in Niger.

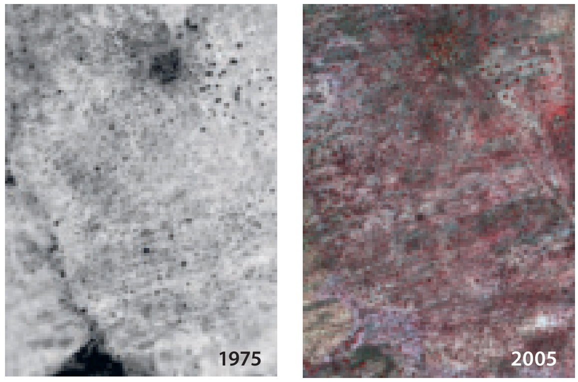

Figure 7.5 Tree density in a site in different years.

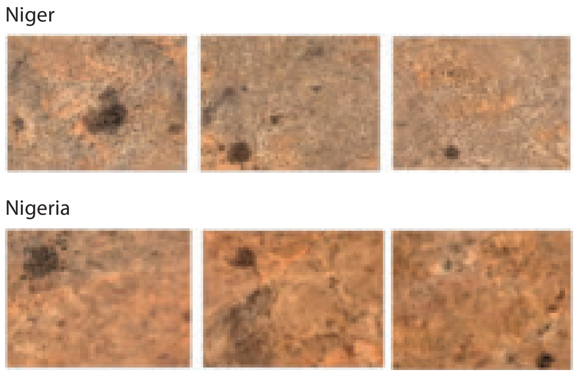

Figure 7.6 Tree density on opposite sides of the Niger/Nigeria border. Source: Google Earth, 2005.

digitata (baobab) have multiple uses and considerable economic potential.

ICRAF (1994) mapped the Sahelian parklands according to climatic gradient.

In Burkina Faso for instance, the results showed the following parkland types according to species dominance.

- *Faidherbia albida* system (30% of farm lands).
- *Faidherbia albida* – *Hyphaene thebaica* (25% of farm lands).
- *Balanites aegyptiaca* (15%).
- *Hyphaene thebaica* – *Balanites aegyptiaca* (10%).
- *Hyphaene thebaica* (8%) and others (12%).

Almost 90% of dominant species in the parkland system are naturally regenerated. This natural regeneration is being assisted through protection and management by local communities throughout the Sahel region in order to accelerate the recovering of tree vegetation in the parklands. Some of the management strategies used by the local communities are pruning, pollarding, identification and protection of the natural regeneration in order to *1)* accelerate the growth, *2)* increase the biomass and fruit production, *3)* reduce shading which has an adverse effect on crop yield, *4)* obtain organic matter to enrich and protect soils, *5)* reduce the incidence of birds and other pests that could destroy crops, *6)* get firewood, and *7)* make trees more resistant to winds. This farmer managed natural regeneration has given positive impacts throughout the Sahel and especially in Niger where a recent study has shown (Larwanou *et al.*, 2006) that the tree cover increased from 0.6% in 1975 to 16.5% in 2005. Aerial photos (Figures 7.5 and 7.6) and satellite images analysis showed that despite a high increase in human population, there are at present 10 to 20 times more trees than there was 30 years ago.

An exploratory study was also conducted in Zinder region, located in the eastern part of Niger. This study showed that farmer managed natural regeneration (FMNR) is a generalized practice in this region (Larwanou *et al.*, 2006). Farmers have developed parklands on almost 1 million hectares. These parklands were dominated by *Faidherbia albida* with a density varying from 20 to over 200 trees per hectare (Table 7.4 and Figure 7.7). This spectacular vegetation cover in Niger has differentiated itself from the northern neighboring Nigeria which has less tree cover (Figure 7.6). These regreening activities were not known to the public outside the involved regions because very few published studies were done.

Table 7.4 Mean number of trees/ha in Niger.

Sites	Number of trees	Standard deviation
Adouna	78	91
Batodi	71	72
Boukanda	57	74
Dansaga	103	122
Dourgou	73	120
Garado Nord	48	49
Gassikayna	45	59
Guidan Illa	60	47
Karebangou	29	25
Kolloma	24	34
Laba	20	51
Maiguizawa	162	249
Tama	189	125

Figure 7.7 Trees in a farmer's field regenerated through FMNR.

7.4.3.2 Changes in soil fertility management

In Niger, degraded land rehabilitation projects have introduced on a larger scale runoff water harvesting techniques (Zai [holes made before sowing to collect water], half-moon and trenches) which have broken hard denuded soils to increase their water storage capacity to reduce runoff. Farmers have increased fertilization efforts in their farms. In 1980, few farmers used organic manure on crop fields; the available manure was only being used on irrigated lands. In 2005, at least 80% (Adam *et al.*, 2006) of interviewed farmers used organic manure in their cereal fields. Most of the farmers who invest in rehabilitating their lands used organic manure.

On sandy soils, vegetation regeneration shows a reduction of wind erosion and the availability of litter to fertilize soils. Parklands development has contributed to increase organic matter in farmers' fields especially where *Faidherbia albida* dominates (Larwanou *et al.*, 2006). A positive change in soil structure and fertility was perceived through:

- progressive smoothing of soil through Zai and half-moon techniques,
- litter fall and decomposition, and capturing of small organic materials brought in by the wind, especially where agroforestry practices are developed.

In areas where natural resources management projects have intervened, 40% to 100% of interviewed farmers affirmed that there is an improvement in terms of soil fertility and agricultural production.

7.4.4 Adaptation and mitigation policy actions and incentives in the Sahel

7.4.4.1 The broader context

Climate change has implications for many sectors. Response measures are needed from local to international levels, and by a diversity of actors (IIED, 2008). Some measures involve being prepared to cope with the impacts, such as disaster preparedness. Others aim at building greater resilience into environmental, economic, social and institutional systems. Resilience refers to the ability of a region, country, city, village or household to protect it from adverse impacts and recover from damage. Building resilience can take many forms depending on the policy level and sector. Diversification is a key strategy in resilience for many countries and communities when faced by risk, since "having your eggs in more than one basket" reduces the likelihood of total loss. Thus building resilience at different levels will often imply finding ways to diversify, whether it is sources of income, forms of energy supply, cropping systems or investment portfolios. Some of the actions that could be considered in Africa at various levels are (IIED, 2008):

- *Continent-wide:*
  1. High level political leadership through Heads of State meetings at the African Union, climate observatories, weather monitoring, forecasts.
  2. Work with regional and sub-regional bodies and the Comprehensive African Agricultural Development Programme to build climate change into Africa-wide initiatives.
  3. Develop business engagement with African decision-makers on climate change challenges, such as at the World Economic Forum.
- *Sub-regional:*
  1. Work with Regional Economic Commissions and political groupings (Economic Commission for West African States, Inter-States Committee for Drought Control in the Sahel, and Economic and Monetary Union for West African States to share ideas and experience.
  2. Agree on management systems for shared river basins, movement of people, and research on drought resistant crops, drought early warning systems.
  3. Lesson learning on tackling climate change – such as happened through the Inter-States Committee for Drought Control in the Sahel in the West African Sahel following droughts in the 1970s and 1980s.
- *Country:*
  1. Mainstream climate change into all areas of government policy, such as energy, water, agriculture, finance, trade, health and education.
  2. Draw up National Adaptation Plans of Action (NAPA), assess investment in new infrastructure, and ensure disaster preparedness, setting up grain reserves, food price subsidies, cash transfers, crop breeding programmes.
  3. Establish public information and education activities to help people understand and respond to the changes underway, using media, radio, schools, etc.
  4. Promote legal framework which strengthens community based systems for land and natural resource management.
  5. Identify areas for possible afforestation and sites for avoided deforestation.
- *District/municipality:*
  1. Plan urban growth to minimize risks from flooding and other disasters.
  2. Set up crop insurance schemes, managing local river catchments, encourage decentralized energy generation, micro-finance.
  3. Link local disaster preparedness with national level plans and information.
  4. Ensure emergency supplies of food and shelter.
  5. Invest in better local water supply systems, small scale dams, soil conservation and water harvesting.
  6. Improve management of key resources – wetlands, grazing, forests.

- *Household/individual:*
  1. Income diversification, migration of some family members, introducing new crops, micro-water harvesting.
  2. Set up savings and micro-finance accounts.

7.4.4.2. Adaptation through policy and technical actions

In the Sahel, various actions have been carried out in terms of policy and technical activities in different areas connected to adaptation to climate change. The most important actions are stated below in a broader range. These are:

- Production and update of National Action Plan for Adaptation (the nine Sahelian countries have their NAPAs).
- Implementation of projects and activities to improve water harvesting, soil fertility and productivity.
- Diversification of agricultural to minimize risks related to climate change.
- Promotion of improved agroforestry practices has been carried out.
- Development and promotion of drought, pest and disease, weed, salinity resistant and high yielding crop varieties for local conditions are being implemented.
- Development of early warning systems to inform farmers and other stakeholders is being carried out.
- Promotion of post-harvest technologies to reduce losses in the field and during storage is being carried out.
- Restoration of wetlands for a better management of natural resources and biodiversity conservation are being implemented.
- Development of research for the improvement of cropping techniques and genetic material is in the programme of various research institutions.

These actions are giving impacts in various ways and need to be pursued and strengthened by new ones.

7.4.4.3 Mitigation policy actions

The policy actions in terms of mitigations are carried out through establishment of programmes at national and regional levels to contain the impacts of climate change. Some of the programmes set up are:

- Inter-States Committee for Drought Control in the Sahel: harmonizing and implementing regional policies.
- Re-greening of the Sahel initiative which conducts field activities and helps to develop policy measures.
- Changes in fiscal policies to support mitigation and adaptation at national levels.
- National Committee for sustainable environment and development (CNEDD): national policies for sustainable development.
- Policies for implementing Multilateral Environmental Agencies (MEA) (establishment of NAPs, DNA, NAPA, etc).
- Promotion of research for use of solar energy, etc.

7.4.4.4 Incentives policy actions

In addition to the aforementioned measures, incentives are also being used to strengthen the efforts of various governments to tackle climate change issues in the Sahel. Some of the incentive actions are:

- Subsidizing seedling production.
- Food for work and assets for planting.
- Subsidized private nurseries.
- Established forest product markets.
- Change in policy for tree tenure and marketing.
- Poverty reduction and food security programmes and Country Policy Frameworks are being developed.
- Investment projects to ensure they are 'climate friendly' and resilient to the risks by climate change prone disasters.

7.5 Conclusion and recommendations

7.5.1 Conclusion

The 'driving forces' of change in the Sahel, both environmental and socio-economic, are highly complex and have led to transformation and continuity. The main opinion is that, the Sahel is undergoing, slowly but inevitably, a profound 'transformation' in the way people relate to the environment and to each other in a fluid and dynamic manner. The other viewpoint is that there is a need to maintain continuity with the past. Sahelian peoples have a rich local tradition to draw on what is able to manage change, better than the kinds of adaptation that are now flowing in rapidly from outside in ecosystem resilience concepts. In the Sahel, actions needed are well defined, inclusive, sensitive to local interests and relevant. The genuine concerns about ecological degradation and the vital role of natural resources in rural livelihood systems should be drawn on analysis of numerous projects initiated since the droughts of the 1970s and 1980s that support natural resource management alone. In dealing with forests and trees, and the emerging issue of climate change in the sub-region, improvement in 'household viability' and other structural measures leading to poverty alleviation should also be addressed (including income generation, employment access, conflict, equitable sharing of ecosystem services). Policy and technical measures that are successful should be reinforced and disseminated in order to restore the vegetation cover, therefore containing the effects of climate change and variability.

7.5.2 Recommendations

7.5.2.1 Action research

- Build understanding of how poor people optimize new knowledge in a context of competing demands of forests and tree products.
- Build understanding of how resource-poor populations in the Sahel understand climate variability and change, associated risks and consequences for their livelihoods.
- Inventory of :
  - initiatives in the West African Sahel to learn from experience and build on existing work,
  - existing interventions, e.g. the Global Mechanism, Sustainable Land Management,
  - capitalizing the enormous value of early work within the CILSS region to create opportunities for learning and exchange of experience within the Sahel region and assure that these links still work,
  - using the enormous energy and resources behind the climate change debate to promote and extend locally tailored interventions which strengthen resilience and rights across the Sahel.

7.5.2.2 Way forward

- Local communities to be empowered to develop their programmes and action plans in natural resources management.
- Develop well defined and concerted initiatives on management of dry forests and parklands at all levels (e.g. re-greening the Sahel initiative).
- Develop research actions on policy issues regarding tree tenure and sustainable management of forests and parklands.
- Develop a concerted environmental information system and making it available at all levels.
- Reinforce cooperation among actors: exchange of experiences and know-how on forest conservation and sustainable utilization for poverty alleviation and environmental protection.

7.5.2.1 Challenging the future

- Develop and promote appropriate (low-cost) agroforestry technologies in the management of dry forests and parklands.
- Promote participatory research in the manage-

ment of dry forests and parklands in collaboration with all stakeholders including local communities and decision-makers.
- Set up a good communication network for best practices on dry forests and parklands for permanent dialogue among actors.
- Define a coherent link between poverty and environmental security policies.
- Better understand the cultural, institutional and policy factors affecting the management of parklands.
- Revisit country policies on natural resources management by incorporating recent research policy findings.
- Develop and implement a wide range of participatory management, enrichment options (at village and community levels) and farmer managed natural regeneration.

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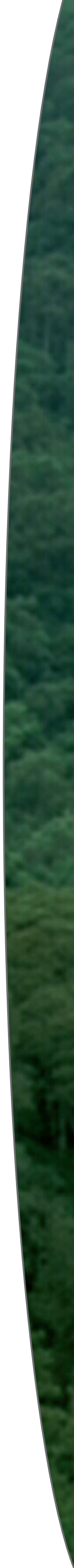
SECTION 3

CLIMATE CHANGE AND AFRICAN WILDLIFE



INTRODUCTION

Section 3 consists of three chapters. The first chapter focuses on wildlife in West and Central Africa, the second chapter deals with wildlife in woodlands and the third chapter describes broader issues of institutions and governance concerning climate change and wildlife.

Although there has been great concern about the state of moist forests in Africa, little has been published on climate change threats to wildlife in African moist forests. However, it is generally acknowledged that negative effects of climate change (e.g. climate warming, shortage of rainfall, exceptional events such as drought or floods, and rising sea level) are having negative impacts on key wildlife habitats and species in West and Central Africa. Chapter 8 in this section deals with a wide range of issues including *1)* the distribution of wildife resources in important conservation areas, *2)* the use of biodiversity resources and related threats, *3)* the manifestations of climate change and their impacts on wildlife resources, and *4)* the adaptation and mitigation measures against climate change and variability that are relevant to the wildlife sector. Scientists suspect that increasing temperatures, in combination with changes in rainfall and humidity, may have significant impacts on wildlife, domestic animals and human diseases (Hofmeister *et al*., 2010). The common observation is that the behavior of many wildlife species can change due to the changing weather patterns. The chapter points out that given the high level of climate variability in West and Central Africa (Kandji *et al*., 2006), impacts of climate change could be regarded as under-estimations. It is therefore probable that increases in mortality of many species in West and Central Africa may be due to climate warming.

Common effects of climate change on species and ecosystems include *1)* changes in the timing of life-history events or phenology, *2)* effects on demographic rates, such as survival and fecundity, *3)* reductions in population size, and *4)* shifts in species distribution ranges.

Chapter 9 describes the state and use of wildlife resources in the woodlands and savannas of East and southern Africa and discusses threats to wildlife resources and opportunities for sustainably managing these resources, impacts of climate change on wildlife and the resources that support wildlife species, as well as adaptation and mitigation approaches to impacts of climate change on wildlife resources. In Africa, most of the wildlife species are found in rangelands (i.e. grasslands and open woodlands or savannas) that are estimated to cover about 13.4 million km^2 or 60% of the continent (de Leeuw and Reid, undated). Except in a few cases, protected areas are exclusively set aside for wildlife conservation; outside these areas, livestock and native herbivores share land, water, forage and diseases, and the fate of wildlife in such areas largely depends on the interactions between wildlife and livestock (Grootenhuis and Prins, 2000). Apparently, ungulates in East African savannas respond to rainfall fluctuations through movements, reproduction or survival, and the responses appear independent of breeding phenology and synchrony, dietary guild, or degree of water dependence. However, extreme events, such as droughts, have been observed to delay onset and reduce synchrony of calving and natality rates while high rainfall advanced onset and increased synchrony of calving and natality rates in some ungulates (Ogutu *et al*., 2010). Both droughts and herbivory (including fire) contribute to the shift in the current balance between woody and grassy habitats in East and southern Africa (van de Vijver *et al*., 1999; Western, 2006). This has implications for the abundance of the browsers and grazers in wildlife conservation areas.

Climate affects wildlife resources through different path-ways and the wildlife sector needs to be adequately equipped to respond to climate change. It is important to understand how climate change is likely to impact on wildlife in order to implement adaptation strategies for the sector.

Chapter 10 proposes the establishment of effective climate adaptation strategies through cooperative work of scientists, managers and policymakers to *1)* identify climate-sensitive species and ecosystems, *2)* assess the likelihood and consequences of impacts, and *3)* identify and select options for adaptation (Hulme, 2005). Although it is widely accepted that climate affects the distribution and abundance of mammals and other wildlife species, there are problems in relating climate change and variability to wildlife population dynamics. The chapter calls for the monitoring and recording of distribution and abundances of target wildlife species over a sufficiently long period of time in order to assess the relationship between population dynamics and climate variables.

Chapter 8
CLIMATE CHANGE AND WILDLIFE RESOURCES IN WEST AND CENTRAL AFRICA

Paul Donfack

8.1 Introduction

The majority of West and Central African countries are experiencing the effects of climate change and variability. Desertification, climate change and loss of biodiversity are currently the most compelling issues in African dry lands and threaten development efforts and jeopardize the livelihoods of the poor (Hamndou and Requier-Desjardins, 2008). Negative effects of climate change (e.g. climate warming, shortage of rainfall, exceptional events such as drought or floods and rising sea level) are having negative impacts on key wildlife habitats and species. Therefore, expansion of protected areas is not only an important strategy to promoting biodiversity conservation but could also be a means to mitigate climate change.

This chapter presents the state of wildlife resources and climate change in West and Central Africa. The emphasis is on *1)* the distribution of wildife resources in important conservation areas, *2)* the use of biodiversity resources and related threats, *3)* the manifestations of climate change and their impacts on wildlife resources, and *4)* the adaptation and mitigation measures against climate change and variability that are relevant to the wildlife sector.

8.2 State of wildlife resources in West and Central Africa

8.2.1 Ecosystems

The West and Central African region is usually divided into two sub-regions: West with 15 countries and Central with 7 countries (Figure 8.1), excluding island states. Though, Cameroon and Chad are politically attached to Central Africa, ecologically they are often considered to be part of West Africa. West Africa extends over 6.14 million km^2 and represents one fifth of the African continent. The region has a variety of ecosystems stretching from the Atlantic Ocean in the south-western portion of the region to the Sahel in the northern portion which is a transition zone between the arid lands to the north (Sahara) and inter-tropical Africa to the south. Different vegetation types cover the region and there are many hydrographical basins situated in different agro-climatic zones (Senegal Basin, Lake Chad Basin, Niger River Basin and Congo Basin). Each of these agro-climatic zones is characterized by different climatic and hydrologic conditions. From the northern to the southern limits of the region annual rainfall varies gradually from 100 mm in the north (northern limit of the Sahel) to more than 1,500 mm (up to 4,000 mm around Mt Cameroon) in the south.

The driest part of the region is made up of what Letouzey (1985) called 'Région soudano-zambézienne', which from north to south corresponds

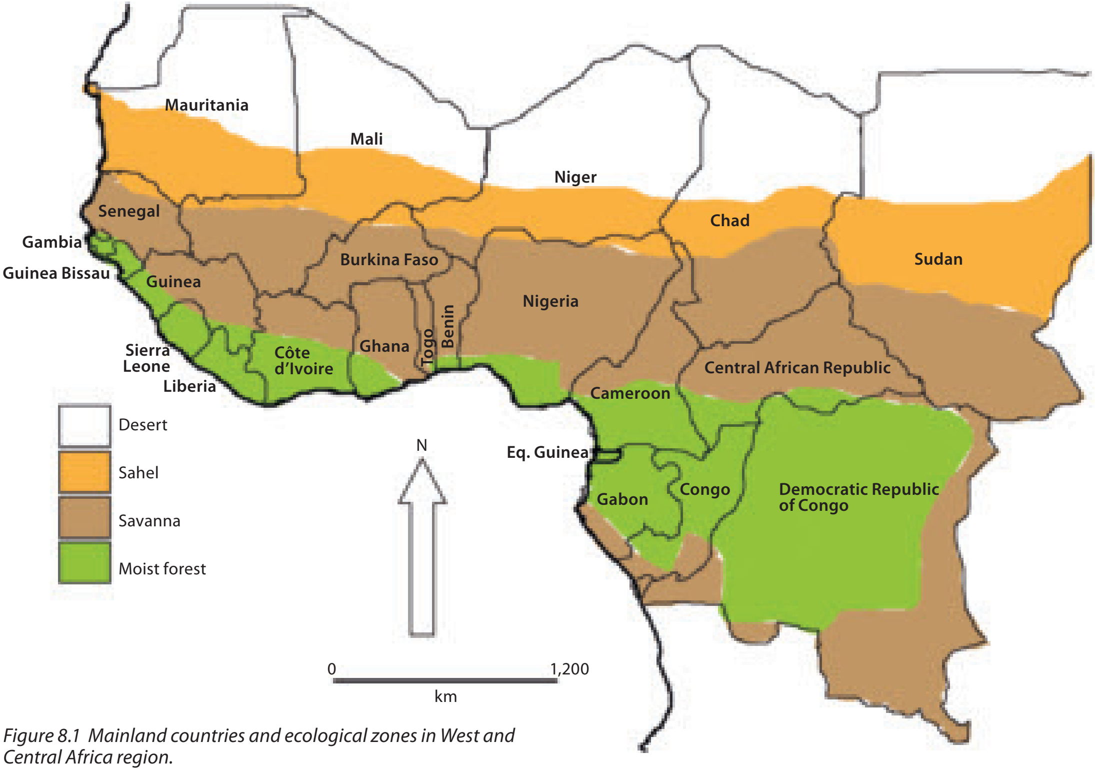


Figure 8.1 Mainland countries and ecological zones in West and Central Africa region.

to the Sahelian domain and the Sudanian domain that represent types of savanna. Within the Sahelian domain, Letouzey (1985) has distinguished the Sahelian sector and the Sahelo-Sudanian sector. The Sahelian domain has two types of vegetation: the spiny steppe and the periodically flooded grasslands. The spiny steppe is dominated by small trees such as *Acacia* spp., *Balanites aegyptiaca*, *Calotropis procera*, *Ziziphus* spp., and grass species like *Aristida* spp., *Chloris* spp.and *Schoenefeldia gracilis*. The second vegetation type is made up of periodically flooded grasslands with grass species like *Echinochloa pyramidalis*, *Hyparrhenia rufa*, *Oryza longistaminata* and *Pennisetum ramosum*. These types of savannas are found in the far north of Cameroon but also in the northern parts of the Central African Republic, Chad, Niger, Mali, Senegal, Mauritania and Burkina Faso.

The subhumid savannas are often made of woody groves and grassy patches in which a few woody species develop (Menaut *et al*., 1990). The subhumid savannas are not different from what Letouzey (1968) calls the Sudanian domain. The Sudanian flora has tree elements such as *Burkia africana*, *Acacia sieberiana*, *Bombax costatum*, *Dalbergia melanoxilon*, *Detarium microcarpum*, *Diospyros mespiliformis* and *Ficus* spp. They are home to wildlife species such as elephants, giraffe, derby elands, lions, wild dogs, panther, cheetah, roan antelope, hartebeest, cobs that are also sensitive to water availability.

The forest ecozone in West and Central Africa consists of moist forests (see chapter 5) comprising of lowland moist forests, mangroves, swamp forests and mountain forests. The moist forests of the Congo Basin cover almost 200 million ha. They represent the second largest tropical moist forests in the world, after the Amazon. In West and Central Africa, geographically there are six moist forests that include the Guinea moist forest (on the coast of West Africa), Congolese coastal forests, Cameroon highlands forests, Northern Congo Basin moist forests, Central Congo Basin moist forests and Western Congo Basin moist forests. These forests play a crucial regulatory role in controlling natural processes like the climate, water quality and carbon sequestration and have a cultural service value. Forests of the Congo Basin play an important role in national and regional economies because of the importance of its biodiversity that include large animals such as elephants, great apes, bongo, various duikers.

8.2.2 Species diversity

Many criteria are used worldwide to classify ecosystems to highlight their biodiversity importance. Among such classes are important ecoregions (WWF, 2000), conservation hot-spots (Myers, 1990), Ramsar Conservation Sites and World Heritage Natural Sites. Hot-spots are biologically rich areas with high biodiversity and a large proportion of endemic species. The Guinea moist forests of Western Africa (Table 8.1) are among the global biodiversity hot-spots (Myers, 1990).

The flora of this hot-spot is closely related to the flora of Central Africa and most genera are widespread throughout both West and Central Africa sub-regions. In addition, the Gulf of Guinea Islands support highly endemic flora (185 endemic species). There are also some important flagship plant species such as oil palm trees (*Elaeis guineensis*), African ebony (*Diospyros gracilis*), Iroko (*Clorophora excelsa*) as well as the genera *Entandophragma* and *Khaya*.

There are about 1,100 species of mammals in Africa, with 320 species found in the hot-spots of West Africa (Conservation International, 2007). The lowland forests of West Africa are home to more than one-quarter of Africa's mammals, including more than 20 species of primates and threatened species such as Jentink's duiker, *Pygmy hippopotamus*, and scattered populations of Western chimpanzees. Five Endemic Bird Areas (EBA) lie partly or entirely within this hot-spot. The Guinea forests are renowned for their primate diversity (almost 30 species). Six of them are endemic to upper Guinea, nine are endemic to moist forests of Nigeria and Cameroon and six to Bioko Island in Equatorial Guinea. The area is also home to great apes such as chimpanzees (*Pan troglodytes*) and gorilla (*Gorilla gorilla gorilla*) and Diana monkey (*Cercopithecus diana*) which is an indicator of forest health. The Guinean moist forests of West Africa are home to 10 species of hornbills, large frugivores that fill an important ecological function as seed dispersers. However, dozens of the region's bird species are threatened by extensive forest clearing; similarly, some flagship species such as black rhinoceros have become extinct while others such as cheetah and wild dog have become rare.

Table 8.1 Endemism in the Guinea.
Source: http://www.biodiversityhotspots.org.

Taxonomic group	Area (ha)	Endemic species	% endemism
Vascular plants	9,000	1,800	20.0
Mammals	320	67	20.9
Birds	785	75	9.6
Reptiles	210	52	24.8
Amphibians	221	85	38.5
Fresh water fishes	512	143	27.9

8.2.3 Biodiversity conservation

While it is important to conserve biodiversity everywhere, current rates of loss, and the limited resources available to address them, require clearly established priorities. Conserving ecoregions will require addressing needs at large temporal and biogeographical scales and focusing on both socio-economic and biological systems dynamics. The setting aside or gazettment of protected areas within each country could be an important approach to achieving this goal. This presupposes effective national policy and site-specific management interventions in conformity with the international requirements. According to the International Union for the Conservation of Nature and Natural Resources (IUCN), a protected area is an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means.

8.2.3.1 Central Africa sub-region

Biodiversity conservation in the Central Africa sub-region is a relatively old practice. The first protected area created was the Albert National Park in Belgian Congo (now Democratic Republic of Congo) in 1925. To date many other protected areas have been gazetted in each country in the sub-region (Figure 8.2 and Table 8.2). These protected areas are situated within different ecosystems including Sahel, Sudanian and Guinean savannas and moist forests.

Protected areas in Central Africa sub-region covers 9.9% of total land area, which is close to that of 9.0% for the West Africa sub-region. It is however important to mention that the process of gazettement of protected areas in most countries of Central Africa is ongoing and therefore is likely to increase in the future.

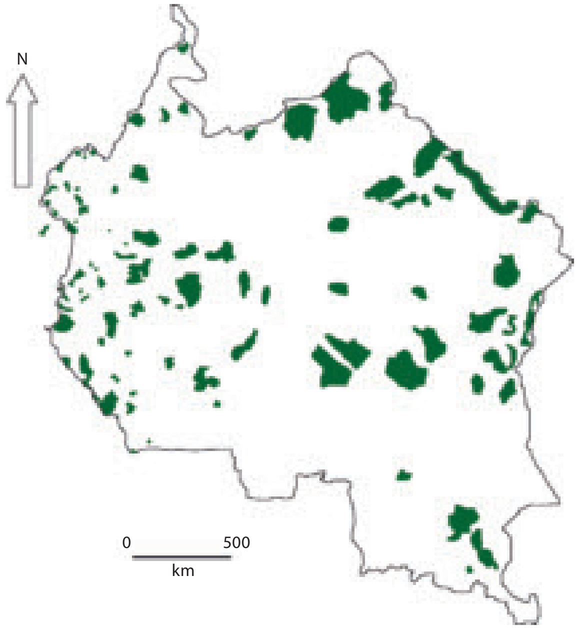


Figure 8.2 Protected areas in the Central Africa sub-region of West and Central Africa region. Based on the World Resources Institute (WRI) (2009).

In Cameroon the protected area network includes 20 national parks among which four are under the process of gazettment, three sanctuaries (Category IV of IUCN), 10 wildlife reserves (Category VI of IUCN) and three zoological gardens (Donfack, 2009). The largest protected areas of

Table 8.2 Protected areas in countries in the Central Africa sub-region.

Country	Area of the country (km²)	Number of protected areas	Extension of protected areas (km²)	Percentage
Cameroon	475,442	36	82,361	17.3
Congo	342,000	14	36,469	11.0
Gabon	267,667	13	30,075	11.0
Equatorial Guinea	28,051	12	6,155	21.97
Central African Republic	622,984	16	68,475	10.99
Democratic Republic of Congo	2,344,860	21	183,853	7.84
Sao Tome and Principe	964	3	295	30.6
Chad	1,284,200	10	122,893	9.57
Total	**5,366,168**	**125**	**557,779**	**9.9**

Cameroon are the Dja Biosphere Reserve (526,000 ha), the Mbam and Djerm National Park (416,512 ha), the Nki National Park (309,362 ha) and the Faro National Park (330,000 ha). There are also 33 safari hunting zones and 19 community hunting zones (MINFOF-WRI-GFW, 2007). The Waza National Park is one of the most important protected areas situated in the southern part of the Sahel (Bauer, 2003) and receiving less than 600 mm of annual rainfall. It contains considerable mammal populations, including species that are increasingly becoming rare in West and Central Africa, such as savanna elephant (*Loxodonta africana africana*), giraffe (*Giraffa camelopardis*), hyena (*Crocuta crocuta*), lion (*Panthera leo*) and various antelope species. The main species (kob) is decreasing progressively due to regular droughts and lack of water in the ponds. It also contains important bird populations, including ostrich (*Struthio camelus*) and crowned crane (*Balearica pavonina*). Bénoué National Park, Faro National Park and Bouba Ndjida National Park are all in the Sudanian savanna zone. The rest of protected areas (Dja Biosphere Reserve, Lobéké NP, Nki NP, Boumba-Bek NP, Campo Ma'an NP, Kurup NP, Mbam and Djerem NP, etc.) in Cameroon are either in the moist forest zone or in the forest-savanna transition zone (Donfack, 2009) and some of these are priority conservation areas.

In Gabon, Minkebé National Park (756,669 ha), Lopé (484,780 ha) and Moukalaba-Doudou (449,548 ha) are the largest protected areas (Category IV of IUCN). The remainder includes Akanda, Plateau Batéké, Monts Birougou, Monts de Cristal, Ivondo, Loango, Mayumba, Mwagné, Pongara and Waka.

In the Republic of Congo, the network of protected areas includes three national parks (Nouabale-Ndoki, Odzala-Kokoua, and Conkouati-Douli) with a total land area of 2,306,377 ha, one biosphere reserve with 147,006 ha (Category IV of IUCN), one community reserve (Lake Tele with 461,815 ha), six wildlife reserves (587,440 ha) (Category VI of IUCN), one chimpanzee sanctuary (8,847 ha) and two gorilla sanctuaries with 134,378 ha corresponding to Category VI of IUCN (Mertens *et al*., 2007).

In the Democratic Republic of Congo, Salonga National Park (3,656,000 ha), Okapi wildlife reserve (1,372,625 ha), Maiko National Park (1,083,000 ha), Virunga National Park (780,000 ha), Upemba National Park (1,173,000 ha) and Bili-Uéré hunting reserve (6,000,000 ha) are among the largest protected areas in the sub-region and fall in Category II of the IUCN classification.

In the Central African Republic, large protected areas include Manovo-Gounda-Saint Floris National Park (1,740,000 ha), the complex Bamingui-Bangoran/Vassako Bolo National Parks (1,156,000 ha) and Zemongo wildlife reserve (1,010,000 ha). They are also equivalent to Category II of the IUCN classification.

In the Republic of Chad, there are Ouadi Rimé-Ouadi Acim wildlife reserve (7,795,000 ha) and Bahr Salamat wildlife reserve (2,860,000 ha), all in Category II of the IUCN classification.

8.2.3.2 West Africa sub-region

Each of the 15 mainland countries in the West Africa sub-region has a number of protected areas (Table 8.3). Five of them, located mainly in the dry Sahel and Sudanian zones, are among the largest protected areas of West Africa (Fondjo, 2009). These are in Burkina Faso with the Sahel Reserve (1,600,000 ha), Mali with the partial wildlife reserve (Category II of IUCN) of Ansongo Ménaka (1,750,000 ha), Mauritania with the Guel Er Richât (1,900,000 ha). Two main large protected areas are in Niger: the National Natural Reserve of Termit and Tin Toumma (10,000,000 ha) and the National Natural Reserve of Aïr and Ténéré (7,736,000) ha.

Besides these protected areas, the West Africa sub-region also has other important conservation areas. In Senegal, for instance, there is the Niokolo Koba National Park with 900,000 ha, considered as an important site for the conservation of wild animals (large mammals) and plants. There is also the Djoudj National Park (12,000 ha) consid-

*Table 8.3 Protected areas in countries in the West Africa sub-region. Source: Chapter author; *database of* http://databank.worldbank.org.

Country	Area of the country (km^2)	Number of protected areas	Extension of protected areas (km^2)	Per-centage
Benin	112,620	5	12,402	11.01
Burkina Faso*	274,200	72	39,211	14.30
Cape Verde*	4,033	1	0.4	0.01
Côte d'Ivoire*	322,460	240	24,185	7.50
Gambia*	11,300	6	441	3.90
Ghana	239,460	21	12,585	5.25
Guinea*	245,857	102	44,746	18.20
Bissau-Guinea*	36,120	9	903	2.50
Liberia*	111,370	16	111	0.10
Mali	1,240,000	18	119,599	9.64
Mauritania	1,030,700	9	42,160	4.09
Niger	1,267,000	5	188,460	14.87
Nigeria*	923,768	6	48,036	5.20
Senegal	196,190	12	16,149	8.23
Sierra Leone	71,740	27	716	0.99
Togo	56,785	6	8,074	14.21
Total	**6,143,603**	**528**	**557,779**	**9.08**

ered as a paradise of birds species. Other protected areas in Senegal include the Ferlo wildlife reserve, the Guembeul Reserve, the Delta of Saloum National Park that harbour birds (pelican, aigrette dimorphe, grand cormoran, *Echasse blanche*) and mammals (dama gazelle and oryx).

Gambia has six protected areas including Abuko Nature Reserve, Kiang West National Park, River Gambia National park, Niumi National Park, Bao Bolon wetland reserve and Tanji Karinti bird reserve.

In Sierra Leone, protected areas include six national parks, two oases for hunting, five wildlife hunting reserves, four forest reserves and ten integral natural reserves.

Liberia has two of the three largest remaining intact blocks of upper Guinea moist forest, which are of incalculable biological value within the sub-region. The main protected area in the country is Sapo National Park. The country harbours endemic species, some of which are nearly extinct (*Pygmy hippopotamus*, Jintink's duiker, the zebra duiker and the Liberian mongoose) outside the country. However, out of 67 species of mammals in Liberia, 13 have become extinct and a similar number is threatened with extinction.

In Côte d'Ivoire, a network of 13 protected areas represents the main ecosystems found in the country. Many of these protected areas (Comoé, Aboukouamékro, Mont Péko, Monts Nimba, etc.) are subjected to high pressure from various factors.

In Ghana, the Ministry of Land and Natural Resources has declared 67 zones as 'Globally Significant Biodiversity Areas' (GSBA), among which are the Krokosu Forest Reserve, Shai Hills Resource Reserve, Bia, Mole National Park, Kya Bobo National Park, Kakum National Park and Ankasa.

Nigeria has an important network of protected areas including 14 national parks, eight strict nature reserves, 39 game reserves. Among them are the Yankari National Park located in the savannas, Gashaka Gumti National Park in the transition between savanna and moist forest and Cross River National Park in the moist forest zone. Other national parks include Baturiya Wetlands, Chad Basin, Gujiba, Ifon, Kainji Lake, Kamuku, Kogo, Kuyambana, Old Oyo and Sambisa.

In Guinea, protected areas include two national parks (Upper Niger and Badiar), one natural integral reserve (Mont Nimba) and one community Forest (Ziama). There is also a transboundary protected area at the Mali border.

Between Burkina Faso, Benin and Niger, there is an important trans-boundary conservation area called the WAP Complex (W National Park, Arly National Park and Pendjari). In the eastern part there is the W National Park which forms the central nucleus, comprising a trans-boundary Biosphere Reserve, surrounded by hunting zones (Kondio, Tapoa-Djerma, Mekrou and Djona, Tamou and Dasso). At the western part, the

Pendjari National Park is situated in Benin and the Arly National Park in Burkina Faso, together with the Singou Reserve. Between the two blocs, there are other conservation areas like Atakora, Mekrou and Koakrana and the partial reserve of Kourtragou. Though the W Transboundary Park appears as an effectively protected space, the neighbouring protected areas are facing serious threats and need rehabilitation.

In addition, the West Africa sub-region has two main endemic zones and two secondary zones for the conservation of birds (Islands of Cape Verde, Forest of North Guinea [Côte d'Ivoire, Ghana, Guinea, Liberia, and Sierra Leone], Low Valley from Niger to Nigeria and Upper Valley from Niger to Mali and Senegal).

8.3 Biodiversity uses in West and Central Africa

8.3.1 Tourism

It is generally recognized that protected areas and other forest resources can constitute natural heritage and spiritual value as well as make a substantial contribution to regional development through tourism. Because of the richness of wild animals and plants in West and Central Africa, protected areas of these sub-regions can be considered as products with high commercial value. The economic uses of biodiversity in the sub-regions include ecotourism, safari hunting, traditional hunting, trade of forest products and conservation-related employment. Many protected areas in West and Central Africa have good potential for the development of wildlife tourism. However, the level of utilization is lower than in other regions such as southern and eastern Africa. The whole system is suffering from poor promotion and organization; improving professionalism of local officials with suitable training is needed to boost the tourism sector.

Through revenue from tourism, protected areas demonstrate their contribution to local economic and social development as well as their role in promoting national growth (e.g. through collection of taxes, job creation, local markets, transport and communication). Protected areas in West and Central Africa are located in moist forests (Côte d'Ivoire, Gabon, Democratic Republic of Congo, Congo, Central African Republic, Cameroon, Equatorial Guinea), Sudano-Guinean savannas and the Sahel (Central African Republic, Burkina Faso, Niger, Mali, Senegal, Benin, Guinea, Togo, Chad, Cameroon). In West and Central Africa, many countries have protected areas suitable for wildlife tourism. In Cameroon, the Waza National Park is one of them. But many other protected areas are managed to receive tourists even if their numbers per year is low (Benoué National Park, Korup National Park). Others are Zakouma National Park (Chad) and Manovo-Gounda St-Floris National Park (Central African Republic). In DRC and Rwanda, the Virunga National Park and the Volcanoes were respectively considered as sites receiving an impressive number of visitors and generating significant portions of income for their respective countries. However, this economic contribution of tourism has been reduced by political crises and civil wars.

8.3.2 Hunting

Unlike in other regions of Africa, the wildlife sector in West and Central Africa is not well developed. In Cameroon, it generates USD 2.0 million for the national economy. In the Central African Republic, 11 community hunting zones (Zones de Chasse villageoise, or ZCV) have progressively been created since 1988 and annual incomes from these zones have increased from less than USD 5,500 in 1993 to USD 262,000 in 2009 (Bouché, 2009; Figure 8.3). These resources are reinvested in socio-economic infrastructures in education, health and water supply. In countries where wildlife utilization is better organized, part of the revenue is distributed to the local populations and the remainder is retained by the State Treasury.

In Cameroon, hunting is an old tradition in the savanna zone and has recently gained importance in the moist forest zone through the safari hunting zone. Benefits from these forms of utilization are shared between central governments (50%), local governments (40%) and local communities (10%) when they are organized into legal entities. With regard to traditional hunting, despite its informal nature, the annual bush meat sales bring more than USD 10,000 in Cameroon. Within the WAP complex, there is a number of hunting zones covering more than 2,752,000 ha. At the moment, the problems facing hunting in West Africa are those of rehabilitation of the environment, re-stocking of wildlife populations and establishing new arrangements for accessing these wildlife populations and effectively involving local communities living around wildlife areas. In addition there is need to resolve wildlife-related conflicts around protected areas because these remain one of the major constraints to the development of the wildlife sector in West and Central Africa.

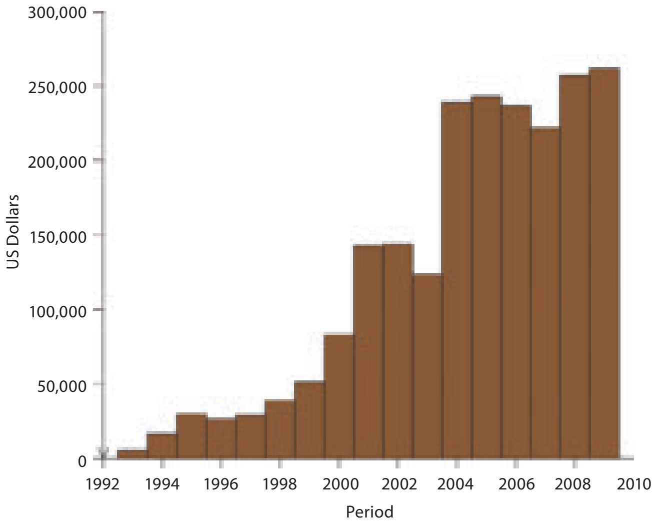


Figure 8.3 Income generated from the community hunting initiative in Central African Republic from 1993 to 2009. Based on Bouché (2009).

8.4 Threats to biodiversity and opportunities for effective management of biodiversity resources

Despite the socio-economic values of biodiversity mentioned above, moist forests of the Congo Basin can be considered as receiving relatively lower levels of pressure than the Amazon. Deforestation due to agricultural practices and development of human settlements were estimated to be lower than 0.5% for the period between 2000 and 2005 (WRI, 2009). Its progression, linked to the development of roads for logging and timber transportation, could become critical given the fact that forest roads represent 30% of the whole road network of the region. In the Central African Republic, for example, wood exported represents 50% of all exports (WRI, 2009).

Climate variability directly affects the national economies of West African countries in general and those of the Sahelian countries in particular. The over-exploitation of wildlife through hunting and poaching activities for subsistence and commercial purposes constitute a serious threat to game mammal species as well as to human populations who depend on wildlife resources for their animal protein needs. Unsustainable levels of hunting could lead to the local extinction or disappearance of vulnerable animal species such as the elephant, the gorilla, mandrill and many other species and causes immediate hardships within rural populations that depend on game for nutritional and economic purposes. Due to current demographic and socio-economic driven changes of lifestyles of human populations, the daily demand for game is particularly high and is increasing. If the system is disturbed, habitat fragmentation could increase as well as loss of threatened species.

In most countries where wildlife resources are utilized, laws and regulations related to wildlife conservation exist but these were mainly developed without taking into account the concerns of indigenous people. The implementation of wildlife utilization projects often collides with the interests of local people. Traditional hunting tends to be confused with poaching, either at traditional hunters' level, or at the level of game guards in charge of law enforcement. Consequently, overhunting is one of the main threats to biodiversity conservation and natural habitats. A survey carried out in Africa has shown that at least 22% of protected areas are being degraded (Conservation International, 2007). West Africa has the highest number of large protected areas and a network of wildlife reserves but most of them are being degraded or fragmented. There are many interactions between protected areas and their surroundings which, in most cases, increase with time, because of the lack of respect for national laws, poor conditions of local communities and the deficiency in the application of the participatory management of protected areas. In contradiction with the ongoing gazettement process of protected areas in most West and Central African countries, management options continue to clash with people's habits or customs. Disappearance of plants and animal species linked to human practices is frequent and often due to the paradox between institutions in charge of implementing conservation strategies and other economic or socially oriented institutions.

Since the establishment of the first protected area in Central Africa, the process of gazettement of new protected areas has continued in most West and Central African countries. This provides an opportunity for taking into account issues of climate change in the establishment of new protected areas in the region. The maintenance of the process of establishing new protected areas in most countries is a clear testimony of the political will to conserve wildlife. The presence of conservation NGOs, some of which have considerable experience in conservation, interest of donors and support from the international community provide additional opportunities for implementing effective management of biodiversity resources in the West and Central African region.

8.5 Impacts of climate change and variability on wildlife resources

Two approaches can be used to assess the impact of climate change. The first is the synchronic approach, which consists of comparing the climax biodiversity in different eco-climatic zones within West and Central Africa with the current state. The second is the diachronic approach, which consists of comparing historical data within the same geographical areas. The climate of West Africa is subjected to recurrent variations of significant magnitude. Severe declines in rainfall were registered between 1968 and 1972. Because of this, major watercourses have registered a decline with a significant reduction in the surface area of main natural wetlands (the case of Lake Chad where the surface area has shrunk from 20,000 km^2 during wet years before 1970 to less than 7,000 km^2 since the early 1990s) (UICN-BRAC, 2007).

Many studies have demonstrated how environmental factors (mainly climate) influence variation in life history traits such as body weight and growth, or population parameters such as sex ratio (Weladji, 2003; Hofmeister *et al.*, 2010). But data focusing on West and Central Africa are rare. The Inter-Governmental Panel on Climate Change (IPCC) predicts that unprecedented rates of climate change will result in increasing average global temperatures, a rise in sea levels, change in global precipitation patterns, including increased amounts and variability, and increased continental drying during summer (IPCC, 2007). Scientists suspect that increasing temperatures, in combination with changes in rainfall and humidity, may have significant impacts on wildlife, domestic animals and human diseases (Hofmeister *et al.*, 2010). The common observation is that the behavior of many wildlife species can change due to the changing weather patterns.

Reduced rainfall and droughts can worsen the already limited water resources crises and increase wildlife habitat destruction, with negative impact on both flora and fauna. Patterns in life history traits and population parameters of various ungulates vary over space and time. Extrinsic climatic fluctuations are important causative factors for such variations. Hance (2009) has shown that forest elephants in Congo consume more than 96 species of plant seeds and can carry the seeds as far as 57 km from their parent tree. Elephant may then be responsible for the dispersal and possibly establishment of more tree species than any other species within their home range. A study carried out by Tchamba (1997) in Cameroon concerns the migration of elephants from Waza National Park to northern Kalamaloué National Park or to the Kaélé area (South) depending on water and food availability. From this example, it is clear that drought is likely to trigger elephant migration and consequently influence tree establishment patterns. The geographic range of many wildlife species could shift from one area to another due to climate change. Drought and extreme temperatures pose potential risks to wildlife that include decrease in surface water for mammals and birds (Figure 8.5). In respect of habitat fragmentation, the species may not be able to adapt to environmental change within and outside protected areas. This is why land-use and land-cover change assessment can be used to update the impacts on nature reserves.

Given the high level of climate variability in West and Central Africa (Kandji *et al*., 2006), impacts of climate change could be regarded as under-estimations. It is probable that increases in mortality of many species may be due to climate warming. Climate change, climate variability and extreme events may also be responsible for changes in seasonal life cycles of many species. Other impacts of climate change on wildlife include changes in phenology and wildlife host-pathogen interactions and disease patterns in wildlife species.

8.6 Potential adaptation to the impacts of climate change in the wildlife sector

In Africa, knowledge of climate change risks is inadequate and pro-active management of greenhouse gases concentration is limited. Adaptation could give positive results in the short term. However, as the issue of climate change is uncertain and may not be easily predictable, it is necessary to apply the precautionary principle to develop policies and plans that could ensure timely adaptation.

In West and Central Africa, there is a large body of knowledge and experience within local

Figure 8.5 a) Importance of water to wildlife populations, and b) drought-related death of wild animals in Waza National Park in Cameroon. Photos from WWF-NSSP records.

communities on coping with climatic variability and extreme weather conditions. Local communities have made preparations based on their resources and their knowledge accumulated through experience of past weather patterns. For example, many communities have been forced to respond to floods, droughts or hurricanes, and lessons can be learned from these experiences and applied to the wildlife sector.

Countries in West Africa and a large part of Central Africa have faced severe climatic conditions in the 1970s. In West Africa, the most noticeable responses to such droughts and pronounced climate variability experienced for the past three decades concerned data collection and analysis. To monitor this situation, the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) was created to collect and manage agro-hydro-climatic data, to set up an early warning system, and to carry out research and training activities mainly through AGRHYMET (Regional Centre for Training and the Application of Agro meteorology and Operational Hydrology). Such an information and knowledge base can be used to develop adaptation strategies to the impacts of climate change on wildlife resources. For example, efforts have been made in managing water resources in Burkina Faso by implementing a policy for the construction of small water reservoirs and even experimenting artificial rain making that can be applied to the management of wildlife populations that suffer high mortality rates due to droughts and lack of surface drinking water (Figure 8.5).

8.7 Conclusions

Protected areas in West and Central Africa cover about 9% of the total area in 2000 (Giraut *et al*., 2003), which is lower than the global mean of 11.5%. However, due to new conservation initiatives such as COMIFAC and its convergence plan, the situation is improving as new protected areas continue to be created. Because protected areas are dedicated to the production of wildlife for socio-economic development, management of these conservation areas must be recognized and granted equal status and legitimacy as other land uses. Protected areas could also be considered as carbon sinks and applied to the mitigation of climate change. Climate change and variability have been presented in this chapter as events with direct impacts on many wildlife species and indirect impacts on their habitats, particularly in protected areas. However, scientific data to demonstrate how climate change is impacting on biodiversity in much of West and Central Africa are limited, in spite of the existence of agro-hydro-climatic data collected through the Permanent Interstate Committee for Drought Control in the Sahel (CILSS). Such an information and knowledge base can be used to develop adaptation strategies to the impacts of climate change in the wildlife sector.

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Chapter 9

CLIMATE CHANGE AND WILDLIFE RESOURCES IN EAST AND SOUTHERN AFRICA

Emmanuel Chidumayo

9.1 Introduction

Africa is rich in wildlife species and apart from their biodiversity significance, the major uses of wildlife resources in East and southern Africa are eco-tourism, safari hunting and local hunting. In most areas that are rich in wildlife species, local people may be heavily dependent on the wildlife resource as a source of bush meat. However, surveys suggest that over 65% of the original wildlife habitat in Africa has been lost (Kiss, 1990) as a result of agricultural expansion, deforestation and overgrazing, which in many cases are a direct result of rapid human population growth and poverty. There is growing evidence that the climate in eastern and southern Africa is warming at a faster rate than has been predicted from global models although no clear trend in rainfall patterns has been observed (but see chapter 2). Nevertheless, extreme events, such as droughts and floods, appear to have increased in frequency in the recent past. Therefore the significant climate change stimuli to which African wildlife resources are likely to be subjected in the near future in East and southern Africa are most likely related to climate warming due to rising temperatures and extreme events, such as droughts and floods. Common effects of climate change on species and ecosystems include *1)* changes in the timing of life-history events or phenology, *2)* effects on demographic rates, such as survival and fecundity, *3)* reductions in population size, and *4)* shifts in species distributions.

This chapter describes the state and use of wildlife resources in the woodlands and savannas of East and southern Africa and discusses threats to wildlife resources and opportunities for sustainably managing these resources, impacts of climate change on wildlife and the resources that support wildlife species, as well as adaptation and mitigation approaches to impacts of climate change on wildlife resources. The chapter ends with a call for the incorporation of predicted climate change impacts into overall wildlife management plans and for the review and modification of existing laws, regulations and policies regarding wildlife management.

9.2 State of the wildlife resources

In Africa, most of the wildlife species are found in rangelands (i.e. grasslands and open woodlands or savannas) that are estimated to cover about 13.4 million km^2 or 60% of the continent (de Leeuw and Reid, undated). Wickens (1983) estimated that the flora of tropical Africa contains more than 7,000 species of trees or shrubs of which at least 75% are browsed to a greater or lesser extent. Hood (1972) identified a total of 14 browse species in a 1.24 ha wet miombo woodland in northern Zambia although only eight of these were most palatable. The browse resource is therefore a key resource for browsing animals, especially in the dry season because of *1)* the diversity of browse species, *2)* the longer production cycle, *3)* the variety of feed components (fresh and dry leaves, flowers and fruits/pods), and 4) the high protein content and minerals (Sanon, 2007).

Africa is rich in wildlife species and the total number of wild ungulates in African woodlands and savannas is estimated at 98 species while the richest assemblages contain more than 30 large herbivore species (Prins and Olff, 1998) which are the most species-rich on earth (Olff *et al*., 2002). The African continent is also rich in mammal species (Figure 9.1) which although dominated by small-sized species (< 5.0 kg body mass) has spectacular large mammals, such elephant (*Loxodonta africana*), hippopotamus (*Hippopotamus amphibious*), buffalo (*Syncerus caffer*), eland (*Tragelaphus oryx*), roan (*Hippotragus equines*) and sable antelopes (*Hippotragus niger*), lion (*Panthera leo*), cheetah (*Acinonyx jubatus*) and leopard (*Panthera pardus*). East and southern Africa are rich in endemic wildlife species. In terms of mammal endemism, the eastern Africa region has 72 endemic species while the southern African region has 65 endemic species but the savannas of West Africa have only 7 endemic mammal species; similarly, East Africa has the highest bird fauna endemism (52 species) and is closely followed by southern Africa with 50 endemic bird species while West Africa trails far behind with 10 endemic bird species (UNEP, 2006).

Within specific conservation areas, the diversity of large herbivores is correlated to habitat diversity (Bonyongo and Harris, 2007; Figure 9.2) and a study in southern Africa showed that there is a strong positive correlation between species richness of woody plants and that of mammals (Qian *et al*., 2009). As a result the exceptional fauna diversity and herbivore biomass density in Africa appear to be directly linked to high spatial heterogeneity of habitats that allows the utilization of the different habitats by the different wildlife species. For example, the different major habitats of the Serengeti ecosystem in Tanzania are used in a complex pattern such that the highly nutritious forage of the short grass plains is available only to the larger migratory species for a few months of

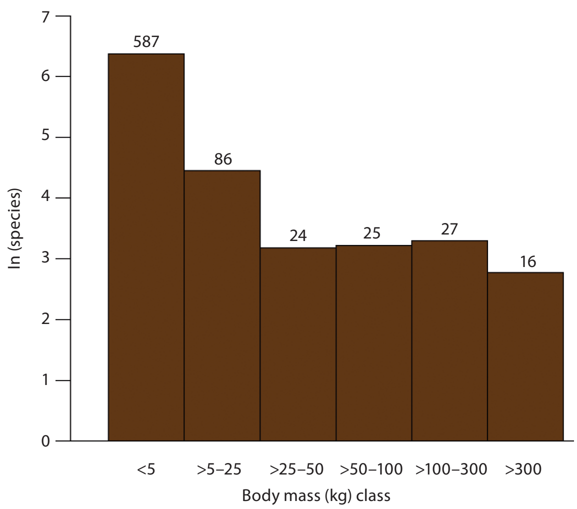

Figure 9.1 The diversity of mammal fauna in Africa. The numbers on top of bars indicate species in each body mass class. Based on de Vivo and Carmingnotto (2004).

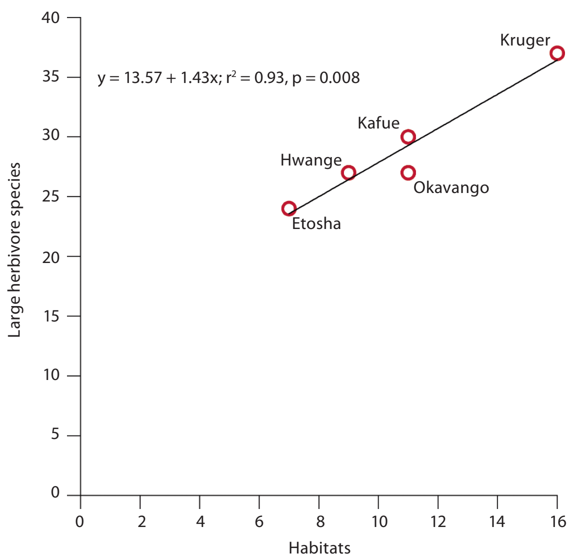

Figure 9.2 Relationship between habitat diversity and large herbivore species in five national parks in southern Africa. Based on Bonyongo and Harris (2007).

the year, the tall grass areas, woodlands and kopjes support species that are resident throughout the year and only the larger herbivores and carnivores obtain their nutrition from all the different major habitat types in the ecosystem (Dobson, 2009).

The protection of biodiversity in Africa is closely associated with protected areas and these can be divided into two broad categories: *1)* those meant for conservation and *2)* those managed for resource utilization. The International Union for Conservation of Nature (IUCN) defines the former as 'protected areas' (Chape *et al.*, 2003) while those established as sites for controlled resource utilization in woodlands and savannas are termed 'forest reserves' (Burgess *et al.*, 2005; Burgess *et al.*, 2007). It is important to note that both 'protected areas' and 'forest reserves' can effectively conserve ecosystems although more often this is more effective in protected areas and specialized forest reserves, such as botanical gardens and sanctuaries.

The distribution of protected areas in the woodland and savanna zones in sub-Saharan Africa is shown in Figure 9.3; the woodlands and savannas of West Africa are most poorly covered by protected areas. Protected areas (6,390 in all) of all categories cover about 2.4 million km^2 (World Resources Institute, 2003). The area under protection represents about 9% of total land area in West Africa, 11% in eastern Africa, 14% in central southern Africa and 16% in south western Africa. The Conference of Parties (COP7) of the Convention on Biological Diversity requires that at least 10% of each of the world's ecological regions be protected (Chape *et al.*, 2005) and this would imply that other than in West Africa, there is adequate coverage of woodland and savanna ecosystems in protected areas in sub-Saharan Africa. Furthermore, the majority of African protected areas are small with an average size of 260 km^2 in West Africa, 430 km^2 in central southern Africa and 670 km^2 and 830 km^2 in eastern and south western Africa, respectively. Thus rangelands adjacent to protected areas are potentially important in the local survival of wild herbivores (Western *et al.*, 2009).

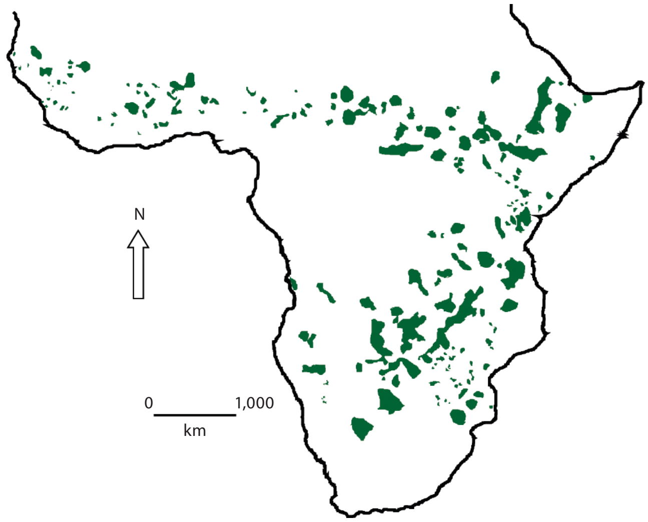

Figure 9.3 Distribution of protected areas in woodland and savanna ecosystems of sub-Saharan Africa, excluding South Africa. Source: World Conservation Monitoring Center (1997).

Except in a few cases, protected areas are exclusively set aside for wildlife conservation. Outside these areas, livestock and native herbivores share land, water, forage and diseases, and the fate of wildlife in such areas largely depends on the interactions between wildlife and livestock (Grootenhuis and Prins, 2000). For example, in East Africa the majority of the populations of native herbivore species occur outside protected areas (Rannestad *et al.*, 2006; Western *et al.*, 2009). This is in sharp contrast to West and southern Africa where most of the native herbivore species are largely confined to protected areas.

9.3 Uses of wildlife resources

Apart from their biodiversity significance, the major uses of wildlife resources in East and southern Africa are eco-tourism, safari hunting and local hunting. Tourism is the principal economic activity in national parks and game reserves (Figure 9.4). For example, with around a quarter of a million people visiting Tanzania's parks each year, the majority of Tanzania's foreign currency earnings come from eco-tourism (Dobson, 2009).

In most wildlife-rich areas, local people may be heavily dependent on the wildlife resource as a source of bush meat. A study by CONASA in the Mulobezi Game Management Area in Zambia revealed that 20% and 78% of the hunters sourced the animals for game meat outside protected areas and controlled game hunting areas, respectively (CONASA, 2001). In this case the most frequently hunted animals were common duiker (S*ylvicapra grimmia*), bush pig (*Potamochoerus porcus*), warthog (*Potamochoerus aethiopicus*), reedbuck (*Redunca arundinum*), roan antelope (*Hippotragus equines*) and buffalo (*Syncerus caffer*). However, where medium-sized and large animals are scarce, even small animals, such as insects, rodents and birds are hunted for consumption and sale (WWF-IUCN Traffic Network, 2001). Hunting of medium and large animals involves dogs, snares and firearms (CONASA, 2001). Illegal hunting of resident and migratory herbivores is widespread in the Serengeti National Park and adjacent areas in Tanzania where bush meat is a source of protein and a means of generating cash income (Loibooki *et al*., 2002). This study also found that illegal hunting was not reduced by participation in community-based conservation programs and estimated that between 52,000 and 60,000 people participated in illegal hunting within protected areas, and that many young men derived their primary source of income from hunting.

Bush meat is sold both locally in rural areas and in urban areas. A study by the WWF-IUCN Traffic Network (2001) demonstrated the importance of 'illegal' bush meat in rural and urban areas of Zambia. In Lusaka urban areas, the share of bush meat that is traded is estimated at 80% while the remainder is for own consumption. Household monthly consumption of bush meat in the Luangwa valley, eastern Zambia, ranged from 4.6 kg in wildlife deficit areas to 36.8 kg in wildlife rich areas (WWF-IUCN Traffic Network, 2001). In rural areas, bush meat is relied upon to a greater extent during times of economic hardship, such as during drought and famine, thereby constituting an important drought and famine coping strategy. Therefore, hunting of wildlife tends to be intensified in dry years when crop yields are low and when livestock may also not perform well. Similar observations have been made in East Africa (Loibooki *et al*., 2002). It has also been observed that the poorer the household, the greater is its reliance on bush meat and should bush meat become unavailable, there is likely to be health impacts in the form of increased levels of malnutrition.

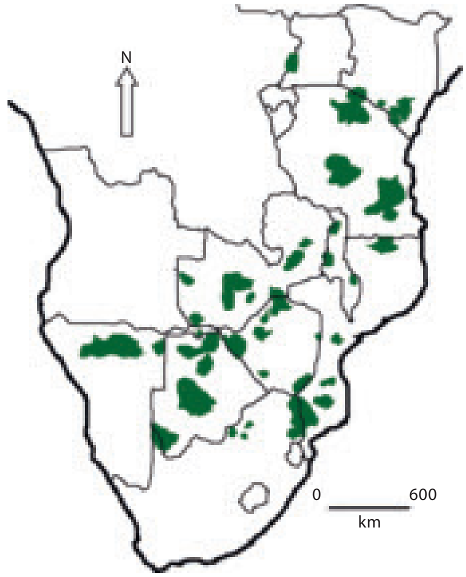

Figure 9.4 National parks and Game Reserves in which eco-tourism is an important economic activity in East and southern Africa. Based on African Safari Company (2003–2008).

9.4 Threats to wildlife resources and opportunities for sustainable management

Surveys suggest that over 65% of the original wildlife habitat in Africa has been lost (Kiss, 1990) as a result of agricultural expansion, deforestation, and overgrazing, which have been fueled by rapid human population growth and poverty. As a result protected areas are becoming increasingly ecologically isolated while wildlife on adjacent lands is actively eliminated (Newmark and Hough, 2000). Efforts to exterminate populations of wild species have taken place in many areas of Africa. This included black rhinoceros south of the Ngorongoro Crater because they were a menace to farmers (Stanley, 2000), wildebeest in Botswana because they were thought to compete for grazing and spread malignant catarrh (Spinage, 1992), elimination of all game to keep disease free corridors along the border between Tanzania and Zambia (Plowright, 1982) and of lions and wild dogs because they were thought to prevent the recovery of game species (Stevenson-Hamilton, 1974).

Erecting fences for the protection of livestock against contagious diseases has sometimes resulted indirectly in local extinction of wildlife species. For example, fences have caused massive mortality in wildebeest in Botswana that were prevented from migrating by fences during droughts (Spinage, 1992). From 1960 to the present, veterinary control fences have been built in Botswana, Namibia, South Africa, Zambia and Zimbabwe. The early fences were mainly directed at the control of foot and mouth disease but, as veterinary research progressed in the latter half of the 20th century, it became apparent that numerous other diseases affecting cattle had to be considered (Morkel, 1988). The fence along the international boundary between Botswana and Namibia was constructed in the early 1960s and disrupted wildlife movement between the two countries, and yet these movements play a critical role in species survival, especially in semi-arid ecosystems.

Perhaps the most important threat to wildlife habitats results from the use of fire and tree felling to create an environment unsuitable for tsetse flies (Ford, 1971) or the felling of trees to increase grass production. The use of fire especially causes a decrease of woody species and an increase in grass cover (Norton-Griffiths, 1979; Van Wijngaarden, 1985; Buss, 1990; Dublin, 1995). The combination of cattle, small-stock and fire over hundreds of years probably has had a profound effect on wildlife herbivores by creating habitats suitable to livestock keeping (Smith, 1992; Stutton, 1993; Marshall, 1994). Also by the provision of water and locating available fodder, domestic stock become extreme generalists and now dominate the rangelands with human assistance (Homewood and Rodgers, 1991).

Africa's terrestrial wildlife resources are also under tremendous pressure from a variety of causes that include habitat loss and excessive illegal harvesting. There has been a general decrease in the populations of most economically important large

Table 9.1 Percent decline in large mammal populations across Kenyan rangelands between the 1970s and 1990s. Based on Newmark (2008).

Common name	Scientific name	Percent decline
Burchell's zebra	*Equus burchelli*	2.0
Buffalo	*Synercus caffer*	8.7
Giraffe	*Giraffa camelopardalis*	20.1
Wildebeest	*Conochaetes taurinus*	22.7
Eland	*Taurotragus oryx*	28.4
Hartbeest	*Alcelaphus buselaphus*	38.3
Lesser kudu	*Alcelaphus imberbisi*	40.5
Topi	*Damaliscus lunatus*	41.4
Gerenuk	*Litocranius walleri*	44.1
Oryx	*Oryx beisa*	49.8
Impala	*Aepyceros malampus*	55.1
Grey's zebra	*Equus grevyi*	55.2
Elephant	*Loxodonta Africana*	55.8
Grant's gazelle	*Gazella granti*	56.6
Thomson's gazelle	*Gazella thomsoni*	70.7
Waterbuck	*Kobus ellipsiprymnus*	72.2
Greater kudu	*Tragelaphus strepsiceros*	80.0

mammal species, such as rhino, buffalo, antelope species (Table 9.1) and lion in both East and southern Africa. Species like the white and black rhino, black wildebeest, crowned crane, velvet gecko and the cape mountain zebra have come critically close to disappearing altogether, but decisive conservation action is allowing their populations to survive and revive. African wild dogs are also endangered in Africa, surviving only in large protected areas (Ledger, 1990). On the other hand, populations of a few species such as elephants, have increased or stabilized, possibly in partial response to trade restrictions imposed by the Convention on International Trade in Endangered Species (CITES) and the artificial supply of water in protected areas, especially in semi-arid zones.

Invasive Alien Species (IAS) are species introduced deliberately or unintentionally outside their natural habitats where they have the ability to establish themselves, invade, out-compete natives and take over the new environments (IUCN, 2000). Invasive Alien Species were mostly introduced into Africa for their economic and aesthetic values, such as commercial timber, cropping, biological control agents and ornamental functions. However, some of these have significant environmental and economic impacts on native biodiversity and ecosystems. In its compilation of the Red Data List of threatened species, IUCN cited IAS as directly affecting 15% of all threatened plants, 30% of all threatened birds and 10% of all threatened mammals (Carlton, 1998). Invasion by IAS in protected areas can change the diversity and distribution of habitats and in turn the distribution and abundance of herbivores. In the Lochnivar National Park in the Kafue Floodplain of Zambia the invasion by *Mimosa pigra*, an IAS, is reducing the grassland habitat which is being replaced by *Mimosa-Dichrostachys* thickets in the floodplain. This has reduced the preferred habitat of the Kafue lechwe (*Kobus leche*, a grazer species) and as a consequence the abundance of lechwe has declined (Figure 9.5).

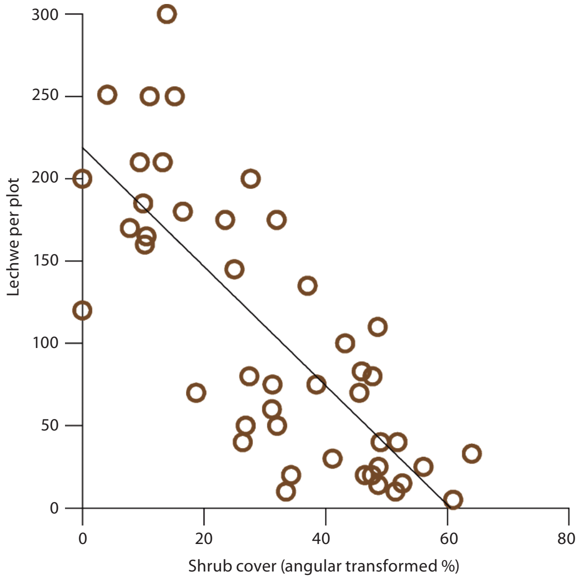

Figure 9.5 Abundance of Kafue lechwe in relation to Mimosa-Dichrostachys *shrub cover in Lochinvar National Park, Zambia. Based on Genet (2007).*

In spite of the above threats to wildlife resources, a number of opportunities exist to improve the management of these resources, including the involvement of local communities in management, trans-boundary cooperation and enforcement of international agreements.

For more than two decades, some African countries have been implementing strategies that support human livelihoods through the sustainable use of biological resources within the context of Community Based Natural Resource Management (CBNRM). In this approach, communities are given rights of access to wild resources and legal entitlements to benefits that accrue from managing the resources. This creates positive social and economic incentives for the people to invest their time and energy in natural resource conservation. Typically, CBNRM initiatives have been implemented in ecologically marginal areas, with limited capacity for other natural resource based economies, such as agriculture. Community Based Natural Resource Management involves *1)* the devolution of control and management responsibilities on natural resources from the State to local people through appropriate legislative and policy changes and *2)* building the technical, organizational and institutional capacity of local communities to assume management responsibilities over natural resources. So far the success of CBNRM has depended on the level of devolution, donor commitment, policy changes and links with tourism and hunting. The key economic driver of CBNRM has been wildlife (large mammals), mostly through trophy hunting and eco-tourism. A major concern about CBNRM, however, has been the limited financial incentives and insufficient devolution of rights to landholders and this is hampering the success of most CBNRM initiatives and needs to be properly resolved.

The trans-boundary nature of biological resources, coupled with their global significance in terms of the goods and services they provide, has motivated African countries to sign and accede to a number of Multilateral Environmental Agreements (MEAs). The MEAs recognize the importance of sustainable biodiversity management in poverty reduction and the lasting improvement of rural livelihoods on the continent. They include the Convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification, the Framework Convention on Climate Change and the International Convention on Trade in Endangered Species (CITES). The MEAs are complimented by regional and sub-regional agreements such as the African Convention on the Conservation of Nature and Natural Resources, the Lusaka Accord and the NEPAD Environmental Initiative. In the recent past a number of trans-boundary conservation areas have been established in East and southern Africa to better manage wildlife species across borders.

Another approach to improving the management of wildlife resources is by placing threatened species on the Convention on International Trade in Endangered species list. This gives the listed species a legal status that prevents them from being interfered with even in areas outside designated nature conservation sites. This approach has been used to conserve wildlife species, such as the elephant, in East and southern Africa.

9.5 Impacts of climate change on resources that support wildlife

Climate change refers to a significant change in the trend of a climate variable, such as temperature or rainfall, over time. It can also refer to a change in the frequency of climatic events, such as floods and droughts (measured as events per given period, e.g. decade). Climate variability refers to the degree of departure of a climate parameter from its mean value. Climate events can also be considered as extreme events if they have a high magnitude of extremity even though their duration may be short. Such extreme events can be distinguished from gradual trends by their statistical extremeness combined with their discreteness relative to the life span of the impacted organism (Jentsch *et al.*, 2007). Changes in mean values of climate parameters, such as temperature or precipitation, may lead to changing species composition of a given ecosystem but the occurrence of extreme events can advance such a process. Currently evidence suggests that the climate in eastern and southern Africa is warming at a faster rate than has been predicted from global models (see chapter 6). With regards to precipitation, except for isolated sites, no clear trend in rainfall patterns has been observed (but see chapter 2) although extreme events, such as droughts and floods, appear to have increased in frequency in the recent past. The significant climate change stimuli to which African wildlife resources are likely to be subjected in the near future in East and southern Africa are most likely related to climate warming due to rising temperatures and extreme events, such as droughts and floods.

Plants are at the base of the food chain and therefore their productivity affects herbivores which in turn support carnivores such as lions. Plant responses to climate change in East and southern

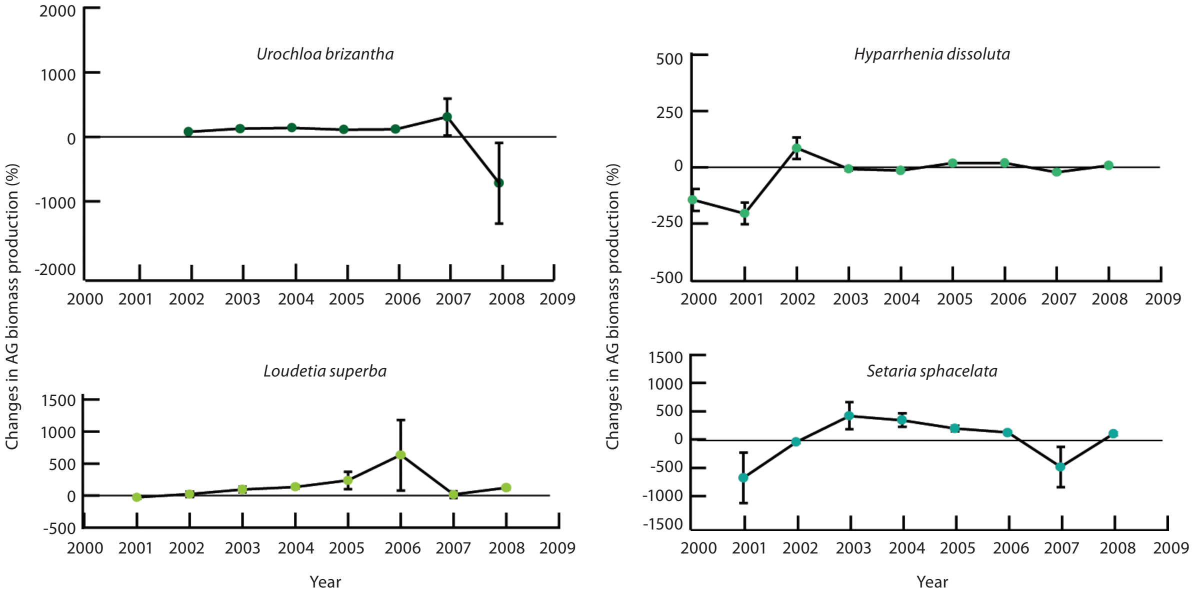

Figure 9.6 Annual changes in aboveground (AG) biomass production of four grasses at a Makeni savanna site in central Zambia under a climate warming period. Based on Chidumayo (unpublished).

Africa have been described in chapter 6 although very limited studies have been conducted in East and southern Africa to assess the impacts of climate change and variability on grasses, trees, forests and water on which wildlife species depend. Observations made at a Makeni savanna site in central Zambia show that the growth of the majority of trees declined due to the additive effects of temperature factors which explained a significant proportion of the variation in tree annual growth (see chapter 6), while the productivity of most grasses at the same site increased under a warming climate (Figure 9.6). Birkett *et al.* (2005) found that although black rhino killed small *Acacia drepanolobium* trees, elephant and drought killed trees of all sizes in the Laikipia region of Kenya (Figure 9.7). This indicates that extreme climatic events may in some cases have more dramatic effects on woodlands and savannas, either on their own or in interaction with other factors, in East and southern Africa, especially in semi-arid zones. In fact, Western (2006) concluded from results of a long-term ecological research project in the Amboseli National Park, Kenya, that woodland and bushland habitats have declined sharply over the past half a century and that grasslands, scrubland and swamps have expanded and projected that woodland habitats will become extinct in the park in the next two decades. The conclusions from these site-specific observations differ from those based on model simulations that show future increases in tropical woody vegetation over East Africa at the expense of grasslands, with regional increases in net primary productivity of 18–36% by 2080–2099 compared with the present-day situation (Doherty *et al.*, 2009).

The functioning of river basins in southern Africa is also likely to be affected by climate change (also see chapter 2), especially through its impacts on woodlands. The Intergovernmental Panel on

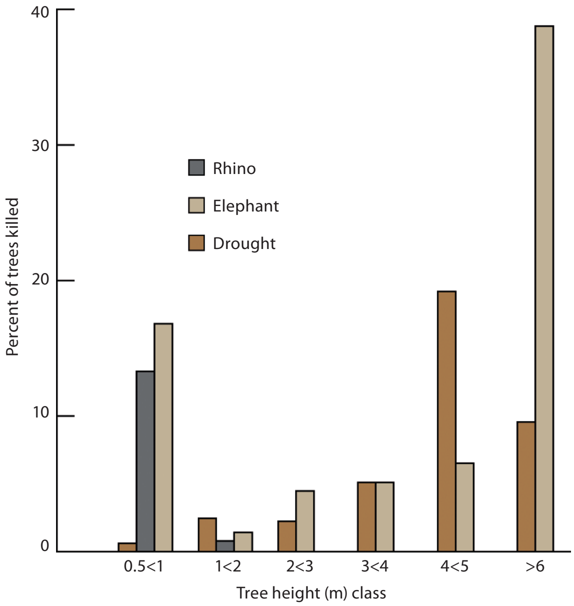

Figure 9.7 Mortality of Acacia drepanolobium *trees caused by drought, elephant and black rhino in the Laikipia region of Kenya. Based on Birkett* et al. *(2005).*

Climate Change (IPCC, 2001) indicates that the major effects of climate change on African water systems will be through changes in the hydrological cycle, i.e. the balance of temperature and rainfall. Analysis has shown that the Zambezi system in southern Africa has low runoff efficiency and a high dryness index which indicates its high sensitivity to climate change. Climate warming is predicted to result in runoff decreases even when precipitation increases due to the large hydrological role played by evaporation, especially from wetlands. Thus increased runoff from loss of forest cover will only worsen water losses from wetland areas due to evaporation that is predicted under a warmer climate. The Zambezi basin contains a number of important national parks in southern Africa that are likely to be negatively impacted by such climate-induced changes in the hydrological cycle.

9.6 Direct impacts of climate change on wildlife

Common effects of climate change on species and ecosystems include *1)* changes in the timing of life-history events or phenology, *2)* effects on demographic rates, such as survival and fecundity, *3)* reductions in population size, and *4)* shifts in species distribution ranges.

In the case of wildlife, food availability and ambient temperature determine energy balance and variation in energy balance is the ultimate cause of seasonal breeding in all mammals and the proximate cause in many (Bronson, 2009). Temperature extremes can impose limits directly through the physiological tolerances of the species. The intensity of a wet season may directly limit opportunities to feed due to wetness while the intensity of the dry season may limit access to surface water for birds and mammals that frequently require it to drink. For example, darker skinned mammals, such as buffalo, elephant, hippopotamus and warthog, due to their reduced hair are particularly sensitive to heat and depend on wallowing as a cooling mechanism (Field and Laws, 1970). Similarly, animals such as buffalo, elephant and waterbuck also need drinking water, whereas other species obtain much of their water requirements from their food. For these reasons, permanent or temporary surface water may influence the distribution of large mammals and some birds whose water requirements include both drinking and wallowing. Warburton and Perrin (2005) reported a reduction in the distribution range of the black-cheeked lovebird (*Agapornis nigrigenis*) in south-west Zambia due to a gradual desiccation of its habitat caused by drought and declining rainfall that have caused the drying up of surface water sources. It has also been observed that larger herbivores, such as kudu (*Tragelaphus strepsiceros*) and giraffe (*Giraffa camelopardalis*), reduce their activity with increasing temperature but because they are forced to feed during all hours of the day, they are thus susceptible to thermoregulatory constraints during foraging compared to small herbivores such as steenbok (*Raphicerus cam-*

pestris) and impala (*Aepyceros melampus*), although most species decreased their time spent feeding and moving on hot days, in favour of resting (Du Toit and Yetman, 2005). It is apparent therefore that larger herbivores are likely to suffer more from thermoregulatory constraints as a result of climate warming than small ones. The abundance of the African lion is also, to a significant extent, determined by climate factors, such as rainfall and temperature (Celesia *et al*., 2009). Statistical analysis suggests that the density of lions decreases with increasing mean temperature and decreasing rainfall and this relationship is best described by the following linear model:

$$Y\ (\text{lions}/100\ \text{km}^2) = 35.8 + 0.016R - 0.016T_{mean};$$
$$r^2 = 0.47,\ F = 12.98,\ P = 0.0001$$

where R is annual rainfall in mm and T_{mean} is annual mean temperature (°C). This model indicates that lion density or carrying capacity in protected areas in sub-Saharan Africa is likely to decline with climate warming and drying.

However, rainfall, more than temperature, appears to regulate aspects of reproduction in most dry tropical African mammals. For example, the abundances of newborn calves in topi, waterbuck, warthog and migratory zebra were best correlated with monthly rainfall and this exerted both negative and positive effects on the abundances of zebra, impala and waterbuck in the Mara-Serengeti ecosystem of East Africa (Ogutu *et al*., 2009). These studies concluded that rainfall underpins the dynamics of African savanna ungulates, and that changes in rainfall due to global warming may markedly alter the abundance and diversity of these mammals. Apparently, ungulates in East African savannas respond to rainfall fluctuations through movements, reproduction or survival, and the responses appear independent of breeding phenology and synchrony, dietary guild, or degree of water dependence. However, extreme events, such as droughts, have been observed to delay onset and reduce synchrony of calving and natality rates while high rainfall advanced onset and increased synchrony of calving and natality rates in some ungulates (Ogutu *et al*., 2010). Observations made in Hwange National Park in Zimbabwe also showed that climate variability strongly affects local elephant population dynamics through changes in surface-water availability caused by variable rainfall and overall population decreased during dry years when the elephant density was high (Chamaillé-Jammes *et al*., 2008). Chamaillé-Jammes *et al*. (2007) suggested that in arid and semi-arid environments, surface water strongly constrains the distribution and abundance of large herbivores during the dry season and that artificial pumping increased surface water availability and reduced its variability over time.

Owen-Smith *et al*. (2005) found that juvenile survival of most ungulates in Kruger National Park, South Africa, was sensitive to annual variability in rainfall, especially in the dry season, and that rainfall also affected adult survival in several species that were in a population decline phase. In the female elephant of semi-arid Samburu National Reserve in northern Kenya, the initiation of the reproductive bout was dependent on conditions during the season of conception but timed so that parturition occurred during the most likely periods of high primary productivity, 22 months later (Wittermyer *et al*., 2007).

Global climate change also presents a potential long-term threat to the East and southern African savanna ecosystems. For example, Dobson (2009) observed that in Serengeti National Park, because the wet season is slowly getting drier while the dry season is getting wetter, wildebeest arrive earlier (two months earlier) for the wet season and unusually early rains for the dry season stimulate the herds to move south into areas that are usually dry and barren at that time of the year. Although earlier movement towards more nutritious grazing might give wildebeest more time to feed before they arrive at the calving grounds in January, their conception times are set by lunar cycles with the rut occurring during full moon in early summer, such that if the wet season rains are diminishing

Table 9.2 Current and modeled (at 2050) species in selected national parks in East and southern Africa using two climate change scenarios. Source: Thuiller et al. *(2006).*

Park	Biome	Current species	HadMC3 scenario			IPCC SRES scenario		
			Species loss	Species gain	Turnover	Species loss	Species gain	Turnover
Kalahari	Desert & xeric shrubland	45	25	6	19	23	7	-16
Etosha	Flooded grassland & savanna	80	22	14	8	18	13	-5
Mt Kenya	Montane grassland & savanna	50	18	25	7	12	26	14
Nyika	Montane grassland & savanna	97	5	10	3	6	4	2
Kruger	Tropical grassland & savanna	87	11	16	5	10	18	8
Serengeti	Tropical grassland & savanna	120	7	6	1	6	3	3

then there will be a reduction in the high-quality forage during lactating. This will ultimately lead to reduced calf survival and the population will slowly decline. In turn this may lead to a reduction in the abundance of the larger predators that depend upon the wildebeest for food.

Both droughts and herbivory (including fire) contribute to the shift in the current balance between woody and grassy habitats in East and southern Africa (van de Vijver *et al.*, 1999; Western, 2006). This has implications for the abundance of the browsers and grazers in wildlife conservation areas. A vulnerability assessment for ungulates (nyala, impala, buffalo, warthog and kudu) in Lengwe National Park, Malawi, revealed that all these species, but especially nyala antelope, could be highly susceptible to climate induced changes in habitat and food supply (Mkanda, 1996). Mkanda observed that thicket clumps which occupy about half of Lengwe National Park comprised the preferred nyala habitat but in times of drought there is a reduction in thicket clumps and woody plant regeneration is poor. As a result the nyala population declines. Scenarios showed that due to climate change, particularly ambient temperature, habitat loss would increase and make nyala vulnerable. It has also been shown in chapter 6 that climate warming is likely to reduce the production of woody plant fruits/seeds and this is likely to reduce the food availability for browsing wildlife species, such as elephant, in many wooded and scrubland national parks in East and southern Africa with negative consequences on the abundance of these herbivores.

Modeling studies have shown that mammals in African national parks will experience changes in species richness. Xeric shrubland national parks are likely to experience significant richness losses not compensated by species influxes (Thuiller *et al.*, 2006; Table 9.2); but other national parks might expect substantial losses and influxes of species but on balance, the national parks might ultimately realize a substantial shift in the mammalian species composition of a magnitude unprecedented in recent geological time. These studies conclude that the effects of global climate and land use change on wildlife communities may be most noticeable not as a loss of species from their current ranges, but instead as a fundamental change in community composition (Thuiller *et al.*, 2006).

Relationships between the geographical distributions of birds and present climate have been modeled for species breeding in both Europe and Africa and the results suggest that there is likely to be a general decline in avian species richness with the mean extent of species' potential geographical distributions likely to decrease (Huntley *et al.*, 2006; Figure 9.9). In particular, species with restricted distributions and specialized species of particular biomes, as well as migrant species, are likely to suffer the greatest impacts. The modeling results showed potential boundary shifts in African

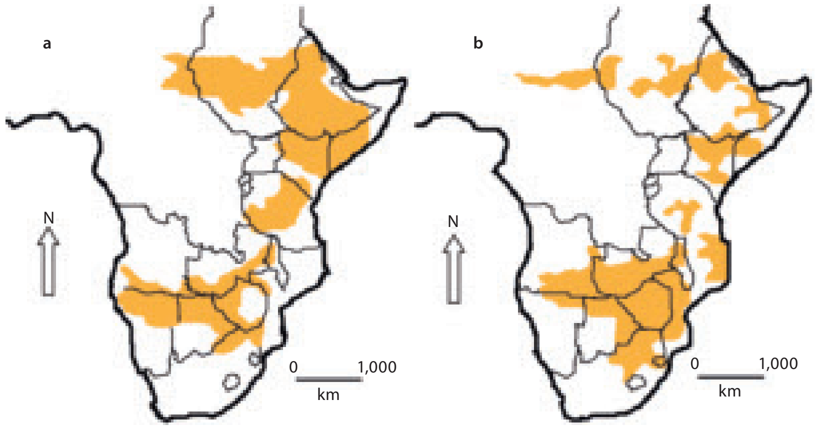

*Figure 9.8 Simulated current a) and future b) distribution of the red-billed hornbill (*Tockus erythrorhynchus*) in East and southern Africa. Based on Huntley* et al. *(2006).*

species of more than 500 km while in general the patterns of changes predicted (Huntley *et al*., 2006) are that:

- species in southern Africa will potentially become more restricted, their distributions contracting towards the Cape;
- species restricted to the Horn of Africa potentially become more restricted, their distributions again contracting within that region (see Figure 9.8);
- species of semi-arid zone, as well as most of those found in East Africa, especially those of montane habitats, potentially become more restricted as many arid areas expand and montane habitats become more restricted or even displaced from lower elevation ranges;
- species associated primarily with equatorial and moist forest habitats will likely not be affected, their distributions being potentially little altered.

These observations are a source of great concern about the continuing effectiveness of networks of protected areas under projected 21st century climate change. Shifts in species' distributions could mean that these areas may cease to afford protection to wildlife species for which they were originally established. For example, a recent study has found that species turnover across the sub-Saharan Africa's Important Bird Area (IBA) network is likely to vary regionally and will vary substantially at over 50% of IBAs by 2085 for priority species (Hole *et al*., 2009). Persistence of suitable climate space across the network as a whole, however, is notably high, with 90% of priority species retaining suitable climate space in existing IBAs in which they are currently found. However, for the remaining 10% of priority species new sites will have to be added to the existing IBAs to ensure their continued survival. Another study has shown that the South African IBAs network is also likely to become less effective for conserving endemic birds under climate change (Coetzee *et al*., 2009).

9.7 Adaptation and mitigation approaches to impacts of climate change on wildlife resources

Adaptation is primarily aimed at tackling localized impacts of climate change; it is therefore perceived to have the potential to reduce adverse effects of climate change but not necessarily prevent all the damage caused by climate change (Hulme, 2005). One of the most commonly used coping/adaptation approach to impacts of climate change on wildlife has been the artificial provision of water to wildlife in arid and semi-arid national parks. This approach has been successfully employed in Hwange National Park, Zimbabwe, to maintain elephant populations, especially during the dry season (Chamaillé-Jammes *et al.*, 2007, 2008). Migratory species naturally migrate from stressed ecosystems to more favourable ecosystems at different periods of the year. However, the conversion of land use to agriculture and settlements along the migration routes is restricting the movements of such species. For example, around Tarangire National park, Tanzania, key corridors and dispersal areas are being lost to agriculture and settlements (Rodgers *et al.*, 2003). At the root of these problems and the challenge of conservation in East and southern Africa is wildlife's inability to compete as a locally valued form of land use and livelihood option. Local communities must be able to derive benefits from wildlife resources occurring on lands surrounding national parks in order to have incentives for conservation. Considerable progress has been made in most countries in creating local wildlife-based benefits from tourism, but major institutional constraints remain unresolved and these are hampering progress towards viable community-based conservation and in turn to the adaptation to impacts of climate change on wildlife resources.

In the past the boundaries of some national parks have been expanded to allow for easy movement and migration of wildlife species. For example, the original boundaries of Serengeti National Park were expanded to include key wet season grazing resources within the Ngorongoro Conservation Area and the short grass plains of the Serengeti that were complimented by wet season habitats in the Mara in Kenya (Dobson, 2009). There are also efforts to create trans-boundary conservation areas by linking parks across borders of two or more countries to increase the range for wildlife species (see chapter 8), thereby increasing the potential of wildlife species to adapt to climate change. Climate envelope models suggest that for some species predicted changes in climate may significantly reduce the suitability of currently occupied habitats. Such threats are likely to be most keenly felt by species with limited dispersal ability. For such situations, adaptive management may involve either improving connectivity of habitats to facilitate natural dispersal or human-aided dispersal to appropriate habitats. Under the latter, success can be improved by ensuring that the size of the introduction is sufficiently large to overcome the risk of Allee effects that can drive small populations towards extinction.

Indeed, a number of potential adaptation strategies exist for reducing the impact of climate change on wildlife resources and these include the following (Mawdsley *et al.*, 2009):

- Increasing the extent of protected areas.
- Improving management and restoring existing protected areas to facilitate resilience.
- Protecting movement corridors and refugia.
- Managing and restoring ecosystem function rather than focusing on specific species or assemblages.
- Translocating species at risk of extinction.
- Reducing pressures on species from sources other than climate change, such as over-exploitation of species and preventing and managing invasive species.
- Evaluating and enhancing monitoring programs for wildlife and ecosystems.
- Incorporating predicted climate-change impacts into species and land-management plans, programs and activities.
- Ensuring that wildlife and biodiversity needs are considered as part of the broader societal climate change adaptation process.
- Reviewing and modifying existing laws, regulations and policies regarding wildlife and natural resource management.

Climate change mitigation addresses the impacts on the climate system. Dobson (2009) has argued that wildlife conservation areas in African savannas have the potential to play a key role in helping slow climate change by considering these areas as carbon sinks. For example, he and others estimate that the Serengeti grasslands remove a net of about 5.24 million tonnes of carbon from the atmosphere each year and after accounting for losses due to fire and run-off, the net annual build-up in the soil is about 0.5 tonne per km^2. It is apparent therefore that the potential for managing East and southern African national parks for climate change mitigation through carbon storage and sequestration and other ecosystem services that could be traded on world carbon markets to off-set the costs of management is huge but remains unexploited.

9.8 Conclusions

East and southern Africa are rich in wildlife resources and have a large number of endemic mammal and bird species that are conserved in protected areas and the major uses of wildlife resources are eco-tourism, safari hunting and local hunting; these activities contribute to local and national economic development and household livelihoods. Africa's wildlife resources are under tremendous pressure from habitat loss and excessive harvesting that are fueled by rapid human population growth and poverty. Invasive alien species pose an additional threat to wildlife in East and southern Africa. Nevertheless, management of wildlife resources can be further improved through more effective involvement of local people and communities, trans-boundary cooperation and enforcement of international agreements.

The significant climate change factors that are likely to affect wildlife resources in East and southern Africa are climate warming and extreme events, such as drought and floods. Very limited studies have been conducted in East and southern Africa to assess the impacts of climate change and variability on resources that support wildlife. However, emerging evidence suggests that climate warming might reduce woody plant production, including fruit/seed production, while there is likely to be an increase in grass production. Drought has also been observed to contribute significantly to tree mortality in the region and climate warming is predicted to negatively affect the hydrological cycle with consequences for surface water availability for mammals and some birds.

Direct effects of climate warming include shifts in onset and duration of rainy seasons and drought on wildlife species, reduction in species distribution ranges, alteration in abundance and diversity of mammals, changes in calving and population growth rates, changes in juvenile survival of most ungulates and changes in species richness of birds and mammals. These changes in wildlife species will have direct serious negative impacts on eco-tourism and game hunting.

The most commonly used adaptation strategies to deal with impacts of climate change in the wildlife sector include artificial provision of water, expansion of protected areas to include migration corridors and seasonal feeding areas and improving connectivity of habitats to facilitate dispersal to appropriate habitats. However, in future it will be important to incorporate predicted climate change impacts into overall wildlife management plans and to review and modify existing laws, regulations and policies regarding wildlife management. In addition, consideration should be given to managing protected areas for climate change mitigation through carbon storage and sequestration, as well as for other ecosystem services.

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Chapter 10
RESPONDING TO CLIMATE CHANGE IN THE WILDLIFE SECTOR: MONITORING, REPORTING AND INSTITUTIONAL ARRANGEMENTS

Emmanuel Chidumayo and Paul Donfack

10.1 Introduction

Climate affects wildlife resources through different path-ways and the wildlife sector needs to be adequately equipped to respond to climate change. It is important to understand how climate change is likely to impact on wildlife in order to implement adaptation strategies for the sector. Establishing effective climate adaptation strategies requires that scientists, managers and policymakers work together to *1)* identify climate-sensitive species and ecosystems, *2)* assess the likelihood and consequences of impacts, and *3)* identify and select options for adaptation (Hulme, 2005). As Berteaux *et al*. (2006) stated "a good understanding of the factors which allow the ecological effects of climate change to be effectively anticipated is critical to both the quality of basic science and its application to public policy". Fundamental to this understanding is the need to monitor and record the distribution and abundances of wildlife species in order to assess the relationships between population dynamics and climate variables. This can only be done if there is adequate capacity to conduct and sustain research at national level. Climate change is a cross-cutting issue and therefore requires special institutional and governance arrangements both at national and international levels. This calls for climate change mainstreaming which involves the inclusion of climate change concerns into development policy, plans, investment decisions and institutions. Within the wildife sector, it is important to build an efficient communication link to reach various stakeholders in order to promote awareness and knowledge about the linkages between climate change and conservation of wildife resources.

This chapter considers issues of monitoring and reporting in the wildlife sector in relation to climate change and discusses the roles of institutions in promoting effective responses to climate change. The chapter first describes the different types of monitoring and capacity building before considering reporting arrangements under the United Nations Framework Convention on Climate Change (UNFCCC) and ends with an overview of institutional and governance arrangements that exist and are necessary in responding effectively to climate change threats and effects.

10.2 Monitoring

Recording, mapping, surveying and sampling are all methods of data collection that provide a basis for the systematic measurement of variables and processes over time. Monitoring refers to systematic observations of parameters related to a specific problem and designed to provide information on the characteristics of the problem and their changes with time. Monitoring therefore differs from surveillance which is the systematic measurement of variables and processes over time with the aim of establishing a series of data in time. Census generally refers to population counts that if repeated over time can be used in monitoring programmes. Monitoring climate change and climate variability means providing good quality climatic and non-climatic data. Information concerning the ongoing situation on the ground for terrestrial ecosystems, biodiversity and protected areas are examples of non-climatic data applicable here.

10.2.1 Climate monitoring

To better understand the local climate with the aim of forecasting the local change, there is a need for a suitable and operational meteorological observing station that is part of an operational national observation network which could also be integrated into regional networks. The network of meteorological stations allows the collection of data on climate parameters to monitor the atmosphere, oceans and terrestrial systems. Among the climate variables that are measured are temperature, rainfall, wind speed, sea surface temperature and sea level. Data to be collected on these variables are useful to the improvement of our understanding of the climate system, detection of climatic change and provision of inputs for climate models and for evaluating adaptation options.

A network of meteorological stations exists within sub-Saharan African countries which routinely records and reports on climate variables, such as rainfall and temperature, although the density of meteorological stations is low (Hansen and Lebedeff, 1987). A regional workshop for Africa organized by the Global Climate Observing System (GCOS) observed that systematic observation networks in Africa are inadequate because there is lack of stations and maintenance. However, even the limited available time-series meteorological data have rarely been used in the wildlife sector to assess impacts of climate factors on wildlife resources.

10.2.2 Ecological monitoring

Although it is widely accepted that climate affects the distribution and abundance of mammals and other wildlife species (see chapters 8 and 9), there are problems in relating climate change and variability to wildlife population dynamics. Krebs and Berteaux (2006) recommend that for us to begin to understand the effects of climate change on wildlife species we need to determine specifically the mechanisms, magnitude and frequency of climate changes that affect wildlife populations and their distribution. Studies of climate-population dynamics require special methodologies which include *1)* correlational analyses, *2)* observational experiments, and *3)* modeling that match climate predictions with distribution and abundance of species (climate envelope models). Each of these approaches has its own advantages and disadvantages.

Fundamental to all these approaches is the need to monitor and record distribution and abundances of target species over a sufficiently long period of time in order to assess the relationship between population dynamics and climate variables. Some effects of climate change and variability on wildlife will be felt through changes in plant production because herbivores are dependent on plant biomass. This means that monitoring plant production and phenology in wildlife habitats is as important as monitoring the abundance of herbivores as the impact of climate factors on herbivores may be exerted through impacts on plant production. Thus habitat and species monitoring need to be conducted simultaneously at specific sites to generate data that can be used to infer bottom-up processes and their potential to amplify the direct effects of climate on wildlife species.

Data to better understand the impacts of climate change in sub-Saharan Africa are limited although it is important to understand the impact of climate change on key wildlife species, as well as the relation between climate and animal populations. However, this can be done only if suitable methodologies are developed, including computer modeling. To achieve this, a suitable monitoring system is needed. Monitoring of biodiversity is important to the assessment of climate change influences on biodiversity. Ecological monitoring, conceived around 1990 focusing mainly on biomonitoring, can be easily adapted to integrate the monitoring of climate change and its impacts. It is easy to establish a representative sample of protected areas for wildlife, with indicators, to monitor climate change in relation to biodiversity parameters. This system can be connected to the regional network of meteorological stations (see above). The Earth's surface to be monitored (whether it is a protected area or not) should be subjected to periodic data collection on *1)* community composition in order to note the appearance and disappearance of species, *2)* changes in the migration trajectory of key species, and *3)* changes in the abundance of endemic species. In Europe monitoring of biodiversity relies on indicator species, such as butterflies; in Africa this could be based on species threatened by human pressure, such as large mammals and other flagship species, including species that are sensitive to climate variations. For plants, the inclusion in the monitoring program of neophytes (introduced plants) can be useful in assessing biotic threats to native biodiversity (OFEV, 2007). It is also important to recognize that although climate plays a significant role in determining species' distribution, other variables such as human population density, land use and soils can have similar, if not more, important roles. Issues of population growth and land use change therefore should be considered in developing adaptive strategies to climate change. Hence the need to collect data on human populations and changes in land cover and use.

Satellite data could be of significant use for the management of the environment. Remote sensing will enable the monitoring of changes in land cover but this technology might be too expensive for sub-Saharan African countries, unless they can be supported. However, the use of remote sensing is very important, especially for large protected areas. New tools such as the Normalized Difference Vegetation Index (NDVI) can be used to build forecasting models at large temporal and spatial scales (Berteaux *et al.*, 2006). Nevertheless, small-scale studies are needed to understand the processes that lead to a correlation between NDVI and the performance of herbivore populations in conservation areas.

10.2.3 Modelling

Description of an unknown situation from some current information is referred to as prediction. In ecology forecasting, models take structural relationships among variables that have been quantified for a given data set and extend these to different situations based on correlations that do not necessarily assume any causal relationships between variables, while predictions describe known or assumed causal relationships (Berteaux *et al.*, 2006). Projections into the future improve our capacity to mitigate or adapt to changes and ecological monitoring plays an important role in the development of projections. However, because climate change is likely to bring novel conditions, projecting the future ecological consequences of climate change is a difficult challenge due to a number of reasons and some of these are:

- One or more important variables may not have been measured which is often a result of simplistic hypotheses concerning climate variables and wildlife.
- It is difficult to disentagle direct and indirect effects of climate variation on wildlife population dynamics due to multitrophic interactions. However, this can be overcome by collecting information on all trophic levels and at multiple temporal and spatial scales. Climate effects on wildlife population dynamics is invariably multifactorial but multifactor hypotheses in ecology tend to be vague and qualitative and therefore rarely provide useful information.
- Uncertainties of the climatic scenarios given by climatologists.

Krebs and Berteaux (2006) observed that correlational studies are a key part of ecological research but warned that they suffer from a massive confounding of variables. For example, climate can be described using a very large number of variables and correlationships, with one or more of these variables likely to be statistically significant. Furthermore, the use of aggregated climatic indices, such as ENSO, to reduce the number of independent variables can make it even more difficult to determine the mechanistic processes by which climate affects wildlife populations. Nevertheless, correlational studies in climate research can be the basis for developing hypotheses that can be tested with additional data.

Experimentation is often preferred in developing an understanding between climate-related variables and wildlife resources. However, since climate cannot be manipulated, the experiments are often observational. Long-term processes are the most difficult to deal with in ecological research. Krebs and berteaux (2006) propose four ways of dealing with this problem:

1. Where good fossil deposits or beds exist, historical records and paleontological data can be used to generate knowledge about the past.

2. Making predictions, knowing that it will take some decades before they can be tested. Therefore, wildlife population monitoring programs should include the monitoring of local climatic variables.

3. Break-up long-term hypotheses into shorter-term ones and test the latter independently. But this approach requires proper coordinated organization of team work to ensure that work addresses the long-term hypotheses.

4. Substitute space for time as long as there is a clear understanding of the mechanisms behind spatial variation in the process being investigated.

Although models have been used to predict effects of climate change on wildlife, especially species ranges, these models have never been empirically tested and therefore their outputs should really be viewed as possible scenarios or forecasts rather than as firm predictions of the future changes. Long-term observations in time and space provide the best validation of ecosystem scale models but long-term records in sub-Saharan African countries rarely go back more than 100 years and therefore future responses remain unknown until they occur, thereby rendering current validations of models of future conditions impossible (Rustad, 2008). Except for the recent work by Kgope *et al.* (2010), there have been virtually no experimental observations on the response of species and communities to climate change in sub-Saharan Africa. And yet experimental manipulations of natural systems or their components are powerful means for determining the cause-and-effect relationships of short-term responses to single or multiple elements of climate change (Rustad, 2006). Nevertheless, there is concern that the results from short-term manipulation experiments may be transient and therefore not reflect the long-term responses of natural systems to climate change.

10.3 Capacity building, research and technology transfer

For sub-Saharan African countries maintaining and reporting of climate change and impacts on wildlife will require billions of dollars. This is why providing financial support to developing countries to help mitigate the effects of climate change and adapt to its impacts is crucial. Climate change costs are estimated at about 100 to 200 billion US dollars, while adaptation costs could reach 86 billion dollars per year (APF, 2009). The funding mechanisms include bilateral and multilateral funds. Among multilateral funds, there is the Adaptation Fund Board linked to Kyoto Protocol, African Development Bank, GEF, UN Development Programme and the World Bank. Among bilateral funds, committed countries include Japan, the UK, the European Commission, Germany and Australia. Many least developed countries have received funding under the UNFCCC to prepare their National Adaptation Plan of Action (NAPA) and many countries have already submitted their

NAPAs that include project proposals related to land-use management, soil conservation measures and erosion control, agroforestry and forestry techniques and management of bush fires. It is recommemded that in future NAPAs should include specific projects on wildlife.

The promotion of practices that reduce the impacts of climate change on biodiversity is an important point to consider. At national level, setting up biodiversity conservation areas and ensuring effective management of those protected areas and their sustainable use should become a priority goal that emphasizes the development of good practices through research, enhancing exchange of good practices and encouraging joint initiatives in sub-Saharan African countries. Working on adaptation and mitigation also requires training. The involvement of research in such programmes is necessary in order to ensure that decision makers, biodiversity users and other intermediaries work together to produce decision support tools for policy development. This is why training schools or wildlife training centers and universities should be requested to adopt curricular modules to improve monitoring of climate change and variability as well as its impacts on wildlife. There is also a need to enhance technical capacity to assess, plan and integrate adaptation needs into sectoral development plans.

10.4 Reporting

The main vehicle for reporting on climate change under the United Nations Framework on Climate Change Convention (UNFCCC) is the National Communications Support Programme that is supported by funding from the UNDP/UNEP/GEF. Through this facility the majority of countries in sub-Saharan Africa prepared the Initial National Communications as a requirement under the UNFCCC and some of these countries are in the process of preparing Second National Communications. The main elements in a National Communication are *1)* national circumstances, *2)* the national greenhouse gases inventory, *3)* programmes containing measures to facilitate adequate adaptation to climate change, *4)* programmes containing measures to mitigate climate change, *5)* other information considered relevant to the achievement of the objectives of the convention, and *6)* constraints and gaps, and related financial, technical and capacity building needs. For the Second Communications, developing countries are requested to include appropriate implementation strategies for the different elements in the communication. Aspects of the strategies should include, among other things, plans to address data gaps and resource allocations for improvement of data collection, in response to identified priorities and needs, information on methodologies and tools available for carrying out the technical studies, linkages between the Second National Communication process and national development priorities. The strategies should also address issues concerning enhanced institutional arrangements to create a sustainable national communication process.

An important objective for preparing a National Communication under the UNFCCC has been to ensure that the document is used to mainstream climate change concerns into the national planning agenda and add value to in-country programming. Thus national mitigation and adaptation projects can be based on the National Communication outputs, although this is rarely the case as many countries submit National Communications to the UNFCCC secretariat largely to meet the demands of the convention. For this reason, Least Developed Countries (LDCs) are now required to ensure that the National Adaptation Programmes of Actions (NAPAs) feed into the preparation of the Second Communications adaptation assessments in order to avoid duplication of efforts and ensure coherent integration of adaptation needs into national development planning. The National Communication Support Programme (NCSP) is intended to sustain capacity-building efforts through technical and policy support, knowledge management, and communications and outreach. This support can be used to organize training and dissemination workshops and for processes that better incorporate climate change into national development.

It is important to build an efficient communication link to reach various stakeholders in order to create awareness about linkages between climate change and conservation of biodiversity. In this regard, conservation NGOs, research institutions, political and economic operators, users of natural resources, the civil society, development partners and donors need to be involved. Establishing networks to share information on the wildlife sector in the region and linkages with other sectors of national economies and global initiatives and processes on climate change and variability is also important.

10.5 Institutional and governance arrangements

Climate change is a cross-cutting issue and therefore requires special institutional and governance arrangements. Currently in many of the African countries, climate change issues are coordinated by institutions that are responsible for either the environment or agriculture. This has resulted in arrangements for addressing and sharing information on climate change that are restricted to a particular sector or specific problems. Furthermore, because most information on climate change relates to agriculture and water resources, little information has been disseminated on other sectors and institutions.

Climate change is often considered as part of the environment and within the sub-Saharan Africa, formal environmental institutions are not well linked to development planning, finance and sector institutions; in many cases environment institutions are separate from development institutions, as well as weaker politically and in capacity terms. The ways in which they do interact are principally for advisory purposes rather than for joint decision-making. Climate mainstreaming is a process of including climate change concerns into mainstream development policy, plans, investment decisions and institutions. Thus climate change mainstreaming is the inclusion of relevant climate change concerns into development policy, plans, investment decisions and institutions. Such mainstreaming is critical for the countries in sub-Saharan Africa where both the economies and people's livelihoods are heavily dependent on natural resources, including wildlife. The drivers of climate change mainstreaming can be varied; ranging from environmental interest groups, international NGOs, politicians and government authorities responsible for international environmental obligations. In addition, donors concerned with coherence of aid and global public goods, and businesses exposed to environmentally discriminating markets, are increasingly driving mainstreaming processes. Among the relevant global processes that need to be mainstreamed are those related to the implementation of protocols, treaties and conventions such as Convention on Biodiversity, United Nations Convention on Desertification, UNFCCC, The NEPAD Environmental Action Plan, The Global Environment Facility (GEF) and Millennium Development Goals (MDGs). In particular Goal 7 of the MDGs, that addresses environmental sustainability through the integration of the principles of sustainable development into national policies and programmes and activities that reverse loss of environmental resources, including wildlife.

It is obvious therefore that capacity development and knowledge sharing are challenges that need to be addressed so that skills can be enhanced and capacity developed within the context of climate change. There is a clear need for scaling up awareness raising actions in sub-Saharan African countries. National Communication on climate change exists and some countries have produced reports as a requirement under the UNFCCC but there are no mechanisms for effectively sharing such information among the countries. There is also a need to seek collaboration with key regional, international and national partners to support the capacity of local institutions and communities and apply relevant knowledge for both mitigation and adaptation. To respond more effectively to climate change, national and regional institutions need to develop coordinated efforts to streamline and align efforts by these institutions in support of climate actions and ongoing UNFCC negotiations (see chapter 4).

Each country in sub-Saharan Africa has specific laws and policies on wildlife that define political and strategic arrangements concerning biodiversity management. Often, these laws and policies are in accordance with sub-regional, regional or international agreements. In this respect, a number of international conventions have been ratified by most of those countries. Among these are the following:

- The Washington Convention of 1973, also known as the Convention on International Trade of Endangered Species (CITES).
- The Convention of Biological Diversity (CBD), signed in 1992 and ratified by most countries.
- The United Nations Framework Convention on Climate Change (UNFCCC), signed in 1992 and ratified by most countries.
- The Convention to Combat Desertification (CCD) in 1994.
- The World Heritage Convention (WHC) or Convention on the Protection of cultural and natural Heritage, adopted in Paris in 1972.
- The Bonn Convention on the protection of migratory species, adopted in 1993.
- The Algier Convention, adopted in 1968 on wildlife Conservation in Africa.
- The RAMSAR Convention on Wetlands, signed in 1971.

In the Central African sub-region, the conservation policy of each country is in accordance with the Yaoundé Declaration (1999) agreed upon by Heads of States from the sub-region and with the Brazzaville Treaty (February 2005). This policy focuses on the conservation and the sustainable management of forest ecosystems of the Congo Basin. Other main political issues include capacity building within institutions, strengthening of research, mobilization of political support and financial resources, and communication of available information. As elsewhere in sub-Saharan Africa, international conservation organizations are progressively being established in the subregion, often with a long-standing tradition of conservation. They include World Wide Fund for Nature (WWF), World Conservation Union (IUCN), Wildlife Conservation Society, (WCS), Bird-Life International, Conservation International (CI) and TRAFFIC International.

Most countries in sub-Saharan Africa have established Ministries in charge of the management of biodiversity or natural resources. Many other institutions provide the bulk of support to nature protection. For example, in the Central African sub-region, the Central Africa Forests Commission (COMIFAC) was created, with the responsibility of monitoring the implementation of the Convergence Plan that regroups priority actions such as transboundary conservation (e.g. Tri Nationale Dja-Odzala-Minkébé (TRIDOM) or Tri Nationale de la Sangha (TNS) Agreements. Many other institutions exist within the Central African sub-region, including the following:

- The Congo Basin Forest Partnership (CBFP) that groups ten countries of COMIFAC, Agencies from donor countries, NGOs, research institutions and the private sector.
- Central Africa Forests Observatory (OFAC).
- The Communauté Economique et Monétaire d'Afrique Centrale (CEMAC), that groups six countries of Central Africa (Cameroon, Gabon, Equatorial Guinea, Central African Republic, Congo and Chad).
- The Communauté Economique des Etats de l'Afrique Centrale (CEEAC) that groups the six CEMAC countries and the DRC, Rwanda and Burundi.
- The Network of Central Africa Protected Areas (RAPAC) that is an association with scientific and technical goals. It focuses on protected areas from eight countries (Cameroon, Chad, Congo, Central Africa Republic, Democratic

Republic of Congo, Equatorial Guinea, Gabon, Sao Tome and Principe) and there are plans to bring in Burundi, Rwanda and Angola.
- The Conférence sur les Ecosystemes de Forêts Denses et Humides d'Afrique Centrale (CEFDHAC).

In West Africa, there are institutions fulfilling important roles in the management of natural resources. They include CILSS (Permanent Inter-State Committee for Drought Control in Sahel), GWP-WAWP (Global Water Partnership-West Africa Water Partnership), Niger Basin Authority, Senegal River Basin Development Authority.

10.6 Conclusions

The main vehicle for reporting on climate change under the UNFCCC is the National Communication Support Programme. However, for us to understand the impacts of climate change on wildlife species, it is necessary to determine specifically the mechanisms, magnitude and frequency of climate changes that affect wildlife populations and their distribution using special methodologies, such as correctional analyses, observational experiments and computer modeling. Fundamental to all these approaches, is the need to monitor and record distribution and abundances of target species over a sufficiently long period of time, coupled with the monitoring of plant production and phenology in wildlife habitats. However, establishing effective climate change adaptation strategies requires that scientists, managers and policy makers work together to *1)* identify climate-sensitive species and ecosystems, *2)* assess the likelihood and consequences of impacts, and *3)* identify and select options for adaptation. However, to effectively mainstream climate change at national, regional and international levels, it is necessary to include relevant climate change concerns into development policy, plans, investment decisions and institutions. With respect to wildlife, it is important to develop a capacity and knowledge base in the context of climate change, particularly concerning monitoring and recording the distribution and abundances of wildlife species over a sufficiently long period in order to have meaningful data to evaluate the effects of climate change on wildlife resources.

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SECTION 4

SOCIO-ECONOMIC AND POLICY CONSIDERATIONS

INTRODUCTION

Section 4 consists of four chapters. The Chapter 11 deals with community based adaptation to climate change, the Chapter 12 describes socio-economic and gender issues related to threats posed by climate change and other non-climate factors and processes, and Chapter 13 is devoted to carbon trade and markets, particularly as they affect Africa. Chapter 14 discusses policy and other approaches to climate change with emphasis on African forestry.

Chapter 11 acknowledges that all parts of Africa will be subject to more extreme day-to-day and season-to-season fluctuations in rainfall as climate change intensifies. This means that African farmers will need to adapt to more extreme and erosive storms, greater likelihood of flood, longer periods of drought, and generally less certain conditions for food and agricultural production. In the face of such challenges, the chapter describes known adaptation technologies including crop improvement, water harvesting and their associated informational and institutional requirements. Some of the informational requirements include giving the right information in the right package to farmers as well as establishing or strengthening institutions to ensure their scaling up. The chapter also reviews the existing informational and institutional gaps, challenges and the way forward with the hope that these will catalyze a re-look at community-based adaptation, increased investment in adaptation and consideration of community-based adaptation as part of the global response in addressing the potential effects of climatic variability and climate change.

Africa's social and economic development is constrained by climate variability and change, habitat loss, over-harvesting of selected species, the spread of alien species, and activities such as hunting and deforestation. Chapter 12 addresses socio-economic issues related to climate change influences on socio-economic and livelihoods dependence on natural resources, including vegetation and wildlife resources, food security and human health as well as the impacts of non-climate factors on natural resources. Climate change is not the only threat that African forests are facing, the chapter points out. They are also subjected to a number of non-climatic factors, often human-induced, that contribute to impacts and vulnerability of African forests. These include poor management, population growth, poverty, policies and governance, competition over resources and conflicts. However, the vulnerability of African forests stems from their central role in socio-economic development. Because of the important role of gender in natural resources utilization and management, the chapter calls for gender considerations when vulnerability and impacts of climate change are assessed and in the implementation of adaptation and mitigation activities.

Africa has a large mitigation potential in the land use sector that can be translated into significant participation in the current and future carbon market opportunities. This potential is underwritten by her large endowment of land and large populations involved in land use based economic activities. However, so far African forests and trees have not been adequately brought forth in the carbon market. Chapter 13 describes the genesis of carbon markets and trade, legal framework for carbon markets, how carbon markets operate, the performance of carbon markets to date, initiatives and experiences in Africa on carbon trade and markets, opportunities and challenges for Africa in carbon trade and markets.

Dealing with the climate change challenge is critical to Africa's economic security and future prosperity and many African governments are moving steadily to implement their national climate change mitigation and adaptation strategies. Chapter 14 examines the context within which policies to bear on climate change are made. Since policies are about issues, the chapter gives a brief account of identified policy issues that are directly and indirectly related to climate change at all levels of societal organization and in different sectors of national and global economies before addressing selected related issues that feature prominently, but are not always confined to the forestry sector.

Chapter 11
COMMUNITY-BASED ADAPTATION TO CLIMATE CHANGE IN AFRICA: A TYPOLOGY OF INFORMATION AND INSTITUTIONAL REQUIREMENTS FOR PROMOTING UPTAKE OF EXISTING ADAPTATION TECHNOLOGIES

Thomas Yatich, Brent Swallow, Oluyede C. Ajayi, Peter Minang and Jaffer Wakhayanga

11.1 Introduction

The global phenomenon of climate change constitutes major threats to Africa (IPCC, 2007). Although the impact of climate change is global, for various reasons including the state of preparedness of the continent, it has been estimated that Africa will be most vulnerable to climate change (Arnell, 2004 and IPCC, 2007). The impacts of climate change in the continent are manifested in various forms including extreme weather patterns, prolonged droughts, flash floods, decline in crop productivity and loss of livestock due to droughts, resurgence of malaria in highland areas, water and pasture scarcities leading to conflicts. The challenges in capacity and the availability of resources and the existence of a high dependence on natural resources increase the risks and uncertainties to livelihoods of the rural poor, as the natural resource base becomes more vulnerable to the vagaries of climatic changes (Denton *et al*., 2000). As a result of these, climate change has the risk of compromising efforts to attain development targets set for the Millennium Development Goals or wiping out some of the modest developments that were already achieved in the continent. Given these challenges, efforts are being initiated to mitigate the effects of the phenomenon and/or to fashion out various coping strategies to assist the population to adapt to climate change with a view to reducing present and future vulnerability. However, adaptation to climate change has to be localized, given that adaptation to climate change is inevitably and unavoidably local (Blaikie *et al*., 1994; Ribot, 1995),

Several adaptation approaches have been advocated. Given the urgency and the potential impacts of climate change, 'community-based adaptation' strategies are currently advocated as the best approach. Community-based adaptation (CBA) is enabling communities to enhance their own adaptive capacity, and empowering vulnerable communities to increase their own resilience to the impacts of climate change (*http://community.eldis.org/Communities/*). It involves strengthening the adaptive capacity of poor communities to deal with the potential impacts of climate change and climatic variability. Currently communities are not key participants in ongoing adaptation iniatives not because they are not recognized, but because climate change responses are at policy levels and shaped by climate negotiations at regional and international levels. Ongoing UNFCCC negotiations on the post-2012 regime are focusing more on 'REDD+'-reducing emissions from deforestation and forest degradation in developing countries – plus conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries as well as financial, technical and capacity strengthening. Many commentators, including Dazé and Chan (2009), argue against the likelihood of these negotiations emphasizing financing mechanisms for community-based adaptation because: *1)* existing funding mechanisms and planning processes under the UNFCCC do not prioritize CBA, *2)* the National Adaptation Programmes of Action (NAPAs) identify vulnerability only on the basis of location-based risk and impacts on key risk averse agricultural sectors, and *3)* lack of scaling up of existing adaptation technologies. Capacity related challenges affect the ability of national level and decentralized state institutions to design, pilot and scale up adaptation strategies at the community level.

Poor linkage between climate change research and communities leads to poor appreciation of technologies developed by the scientific community as well as integration of lessons and experiences from community coping strategies. National-level initiatives are driven by collective action at the international level. Subsequently, local level mainstreaming of climate change strategies are top-down and rarely evidence-based. In Africa, poorly resourced agricultural research (World Bank, 2008) has worked against technology development and dissemination. Agricultural extension has faltered over the years because of policy changes as well as lack of institutional capacity due to poor investments. Kenya's extension approach, for example, has shifted from a robust effective supply driven approach to a challenges-ridden demand driven approach. Initially the extension approach provided a platform for farmers' participatory learning, scientists-to-farmers interaction and pathway for dissemination of agricultural technologies. Pathways for knowledge to action are therefore impeded by poor extension service provision approaches and lack of robust approaches to enhance use of scientific evidence by communities. At the institutional level, failures of markets, governments and local organizations to resolve resource allocation and public good challenges further weaken the adaptive capacity of local communities to adapt to the impacts of climate change.

Despite these challenges adaptation technologies have continued to be developed by international, regional and national research institutes. These technologies are rarely adopted by farmers. In this paper we enumerate on these technologies and propose strategies for enhancing their uptake as the best approach for promoting community-based adaptation. We have also suggested institutional and informational requirements to enhance uptake and lesson learning from adaptation strategies of communities.

11.2 Known adaptation technologies

Research and development efforts over the last twenty years have established a number of technologies and practices that are known to be suitable for the kinds of extreme climate conditions that are emerging across the African continent. Some of these case studies have learnt lessons from experiences of communities with coping strategies including *inter alia* adjustments in cropping and animal practices (Paavola, 2004; Orindi and Eriksen, 2005). These strategies will not be enough to respond to the impacts of climate change (Kandji *et al.*, 2007), but they could be enhanced and complemented through the development, adoption and scaling up of agricultural technologies. Barry and Skinner (2002) categorized adaptation options into: *1)* technological developments, *2)* government programs and insurance, *3)* farm production practices, and *4)* farm financial management. In this paper we have used this typology to order and guide our discussions on technology adaptation options. Although the focus of the paper is on agricultural technologies, they are not mutually exclusive from farm production practices.

Agricultural technologies have the potential to enhance the adaptive capacity of smallholder farmers, although their adoption is affected by various factors. It is generally agreed that these technologies will potentially improve resilience and reduce vulnerabilities of different farming systems. Agricultural technologies have been developed over the years, but their uptake is limited by several factors including *inter alia* high costs associated with technology adoption, poor information flow from technology developers to the farmers, lack of financial support infrastructure, cognitive related challenges and poor extension service provision to the farmers. The following is an overview of some of the technologies developed over the last 20 years.

11.2.1 Crop development

Agricultural research has focused more on improving crop yields. As the uncertainty of climate change effects become clearer and warnings by the Intergovernmental Panel on Climate Change (IPCC) reports, 'climate-proofing' of crops has become crucial – switching crop research to climate adaptation. The Consultative Group on International Agricultural Research (CGIAR) institutes are now investigating how to make crops more resilient to environment stresses. National agricultural research institutes like Kenya Agricultural Research Institute (KARI) have also developed new cultivars that are stress tolerant. The International Maize and Wheat Improvement Centre (CIMMYT) with the International Institute of Tropical Agriculture (IITA), national agricultural research institutes in sub-Saharan Africa, advanced research institutions, private sector seed companies, and nongovernment and community-based through the Drought Tolerant Maize for Africa (DTMA) iniative, have developed high yield stress tolerant maize varieties for 13 countries in East and Southern Africa. It has been established that the drought tolerant maize varieties produce about 20–50% more grain than other maize varieties, under 'mid-season drought' conditions (*http://www.cimmyt.org/english.docs/ann_report/2007/pdf/ar07_stress.pdf*).

The International Centre for Maize and Wheat Improvement (CIMMYT) and its national partners have used participatory crop breeding techniques to develop and promote the adoption of stress tolerant crops among hundreds of thousands of farmers in East and southern Africa. In the Sahel, the International Centre for Agricultural Research in the Semi-Arid Tropics (ICRISAT) specializes in developing stress tolerant crops including millet and cowpeas that are well adapted to low and highly variable climatic conditions (CGIAR, 2008). Efforts by the CGIAR harvest centres to develop stress tolerant crop priorities are complemented by efforts by regional policy institutions like the Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles/West and Central African Council for Agricultural Research and Development (CORAF/WECARD). In Sahelian parklands, CORAF/WECARD has initiated various research activities such as DNA extraction of tamarind and baobab trees aimed at improving their adaptation to drought. CORAF/WECARD has also screened and characterized cowpea and sorghum from the sub-region with the results charged as promising (CORAF/WECARD, 2008). The regional centre for breeding stress tolerant crop and tree species is at Thies, Senegal.

11.2.2 Resource management innovations

As a response to moisture insufficiency, research and development institutions have developed resource-based innovations. The literature gives a range of innovations including water harvesting and market-based approaches. Water harvesting is still practiced by relatively few farmers and communities, despite the fact that there are a number of proven technologies. The World Agroforestry Centre hosts a water harvesting network for southern and eastern Africa (SEARNET) that draws together and supports efforts in a number of countries. The Water Harvesting programme has over the years provided technical support to farmers and national research systems to promote uptake of technologies. Reduced tillage technologies such as Conservation agriculture and improved fallows are gaining momentum in Africa, although still in their infant stages. In Zambia, farmers are adopting animal-drawn implements that help prepare land for crop production without large losses in ground cover or soil moisture. Elsewhere in southern Africa, hundreds of thousands of farmers are using nitrogen-fixing trees as improved fallows, thus restoring soil nutrients, retaining soil moisture, and increasing infiltration rates (Akinnifesi *et al.*, 2008).

Reward schemes for environmental services have been gaining momentum in Africa. Apart from promoting ecological benefits, reward schemes promote less erosive and more beneficial land use systems. This improves resilience of different ecosystems to climatic change and variability. Designing and implementing rewards for environmental services (RES) is a daunting task given the information and institutional requirements associated with such schemes. ICRAF and partners are implementing a project on pro-poor rewards for environmental services in Africa (PRESA) which is aimed at fostering fairs and workable reward mechanisms that can benefit stewards of ecosystem services in East and West African highlands. PRESA and partners are also implementing carbon sequestration projects that not only act as carbon sinks, but provide alternative income streams for participating farmers. Annual crops now comprise less than half of farm income in many countries, with vegetables, dairy and tree crops taking on greater importance.

11.2.3 Water efficient trees

Water scarcity is increasing in much of Africa, with countries like Rwanda, Burundi and Kenya already classified as water scarce. Climate change predicts that a 10% drop in rainfall can reduce river flow by 50% (Chin Ong, 2006). Water scarcity is particularly severe in water catchments where farmers and urban residents share available water supplies. Many of those same areas are also experiencing shortage in wood products, prompting rapid uptake of fast-growing trees such as clonal eucalyptus from South Africa. The World Agroforestry Centre has recently synthesized research results on water efficiency of tree-based systems and established principles for water-efficient tree production. The synthesis recommended for better tree alternatives and making appropriate trade-offs. Research by the World Agroforestry Centre (ICRAF) and its partners show that leaf phenology or shedding has very important effects on seasonal water use. Native deciduous trees – which drop their leaves in the dry season – can help match the water use of trees to the long-term rainfall pattern. This means less impact on river flow, while producing high value to farmers in terms of timber and fodder. Such species can also be very suitable for intercropping with crops. This is illustrated in Figure 11.1.

The question is what are the best tree alternatives? Will these be better than the water thirsty trees such as eucalyptus? As illustrated in Figure 11.1 the alternative tree species have different water demands during different seasons. With climate change and subsequent decline in water and availability of moisture, these trees will continue providing important ecosystem services and products. Alternative tree species will not only use less water during dry seasons by shedding their leaves. Some of the alternative tree species include *Cordia Africana*, *Melia volkensii* and *Croton machrostachys*.

Cordia Africana is found widely throughout dry to moist regions in sub-Saharan Africa, ranging from Guinea in West Africa to Ethiopia to South Africa. In Kenya, *Cordia* displays bimodal shedding of its leaves in time with the rainfall pattern and is suitable for intercropping with coffee. It has the potential to improve on the quality of coffee and also provide other ecosystem services associated with coffee. *Cordia* is also a forage tree and flowers between March and October (Fichtl and

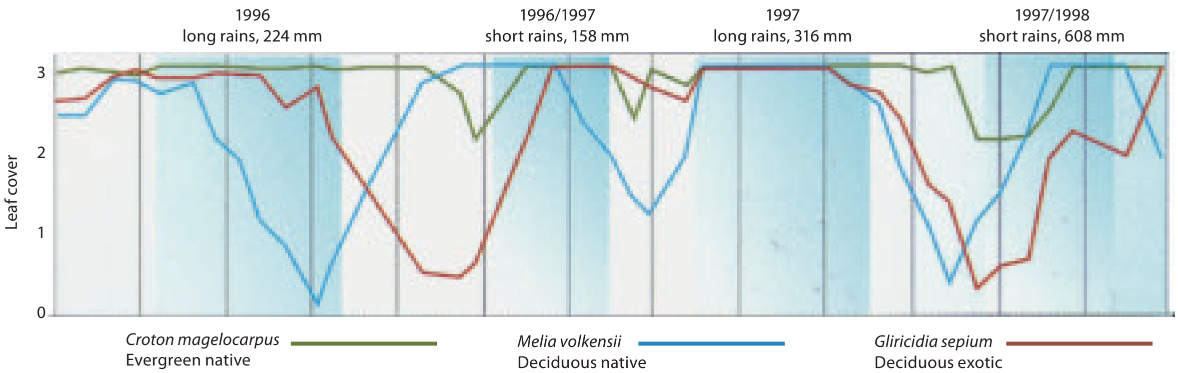

Figure 11.1 Rainfall demand by evergreen and deciduous trees. Source: Chin Ong et al.*, 2006.*

Admasu, 1994). It is therefore good for beekeeping and honey production. *Cordia* is also a source of excellent high-value timber that is suitable for furniture, mortars, windows and house doors and therefore would replace timber provided by eucalyptus. *Cordia* is not as fast growing as eucalyptus.

Melia volkensii, a deciduous species, displays a major reduction in leaf cover during both the long and short rainy seasons in Kenya, closely matching the rainfall pattern. This tree species is drought-resistant and found in semi-arid areas of Ethiopia, Kenya and Tanzania. *Melia* is highly prized for its valuable timber that is termite resistant, both when alive and dead (Mulatya, 2000). Compared to *Cordia* and even fast growing thirsty trees, *Melia* has the added advantage of being harvested in reasonably short rotations. In Machakos in Kenya, *Melia* was found to produce poles in less than three years and timber in less than five years from coppiced stems (Ong *et al*., 2002). Other uses of *Melia volkensii* include *inter alia* construction and carving, fuel, fodder, mulch and green manure. All of these unique features add up to economically favourable options for farmers (Ong *et al*., 2002; Mulatya, 2000, 2006). Its climate change benefits with regards to water use efficiency enhance its benefits to smallholder farmers.

Croton machrostachys is suitable for intercropping with coffee and is found more or less throughout tropical Africa in montane forest and evergreen bushland areas that receive between 700 and 2,000 mm annually. These trees experience extended flowering seasons in most areas, peaking in March–June and May–July, providing excellent bee forage. The cream-coloured, soft wood is used for indoor carpentry, furniture, veneers, tool handles, boxes and crates. Many parts of the tree have medicinal value, including the fruit and the roots are used to treat venereal diseases, and the juice from the leaves which is used to treat skin diseases like ring worm (Fichtl and Admasu, 1994).

11.2.4 Flexible livestock production strategies

Mobility, grazing reserves and communal water management are important strategies used by African livestock keepers to cope with variable rainfall conditions. The *Borana* people in southern Ethiopia have elaborate institutions for ensuring that their livestock are able to maintain access and good care for water points and pastures. The *Sukuma* people of western Tanzania have revived their customary *ngitili* arrangement for reserving dry-season grazing areas. Recently the Kenyan

Government and civil society have implemented an off take program for livestock to reduce the adverse effects of prolonged droughts. Capacity building for farmers on diversification and re-stocking has also been undertaken by NGOs like Oxfarm and Semi-arid Rural Development Programme, an SNV-GOK initiated programme.

Research institutes are working with smallholder farmers to try out some of the agricultural technologies discussed above as a way of adapting to potential climate change. Provision of information has the potential to stimulate adaptation. This is however limited by the institutional and informational challenges. Research and approaches to sharing information also present challenges to the Consultative Group on International Agricultural Research (CGIAR) centres and national research systems. Institutional factors constraining the adoption of agricultural technologies and support infrastructure include changing commodity prices, trade agreements, resource use rights, government subsidies and support programs. Institutional and information needs for enhancing the uptake of agricultural technologies by farmers are discussed in the next section.

11. 3 Information and institutional needs

Different adaptation strategies will need different information and have different institutional needs. The identification of the knowledge gaps and institutional needs associated with each of the adaptation strategies is useful information for farmers, policy makers, technocrats, research institutes, national research systems, national level climate change negotiators, universities, regional level policy processes and non-state actors.

11.3.1 Information needs

The use of research results to inform action by farmers and farmers' organizations is constrained by the poor linkage between two domains: knowledge/science and action domains. Often knowledge produced by scientific institutions does not translate into action by 'actions institutions' because of the lack of boundary objects. The boundary objects/agents who straddle the multiple and varied boundaries between stakeholders, translating, communicating and facilitating linkages between knowledge and action are often lacking and this limits action by action institutions. However developing more nuanced tools, approaches and methodologies that address the needs of action institutions would bridge the gap between science and practice. This is only possible if the six classes of boundary work are understood (Table 11.1). Meine van Noordwijk (2008) identified and expounded on the six classes of boundary work by linking knowledge and action to typify the relationship between the knowledge and action domains.

Based on Table 11.1, Meine van Noordwijk (2008) and Guston *et al*. (2000) developed typologies of boundary organizations based on a 0, 1 and ≥2 classification of actors and ways of knowing. Meine van Noordwijk (2008) further identifies six classes of boundary spanning activities as:

0. A ⇔ A, no K, meaning not informed by any science.
I. K ⇔ K, no A, knowledge not influencing any action.
II. K ⇔ A – the archetypal boundary work of technology transfer, science-policy advice, public funding for science and *decision support systems*; the IPCC effort falls within this class with its 'policy relevant' but not 'prescriptive' synthesis of science.
III. K ⇔ (A ⇔ A) – boundary work such as 'joint fact finding' that can emerge at a certain stage in (mediated) political negotiations.
IV. (K ⇔ K) ⇔ A – integrated assessments, such as the Millennium Ecosystem Assessment (MEA).
V. (K ⇔ K) ⇔ (A ⇔ A) – *negotiation support systems* and the emerging reward mechanisms for environmental systems, where both the articulation of knowledge and the actions are negotiated.

Table 11.1 Typology of boundary organizations on the interface of knowledge and action, with examples of six classes of boundary work. Source: Meine van Noordwijk, 2008.

	0 None	1 Decision	≥2 Collective action
0 Conjecture and ignorance	*Daily life of you and me*	A *Ignorant decisions*	$A_1 \Leftrightarrow A_2$ *Ignorant politics* (0)
1 One truth	K *Science* *Knowledge for own sake*	$K \Leftrightarrow A$ (II) *Technology transfer,* *Scientific policy advice such as IPCC,* *Decision support systems – DSS*	$K \Leftrightarrow A_1 \Updownarrow A_2$ (III) *Joint fact-finding*
≥2 Multiple ways of knowing	$K_1 \Leftrightarrow K_2$ (I) *Interdisciplinary, tacit + Scientific knowledge*	$K_1 \Updownarrow K_2 \Leftrightarrow A$ (IV) *Integrated assessments such as MEA*	$K_1 \Updownarrow K_2 \Leftrightarrow A_1 \Updownarrow A \Updownarrow A_2$ (V) *Negotiation support systems – NSS, RUPES*

In most cases the boundary spanning activities that best explain the links between the 'scientific' and 'farmer' domains are A⇔A and K⇔K. It is desirous to have the rest four but this is constrained by different factors including knowledge gaps. For agricultural technologies to be adopted scientists have to provide knowledge that would be required by the farmers as well as by policy makers at different scales. Information gaps are also useful for different policy domains. In Table 11.2 (next page) we have broken down the different categories into specific agricultural technologies and provided some of the requisite information required for successful adoption by farmers. Decision makers and technocrats such as planners also require such information to improve their decision making as well as provide extension advice to the farmers. Information gaps and needs vary from one technology to another. To best exploit these known technologies, there is need for better information for farmers, regional planners and policy makers. Table 11.2 presents a summary of some of these information needs.

11.3.2 Institutional needs

Availability of better information may need to be augmented by changes in institutions. In this paper we have viewed institutions as organizations, establishments, foundations, societies, or the like, devoted to the promotion of a particular cause or programme, especially one of a public, educational or charitable character. Institutions are also the act of instituting or setting up establishment: *the institution of laws (http://www.dictionary.com).* Institutions established at the national, sub-national and local levels are determined by response mechanisms to climate change at the global level. Institutions at the national level are organized into policy domains: forestry, agriculture, water, etc. These domains operate vertically and there is lack of cross-sectoral coordination. Climate change is a cross-sectoral issue that requires cross-sectoral coordination. Knowledge, in this case, agricultural technologies, is passed through institutions and policy domains (Figure 11.2) with factors like levels of income, property rights, extension service provision, governance, levels of education, state of market infrastructure and proximity to urban centres determining the rate of adoption and scaling-up of agricultural technologies. In most cases

Table 11.2 Summary of information needs.

Adaption strategy	**Farmers' information needs**	**Regional/national planners' and policy makers' needs**
Stress-tolerant crops	Suitable tested germplasm, reliable germplasm suppliers, management needs and other input needs.	Long-term climate trends, adoption of existing or development of new varieties.
Water harvesting and storage	Individual or group approaches, appropriate harvesting technology, opportunities for public support, licensing requirements.	Appropriate technologies, returns to small or larger-scale water harvesting, climate scenarios for planning storage capacity.
Flexible livestock production strategies	Market risks and opportunities, production risks, hardy breeds, reliable sources of parent stocks, husbandry practices.	Tradeoffs between investment security and flexibility.
Diversified production and marketing strategies	Market risks and opportunities, technologies and management needs, complementarity.	Trade-offs between specialization and diversification, farmers' motivations and interests, range of options.
Conservation agriculture and improved fallows	Benefits and costs of technologies, benefits of collective action.	Geographic suitability and targeting of technologies.
Reward schemes for environmental services	Obligations of the farmer in service provision, benefits, monitoring and evaluation.	RES vis-à-vis policy implementation, appropriate policies to support RES design and implementation.
Water-efficient tree species and cultivars	Market opportunities for products, germplasm suppliers, economic returns, farm and local trade-offs between production and water use.	Trade-offs between production and seasonal water use in watersheds, invasiveness risks, production risks, tree suitability assessments.

Table 11.3 Summary of institutional needs.

Adaption strategy	**Institutional needs**	Options for meeting institutional needs
Stress-tolerant crops	Research, extension, output markets and germplasm supply systems that support a range of crops, as well as genetic adaptation of existing crops to harsh conditions.	Public research and extension institutions that give particular attention to crops that are well adapted to climatic stresses, participatory genetic improvement
Water harvesting and storage	Appropriate technologies for water harvesting are available and supported for the household, community and regional scales. Better integration of planning for water and agricultural development.	Water harvesting is mainstreamed into agricultural extension, targeted public investment for community and public water infrastructure.
Flexible livestock production strategies	Effective mechanisms for group tenure, incentives for maintaining group tenure; technical innovations to add value to grazing reserves, management of conflict between pastoral groups sharing rangelands.	Public research and mainstreaming in emerging livestock and fisheries policies. Sharing of research results and institutionalizing improvements in livestock systems.
Diversified production and marketing strategies	Extension systems and agricultural development strategies support infrastructure of general, versus commodity-specific, value.	Pluralistic and participatory extension.
Conservation agriculture and improved fallows	Innovative research and extension approaches.	Public research and extension institutions and institutions for sharing information and capacity building.
Reward schemes for environmental services	Enabling environment for the design and adoption of RES. Institutional arrangements for implementation, monitoring and evaluation.	Action research to provide solid scientific evidence base as well as using existing and site-specific networks as entry points.
Water-efficient tree species and cultivars	Cooperation and shared understanding between forests, hydrologists, ecologists and social scientists. Removing blockages on germplasm for indigenous species.	Cross-sectoral promotion of water efficient tree species and working through mandated bodies like national environment management authorities.

there are challenges to institutional capacity that can be said to be ideological, historical, structural or even sometimes perceptive. In the case of germplasm development, farmers are rarely aware of its availability. This would require public and private sector investment in providing information as well as establishing support infrastructure. In Table 11.3, we discuss requisite institutional needs for each adaptation technology and propose options of meeting those institutional requirements. In section 11.4 we also explore various institutional and policy needs for community-based adaptation to climate change.

To effectively promote adoption of agricultural technologies, the six classes of boundary spanning activities must be understood in the contexts of feedbacks, strong or weak, across the different multilevel regime structures. Within each level, there are sector-based policy domains (in this paper we have used agriculture, forestry, energy, water and wildlife) which relate with climate change adaptation in different ways, a relationship that is limited by vertical planning and regime structures pursued by different African institutions.

The national level sub-unit is charged with policy formulation and implementation facilitation. Lower level sub-units are mainly responsible for translating policy provisions into action with lessons and experiences feeding into the national level policy formulation sub-unit. National level lessons and experiences feed into regional and international level negotiations and decisions. Policy, plans, programmes and projects implementation at the climate change adaptation is rarely informed by research and rarely translates to action by farmers at the lowest regime structure. Implementation of policies, plans, programmes and projects is also affected by complexities associated with multilevel governance systems (Figure 11.2). Regional-level initiatives influence and are shaped by what is happening at the national-level domain. Discussions at the international level on several policy areas and collective learning and action initiatives influence what is happening at the national and country-level domains. International level negotiations and collective action are also influenced by what is happening at the regional and national levels. Adaptation to climate change or any other large-scale environmental problems are then nested in the different levels of governance providing opportunities of learning lessons across different levels.

As is discussed above it is obvious that adaptation to climate change at the community level is lacking if not minimal. Given this situation, what therefore needs to be done at the policy level to unlock community-based adaptation to climate change?

11.4 Enhancing interactions between knowledge and actions institutions

Having discussed existing technologies and farmers' information and institution needs, and to avoid these being prescriptive, we explore and propose what is required to promote feedback between knowledge and action domains at the local level in this section. This is because adoption of some of these technologies among smallholder farming communities has generally lagged behind scientific and technological advances thereby reducing their potential impact (Ajayi *et al.*, 2008; Franzel and Scherr, 2002). A recent review indicates that the adoption of technologies depends on several factors that are technology-specific, household-specific, policy and institutions context within which they are disseminated and geo-spatial factors (Ajayi *et al.*, 2007). As a result, efforts to improve adoption of the technologies necessitate a thorough analysis of the biophysical, economic, social, and cultural constraints which have been barriers to using these promising and renewable technologies.

It will be difficult to have mass adoption of the technologies discussed above given the existing multiple interests and stakes. In the case of water efficient trees there is need to provide information to farmers by: *1)* sharing existing understanding with farmers and policy makers interested in banning

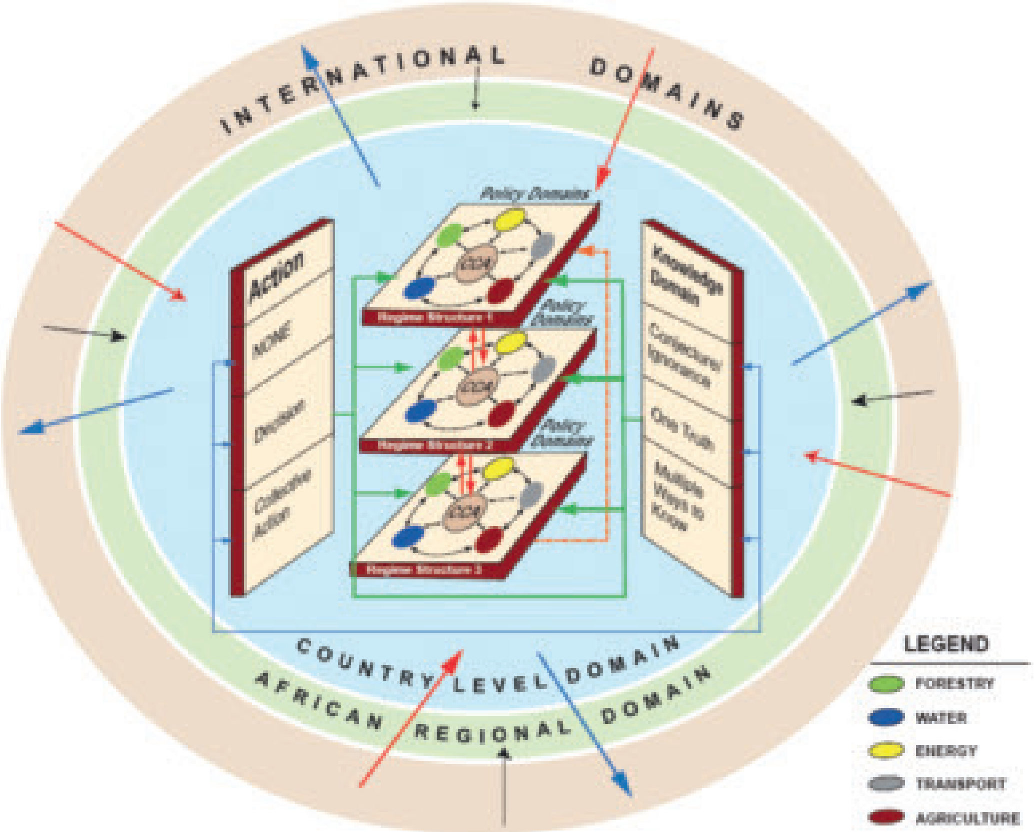

Figure 11.2 Relationships between different domains and how nested climate change adaptation (CCA) could be addressed through interactions between action institutions and knowledge systems. Source: Yatich et al. *(2008).*

eucalyptus or finding alternatives; *2)* enhancing knowledge of a range of species to widen choices for farmers, and *3)* geographical targeting of catchments for more or less attention to water use, including water taxes by evoking the polluter-pays-principle. In some cases rewards for environmental services has been used where farmers are given incentives to remove water thirsty trees. In Mt. Kenya East for example, certification programmes for smallholder outgrower schemes for tea have been developed and includes removal and replacement of water thirsty trees. Currently ICRAF and partners are piloting river care/water care programs in Mt. Kenya East would involves planting of water efficient trees such as *'moringa'*

Some of the institutional needs for promoting water efficient trees/alternatives include getting around the bias in African conservation and forestry against indigenous trees. Ashley, Russell and Swallow (2006) studied the policy terrain affecting agroforestry around protected areas in Mali, Cameroon and Uganda, and generally found that forestry and agroforestry extension was weak and biased toward exotic trees. Changing the approach however requires providing alternative trees species to farmers as well as providing policy makers at various levels with guidelines on how to manage the water use of different tree species (e.g. no planting of fast-growing evergreens near areas of permanent water sources). The World Agroforestry Centre has provided evidence-based guidelines on where to plant specific tree species relative to their water use efficiency (Swallow and Rumley, 2006).

To ensure that the knowledge gaps are made at a strategic level, there is need to rethink agricultural research and education.

11.4.1 Agricultural research and extension

To inform decision making and support community-based adaptation and mitigation through scaling up of existing technologies, research must focus on:

- *Answering the right questions.* The right questions must be raised and answered with communities. Perhaps agricultural and climate science research have been asking and solving the wrong questions, at least from the perspective of national agricultural research systems. This could be attributed to the failure of international institutions to influence policy processes because of poor link of research results to national interests or science-policy communication disconnect. Much of the research results have had only modest impact on policy making processes due to this communication disconnect. It is therefore recommended that international research institutes realign their research to be relevant to the interests of national governments and national research systems (NRIs) by: *1)* undertaking joint planning with NRIs, *2)* undertaking targeted capacity building e.g. in climate change negotiation, and *3)* providing relevant information to farmers and communities.
- *The science-policy dialogue.* Provides a knowledge base and discussions among representatives from broader public viewpoints including policymakers, researchers and other stakeholders. The participation of public stakeholders is important given that policies emerge from policy processes that are themselves embedded in political processes (Ajayi *et al.*, 2009). The World Agroforestry Centre (ICRAF) has tried to address this challenge through the design and adoption of negotiation support systems (NSS) in Southeast Asia for purposes of linking knowledge systems to action. Negotiation support systems are now being expanded to Africa through ICRAF's work on compensation and rewards for environmental services currently being tested in different agricultural landscapes across Africa. NSS requires the use of science to inform decisions at community level as well as ensuring an enabling policy environment.
- *Provision of information and data.* Provision of information to farmers catalyzes adaptation. To produce and avail relevant information to farmers, requisite data for predicting huge climate uncertainty is lacking. This is because of the poor collaboration between Meteorological and Hydrological services with line ministries, and research institutes. More cross-sectoral coordination is warranted to improve the current scenario. Institutions need to work closely with national-level partners to ensure capacity building and uptake of their research results (Stockholm Environment Institute, 2008).
- *Linking climate change research to the broader context.* Broader issues of agriculture often hide the importance of climate change at farmer or national level. Research undertaken in Machakos by ICRISAT indicated that farmers attributed declining crop productivity to climate change, but when ICRISAT analyzed other factors from a broader context, declining crop productivity was linked to declining trends in the use of fertilizers (CGIAR, 2008). Rainfall trends were established to have remained constant over the years. This is because of government's policy rather than climate change. In Malawi,

the heavy attention to fertilizer subsidy as a way of improving crop productivity has obscured the need for attention on climate change. Fertilizer tree technologies advocated by the World Agroforestry in Malawi and Zambia are slowly being seen as more sustainable as research is linked to the broader context-seeing food security in the context of climate change mitigation and adaptation. There is a need to initiate new institutional forms to bring science (technology development) and policy making together to examine climate change through a sustainable multi-faceted development lens (Ajayi *et al*., 2009).

- *Participatory action research.* Scientists often ignore lessons and experiences that local communities have gained over the years as they adapt to the impacts of climatic variability. ICRISAT's research on adoption of new crop varieties in the Sahel shows that farmers eagerly adopt new crop varieties but over time they discard them and go back to their traditional crop varieties (CGIAR, 2008). Further research showed that the traditional varieties were more adopted than those developed and promoted by scientists. The same is true in Malawi for local open pollinated maize versus improved maize variety. Building on existing coping and adaptive strategies of local communities is therefore important. It is prudent to see climate change as an integrative science requiring integrating both local and scientific knowledge with local circumstances. However, this also calls for proper needs assessment in development for promotion of new technologies.
- *Community of practice.* Platforms for sharing lessons and experiences are lacking. National and regional platforms will provide avenues for learning lessons and act as springboards for country-based or collective action for climate change. Through these platforms, there will be review of adaptation initiatives, methodologies, tools and approaches. PRESA (Propoor rewards for environmental services in Africa) community of practice (CoP) focuses on rewards for environmental services (RES) including carbon sequestrations by bringing together payment for environmental services (PES) innovators to share information on assessment tools, negotiation approaches and partnerships. Existing platforms should re-look at their focus and expand to include climate change mitigation and adaptation. Platforms for promoting adaptation at the community level are however lacking.

Use of research results and data at the national level are complicated by monocentric governance systems with distributed regime structures and excessive red tape. Disconnects between science-based evidence and policy implementation at different levels exist because policy implementation is left to the discretion of technocrats at different levels. Mainstreaming of adaptation in country policies plans and programmes need to learn lessons and be informed by science-based evidence so as to scale out some of the existing adaptation technologies. These would require strategic policy formulation with focus at the community level and climate change adaptation.

11.4.2 Strategic policy development

In developing countries, the lack of strategic policy formulation to deal with emerging threats of climate change is likely to heighten its impacts at various levels with the adverse impacts on smallholder farmers. Existing policies and laws are sectoral, some outdated, others duplicative in nature or altogether contradictory to one another. Despite these weaknesses, it is worth noting that policy domains steer government interventions, influence markets and market transactions, concern the immediate decisions of consumers, and have important impact on the behaviour of policy makers and communities.

When a vertical policy approach is adopted, linkages between different policy domains are likely to promote waste of resources and duplication of efforts as these domains will operate as autonomous entities within existing governance systems (Yatich, 2007). Addressing, promoting and balancing feedbacks across the different policy domains are crucial from a planning perspective. Mainstreaming climate change adaptation is likely to remain as a challenge in the face of differing mandates among regime sectors, failure of governments to promote cross-sectoral policy formulation and implementation as well as power relations that shape feedback mechanisms among the different sectors. For purposes of promoting community-based adaptation, strategic policy development should therefore focus more on promoting cross-sectoral coordination and decentralization and devolution.

11.4.3 Institutional adaptation

Ongoing economic and institutional reforms in African economies have created constraints and opportunities for climate change adaptation. Reed (2004) enumerates these opportunities as the dismantling of state-controlled marketing systems, the removal of bureaucratic obstacles to initiating small-scale enterprises, the opening of market outlets for new crops and products, and the opening of some political structures to public participation. Institutional reforms have also created constraints for the poor: entrenchment of political and economic elites, new resource management regimes that preclude access for the poor, decentralization reforms that shift power to regional power brokers but not to the poor, and increased vulnerability to economic shocks that threaten the meager asset base of the rural poor (Reed, 2004). These constraints do not prepare the poor to adapt to climate change or promote interventions at the strategic level to boost the resilience of systems against impacts of climate change.

In many countries, smallholder farmers rarely influence government policy on climate change because they do not interact with climatologists, and they seldom have umbrella organizations that possess the required national visibility and with sufficient political clout to influence policies. Climate change adaptation is neither the traditional mandate of meteorological services, nor agriculturalists. In whose realm does climate change lie? How is it handled by several sectors and how do the sectors interact with each other? Perhaps we defer these questions for another paper. The failure of African governments to adequately deal with these questions creates some confusion among institutions responsible for climate change. Consequently, adaptation interventions are developed at levels that are not operational. Agricultural decision makers fail to make the right decisions because of the inability of agricultural technocrats to offer strategic advice. In some instance there is overemphasis on the impacts and multiplier effects of climate variability because they are perceived as real. Despite increased collective action and awareness at the international level and looming threat of climate change, national-level institutional adaptation innovations do not match the '*dynamism*' of climate change and rarely are farmers/communities involved. African governments are at different levels of putting in place appropriate institutional frameworks for dealing with climate change adaptation at regional and national levels. At a strategic level climate change adaptation has not been adequately mainstreamed in the existing policies, laws, plans, projects and programmes. Institutional arrangements that will wholly be charged with the mandate of climate change adaptation are yet to be established.

11.5 Gaps and way forward

In this synthesis we have provided an overview of existing agricultural technologies with the potential to enhance farmers' and communities' adaptation to climate change. Knowledge gaps and institutional needs have also been discussed including what needs to be done at strategic levels to ensure adoption of agricultural technologies. Challenges however still abound. These include re-orienting research to meet the needs of farmers and policy makers, i.e. promoting research to address the gaps summarized in Table 11.2 and 11.3 on informational and institutional needs. With focus on these needs, uptake will be possible depending on provision of the information to farmers and establishing requisite institutions to promote adoption. The way information is packaged and passed onto the farmers and communities influences adoption of technologies. Lessons and experiences learnt through ongoing trials of these technologies, needs to inform scaling out. Linking extension to communities' needs to enhance adaptation to climate change has gaps including weaknesses of extension approaches. If extension service provision is demand driven, its success would be dependent on how proactive farmers are, levels of education and other motivating factors, e.g. demand for their agricultural products, supportive policies and legislation and existing market infrastructure.

11.6 Conclusion

The failure to realize improved technology adoption by communities as a climate change adaptation strategy can be attributed to the failures of the scientist to provide information to farmers and communities. Meeting the institutional needs for the promotion and adoption of technologies is the responsibility of policy makers. Research should however be re-oriented so that the information needs of farmers and communities are realized. This includes shifts from focus on improving agricultural productivity to 'climate proofing'-ensuring that we adapt to the uncertainties of climate change but at the same time enhance food security. The institutional infrastructure including cross-sectoral coordination for community-based climate change adaptation, need to be addressed at a more strategic level, but distributive enough to meet the needs of communities living under different biophysical and social conditions. This requires strategic policy development as well as institutional adaptation. It is hoped that this paper will catalyze and reshape ongoing debates on adaptation to climate change.

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Chapter 12
SOCIO-ECONOMIC AND GENDER RELATED ASPECTS OF CLIMATE CHANGE IN AFRICA

Balgis Osman-Elasha, Emmanuel Chidumayo and Paul Donfack

12.1 Introduction

The major ecozones in Africa have been described in chapters 2 and 5 to 7, which have also highlighted the biological and environmental importance of these ecological regions. These ecosystems also contribute significantly to national economies and the sustenance of livelihoods. For example, Africa's moist forests are extremely important for their biodiversity value and support to livelihoods (Brockington, 2002) but are also sensitive to global climate change and may be so severely impacted in structure and function that their services can be greatly threatened (Betts *et al*., 2008). Over 270 million people, representing 40% of the continent's population, live and depend on forests, woodlands and savannas for their livelihoods. These vegetation types in Africa have been cited in scientific literature as vital to reducing the continent's poverty; they provide a frontier for agricultural expansion, the manure needed to nourish crops, and grazing areas for livestock and wildlife. However, in some dry lands of Africa, the heavy dependence of the rural poor population on natural resources for subsistence has largely contributed to deforestation, land degradation and desertification. The Intergovernmental Panel on Climate Change (IPCC, 2007) report concluded that "climate change, interacting with human drivers such as deforestation and wild fires, is a threat to Africa's ecosystems". The same IPCC report further states that the frequency of extreme events, such as droughts and floods is expected to increase, exacerbating the losses already experienced due to drought and land degradation, and creating additional threats to natural ecosystems.

This chapter addresses socio-economic issues related to climate change influences on socio-economic and livelihoods dependence on natural resources, including vegetation and wildlife resources, food security and human health as well as the impacts of non-climate factors on natural resources. The chapter also considers effects of climate change on women and youth.

12.2 Climate change and dependence on forest products

Africa's forests and woodlands have multiple uses for local communities, ranging from construction materials, foods, energy, medicines, catchment protection, soil protection, and shade, habitat for wildlife and bees, grazing as well as cultural values. Africa's social and economic development is constrained by climate variability and change, habitat loss, over-harvesting of selected species, the spread of alien species, and activities such as hunting and deforestation.

The Centre for International Forestry Research (CIFOR) defines non-timber forest products (NTFPs) as products or services other than timber produced in forests. For example, fruits, nuts, vegetables, fish, game, medicinal plants, resins, essences, barks, and fibres such as bamboo, rattans and other palms and grasses (Belcher, 2003). Non-timber forest products are harvested from forest areas and are produced in farmers' fields. Non-timber forest products could be directly negatively impacted by climate change through its impacts on the forest resources. They can also be indirectly impacted by climatic changes on local livelihoods, particularly agriculture, which force people to depend more and more on products from forests and trees. In many rural sub-Saharan Africa communities, NTFPs may supply over 50% of a farmer's cash income and provide the health needs for over 80% of the population, particularly among forest-dependent populations (FAO, 2004) (Box 12.1). However, expected decreases in rainfall, and increased severity and frequency of drought, can exacerbate current exploitation pressures on forests and trees and expansion of agriculture into forest lands. Research carried out by the Tropical Forest and Climate Change Adaptation (TroFCCA) project of CIFOR in some local communities in northern Burkina Faso indicates significant reduction in the distribution and availability of some NTFP species and high variability in their productivity, making forest-dependent communities more vulnerable. These changes are attributed to rising temperatures and changing rainfall patterns in addition to human activities such as deforestation, agricultural expansion, over-harvesting, annual bush fires and overgrazing, (Idinoba *et al.*, 2009).

Forests provide direct and indirect employment for a large number of people in Africa in collecting fuelwood, forest fruits, honey, resins, gums and others for consumption as well as for selling as 'employment of last resort' (Angelsen and Wunder, 2003). For example, in Cameroon, the small-scale and informal forestry sector employs an estimated 100,000 men and women, mainly related to NTFPs. This compares well with the 135,000 jobs

Impacts of climate change on gum Arabic production

Gum arabic from Sudan is obtained from *Acacia senegal* trees by tapping that involves the removal of pieces of bark 10–30 cm long and 2–4 cm broad to form wounds. The gum exudes in the form of small droplets from the wounds that steadily grow in size until they become nodules of 2–5 cm diameter. These nodules are ready to be picked for sale after about 4–6 weeks. The main gum-producing regions of the Sudan are those falling in the *Acacia senegal* savanna vegetation type, which covers most of Kordofan and Darfur states and parts of White Nile state. The clay plains of east and central Sudan contribute only about 25–30% of the total production of Sudanese gum arabic. Gum arabic has remained an important cash crop for Sudanese peasants in the arid and semi-arid areas over thousands of years. Its production is going to remain, for a long time to come, a peasant industry for millions of smallholders in areas where other income-generating activities are not available.

The gum tree itself is essential for sustaining the farming system and has the advantage that the gum tree *Acacia senegal* var. *senegal* occurs naturally over the large area known as the Gum Belt, which covers 40–50% of the total area of the country. An assessment of current and long-term impacts of climate change on gum arabic production has been conducted in Sudan under the auspices of the Sudan's First National Communication to the UNFCCC (GoS, 2003). The study indicated that a rise in temperature associated with increased water stress would lower gum arabic production significantly. A southward shift in the natural distribution of this tree species is already being detected and is projected to continue with declining rainfall. It is estimated that this will result in a reduction in gum arabic production, region-wide, of between 25% and 30%.

Box 12.1

provided by the formal forestry sector in all nine West and Central African countries – including Cameroon – combined (Karsenty, 2007). In South Africa, the forestry sector employs close to 170,000 people.

Collection and sale of NTFPs can provide employment during slack periods of the agricultural cycle and provide an income buffer against climatic risk and household emergencies. Due to climate change impacts on the productivity and diversity of forest products, forest exports in many African countries are expected to be affected. These include, for example, the export of timber, nuts, fruit, gum and other forest products which generate 6% of the economic product of African countries (FAO, 1999). These important products play a key role in the livelihoods of African rural households as sources of income when traded in local, regional, and international markets. So far very few studies have focused on the impact of climate change in the consumption and trade of NTFPs. Based on Easterling *et al.* (2007), the impact of climate change on NTFPs is an area that requires greater attention from the research community.

12.3 Climate change and dependence on wildlife resources

Apart from their biodiversity significance, the major uses of wildlife resources in East and southern Africa are eco-tourism, safari hunting and local hunting. The major beneficiaries of wildlife resource utilization are *1)* local people whose livelihoods are historically and culturally dependent on wildlife products, such as bush meat, *2)* government which derives revenue from wildlife-based tourism, *3)* the private sector (both foreign and local) that operates tourism facilities, and *4)* foreign tourists that view wildlife resources in national parks and hunt game. Wildlife-based tourism has great potential for economic development in sub-Saharan Africa, especially in woodland and savanna countries of East and southern Africa. Tourism is the principal economic activity in national parks and game reserves in East and southern Africa. For example, with around a quarter of a million people visiting Tanzania's parks each year, the majority of Tanzania's foreign currency earnings come from eco-tourism (Dobson, 2009). At local level, tourism can generate considerable revenue (Figure 12.1) for the local economy.

Safari game hunting is conducted in game hunting areas and can be a more lucrative economic activity than eco-tourism. The beneficiaries of safari hunting are governments, private enterprises and local communities and many countries have some kind of mechanism for sharing benefits from game hunting among all these stakeholders.

In most areas that are rich in wildlife species, local people may be heavily dependent on the wildlife resource as a source of bush meat. In fact, Walter (2001) listed bush meat as an important non-wood forest product in the majority of countries in eastern and southern Africa (Figure 12.2). About 60% of the rural population in the Kafue River Basin in Zambia derive some income from game meat selling (Chidumayo *et al.*, 2004). However, much of the trade in bush meat is con-

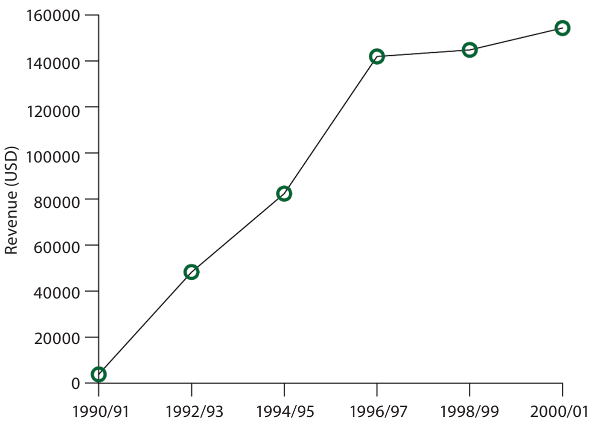

Figure 12.1 Revenue from tourism in Tarangire National Park, Tanzania. Based on Rodgers et al. *(2003).*

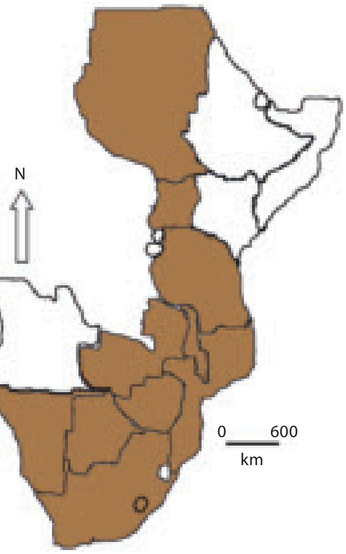

Figure 12.2 Countries in East and southern Africa in which hunting for and trading and consumption of bush meat are important economic and livelihood activities. Based on Walter (2001).

sidered 'illegal' because meat is obtained without government permits.

Even though the wildlife sector is not well developed in many countries of Central and West Africa, many protected areas in West and Central Africa have good potential for the development of wildlife tourism while hunting is an important subsistence and commercial activity in some countries. For example, in Cameroon, hunting is an old tradition in the savanna zone and has recently gained interest in the forest zone through the safari hunting scheme. Benefits from such forms of utilization are shared between central governments (50%), local governments (40%) and local communities (10%) when they are organized into legal entities. With regard to traditional hunting, despite its informal nature, the annual bush meat sales bring more than USD 10 million in Cameroon.

Bush meat significantly contributes to the means of subsistence of rural populations, who are generally poor. It is a source of financial revenue for the rural people and according to Ajayi (1971), about 80% of animal protein consumed by the rural populations of the forest area of Cameroon is derived from game.

In the Congo Basin, about 80% of the meat from wildlife and almost one million tonnes of game for sale are consumed each year (WWF, 2002). Game trade represents the equivalent of USD 1 to 2 million per year in monetary value but it is largely unregulated. The marketing of game is generally informal and illegal. However, estimates in West and Central African countries suggest that game is important both in trade and as a source of food for humans. In the Congo Basin, bush meat trade seems to be the first threat to wildlife (BTCF, 2002; WWF, 2002).

Climate change has the potential to shift the configuration and diversity of woody and grassy habitats in wildlife conservation areas and since wildlife species diversity is correlated to habitat diversity (see chapter 9), it follows that climate change may also impact negatively on wildlife species diversity. The loss of woody habitat in Amboseli National Park in Kenya is already causing a loss of large mammal diversity, particularly browsing species (Western, 2006). The large carnivores are also declining as a result of declining populations of herbivores in many East and southern African parks. Such trends will be of crucial importance in reducing the huge economic potential of national parks as sites for eco-tourism and controlled game hunting areas for safari hunting. Most tourists come to game parks to photograph lions, leopards and cheetahs while large species are most valued by humans as food or hunting trophies (Dobson, 2009). There is a high correlation between the status of wildlife populations and revenue generated from the utilization of wildlife resources (Table 12.1), indicating that there is a financial value to be gained from better management of wildlife species and their habitats under the different climate change scenarios. Thus the loss of wildlife populations arising partly from climate change (see chapters 8 and 9) can have serious negative impacts on both local and national economies.

Table 12.1 Levels of local community incomes from wildlife utilization and the state of wildlife populations in some game management areas in Kafue River Basin, Zambia. Source: Chidumayo et al. *(2004).*

Game management community	Status of wildlife populations		Income (USD) received	
	Status	Rank	1991	1994
Kasonso-Busanga (GMA 38)	High	3	4,299	29,202
Mumbwa (GMA 45)	High	3	12,918	26,111
Lunga-Luswishi (GMA 31)	Very low	1	5,078	97
Bilili-Springs (GMA 54)	Low	2		634
Namwala (GMA 49)	Low	2		235
Kafue Flats (GMA 48)	High	3	5,186	14,326

Although a large and extensive network of national parks and other protected areas has been established in many ecozones of Africa, these parks are insufficient to conserve wildlife and key habitats. Tarangire National Park, for example, contains less than 15% of the annual ranges of migratory species such as zebra, wildebeest and elephant (Rodgers *et al*., 2003). It has also been shown in chapter 9 that under climate change scenarios, most parks in East and southern Africa will lose some wildlife species while distribution ranges for some will change. This will have serious implications for the tourism sector in the region. Worse still, many of the conservation areas are small (see Figure 9.3 in chapter 9). For example, around Tarangire and throughout the East African region, wildlife is dependent on communal and private lands for effective conservation of migratory routes and dispersal areas (Rodgers *et al*., 2003). According to Dobson (2009), there appears to be a strong relationship between park size and extinction rate. Smaller parks lose more species and they tend to lose those with larger area requirements, particularly carnivores and if larger herbivores need larger areas to support them, they should be expected to disappear first from small national parks. Climate change is likely to speed up the rate of disappearances with negative consequences for industries and livelihoods based on wildlife species.

12.4 Influence of climate change on food security

Desertification in Africa is strongly linked to poverty, migration and food security, since people living in poverty have little choice but to overexploit the land. Currently two thirds of the continent is desert or dry land, a situation that is going to be aggravated by climate change (FAO, 2003). Due to the social and economic importance of natural resources in many African countries, combating desertification and promoting development are virtually one and the same thing. According to Seppälä (2009), higher temperatures – along with the prolonged droughts, more intense pest invasions, and other environmental stresses that could accompany climate change – would lead to considerable forest destruction and degradation with negative effects on livelihoods and socio-economic development.

Major environmental challenges currently facing the continent include deforestation, soil degradation and desertification, declining biodiversity and water scarcity. There is an increasing literature on deforestation, land degradation, and water logging and their contribution to declining capacity of sub-Sahara Africa to feed itself (FAO, 2002). An FAO (2008) report indicated that low crop yields and poor harvest attributed to frequent fluctuations in rainfall, coupled with food shortages, have always resulted in low incomes and chronic food insecurity, a situation that leaves farming families acutely vulnerable to the smallest hazard or shock and takes them closer to the poverty line. A World Food Program (WFP) report of 2002 stated that in sub-Sahara Africa, because there are poor harvests, individuals often sell off livestock and assets to purchase food, hence completely depleting their livelihood capitals. Seppälä (2009) notes that the decreased rainfall and more severe droughts are expected to be particularly stressful for forest-dependent people in Africa who look to forests for food, clean water and other basic needs. For these people, climate change could mean more poverty, food insecurity, deteriorating public health, and social conflict. For these reasons, FAO (2003) considers that "poverty alleviation and environmental protection in sub-Saharan Africa will remain the most important priorities over the next two decades" and proposes the adoption of new approaches that give more priority to strategies for enhancing the contribution of forestry to the economic, social and environmental interests of Africa.

According to GIEC (2007), the agriculture sector in West African countries is expected to lose between 2% and 4% of the Gross Domestic Product (GDP) by 2100 due to climate change and variability. In contrast, case studies carried out in Senegal, Mali, Burkina Faso and Niger estimated that yields of crops like millet and sorghum could decrease between 15% and 25% in Burkina Faso and Niger by 2100 and that yield of rice could increase from 10% to 25% for irrigated rice and from 2% to 10% for pluvial rice (CEDEAO, SAO, OCDE, 2008, in Hamndou and Requier-Desjardins, 2008).

12.5 Climate change and other economically important natural resources

Forest management is considered a key to water resources management in particular and to upland resources development in general. Forest is tightly linked to watershed development. The loss of 'cloud forests' through fire since 1976 has resulted in 25% annual reduction of fog water (the equivalent of the annual drinking water of one million people living in Kilimanjaro) (Agrawal *et al.*, 2003; Hemp, 2009). Any changes to forests that protect watershed areas can have severe impacts on the quantity and quality of water supplied to downstream areas since these forested catchments usually supply water for domestic, agricultural, industrial and other needs in downstream regions (FAO, 2007a). For example, a study conducted in Sudan to assess the impacts of deforestation in the Ethiopian highlands, the headwaters of the Blue Nile, on agriculture and hydro-power generation, revealed that the on-going deforestation in Ethiopia has largely impacted the irrigated agriculture in Sudan, as well as the hydro-power generation from Al Rosairis Dam (ElFadul, 2005).

Biomass, a major source of energy in rural areas, represents about 70% of total energy consumption in Africa (FAO, 2004). In some countries biomass accounts for 90% of total energy use, e.g. in Uganda (Bizzari, 2009) and Tanzania (Paavola, 2003). Climate change threatens the availability of biomass energy, through species shifting and changes in species composition. It is not only climate change that affects the availability of and accessibility to fuelwood in Africa but also the increasing deforestation which lead to land degradation and desertification. Presently, almost half (46%) of Africa's land area is vulnerable to desertification (Granich, 2006). Nevertheless, consumption of fuelwood is expected to increase with increases in population to about 850 million m^3 by 2020 (as compared to 635 million m^3 in 2000) (FAO, 2001). In addition, urban demand for charcoal is expected to increase leading to further deforestation and ultimate degradation of African forests and woodlands. Unless energy alternatives to firewood and charcoal and other sources of income for people whose lives depend on forests are found and promoted, deforestation will continue unabated.

12.6 Influence of climate change on human health

The burden of obtaining safe drinking water and sufficient water for proper sanitation and hygiene is more profound for the poor who very often live in degraded environments and who are predominantly women and children. Currently 20% of the total occurrence of disease in the developing world and 34% in sub-Saharan Africa is associated with environmental degradation, lack of access to safe affordable water and sanitation (WHO, 2009). Forest loss can contribute directly to the severity of these health problems through disruption of the water cycle and increased soil erosion, as well as indirectly through its effects on local and global climate change which in turn can have a profound effect on the survival and spread of disease pathogens (Houghton *et al*., 2001). The loss of forest ecosystem services due to climate change will worsen public health and related problems. The impact of climate change on NTFPs, particularly medicinal plants, will also deprive the local people of a cheap source of treatment and threatens their health security. The impact of climate change on the availability of fuelwood could indirectly impact human health, through its impact on water and food sanitation as well as its impact on the nutritional value of diet (Barany *et al*., 2001).

A report by a WHO Task Group has warned that extreme climatic changes such as floods and droughts may have important impacts on human health (WHO, 2009). Dry conditions over long periods could increase hazards of forest fires, which could pose serious health respiratory problems. Moreover, the forest and environmental deterioration could lead to out-migration from rural to urban areas. This could impact health in many ways as displaced people may face situations of scarce clean drinking water, sewage and rubbish disposal, food security and poverty problems. Additionally, the vulnerability of the urban population to natural disasters and diseases, especially HIV/AIDS and atmospheric pollution are well recognized (UNEP, 1994).

Increasing temperature is expected to provide the optimum conditions for the growth of some vectors such as the mosquito. There is evidence that in some sites in the highlands of East Africa, a warming trend over the last 30 years has improved conditions for the growth of mosquito populations and therefore the probability of malaria transmission and highland epidemics (Pascual *et al*., 2006). A study of the microclimate change due to land-use change such as swamp reclamation for agricultural use and deforestation in the highlands of western Kenya, found that tree removal creates suitable conditions for the survival of *Anopheles gambiae* larvae and consequently increased risks of malaria (Munga *et al*., 2006). Average ambient temperatures in the deforested areas of Kakamega in the western Kenyan highlands was 0.5°C higher than that of forested areas, that enhanced mosquito larval-to-pupal development (Afrane *et al*., 2006). Similar linkages between deforestation and increasing malaria incidence have been observed in the Amazon Basin (Olson *et al*., 2010, Box 12.2).

Deforestation and malaria in the Amazon Basin

Most malaria cases in Brazil occur in the Amazon Basin where logging rates increased from 12,000 km^2 in 1999 to 20,000 km^2 per year in 2006. Apparently, *Anopheles darlingi* mosquitoes, that are the main vectors of malaria in the Basin, are more abundant in modified landscapes where partially deforested sites provide sunlit microhabitats that provide ideal conditions for mosquito larvae development and survival. A study conducted in Mâncio Lima County in Brazil on the border with Peru confirmed that cleared land is associated with higher malaria risk (Olson *et al*., 2010). The study noted that biting rate and larval count increase with more deforestation: mean biting rate was 8.33 per night in areas with over 80% deforestation compared to 0.03 per night in areas with less than 30% deforestation. Between 1997 and 2006 deforestation increased from 6.6% to 26.0% and the best predictor of malaria risk in Mâncio Lima County was deforestation during the first part of this period. After adjusting for access to medical care, health district size and spatial trends, the study showed that a 4.3% change in deforestation from 1997 to 2000 was associated with 48% increase of malaria incidence.

Box 12.2

12.7 Influence of climate change on cultural resources and values

Forests provide many social, spiritual and aesthetic benefits. Social benefits provided by forests include recreation, tourism, education and conservation of sites with cultural or spiritual importance (FAO, 2005). In rural areas of Africa, tree shade is a gathering place where villagers confer to discuss their daily lives, solve their problems or enjoy tea and coffee. Sometimes big trees act as a market place where people exchange and sell goods. Sometimes trees act as courtyards where villagers meet to solve their local conflicts and disputes (Seppälä, 2009). In arid and semi-arid zones of Africa, forests occupy areas that are almost too dry to support forests and are consequently very sensitive to changes in the severity or frequency of droughts, which in turn could impact forest-related socio-economic and cultural aspects of local communities (Seppälä, 2009). It is important for forest managers and planners to take these cultural and spiritual values into consideration when developing forest development strategies and mitigation plans. It is equally important to consider them in community-level adaptation efforts.

In many countries certain cultural, social and spiritual values are associated with some NTFPs such as the use of Frankincense or *Olibanum* which exudates from *Boswelia* trees for making incense in traditional ceremonies in Sudan and Kenya (Chikamai and Kagombe, 2002), and sometimes as medicine. The NTFPs, though not easily quantified, may in some cases be as important to people as the economic value (Davidson-Hunt *et al*., 2001); an issue that is often overlooked.

12.8 Gender aspects of climate change

Gender is the division of people into two categories, 'men' and 'women'. Through interaction with caretakers, socialization in childhood, peer pressure in adolescence, and gendered work and family roles, women and men are socially constructed to be different in behavior, attitudes and emotions. The gendered social order is based on and maintains these differences (Borgatta and Montgomery, 2000). Gender relations refer to a complex system of personal and social relations of domination and power through which women and men are socially created and maintained and through which they gain access to power and material resources or are allocated status within society (IFAD, 2000). The impact of climate change on gender relationships with respect to access to and use of forests resources and on forest sustainability is gaining a growing attention from scholars and practitioners. More focus is being given to assessing and understanding the different benefits that women and men derive from forestry services, recognizing gender differences in access to, control and knowledge of forest resources, and identifying the significant differences in access of women and men to forest-related decision making, institutions and economic opportunities (IUCN, 2009).

It is generally recognized in Africa that forests are important for the rural poor, the majority of whom are women, and who often do not own land but do use forest resources for subsistence and income generation (Agrawal, 2002). It is now well established by climate science that Africa will be disproportionately affected by climate change, (IPCC, 2007), which poses a significant challenge to the achievement of sustainable development for the rural poor, especially women, who are expected to suffer most from its impacts. Their vulnerability stems from their central role in socio-economic development. Gender considerations need to be recognized, not only when vulnerability and impacts of climate change are highlighted but also in relation to adaptation and mitigation efforts. The millennium development goals recognize the need to promote gender equality and empower women to participate in all facets of economic and social life with the aim of achieving sustainable development. Greater efforts are needed in order to achieve the objective of mobilizing and empowering women and men in Africa to address global environmental challenges such as climate change (UNDP, 2001).

Although it is widely known that women are active actors in the protection and management of forest resources, Agarwal (2002) observes that women are often excluded from participation in forestry-related decision making for various reasons including rules governing the community forestry groups, social barriers stemming from cultural constructions of gender roles, responsibilities and expected behavior, logistical barriers relating to the timings and length of organizational meetings, and male bias in the attitudes of those promoting community forestry initiatives. He pointed out that the need for understanding this deprivation is critical as women continue to be among the poorest in many developing countries and their dependence on forest resources for subsistence, will assume even greater importance as they face new challenges due to increasing global interconnectedness and climate change.

For centuries, women have passed on their skills and local experiences on natural resource management and acquired valuable knowledge that will enable them to contribute positively to the identification of appropriate adaptation and mitigation measures if their knowledge is tapped. For example, the Kenya's Greenbelt Movement, founded by Nobel Peace Laureate Wangari Maathai and the World Bank's Community Development Carbon Fund, signed an emissions reductions purchase agreement to reforest two mountain areas in Kenya. Women groups will plant thousands of trees, an activity that will also provide poor rural women with a small income and some economic independence. Women's empowerment through this process will also capture 350,000 tonnes of carbon dioxide, restore soil lost to erosion and support regular rainfall essential to Kenya's farmers and hydro-electric power plants (IUCN, 2009).

Women can play an important role in supporting households and communities to mitigate and adapt to climate change. Across Africa, women's leadership in natural resource management is well recognized. Women typically gather forest products for fuel, fencing, food for the family, fodder for livestock and raw materials to produce natural medicines, all of which help to increase family income while men are involved in timber extraction and the use of NTPs for commercial purposes (UNDP, 2001). Due to this division in labour, women living near the forest are differently and disproportionately harmed by deforestation and have stronger interest in forest conservation and sustainable use. Meinzen-Dick *et al*. (1997) stressed the need for giving due attention to gender differences in property rights since it can improve the outcomes of natural resource management policies and projects in terms of efficiency, environmental sustainability, equity, and empowerment of resource users. They indicated that security of women's property rights and access to forest and tree resources serve as an important incentive for their adopting resource conserving measures (Mwangi *et al*., 2009).

Finally, it is essential that forestry projects aiming at addressing mitigating and/or adaptation to climate change adopt a gender-based approach that incorporates the gender differences between women and men, i.e. socially-defined differences in terms of roles and responsibilities, problems, needs and priorities and knowledge of and access to and control over forest and tree resources. It is equally important to promote participation of women in forestry development policies, strategies and capacity-building initiatives related to the conservation and sustainable management of forests and trees and their use. National forests legislations should also be reformed in order to protect women's rights concerning forest resources in Africa.

12.9 Vulnerabilities of forests to non-climatic factors

Climate change is not the only threat that African forests are facing. They are subjected to a number of non-climatic factors. This part of the chapter focuses on these non-climatic and often human-induced factors that contribute to impacts and vulnerability of African forests. They include poor management, population growth, poverty, policies and governance, competition over resources and conflicts.

12.9.1 Management of natural resources

Globally, humans have large and pervasive influence over the different natural systems. They present an important part of most ecosystems and many ecosystems have been heavily modified by them. As a consequence, ecosystems function in a context of multiple human influences and interacting factors (Worm *et al.*, 2006). Historically, human activities have largely shaped the natural ecosystems through, for example, introducing new species, or moving non-native species from one ecosystem to another. Even without climate change, African forests are shrinking at a high rate as a result of deforestation and over-logging (forests are lost annually at an estimated rate of more than 5 million ha [FAO, 2007b]).

Paeth (2007) concluded that, for at least the first part of this century, the local impacts of deforestation would be more devastating to tropical Africa than direct impacts resulting from climate change and therefore vegetation protection at the national scale may directly contribute to mitigation of the expected negative implications of future climate change in Africa. In the long term, significant shifts in the spatial distribution and extent of tropical forests are very likely, not least because of the interaction of climate-change impacts with the many non-climatic environmental changes taking place in the tropics (Huntingford *et al.*, 2008; Nepstad *et al.*, 2008).

The close relation between humans and forests and the many linkages between human livelihoods and forest ecosystems, make it generally difficult to attribute ecological changes directly or solely to the effects of climate change. This is why the question of attribution to climate change is always associated with forestry. Further assessments and studies are needed to address the issue of attribution in relation to tropical forest, particularly in Africa, where changes in climate will interact with the many underlying human-induced changes in the environment, and contribute to deforestation and land degradation.

Slash and burn agriculture, coupled with the high occurrence of lightning across Africa, is thought to be responsible for a large proportion of wildfires. The dynamics of savannas and woodlands are strongly linked to fires, so any likely changes in fire intensity and frequency will have unknown consequences on vegetation (Menaut *et al.*, 1990). For example, the upland rice cultivation under slash-and-burn shifting cultivation, especially in sub-Saharan Africa, has resulted in destruction of forest vegetation and this could further increase deforestation in these areas, if the cultivation expands (FAO, 2007a).

While traditional national forest inventories provide an overall assessment of forest carbon stocks, additional analysis is needed to attribute stock changes to specific climatic change-related events. Some studies have documented responses of ecosystems, plants and animals to climate changes that have already occurred (Parmesan, 2006; Rosenzweig *et al.*, 2007). These studies, although mainly conducted in the temperate forests, demonstrate many direct and indirect effects of climate change on ecosystems.

Evidence of the ecological impacts of climate change becomes more convincing when trends are observed among hundreds of species rather than relying on studies of a few particular species (National Research Council, 2008). Based on a study by Bigelow *et al.* (2003), one of the most noticeable indications of climate change is the northward extension of northern temperate forest, which reflects warmer summers than at present. In the tropics the more vegetated conditions inferred from pollen records in the now dry sub-Saharan ecozones indicating the prevalence of wetter conditions in the distant past in these zones (Braconnot *et al.*, 2004) and demonstrating the impact of climate change on the distribution of vegetation types.

12.9.2 Population growth

Tropical forests and rangelands are under threat from population pressures and systems of land use. Logging, land conversion to agriculture and settlements, wild fires, cutting for firewood and charcoal, and civil unrest are identified as the primary causes of deforestation in Africa. Many of these pressures are driven by population growth. Apparent effects from these pressures include rapid deterioration in vegetation cover, biodiversity loss and depletion of water availability through destruction of catchments and aquifers (Watson *et al*., 1997; Achard *et al*., 2002). According to FAO (2005), globally net carbon stocks in forest biomass decreased by about 4,000 Mt CO_2 annually between 1990 and 2005, with the largest annual net loss of forested area occurring in Africa. Africa suffered a net loss of forest area exceeding 3.6 million ha per year between 2000 and 2005. The greatest losses occurring in heavily forested countries, which are generally accompanied by huge losses of fertile soil and some areas across the continent are said to be losing over 50 metric tonnes of soil per hectare per year (FAO, 2005). Based on (IPCC, 2007) carbon stocks in forest biomass in Africa, Asia and South America decreased but increased in all other developed regions. This clearly shows the direct link between climate change and development. Field inventories of forest species have also shown a 25–30 km shift in the Sahel, Sudan and Guinean vegetation zones in West Africa in the past half century (Gonzalez, 2001).

12.9.3 Poverty

Local people in Africa have very close relationship with trees and forests, as they represent to them important assets for reducing poverty and increasing their livelihood options. Poverty is a major cause and consequence of environmental degradation and resource depletion that threatens the sustainable livelihoods and human security in Africa (Osman-Elasha, 2008). Various studies provide evidence that the loss of forest cover is the main cause of soil degradation and productivity decline in Africa (FAO, 2002). In the absence of trees the impacts of environmental factors, such as wind and water run-off, become harsher and reinforce to rob the soil of its fertility. The impact of land degradation is then reflected in productivity decline, low harvest, hunger and the increase in poverty levels. The cycle then goes on since the poor, with shorter time-horizons, and usually less secure access to natural resources, are unable and often unwilling to invest in natural resource management. Poverty makes recovery from impacts of hazardous climatic events, which are projected to increase under climate change scenarios, extremely difficult and contributes to lowering social and ecological resistance.

A number of countries, such as Cameroon, Nigeria and Ethiopia, have identified poverty as a major contributing factor to deforestation (World Bank, 2007). This could be explained by the fact that high dependence on natural resources forces people to over-exploit the surrounding forests and woodlands. The ongoing deforestation leads to land degradation and loss of soil fertility, which eventually weakens livelihoods of local people, undermines their ability to recover, and pushes them towards chronic poverty and destitution. Coupled with the aggravating impact of climate change, this could finally create a vicious circle that engulfs more and more people in rural areas of Africa.

12.9.4 Policies and governance

Sustainable forest management is essential for reducing the vulnerability of forests to climate change. The current failure to implement it limits the capacity of forests and forest-dependent people to adapt to climate change. Based on the WG3 of the IPCC (2007) report, forests in Africa have historically passed through two types of governance. Firstly under traditional systems controlled by families, traditional leaders and communities where decisions regarding land allocation, redistribution and protection were the responsibility of local leaders and forest and range resources managed for multiple benefits. Secondly the central government systems in which land-use policies are sector-based, with strong governance in the agricultural sector. Agriculture expansion policies typically dominate land use at the expense of forestry and rangeland management. This has greatly influenced present day forest and range policies and practices and resulted in vast land degradation. Out of 649 million forested ha in Africa in 2000, only 5.5 million ha (0.8%) had long-term management plans, and only 0.9 million ha (0.1%) were certified on the basis of sound forestry standards (FAO, 2001; IPCC, 2007). This is mainly attributed to the inadequacy of robust institutional and regulatory frameworks, trained personnel, and secure land tenure which have largely constrained the effectiveness of forest management in many developing countries including those in Africa (IPCC, 2007)

In many situations there are significant governance-related barriers to action that could exacerbate the impact of climate change on forests, including a lack of accountability, unclear property rights and corruption. Adger (1999) and Adger *et al*. (2003) highlighted the lack of support infrastructure and effective governance system that can further increase vulnerability to climate change impacts. Traditional forms of forest governance that focus on hierarchical, top-down policy formulation and implementation by the nation state and the use of regulatory policy instruments are not flexible enough to meet the challenges posed by climate change (Seppälä, 2009). The issue of poor governance related to forest management is also highlighted by Agrawal (2007), who revealed significant levels of logging that were being carried out in forests nominally under government control in some African countries with moist forests. The Agrawal (2007) estimates that illegal logging in developing countries results in a loss of USD 15 billion every year and Keller *et al*. (2007) also explained that the limited enforcement of concession agreements in most countries in Africa and Southeast Asia has also meant that legal logging in concessions exists side by side with costly and unsustainable levels of illegal logging.

On the other hand, changes in policy that promote sustainable forest management and the maintenance of forest ecosystem services will at the same time reduce the vulnerability of forest-dependent people. This includes policies that involve communities and aim at improving conservation and sustainable utilization of forest ecosystem goods and services. Evidence from many case studies in Sudan suggests that integrated forest management where communities have access rights to forest lands and are involved in management is a key factor favouring the restoration of forest carbon stocks (IUCN, 2004). Such projects provide examples of a collaborative system for the rehabilitation and use of the forest land property based on defined and acceptable criteria for land cultivation by the local people and for forest sustainability.

12.9.5 Competition over resources and conflicts

Numerous studies indicate that there is a connection between climate change on the one hand and security and violent conflicts on the other (Boko *et al*., 2007). Illegal forestry activities and poor governance in Africa are among the factors that can trigger conflict between different land users. Widespread violence in turn makes forestry conservation efforts ineffective. External intervention, particularly when driven by fast revenues and benefits can also cause local resentment and subsequent conflicts.

In several parts of Africa, timber has become associated with violent conflict. Based on UNEP (2006), the links between timber exploitation and conflict have generally two objectives:

- To use the revenues from the timber trade for purchasing arms and weapons which in turn fuel more conflicts.
- The illegal felling and exploitation of timber may itself be a direct cause of conflict. This may be because of disputes over, for example,

ownership of forest resources, local environmental degradation, the distribution of benefits, or social conflicts.

Although conflicts may sometimes isolate people from forest areas and consequently provide unintended protection from investors and intruding communities, many cases of abuse and illegal felling of commercial tree species by army officers have been reported, e.g. during the war in southern Sudan (FNC, 2009). Refugee migrations are causing further pressure on the environment, with major population movements due to conflict but also increasingly as a result of food and water shortages. Western Africa is a classical arena where refugees have impacted negatively on different types of natural resources, as over one million Sierra Leonean and Liberian refugees fled across their borders within the Upper Guinea forests of Guinea and Côte d'Ivoire clearing forests for farmland, felling trees for the construction of refugee camps, logging and mining (Bishop and Garnett, 2000).

Negative effects of deforestation include water pollution, heath hazards, declining agricultural land and production, timber and fuel wood shortages and loss of biodiversity. Deforestation around refugee settlements is a common phenomenon in the arid and semi-arid lands and savannas of Africa. Clearing for settlement, crops, extraction of timber for commercial and domestic use and removal for fuel and charcoal production around settlement nodes have devastating impacts on forest cover. For example, the UNHCR found that, based on 1989 estimates, roughly 11 million trees, representing a deforestation of over 12,000 hectares, were cut for providing shelter for refugees during the initial period of refugee influxes in Africa (Cardy, 1993). In addition, about 4 million tonnes of fuelwood were consumed by refugees in Africa. The factors affecting the extent of the environmental impact of refugees include the numbers of the refugees, the conditions under which they are settled, the available infrastructure and employment opportunities (Black, 1993; Crisp, 2003).

12.10 Conclusions

Africa's forests and woodlands have multiple uses for local communities, ranging from construction materials, foods, energy, medicines, catchment protection, soil protection and shade, habitat for wildlife and bees, grazing as well as cultural values. Wildlife resources in sub-Saharan Africa have great potential for economic development in which tourism and game hunting are the principal economic activities. However, Africa's social and economic development is constrained by climate variability and change, habitat loss, over-harvesting of selected species, the spread of alien species, and activities such as hunting and deforestation. In addition, desertification in Africa is strongly linked to poverty, migration and food security, since people living in poverty have little choice but to overexploit the land. Currently two thirds of the continent is desert or dry land, a situation that is going to be aggravated by climate change.

Climate change is not the only threat that African forests and wildlife resources are facing. They are subjected to a number of non-climatic factors that include poor management, population growth, poverty, policies and governance, competition over resources and conflicts. Nevertheless, forest management is considered a key to water resources management. Any changes to forests that protect watershed areas can have severe impacts on the quantity and quality of water supplied to downstream areas since these forested catchments usually supply water for domestic, agricultural, industrial and other needs in downstream regions.

Increasing temperature is expected to provide the optimum conditions for the growth of some vector organisms, such as the mosquito, that will impact negatively on human health. It is now well established by climate science that Africa will be disproportionately affected by climate change which poses a significant challenge to the achievement of sustainable development for the rural poor, especially women, who are expected to suffer most from its impacts. Their vulnerability stems from their central role in socio-economic development. Gender considerations need to be recognized, not only when vulnerability and impacts of climate change are highlighted but also in relation to adaptation and mitigation efforts.

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Chapter 13
AFRICAN FORESTS AND TREES IN THE GLOBAL CARBON MARKET

Willy R. Makundi

13.1 Introduction

13.1.1 Genesis of carbon markets and trade

In 1988, after noting the increasing scientific evidence and concern that anthropogenic emissions of greenhouse gases may have been dangerously interfering with the global climate, the United Nations General Assembly (UNGA) instructed The United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to form the Intergovernmental Panel on Climate Change (IPCC), with a mandate to provide policy makers with authoritative scientific information to address the global climate change problem. The process culminated into the United Nations Framework Convention on Climate Change (UNFCCC), which was opened for signature at the Earth Summit in Rio de Janeiro in June 1992, when it was signed by 154 states and the European Community. The Convention entered into force on March 21, 1994, and now has near universal membership, having been ratified by over 190 countries.

The UNFCCC committed the parties to stabilize atmospheric concentrations of greenhouse gases "at a level that would prevent dangerous anthropogenic interference with the climate system", by adhering to the principle of common but differentiated responsibilities (UNFCCC, 1992). The Conference of the Parties to the Convention met annually and launched the process to operationalize the objectives of the Convention.

In 1997 the Kyoto Protocol (KP) to the Framework Convention on Climate Change was signed (UNFCCC, 1997a) and came into force in February 2005. So far, the treaty has been acceded to by over 166 parties. The Protocol committed signatories to reduce emissions of greenhouse gases into the atmosphere, given their common but differentiated responsibilities. Parties in Annex I (developed countries and those in transition from centrally planned economies to market economies) took binding commitments under the Kyoto Protocol to reduce emissions by an average of 5.2% of their 1990 emission levels, excluding emissions from aviation and international shipping.

On their part, non-Annex I (developing) countries agreed to collaborate with Annex I parties to assist them meet their binding commitments while pursuing sustainable development. This interaction is encapsulated in the protocol's Article 12 – Clean Development Mechanism (CDM) that allows emitters to reduce emissions in non-Annex I countries and use part or all of the emission reductions to meet their obligations under the Protocol. CDM is one of three flexible mechanisms under the Protocol involving carbon trading/offsets, the other two, international Emission Trading (ET) and Joint Implementation (JI) being restricted to Annex I countries.

Legally binding, quantified emission reduction obligations only became part of international law with the entry into force of the Kyoto Protocol, marking the beginning of regulated emission trading in carbon and the regulated carbon market.

13.1.2 Legal framework for carbon markets and trade

There are two types of carbon markets, that is the regulated and the unregulated markets. For the regulated markets, *Article 4* of the Convention forms the operational basis for *emission reduction* and *Article 3* of the Protocol provides binding *emission reduction commitments* to 35 Annex I countries. Flowing from the above mentioned two articles, we obtain from *Articles 6* and *12* of the Protocol the basis for carbon markets and trading – the Flexible Mechanisms, in the form of Joint Implementation (JI) and Emission Trading (ET) for Annex I and Clean Development Mechanism (CDM) between Annex I and Non-Annex I parties (UNFCCC, 1997a, *op. cit.*).

Preceding the Kyoto-derived carbon market, a *Compliance Market (Voluntary Carbon Market)* had existed, by and for companies, individuals and communities that wanted to voluntarily reduce their carbon footprint. This market has its roots in the environmental movements in western countries such as the US, Europe, Japan and Australia dating back to the late seventies and early eighties. Understandably, the market is smaller and with less stringent rules than the regulated market.

More recent developments have sought to revamp the carbon markets by expanding both the scope and parties' commitments in the next commitment period. In 2006, COP13 put forth the Bali Action Plan calling for deeper implementation of the Convention and seeking to expand the scope of mitigation (UNFCCC, 2008). COP15 resulted in the 2009 Copenhagen Accord that pending agreement on modalities and procedures will potentially deepen and broaden the carbon market, by

- formalizing the Bali Action Plan from Decision 1/CP.13 to extend the Protocol to a second commitment period beyond 2012,
- formalizing Decision 2/CP.13 to include Emission Reductions from Deforestation and forest Degradation (REDD+) in the emission reduction sector, with a keen view to eventually including it in the carbon market and trade,
- bringing in the United States of America (USA) into the global carbon market, as the second largest GHG emitter that never ratified the Kyoto Protocol, and
- expanding the scope of mitigation to include conserving and further enhancement of forest carbon stocks in developing countries and also introducing Nationally Appropriate Mitigation Actions (NAMAs) that potentially covers all sectors. How much of the NAMAs carbon will be tradeable will be a function of post COP15 further negotiations.

13.1.3 How carbon markets operate

All the carbon markets are unique in that they have different operating systems. The regulated market so far is a project-based market rooted in the concept of a baseline and credit system. The emission reductions are created and traded through a given project or activity (JI and CDM). On the other hand, the allowance market is a cap-and-trade system, where emission allowances are defined by regulations at the international, national, regional or firm level – Kyoto-ET, EU-ETS or domestic regulations, e.g. UK, Australia, Japan, Canada, Korea, or firms, e.g. BP, Shell. There is a structural linkage between EU-ETS and project-based mechanisms.

In the voluntary market, individuals and companies account for and trade their greenhouse gas emissions on a voluntary basis (e.g. carbon and travel compensation schemes). Several companies have expressed interest in buying project-based credits (Certified Emission Reductions [CERs] and Emission Reduction Units [ERUs]).

For African countries, under the current global carbon trade regime, the Clean Development Mechanism provides the widest opportunities for their participation. The CDM has the following key characteristics:

- allows Annex I parties to purchase CERs from Non-Annex I parties through eligible projects,
- requires that the project must contribute to sustainable development (SD) as per the host country's SD criteria,
- is run by the Executive Board with a few supporting groups, panels and teams, e.g. Methodology Panel, Accreditation Panel, Afforestation/Reforestation Working Group, Small Scale Working Group, Registration Issuance and Transfer teams,
- has modalities and procedures guiding the whole process from project proposal, verification, methodologies for baselines and monitoring, accreditation to certification and crediting.

13.1.4 Performance of global carbon markets

Table 13.1 shows the status of CDM projects in the processing cycle by May 2009.

Transaction volumes and values in all carbon markets in 2006 and 2007 were as summarized in Table 13. 2 below.

The distribution of CDM projects has been strongly skewed by sector and geographical regions. As shown in Table 13.3, two thirds of all CDM projects in 2008 are in the renewable energy sector, generating two fifths of all CERs. Emissions reductions in the land use sector contribute less than 1% of total reductions with only nine projects in afforestation and deforestation, as mentioned above.

Domination of the CDM market by four countries: China, India, Brazil and Mexico, holding 75% of CDM projects is clearly illustrated in Figure 13.1, while Table 13.4 shows that over 95% of projects and CERs are in the Asia-Pacific and Latin American regions, with Africa fielding about 2% of projects and 3.3% of projected CERs by 2012.

The skewed geographical distribution of projects extends to the voluntary carbon market where Asia also dominates the market with two-fifths of the projects, with Africa hosting only 2% of the projects (Table 13.5) (VCS, 2008 *op. cit.*).

It is noteworthy that close to half of the projects in the voluntary market are located in Annex I countries (in North America, Europe & Russia and Australia).

In 2008/2009 the world economy faced a protracted financial crisis that led to a downturn

Table 13.1 Status ofCDM projects, May 2009. Source: UNFCCC CDM website, 2009..

Status	Number
In registration process	202
Withdrawn or rejected	136
Projects at validation	2,935
Registered no CER issuance	1,096
Registered CER issued	500
Total registered	**1,596**
Total projects	**4,869**

*) Estimated to exceed USD 126 billion in 2008 and USD 150 billion in 2009 (same size as the music industry), with CDM accounting for about USD 20 billion in 2008 (Ecosecurities, 2009).
**) 2007 regulated markets value per CER = USD 22/tCO_2e. Voluntary = USD 5/tCO_2e.

Table 13.2 Transaction volumes and values in all carbon markets, 2006 and 2007. Source: Ecosystem Marketplace, New Carbon Finance, World Bank, 2008.

Market	Volume (MtCO_2e)		Value** (million USD)	
	2006	2007	2006	2007
1. Voluntary OTC market	14.3	42.1	58.5	258.4
2. CCX	10.3	22.9	38.3	72.4
3. Total voluntary markets	24.6	65.0	96.8	330.8
4. EU-ETS	1,104.0	2,061.0	24,436.0	50,097.0
5. Primary CDM	537.0	551.0	6,887.0	6,887.0
6. Secondary CDM	25.0	240.0	8,384.0	8,384.0
7. Joint Implementation	16.0	41.0	141.0	495.0
8. New South Wales	20.0	25.0	225.0	224.0
9. Total regulated markets	**1,702.0**	**2,918.0**	**45,072.0**	**66,087.0**
10. Total global market* (USD billion)	**1,727**	**2,983.0**	**40.17**	**66.42**

Table 13.3 CDM projects in the pipeline (global) by type, 2008. Source: Risoe CDM/JI Project Pipeline and Analysis (http://cdmpipeline.org)*, 2009.*

Major type	Number	%	KCERs	%
HFCs, PFCs & N_2O reduction	97	2.0	132,528	22.0
Renewable energy	2,877	63.0	241,259	39.0
CH_4 (reduction & cement & coal mine/bed)	704	16.0	105,724	17.0
Supply-side EE	468	10.0	79,362	13.0
Fuel switch	140	3.1	44,408	7.2
Demand-side EE	207	4.6	7,120	1.2
Afforestation/Reforestation	39	0.9	2,205	0.4
Transport	9	0.2	981	0.2
Total	**4,541**	**100.0**	**613,587**	**100.0**

Table 13.4 Regional distribution of CDM Projects in the pipeline (2004–2009). Source: Risoe CDM/JI Project Pipeline and Analysis (http://cdmpipeline.org/)*.*

Total in the CDM pipeline	Number	%	KCERs	2012 CERs	%	Population	Per cap.
Latin America	873	18.4	80,486	421,214	14.4	449	0.94
Asia & Pacific	3,657	77.3	516,698	2,358,509	80.4	3,418	0.69
Europe & Central Asia	48	1.0	4,105	17,541	0.6	149	0.12
Africa	102	2.2	21,085	97,966	3.3	891	0.11
Middle East	53	1.1	7,783	36,583	1.2	186	0.20
Less Developed Countries	4,733	100	630,156	2,931,813	100	5,093	0.58

Notes:
- The regional share of the global market has remained constant.
- Even though African countries are making some progress; their share of the CDM market is low in all comparisons.

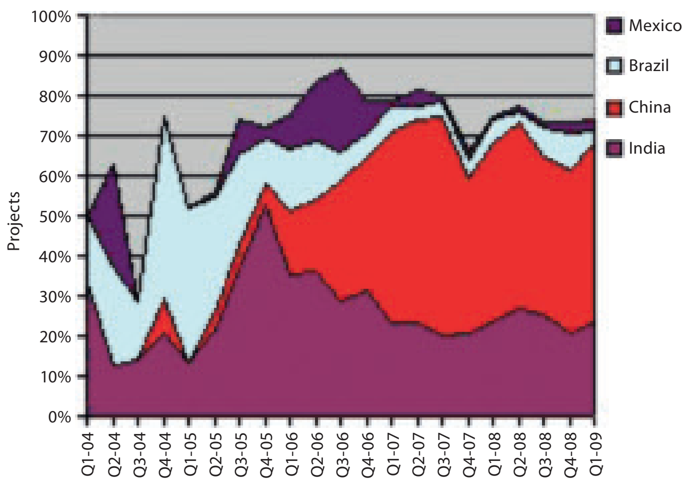

Figure 13.1 Regional distribution of CDM projects (market dominated by four countries), 2004 – March 2009. Source: Risoe CDM/JI Project Pipeline and Analysis (http://cdmpipeline.org/)*.*

Table 13.5 2007 Voluntary market (OTC) transaction by region.

Location	%
Asia	39
North America	27
Europe & Russia	13
Australia	7
South America	7
Africa	2
Others	5

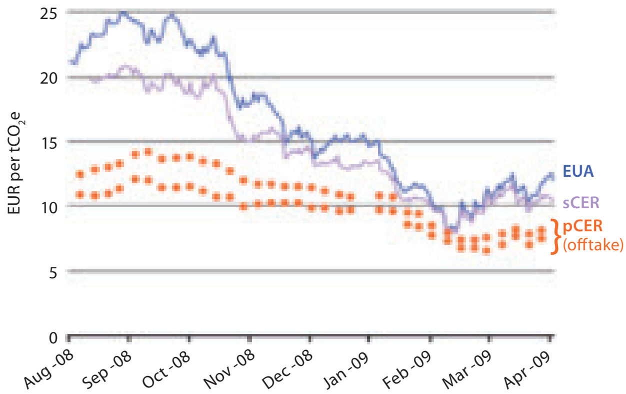

Figure 13.2 Recent trends in the carbon market 2008–2009. Source: Capoor and Ambrosi, 2009.

in global economic activity which in turn affected the carbon market negatively (Figure 13.2). The onset of this crisis, combined with the then existing uncertainties about future global climate change governance regime led to a steep decline in CER market prices in 2008, when the primary CDM market contracted (Capoor and Ambrosi, 2008; 2009). A similar reduction occurred in the price of carbon credits (CERs – carbon credits under the CDM; EUAs – carbon allowances under the EU-ETS), which saw the primary CDM market price fall to USD 10/EUR 7 in February 2009 (Figure 13.2). There are signs of recovery in the CDM market.

13.2 Initiatives and experiences in Africa on carbon trade and markets

13.2.1 Africa's participation in the CDM

Table 13.6 shows the cumulative number of CDM projects in Africa from the inception of the Kyoto Protocol in 2004 to 2009, while Table 13.7 shows the distribution of CERs by African countries in CDM projects in the pipeline in 2008.

As of mid-2009, there were 102 CDM projects in Africa (Table 13.6) with total CERs valued at about USD 1 billion. About one third of these projects were in South Africa and Nigeria, with the bulk of the CERs coming from industrial projects and methane capture (Table 13.7), with the two countries accounting for over half of the total CERs in Africa. Though Nigeria has only four of the projects on the continent, it has more than 26% of the CERs mostly due to the large oil field CH_4 capture project that replaced flaring.

There are many reasons underlying Africa's dismal performance in the carbon market so far. Historically, compared to Asia-Pacific and Latin America, the continent has lagged behind in collaborative mitigation efforts beginning with the 1980's pilot phase Joint Implementation (JI) programme that later became Activities Implemented Jointly (AIJ) where developing countries hosted GHG mitigation pilot projects funded by developed countries (UNFCCC, 1997b; UNFCCC, 1999).

Underlying this lukewarm response to climate change mitigation by Africa is the historical suspicion surrounding the evolution of the climate change debate, with many African countries harbouring concerns that they, instead of the real perpetrators which are the developed and industrial countries, were being made to shoulder responsibilities to clean up the global environment that was soiled by their wealthy cousins. Also contributing to this slow response is the lack of significant industrial emissions on the continent, coupled with some reluctance by environmental groups especially in the west to involve the land use sector in emission reduction efforts.

13.2.2 Sectoral distribution of CDM projects in Africa

Similar to the global picture, the sectoral distribution of CDM projects in Africa is dominated by renewable energy projects followed by landfill emission reduction or methane capture, accounting for two-thirds of CDM projects on the

Table 13.6 *Cumulative number of projects in Africa since the Kyoto Protocol came into force. Source: Risoe CDM/JI Project Pipeline and Analysis (*http://cdmpipeline.org/*).*

Country/Year	2004	2005	2006	2007	2008	2009
Egypt	0	0	5	7	12	12
Morocco	1	4	5	5	10	10
Tunisia	0	0	2	2	2	2
North Africa	**1**	**4**	**12**	**14**	**24**	**24**
Cameroon	0	0	0	0	0	1
Cape Verde	0	0	0	0	0	1
Congo DR	0	0	0	0	2	2
Côte d'Ivoire	0	1	1	1	2	2
Ethiopia	0	0	0	0	1	1
Kenya	0	0	1	4	7	9
Liberia	0	0	0	0	0	1
Madagascar	0	0	0	0	1	1
Mali	0	0	0	1	2	2
Mauritius	0	0	0	1	1	1
Mozambique	0	0	0	1	1	1
Nigeria	0	2	2	2	4	6
Rwanda	0	0	0	0	1	1
Senegal	0	0	0	1	2	2
South Africa	1	7	16	23	27	29
Swaziland	0	0	0	0	1	1
Tanzania	0	0	1	2	5	6
Uganda	0	1	1	2	8	10
Zambia	0	0	0	0	1	1
Sub-saharan Africa	**1**	**11**	**22**	**38**	**66**	**78**
Total Africa	**2**	**15**	**34**	**52**	**90**	**102**

Table 13.7 *CDM projects in the pipeline in Africa 2008. Source: Risoe CDM/JI Project Pipeline and Analysis (*http://cdmpipeline.org/*).*

Country	Number	kCERs by 2012	% of CERs
South Africa	28	24,314	26.6
Egypt	12	16,673	18.2
Morocco	10	3,006	3.3
Uganda	9	1,175	1.3
Kenya	8	3,402	3.7
Tanzania	6	3,758	4.1
Nigeria	4	23,821	26.1
Côte d'Ivoire	2	5,974	6.5
Mali	2	281	0.3
Tunisia	2	4,125	4.5
Senegal	2	1,103	1.2
Mauritius	1	1,764	1.9
Mozambique	1	228	0.2
Madagascar	1	210	0.2
Zambia	1	588	0.6
Ethiopia	1	181	0.2
Swaziland	1	252	0.3
Rwanda	1	74	0.1
Cameroon	1	460	0.5
DR Congo*	1	–	–
Total	**96**	**91,390**	**100**

*) Missing data on CERs 2012.

continent (Figure 13.3). Whereas Afforestation/Reforestation projects account for less than 1% of CDM projects in the world, in Africa they account for 10% of CDM projects. This trend is promising as it signifies that there is a large potential in sequestering carbon on land in Africa compared to the small emission reduction potential from fossil fuels and industry.

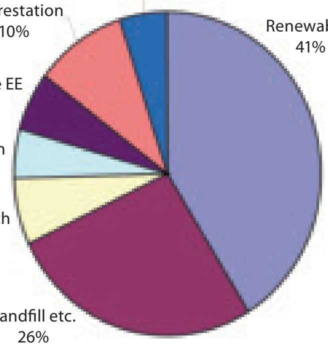

*Figure 13.3 Sectoral distribution of CDM projects in Africa. Source: Risoe CDM/JI Project Pipeline and Analysis (*http://cdmpipeline.org/*).*

13.2.3 Afforestation/Reforestation (A/R) CDM projects

As noted earlier, there has been a dearth of CDM projects in the land use sectors. As at the end of 2009, there were only four *registered* forestry CDM projects, namely in China, Macedonia, India and Uganda. By March 2009, there were only 39 A/R projects *in the pipeline* globally, about a third of which were in Africa (Table 13.8).

A key question is: "Why dwell on forestry mitigation projects in Africa?" There are many factors that make A/R activities pivotal to Africa's contribution to the global climate mitigation effort, including but not limited to:

1. Africa has an abundance of land (Figure 13.4) and, since land is the key A/R input, the continent has a high potential for carbon sequestration. Despite having close to 900 million inhabitants, due to the vastness of the continent (about 3.1 billion hectares) large swathes of land remain available for afforestation and reforestation.

2. In a global forestry mitigation potential study – GCOMAP (Sathaye *et al.*, 2006), analysis of the availability of land for mitigation in the forestry sector showed that in Africa:

- At least 200 million hectares are available for A/R, from the large areas of past deforestation and grasslands not currently used for grazing or significant wildlife management.
- There is a large potential for forestation because the current rate of planting of less than 200,000 hectares per year will not meet the growing demand for wood products by fast growing populations and economies. China, for example, has more than 60 million hectares of short and long rotation plantations; India has 40 million hectares, while Africa has only 8.5 million hectares (Sathaye *et al.*, *op. cit.*).
- There is a significant comparative advantage in CDM investments in forests and wild lands in Africa due to relatively lower cost of forestation and much shorter rotation age to achieve maximum accumulation of carbon. The price of inputs, especially land rent and labour is quite

Table 13.8 A/R CDM Projects in the pipeline in Africa (as of March 1st, 2009). Source: Risoe CDM/JI Project Pipeline and Analysis (http://cdmpipeline.org/).

Uganda	5
Tanzania	3
DRC	2
Mali	1
Ethiopia	1
Total Africa	12
Global	**39**

Figure 13.4 Key actors in the climate change mitigation effort fit into Africa's land mass. Source: Compiled from Googlemaps.

low compared to other regions and the growth rate of trees is much faster due to ambient conditions and length of growing period.
- Given the potential in the land use sectors, Africa can bring to the mitigation table a very large number of CERs from the land use sector compared to those from the energy and other sectors of the economy.
- Investing in CDM in the forestry sector in Africa accentuates other environmental and economic benefits derived from A/R on a continent without enough forestation.
- Africa has a high deforestation rate, estimated at 5 million hectares per year. If a significant amount of this area is brought under REDD, hundreds of millions of tonnes of avoided emissions will be gained and that can translate to billions of dollars.

It has to be borne in mind that the actual A/R CDM and REDD area achieved will depend on national eligibility, competition for land, land use policy and meeting the criteria under the respective modalities and procedures.

13.2.4 Key elements of forest mitigation potential in Africa

Under the current modalities and procedures for CDM, as well as general understanding of the Copenhagen Accord, many opportunities are brought forth for mitigation in the forestry sector in Africa. Key factors contributing to this high potential include:

- Many ecosystems are potentially eligible for afforestation and reforestation projects in Africa. These include deforested lands that are not recovering, degraded lands, low carbon density landscapes such as grasslands, thickets and bush-lands, and low carbon multiple-use lands, e.g. agroforestry and pastoral-silvicultural lands.
- Existing economic factors point to a fast growing domestic and export demand for forest products and services. The rising demand will require to be met from new forests if the continent does not want to exhaust its natural forests which are already under a lot of pressure in many African countries. The rising demand to nurture and replenish wildlife ecosystems opens additional opportunities for tailored forestation in these areas.
- Africa has the knowledge and skills to implement mitigation projects in the forest sector. There is a small but growing cadre of local forestry and wildlife professionals capable of implementing forestry carbon projects/programmes.
- The miniscule current and past investments in traditional forestry make it imperative to explore these new creative avenues for channeling investment funds into forestation. As mentioned earlier, Africa adds about 200,000 hectares of plantations annually compared to China and India which annually add 1.4 million hectares and 650,000 hectares respectively (Sathaye *et al.*, *op. cit.*).
- Africa has had strong historical inter-linkages between people, power, land, forests and trees. Effective forestation programs can exploit this relationship by mobilizing A/R activities in areas where people will take ownership of these projects in order to enhance their social power in addition to the economic benefits derived.

Table 13.9 shows the potential land area available for forestation in Africa, given the baseline rates of deforestation and conventional afforestation and deforestation in the 21st century. According to the GCOMAP model on global mitigation potential in the forest sector, the baseline cumulative area under plantations by 2100 is projected to be about 20 million hectares, compared to about 350 million of baseline deforestation in the same period. Even if 50% of the deforested area is utilized for other land uses like agriculture, infrastructure and settlements, there will still be about 200 million hectares available for afforestation and reforestation, assuming that the CDM modalities and procedures will be amended to expand the scope

Table 13.9 Estimated potential baseline area in Africa for CDM (A/R) and REDD-Plus (million ha).
Source: GCOMAP – Sathaye et al., op. cit., 2006.

Year	2050	2100
Short rotation	4	8
Long rotation	5.75	11.50
Total forestation*	9.75	19.50
Deforestation	204.67	347.90
Forest area gained	**- 194.92**	**- 328.41**

*) Modified CDM with expanded land eligibility under Copenhagen Accord.

Table 13.10 GCOMAP Carbon gain potential in Africa for the price scenario of USD 37/tCO_2 + 5%/yr for the next century.
Source: GCOMAP – Sathaye et al., op. cit., 2006.

Year	2050 (MtC)	2100 (MtC)
Short rotation	55	687
Long rotation	145	1,857
Total forestation	200	2,544
Deforestation	6,806	6,222
Net C-gain	**7,006**	**8,766**

of land eligibility for climate change mitigation efforts in the ongoing post-COP15 negotiations. This is more likely given the inclusion of NAMAs in the forestry sector and other land uses.

Estimates from the same model project a gain of 25.4 million tonnes of C per year (123 mi tCO_2) from A/R over the next century, and a large 62.2 million tonnes of C per year (228 mi tCO_2) from reduced deforestation – assuming a carbon price scenario of USD 37/tCO_2 growing at 5% per year from year 2000 (Table 13.10). These values provide a general appreciation of the amounts of carbon that can be sequestered in African forests and trees, and also an indication of the vast amounts of money that can be gained from such activities. These values are roughly comparable from the two other major global forest mitigation models – GTM and IMAGE (Alcamo *et al.*, 1998; EMF22, 2005).

13.3 Opportunities and challenges for Africa in carbon trade and markets

13.3.1 Context

The CDM was created to promote the hosting of GHG emission reduction projects by developing country parties to the KP, using finance provided by developed/industrial country parties (Annex I) as a win-win-win situation, with the Annex I party meeting part of its emission reduction commitments at a cheaper cost, while the developing country achieves some sustainable development goals.

The CDM was established under Article 12 of the Kyoto Protocol, which was agreed upon in 1997. The detailed modalities and procedures for its operationalization were subsequently agreed upon by parties in 2001, as part of the Marrakech Accords (UNFCCC, 2001). In that same year, the CDM Executive Board (CDM-EB) was formed and began building the structure and process of the international CDM system. The first CDM projects were officially registered with the Executive Board in 2004, and since then the number of projects in the pipeline has continued to grow steadily.

13.3.2 Scopes: eligible GHGs and key sectors under the CDM

The Clean Development Mechanism is one of the important mechanisms of the KP for the reduction of the atmospheric concentration of GHGs, in order to mitigate human-induced climate change. The IPCC identified six types of gases (Table 13.11) whose emission reduction is the objective of the Protocol, while the Executive Board of the Protocol, identified 15 key sectors from which the parties can target emission reduction activities as follows:

- Energy industries (renewable and non-renewable sources).
- Energy distribution.

Table 13.11 Types of GHGs and their Global Warming Potential (GWP). Source: IPCC (2001).

Greenhouse gas	Chemical symbol	Global warming potential
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydro-fluorocarbons	HFC-23 HFC-125 HFC-134a HFC-152a	11700 2800 1300 140
Per-fluorocarbons – Tetrafluoromethane – Hexa fluoroethane	 CF_4 C_2F_6	 6500 9200
Sulphur hexafluoride	SF_6	23900

- Energy demand.
- Manufacturing industries.
- Chemical industries.
- Construction.
- Transport.
- Mining/mineral production.
- Metal production.
- Fugitive emissions from fuels (solid, oil and gas).
- Fugitive emissions from production and consumption of halocarbons and sulphur hexafluoride.
- Solvents use.
- Waste handling and disposal.
- Afforestation and reforestation.
- Agriculture.

13.3.3 Eligible Land Use and Land Use Change and Forestry (LULUCF) activities and projects in carbon markets

While emission reduction can be achieved in all the sectors listed above, the land use sector has the greatest potential for CDM opportunities in Africa, due to the relatively large amount of actual and potential emissions, as well as the ability to sequester carbon on the vast area of land. Four main areas in this sector avail themselves to carbon finance:

1. Afforestation and reforestation.
2. Reduced deforestation and forest degradation.
3. Agriculture, livestock, agroforestry (agrisilviculture and pastoral-silviculture).
4. Bio-energy including, biofuels and energy efficiency.

More importantly, the carbon finance opportunities in the land use sector also fall in priority areas, in terms of projects and programmes that enhance the ability of vulnerable African countries to adapt to climate change.

Projects in the LULUCF sector, often called ‘sinks' projects, essentially take carbon sequestration into account and, accordingly, generate tradeable emission reduction units. At present, CDM projects are limited to activities in afforestation and reforestation (A/R). In principle, however, LULUCF projects could include the implementation of other sustainable agricultural practices (like conservation farming) as well as slowing deforestation and forest degradation under the Copenhagen Accord.

As shown in Table 13.12, there are more biocarbon projects in Africa than the total number of CDM projects, and this is mostly due to the proliferation of voluntary carbon market projects.

13.3.3.1 Afforestation and Reforestation (A/R)

Despite the fact that A/R was included as a legitimate activity in the Marrakech Accords, only four forestry CDM projects were registered across the world as at the beginning of 2009 and only nine by October 2009, including the only A/R project in Africa (Uganda) registered in October 2009. By contrast, more than 5,000 projects in the other sectors are in the pipeline across the world. This trend points to some technical, procedural and implementational problems associated with A/R CDM projects, hurdles that are currently more pronounced in Africa than in other regions.

Table 13.12 National bio-carbon projects in African countries compared to energy related projects. Source: Chomba and Minang, 2009; and http://cdmpipeline.org/, op. cit.

Country	Total bio-carbon projects	CDM projects in the pipeline	Comments
Madagascar	20	1	More A/R projects than energy related projects
Uganda	15	10	More A/R projects than energy related projects
Ethiopia	13	1	More A/R projects than energy related projects
Kenya	8	14	More projects in the energy sector than A/R
Senegal	7	0	More A/R projects than energy related projects
Tanzania	7	5	More A/R projects than energy related projects
DRC Congo	5	1	More A/R projects than energy related projects
Mali	5	2	More A/R projects than energy related projects
Cameroon	4	1	More A/R projects than energy related projects
Mozambique	4	1	More A/R projects than energy related projects
South Africa	4	27	More projects in the energy sector than A/R
Egypt	0	12	Only energy sector projects
Morocco	0	10	Only energy sector projects
Total	**92**	**87**	

A/R projects are expected to show substantial developmental benefits for project proponents (smallholders, communities). The design and implementation of A/R projects must be based on a sound understanding of related household and community activities.

Afforestation or reforestation of most of the savanna woodlands in Africa does not hold a large carbon potential due to the inherent low productivity of these dry areas. Exceptions are riverine and groundwater floodplains where the carbon density, estimated at about 60 tC/ha (IPCC, 2004), is much higher than the average carrying capacity of the general savanna woodlands on the continent. Moreover, close to 50% of the biomass is below ground in these arid areas of less than 1,000 mm annual rainfall (IPCC, 2004, *op. cit.*), the estimated soil organic carbon being about 20 tC/ha in the top 30 cm of soil. The low productivity of African savanna woodlands thus clearly offers slim opportunities for effective carbon sequestration through afforestation and reforestation, except where significant amendments like fertilization or irrigation are undertaken but, given the cost implications and the severe water stress in much of the continent, such amendments are unlikely options.

Afforestation and reforestation of the more fertile and water abundant ecosystems offer a more attractive potential in terms of carbon benefits, but in most African countries, the same areas are the priority for agriculture, settlements and conservation. This provides a clear conflict for land use, given the emphasis on food production against the long rotation period required by forests.

13.3.3.2 Biomass energy efficiency

Most of sub-Saharan Africa depends predominantly on biomass energy in the form of fuelwood and charcoal to meet the bulk of their energy requirement. Tanzania is a typical example of biomass energy dependence in the region, with woodfuel consumption of 250 kg/month per household accounting for about 70% of total primary energy consumption (Makundi, 2010). Biomass energy consumption has been growing with population at a constant rate of about 3% per year, with about 90% of the energy consumed mainly by the residential and commercial sector for cooking, water heating and other domestic and commercial purposes. The industrial sector accounts for the remaining 10%.

Long-term prospect for sustained supply of fuelwood and charcoal is threatened by deforestation, wanton tree removal and forest degradation in all parts of the continent. This is further exacerbated by the widespread use of inefficient technologies for conversion of wood to charcoal and for burning of fuelwood and charcoal in stoves.

A variety of problems beset the biomass sector as the main supplier of primary energy in Africa. The most profound problem emanates from the need to meet the increasing energy demand of a rapidly expanding population, given the natural resource landscape, with pressure of the timber industry on the forests, wild fires, shifting agricultural practices and inefficient production and use of fuelwood and charcoal.

Resources of biomass other than fuel wood and charcoal that are environmentally friendly include crop and sawdust residues, animal and municipal waste, wood shavings and bark. In addition, energy crops such as sugar cane, palm and jatropha could be processed to liquid fuels as substitutes for petroleum products. So far, the use of these resources has not been fully exploited and as such there is a significant potential in generating carbon credits via the renewable energy and alternative technologies route. Three biomass technologies are recommended for GHG mitigation and are thus of priority to the region for CDM and voluntary carbon (VC) projects: *1)* efficient kilns and woodfuel stoves, *2)* utilization of industrial residues for combined heat and power production, *3)* production and use of liquid bio-fuels to substitute biomass use and/or supplement the use of fossil fuels.

1. *Improved woodfuel stoves*. Traditionally, cooking is undertaken predominantly using firewood, charcoal or crop residues as fuel, on a three-stone fireplace or a simple energy inefficient charcoal stove. The disadvantages of the traditional methods include:

- High fuel consumption due to their inefficiency.
- Slow cooking rate as most heat is dissipated away from the target surface.
- Smoke from the fuel cannot be controlled or channeled out of the cooking environment. The users (mostly women and children) therefore inhale smoke and this has serious health consequences.
- Babies and children are at serious risk from the exposed flame from the stove, a common cause of horrific household accidents.

Efficiencies of traditional stoves range between 10 and 20%, while improved stoves with efficiencies up to 35% could be promoted to reduce woodfuel consumption by about 40% (Makundi, 1998). Much more efficient but more expensive stoves do exist. Though national initiatives have been started to promote the use of efficient stoves, there is room for improvement. This is an area that can be tapped by CDM and VC project proponents, to generate large amounts of carbon credits while meeting sustainable development aspirations of African countries, in the area of biomass energy use. Exploiting such Copenhagen-based mechanisms as Fast Start Funding, programmes in efficiency improvements in biomass conversion and utilization as energy can be initiated to produce large amounts of emission reductions that can further be leveraged into carbon market investments.

2. *Co-generation of heat and power from industrial residues.* Wood-based factories can use wood waste such as sawdust and shavings for co-generation of heat and power. This will contribute to reducing dependence on fossil fuels or over-reliance on hydropower, especially given the projected impacts of global climate change on hydrological resources – diversification of energy mix. There is significant carbon emission reduction potential associated

with co-generation that can be used in CDM and VC projects.

3. *Biofuels – biogas and biodiesel.* Use of biogas as a source of energy generally falls under the ambit of emission reduction in forests to the extent it substitutes for unsustainably procured biomass. Biodiesel can also be considered a potential carbon market area under forests in that large areas for biofuels production will be under the jurisdiction of forests, or will replace existing low carbon density forests.

In Africa there has been a heightened interest in biofuels as price of fossil fuels has increased, with expectations of further increases as a result of growing world demand mostly caused by the breakneck pace of economic growth of China, India and Brazil. In addition to price driven substitution, more African countries are looking at biofuels for energy security purposes. Many companies from Asia and the West, which are eyeing biofuels as a path to the carbon market, have leased large tracts of land in Africa for biofuel production. For example, by March 2009 the official figures show that there were about 20 companies that requested land for commercial biofuel production in Tanzania, with land requested area varying from 30,000 to 2 million hectares (Sulle and Nelson, 2009).

Biofuels may also provide a new source of agricultural income in rural areas, and a source of improvements in local infrastructure and broader development. Biofuel production is not necessarily done only by large farms or foreign investors, but can be carried out by smallholder farmers as well. Biofuel crops such as oils (palm, coconut, jatropha and sunflower) may provide important new opportunities for improving the returns from agriculture, including on relatively unproductive or infertile lands. Farmers can therefore take advantage of the carbon market as additional source of revenue from intercropping with biofuel crops.

External interest in biofuel production in African countries is driven largely by the low cost of land and labour in rural Africa (Cotula *et al*., 2008). Investors are targeting many areas of land which are perceived as being 'unused' or 'marginal' in terms of their productivity and agricultural potential. With interest in allocating such areas for biofuel increasing, the security of land tenure and access or use rights on the part of local resident communities across rural African landscapes is potentially at risk.

13.3.3.4 Reduction of Emissions from Deforestation and forest Degradation (REDD)

In the 2007 Bali roadmap towards a new climate change regime for the second commitment period and beyond, it was agreed to expand the sectoral scope so as to include emission reduction from deforestation and forest degradation, including through sustainable management of forests (REDD+). Through the Bali Action Plan (1/CP.13 and 2/CP.13), COP decided to launch a comprehensive process to enable full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012 (UNFCCC 2007: Decisions 1/CP.13 and 2/CP.13).

The Copenhagen Accord in Decisions 6/CP.15 and 8/CP.15 formally endorses REDD+ and proposes a preliminary mechanism for financing the programme, initially via positive incentives (UNFCCC, 2009a). Decision 7/CP.15 also does not exclude REDD+ from applicable market mechanisms when conditions allow.

REDD+ is a new direction in forest conservation that will require countries to take into account existing research on deforestation and lessons learned from previous forest conservation initiatives in order to formulate effective policies that measurably and verifiably reduce emissions from deforestation and forest degradation. Pending the development of modalities and procedures for monitoring, reporting and verification for REDD+, African countries need to lay the foundation for realizing the potential in this new carbon sector (REDD readiness). Key steps that need to be taken in order to fully exploit the new avenue for conservation and earning carbon resources include:

1. Preparing the necessary preliminary conditions for participation by those institutions entrusted with management of forests in each country. These steps will include undertaking baseline studies of deforestation and forest degradation in the country that include identifying the factors and processes underlying deforestation and forest degradation. It has become standard practice to distinguish between proximate and underlying causes. Proximate causes refer to the activities involved in deforestation and forest degradation, and include agricultural expansion, settlements and infrastructure extension, and wood extraction. Underlying causes are demographic, economic, technological, policy, institutional, and cultural factors (Geist and Lambin, 2002).
2. Undertaking studies to identify effective measures to reducing deforestation and forest degradation.
3. Implementing those identified measures consistent with each country's forest conservation and sustainable development objectives.
4. Seeking financing from the Copenhagen Financing mechanisms and from bilateral and multilateral sources to enable implementation of the proposed measures. Such sources may include, but are not limited to, the Norway's International Climate and Forests Initiative (NICFI), the World Bank's Forest Carbon Partnership Fund (FCPF), Congo Basin Forest Fund (CBFF) and the UN-REDD, to mention a few.
5. Encouraging local communities, private parties and development partners to implement requisite specific measures in locales that can reduce deforestation and forest degradation.
6. Using the available resources mentioned above to intensify the protection of natural forests and vulnerable ecosystems via public programmes as well as encouraging private efforts, allowing the intervener to retain any resulting carbon credits and other incidental benefits.

REDD+ strategies must include policies outside the forestry sector narrowly defined, such as the agriculture and energy sectors. Better coordination across sectors is the key to dealing with non-forest drivers of deforestation and degradation (Angelsen and Kaimowitz, 1999). Four types of policies that could reduce deforestation are policies to depress agricultural rent, increase and capture forest rent, to directly regulate land use and finally, the cross-sectoral policies that underpin the first three. These policies and programmes under Copenhagen can come under Nationally Appropriate Mitigation Actions (NAMAs) and in the future they may even be tradeable depending on the role given to the market versus public funding of REDD+. The specific measures, policies and programmes to be attempted may include:

1. Reducing rent from extensive agriculture in areas that have persistent deforestation caused by conversion of forests to agriculture. This can be achieved through:
   a) measures to depress the targeted agricultural prices;
   b) creation of off-farm income generating opportunities;
   c) supporting intensive agricultural sector near the deforestation frontiers with selective support of extensive agriculture where necessary;
   d) instituting measures to curb deforestation that accompany new roads through forested areas; and
   e) instituting policies to secure land rights in agricultural areas.
2. Increasing forest rent and its capture by forest owners in order to encourage retaining land under forests through:
   a) higher prices for forest products not derived from deforestation;
   b) instituting and strengthening community forest management (CFM) so as to enhance the capture of local public goods and services from forests;
   c) introducing and strengthening the regime of payment for environmental services (PES) such as water, ecotourism and carbon.

3. Regulating land use and land use change directly through enforcement of existing laws on forest protection, ordinances and directives on allowable land use in various ecosystems.
4. Putting in place or implementing existing cross-cutting policies that moderate land use change, especially those curtailing illegal logging and land cover change.

Other important broad measures and policies include decentralization and good governance, especially anti-corruption measures in the forest sector.

13.3.3.5 Forest industry and wood products

The forest sector can accrue carbon credits by utilizing wood waste and sawdust, as pointed out above, to produce power for use by the wood industry or for selling to the national grid. The credits will depend on the carbon intensity of the power supply being substituted, with those countries more dependent on fossil fuels for power generation having more potential for emission reductions using co-generation from wood and wood waste. These credits from co-generation are currently eligible under CDM and VCM.

A new avenue that may be pursued under the Copenhagen Accord is efficiency improvements in conversion of logs to wood products. The current milling efficiency in tropical Africa is about 40%. Raising this value to 65% via installation of newer vintage mills will reduce the associated emissions by the same proportion, and these can be sold in the voluntary market or credited in NAMAs under the Copenhagen Accord. The exact crediting will depend on the modalities and procedure arising from the Accord.

13.3.3.6 High carbon landscapes

Storage of carbon in land increases the carbon density of the landscape. Biocarbon initiatives including soil carbon storage, erosion control, agroforestry (agro-pastoral-silviculture), enhancement of litter retention in forest and agricultural lands, forestation of low biomass lands to increase equilibrium carbon density, among other ways, have carbon benefits, some of which are eligible for the CDM/VC and some for NAMAs under Copenhagen.

13.3.3.7 Scopes under Voluntary Carbon Market

Voluntary Carbon Standards (VCS) is a non-profit organization attempting to standardize carbon accounting procedures both under the CDM and other compliance systems. VCS recently issued guidelines for A/R and other AFOLU bio-carbon projects (VCS, 2008). The VCS 2008 guidelines permit not just A/R projects but the broad spectrum of AFOLU, Improved Forest Management (IFM), and reduced emissions from deforestation and forest degradation (REDD). IFM includes:

1. conversion from conventional logging to reduced impact logging;
2. conversion of logged forests to protected forests;
3. extending the rotation age of evenly-aged managed forests; and
4. conversion of low productivity forests to high productivity forests.

With regard to REDD, the VCS will accept credits from projects that avoid planned deforestation, planned frontier deforestation and degradation and those that avoid unplanned mosaic deforestation and degradation. As such, the project proponents may combine a variety of activities spanning the four general AFOLU categories (A/R, ALM IFM, REDD) into a single VCS project as long as separate risk assessments are applied to each project category.

13.4. Enhancing participation by African forestry sector in carbon trade and markets

As mentioned earlier, Africa hosts less than 4% of all CDM projects and 2% of the voluntary carbon projects, with about a third of the CDM projects being in the forestry sector. The relatively low number of CDM projects in Africa is due to unique barriers in accessing the carbon market in general, with the forestry sector facing even stiffer sector specific challenges (UNEP/UNDP, 2006)

13.4.1 Barriers in realizing the CDM/REDD+ potential in A/R in Africa

The most common barriers to A/R projects in general but more pronounced for Africa include:

1. Political instability. Investment in forestry, especially in forestation is a long term investment usually extending to many decades. Political instability discourages foreign investors in general but more so those long term projects on land. Even if there are a few spots on the continent where there has been some strife, there is a generalized perception of political instability hovering over the continent.
2. Lack of political enthusiasm for land-based activities tied to long term western countries' interest, given historical realities that include vicious colonialism. Indeed, by the end of 2009, only ten African countries had submitted a national definition of forests to the UNFCCC, which is a pre-requisite to participation in CDM in the forest sector.
3. High transaction costs for large projects, estimated at an average of USD 200,000 per project from inception through registration (PIAD, 2003). This impedes investments in CDM in general, but more so where the other factors accentuate the risk involved. Smaller projects cost an average of USD 50,000 but even this is still high for domestic project proponents especially given the high rate of rejection at the registration stage.
4. Restrictions of project scale. From the beginning of CDM, the limit for small scale projects, which are eligible for special treatment by the Executive Board was set at 8KtCO_2, though this has now been increased to 15KtCO_2 per project. This small size of eligible projects under the expedited processing has made A/R projects unattractive to developers and buyers.
5. Temporary nature of forestry credits (t-CERs and l-CERs, see box 13.1) makes them unattractive to buyers since they expire and must be replenished. Mechanisms such as insurance or buffer schemes have to be sought in the Copenhagen Accord to make land-use cre-

The temporary nature of forestry emission reduction credits

Under CDM the issue of non-permanence of emission reductions is resolved via the use of temporary (t-CERs) and long-term (l-CERs) for crediting instead of permanent CERs. t-CER and l-CER must be replaced at the end of their certified period. As defined in 5/CMP.1, Annex, paragraph 1(g):

'Temporary CER' or 't-CER' is a CER issued to project participants in an afforestation or reforestation project activity under the CDM, which, subject to the provisions of section K of the CDM Guidelines, expires at the end of the commitment period following the one in which they are issued.

'Long-term CER' or 'l-CER' is a CER issued for an afforestation or reforestation project activity under the CDM, which, subject to the provisions in section K of the CDM Guidelines, expires at the end of the crediting period of the afforestation or reforestation project activity under the CDM for which it was issued". When retired l-CERs expire, they must be replaced by other Kyoto units such as AAU, CER, ERU or RMU. Unlike t-CERs, expired l-CERs cannot be replaced by other l-CERs.

Box 13.1.

dits permanent and fungible with other sector CERs.

6. Limited number of buyers due to exclusion of A/R CERs from the largest carbon buyer, the EU-ETS.
7. Uncertainty (social and legal). Uncertain tenurial arrangements, community participatory component and land-use conflicts reduce attractiveness in land-based carbon investments.
8. Lack of national policy, strategy and guidelines for participation in carbon markets. Many African countries have only *ad hoc* reactive frameworks for participation in carbon markets and lack comprehensive guidance and strategy.
9. Lack of financing from local banks. Up until the end of 2009, only Stanbic Bank had a fully fledged carbon investment department at the headquarters in South Africa and had posted some capable carbon investment experts in some of its branches in other African countries. Without local financial institutions being willing and able to finance carbon project activities, local participation becomes limited and stunted.
10. Lack of insurance for carbon projects. The African insurance sector must recognize the new opportunities in carbon market and underwrite such investments. Forest carbon investment has a higher risk than most other investments, due to possibilities of fire, disease, encroachment, illegal harvesting, and so on. As such the sector would benefit more than other sectors from an active insurance service.

13.4.2 Catalyzing CDM in Africa

Having noted the regional imbalance in CDM project distribution in the world, and noting the objectives of the Convention and the Protocol, the United Nations in 2006 launched the *'Nairobi Framework'* with the specific purpose of catalyzing CDM in Africa (UNDP/UNEP, 2006). The Framework has the following five objectives, considered to be key priority targets in order to move the CDM forward in Africa.

- Build and enhance capacity of Designated National Authorities (DNAs) to become fully operational.
- Build capacity in developing CDM project activities.
- Promote investment opportunities for projects.
- Improve information exchange/outreach/sharing of views on activities/education and training.
- Set the platform for Inter-agency coordination.

13.4.3 Removal of key hurdles

Since the launching of the Nairobi Framework in 2006, some efforts have been undertaken to remove some of the identified hurdles and barriers to the diffusion of CDM in Africa, specifically to address the regional and sectoral imbalance:

- The CDM Executive Board (EB) has streamlined the Process from Inception (PCN) through Issuance, effective 2008 to attract more projects from Least Developed Countries and Africa with a focus on bringing on line more projects from Forestry. This initiative has included *1)* the use of tools, *2)* revised methodologies, *3)* consolidation of methodologies, *4)* introduction of Programme of Activities (PoA) to bundle small projects under one PDD.
- EB is open to and has been assembling and considering suggestions from stakeholders especially in Africa and in LULUCF.
- There is now a CDM Bazaar (*http://www.cdmbazaar.net*) to facilitate meeting of Project Proponents (PPs), Sellers and Buyers of CERs, Financiers and Insurers etc. This Bazaar is housed at the UNEP Center Risoe in Denmark.

13.4.4 State of preparedness/readiness of African countries for emerging initiatives in carbon trade and markets

The single most important emerging carbon initiative for Africa and indeed for the land-use sectors is REDD+. Tropical forests cover only 12% of the world's terrestrial land area but contain 40% of the world's terrestrial carbon (UNFCCC, 2004, *op. cit.*). Part of this pool is the carbon that is vulnerable via deforestation and degradation, namely volatile carbon – 100% of vegetation and 25% in soils. As shown in Table 13.13, the volatile carbon in DRC alone is about 5 times the annual global carbon emissions from all sectors. This indicates the importance of reducing or protecting emissions from the African land use sectors.

Table 13.14 shows the estimated rate of deforestation in the countries with most vulnerable terrestrial carbon.

Any measures to implement REDD+ have to pay attention to the magnitude of the potential emission reductions involved. Overdependence on land based economic activities for the rapidly expanding population in the forested parts of Africa, together with illegal conversion of forests such as via clear cutting, points to a large potential emission reduction from African forests.

Table 13.13 Forest Volatile Carbon (Gt C) distribution in selected countries. Source: Terrestrial Carbon Group, 2009.

Country	Vegetation	Soil	Total
Brazil	76.6	10.4	86.9
DRC	34.0	5.1	39.2
Indonesia	21.5	5.7	27.3
China	13.5	4.6	18.1
India	4.8	1.4	6.2
Malaysia	3.8	0.8	4.6
Tanzania	3.4	0.7	4.1
Vietnam	0.8	0.2	1.0
Nepal	0.5	0.2	0.7

Table 13.14 Annual deforestation rates for major tropical countries. Source: FAO 2005, p. 191.

Country	Land area	Forest area		Deforestation	
	Kha	Kha	%	Kha	%
Brazil	851,488	477,698	57	2,822	0.52*
DRC	234,486	133,610	59	461	0.38
Indonesia	190,457	88,495	49	1,871	1.61

*) Has recently declined by 45% due to the global economic slump.

13.4.5 Participation by forest growers in the carbon market

Access to the carbon market by African forest and tree growers – especially small scale tree planters, is currently dependent on the two existing mechanisms, that is the CDM and VCS. A few REDD pilot projects are also underway in a few African countries.

CDM has strict eligibility criteria for land to be used for CDM. Other legal requirements arise from the Marrakech Accord and the Kyoto Protocol stipulations. As shown in the Annex to the Protocol (UNFCCC, 2005) on definitions, modalities, rules and guidelines relating to land use, land-use change and forestry activities under the Kyoto Protocol, these will impact the possibility and ease of participation by African tree growers and farmers. The following are the key constraints and binding conditions.

13.4.5.1 Key definitions applicable in the forestry carbon market

Article 12 of the Protocol limits the eligibility of land use, land-use change and forestry project activities to those involving afforestation and reforestation activities. To functionalize this limitation, strict definitions of land use and activities must be adhered to as well as a clear legal interpretation of the relevant aspects of modalities and procedures. The applicable definitions and legal advice is presented hereunder:

a) *Forest* is a minimum area of land of 0.05–1.0 hectare with tree crown cover (or equivalent stocking level) of more than 10–30 per cent with trees with the potential to reach a minimum height of 2–5 meters at maturity in situ.

A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10–30 per cent or tree height of 2–5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest.

b) *Afforestation* is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.

c) *Reforestation* is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989.

There has not yet been an agreement regarding the applicable definitions from the Copenhagen Accord, but it is not expected that they will abrogate those arising from Kyoto but rather broaden them.

13.4.5.2 Conclusions to the legal background for A/R (UNFCCC, 2005, *op. cit.*)

1. The term eligibility is used only in connection with activity, namely afforestation and reforestation.
2. There is no definition of eligibility of land, hence any procedures for demonstration of eligibility of land are not directly based on the Marrakech Accord.
3. Afforestation and reforestation are defined as direct human-induced conversion of land, i.e. both require land use conversion to be eligible for A/R CDM project activities.
4. Definition of forest is based on two features:
   - Current: crown cover, and
   - Potential: height.
5. Procedures to define eligibility of activity for the first commitment period shall be based on:
   - Assumption that tree planting for the CDM purposes involves species and management practices which will lead to creation of a stand that will have crown cover and height greater than the thresholds invoked in the definition of forest. This shall be substantiated in the PDD.
   - Testing that the planting is a land use change.
   - Testing that the reforestation activities will be limited to planting occurring on those lands that did not contain forest on 31 December 1989.

   Further assumptions that:
   - In land use practice, the crown cover is the only feature that may be assessed precisely in the current and past situations (e.g. using EO, land cover maps, forest maps or PRA).
   - Potential of trees to reach a minimum height of 2–5 meters at maturity in situ may be assessed based on site conditions, tree species used and management practices applied. This is doable for both current and past conditions.

Given the strict criteria for A/R CDM and the complexity of modalities and procedures, participation of tree growers and small scale forest owners will need an organizing entity such that they participate as a group in a cooperative or under a carbon facilitating company that can incur the initial cost and organize the farmers participation, including the handling of the carbon trading. It is unlikely that individual tree growers and small scale farmers could effectively and beneficially participate in the CDM market.

The VCM is less stringent but due to existence of all sorts of players, farmers will also need an umbrella organization to be able to take advantage of the carbon market. The government should have a policy and protective role to play in order to guard the farmers' interest.

13.4.5.3 African participation in the carbon market after the first commitment period

As mentioned earlier, the Copenhagen Accord, and later the Cancún Agreements have brought forth REDD+ and NAMAs, with a clear expectation of the extension of the Kyoto Protocol. After COP14 in Poznan, the concept of REDD was extended to include sustainable management of forests, thus REDD+ came into being in the Copenhagen Accord and consolidated by the Cancún Agreements. In addition to REDD+, there is a drive towards including Agriculture, Forestry and Other Land Uses (AFOLU) as a comprehensive mitigation package in the land sector. Such a move will widen the scope significantly for participating by small scale growers and farmers since the most effective measures to implement REDD+ require interventions in the agricultural and other land use sector.

The adoption of NAMAs and public creative financing mechanisms will allow for the mainstreaming of low carbon economic development profile and high carbon landscapes. These can directly be brought into the carbon market or can leverage private investments in forestry for carbon trade.

13.5 Conclusion

Africa has a large mitigation potential in the land use sector that can be translated into significant participation in the current and future carbon market opportunities. This potential is underwritten by her large endowment of land and large populations involved in land use based economic activities. Recent global mitigation models show that African forests and trees have a likely potential for sequestering about 123 million tonnes of carbon dioxide (CERs) per year and reducing emissions by about 228 million tonnes of carbon dioxide per year from avoided deforestation. So far carbon market data show that African forests and trees have barely been brought forth into the market. By 2009, the total amount of CDM CERs from Africa was about 21 million out of 630 million global CERs, of which forestry's contribution was a miniscule 0.4 percent of the global total.

A number of reasons have been put forward to explain the poor performance in carbon projects and programs, including but not limited to, high transaction costs, the complexity of rules and requirements, weak human and institutional capacity coupled with poor governance and perceived higher risks on the continent. Though the cost per project is declining from the high of USD 200,000 due to various interventions by the CDM Executive Board, such as simplification of procedures and bundling of projects, this element remains the most universally referred to impediment to participation of African players in the market.

There is an urgent need to increase the human capacity needed for effective participation in the market from project proposal development to implementation and carbon market operations. Weak governance constitutes a significant barrier especially in the forest sector but this needs a comprehensive approach coupled with development of democratic and civil institutions. Concerted effort for risk reduction and marketing of Africa where the risk perception is undeserved will increase the attractiveness of the African carbon opportunities to buyers.

Africa's potential in the land use sector is enormous. African countries should prepare for active participation in this new and fast growing market, taking advantage of the land use sector where they have a clear comparative advantage. Key to the effective positioning of the continent in benefiting from the carbon market is the necessity to develop carbon policies, strategies and guidelines within the framework of national and international climate change policy.

Acronyms

AAU	Assigned Amount Units (levels of allowed emissions over the 2008–2012 commitment period)
AFOLU	Agriculture, Forestry and Other Land Uses
ALM	Agricultural Land Management
A/R	Afforestation/Reforestation
CBFF	Congo Basin Forest Fund
CDM	Clean Development Mechanism
CFM	Community Forest Management
COP/MOP	Conference of the Parties/Meeting of the Parties
DNA	Designated National Authorities
DRC	Democratic Republic of Congo
EB	CDM Executive Board
ERU	Emission Reduction Unit (issued for emission reductions or emission removals from JI projects)
EO	Earth Observations
ET	Emission Trading
EUAs	European Union Allowances (carbon allowances under the EU-ETS)
EU-ETS	European Emission Trading Scheme
FCPF	Forest Carbon Partnership Fund (World Bank)
GTM	Global Timber Model
IFM	Improved Forest Management
IMAGE	Integrated Model to Assess the Global Environment
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
KP	Kyoto Protocol
l-CERs	Long-term Certified Emission Reduction Units
NAMAs	Nationally Appropriate Mitigation Actions
NICFI	Norway's International Climate and Forests Initiative
OTC	Over The Counter market
PCN	Project Concept Note
PDD	Project Design Document
PES	Payment for Environmental Services
PP	Project Proponent
PRA	Participatory Rural Assessment
REDD	Reduced Emissions form Deforestation and forest Degradation
RMU	Removal Units (credits issued for net sink enhancements achieved by eligible activities under Articles 3.3 and 3.4)
t-CERs	Temporary Certified Emission Reduction Units
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
UN-REDD	United Nations Reduced Emissions from Deforestation and forest Degradation Program
VCM	Voluntary Carbon Market
VCS	Voluntary Carbon Standard
WMO	World Meteorological Organization

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Chapter 14
CLIMATE CHANGE IN AFRICAN FORESTRY: THE BROADER POLICY CONTEXT

Godwin Kowero and Yonas Yemshaw

14.1 Introduction

Climate change is the greatest social, economic and environmental challenge of our time. Scientific evidence confirms that human activities, such as burning fossil fuels (coal, oil and natural gas), agriculture and forest clearing, have increased the concentration of greenhouse gases in the atmosphere. As a consequence, the earth's average temperature is rising and weather patterns are changing. This is affecting rainfall patterns, water availability, sea levels, droughts and bushfire frequency, putting at risk African coastal communities, human health, agriculture, tourism and biodiversity for current and future generations. The climate is already changing, with more frequent and severe droughts, rising sea levels and more extreme weather events.

The IPCC's Fourth Assessment Report suggests that in a 'business as usual' scenario where world-wide economic growth continues and based on fossil fuels, climate change caused by temperature rise is very likely to have widespread and severe consequences, including significant species extinctions around the globe, real threats to food production, and severe health impacts, with dramatic increases in morbidity and mortality from heat waves, floods and droughts (IPCC, 2007).

The environmental impacts of climate change have flow-on effects for all aspects of human society. As the Stern (2006) Report states: "The evidence shows that ignoring climate change will eventually damage economic growth. Our actions over the coming few decades could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes. Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries. The earlier effective action is taken, the less costly it will be."

There are significant risks of unpredictable, potentially large and irreversible, damage worldwide. The frequency and severity of extreme drought is increasing. Higher temperatures cause a higher rate of evaporation and more droughts in some areas of Africa. Warmer temperatures affect human health via increased prevalence of some infectious diseases. There have been some changes in the ranges of plants and animals that carry disease, like mosquitoes. Warming has also caused and will continue to cause changes in the timing of seasonal events and the length of the growing season thereby affecting, among others, agriculture and land based activities.

With several forest types on the African continent, forest ecosystems will respond to global warming in a variety of ways as has already been mentioned in other chapters of this book. Suffice to add and reinforce that the projected increase in temperature will likely shift the ideal range for some forest species. As temperatures warm, species may either move to a cooler habitat or die. If the climate changes slowly enough, warmer temperatures may enable tree species to colonize higher altitudes. Mountain forests could be the first to disappear because when temperatures increase and rainfall decreases, the zone in which they thrive shrinks. Many factors, including the pace at which different species colonize new areas, determine the future composition of forestlands. Where species move into new areas more slowly than other tree species migrate out, the species previously common will still grow, but likely at a different density. Those that are particularly vulnerable include the already endangered tree species, coral reefs and coastal mangroves. Carbon dioxide dissolving into the oceans will continue to make seawater more acidic, and this has potential adverse impacts on coral reefs and other marine life. Mangrove forests, which support fisheries, are highly vulnerable to rising sea levels and to drought.

Forests are strongly affected by a number of disturbances, including fire, drought, insects and diseases. Relatively minor changes in climate can increase forests' vulnerability to droughts, insects and fires. Under the global warming scenarios, insect and pathogen outbreaks will likely increase in severity. In some African woodlands and rain forests, rapid climate change and accompanying extreme events, such as droughts and floods, could lead to increased diseases and insect populations and attacks that could increase tree mortality and, in some cases, replace forests by grasslands. Fires, for example, may become more frequent (Barlow and Peres, 2004; FAO, 2006a). The amount of forest area burned might increase substantially, especially as the amounts of brush and other fuels increase and subsequent droughts combine to increase fire occurrence. Some of the models indicate that forest productivity may increase in certain areas, leading to increased supply of certain types of timber, though possible productivity loss through interactions with extreme events and other disturbances will likely outpace these gains.

In addition, urban and rural settlements, roads and highways, as well as agricultural fields and other human activities limit available habitat and create barriers to the migration of plants and animals. Forests in protected areas like those in national parks and protected national forests were established without considering the possibility of changing climates. Rapid climate shifts may reduce appropriate native habitats within protected areas while developments outside the boundaries of the protected areas could make adjacent new habitat unavailable and limit the creation of migration corridors. Changes in the quality of the habitat could influence the choices animals make in the landscape, and therefore influence their movements and distribution and other population dynamics, including making some wildlife species endemic or extinct (Hassan, 2007; Caughly and Sinclare, 1994). Further, changes in land use, for example due to deforestation, land degradation and urbanisation, limit the range of wildlife areas and bring wildlife and human beings into contact. This has led to increased human–wildlife conflicts, in addition to human contacts with disease carrying organisms, such as rodents (Perry and Fetherston, 1997). Diseases can spread rapidly from wildlife to domestic animals and vice versa, and with devastating effects.

Therefore, dealing with the climate change challenge is critical to Africa's economic security and future prosperity. The scale of the challenge is now widely recognized (IPCC, 1996, 2001) and many African governments are moving steadily to implement their national climate change mitigation and adaptation strategies.

This chapter examines the context or framework within which policies to bear on climate change is made, and will probably continue to be made. Since policies are about issues, the chapter starts with a brief account of identified policy issues that are directly and indirectly related to climate change, globally, at African regional level, at national and personal levels and in different sectors of national and global economies. It then addresses selected related issues that feature prominently, but are not always confined to the forestry sector. However, because measures relevant wildlife resources are adequately discussed in section 3 of this book, this chapter will be devoted to issues relevant to the forestry sector and only make brief reference to the wildlife sector where appropriate.

14.2 The policy environment

Climate change dialogue and policy has evolved rapidly in recent years. Debate about climate change has moved on from discussions about whether change is happening and whether humans have caused it, to what should be done about it and how. However, the debate is now gravitating more towards the relative allocation of responsibilities between developed and developing nations both to reduce emissions and shoulder the cost of adaptation.

The burden of climate impacts is highly uneven. While developed countries emit the majority of GHGs, developing countries, especially those in Africa, are more vulnerable because of warmer temperatures, less precipitation and more ecological and climatic variation across the continent. This situation is exacerbated by greater dependence on agriculture, forests and natural resources, limited infrastructure and low-input extensive agriculture, low income, poverty and malnutrition as well as poor social services (health and education) prevalent in developing countries.

Developing countries' ability to cope, therefore, depends to a large extent on the careful choice of policy actions by their governments and the international community as well as the strategic targeting of areas for policy interventions. In this regard, it is very important to scrutinize the impacts of current policies vis-à-vis climate change and incorporate climate variability and change into future policies. Some of the climate policy actions can come in form of incentives and investment to create and deploy improved technology and management techniques, as well as effective public policy on economy and livelihood diversification. These practical policy actions, however, are surrounded by complex policy questions such as:

- Which options are most likely to have an impact and should be encouraged?
- How can activities that might not provide financial benefit to individuals and businesses be promoted?
- What is the best way to incorporate climate change issues into existing policies?

In general the policies will largely revolve around cultivating appropriate responses to climate change, through adaptation to and mitigation of adverse effects of climate change. However, in Africa for such policies to be effective, recognition has to be given to the complex and yet unclear inter-relationships between food, agriculture, energy sources and use, natural resources (including forests and woodlands) and the African people, in addition to the environment in which all these sectors operate. Policy decisions on climate change will most invariably cover several sectors of the national economies and have to be linked to broader societal development initiatives and policies like the Millennium Development Goals and Poverty Reduction Strategies, in addition to those that are country specific.

In the forestry sector the debate and resources have so far been targeted much more on mitigation of climate change and much less on adaptation to climate change by humans, forests and trees. Mitigation efforts are important in avoiding impact of climate change; however, adaptation activities are very important in alleviating the non-avoidable climate change effects. Clearly there is a need to maintain a good balance between adaptation and mitigation in terms of attention and resources. For if people cannot adapt to the already felt effects of climate change, like the droughts and floods which can increase poverty and dependence on natural forest resources, how can they build up capacity to mitigate or prevent emissions from increasing? ORGUT Consulting AB (2008) emphasizes that "the scale and seriousness of climate change impact within the next few decades on countries of the developing world will not depend on mitigation efforts but on the efficiency of adaptation measures". There is therefore a case for putting up policies and other measures that will increase adaptation to climate change in order to reduce vulnerability and increase capacity for mitigation, and starting with the variety of options available in various countries, and especially learning from indigenous knowledge and practices.

14.3 Mitigating adverse effects of climate change in the forestry sector

Given that current climate change is primarily caused by human activities, the challenge is to find ways of mitigating, or lessening, the negative contribution that human activities make through GHG emissions. And this appears to be the most convenient way out following the increased focus by the international community on measures to reduce these emissions.

The emphasis in mitigating climate change in the forestry sector has evolved from Reducing Emissions from Deforestation and Forest Degradation (REDD), that in addition to reducing emissions from deforestation and forest degradation includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+).

Therefore policy and related decisions on REDD+ in Africa will invariably focus on:

- How to reduce or avoid deforestation and forest degradation.
- Level of deforestation and forest degradation permissible for socio-economic development.
- The compatibility of forest conservation with livelihoods of communities that depend on the same resources, as well as incomes that could accrue to other stakeholders from the same resources; or in other words how to handle the opportunity costs of forest conservation.
- Introduction of sustainable forest management to the majority of African forests, its improvement where it is nascent, and compatibility with the many expectations on forest resources by various stakeholders.
- How to enhance forest carbon stocks.

Many of the components of REDD+ are not new to the forestry sector in Africa. Therefore as a point of departure one has to first look at policies and other experiences on activities and programmes that deal with deforestation and forest degradation, forest conservation, sustainable forest management (SFM), and enhancement of carbon stocks in the forestry sector.

14.3.1 Experiences with combating deforestation and forest degradation

The forest policies that have been implemented in Africa since many of the countries became independent some 50 years ago have targeted reducing deforestation and forest degradation. In many countries there have been restrictions on access to forests for livestock grazing, human settlements and crop production. Efforts have also been made to regulate deforestation through selective harvesting of natural forests, and in many cases guided by annual allowable cut in order to sustain timber supplies. In addition, there are national forest programmes (nfps) in many African countries and programmes/projects/activities that implement various international agreements, initiatives and conventions, like the United Nations Convention on Biodiversity (CBD), United Nations Convention on Combating Desertification (UNCCD) and the Non-Legally Binding Instrument on all forest types by the United Nations Forum on Forests (UNFF-NLBI). All of these target unwanted deforestation and forest and land degradation. In short African countries have invested considerable resources in implementing both nationally crafted policies and those from international initiatives to improve forestry.

The forest sector continues to support local livelihoods and national economies, and protect the environment. However, despite all these good contributions deforestation and forest degradation continue to increase in many African countries. The forest cover continues to decline, and many forest and related problems either have worsened or are yet to be contained. For example, Africa still depends mostly on unsustainable supplies of woodfuel. Industrial timber supplies are declining in several countries that were net exporters of the same in the recent past. The landscape is littered with dilapidated forests and mosaics of cropland, patches of forests and open land where continuous belts of forests used to stand. Rivers that had headwaters in some forests are either dry or are drying up because the water regulatory functions of the forests have been impaired. And the list goes on and on.

According to FAO (2011) forest loss in Africa in the decade 1990–2000 stood at 0.56% per year and declined marginally to 0.49% per year between 2000 and 2010. However, variations occur in the different sub-regions (Table 14.1).

Deforestation and most probably forest degradation, when examined at sub-regional basis, is increasing in the more open forests (dry forests) and woodlands of northern, eastern and southern Africa. In Central and West Africa deforestation and probably forest degradation appears to peak. However, on a country to country basis the picture is different, with some countries having increased or slightly reduced their deforestation rates. Also variations occur within countries, with forest cover increasing in some districts and declining in others.

Table 14.1 Annual forest loss in Africa between 1990 and 2010. Source: FAO (2011).

	Annual change rate (%)	
	1990–2000	2000–2010
Central Africa	-0.25	-0.26
East Africa	-0.92	-1.01
North Africa	-0.72	-0.05
Southern Africa	-0.50	-0.53
West Africa	-1.10	-1.12
Total Africa	**-0.56**	**-0.49**
World	**-0.20**	**-0.13**

The dry forests and woodlands support the bulk of the African people, livestock and wildlife; and cover almost three times the area under rain forests. They also support almost five times more people than those supported by the rain forests. In these forests deforestation and forest degradation are closely related to human and animal interactions with the forests and woodlands for survival. On the other hand, in the tropical rain forests deforestation and forest degradation is not so much due to support of human livelihoods (though this is increasing), but related more to timber harvesting and processing.

According to FAO (2009) the main causes of forest area changes in Africa are direct forest conversion to small scale permanent agriculture (59%), direct conversion to large scale permanent agriculture and industrial forest plantations (12%), intensification of agriculture in shifting cultivation areas (8%), gains in forest area and canopy cover (8%), expansion of shifting cultivation into undisturbed forests (4%) and other causes (9%). Clearly direct conversion of forests into permanent agriculture is the main cause for forest cover change in Africa, accounting for 71% of the observed change.

In general, the emerging picture is one of long experience in Africa, for almost half a century, in controlling deforestation and forest degradation without significant gains. Reasons for this could include policy failures or absence of relevant policies in both forestry and related sectors. Secondly, deforestation and forest degradation are accelerating at a faster pace in the dry forests and woodlands as opposed to the tropical rain forests. Thirdly, the forces behind deforestation and forest degradation are similar in both forest types, but with industrial harvesting being the main reason in closed forests and support to human, livestock and wildlife survival predominant in the dry forests and woodlands. Fourthly, direct conversion of forests into permanent agriculture is the biggest driving force for deforestation. Fifthly, deforestation and forest degradation are linked to overall national socio-economic development. And lastly, deforestation

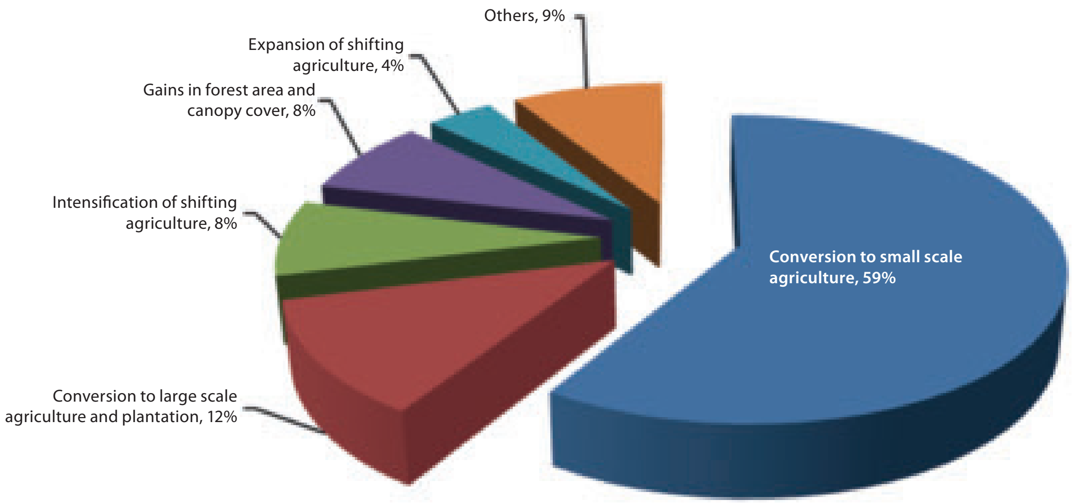

Figure 14.1 Main causes of forest area changes in Africa. Based on FAO (2009).

and forest degradation is not happening uniformly within the sub-regions or within countries. This underlines the essence of combining national and location-specific policies and other measures to address these issues.

Effective implementation of REDD+ in Africa, and specifically with respect to reducing deforestation and forest degradation, will therefore have to take into consideration at least these seven observations. There will be need to examine the adequacy of policies and institutional aspects that guide implementation of activities that target deforestation and forest degradation at national, sub-regional and regional levels. There cannot be a single forestry related policy guidance for the whole of Africa that can adequately contain deforestation and forest degradation. These two phenomena are intertwined with the overall process of socio-economic development. African forests and trees underpin key sectors of the economies of many African countries, providing the bulk of the energy needs, supporting crop and livestock agriculture, wildlife and tourism, water resources and livelihoods. It is therefore necessary to adequately involve these and other sectors in developing policies, incentives and activities that will eventually result into reduction of emissions from deforestation and forest degradation. The opportunity cost associated with measures other sectors take in this direction should be taken care of if these policies and activities are to be attractive and effective. ORGUT Consulting AB (2008) notes that any policy intervention will require a "…detailed understanding of the complex set of proximate causes and underlying driving forces affecting forest cover changes in a given location…".

14.3.2 New and emerging drivers of deforestation

14.3.2.1 Increasing demand for food

Changes in food demand, in totality and by patterns, hold potential to increase deforestation through increased demand for cropland. ORGUT Consulting AB (2008) reports a 75% decline in real food prices between 1974 and 2005 followed by a 75% price increase between 2005 and 2008 for practically every food commodity. The drastic price increase is reported to be a combination of factors that include rapid income growth in low income countries that was associated with increased food consumption (because people could afford to eat better) and changing patterns of food demand. Africa has been registering positive economic growth since the mid-1990s after decades of economic decline. For example, Sala-i-Martin and Pinkovskiy (2010) report that from 1995 poverty in Africa has been falling steadily, with income distribution increasingly becoming less unequal than it was in 1995, and with the poor taking a considerable proportion of this growth. Food demand will continue to increase in Africa as a result of increasing population (one billion people in 2010) and changes in food patterns, putting more pressure on the declining natural forest estate for cropland.

14.3.2.2 Demand for and production of biofuels

Another factor affecting the dramatic global food price rises has been argued to be the rapidly rising fossil fuel prices, going well above USD 100 per barrel of oil in 2008. Biofuels are liquid fuels manufactured from biomass (Cotula, 2008). This rise in prices of fossil fuels has increased the profitability of biofuels, making it more profitable to divert maize and other food crops to biofuel production, because with oil prices ranging between USD 60 and 70 per barrel biofuels become competitive with petroleum in many countries (ORGUT Consulting AB, 2008). The increased production of biofuels has reduced the supply of crops like maize and some oil crops for food, thereby increasing their prices to consumers.

There is also a shift in patterns of food consumption as incomes improve. With the noted improvements in poverty in Africa and a high rate of urbanization these patterns are likely to be more visible in the not too distant future.

All these factors combine to exert more pressure on land in order to meet demands for food and biofuels. Currently biofuel in Africa is mainly bioethanol derived from starch crops like maize and sugar cane, and biodiesel derived from vegetable oils like those derived from jatropha, soy, and palm. There has yet to be developed technologies (second generation technologies) for producing lignocellulosic bioethanol that could be derived from grasses, bushes and trees.

The production of biofuels competes with food crops for land, labour, capital and entrepreneurial skills. Further, they can also result in undesirable environmental impacts such as deforestation, soil depletion and biodiversity loss. In other words, the ‘fuel versus food’ debate is raising the alarm on the need to avoid the dangers of negative socio-economic and environmental impacts that could be associated with competition for agricultural land, land ownership, and insufficient value creation for local farmers, among others. These challenges appear to be further exacerbated due to limited availability and sharing of information and experiences on biofuel in the African region, as well as between African and the outside world.

Unfortunately, as this debate goes on, the major fuels of concern for the majority of the African people, firewood and charcoal are neglected in the debate. They are of much greater concern for Africa. Their sustained supply is critical, and so is containing the deforestation and land degradation associated with their supply.

In formulating policies and other measures to contain climate change, one has therefore to consider the combined effect of deforestation and land degradation arising from production and consumption of firewood and charcoal, in addition to that which could arise from the production of first-generation biofuels.

The implementation of large scale biofuel undertakings, especially in form of large scale plantations, has the potential to constrain the achievement of multiple goals for rural development that are not always compatible. The development of comprehensive and effective biofuel policies and strategies in African countries is therefore imperative. Policy and strategic frameworks should at least outline clear pathways for efficient production, employment creation, market development and marketing, prevention of land use conflicts, and improvement of livelihoods and national economies. It is advisable that these frameworks are formulated and guided by a set of principles and long-term goals that form the basis for making rules and guidelines to give an overall direction to planning and development. In this regard, biofuel policies and strategies in Africa should focus on at least four key areas, in addition to the several policy recommendations in FAO (2008) and Cotula *et al.* (2008).

First, they should aim at protecting the poor. High energy prices initiate or exacerbate price volatility of agricultural commodities, and could adversely impact on food security. Therefore, safety nets are required to protect the poor net food buyers.

Second, bioenergy policies and strategies should take advantage of opportunities. Biofuel demand is potentially the largest source of new demand for agricultural commodities. African countries, in particular, are well-positioned to benefit from increased global demand for biofuel related agricultural commodities, if proper policies are formulated and effectively implemented.

Third, biofuel policies and strategies should facilitate development of markets and growth in trade in biofuels. For example, governments could grant exemption of biofuels from overall fuel taxes in order to encourage their production and consumption, hence stimulating an increase in employment and incomes to farmers.

Fourth, biofuel policies and strategies should ensure environmental sustainability. Future support for biofuels is likely to be assessed against sustainability criteria. For example, incentives for biofuels production on degraded lands and restrictions on types of land to be used for the production of biofuels such as wetlands, grasslands, and undisturbed forests hold potential for environmental protection.

Consideration in biofuel policies and strategies should not be limited to first-generation biofuels, but also be expanded to the broader field of bioenergy so as to include sustainable management of forests and woodlands in order to secure sustained supplies of firewood and charcoal. In addition, policies should seek to improve efficiency in harvesting trees for firewood, in the use of firewood, and in charcoal production. The production and use of fuelwood (firewood and charcoal) merits much more attention in bioenergy policies since the majority of people in Africa use these fuels for cooking, heating, drying/curing agricultural crops like tea, tobacco and fish.

Eventually the main land based activities like crop production, livestock keeping and forest production, will have to be harmonized with biofuel production since they will all make claims on same land. Such harmonization should be guided by policies and actions that ensure that these activities are planned and implemented in ways that minimize emissions from deforestation and forest and land degradation. Therefore, if Africa is to take full advantage of the opportunities from bioenergy it will require a functioning hierarchy of policies, strategies, programs and projects.

14.3.3 Reducing deforestation and forest degradation, increasing forest conservation and eliminating poverty

ORGUT Consulting AB (2008) reports that efforts to support poverty reduction through forest projects funded by ODA over the last few decades have not achieved their desired objectives. Also projects that employ 'payment for environmental services' (PES), the approach implicit in REDD+, are also observed to have had mixed results. Further, experience with forest carbon projects are also reported to generate few benefits for the poor. Peskett and Harkin (2007) report that forestry carbon projects are risky investments in developing countries because forest carbon storage can easily be reversed by people either using the forests and/or the land on which they stand. This therefore affects the permanence of carbon emissions reductions.

As observed earlier the highest deforestation and forest degradation rates in Africa occur in the dry forests and woodlands where the pressure for land is continuously increasing, poverty is rampant, livelihood options are few and climate change effects are severe and are expected to become even more severe. And many of the countries also have weak institutional structures for forest governance. In addition land and forest tenure and rights of access to forest and woodland resources are either not clearly defined or are non-existent to many people. Within such an environment it becomes very difficult to implement policies that will not allow or will seriously restrict people from, for example:

- cutting trees and clearing forests for cropland,
- collecting fodder for livestock or grazing livestock in the forests and woodlands,
- collecting firewood and burning charcoal,
- harvesting timber and poles for domestic housing needs,
- collecting a myriad of non-forest products that support their livelihoods.

These are the activities that are prevalent in African dry forests and woodlands, activities which hold potential to reduce poverty.

REDD+ policies in specific forest types will therefore have to address the allowable deforestation needed for socio-economic development and provide access for people who depend on these resources but in a regulated way that minimises adverse impacts on the resources and at the same time contributes to their conservation. In other words REDD+ policies will have to factor in tenurial and access rights to all who depend on forests and woodland resources and in ways that adequately address the associated opportunity costs so as to realise meaningful reduction of emissions.

When construed in this manner REDD+ could then be implemented in a given area with the goal of reducing emissions and with constraint that the people who depend on that forest resource will not be made worse off through such a process. This is because the objective of reducing emissions and that of poverty reduction can hardly be achieved on the same forest. There has to be some trade-off between the two objectives. Implementation of REDD+ cannot guarantee that poverty will be eliminated, and that should not be the focus of REDD+ because poverty alleviation can only be brought about by a much broader set of carefully structured and implemented policies and activities. Therefore the implementation of REDD+ should be guided by policies and programs that focus on attaining a certain level of reduction of emissions while not adversely affecting the poor. This approach is similar to that of managing wildlife resources in game reserves and animal parks, with wildlife management as a primary goal in essentially forested areas; or managing natural forests for industrial timber production as the primary goal, while also securing the achievement of other important objectives. This means that all activities that support livelihoods, incomes to governments and other flows to key stakeholders should first be evaluated as to their potential to reduce forest cover and eventually impair the capacity of the forest as a sink. This is the underlying principle in multiple use management of forest resources. Some of the uses will have more impact on forest cover than others (Figure 14.2).

Many activities, like collection of firewood, edible fruits and other foods, honey and medicines from the forests, and livestock grazing if carefully

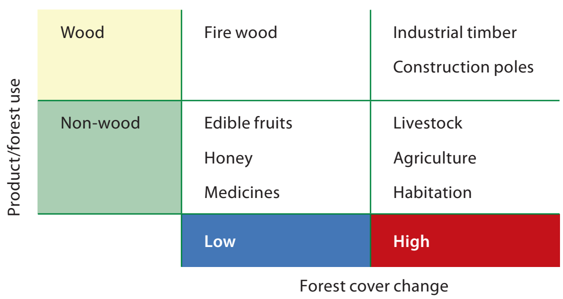

Figure 14.2 Relationship between forest product extraction/forest use and forest cover change.

planned and supervised, might not disturb the forest cover. They can be undertaken in the forest that is also managed under a REDD+ objective. However, some activities like harvesting industrial timber and poles for housing construction in rural areas, clearing patches of the forest for agriculture and habitation, as well as grazing livestock that browses on young trees and even destroys trees, will reduce the forest cover. In the dry forests and woodlands harvesting for industrial timber, if done carefully will not reduce the forest cover appreciably. In many such forests this means taking out 1–3 m^3 per hectare or a few trees per hectare. It is the logging operation that might open up the canopy further, for example through logging road construction and felled trees falling on others. To incorporate industrial timber harvesting, estimates of canopy cover change due to logging should be made and the effect of such operations on the capacity of the forest to sequester carbon estimated, so as to enable the calculation of the desired level of reduction of emissions. Within such a context it will be possible to determine the REDD+ target for a forest that would allow for harvesting of industrial timber and poles. Therefore a forest can be managed with multiple objectives like production of industrial timber and non-timber forest products, grazing of livestock, reduction of carbon dioxide emissions, protection of soils and water supplies, and production of building poles. Therefore REDD+ introduces the necessity to include a desired level of reduction of emissions as one of the objectives for forest management.

Lastly, the benefits that are generated by implementing REDD+ activities would require policies that guide their equitable distribution among the different stakeholders, and in ways that will provide positive incentives that would eventually change behavior and actions away from deforestation and forest degradation. The policies should also facilitate the promotion of compliance with rules and regulations and other activities that will enhance sustainable management and use of the forest resources.

14.3.4 Approaches more specific to the forestry sector

Much of the deforestation and degradation of forests, which in turn contributes to climate change, can be prevented through sustainable management of Africa's forest resources. In this regard, it is essential to adopt policies, approaches and practices that promote SFM. The adoption of SFM practices should be context specific based on the forest types and the socio-economics of the people who depend on the resources.

The national forest programs (nfps) are essential instruments of SFM at the national and sub-national levels. The nfps entail a wide range of approaches to policy in the forest sector for the implementation of the complete policy cycle. This ranges from policy formulation and policy implementation to policy monitoring and policy reforming. The national forest programs have come out of international forest policy dialogues, and as such they serve as a consensual framework for sustainable forest management. In this way, nfps positively contribute to climate change mitigation and adaptation in the context of SFM.

Within the context of nfps, countries can be encouraged to set targets to reduce deforestation over a chosen period with the aim of achieving minimal deforestation rates by target years. This could be done by specifying clear and separate commitments for both avoided gross deforestation and forest degradation on one hand, and increased sequestration through forest restoration and sustainable forest management on the other.

The primary use of African forests and trees is for domestic energy. Hence, policies and approaches that improve energy efficiency are critical. This includes improving not only the efficiency with which biomass energy is consumed but also the efficiency with which trees and forests are harvested and converted to energy and other products for both domestic and industrial uses. This can significantly reduce deforestation and forest degradation.

Consideration should also be given to policies that increase the supply of forest and tree products and services. With declining forest estate and increasing demand of these products and services due to population growth and socio-economic development more forest and tree resources are needed (Varmola *et al*., 2005; FAO, 2006b). Policies and incentives are, therefore, needed to support growth of private sector, local communities and individuals in forest and tree business. The Clean Development Mechanism (CDM) (and its post 2012 version) and REDD (in its various forms – REDD, REDD+, etc.) fare differently under the diverse African conditions, given the critical role of forests and trees in the African socio-economic fabric. The Clean Development Mechanism is restricted to afforestation and reforestation, as defined under the Kyoto Protocol, and this does not suit many African forestry conditions. It is difficult for Africa to adequately participate in CDM activities because of the conditionalities and complexities involved in the process. The procedures, costs and capacity requirements for developing qualified CDM projects seriously inhibit Africa's participation in this mechanism. Hence relative to other regions of the world, there has been little interest in CDM in African forestry. Political and tenurial uncertainties, together with unstable investment environment, have also contributed to diminished interest on the part of CDM investors in the forest sector.

African countries will need assistance to build their capacity to assess forests both for their ability to maintain or increase human resilience to climate change, or to assess where forests are specifically vulnerable to climate change. Countries need to continuously monitor their forest ecosystems and changes in them in order to be able to make continuous adjustments.

Management practices that maintain essential ecosystem services should also be promoted while ensuring that national forest programs address climate change impacts, vulnerabilities and options for adaptation. These include maximizing juvenile and reproductive population sizes and genetic variations of planted seedlings, including maintaining inter-population movement of pollen and seeds. Levels of slash need to be minimized through reduced impact logging. Stronger fire control measures need to be put in place as well, such widening buffer strips or fire breaks (Guariguata *et al*., 2008).

Markets have to be developed for environmental services (particularly those arising from water protection, climate change and biodiversity), and based on secure property rights in order to provide the revenue required to support the provision of those services; as well as serving as a more equitable way for society to exert influence over which national and global values are delivered.

New and hybrid modes of forest governance are required to replace the traditional mode of forest governance in order to handle higher levels of uncertainty associated with climate change and the complexity of climate change brought about by the wide range of new actors and interest groups. This situation is further complicated by spillover effects from policies in other sectors like agriculture and transportation. Therefore it is necessary to promote the transparent, inclusive and accountable way of governance of forests to achieve fair and effective outcomes (Seppälä *et al*., 2009).

As part of good governance, countries in the south and in the north need to take into account climate commitments regarding their procurement and consumption of goods that drive deforestation. This can be facilitated by developing and helping to implement sustainability standards for biofuels, timber products, agriculture and livestock products, through procurement policies and other mechanisms. The approach should be building on the criteria and standards already developed or being developed under various forestry processes while continuing to develop product tracking mechanisms and passing laws that exclude the import of illegally or unsustainably produced products. This should go hand in hand with the need to ensure that sufficient sustainable forest resources are available.

Related to governance are concerns for indigenous people and forest dependants. The definition of indigenous people could be complicated by various local political situations. However, it is vital to support the rights of indigenous peoples and marginal forest communities if these initiatives are to succeed. Therefore the rights of indigenous peoples and other forest dependents have to be considered in a transparent and participatory manner. In addition the free and prior informed consent of these communities will have to be obtained when setting aside forest lands for REDD+ purposes (Smith and Scherr, 2002). Financial and economic opportunities provided by the communities participating in REDD+ activities should be attributed to them and in an equitable manner.

Carbon trade related to the African forestry sector is still small, but with potential to grow. The constraints in trade include high transaction costs of engagement (Schlamadinger and Marland, 2000; Torvanger *et al.*, 2001). Also lacking is adequate information on carbon benefits to potential buyers, information on project partners, and capacity for organizing project participants and ensuring parties fulfill their obligations. Transaction costs per unit of emission reduction are higher for projects involving many smallholders and forest communities.

Carbon trading therefore requires effective integration from global governance of carbon trading to sectoral and micro-level design of markets and contracts, and investment in community participation in the markets. The impacts of climate policies on economic growth, agriculture, food security and poverty in developing countries can be influenced by level of caps by sector and industry, sector specific mitigation options, incentive for international carbon trade, as well as transparency and complexity of administration.

There is also a need to increase considerably the support to existing forest and related initiatives and programmes. Existing national forest programmes (nfps) in many African countries and programmes/projects/activities that implement various international agreements, initiatives and conventions (like CBD, UNCCD, and UNFF-NLBI); all target unwanted deforestation and forest and land degradation. Support to these initiatives in Africa will considerably facilitate the attainment of the REDD+ objectives.

Whether or not there is carbon money through REDD+, the practice of forestry should be remolded within the context of designing plans and implementing them in ways that minimize these emissions. That should become another dimension of the forestry ethic or culture.

14.3.5 Other related issues

Other policy tools for mitigation include setting of national emission reduction targets, carbon capture and storage as well as encouraging greener technologies to reduce emissions. Technological innovation in forestry and ex-sectors tends to be market-led and is directed towards maximizing output, quality and profit. Potentially there are, however, technological innovations that could contribute to the public good and benefit society at large (such as mitigating GHG emissions). However, since the potential for making profit from innovations that deliver public goods is limited, research and development in this area has been rather constrained. The intervention by governments and other institutions is therefore required to direct research and technology development to those areas that will help the wider public through reduction of the GHG emissions. Equally important, the private sector should be encouraged to invest in a wide-ranging portfolio of low-carbon technologies. Despite the availability of such technologies for energy, transportation and manufacturing, there is little motivation for the industry to use them. Often, widespread use of new technology is most likely when there are clear and consistent policy signals from governments, and of course the markets.

14.4 Adaptation to adverse effects of climate change

Another response to climate change is adaptation. Adaptation is defined as the adjustment in natural or human systems to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Science is telling us that some effects of climate change are already unavoidable in the short term. In Africa many societies have adapted, and continue to adapt, to many vagaries of climate change and variability like floods and droughts. But the intensity with which climate is changing, in addition to many difficult conditions experienced on the continent that include poverty, diseases, crop failures, low incomes and global recession, among others, will seriously weaken the human, animal and plant resilience to climate change and variability.

Climate is also affecting the forests and trees. These support virtually all life on land on the continent. How forests and trees are adapting to climate change is yet to be adequately addressed. Understanding this is critical to designing any effective mechanisms to deal with climate change using forests and trees. The forestry sector has to design adaptation measures for its forests in order to ensure that services provided by forests and trees are not impaired by climate change. Such measures will vary with forest type, location, management objectives, expectations from climate change effects, among other factors. It is very critical that any adaptation frameworks ensure that forest managers have the flexibility to select the most appropriate measures to suit their specific situations (Seppälä *et al.*, 2009).

Other than forests, climate change is negatively affecting wildlife and has contributed to increasing human-wildlife conflicts. Responses to minimize impacts of climate change on wildlife should include expansion of protected areas, where possible, and limiting commercial hunting, as well as enhanced trans-boundary cooperation and enforcement of international agreements. A strategy for stemming habitat loss and 'overharvesting' could also contribute to addressing this issue.

Nevertheless, adaptation has taken place and continues to do so in many places without policy intervention. For instance, as farmers recognize the impact of climate change on crop yields, they alter their practices to maximize yields in a new situation. Farmers may change the timing of farm operations, the choice of crops or livestock breed or the mix of their enterprises. Policy intervention and incentives may be required, however, to ensure that farmers can respond when they need to and that support is available as farmers consider their options.

Governments need to ensure that the right mix of policies and tools are available to African farmers, businesses, households and communities to understand and prepare for or anticipate climate change pressures before they occur, as well as to adapting to the climate change that is already here. For example, adapting to the unavoidable impacts of climate change will require African governments to change the way they manage natural resources and deliver public services.

Adaptation to climate change could also be construed as an extension of good development policy, like promoting growth and diversification of the economy in order to increase options for investment, employment and incomes of farmers; increasing investments in research, development, education and health; and creating markets for environmental services like carbon and water. Included in these good policies are those that enhance the national and international trade system; facilitate better ways for handling natural disasters by enhancing resilience, improving disaster management, and promoting risk-sharing that includes social safety nets and weather insurance.

Effective adaptation policies require judicious selection of measures within a broader policy context and strategic development framework. They must go beyond conventional good development policy to explicitly target the impacts of climate change, particularly the impacts on the poor. Market signals are essential factors in determining the necessary responses to a changing environment. But they often involve potentially expensive time lags and overlook equity. Climate change adaptation must therefore be timely and proactive, and not merely reactive.

Adaptation to climate change in Africa is urgent and requires substantial resources. It is unlikely that developing countries, in particular the least developed countries, have the financial resources and technical knowledge for the required anticipatory and planned interventions. Financial and technical assistance will also be required for the additional costs of designing and implementing interventions. Climate change is local and location specific. Methodologies to assess adaptation need to analyze local impacts in detail in order to understand and plan relevant interventions but recognize that, at implementation, it will be necessary to include the interventions into larger scale/national adaptation programmes.

14.5 Conclusions

This chapter has examined the context within which policies on climate change are made at different geographical and organizational levels and at different sectors of national and global economies. This concluding part of the chapter highlights the key issues raised in the chapter.

14.5.1 Climate change in a broader context

In Africa, it is critical that climate change measures are pro-poor because they are the ones affected and will continue to be affected more seriously. And they do not have resources, including financial and technological support to cope with adverse effects of climate change.

Policies, strategies, and programmes that are most likely to succeed are those that will link with efforts aimed at alleviating poverty, enhancing food security and water availability, combating land degradation and soil erosion. They should also address the erosion of biological diversity and ecosystem services as well as how to enhance adaptive capacity within the framework of sustainable development.

Climate change policy hold potential to create a product (carbon) for pro-poor investment, thereby enhancing the profitability of environmentally sustainable practices. In order to exploit such a potential it will be necessary to address a number of constraints including social inequalities, access to land and natural forest resources (Smith and Scherr, 2002) access to credit, education and decision-making. The Millennium Development Goals and Poverty Reduction Strategies provide the framework for integrating climate change adaptation and mitigation into development policy.

Risk transfer mechanisms should be included in adaptation strategies from the national to the household level. Economic diversification within sectors needs to be prioritized to reduce dependence on climate-sensitive resources like water, trees and forests, wildlife, agricultural crops and livestock. This is particularly important for countries that rely on narrow ranges of climate-sensitive economic activities, such as the export of limited climate-sensitive crops as well as on wildlife based tourism.

Among the rural poor, there are many concerns that are more immediate than tackling climate change. This can hinder the adoption of climate change measures. The priorities of current forestry and ex-sector policies (that have been made with minimal attention to climate change) drive the economies of individual countries, and can therefore represent a barrier to taking up additional measures for climate change adaptation and mitigation because they lack provisions for this. Therefore reforming such policies would be one way of removing such barriers.

Availability of reliable and sufficient and timely information is also crucial, and this is actually one of the big constraints in climate change work. At this early stage of addressing climate change, national governments could, for example, intervene in order to ensure that appropriate information is available through their own sources and by catalyzing the establishment of an information base that links with a network of media, private sector, academia and research, non-governmental organizations and other stakeholders.

The level of awareness of the climate change challenge, as well as of the roles forests and trees have in it, has improved significantly in recent times. However, more political will is needed to make this awareness impact on policy. Policies will be more effective when consideration for mitigation is also linked to adaptation.

Issues of reliable measurement (IPCC, 2000), reporting and verification system (MRV) remain a concern. Establishing international capacity and advisory services, regional centers and networks to support activities like forest carbon trading, measuring soil carbon, linking local/rural communities to global markets and mediating between investors and local communities, in addition to capacity building at national and local levels, are critical. Further, such centers and networks could facilitate the simplification of procedures for small scale projects to effectively trade in carbon.

Serious efforts should be made to enhance the governance of global, regional and national financial facilities to effectively and efficiently manage funding flows for both mitigation and adaptation initiatives.

It is important to ensure that policies at all levels recognize and result in mechanisms that promote sustainable forest management and encourage substitution and the sustainable use of renewable resources. This means that policies and activities for implementation of REDD+ will have to be aligned with other national policies, plans and programmes.

14.5.2 Climate change and forest resources

Because of the diversity of forest types and conditions, deforestation profile, as well as capacities of individual African countries, there is a need for context specific policy and action to climate change with focus on creating new value-added for propoor investment.

Forests should not only be viewed as carbon sinks, but their relevance should also include their role in the socio-economic lives of the African people, as well as the ecosystems services they provide.

Any strategy to address climate change in Africa must also enhance the livelihood of people who depend on forests; the rights of indigenous people, women, youth and other vulnerable groups through clarifying tree and land tenure and rights.

Support should be given to existing policies, incentives plans and activities, in the public and private sectors, by local communities and individuals and other actors that increase supply of forest and tree products and services, because they do not only target reducing deforestation and degradation, but also increase sequestration of carbon through reforestation and afforestation. These are the key to containing adverse climate change impacts.

Policies and approaches that improve energy efficiency are critical, given the overwhelming dependence on forests for energy in Africa. Demand side interventions should focus on increasing efficiency and sustainability of harvesting, processing, as well as consumption of forest products for various purposes, notably for energy, food, and fibre.

The Clean Development Mechanism restriction to afforestation and reforestation as defined under the Kyoto Protocol does not suit many African forestry conditions. This is in addition to the complex CDM modalities and procedures, among other constraints that hinder development of qualified CDM projects.

The REDD, in its various forms (REDD+, etc.), must not be seen as a sector specific issue, but must be integrated into overall national development planning, while remaining consistent with overall global mitigation strategy. The scope of REDD is limited and needs to be expanded to cover all types of land uses including agriculture, agroforestry and other land uses (AFOLU). To improve on REDD initiatives it is necessary to learn from the failings of CDM.

Forest types and conditions in Africa are very diverse and interact with climate in complex ways. For each forest type and condition, there is need for accurate data, for example on forest cover, deforestation, degradation and biomass productivity, since these are crucial in determining the role and capacity of the forests in mitigating and adapting to climate change. African countries therefore have to address climate change more seriously in their forest policies and plans by building the knowledge and information base, in addition to their capacity to engage effectively in global arrangements for addressing climate change. The existing knowledge base and capacity in Africa to respond to climate change through the forest sector is weak.

14.5.3 Climate change and wildlife resources

Climate change is negatively affecting wildlife and increasing human-wildlife conflicts. Policies and strategies for stemming such conflicts, in addition to containing habitat loss and 'overharvesting' are required in many countries.

Responses to minimise impacts of climate change on wildlife should, for example, include expansion of protected areas where possible, limiting commercial hunting, as well as enhanced trans-boundary cooperation and enforcement of international agreements.

Establishing seasonal feeding areas and improving connectivity of habitats to facilitate dispersal to appropriate habitats are some of the measures that could be included in climate change adaptation strategies for wildlife.

Involvement of local people in planning and implementation of interventions in wildlife management and use is critical to securing local level participation, sharing of costs and benefits, and limiting human-wildlife conflicts.

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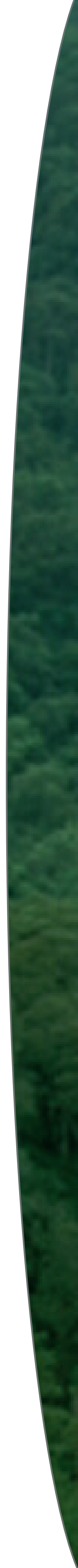
SECTION 5

KEY OBSERVATIONS



Chapter 15
SOME KEY OBSERVATIONS AND ISSUES ON CLIMATE CHANGE AND AFRICAN FOREST AND WILDLIFE RESOURCES

Godwin Kowero, David Okali, Emmanuel Chidumayo and Mahamane Larwanou

Introduction

This chapter presents some highlights on each of the preceding chapters. It therefore provides the reader who cannot read through the book with an idea of the main observations and issues raised in each chapter. By reading this chapter, the reader will be able to select the chapters requiring further reading in order to obtain more details. For easy reference, the sub-sections in this chapter are based on the titles of preceding chapters.

Chapter 2: Climate change processes and impacts

1. *Human-induced climate change is expected to continue* in the 21st century in response to the continued increasing trend in global greenhouse gases (GHGs) emissions.

2. *Although climate change is affecting all countries* of the world, a major impact of climate change in sub-Saharan Africa is its adverse effects upon the natural resource base. Countries in this region of Africa are expected to be hit earliest and hardest because the livelihoods of its inhabitants are largely dependent on the utilization of climate-dependent natural resources.

3. *As elsewhere in the world, an increasing trend* in surface mean temperature has been observed for the African region using historic climate data. The trend in annual precipitation indicates a small but statistically significant decline in rainfall over Africa.

4. *Many of the forests in Africa are situated in high altitude* mountain regions, and are important sources of water. They act as storage and distribution sources of water to the lowlands, providing the greater part of the river flows downstream. Careful management of mountain water resources must therefore become a global priority in a world moving towards a water crisis in the 21st century. Reduced water availability will have adverse health effects. The water supply situation in Africa is already precarious and the water stress will be exacerbated with climate change. Less water will result in increasing gastrointestinal problems. As water resource stresses become acute in future water-deficit areas of Africa as a result of a combination of climate impacts and escalating human demand, the conflict between human and environmental demands on water resources will intensify. In addition, because maintenance of healthy ecosystems is an underpinning to economic sustainability, there is need in each water basin management unit to identify and factor into development projects the need for environmental flows.

5. *Africa's vulnerability to climate change* and its inability to adapt to these changes may be devastating to the agriculture sector, the main source for

livelihood to the majority of the population. The vulnerability is due to lack of adapting strategies, which are increasingly limited due to the lack of institutional, economic and financial capacity to support such actions.

6. *The utmost concern should therefore be a better understanding* of the potential impact of the current and projected climate changes on African agriculture and to identify ways and means to adapt and mitigate its detrimental impact.

Chapter 3: Adaptation to and mitigation of climate change in forestry

1. *Globally, forest ecosystems have also experienced various threats* due to the impacts of climate change. These threats vary with regions, but are generally reflected through changes in growth rates, species composition and density and shifting of ecosystems. Expected impacts for Africa include the loss of biodiversity and vegetation cover as well as the degradation of soil productive capacity. The various manifestations of the impacts have been attributed to factors like recurrent droughts and climate variability. Human factors such as deforestation have for long been identified as catalytic factors to climate change in contributing to accelerating the impacts of climate change on forest ecosystems.

2. *Many changes have already been observed in Africa's forests* and other tree-based ecosystems that can largely be attributed to climate variability and change, particularly drought. The loss of forest resources is seriously impacting people's livelihoods and well-being in Africa, as well as on the incomes of various nations and on the environment. Various adaptation and mitigation measures have been developed and in some cases adopted in response to these impacts in Africa. Sustainable forest development in Africa requires integrating livelihood, climate adaptation and mitigation initiatives with forestry, agriculture and other land based activities.

3. *While Africa is the region most vulnerable* to the negative impacts of climate change, it also has low adaptive capacity. Forests can play a key role in improving adaptive capacity of human societies. This is especially true for rural populations in Africa. The diversity of functions and services provided by forests, such as the provision of wood and non-wood forest products, soil fertility, water regulation and biodiversity conservation, give the forests a potentially significant role on adaptation approaches undertaken through different natural resources and land based sectors including agriculture, water, energy and rangeland management. Moreover, trees and shrubs in farming systems, including agroforestry, have always played an important role in protecting agricultural soil from erosion and sand storms, thus contributing to sustainable agricultural production and food security.

4. *Autonomous adaptation in the context of this book* is used to describe local community measures that include traditional knowledge and practices. These have been spontaneously developed and used by African communities in their attempts to cope with past and current climate viability and change. A number of studies have shown that African communities, particularly at the local level, have historically developed coping strategies to adverse climatic conditions and are currently making efforts to adjust to observed environmental changes. Trees and forest products have always been part of their coping strategies e.g. in agroforestry systems and use of various non timber forest products (NTFPs), particularly during drought. However, and despite the intimate understanding of the forests by these local communities, the unprecedented rates of climate change are expected to jeopardize their ability to adapt to present and future changed conditions.

5. *Planned adaptation is the result of a deliberate policy decision*, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state. Planning adaptation is essential in order to realize the full potential of forests and trees in sustainable development in Africa, both to meet the immediate and future needs of increasing populations and to provide the continuity of the natural resource base. Achievement of this goal re-

quires a comprehensive approach in which a wide range of contributions of forest resources to society is fully appreciated and supported. Planned adaptation measures in forestry, more than any other sector, ought to be considered holistically and in coordination with other sectors. It is equally important to create synergies with interventions aiming at controlling desertification, land degradation and conserving biodiversity, among others. The synergy between adaptation to climate change and biodiversity conservation requires a unifying strategy in order to enhance the sustainability of the forest resource pools on which poor communities directly depend for their livelihoods. Therefore, ecosystem-based adaptation, which integrates biodiversity and provision of ecosystem services into an overall climate change adaptation strategy, can be cost-effective, generate social, economic and cultural co-benefits, and can help maintain resilient ecosystems

6. *One of the biggest challenges for forest planners* in the future will be to increase the general awareness about the role of forests and trees in adaptation to climate change impacts, and to develop livelihood adaptation strategies that ensure the continuity in the provisioning of forest ecosystem goods and services that continue to contribute to food security and poverty alleviation on the continent. Use of indigenous knowledge and local coping strategies should be promoted as a starting point for planning adaptation. Some of the barriers for dealing with forest adaptation include limited economic resources and infrastructure, low levels of technology, poor access to information and knowledge, inefficient institutions, and limited empowerment and access to resources. The range of measures that can be used to adapt to climate change is diverse and includes changes in behavior, structural changes, policy based responses, technological responses or managerial responses.

7. *The National Adaptation Plans of Action (NAPAs)* are provided for through Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC) which requires Non-Annex 1 parties to formulate national and regional programmes to facilitate measures for adequate adaptation to climate change. In many African countries, adaptation strategies were developed either from the NAPAs or were related to other individual governments' efforts in undertaking activities to cope with the effects of climate change. Some adaptation strategies and actions implemented in African countries have involved many stakeholders (local communities, local governments, civil servants, governments, etc.) with variable results. There are examples of failed adaptation strategies and actions as well as successful experiences.

8. *Mitigation of climate change is an anthropogenic intervention* to reduce the sources or enhance the sinks of greenhouse gases. Nationally Appropriate Mitigation Actions (NAMAs) are voluntary emission reduction measures undertaken by developing countries and are reported by national governments to the UNFCCC. They are expected to be the main vehicle for mitigation action in developing countries, and can be policies, programs or projects implemented at national, regional or local levels. The NAMAs are a relatively new concept, and consequently opportunities for developing countries to develop NAMAs to support low carbon development and mobility have not been fully realized.

9. *The Kyoto Protocol has established innovative mechanisms* to assist developed countries to meet their emissions commitments. The Protocol created a framework for the implementation of national climate policies, and stimulated the creation of the carbon market and new institutional mechanisms that could provide the foundation for future mitigation efforts. The first commitment period of the Kyoto Protocol, within which developed countries included in Annex 1 to the Protocol are to achieve their emission reduction and limitation commitments, ends in 2012. The Protocol has an accounting and compliance system for this period, with a set of rules and regulations. Developed countries are under an obligation to demonstrate that they are meeting their commitments.

10. *At the 16th UNFCCC Conference of Parties (COP16)* in December 2010, considerable progress was made through *'Decision 1/CP.16, The Cancún Agreements: Outcome of the work of the Ad-Hoc Working Group on Long-term Cooperative Action under the Convention'*. The Cancún Agreements took a step further and came up with several decisions including the establishment of a Green Climate Fund to be operated by the Convention. Also measures to capacity building and technology development and transfer are provided for in the Cancún Agreements. Also the Cancún Agreements provide "Guidance and safeguards for policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+)".

Chapter 4: Forests in international arrangements on climate change: the African experience and perspective

1. *The United Nations Framework Convention on Climate Change (UNFCCC)* and its subsidiary agreement, the Kyoto Protocol, provide the global framework for actions to respond to climate change. Implementation of the Convention and its subsidiary agreements is governed by international arrangements made at Conferences of Parties to the Convention (COPs), or at meetings of signatories to the subsidiary agreements.

2. *Despite the fact that both the UNFCCC and the Kyoto Protocol recognize* the importance of forestry for addressing climate change, forestry, and in particular African forestry, has not featured significantly in arrangements such as the Clean Development Mechanism (CDM) for addressing climate change.

3. *Reasons for the poor participation of African forestry* in arrangements such as CDM include:

a) Prohibitive costs and lack of investment capital to develop forest projects over the many years before income from emission trading starts to accrue;

b) Lack of private investors for afforestation and reforestation, since these activities have typically been carried out through government or donor supported development projects in most of Africa;

c) Uncertain markets for emission reductions, especially the reluctance by many buyers in developed countries to consider credits from forestry activities; and

d) The requirement for projects to demonstrate additionality and absence of leakage (emissions shifted elsewhere as a result of the project) is difficult to fulfill, since most African countries rely heavily on wood fuel for domestic energy.

4. *Although the African continent remains the most vulnerable* to climate change, especially as it lacks the capacity to adapt to the changes, African voices are scarcely heard at international climate change negotiations. Reasons for this include *1)* inadequate representation because of limited funds, *2)* lack of continuity in following debates because of frequent changes in delegates, *3)* inadequate preparatory meetings at both regional and country levels, because of funding constraints, and *4)* language barriers to accessing and exchanging information among anglophone, francophone and lusophone African delegates.

5. *Improvement of African participation at international negotiations* is being pursued, among other ways through the development of a Comprehensive Framework of African Climate Change Programme, under the aegis of the African Ministerial Conference on Environment (AMCEN), which, among other things, seeks to *1)* develop a shared vision, accommodating African priorities for sustainable development, poverty reduction and attainment of the MDGs in any future climate change regime, and *2)* simplification of procedures and the removal of conditionalities to provide access to international climate funds.

6. *The Green Climate Fund, the establishment of which was agreed* at the recently concluded COP16

in Cancún, Mexico, is the latest in a long list of bilateral and multi-lateral mechanisms for funding and mobilizing resources to accommodate the forestry sector in the climate change regime. While African forestry has not benefitted much from notable funding mechanisms like the Clean Development Mechanism (CDM) of the Kyoto Protocol, because of definitional problems for afforestation and reforestation, coupled with the rules that govern CDM, emerging initiatives such as Reducing Emissions from Deforestation and Forest Degradation (REDD) open up new funding opportunities.

7. *Climate change and the international instruments dealing with it* have created a gamut of new challenges, opportunities and tasks for the forest sector. Meeting these successfully requires fresh perspectives, modified priorities, new knowledge, skills and creativity. The way forward will be for African negotiators to get familiar with key principles of both the UNFCCC and the Kyoto Protocol, as various articles in the treaties are very explicit on the commitments of both developed and developing countries in reducing emissions and financing.

Chapter 5: Climate change and African moist forests

1. *African moist forests include the extensive lowland forests* that are concentrated in West and Central Africa, and the not so extensive, but widely scattered, high altitude broadleaf forests referred to sometimes as the Afromontane archipelago. Lowland moist forests approximate to closed forests of FAO (2001) and together with woodlands cover about 650 million ha or 21.8% of Africa's total land area.

2. *African moist forests are the principal base* for industrial wood production in countries where they occur and, like other forests on the continent, are intricately linked to the socio-economic and productive systems of people in Africa, supporting, besides industrial wood production, livelihoods that are based on agriculture, extraction of wood for energy and housing, and collection of non-wood products for food, medicine and various other uses. African forests, in fact, serve as 'livelihood safety nets', helping communities that live by them to overcome shocks from natural disasters and economic or climatic vagaries. They also function to maintain the quality of the environment, and command international attention because of their rich biodiversity and the unique products this provides, as well as their high productivity and potential to influence climate.

3. *Since African moist forests are among ecosystems* expected to be most affected by climate change, it is important that their vulnerabilities and those of the people who depend on them be well understood, in order to facilitate timely response to climate change impacts. Furthermore, since tropical forests are increasingly being considered as critical components of strategies for addressing climate change, it is important that the status of African moist forests be well understood, for effective use of the forests in addressing climate change.

4. *The bulk of the lowland moist forests in Africa* is located in the Central African sub-region, and is dominated by the forest of the Congo Basin, where, on the average, close to 60% of the land area is recorded as being under forest cover. The Congo Basin moist forest is, in fact, the second largest contiguous block of forest in the world after the forest of the Amazon Basin.

5. *Lowland moist forests contain over 80% of the wood volume* and biomass and more than 70% of the carbon stock in forests in Africa, representing 13, 22 and nearly 18 per cent of the world's forest stock of wood by volume, biomass and carbon, respectively. The carbon stocking in the Congo Basin alone is, as frequently reported, equivalent to four years' global carbon emission.

6. *African moist forests are currently under considerable pressure* from human use and are also impacted by climate change, at the same time that interest is increasing in their potential to contribute to climate change mitigation and adaptation strat-

egies. The impact of climate change is reflected mainly in the increasing rate of species loss, but the effect on forest productivity, which is critical for knowing the extent to which African moist forests serve as a sink for or a source of carbon dioxide are not yet well understood.

7. *Engaging African moist forests in forest-based mechanisms* for addressing climate change faces the challenge of reducing human use of forests at the same time as meeting the livelihood needs of the majority of Africans who depend on forests. The debate on the emerging mechanism of reducing emission from deforestation and degradation of tropical forests, REDD, centres largely on how to meet this challenge. Inclusion of African moist forests in global arrangements to respond to climate change must take into account, and provide resources and technologies to develop the full range of activities in Agriculture, Forestry and Other Land Uses (AFOLU), that avoided deforestation will forego.

8. *To engage effectively in global forest-based arrangements* for addressing climate change, African countries must themselves develop the expertise, improve the knowledge base especially on their forest resources, and create the enabling environment through policy reforms and establishing the necessary institutional, legislative and administrative framework. Policies must be reformed to clarify and secure forest land and trees ownership, tenure and rights, taking equity and gender considerations fully into account, so that benefits from the engagement reach the grassroots

9. *Tackling the challenges of engaging African moist forests* for effective participation in combating climate change may in the long run lead to the establishment of sustainable ways of managing the forests.

Chapter 6: Climate change and the woodlands of Africa

1. *Climate affects forest condition but forests also affect climate*. The forest sector in Africa therefore needs to be adequately equipped to respond to climate change. It is important to understand how climate change is likely to impact on forests in order to implement adaptation strategies for the sector. In the same vein, the forest sector needs to improve the management of forests to mitigate climate change, especially through the reduction in CO_2 emissions from deforestation and forest degradation and carbon sequestration from the atmosphere. Improved management of forests, e.g. through the protection of forested watersheds, will also contribute to sustainable water supplies for human use, agriculture, fisheries, wildlife and hydropower generation and ultimately improve livelihoods, food security, poverty reduction and a healthy environment.

2. *Currently little is known about the potential of woodlands* in Africa to adapt to climate change. Models suggest that climate change will cause shifts in the ranges of many vegetation communities but it is also possible that different species respond differently to climate factors and therefore may respond differentially to climate change. If this is true, then understanding the responses of individual species, especially the dominant species, is of paramount importance to the development of forest-based adaptation strategies. If climate warming reduces the productivity of woodland trees, then their role in mitigation against climate change through carbon sequestration may be reduced. Climate change may also affect forest regeneration and afforestation. Thus both climate response and mitigation by forests need to be assessed so that informed strategies and measures can be made to address the role of forests in climate change.

3. *Harvesting strategies need to be adapted to changed climate*. Given the predicted decline in tree growth, current sustainable wood and timber harvesting rates may represent overestimations for the future climate scenarios. Clear trade-offs will have to be worked out between maximizing average harvest and minimizing the risk of population collapse. Indirect consequences of species harvest on non-target species may require special attention where a common resource base is likely to change

under climate change. Under certain circumstances, current harvesting regimes may no longer be sustainable and will require reformulation or redesigning, as parts of the adaptation process.

4. *Establishing effective climate adaptation strategies* requires that scientists, managers and policy-makers work together to *1)* identify climate-sensitive species and systems, *2)* assess the likelihood and consequences of impacts, and *3)* identify and select options for adaptation . It is also important to recognize that although climate plays a significant role in determining species' distribution, other variables such as human population density, land use and soils can have similar, if not more, important roles. Issues of population growth and land use change therefore should be considered in developing adaptive strategies to climate change.

5. *Climate envelope models suggest that for some species* predicted changes in climate may significantly reduce the suitability of currently occupied habitats. Such threats are likely to be most keenly felt by species with limited dispersal ability. For such situations, adaptive management may involve either improving connectivity of habitats to facilitate natural dispersal or human-aided dispersal to appropriate habitats. Under the latter, success can be improved by ensuring that the size of the introduction is sufficiently large to overcome the risk of Allee effects that can drive small populations towards extinction.

Chapter 7: Climate change in the West African Sahel and savannas: impacts on woodlands and tree resources

1. *The 'driving forces' of change in the Sahel*, both environmental and socio-economic, are highly complex and have led to transformation and continuity. The Sahel is undergoing, slowly but inevitably, a profound 'transformation' in the way people relate to the environment and to each other in a fluid and dynamic manner.

2. *There is a need to maintain continuity with the past*. Sahelian peoples have a rich local tradition to draw on what is able to manage change, better than the kinds of adaptation that are now flowing in rapidly from outside in ecosystem resilience concepts.

3. *In the Sahel, actions needed should be well defined*, inclusive, sensitive to local interests and relevant. The genuine concerns about ecological degradation and the vital role of natural resources in rural livelihood systems should be drawn on analysis of numerous projects initiated since the droughts of the 1970s and 1980s that support natural resource management alone.

4. *In dealing with forests and trees*, and the emerging issue of climate change in the sub-region, improvement in 'household viability' and other structural measures leading to poverty alleviation should also be addressed (including income generation, employment access, conflict, equitable sharing of ecosystem services). Policy and technical measures that are successful should be reinforced and disseminated in order to restore the vegetation cover, therefore containing the effects of climate change and variability.

Chapter 8: Climate change and wildlife resources in West and Central Africa

1. *Protected areas in West and Central Africa cover about 9%* of the total area in 2000 which is lower than the global mean of 11.5%. However, due to new conservation initiatives such as COMIFAC and its convergence plan, the situation is improving as new protected areas continue to be created.

2. *Because protected areas are dedicated to the production of wildlife* for socio-economic development, management of these conservation areas must be recognized and granted equal status and legitimacy as other land uses.

3. *Protected areas could also be considered as carbon sinks* and applied to the mitigation of climate change. Climate change and variability have been presented in this chapter as events with direct impacts on many wildlife species and indirect impacts on their habitats, particularly in protected areas.

4. *In West and Central Africa, there is a large body of knowledge* and experience within local communi-

ties on coping with climatic variability and extreme weather conditions. Local communities have made preparations based on their resources and their knowledge accumulated through experience of past weather patterns.

5. *Scientific data to demonstrate how climate change is impacting* on biodiversity in much of West and Central Africa are limited. To contain this situation, the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) was created to collect and manage agro-hydro-climatic data, to set up an early warning system, and to carry out research and training activities mainly through AGRHYMET (Regional Centre for Training and the Application of Agro meteorology and Operational Hydrology). Such an information and knowledge base can be used to develop adaptation strategies to the impacts of climate change on wildlife resources.

Chapter 9: Climate change and wildlife resources in East and southern Africa

1. *Africa is rich in wildlife species* and apart from their biodiversity significance, the major uses of wildlife resources in East and southern Africa are eco-tourism, safari hunting and local hunting. In most areas that are rich in wildlife species, local people may be heavily dependent on the wildlife resource as a source of bush meat. The significant climate change stimuli to which African wildlife resources are likely to be subjected in the near future are most likely related to climate warming due to rising temperatures and extreme events in Africa, such as droughts and floods. Surveys suggest that over 65% of the original wildlife habitat in Africa has been lost as a result of agricultural expansion, deforestation and over-grazing, which have been fueled by rapid human population growth and poverty. As a result, protected areas are becoming increasingly ecologically isolated while wildlife on adjacent lands is actively eliminated.

2. *Rainfall, more than temperature, appears to regulate aspects of reproduction* in most dry tropical African mammals. Modeling studies have shown that mammals in African national parks will experience changes in species richness. Models describing relationships between the geographical distributions of birds and present climate for species breeding in both Europe and Africa suggest that there is likely to be a general decline in avian species. These observations are a source of great concern about the continuing effectiveness of networks of protected areas under projected 21st century climate change. However, a number of potential adaptation strategies exist for reducing the impact of climate change on wildlife resources and these include *1)* increasing the extent of protected areas, *2)* improving management and restoring existing protected areas to facilitate resilience, *3)* protecting movement corridors and refugia, and *4)* reducing pressures on species from sources other than climate change, such as over-exploitation of species and preventing and managing invasive species.

3. *Effects of climate warming mediated mainly through shifts* in onset and duration of rainy seasons and drought include reduction in species distribution ranges, alteration in abundance and diversity of mammals, changes in calving and population growth rates, changes in juvenile survival of most ungulates and changes in species richness of birds and mammals. These changes in wildlife species will have direct serious negative impacts on ecotourism and game hunting.

Chapter 10: Responding to climate change in the wildlife sector: monitoring, reporting and institutional arrangements

1. *Satellite data could be of significant use for the management* of the environment. Projections into the future improve our capacity to mitigate or adapt to changes and ecological monitoring plays an important role in the development of projections. However, because climate change is likely to bring novel conditions, projecting the future ecological consequences of climate change is a difficult challenge due to a number of reasons. Although models have been used to predict effects of climate change on wildlife, especially species ranges, these models

have never been empirically tested and therefore their outputs should really be viewed as possible scenarios or forecasts rather than as firm predictions of the future changes. Long-term observations in time and space provide the best validation of ecosystem scale models but long-term records in sub-Saharan African countries rarely go back more than 100 years and therefore future responses remain unknown until they occur, thereby making current validations of models of future conditions tentative.

2. *It is important to build an efficient communication link* to reach various stakeholders in order to create awareness about linkages between climate change and conservation of biodiversity. Climate change is a cross-cutting issue and therefore requires special institutional and governance arrangements. Currently in many of the African countries, climate change issues are coordinated by institutions that are responsible for either the environment or agriculture. This has resulted in arrangements for addressing and sharing information on climate change that are restricted to a particular sector or specific problems. Furthermore, because most information on climate change relates to agriculture and water resources, little information has been disseminated on other sectors and institutions.

Chapter 11: Community-based adaptation to climate change in Africa: a typology of information and institutional requirements for promoting uptake of existing adaptation technologies

1. *Poor linkage between climate change research and communities* leads to poor appreciation of technologies developed by the scientific community as well as integration of lessons and experiences from community coping strategies. National-level initiatives are driven by collective action at the international level. Subsequently, local level mainstreaming of climate change strategies are top-down and rarely evidence-based. Pathways for knowledge to action are therefore impeded by poor extension service provision approaches and lack of robust approaches to enhance use of scientific evidence by communities. At the institutional level, failures of markets, governments and local organizations to resolve resource allocation and public good challenges further weaken the capacity of local communities to adapt to the impacts of climate change. Despite these challenges adaptation technologies have continued to be developed by international, regional and national research institutes; consequently these technologies are rarely adopted by farmers.

2. *As a result of climate change, all parts of Africa* will be subject to more extreme day-to-day and season-to-season fluctuations in rainfall. This means that African farmers will need to adapt to more extreme and erosive storms, greater likelihood of flood, longer periods of drought, and generally less certain conditions for food and agricultural production.

3. *Given the potential impacts of climate change* and the urgency of the threat, 'community-based-adaptation (CBA)' strategies appear to be the best approach. But, adoption of CBA is hampered by the fact that communities are scarcely key participants at policy levels, or at climate change negotiations at regional or international levels, where climate change responses are articulated and shaped.

4. *A number of technologies* – particularly those focused on water management – are likely to have great relevance for Africa's agriculture in responding to climate change. Known adaptation technologies, including *inter alia* crop improvement and water harvesting technologies, need to have their associated informational and institutional requirements established or strengthened to ensure their scaling up to reach a large community of African farmers. Some of the informational requirements include giving the right information in the right package to farmers.

5. *The pursuit and promotion of agricultural technologies* by focusing on information and institutional needs will require strategic policy and institutional development within a system of global

governance that links effectively with national and community-level adaptation initiatives.

6. *Meeting the institutional needs for the promotion* and adoption of technologies is the responsibility of policy makers. Research should however be re-oriented so that the information needs of farmers and communities are realized. This includes shifts from focus on improving agricultural productivity to 'climate proofing' – ensuring that we adapt to the uncertainties of climate change but at the same time enhance food security.

7. *It is the hope that this review of the existing informational and institutional gaps* and challenges to effective transfer of known adaptation technologies will catalyze a re-look at community-based adaptation, increased investment in adaptation and consideration of community-based adaptation as part of the global response in addressing the potential effects of climatic variability and climate change.

Chapter 12: Socio-economic and gender related aspects of climate change in Africa

1. *In many rural sub-Saharan Africa communities*, non-timber forest products (NTFPs) may supply over 50% of a farmer's cash income and provide the health needs for over 80% of the population, particularly among forest-dependent populations. However, expected decreases in rainfall, and increased severity and frequency of drought, can exacerbate current exploitation pressures on forests and trees and expansion of agriculture into forest lands. Forests provide direct and indirect employment for a large number of people in Africa in collecting fuelwood, forest fruits, honey, resins, gums and others for consumption as well as selling as employment. These important products play a key role in the livelihoods of African rural households as sources of income when traded in local, regional, and international markets.

2. *The major beneficiaries of wildlife resource utilization* are *1)* local people whose livelihoods are historically and culturally dependent on wildlife products, such as bush meat, *2)* government which derives revenue from wildlife-based tourism, *3)* the private sector (both foreign and local) that operates tourism facilities, and *4)* foreign tourists that view wildlife resources in national parks and hunt game.

3. *Increasing temperature is expected to provide the optimum conditions* for the growth of some vectors such as the mosquito. There is evidence that in some sites in the highlands of East Africa, a warming trend over the last 30 years has improved conditions for the growth of mosquito populations and therefore the probability of malaria transmission and highland epidemics.

4. *Women can play an important role in supporting* households and communities to mitigate and adapt to climate change. Across Africa, women's leadership in natural resource management is well recognized. Women typically gather forest products for fuel, fencing, food for the family, fodder for livestock and raw materials to produce natural medicines, all of which help to increase family income while men are involved in timber extraction and the use of NTPs for commercial purposes. It is essential, therefore, that forestry projects aiming at addressing mitigation and/or adaptation to climate change adopt a gender-based approach that incorporates the gender differences between women and men.

Chapter 13: African forests and trees in the global carbon market

1. *Africa has a large mitigation potential in the land use sector* that can be translated into significant participation in the current and future carbon market opportunities. This potential is underwritten by her large endowment of land and large populations involved in land use based economic activities. Recent global mitigation models show that African forests and trees have a likely potential for sequestering about 123 million tonnes of carbon dioxide (CERs) per year and reducing emissions by about 228 million tonnes of carbon dioxide per year from avoided deforestation.

2. *So far carbon market data show that African forests* and trees have barely been brought into the market. By 2009, the total amount of CDM CERs from Africa was about 21 million out of 630 million global CERs, of which forestry's contribution was a miniscule 0.4% of the global total.

3. *A number of reasons have been put forward to explain the poor performance* of Africa in carbon projects and programs, including, high transaction costs, the complexity of rules and requirements, weak human and institutional capacity coupled with poor governance and perceived higher risks on the continent. Though the cost per project is declining due to various interventions by the Clean Development Mechanism (CDM) Executive Board, such as simplification of procedures and bundling of projects, this element remains the most universally referred to impediment to participation of African players in the carbon market.

4. *The most common barriers to afforestation/reforestation projects in general*, but more pronounced for Africa, include political instability, lack of political enthusiasm for land-based activities tied to long term western countries' interest, restrictions of project scale and temporary nature of forestry credits.

5. *Key to the effective positioning of the continent* in benefitting from the carbon market is the necessity to develop carbon policies, strategies and guidelines within the framework of national and international climate change policy.

6. *While emission reduction can be achieved in most sectors*, the land use sector has the greatest potential for CDM opportunities in Africa, due to the relatively large amount of actual and potential emissions, as well as the ability to sequester carbon on the vast area of land. More importantly, the carbon finance opportunities in the land use sector also fall in priority areas, in terms of projects and programmes that enhance the ability of vulnerable African countries to adapt to climate change

7. *There is an urgent need to increase the human capacity* needed for effective participation in the market, from project proposal development to implementation and carbon market operations. Weak governance constitutes a significant barrier especially in the forest sector, but this needs a comprehensive approach, coupled with development of democratic and civil institutions. Concerted effort for risk reduction and marketing of Africa, where the risk perception is undeserved, will increase the attractiveness of the African carbon opportunities to buyers.

Chapter 14: Climate change in African forestry: the broader policy context

1. *Developing countries' ability to cope with climate change* depends to a large extent on the careful choice of policy actions by governments and the international community, as well as the strategic targeting of areas for policy interventions. It is therefore very important to scrutinize the impacts of current policies vis-à-vis climate change and incorporate climate variability and change into future policies. Some of the climate policy actions can come in form of incentives and investment to create and deploy improved technology and management techniques, as well as effective public policy on economy and livelihood diversification. In the forestry sector the debate and resources have so far been targeted much more on mitigation of climate change and much less on adaptation to climate change by humans, forests and trees. Mitigation efforts are important in avoiding impact of climate change; however, adaptation activities are very important in alleviating the non-avoidable climate change effects. Clearly there is a need to maintain a good balance between adaptation and mitigation in terms of attention and resources.

2. *The forest policies that have been implemented in Africa* since independence, some 50 years ago, have targeted reducing deforestation and forest degradation. In many countries there have been restrictions on access to forests for livestock grazing, human settlements and crop production. Efforts have also been made to regulate deforestation through selective harvesting of natural forests, and in many cases

guided by annual allowable cut in order to sustain timber supplies. In addition, there are national forest programmes (nfps) in many African countries and programmes/projects/activities that implement various international agreements, initiatives and conventions which target unwanted deforestation and forest and land degradation. However, despite all these good contributions deforestation and forest degradation continue to increase in many African countries. The dry forests and woodlands support the bulk of the African people, livestock and wildlife and cover almost three times the area under rain forests. They also support almost five times more people than those supported by the rain forests. In these forests, deforestation and forest degradation are closely related to human and animal interactions with the forests and woodlands for survival.

3. *New and emerging drivers of deforestation* include increasing demand for food and demand for and production of biofuels. New and hybrid modes of forest governance are required to replace the traditional mode of forest governance in order to handle higher levels of uncertainty associated with climate change and the complexity of climate change brought about by the wide range of new actors and interest groups. It is very critical that any adaptation framework ensures that forest managers have the flexibility to select the most appropriate measures to suit their specific situations. Governments need to ensure the right mix of policies and tools are available to African farmers, businesses, households and communities to understand and prepare for or anticipate climate change pressures before they occur, as well as to adapting to the climate change that is already here. Adaptation to climate change in Africa is urgent and requires substantial resources. It is unlikely that developing countries, in particular the least developed countries, have the financial resources and technical knowledge for the required anticipatory and planned interventions. Financial and technical assistance will also be required for the additional costs of designing and implementing interventions. Climate change is local and location specific. Methodologies to assess adaptation need to analyze local impacts in detail in order to understand and plan relevant interventions but recognize that, at implementation, it will be necessary to include the interventions into larger scale/national adaptation programs.

Acronyms

AAU	Assigned Amount Units (levels of allowed emissions over the 2008–2012 commitment period)
ADB	Asian Development Bank
AfDB	African Development Bank
AFF	African Forest Forum
AFOLU	Agriculture, Forestry and other Land Uses
AFP	Agence France-Presse
AIJ	Activities Implemented Jointly
ALM	Agricultural Land Management
AMCEN	African Ministerial Conference on Environment
APF	Africa Partnership Forum
AR4	Fourth Assessment Report
A/R	Afforestation/Reforestation
AWP-LCA	Ad Hoc Working Group on Long-term Cooperative Action
BMU	German Federal Environmental Ministry
BNRCC	Building Nigeria's Response to Climate Change
CAADP	Comprehensive African Agricultural Development Programme
CAR	Central African Republic
CARPE	Central Africa Regional Project for the Environment
CATIE	Tropical Agriculture Centre for Research and Higher Education (Centro Agronómico Tropical de Investigación y Enseñanza)
CBA	Community-based adaptation
CBD	Convention on Biological Diversity
CBFF	Congo Basin Forest Fund
CBNRM	Community Based Natural Resource Management
CDM	Clean Development Mechanism
CEDEAO	Communauté Economique des États de l'Afrique de l'Ouest
CEEAC	Communauté Economique des Etats de l'Afrique Centrale
CEFDHAC	Conférence sur les Ecosystemes de Forêts Denses et Humides d'Afrique Centrale
CEIF	Clean Energy Investment Framework
CEMAC	Communauté Economique et Monétaire d'Afrique Centrale
CEP	Cool Earth Partnership
CER	Certified Emission Reduction
CERCOPAN	Centre for Education, Research & Conservation of Primates and Nature
CFM	Community Forest Management
CGIAR	Consultative Group on International Agricultural Research
CIDA	Canadian International Development Agency

CIF	Climate Investment Fund
CIFOR	Center for International Forestry Research
CII	Country Implementing Institution
CILSS	Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel
CIMMYT	International Maize and Wheat Improvement Centre
CITES	Convention on International Trade of Endangered Species
CNEDD	Conseil National de l'Environnement pour un Développement Durable
COMES	Common Market for Eastern and Southern Africa
COP	Conference of the Parties
CORAF/WECARD	Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles/ West and Central African Council for Agricultural Research and Development
CPF	Collaborative Partnership on Forest
DNA	Designated National Authority
DRC	Democratic Republic of Congo
DSS	Decision Support Systems
DTMA	Drought Tolerant Maize for Africa
EB	CDM Executive Board
EBA	Endemic Bird Areas
EBRD	European Bank for Reconstruction and Development
ECCAS	Economic Community of Central African States
EMF	Eclipse Modeling Framework
ENDA	Environmental Development Action
ENSO	El Niño Southern Oscillation
EO	Earth Observations
ERU	Emission Reduction Unit
ET	Emission Trading
ETF-IW	Environmental Transformation Fund – International Window
EUAs	European Union Allowances (carbon allowances under the EU-ETS)
EU-ETS	European Union's emissions trading scheme
EUR	European Euro
EUMETSAT	European satellite agency
FAO	Food and Agricultural Organization of the United Nations
FCPF	Forest Carbon Partnership Fund (World Bank)
FEGS	Forest Ecosystem Goods and Services
FEWSNet	Famine Early Warning System Network
FFEM	French Global Environment Facility
FMNR	Farmer Managed Natural Regeneration
FSCCPs	Framework of Sub-regional Climate Change Programmes
GBP	Great Britain Pound
GCCA	Global Climate Change Alliance
GCMs	General Circulation Models
GCOMAP	Generalized Comprehensive Mitigation Assessment Process
GCOS	Global Climate Observing System
GDP	Gross Domestic Product

GEF	Global Environment Facility
GFDL-A2	Geophysical Fluid Dynamics Laboratory Coupled Model
GFW	Global Fund for Women
GHG	Greenhouse gas
GoS	Government of Sudan
GPG	Good Practice Guidance
GSBA	Globally Significant Biodiversity Areas
GTM	Global Timber Model
GTM	Grounded Theory Method
GWP-WAWP	Global Water Partnership – West Africa Water Partnership
HadCM	Hadley Center Coupled Model
HFC	Hydro-fluorocarbons
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
IADB	Inter-American Development Bank
IAS	Invasive Alien Species
IBA	Important Bird Area
ICI	International Climate Initiative
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Centre for Agricultural Research in the Semi-Arid Tropics
IEA	International Energy Agency
IETA	International Emissions Trading Association
IFAD	International Fund for Agricultural Development
IFCI	International Forest Carbon Initiative
IFM	Improved Forest Management
IIED	International Institute for Environment and Development
IITA	International Institute of Tropical Agriculture
IMAGE	Imager for Magnetopause to Aurora Global Exploration
IMAGE	Integrated Model to Assess the Global Environment
INFORMS	Integrated Forest Monitoring System
IPCC	Intergovernmental Panel on Climate Change
IUCC	Information Unit on Climate Change
IUCN	International Union for Conservation of Nature
IUFRO	International Union of Forest Research Organizations
JI	Joint Implementation
KARI	Kenya Agricultural Research Institute
KP	Kyoto Protocol
KSLA	Royal Swedish Academy for Agriculture and Forestry
LDCF	Least Developed Countries Fund
LULUCF	Land Use and Land Use Change and Forestry
l-CERs	Long-term Certified Emission Reduction Units
MDGs	Millennium Development Goals
MEA	Multilateral Environmental Agreements
MINFOF	Ministère des Forêts et de la Faune
MOP	Meeting of the Parties

MRV	Measurable, Reportable and Verifiable
NAMAs	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programme of Action
NCSP	National Communication Support Programme
NDVI	Normalized Difference Vegetation Index
NEPAD	New Partnership for Africa's Development
nfps	National Forestry Programmes
NGO	Non-Governmental Organization
NICFI	Norway's International Climate and Forests Initiative
NIMET	Nigerian Meteorology
NOAA-AVHRR	National Oceanic and Atmospheric Administration – Advanced Very High Resolution Radiometer
NRIs	National Research Institutes
NSS	Negotiation Support Systems
NTFPs	Non-timber Forest Products
OFAC	Central Africa Forests Observatory
OTC	Over the Counter Market
PCN	Project Concept Note
PDD	Project Design Document
PES	Payment for Environmental Services
PP	Project Proponent
PRA	Participatory Rural Assessment
PRESA	Pro-poor Rewards for Environmental Services in Africa
RAPAC	Network of Central Africa Protected Areas
REDD	Reduced Emissions from Deforestation and Forest Degradation
RES	Reward for Environmental Services
RMU	Removal Units (credits issued for net sink enhancements achieved by eligible activities under Articles 3.3 and 3.4)
SBSTA	Subsidiary Body on Scientific and Technological Advice
SCCF	Special Climate Change Fund
SCCU	Special Climate Change Unit
SD	Sustainable Development
SEARNET	Network for Southern and Eastern Africa
SFM	Sustainable Forest Management
SHD	Semi humid dry
Sida	Swedish International Development Cooperation Agency
SNV-GOK	The Netherlands Development Organisation – Government of Kenya
TAR	Third Assessment Report
t-CERs	Temporary Certified Emission Reduction Units
TroFCCA	Tropical Forests and Climate Change Adaptation
TRIDOM	Tri Nationale Dja-Odzala-Minkébé
UK	United Kingdom
UNCCD	United Nations Convention on Combating Drought and Desertification
UNCED	United Nations Conference on Environment and Development

UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCC	United Nations Framework Convention on Climate Change
UNFF-NLBI	United Nations Forum on Forests – Non-Legally Binding Instrument on all type of forests
UNGA	United Nations General Assembly
UNHCR	United Nations High Commissioner for Refugees
UNIDO	United Nations Industrial Development Organization
UN-REDD	United Nations Reduced Emissions from Deforestation and Forest Degradation Programme
USA	United States of America
USAID	United States Agency for International Development
USD	United States Dollar
VC	Voluntary Carbon
VCM	Voluntary Carbon Market
VCS	Voluntary Carbon Standards
WAP	West African Parks
WCED	World Commission on Environment and Development
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resources Institute
WSS	World Summit on Sustainable Development
WUE	Water Use Wfficiency
WWF	World Wildlife Fund
ZCV	Zones de Chasse villageoise

There is growing evidence that climate change and variability is impacting on forests and forest ecosystems in Africa, and therefore on the livelihoods of forest dependent communities, as well as on national economic activities that depend on forest and tree products and services. Africa is one of the most vulnerable regions in the world to climate change. Although the IPCC has published four Assessment Reports (ARs) that provide scientific information on climate change and variability to the international community, currently little is known about the potential of African forests and trees to adapt to climate change as well as on their potential to influence climate change.

This is perhaps the first book that, based on what is known, systematically addresses climate change issues in the context of African forests, trees and wildlife resources, and therefore brings to the fore the forest and wildlife-climate change debate within and beyond the African continent. Africa has vast areas under forests and tree resources, and more than anything else these resources are at the centre of the socio-economic development and environmental protection of the continent. African forests and trees are also renowned for their habitats for wildlife resources. Climate change is argued to have the potential to adversely affect both forest and wildlife resources in almost all African countries.

This book is therefore timely in that it highlights to all stakeholders, and in a systematic manner, the climate change issues relevant to the African forestry and wildlife sectors, with the view of increasing the understanding of these relationships and facilitating the development of strategies for these sectors to increase their contribution, at various levels and fora, to addressing the vagaries of climate change. The book also outlines the opportunities that climate change brings to the various development sectors of African nations.

Emmanuel Chidumayo is a leading ecologist of African woodlands and savannas and author of *Miombo Ecology and Management* (1997), and co-edited *The Dry Forests and Woodlands of Africa: Managing for Products and Services* (2010).
David Okali is an emeritus professor of forest ecology, University of Ibadan, past President of the Nigerian Academy of Science and currently Chairman of the Nigerian Environmental Study/Action Team (NEST); author of *Climate Change and Nigeria: A Guide for Policy Makers* (2004).
Godwin Kowero is a professor of forest economics and policy analysis, co-edited *Policies and Governance Structures in Woodlands of Southern Africa* (2003), and currently is the Executive Secretary of the African Forest Forum.
Mahamane Larwanou is an ecologist/agroforester with experience in dryland ecosystems, especially the Sahel region of West Africa, and currently is a Senior Programme Officer with the African Forest Forum.

The African Forestry Forum (AFF) is an association of individuals who share the quest for and commitment to the sustainable management, use and conservation of the forest and tree resources of Africa for socio-economic wellbeing of its peoples and for the stability and improvement of its environment. AFF provides a platform for information sharing and expertise and creates an enabling environment for independent and objective analysis, advocacy and advice on relevant policy and technical issues pertaining to achieving sustainable management, use and conservation of Africa's forest and tree resources as part of efforts to reduce poverty, promote economic and social development and protect the environment.

African Forest Forum
P.O. Box 30677-00100, Nairobi, KENYA
Tel: +254 20 722 4203, Fax: +254 20 722 4001
www.afforum.org