A PLATFORM FOR STAKEHOLDERS IN AFRICAN FORESTRY

VULNERABILITY OF BIOSPHYSICAL AND SOCIOECONOMIC SYSTEMS IN SAVANNAHS AND WOODLANDS OF WEST AND CENTRAL AFRICA TO CLIMATE CHANGE

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Vulnerability of biosphysical and socioeconomic systems in savannahs and woodlands of West and Central Africa to climate change

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Acronyms and abbreviations

CIFOR	Center for International Forestry Research
FAO	Food and Agricultural Organization of the United Nations
GDP	Gross Domestic Product
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IUFRO	International Union of Forest Research Organizations
ODI	Overseas Development Institute, London
PSP	Permanent Sample Plots
SADC	Southern African Development Cooperation
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

Tropical woodlands and savannahs are associated with areas where there is an annual dry season of sufficient duration and intensity, and most of woody plants shed their leaves and grasses dry out. The accumulations of the dry fuel permits fires every year, and the fires help prevent complete domination by woody plants. These ecosystems are overexploited as a result of crop farming and/or overgrazing associated with fuelwood gathering.

Africa is composed essentially of woodlands and savannahs with rain forests occupying 7% of the land area. They occur extensively in West and Central Africa. The woodlands and savannahs serve important ecological functions and provide wood and non-wood forest products that contribute significantly to human well-being at local, national and global levels. The non-wood products include fruits, vegetables, nuts seeds, roots, mushroom, spices, bush meat, bee products, edible insects, eggs and medicines, which are particularly important in the lives of the communities dwelling in them. The products also play important roles in the national economies of many countries of West and Central Africa.

Agriculture, i.e. crop production and animal husbandry, is the main occupation of the rural dwellers in these ecosystems that depend on the produce for subsistence and income. Much of the crop land is rain-fed and, therefore, vulnerable to climate variability that is characterized by periodic droughts and occasional floods that frequently cause crop failures during which the coping strategy of inhabitants is gathering of wild foods and resources from the vegetation. Maintaining the flow of these goods and services requires healthy ecosystems in the face of human-induced climate change.

Already, scientific evidence in Africa shows that climate change directly impacts on key development sectors, such as water resources, land, forests, biodiversity, tourism and agriculture that are crucial for livelihoods, food, health and security of local communities. Furthermore, future projections indicate that these impacts are likely to worsen overtime.

Anthropogenic activities, through industrial activity, fossil-fuel consumption, deforestation and land use change, have increased the concentrations of greenhouse gases in the atmosphere, which are causing changes in global temperatures, precipitation patterns and sea levels as well as melting of glaciers. Although Sub-Saharan Africa contributes less than 4% of the world's total emissions of greenhouse gases, the warming is expected to be greater in the region than the global average, with warming being greatest in drier sub-tropical regions. Scientists have also predicted that the region's diverse climate factors and ecological systems have already been altered by global warming and under further damage in the years ahead. Furthermore, the anticipated climate change poses great threats to food, water security, public health, natural resources and biodiversity. Climate change and variability in woodlands and savannahs of West and Central Africa have resulted in and are

expected to contribute to the changing weather patterns, changing seasons, extreme weather events, floods, droughts, wildfires and windstorms. These events affect and have affected biodiversity, livelihoods and socio-economic activities. It would diminish industrial production and weaken the infrastructure base for socio-economic activity, resulting in reduced development.

Agricultural production, an important economic activity playing crucial role in food security in woodlands and savannahs of West and Central Africa, is mostly rain-fed and finely tuned to climate. It would be hard hit as droughts and flooding worsen, temperatures and growing seasons change as a result of climate change and variability, and farmers and herdsmen will be forced off their land. The impacts of climate would result from the changes in temperature, precipitation and CO_2 concentration or indirect effects through changes in soil moisture content and incidence of pests.

Diversity of animals and plants on which the rural communities in woodlands and savannahs of West and Central Africa depend are already adversely affected and would continue to be affected by climate change. The incomes and livelihoods of the rural communities who rely on the products are declining as a result. This is due to the effect climate change has on biodiversity through increased frequencies of wildfires, drought, floods, altered patterns of pests and diseases, and alteration of both aquatic and terrestrial habitats.

The temporal and spatial changes in temperature, precipitation and humidity that are expected to occur under different climate change scenarios would affect the biology and ecology of disease vectors and, consequently, the risk of disease transmission such as malaria, meningitis and other parasitic disease, and parasites, such as tsetse fly. This would lead to big drain on the economies of countries of West and Central Africa through death, medical costs and lost productivity. Changes in the impacts of climate change on other less climate sensitive vector diseases, such as filariaris, onchocerciasis and schistosomiasis is not clear and may take a long time to be evident.

The livelihoods of communities, especially the rural poor and national economic activities that depend on agriculture, and goods and services provided by woodlands and savannahs would be adversely affected as a result of climate change. Water shortages and unpredictable rainfall, in combination with continued population growth and increased land degradation, would impact on these ecosystems and their capacity to continue to provide immediate livelihood needs.

Climate variability and change would impact water supply through droughts and floods. The water shortage and the pollution that it will cause will be the most significant problems not only due to their impacts and consequences, but also because they drive or contribute towards other problems, including spiralling effect since the shortages cause more unsustainable harvesting of resources and, thus, more degradation.

Climate variability, including the resultant extreme events, such as storms, floods, especially flash floods and droughts, have impacted and continued to impact infrastructure, such as human settlements, electricity and transportation in woodland and savannah zones of West and Central Africa. The extreme weather events would continue to pose significant threat to the countries in the sub-region in achieving their national goals in road construction, housing, conservation of environment and agriculture.

In spite of the above negative impacts of climate change and variability, there are uncertainties about the outcomes of interacting factors (temperature increase, variability in precipitation, extreme events, CO_2 fertilization, frequency and intensity of wildfires). Hence, there is a necessity of generating more knowledge through monitoring climate factors in relation to composition, dynamics, growth, phenology, productivity, structure and functioning of woodlands and savannahs and synthesizing data collected across different sites. This requires the establishment of permanent sample plots (PSPs) to be re-sampled periodically and monitored to generate the necessary data and information on vulnerability to and impact of climate change and variability of these ecosystems.

There is dearth of data and information on existing PSPs in savannahs and woodlands of West and Central Africa. It is recommended that one ha new PSPs be established in Strict Nature Reserves in some selected countries of the sub-region for generation of data and information, and modelling impacts of climate change in woodlands and savannahs. When established, the plots should be geo-referenced and the boundaries marked out with permanent markers for future reference. Data and information on vegetation, soil and climate factors should be collected from the plots, and tracked by re-sampling periodically and monitoring to observe changes. Scientists who are still actively engaged in research and are institutionally based in each of the countries should be appointed to monitor, and collect data and information from the plots.

CHAPTER1 Introduction

Woodlands are vegetation stands with small or medium size trees and whose crowns are almost continuous, but through which light is able to penetrate widely. They have partial grass cover, and the tree layer is virtually continuous (40-60%). Savannahs comprise continuous grass cover and trees or shrubs varying in density, frequently with twisted stems. Woodlands and savannahs are associated with tropical areas where there is an annual dry season of sufficient duration and intensity in which most of the woody plants shed their leaves, and grasses dry out. This accumulation of dry fuel permits fires every year or 2-4 years, and the fires help prevent complete domination by the woody plants. The fires in tropical savannahs and woodlands remain an important source of CO_2, CH_4, N_2O, NO, NO_2 and tropospheric O_3. WHITE (1983) in his work on African vegetation maintains that due to variations in the definition of the savannah it is no longer possible to use the term in precise classificatory sense. Instead he designated the different types of savannah as woodland, wooded grassland, bush and bushed grassland. The dry zones in West and Central Africa, classified as Sudanian vegetation (WHITE, 1983), which are dominated by open woodlands and their degraded patterns comprise the Sudanian Regional Centre of Endemism, covering an area of 3.7 million km^2. Across the globe, there is much concern over what is referred to as the 'savannization' of tropical forests, but this is primarily a structural reference to loss of trees from tropical forest areas to clear felling or logging, often, followed by fires (BARLOW AND PERES, 2008). These vegetation formations are often overharvested as a result of overgrazing associated with fuelwood extraction and crop farming.

Scientific evidence in Africa shows that climate change directly impacts on key development sectors, such as water resources, land, forests, biodiversity, tourism and agriculture that are crucial for livelihoods, food security and health. Furthermore, future projections note these impacts are likely to worsen over time and pose great threats to food and water security, public health, natural resources and biodiversity in woodlands and savannahs in West and Central Africa. Understanding climate change and variability and the response of these ecosystems, has a key role for the future management of woodlands and savannahs for climate change mitigation and adaptation. Therefore, there is a need to review the available information on vulnerability of biophysical and socio-economic systems in woodlands and savannahs of West and Central Africa to climate change and identify the likely impacts of climate change on these systems. It is also necessary to identify and recommend some PSPs that would be used for long-term monitoring of impacts of climate change impacts on savannahs and woodlands in West and Central Africa. Biophysical system is defined here as the abiotic and biotic environment of organisms, and includes the factors that have influence in their survival, development and evolution. The socio-economic system is the intertwined relationship among economy, society and social relations. It includes systems of production and distribution of goods as well as allocation of resources and the nature of social relationships in a society.

The objectives of this study were to:

(i) review available information on climate change vulnerability of biophysical (i.e., soil, water, and biological resources) and socio-economic (i.e. human health, livelihoods, products, trade and development) systems in woodlands and savannahs of West and Central Africa;

(ii) review and assess available data and information on PSPs in woodlands and savannahs of West and Central Africa and evaluate the current status and potential of such plots to be used for the generation of data and information for determining and modelling impacts of climate change in woodlands and savannahs (i.e. tree and stand health, regeneration, growth and productivity) and REDD+ requirements, including monitoring, reporting and verifications (MRVs), and biodiversity safeguards in woodlands and savannahs of West and Central Africa; and

(iii) identify and describe existing PSPs in woodlands and savannahs of West and Central Africa that can be supported for long term monitoring, initially for a 5-year period, and propose institutional arrangements for the sustainable management and monitoring, including periodic re-measurements, of forest and tree resources and factors affecting them in the identified PSPs.

The study was accomplished mainly by the use of existing literature and personal communications with individual scientists and organizations working in woodlands and savannahs of West and Central Africa. Scholarly journal articles, publications by international organizations, departments and ministries and country/national reports were consulted. Visits to some existing PSPs to assess their current status were made. Data and information from these sources were used in compiling this report.

CHAPTER 2 Woodlands and savannahs in West and Central Africa

CHARACTERISTICS OF WOODLANDS AND SAVANNAHS

Woodlands and savannahs are vegetation stands with continuous grass cover and trees or shrubs varying in density. They are characterized by having dry seasons of sufficient durations and intensities that cause most of the woody species to shed their leaves, and the grasses to dry out and burn. The trees are thick-barked, fire-tolerant, mainly, deciduous and possess remarkable powers of developing fresh sucker growth after fire. The grasses also possess remarkable powers of re-growth after the dead grass is burnt by fire. Both trees and grasses are not tolerant to shade. Because of their shade intolerance, the trees are unable to recruit in shaded conditions and the grasses indirectly depend on fires to maintain their light levels. In well-developed woodlands, the tree crowns are more or less touching each other. The trees are mostly broadleaved and in some places cast a shade deep enough to suppress grass. Wherever the canopy is open, however, grasses are dominant. The woody species are broadleaved and thornless in humid savannahs, and partly fine-leaved thorny as well as partly broadleaved and thornless in semi-arid savannahs while in arid savannahs, fine-leaved thorny woody species are dominant. Recurrent fire and farming tend to make the vegetation more open and modify the floristic composition of the woodlands and savannahs.

EXTENT AND DYNAMICS

The bulk of tropical savannahs and woodlands occur between 30° S and 20° N. These ecosystems lie between the equatorial rain forests, and the deserts and semi deserts of Africa, Australia and South America. Africa is composed essentially of savannahs and woodlands with rain forests occupying only about 7% of the land area. The African savannahs and woodlands are located in the 200-1800 mm rainfall belt on both sides of the equator from about 29° S - 16° N (Johnson and Tothill, 1985). The savannahs in West Africa are about 450-800 km wide from north to south and up to 5,600 km from east to west (Okigbo, 1985). North of the equator, the savannahs cover most of Senegal, Gambia, the southern third of Mali, the southern margin of Niger and Chad, Guinea-Bissau, most of Guinea, parts of Sierra Leone, the northern half of Cote d'Ivoire, most of the northern half and southeastern coastal area of Ghana, Burkina Faso, Togo and Benin, and 80% of Nigeria except a narrow central strip (Okigbo, 1985). In Central Africa, they occur in the northern half of Cameroon, Central African Republic, 15% Gabon and extreme northern areas of Congo, and south of the equator they cover large areas of Angola (Onochie, 1977). The miombo woodlands in Central and Southern Africa are the same as broad-leaved savannahs (FROST, 1996). These ecosystems support large numbers of herbivores, possess significant faunal diversity and constitute the main rangeland areas of Central and West Africa, providing fodder for wild and domestic animals.

Woodlands and savannahs are burnt once every 2-4 years (CHIDUMAYO, 2004; SANKARAN ET AL., 2007) and annually, respectively, during the dry season when the grasses and other herbaceous species dry out and there is accumulation of dry fuel. After the burning, the ground becomes bare and blackened and the trees leafless. When the rains are about to begin the trees develop leaves and flowers. The burnt grass tussocks also give rise to new green shoots or flush. During the rainy season, the grasses grow faster and the tree canopies become denser. Towards the end of the dry season, the grasses and herbaceous species produce flowers and fruits. When woodlands and savannahs are protected from fires, the woody density increases and the growth of grasses is reduced. When the woodlands and savannahs are cleared for farming, the stumps of woody species soon regenerate through coppices and sucker shoots on abandoned farmland, which is not burnt fiercely. The re-growth shoots are prevented from growing into trees with continued and fierce fires. Thus, fires control the balance of cover between trees and grasses, and in conjunction with farming, determines the dynamics of the woodlands and savannahs.

SOCIO-ECONOMIC IMPORTANCE OF WOODLANDS AND SAVANNAHS

Woodlands and savannahs serve important ecological functions and provide wood and other products that contribute significantly to human well-being at local, national and global levels. About 75% of the poorest people in West and Central Africa live in rural areas where they depend on agriculture and natural resources for livelihoods and to survive. For example, a review of the Poverty Reduction Strategy Programmes (PRSPs) for several countries (Burkina Faso, Mali, Ghana, Niger and Senegal) where data are available showed that between 86 and 93% of the poor live in rural areas. The savannahs and woodlands provide wood and non-wood products, such as fruits, vegetables, nuts, seeds, roots, mushrooms, spices, bush meat, bee products, edible insects, eggs and medicines, which are, particularly, important in the lives of the communities dwelling in them. The products play an important role in the life and well-being of the communities as well as national economies of many countries of the sub-regions. They also provide subsistence, employment and income, particularly, for the rural poor of the sub-regions, and support household-based enterprises. For example, ARNOLD AND TOWNSON (1998) estimated that, perhaps, 15 million people in Sub-Saharan Africa derive, at least, part of their income from forest products. In rural areas of many countries, a significant relationship exists between food security and degree of contribution of non-wood products to households (ODEBODE, 2003). Many of the people depend on these products to sustain their way of life, including their culture and religious traditions (POSEY, 1993; UNESCO, 1996; LAIRD, 1999; PARKINSON, 1999). These ecosystems provide grazing resources by providing fodder for domestic livestock and wild animals because of significant presence of grasses; about 80% of grazing lands of Africa are in savannahs (SCHOLES AND ARCHER, 1997).

The ecosystem services provided by these ecosystems include the conservation of soil and water resources, conservation of biological diversity, amelioration of local climate, carbon storage and regulation of the carbon cycle as well as moderating flows of energy and water. For instance, most of the river basins in Sub-Saharan Africa are either located or have most of their headwaters in the woodland and savannah zones where the vegetation plays a crucial role in sustaining river flows and water supplies (CHIDUMAYO, 2011). Agriculture, i.e. crop production and animal husbandry, is the main occupation of the rural dwellers in these ecosystems that depend on the produce for subsistence and income. The bulk of the food consumed in West and Central African countries are produced in these ecosystems. 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 failures during which the coping strategies of inhabitants are gathering of wild foods and resources from the vegetation (CHIDUMAYO, 2011). Maintaining the flow of these goods and services requires healthy ecosystems in the face of human-induced climate change.

THREATS TO WOODLANDS AND SAVANNAHS

Natural woodlands and savannahs of West and Central Africa are declining mainly due to agricultural expansion, overharvesting of vegetation resources, especially, to supplement human and livestock needs in times of scarcity, increased fuelwood collection, overgrazing, bushfires and fast urbanization, industrialization and drought. KIGOMO (2003) indicated that 48, 32, 12 and 9% of woodland degradation was due to overgrazing, which is concentrated in semi-arid areas, agricultural activities, deforestation and resource overexploitation, respectively. Commercial or subsistence agriculture to meet the food requirements of the growing population and foreign currency needs of the countries of West and Central Africa has resulted in growing pressure to increase the area under agriculture, leading to extensive clearing of woodlands and savannahs. Owing to over-cultivation, the regeneration of trees and shrubs is being hampered by the cultivator. The greatest impact of agriculture has been in West Africa, where more than 50% of woodlands have been converted to agricultural use (CHIDUMAYO, 2011).

Populations living in and around woodlands and savannahs exploit vegetation resources for fuelwood, timber and medicinal purposes. They harvest foliage of plant species as top-feed for human beings and livestock. They also collect huge amounts of seeds and pods of trees and shrubs for subsequent preparation of food. The scale on which seed collection and cutting of plants is carried out has adverse effect in the natural process of regeneration, growth and productivity of certain species. A lot of people in the woodlands and savannahs depend on wood as fuel for cooking and heating. For instance, in Nigeria, fuelwood and charcoal account for over 80% of natural energy consumption (FOLEY, 1986). Most of the villagers in rural areas procure fuelwood free from their own field or unoccupied lands. Clear-felling of trees for commercial firewood without any thought being given to regeneration is common practice. In the Sudan and Sahel savannahs, roots of woody species are 'mined out' for fuel so that the possibility of self-regeneration is slim, even if the people could afford to set aside land for this purpose.

Natural woodland and savannah vegetation of West and Central Africa is used mostly for grazing livestock. Livestock browse on shrubs and trees and graze on the herbaceous species. The herdsmen climb trees such as *Afzelia africana* Sm., *Detarium* and *Acacia* species to cut/lop down the foliage to provide supplementary feed for their livestock in the dry season because of reduction in the supply of grass both in quantity and quality. In the high-density livestock areas of the ecosystems, excessive lopping for browse has reduced many trees to mere skeletons. Overgrazing is a serious problem in the Sudan-Sahel belt where overstocking, often, results in serious damage to the vegetation. The resulting pressure from overgrazing, over-browsing and lopping of vegetation for fodder is a major contributor to deforestation and desertification.

Land use in the woodlands and savannahs is intimately associated with regular use of fire. The vegetation is periodically burnt, either naturally or purposefully. The intensity of the fires is largely a function of the standing crop of grass during the dry season, which is a product of the amount of rainfall and plant production during the previous wet season and the extent of herbivores. Because of their higher fuel load, fires in moist savannahs are usually more intense than those occurring in the drier savannahs. These fires not only consume the grass vegetation and litter, thereby, exposing the soil to erosion, but also destroy the trees of the woodlands. Thus, fire interacts strongly with grazing in that it exerts considerable control on the build-up of woody species, while grazing affects the fuel loads, which are largely the product of grass biomass. Droughts in the woodlands and savannahs, especially, in the Sahelian Zone have become more frequent since the late 1960s. Long and recurrent drought causes soil erosion, thus, accelerating the on-going process of desertification of the Sudanian-Sahelian Zones. Reduction in the area and vegetation cover of the woodlands and savannahs limits their carbon sequestration and, thus, contributes to global climate change, exposes the soil and worsens the impacts of drought and flooding.

CHAPTER 3 Climate change

The United Nations Framework Convention on Climate Change (UNFCCC) defined climate change in Article 1 as “a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods” (United Nations, 1992). Human activities through industrial activity, fossil-fuel consumption, and deforestation and land use changes have increased the concentrations of greenhouse gases in the atmosphere. The consequent increase in infrared radiation captured in the atmosphere, is causing changes in global temperatures, precipitation patterns and sea-levels as well as the melting of glaciers. It is not possible to predict precise future climate conditions, but the scientific consensus is that global land and sea temperatures are warming under the influence of greenhouse gases, and will continue to warm regardless of human intervention for at least the next two decades (IPCC, 2007a). However, IPCC (2001) reported that climate change caused a global average surface temperature increase of about 0.6°C during the 20th Century and current temperatures are predicted to increase further - between 1.4 and 5.8°C by 2100 - depending largely on the level of fossil-fuel consumption. Most of the observed increase in temperature will likely be due to the increase in anthropogenic greenhouse gas concentrations (IPCC, 2007b).

In Africa, climatic records show warming of 0.7°C in most of the continent during 20th Century, a decrease in rainfall over large portions of the Sahel and increase in rainfall in East and Central Africa. Hulme et al. (2001) reported that since 1900, mean surface temperature in Africa has increased by only 0.5°C, yet by 2100, it could increase by 2-6°C. Experts predict that dry areas across West and Central Africa will become drier and wet areas wetter, with longer and more frequent dry periods (IFAD, 2011). A decline in annual rainfall has been observed in West Africa since the end of the 1960s, with a decrease of 20-40% noted in the periods 1931-1960 and 1968-1990 (IFAD, 2011). This long-term decline caused a 25-35 km southward shift of the Sahelian, Sudanese and Guinean ecological zones during the second half of the 20th Century. As a result, the flora and fauna have been lost, and sand dunes have shifted in the Sahel with negative consequences for crop and livestock production, and the rural communities that depend on agriculture for their livelihoods. An additional stress factor for West Africa, particularly the Sahel, is that, on average, temperatures have been rising faster than the overall rate of global warming (IFAD, 2011). The increase has varied between 0.2 and 0.8°C since the end of the 1970s (IFAD, 2011). Although Sub-Saharan Africa contributes less than 4% of the world’s total emissions of greenhouse gases (Fleshman, 2007), IPCC (2007b) expects the warming to be greater in the region than global average, with warming being greatest in the drier sub-tropical regions. Scientists have also predicted with “very high confidence” that the diverse climates and ecological systems in the region have already been altered by global warming and will undergo further damage in the years ahead (FLESHMAN, 2007).

Furthermore, IPCC (2001) has stated that anticipated climate changes pose great threats to food and water security, public health, natural resources and biodiversity. Thus, climate change in woodlands and savannahs of Central and West Africa has resulted in and is expected to experience changing weather patterns, changing seasons, extreme weather events, floods, droughts, wild fires and windstorms. These events will have profound impacts on biodiversity, livelihoods and socio-economic activities. They will also affect the length of growing seasons as well as crop and livestock yields, and bring about increased risk of food shortage, insecurity as well as pest and disease incidence, putting the populations of the sub-regions at greater health and livelihood risks. It will diminish industrial production and weaken infrastructure base for socio-economic activity, resulting in reduced development.

CHAPTER 4 Vulnerability to and impacts of climate change

CHIDUMAYO (2011) defined woodland vulnerability to climate change as 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. West and Central Africa are already showing the effects of climate change and variability. KALAME ET AL. (2008) reported that in parts of West Africa sub-region, intense or frequent extreme climate events of droughts or floods, high temperatures and windstorms are apparent. These climate change effects in West and Central African savannahs and woodlands will impact key sectors of development, such as water availability, agriculture, human health, natural ecosystems and natural resources.

WATER AVAILABILITY

Among the most worrying effects of global warming is the impact on water supply. Water shortage is rated as the most significant problem not only due to the impacts and consequences, but also because it drives or contributes towards other problems, including a spiralling effect, as the shortages cause more unsustainable harvesting of resources and, thus, more degradation (TIEGA, 2010). ASHTON (2002), and FIKI AND LEE (2004) have stated that climate change may become a contributing factor to conflicts in the future, particularly those concerning resource scarcity, for example scarcity of water. Efforts to provide adequate water resources for communities in woodlands and savannahs of West and Central Africa will be compounded by climate change, especially changes in climate variability through drought and flooding. Some humid areas of the woodlands and savannahs are likely to benefit increased rain, but the arid and semi-arid areas of these ecosystems are expected to become drier. Flood-prone areas, on the other hand are likely to become wetter as rainfall patterns shift, causing floods to become more frequent and diverting resources from development to emergency relief (FLESHMAN, 2007). For instance, the massive flooding in Nigerian savannah zones in 2012, partly as a result of excessive rainfall due to the delay in the movement of the Inter Tropical Convergence Zone, displaced a lot people from their homes as internal refugees forcing the Federal Government of Nigeria to release a lot of money that could have been used for development projects to cater for needs of the displaced people.

The water sector is strongly affected by, and sensitive to, changes in climate (including periods of climate variability) (BOKO ET AL., 2007). Changes in precipitation and enhanced evaporation could have profound effects in some lakes and reservoirs and will also increase variability in ground water recharge and river flow, thus, affecting all water sources. Studies of climate variability in West Africa have shown that lakes and reservoirs respond to climate variability via pronounced changes in storage, leading to complete drying up in many cases (e.g. GRAHAM, 1995; TIEGA, 2010). Evidence of inter-annual lake-level fluctuations and lake volatility, for example, has been observed since the 1960s, probably owing to periods of intense droughts followed by increases in rainfall and extreme rainfall events in the late 1997 (BOKO ET AL., 2007).

Some water bodies in the ecosystems have been reported to be drying up as a result of changes in climate, which have reduced rainfall that once kept such water bodies and their feeder rivers full. For instance, Lake Chad, a vast water body of freshwater at the intersection of Niger, Chad, Nigeria and Cameroon, has steadily retreated from its former shores over the past 30 years, raising the prospect that the lake, which was one of Africa's largest, could vanish entirely (FLESHMAN 2007). TIEGA (2010) reported that the lake's volume decreased by 95% from 1963 to 2007. This has led to continuing decline in local access to water, crop failures, livestock deaths, collapsed fisheries and other wetland services (TIEGA, 2010) such that the prospects for 20 million people who depend on the lake and its rivers for water, fishing and growing vegetables are less certain (FLESHMAN, 2007). The shrinkage has impacted negatively on large-scale irrigation schemes in Nigeria, on recession agriculture in Niger, Cameroon and Chad (TIEGA, 2010). After the 1997 flood, very high river-flows were recorded in the Congo River at Kinshasa (CONWAY ET AL., 2005).

Apart from the Congo rivers, the major rivers in West and Central Africa originate from and transverse several semi-arid to arid areas of the woodlands and savannahs of West and Central Africa on their way to the coast. For instance, the Fouta Djallon Highlands, which consist of mountainous landscapes in Guinea that extend into Cote d'Ivoire, Guinea Bissau, Mali, Liberia, Senegal and Sierra Leone are the source of major rivers in West Africa, notably the Gambia, Niger and Senegal Rivers that flow to the coast. Because they originate from high temperature areas, evaporative losses are high and climate change-induced higher temperatures will enhance the evaporative losses of these rivers unless they are compensated by increased rainfall. Run-off is also likely to be further reduced. The incidence of perennial rivers turning into seasonal rivers will increase as a result of an increased incidence of seasonal cessation during the hot dry season in savannahs and woodlands. Thus, drought periods will increase now and translate into critical water shortages for industrial and urban domestic supplies (MAGADZA, 1996).

LOSS OF BIODIVERSITY

Climate change-induced variations in temperatures and rainfall and other climatic variables will affect diversity of plants and animals in woodlands and savannahs of West and Central

Africa through increased frequencies of wild fires, drought, floods, and altered patterns of pest and disease incidence, the spread of invasive species and loss or alteration of both aquatic and terrestrial habitats. Tree species, which the rural communities in woodlands and savannahs of West and Central Africa depend on, are disappearing as a result of hotter and drier conditions. Hence, the incomes and livelihoods of the rural communities that rely on tree products are declining. Climate change is expected to exacerbate these impacts.

"Rapid ecosystem switches[1]" that are expected to occur with the interaction of climate change with changing disturbance regimes (e.g. habitat loss, overexploitation, species introduction, and loss and excessive nutrient loading of freshwater and coastal ecosystems) would be accompanied by drastic species shifts and even species extinction, which will impact biodiversity resources. As the climate continues to change, there will be biodiversity shifts and the ranges and distribution of many species will change, with the resulting effects on availability, accessibility and quality of resources upon which human and wildlife populations rely on (GANDIWA AND ZISADZA, 2010). This will have implications for protection and management of wildlife, habitats, protected areas and forests (PROWSE ET AL., 2009). Burning of woodlands and savannahs has resulted in the evolution of ecosystems with high biodiversity and facilitated the rise of C_4-grass-dominated floras and associated fauna (BOND ET AL., 2005). The predicted increase in climate variability has led several authors to suggest that the frequency, severity, seasonality and extent of vegetation fires that are critical in maintaining these systems will increase (OTTICHILO ET AL., 1991; CHERFAS, 1992; TORN AND FRIED, 1992; KENDALL ET AL., 1997; LEVINE ET AL., 1999; DESANKER ET AL., 2001).

Also, the increased frequency and severity of drought in the woodlands and savannahs in West Africa will increase the fire–fuel load, and, thus, potentially increase the frequency and intensity of fires with severe consequences for biodiversity. The increased fire frequency and grazing regimes, in conjunction with changes in climate characteristics affecting soil moisture status, relative humidity or drought stress, will greatest influence woody and grass species composition in the woodlands and savannah. PARTON ET AL. (1994) have reported that the balance between herbaceous and woody vegetation is sensitive to climate in most grasslands/savannah regions. Changes, such as replacement of grasses with woody species, can occur quite quickly (GRIFFIN AND FRIEDEL, 1985; WESTOBY ET AL., 1989) within a decade or so in response to a mixture of reduced grazing regimes, fire suppression and climate variability. Fires limit tree growth and have a pronounced influence on the amount of biomass burned.

[1] The abrupt or rapid changes in ecosystem status and services caused by passing a threshold where core ecosystem functions, structures and processes are fundamentally changed at which point rapid shifts to new state occur.

However, increasing CO_2 concentration will result in increased tree growth and woody thickening, which will allow trees to grow above a threshold where fire will maintain an open structure (Rohde et al., 2006). Also, Ainsworth and Long (2005) have reported that trees and shrubs show higher CO_2 responsiveness than do herbaceous forms. Bond et al. (2003) have reported that the savannahs may be shifting towards greater tree dominance as atmospheric CO_2 rises with diminishing grass suppression of faster growing tree saplings. The resulting more densely forested landscape, whilst beneficial for biomass and carbon storage, will be deleterious to wildlife. Also, because domestic livestock, with the exception of goats, predominantly eat grass, changes in tree cover will impact livestock production by decreasing livestock carrying capacity as a result of suppressive effects of trees on grass production in the woodlands and savannahs. The change could affect the physiology of the plants and, thereby, adversely affecting their survival, and reducing the population of the frugivorous animals and birds that feed on them.

Geographical shifts in the ranges of individual species and changes in productivity in the woodlands and savannahs may have been caused by climate change, which alters the spatial and temporal patterns of temperature and precipitation, the two fundamental factors determining the distribution and productivity of vegetation. For instance, in West Africa, the long-term decline in rainfall from the 1970s to 1990s has caused a 25-35 km shift southward of the Sahelian, Sudanese and Guinean ecological zones in the 20th Century (Gonzalez, 2001). This has resulted in a loss of grassland and acacia, the loss of flora/fauna and shifting sand dunes in the Sahel (European Climate Forum and Potsdam Institute, 2004). Gonzalez (2001) reported a significant decline in the number and density of tree species in the Sudanese, Guinean and Sahelian ecological zones over the latter half of the 20th Century as a result of this shift, which he equated to a biome shift of 500-600 meters per year.

Loss or alteration of terrestrial habitats by climate change will impact the species concentrated in the savannahs. Already, changes in climate predicted for 21st Century could alter the distribution range of antelope species (Hulme, 1996) of which 90% of the global total of 80 species are concentrated in Africa (Macdonald, 1987). Also, Magadza (1996) has reported that large mammals such as elephant, buffalo, hippopotamus and large antelopes are likely to be threatened by climate change. Migration of species of both animals and unassisted plants to areas with more suitable climate would be also affected by climate change alteration of ecosystem characteristics. This could cause extinction of species with limited distribution range, poor dispersal abilities, and habitat specialists and without adaptive strategies. Flooding could dislodge animals from their natural habitats rendering them vulnerable to predators just as floods in the savannahs of Nigeria in 2012 dislodged animals comprising hippopotamuses, crocodiles and snakes among others from their natural habitats.

An increase in the frequency of drought in the biomes has resulted in episodic die-off of woody vegetation and resulted in degradation. For instance, some species valuable for non-timber forest products in Burkina Faso, e.g. *Adansonia digitata* L., *Diospyros mespiliformis* Hochst. ex A. DC. and *Anogeissus leiocarpus* (DC.) Guill. & Perr., have become locally exterminated, which has been attributed to recurrent droughts (IDINOBA ET AL., 2009). Furthermore, dry woodlands and savannahs in semi-arid and sub-humid areas will be increasingly subjected to drying in the next century as well as increasing land-use intensity, including conversion to agriculture (DESANKER ET AL., 1997).

Water shortage contributes to the loss of biodiversity and increasing loss and modification of ecosystems (TIEGA, 2010). As the lakes and other water bodies in these ecosystems dry up and change to terrestrial habitats as a result of climate change and disturbance, their biodiversity will be lost. For example, Lake Chad, which is strategic for global biodiversity, being home to 120 species of fish as well supporting 372 bird species has changed from open water to marshy environment and about 50% of wetlands have been lost (TIEGA, 2010). The impact of this phenomenon is most felt in the collapse of some fisheries and recessional rice cultivation as well as sedimentation in rivers and other water bodies, which led to the colonization of species of the silted sites, e.g. *Typha* grass as a major problem and quelea birds as invasive pests prevalent all over the basin (TIEGA, 2010).

Changes to the biodiversity of these ecosystems due to climate change may be aggravated by other human-induced changes in the natural environment adversely affecting the goods and services they provide to the communities that depend on them.

AGRICULTURE

Agricultural production, an important economic activity and playing a crucial role in food security in woodlands and savannahs of West and Central Africa, is mostly rain-fed and finely tuned to climate. Thus, it is highly vulnerable to changes in climate variability, seasonal shifts and precipitation patterns, making the threat of climate change particularly important in the ecosystems. It is likely to be hit hard as droughts and flooding worsen, temperatures and growing seasons change, and farmers and herdsmen are forced off their land. The expected warmer climates and changes in precipitation will destabilize agricultural production. MENDELSOHN ET AL. (2000) reported that West and Central Africa are expected to have agricultural losses ranging from 2-4% while Northern and Southern Africa are expected to have losses of 0.4-1.3%.

The impacts of climate change on crops in woodlands and savannah zones of West and Central Africa are either due to changes in temperature, precipitation and CO_2 concentrations or indirect effects through changes in soil moisture content and incidence of pests and diseases. Past and current assessment of climate change impact on African agriculture clearly showed uniformly negative impacts on crop yields. In most of Africa, water availability is projected to have the greatest impact on plant species (IPCC, 2001). The observed decline in rainfall (MALHI AND WRIGHT, 2004; NIASSE ET AL., 2004) and increase in mean annual temperatures by approximately 0.5°C (ERIKSEN ET AL., 2008) and the projected future annual warming range from 0.2°C to more than 0.5°C per decade (HULME ET AL., 2001) across Africa will adversely affect crop yields in the ecosystems. For instance, FISCHER ET AL. (2002) using an agro-ecological zoning that identified suitability of land for agricultural production and simulated the changes in availability of suitable agricultural land that can be expected from climate change, which covered several countries, showed that for rain-fed cereal production based on one crop per year, land currently under cultivation would experience a decrease in production potential by - 3.5%.

Furthermore, CLINE (2007) used temperature and precipitation projections (2070 - 2099) from six climate models to obtain change in crop yields. The result showed that, with a 2°C warming, there would be sharp declines in crop yields in tropical regions, and for Africa, these decreases would range from 5-10%. Atmospheric CO_2 concentration influences plants by altering water-use efficiency, photosynthetic rates, light use and nutrient use efficiency (BOND ET AL., 2005). Increased atmospheric CO_2 will affect crop yields in the woodland and savannah zones by either offsetting or even reducing expected increases in respiration from a temperature increase alone and likely improving water-use efficiency and growth in C_3 crop species (such as rice, cassava and potato) in water-limited environment though C_4 crop species (maize, sugar cane and sorghum) are unlikely to be affected directly by changes in CO_2 concentrations. Increasing CO_2 will likely result in lower forage quality because of higher carbon:nitrogen ratios and higher concentration of unpalatable and/or toxic compound in plants (FAJER ET AL., 1991).

IPCC (2007) notes that in the low latitudes of the tropics, many wet areas will get wetter and dry areas, drier, aggravating drought and flood tendencies. The increasing temperature and decreasing rainfall have led to frequent drought and desertification in the woodlands and savannahs. The desertification in the woodlands and savannahs that resulted from climatic variations and human activities has caused reduction or loss in soil productivity, vegetation, cultivated and pasture lands. All these will combine to reduce crop harvests, constrain livestock husbandry and, consequently, the incomes of rural people diminish. For instance, ODJUGO AND IKHUORIA (2003) observed that Nigeria north of 12° N is under severe threat of desert encroachment, and sand dunes are now common features of desertification in states like Yobe and Borno in Sahel savannah and Sokoto and Katsina in Sudan savannah zone. These migrating sand dunes have buried large expanse of arable lands, thus, reducing viable agricultural lands and crop production. This has prompted massive emigration and resettlement of people from Sahel and Sudan savannah to Guinea savannah and the rainforest belt. Many cattle Fulanis with their herds are now permanently settled or roaming within the Guinea savannah and the rainforest belt. This has increased pressure on land in these zones resulting in conflict between the cattle Fulanis and the crop growing natives of the Guinea savannah over the right to the land, which in most cases resulted in destruction of their farmlands by the cattle. YUGUNDA (2002) and YAQUB (2007) reported that such clashes resulted in the death of 186 people in six northern states in Nigeria. Heavy rainfalls caused by climate change have caused flooding, inundation of farmlands and crop failure, thus, destroying agricultural-based economy and threatening by a food crisis. A further consequence of climate on agriculture is wind erosion, which is most severe in arid zones of the woodlands and savannahs where ground cover is poor and increased by deforestation. Crop production and livestock rearing, the main sources of livelihoods, are increasingly threatened by effects of climate change. Pastoralists are forced to move from north to south to feed their animals, thus, encroaching on agricultural areas (IFAD, 2011).

The woodlands and savannahs of West and Central Africa are particularly used for livestock production, and domestic livestock are concentrated in the areas. Many people depend on livestock and their products for some part of their livelihoods and others as their primary source of income. The impacts of climate change on livestock are likely to be felt from an increased severity and frequency of drought in the woodlands and savannahs. Deterioration of pastures during drought and periods of overgrazing can result in poor health and death of livestock, which impacts on food and livelihood security of those who own livestock. In times of water scarcity, when livestock are forced to use the same water resources as humans, diseases are transferred from humans to animals and vice versa. There will also be increased competition for grazing resources, livestock losses and conflict with recurring drought. Increased precipitation is likely to be harmful to grazing animals because it implies a shift from grassland to forests, an increase in harmful disease vectors and, also, a shift from livestock to crops.

The distribution of pests and diseases that affect crops and livestock which are controlled by climate variables, especially temperature, wind and humidity would be altered as a result of climate change. Increased variability of rainfall and changes in temperature will create more suitable conditions for new pests or old pests, such as ticks, tsetse flies and locust to expand their territories. Their incidence would also increase. Crop species and livestock may have to face new competitors, predators, diseases and alien species for which they have no natural defense in the biomes. For instance, Hulme (1996) reported that livestock productivity and distribution could indirectly be influenced via changes in the distribution of vector-borne livestock diseases, such as trypanosomiasis and the tick-borne diseases and corridor disease.

The fishing industry, an important source of revenue, employment and proteins, is also likely to suffer as lakes and rivers dry up and rising water temperatures destroy commercial fish species (FLESHMAN, 2007). The industry contributes over 6% of Senegal's GDP (NJAYA AND HOWARD, 2006), and 47% of animal protein intake comes from fisheries (FAO, 2005).

HUMAN HEALTH

The health of communities in the woodlands and savannahs that have been impacted by several causes, including poverty, will further be stressed by climate change. The temporal and spatial changes in temperature, precipitation and humidity that are expected to occur under different climate change scenarios will affect the biology and ecology of disease vectors and intermediate hosts and consequently the risk of disease transmission (GITHEKO ET AL., 2000), such as malaria and other parasitic diseases and parasites like tsetse fly. Malaria is the single greatest killer of African children and imposes a US$12 billion annual drain on African economies through death, medical costs and lost productivity (FLESHMAN, 2007). The economic burden of malaria is estimated as an average annual reduction in economic growth of 1.3% for those African countries with the hardest burden (GALLUP AND SACHS, 2001). The mosquitoes that spread it within a relatively narrow range of temperature and moisture, and some infected areas may become malaria free as they become drier (FLESHMAN, 2007). Yet, simultaneously, regions outside the malaria zone may become infested as they get hotter and wetter (FLESHMAN, 2007). Thus, warmer temperature and higher rainfall in the woodlands and savannahs is likely to increase the transmission of malaria because of reduction in larval development period (BOKO ET AL., 2007). Furthermore, flooding could facilitate breeding of malaria vectors and, consequently, malaria transmission (WARSAME ET AL., 1995) in arid areas of the savannahs and woodlands. On the other hand, increased warming will have a negative effect at the high end of the temperature range of mosquito vectors (GITHEKO ET AL., 2000). The negative effect of reduced precipitation and drought have been observed in Senegal where *Aedes funestus* has virtually disappeared and malaria prevalence has dropped by more than 60% over the last 30 years (FAYE ET AL., 1995).

Other vector-borne diseases that are also of importance with respect to climate variability and change are cholera, plague, Rift Valley Fever, meningitis, schistosomiasis, onchocerciasis, filariasis, leishmaniasis, yellow fever and tick-borne haemorrhagic fever for which the tropical climate is favourable. The savannahs of West and Central Africa are the major meningitis belt of Africa. MOLESWORTH ET AL. (2003) reported that about 162 million people in Africa live in areas with a risk of meningitis. Major epidemics occur every 5-10 years within the African meningitis belt. They usually start in the middle of the dry season and end a few months later with the onset of the rains (GREENWOOD, 1984). Low humidity (TIKHOMIROV ET AL., 1997), dusty conditions and other environmental factors predispose populations to meningococcal meningitis. SULTAN ET AL. (2005) have reported that wind speeds in the first two weeks of February experienced 85% variation in the number of meningitis cases, thus, linking the infection to climatic factor. Recent data from West Africa indicate that the risk of a new epizootic of Rift Valley Fever, a disease considered to be a relatively benign zoonoses for humans that periodically developed in domestic animals following heavy rains (LEFEVRE, 1997), is increasing in the region (FONTENILLE ET AL., 1995) with significant exposure to the virus among livestock herders and wildlife rangers during the dry season (OLALEYE ET AL., 1996). Flooding will cause the pollution of water of streams and other sources of rural domestic water supplies by introducing parasites such as giardia, amoeba and cryptosporidium into drinking water (ALTERHOLF ET AL., 1998).

Vector species in West and Central Africa are adapted to ecosystems ranging from humid forests to dry savannahs (GITHEKO ET AL., 2000). As these ecosystems change, so will the distribution of vector species. For instance, in Senegal, *Biomphalaria pfeifferi* snails transmit *Schistosoma mansoni* during the rainy season while *Bulinus globosus* is responsible for transmission of *S. haematobium* during the dry season (ERNOULD ET AL., 1999). Thus, long-term changes in climate change can be expected to alter the distributions of snails and, in turn, the disease pattern (GITHEKO ET AL., 2000). The same trend is expected of trypanosomiasis vectors *Glossina morsitansis*, mainly a savannah dweller, and *G. palpalis*, a riverine species preferring to rest under dense vegetation (GITHEKO ET AL., 2000). Factors that alter the resting sites for adult tsetse flies, such as long-term changes in rainfall can affect the epidemiology and transmission of trypanosomiasis, though long-term change in vegetation is a slow process (GITHEKO ET AL., 2000). However, the impact of climate change on the transmission of other, less climate sensitive, vector-borne diseases, such as filariasis, onchocerciasis and schistosomiasis, is not clear and may take long time to be evident (DESANKER ET AL., 2001).

SOCIO-ECONOMICS AND LIVELIHOODS

Over 270 million people, representing 40% of Africa's population, live and depend on forest, woodlands and savannahs for their livelihood (OSMAN-ELASHA ET AL., 2011). Also, FAURES AND SANTINI (2008) reported that in Sub-Saharan Africa, rural poverty accounts for 90% of total poverty, and approximately 80% of the poor depend on agriculture and natural resources for their livelihoods. These ecosystems also contribute significantly to national economies. For instance, in many rural Sub-Saharan 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 (FAO, 2004). The economic and human welfare impact of climate change on the woodlands and savannahs can be severe for the many poor rural communities as well as national economic activities that depend on the woodlands and savannahs for food, fodder, fuelwood, medicines and various ecosystems services. Water shortages and unpredictable rainfall, in combination with continued population growth and increased land degradation would impact on the ecosystems and their capacity to provide immediate livelihood needs.

Non-timber forests products provide subsistence, employment and income, particularly, for the rural poor and support small household-based enterprises in these woodlands and savannahs. Many use traditional medicines and trade on medicinal products obtained from many medicinal plants from these ecosystems. FAO (2001) reported that the ratio of traditional healers to western trained doctors reaches 150:1 in some African countries. The projected increase in the frequency of extreme events, such as droughts and floods, as a result of climate change is and will continue to exacerbate the losses already experienced due to drought and land degradation, creating additional threats to woodlands and savannahs of West and Central Africa. Furthermore, reduction in water quantity predicted (SCHOLZE ET AL., 2006) will reduce water available for plants and productivity and yield, leading to reduction in goods and services to the people, especially, the rural poor, who depend on them. Longer droughts and more severe floods could also reduce agricultural yields and put more pressure on these ecosystems to meet the needs of stressed people. Rising temperatures and changing rainfall patterns, in addition to human activities, such as deforestation, agricultural expansion, over harvesting, annual fires and overgrazing (IDINOBA ET AL., 2009), have been reported to have caused the significant reduction in the distribution and availability of some species with NTFPs and high variability in their productivity, making forest-dependent communities more vulnerable. This was observed in northern Burkina Faso from the research carried out by Tropical Forest and Climate Change Adaptation (TroFCCA) project of the Center for International Forestry Research (CIFOR) (IDINOBA ET AL., 2009).

Except in oil producing countries, the economies of West and Central Africa countries rely heavily on exploitation of the natural resources with agricultural sector being the mainstay. For instance, ANDERSON ET AL. (2006) reported that between 60 and 90% of the labour force are in the rural sector, and between 16 and 45% of Gross Domestic Product (GDP) generated by the Forest Sector in Burkina Faso, Mali, Ghana, Niger and Senegal.

Livestock will be affected through high temperature effects on large farm animals, like cattle, which are not heat tolerant, and increased rainfall is likely to be harmful to grazing animals because it implies a shift from grasslands to forests and increase in harmful disease vectors and a shift from livestock to crops (SEO AND MENDELSSOHN, 2006).

Even though the Wildlife Sector is not well developed in countries of West and Central Africa, many protected areas in woodlands and savannahs of the sub-regions have good potential for the development of wildlife tourism (OSMAN-ELASHA ET AL., 2011). Climate change has the potential to shift the configuration of woody and grassy habitats in wildlife conservation areas since diversity of wildlife species is correlated to habitat diversity, which, invariably, will impact the diversity of wildlife species (OSMAN-ELASHA ET AL., 2011), adversely affecting wildlife tourism development and the revenue to be generated from the utilization of wildlife resources. This would impact on both local and national economies.

The communities living in and around woodlands and the savannahs highly value the vegetation for a number of cultural, social and spiritual reasons. For many indigenous and traditional societies forests are sacred and sometimes supernatural places linked to both religious beliefs and the very identity of some communities and peoples (PARKINSON, 1999). The existence of 'sacred groves' in many communities is a manifestation of this spiritual role, which has contributed to vegetation and biodiversity conservation. In rural areas of West and Central Africa, tree shade is where villagers confer to discuss their daily lives, solve problems or enjoy tea and coffee (OSMA-ELASHA ET AL., 2011). Sometimes trees act as courtyards where villagers meet to solve their local conflicts and disputes (SEPPALA ET AL., 2009), and in some cases, big trees act as a market place.

SETTLEMENTS AND INFRASTRUCTURE

Climate variability, including the resultant extreme events such as storms, floods, especially flash floods and drought have impacted and continued to cause impacts on infrastructure, such as human settlements, industry, electricity and transportation in woodland and savannah zones of West and Central Africa. Flooding as a result of heavy rains will cause considerable damage to property and infrastructure, such as road, dams, power generation and railway network, and disrupt communications among settlements, impeding movement of goods and persons in woodland and savannah zones of the sub-regions. For instance, flooding caused by excessive rainfall experienced in 2012, and the release of water from Lagdo Dam in Cameroon and Kainji Dam in Nigeria caused flooding in most north-central states in the Guinea and Sudan savannah zones of Nigeria, destroying farmlands, buildings, submerging government infrastructure and flooding the Lokaja-Abuja road, making it impassable and leaving many motorists and travellers stranded. ATTAH (2012) reported that no fewer than 400,000 farmlands and 36,000 houses were destroyed, and over 750 people were rendered homeless by floods in Jigiwa State alone in the Sudan savannah zone of Nigeria.

The combination of urban population pressure and decreasing water supply in catchment areas will reduce stream flow, which, in turn, limits hydropower production and the industrial productivity that depends on energy.

Negative impacts of climate change could create a new set of refugees, who may migrate into new settlements, seek new livelihoods and place additional demands on infrastructure (MYERS, 2002; MCLEMAN AND SMIT, 2005). Thus, extreme weather events as a result of climate change, such as flooding, would continue to pose significant threat to countries of West and Central Africa in achieving their national goals in agriculture, road construction, housing, health and conservation of environment.

CHAPTER 5 Knowledge generation and permanent sample plots

Long-term changes in vegetation are best studied by means of permanent sample plots (PSPs). Changes in flora and fauna in successive seasons through the year or successive years are, then, followed by setting PSPs. Such plots are clearly marked out with permanent markers and geo-referenced to relocate them in the future. The plots are re-sampled at regular intervals to record plant and animal life and habitat factors. Long-term monitoring in PSPs will allow changes in woodland and savannah stand growth, recruitment and mortality rates to be calculated. Not much information is available, especially on vulnerability to and impact of climate change on the composition, structure, dynamics, productivity and function of woodlands and savannahs of West and Central Africa from long-term monitoring of woody and grass species, within PSPs. Woodlands and savannahs in West and Central Africa are almost certainly undergoing major shifts in composition, structure, dynamics, productivity and function since the physical, chemical and biological environment in which species in woodlands and savannahs occur are being altered as a result of climate change and variability. Hence, the need to establish PSPs in woodlands and savannahs of West and Central Africa to generate specific data and information through monitoring climate factors in relation to composition, structure, dynamics, productivity and function of woodlands and savannahs that could significantly contribute to woodland- and savannah-based climate change mitigation and adaptation in West and Central Africa.

STATUS OF CURRENT KNOWLEDGE ON CLIMATE CHANGE AND WOODLANDS AND SAVANNAHS

Most of the information on the effects of climate change and variability on woodlands and savannahs of West and Central Africa are mainly predictions with little hard data and information on the vulnerability to and impacts to climate change of these ecosystems. Therefore, there are uncertainties about the outcomes of interacting factors (temperature increase, variability in precipitation, extreme events, CO_2 fertilization, wildfire, etc.), hence, the necessity of generating more knowledge through monitoring climate factors in relation to composition, structure, phenology, growth, regeneration, dynamics, productivity and function of woodlands and savannahs, as well as synthesizing data sets collected across different sites. For instance, there is a need for better information on the temporal and spatial character of fire and its impacts on land cover in order to understand the changing nature of the impact of fire on woodlands and savannahs in West and Central Africa. Also, there is a need to understand the effects of changing atmospheric CO_2, temperature and precipitation with fire on the ecosystems. This requires establishment of PSPs in woodlands and savannahs in some representative countries across West and Central Africa to generate accurate data and information on the above parameters through periodic re-sampling and monitoring of the plots to be used in the efforts for climate change mitigation and adaptation in the sub-regions.

PERMANENT SAMPLE PLOTS

There is dearth of data and information on existing PSPs in woodlands and savannahs of West and Central Africa. This could be partly attributed to the fact that when they were established, their geographical locations (latitudes and longitudes) were not recorded because of lack of Global Positioning System (GPS) technology in the sub-regions. After the advent of GPS, those who established them did not bother or forgot to go and geo-reference them. In publications accessed for this study, authors just stated that data were collected from PSPs without indicating their geographical locations. Also, requests for information on the location of the PSPs sent to scientists and international organizations did not bring any result. Furthermore, the local visits to PSPs established by the Forestry Research Institute of Nigeria and Nigerian Man and Biosphere (MAB) Committee showed that some of them were either highly degraded or completely deforested and converted to farmlands or settlements. For instance, in the 1980s, the Nigerian Man and Biosphere National Committee (MAB-3 Project) established ten one ha PSPs in different parts of Nigerian savannahs (Southern and Northern Guinea and sub-Sudan savannah types) in the Kainji Lake Basin to study the effect of anthropogenic activities on the Nigerian savannahs. During visits to the sample plots, 80% of the PSPs (except MAB plots 6 and 7 within the protected Kainji Lake National Park) have been completely cleared and converted into farmlands or settlements. Unfortunately, when these MAB sample plots were established their geographical positions were not taken.

RECOMMENDATIONS

Permanent sample plots are badly needed to monitor and evaluate the response of woodlands and savannahs in West and Central Africa to climate change. Apparently, the existing PSPs are no longer useful. Hence, it is highly recommended that new one ha PSPs be established to generate data and information as well as modelling the impacts of climate change on woodlands and savannahs in West and Central Africa. These sample plots should be established within protected Strict Nature Reserves in selected countries in West and Central Africa. This recommendation is based on the lesson learnt from the fate of PSPs established by the Nigerian MAB project where only two out of ten are still existing and intact. During the establishment of the new PSPs, their boundaries should be clearly marked out with permanent markers and geo-referenced for future reference or relocation.

All plant species in each plot should be identified. Also, the woody species should be permanently tagged, completely enumerated and their diameter or girth at breast height (DBH/GBH) (1.3 m) measured. The leaf phenology (deciduous or evergreen) of the woody species should be determined. Woody species within each plot should be tracked through time to monitor temporal changes in their species composition, stem growth and mortality as well as the amount of carbon stored in the biomass of live individuals through re-sampling the plots periodically. Measurements of DBH/GBH of individuals of woody species should be carried out each time the plots are revisited periodically. Data on dead and newly recruited individuals of woody species should be collected to generate information on their mortality and recruitment. Also, soil samples should be collected per plot down to 50 cm (0-15 and 15-50 cm) depth to determine the amount of carbon as well as nutrient distributions with soil density, texture and groundwater level. Climatic data could be collected from nearby meteorological station(s) and the microclimatic conditions recorded on-site. Scientists who are currently actively engaged in research and institutionally based in each of the countries should be appointed to monitor and collect the data and information from the plots.

CHAPTER 6 Conclusions

Tropical woodlands and savannahs are associated with areas where there is an annual dry season of sufficient duration and intensity, and most of the woody species shed their leaves and grasses dry out. The accumulation of the dry fuel permits fires every year or 2-3 years, and the fires help prevent complete domination of woody plants. They occupy extensive areas in West and Central Africa. These ecosystems serve important ecological functions and provide wood and NWFPs that contribute significantly to human well-being at local, national and global levels. Anthropogenic activities through industrial activity, fossil-fuel consumption, deforestation and land use changes have increased the concentrations of greenhouse gases in the atmosphere, which is causing changes in global temperatures, precipitation patterns and sea levels as well as melting of glaciers. Climate change and variability, as a result of increasing greenhouse gases in the atmosphere, have already resulted in and are expected to contribute to changing weather patterns, changing seasons, extreme weather events, frequency and intensity of floods, droughts, wildfires and windstorms in woodland and savannah zones of West and Central Africa. These events have already affected and will further affect agriculture, biodiversity, human health, water resources, infrastructure and socio-economic activities in the years ahead in these zones.

However, there are uncertainties about the outcomes of interacting factors (temperature increase, variability in precipitation, extreme weather events, CO_2 fertilization, increase and intensity of wildfires) in woodlands and savannahs of West and Central Africa, justifying the necessity of generating more knowledge through monitoring climate factors in relation to composition, structure, phenology, growth, regeneration, dynamics, productivity and functioning of these woodlands and savannahs as well as synthesizing data collected across different sites. This requires the establishment of PSPs in woodlands and savannahs of selected countries in West and Central Africa to generate accurate data and information through periodic re-sampling and monitoring of the plots. The data and information so collected will be instrumental in identifying, developing and implementing proactive and reactive measures for the mitigation and adaptation of climate change.

There is death of data and information on existing PSPs in woodlands and savannahs of West and Central Africa. It is recommended that one ha new PSPs be established in Strict Nature Reserves in savannahs and woodland ecosystems of selected countries in the sub-region to generate data and information for modelling impacts of climate change on these ecosystems. This is important because of the uncertainties over the projections about regional patterns of rainfall and soil moisture, especially in West Africa, and the little information available about the frequency and intensities of extreme weather events, fire and CO_2 fertilization, and their potential impacts on the woodlands and savannahs.

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