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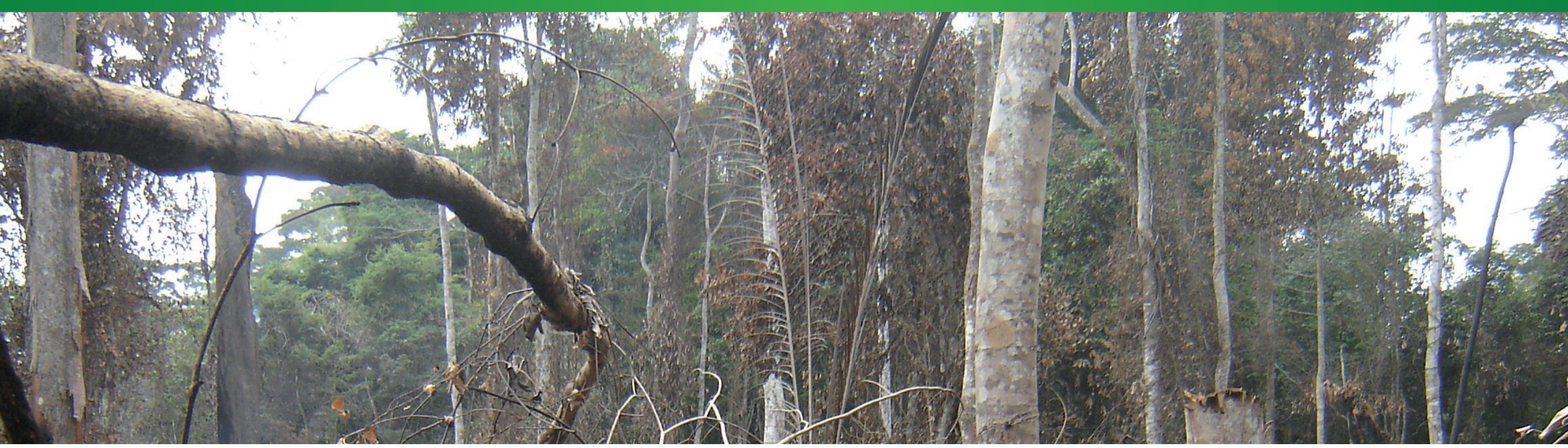
# VULNERABILITY OF BIOPHYSICAL AND SOCIO-ECONOMIC SYSTEMS IN MOIST TROPICAL FORESTS IN WEST AND CENTRAL AFRICA TO CLIMATE CHANGE



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# Vulnerability of biophysical and socio-economic systems in moist tropical forests in west and central Africa to climate change

Muoghalu Ikechukwu Joseph

 

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# Acronyms and abbreviations

| | |
|---|---|
| FAO | Food and Agricultural Organization |
| IITA | International Institute of Tropical Agriculture |
| IPCC | Intergovernmental Panel on Climate Change |
| ITCZ | Inter-tropical Convergence Zone |
| IUCN | International Union for Conservation of Nature |
| IUFRO | International Union of Forest Research Organization |
| NIMET | Nigerian Meteorological Agency |
| REDD | Reducing Emissions from Deforestation and forest Degradation |
| TAR | Third Assessment Report |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNFCC | United Nations Framework Convention on Climate Change |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNESCO-WWAD | United Nations World Water Development |
| WRI | World Resources Institute |

 

# Executive summary

Tropical forest of Africa represents 18% of the world total and covers over 3.6 million km$^2$ in West, East and Central Africa. The bulk of tropical forests in Africa are found in West and Central Africa with the forests in Congo Basin of containing the largest remaining contiguous expanse of moist tropical forests (MTFs) in Africa and the second largest in the world after the Amazon forest.

The West and Central African MTFs are characterized by annual rainfall of 1,400 - 4000 mm, and include moist deciduous and rain forests at low altitudes and Afromontane broadleaved forests at higher altitudes (> 900 m elevation).

A large fraction of populations who live in rural areas depend on the MTFs for many of their subsistence and export of timber, and non-timber forest products generate income for countries in West and Central Africa.

The large expanse of MTFs in West and Central Africa holds much of Africa's carbon, and the general vulnerability of the people and economies make the sub-regions important for consideration in terms of impacts from climate change. However, lack of accurate climate forecasting makes it difficult to accurately predict future conditions of climates in the sub-regions. But, there is still a need to consider the likely impacts of climate change on forests and the people who are dependent on forest products and services in order to put in place adaptive strategies for the people.

Climatic records show that the African continent is warmer than it was 100 years ago with warming of approximately 0.7 °C in most of the continent during the 20th Century, a decrease in rainfall over large portions of the Sahel and increase in rainfall in east-central Africa. During this century, this warming trend and changes in precipitation patterns are expected to continue accompanied by a rise in sea level and increased frequency of extreme weather events.

The changes in temperature and rainfall will alter the environmental conditions to which trees in MTFs in Central and West Africa are adapted and expose them to new pests and diseases. The rich biodiversity, some of which concentrated in several centres of endemism of the MTFs, is at risk through extinction of species as a result of climate change.

Increased flooding, as a result of storm surges, intense rainstorms and sea-level rise, will expose large numbers of people to immediate deaths and injuries from drowning, infectious diseases and exposure to toxic substances. It will also affect agriculture and cause damage to property and infrastructure, e.g. roads, dams, power generation and communication.

 

Predicted higher temperatures and altered precipitation would adversely affect agriculture by reducing the production potential of many crops grown in the moist forest regions and cause disease infection. Furthermore, higher temperatures will accelerate the decay of soil organic matter. The impact on agriculture as a result of increasing atmospheric carbon dioxide in the zone will be complicated by the effects carbon dioxide has on crop plants besides its alteration of their climate regime.

The temporal and spatial changes in temperature, precipitation and humidity that are expected to occur under the different climate scenarios will affect the biology and ecology of vectors as well as intermediate hosts and, consequently, increase the risk of transmission of diseases such as malaria, cholera, Rift Valley Fever, plague and other vector-borne diseases.

The anticipated future impact of climate change on water resources are likely to result in increase in water runoff in Central Africa but a decrease in West Africa and increased potential evapotranspiration, which would lead to reduction in soil water and changes in precipitation. The enhanced evaporation could have profound effects on some lakes and reservoirs leading to their complete drying out in many cases. Rising sea level will result in the pollution of most of the water resources along the coast by intrusion of sea water.

Reduction in water quantity will lead to a reduction in water available for tree and forest growth, leading to reduced forest productivity and yields that would bring a gradual decrease in forest cover. This will have far reaching consequences to households depending on the MTFs of West and Central Africa.

Thus, current knowledge indicates that MTFs are being or will be negatively affected by climate change (shifts in species composition and functional groups, reduction in productivity and resilience, impacts on biodiversity, human health, agriculture, water, socio-economic development and livelihoods).

In spite of the above, there are uncertainties about the outcomes of interacting factors (temperature increase, variability in precipitation, extreme events, carbon dioxide fertilization and wildfires). Hence, there is a necessity of generating more knowledge through monitoring climate factors and forest phenology as well as growth and regeneration of the woody species, and synthesizing cross-site data in West and Central Africa. The emphasis should be on examining the effects of changes in climate variables (temperature and precipitation) and atmospheric carbon dioxide concentration on the MTFs. This is because temperature, water availability and carbon dioxide are significant in relation to climate change among the many climatic variables that are important for plant growth. This is particularly so because of the predicted increase in atmospheric $CO_2$ in the future causing temperature rises and, possibly, climatic shifts. There is, also, a need to collect more accurate estimates of the cover and rates of change of MTFs as a result of deforestation, forest degradation and regrowth in West and Central Africa.

This requires the use of permanent sample plots (PSPs) to collect the necessary data and information. However, there is a great paucity of information on PSPs used in the vegetation studies in MTFs of West and Central Africa Strict Nature Reserves (SNRs) with available data and information that are suggested for use in monitoring impacts of climate change in the MTFs. One-hectare permanent sample plots should be established in selected SNRs within MTFs in representative countries across West and Central Africa to generate data and information to be used for forest-based climate change mitigation and adaptation through periodic re-sampling and monitoring of the plots.

 

# CHAPTER 1 Introduction

The tropical forest resources in Africa represents 18% of the world total and cover over 3.6 million km$^2$ in West, East and Central Africa. This total area can be subdivided into 2.69 million km$^2$ (74%) in Central Africa, 680,000 km$^2$ (19%) in West Africa and 250,000 km$^2$ (7%) in East Africa (SOMMER, 1976). Thus, the bulk of African tropical forests are found in Central and West Africa with the forests in the Congo Basin containing the largest remaining contiguous expanse of moist tropical forest (MTFs) in the African continent and the second largest in the world, after the Amazon forest. This immense biome constitutes about 15% of the world's remaining MTFs (FAO, 1988) encompassing the entire land mass of Democratic Republic of Congo, Equatorial Guinea and Gabon, most of Cameroon and Congo, and a small part (southern corner) of the Central African Republic. WRI (1996) indicated that only 8% (0.5 million km$^2$) of Africa's forests remain as "frontier forests"[1.]

IPCC (2007) has reported that MTFs, as a whole, are among the ecosystems expected to be most affected by climate change. The large expanses of MTFs, which are found in West and Central Africa hold much of Africa's carbon, and the general vulnerability of the people and economies of the sub-regions makes the sub-regions of Africa important for consideration in terms of impacts from climate change. For example, it is estimated that 46 billions of carbon stock are stored in forest of the Congo Basin (NASI ET AL., 2006). These forests are currently under threats from deforestation and degradation with various degrees of intensity and pace varying from one country to another. According to FAO (2009), the countries in West Africa with moist forests collectively lost 710,000 ha or about 1.9% of their forest covers between 2000 and 2005. The corresponding figures for the countries of Central Africa with much larger expanse of forests are 611,000 ha or 0.38%. If the clearing rates continue to rise, a substantial amount of carbon will be released into the atmosphere in the form of carbon dioxide, thus, contributing to global climate change.

There is growing evidence that climate change, additional stressor factor, is impacting on forests and forest ecosystems in West and Central Africa and, therefore, the livelihoods of dependent communities as well as national economic activities that depend on forest and tree products and services. HULME (1996) and IPCC (1998) concluded that the African continent is particularly vulnerable to the impacts of climate change because of factors such as widespread poverty, recurrent droughts, inequitable land distribution and overdependence on rain-fed agriculture. The key vulnerable sectors identified by IPCC (2007) include agriculture, food supply, infrastructure, health, and water resources. Sub-

[1] Frontier forest is, essentially, natural/primary forest of sufficient size to support ecological viable populations of indigenous species (WRI, 1996).

 

Saharan Africa is expected to suffer most, not only in terms of reduced agricultural productivity and increased water insecurity, but also in increased exposure to coastal flooding, extreme climatic events and increased risks to human health. The vulnerability to climate change is exacerbated by a number of non-climatic factors, including endemic poverty, hunger, high prevalence of disease, chronic conflicts, low levels of development and low adaptive capacity.

The impacts of climate change will diminish the capacity of the forests to provide goods and services, have far reaching, mostly, adverse consequences for the livelihoods of forest-dependent communities, particularly in Africa where the capacity to adapt is low (Okali, 2011).

As stipulated in the Terms of Reference, 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 MTFs and woodlands and savannas in West and Central Africa;

(ii) review and assess available data and information on permanent sample plots (PSPs) in MTFs and woodlands and savannas in 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 modeling impacts of climate change in MTFs and woodlands and savannas (i.e., tree and stand health, regeneration, growth and productivity) and REDD+ requirements, including MRVs and biodiversity safeguards in MTFs and woodlands and savannas in West and Central Africa; and

(iii) identify and describe existing PSPs in moist forests and woodlands and savannas in 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.

This report, therefore, presents a review on climate change vulnerability of biophysical and socio-economic systems in MTFs of west and central Africa.

The study was conducted by an extensive search for papers published in academic journals, publications by international organizations, and country/national reports on tropical forests, especially those of West and Central Africa, climate change and variability and the impacts on MTFs, and on permanent sample plots used in the study of forest structure, productivity, dynamics and functioning in MTFs in West and Central Africa. Individual scientists and international organizations working in the MTFs of West and Central Africa were also personally contacted for information on some aspects of this study. Visits to some known permanent sample plots to assess their current status were made. Information from these sources was used to accomplish this study.

 

# CHAPTER 2 Tropical moist forests in West and Central Africa

## CHARACTERISTICS OF TROPICAL MOIST FORESTS

Tropical moist forests (TMFs) include all forests within the humid tropics where annual rainfall exceeds the amount of water lost through evaporation and transpiration (IUFRO, 2010). There are about 70 countries located within the humid tropical forest region, including 31 in Africa. The forests cover extensive areas on the African continent but are concentrated in West and Central Africa, where they are the principal base for industrial wood production (Okali and Eyog-Matig, 2004). The African moist forests are characterized by annual rainfall of 1,400 mm to more than 4000 mm. The average monthly rainfall does not exceed 100 mm throughout the year (White, 1983). The length of growing period ranges between 271-365 days per year (Pardey et al., 2007). The MTFs in Africa include moist deciduous forests at low altitudes under rainfall regimes of 1,000-2,500 mm per annum and true rain forests, also, at low altitudes but higher rainfall regimes (over 2,500 mm per annum) referred to collectively as rain forests. Moist forests at higher altitudes (especially the Afromontane broadleaved forests at > 900 m elevation), though widely scattered in distribution, cover less area (Okali, 2011). These forests are characterized by relatively tall, mostly evergreen broadleaved trees, with a closed canopy usually composed of a high diversity of tree species. There are also abundant palms, climbing plants (lianas and vines), epiphytes and hemi-epiphytes. Many of the trees often have large buttresses for mechanical support to withstand stresses due to wind or gravity and relatively large leaves. The bark of the trees is usually thin, making them fire sensitive, and, generally, smooth and light coloured. There is also high diversity of animals.

## EXTENT AND DYNAMICS/TRENDS

The moist tropical forest zone, largely, encompasses locations in West Africa (48 million ha) and Central Africa (202 million ha) (IUFRO, 2010; Table 1). The rain forests of the Congo Basin, which contain about 91% of Africa's remaining rain forests, occur in this zone (IITA, 2000). This region is identified as an important centre of biodiversity and endemism (IUFRO, 2010). The rain forests of West Africa, also known as Upper Guinean Forests, cover 10.9 million ha (IUFRO, 2010) and have been designated as one of the global biodiversity hotspots (Myers et al., 2000). They are known to contain a large number of species of both fauna and flora. It is estimated that the West African rainforest zone contains 2800 vascular forest plant species of which 650 are endemic and 400 species considered rare (Poorter et al., 2004). The Afromontane forests are found in the west of

Cameroon and east of the Democratic Republic of Congo. JAGTAP and CHAN (2000) have reported that as a result of human-induced disturbances, the forest now is composed of a mosaic of different land use types, patches of secondary forests and fallow vegetation, and small remnants of primary vegetation.

### Table 1. Area cover of lowland moist tropical forest in west and central Africa

| Country | Extent of forests (2005) | | |
|---|---|---|---|
| | Forest area ('000 ha) | Proportion to total land area (%) | 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 | 42,380 | 24.5 | 411 |
| **Central Africa** | | | |
| Angola | 59,104 | 47.4 | 3,570 |
| 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 | 282,552 | 56.7 | 5,476 |

**Source**: Adapted from FAO (2009).

After the MTFs have been destroyed or disturbed by natural or anthropogenic factors, such as fire, logging, hurricanes, tree falls or swidden agriculture, a natural regeneration begins through a series of vegetational stages (Richards, 1955; Swaine and Hall, 1983). The rate of change of the forest structure and composition is strongly influenced by the nature and extent of residual vegetation in the form of resprouts, remnant trees and shrubs, seedling/saplings and/or the soil seed bank (Uhl et al., 1981, Galindo-Gonzalez et al., 2000; Elmqvist et al., 2001; Chadzon, 2003). Thus, the structure and dynamics of forest vegetation reflect complex interplay of disturbance events and regeneration processes taking place through time and space (Chadzon, 2003).

# SOCIO-ECONOMIC IMPORTANCE OF TROPICAL MOIST FORESTS

The MTFs are intricately linked to the socio-economic and productive systems of people in Africa (Okali, 2011). The forests provide firewood, timber, traditional medicines, staple foods and drought emergency foods. Because a large fraction of the population lives in rural areas, they depend on the forests for many of the subsistence needs. Also, the export of timber, nuts, fruits, gums and other forest products generates income for the countries in the sub-region. Exports of timber products contribute more than 60% of GDP in some Central and West Africa countries (IUFRO, 2010). There is also considerable economic contribution from the production and sale of gums and resins, medicinal plants, honey and beeswax, bush meat and other non-timber forest products (Sunderland et al.,1998) and the small scale trade in forest products (Shackleton et al., 2007). Moreover, the forest trees and shrubs provide ecosystem services of carbon sequestration, storing and transpiring water required for precipitation, maintaining soil fertility and providing habitats for a diverse array of plant and animal species. They have also commanded international attention because of their rich biodiversity and unique products they provide as well as their high productivity and potential to influence climate change (Okali, 2011). They also provide home and cultural basis for the Baka (one of the so-called 'pygmy' groups), a semi-nomadic hunter-gatherer people of Central Africa.

# THREATS TO TROPICAL MOIST FORESTS

Tropical moist forests are under threat and in full retreat in West and Central Africa because of massive deforestation and forest degradation with all the implications. The situation is caused by overexploitation or unplanned exploitation, slash-and-burn agriculture, selective logging, intensive fuelwood collection, rapid population growth, increasing infrastructural development and conflicts. Other threats include increasing wildfires, droughts, floods as well as pest and diseases as a result of climate change and variability. The major threat to the forests is the conversion to some other land use, such as agriculture (subsistence farming and plantations of economic tree crops, such as cacao, oil palm, rubber, kola nut and fast growing tree crops such as teak, gmelina and eucalypts) in addition to other threats emanating from urbanization, industrialization and other infrastructural development. Degradation of the forests is evident from the poor structure of extant forest, the rampant growth of climbers, tangles, the loss of species many of which seem to have been locally exterminated, and the drastic reduction in the size of timber logs available for milling (ONOCHIE, 1990). For instance, according to FAO (2001), close to 12 million ha of forests were lost in West Africa from 1990-2000, whereas West and Central Africa put together, an estimate area of close to 15 million ha were lost between 2000 and 2010 (CHAKRAVARTY ET AL., 2012). In Central Africa, with estimated population of close to 80 million inhabitants, of which 65 million currently live in or near the forest (FAO, 2003), local communities use bush fires as a technique for farming and hunting. The main concern as these forests disappear is the rapid loss of unique flora and fauna, resulting in reduction of populations of wild animals and plants. The forests are undergoing changes in structure, dynamics, productivity and function as a result of these disturbances. The remaining forests are also undergoing changes because of the alteration of the physical, chemical and biological environment that the species are adapted to due to climate change and variability.

 

# CHAPTER 3 Climate change and variability: an overview

## DEFINITION AND INDICATORS

The United Nations Framework Convention on Climate Change (UNFCCC) in Article 1defines climate change as “a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (United Nations, 1992). Okali (2010) stated that from reports of IPCC, the now well-known and widely quoted main indicators of climate change are:

- global warming: the rise in the earth’s surface temperature at a rate faster than it had done for 1000 years, the general mean global temperature of 15°C having risen by 0.3 to 0.6°C since 1900;
- ice-caps and glaciers in the cold regions melting, global snow cover decreased by 10% between 1960 and 2000;
- melting ice and thermal swelling of the oceans leading to sea-level rise;
- global mean sea-level having risen by 10 to 25 cm over the last 100 years, and projected to rise by 0.09 to 0.88 cm in the next 100 years; and
- correlated increases in the atmospheric concentrations of greenhouse gases ($CO_2$, $CH_4$, $N_2O$, etc.). Concentrations of these gases in the atmosphere have risen dramatically since the industrial revolution of the 19$^{th}$ Century coinciding with the rapid rise in the combustion of fossil fuels, beginning with coal, then to oil and gas for energy.

Closely associated with these primary indicators are the consequences of changing weather patterns, changing seasons, extreme weather events, floods, droughts, forest fires, heat waves, ocean acidification, all with profound impacts on biodiversity, livelihoods and socio-economic activities (Okali, 2010).

Also, climatic records in Africa show that the continent is warmer than it was 100 years ago (IPCC, 1996) with warming of approximately 0.7°C in most of the continent during the 20th Century, a decrease in rainfall over large portions of the Sahel, and increase in rainfall in east-central Africa (IPCC TAR, 2001). Climate change scenarios for Africa, based on the results from circulation models using data collected by the Intergovernmental Panel on Climate Change (IPCC) Data Distribution Center (DDC), indicate future warming across

 

Africa ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario). This warming is greatest over the interior of semi-arid and margins of the Sahara and Central Southern Africa. Over the next century, this warming trend, and changes in precipitation patterns are expected to continue and be accompanied by a rise in sea level and increased frequency of extreme weather events.

# VULNERABILITIES TO CLIMATE CHANGE

According to the IPCC (2007) vulnerability is "the degree to which geophysical, biological and socio-economic systems are susceptible to or unable to cope with adverse impacts of climate change, including climate variability and extremes". The term vulnerability may, therefore, refer to the vulnerable system itself, e.g. low-lying islands or coastal cities, the impact to this system, e.g. flooding of coastal cities and agricultural lands or forced migration, or the mechanism causing these impacts, e.g. disintegration of the ice sheet in West Antarctic.

Anthropogenic warming has already caused many changes in forests. As large, extensively managed, long-lived ecosystems, often on marginal sites, forests respond sensitively to climate changes, together with people, societies and economic activities that depend on them (BERNIER AND SCHOENE, 2008). IPCC (2007) rated boreal, mountain, Mediterranean, mangrove and MTFs as the forest ecosystems most likely to be affected by climate change. Forests also influence climate change, as sources of greenhouse gases when they are destroyed and as sinks for carbon when they grow and expand (BERNIER AND SCHOENE, 2008).

In the Bali Action Plan, adopted by the thirteenth Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 2007 (UNFCC, 2008), it has been proposed that forests in developing countries be considered as a prime tool for climate change mitigation. Accordingly, activities currently addressed include reducing emissions from deforestation and forest degradation in developing countries (REDD) and conservation and enhancement of carbon stocks through sustainable forest management (REDD+).

Africa is one of the most vulnerable regions in the world. According to IPCC (1990), climate change could increase average temperatures and cause considerable changes in regional and seasonal patterns of precipitation. Recent studies have indicated a greater warming trend and a notable spatial and temporal variability of rainfall in Africa (NICHOLSON ET AL., 2000; CHAPPEL AND AGNEW, 2004, DAI ET AL., 2004; MALHI AND WRIGHT, 2004; KRUGER AND SHONGWE, 2004; HULME ET AL., 2005; NEW ET AL., 2006). For instance, a decadal warming rate of 0.29°C in the African tropical forests (MALHI AND WRIGHT, 2004), and 0.1 to 0.3°C in South Africa (KRUGER AND SHONGWE, 2004) have been reported. Increase in the number of warm spells in southern and western Africa and a decrease in number of extremely cold days between 1961 and 2000 has been also reported (NEW ET AL., 2006). Furthermore, large inter-annual rainfall variability has been reported over most of Africa and for some regions substantial multi-decadal variability. In West Africa, a decline in annual rainfall has been observed since the 1960s with a decrease of about 20-40% noted between 1931-1960 and 1968 -1990 (NICHOLSON ET AL., 2000, CHAPPAL AND AGNEW 2004; DAI ET AL. 2004). Malhi and Wright (2004) have also reported declines in mean annual precipitations of around 4% in West Africa, 3% in North Congo and 2% in South Congo, all in MTFs, for the period 1960-1998. NICHOLSON ET AL. (2000) have however, reported a 10% increase in annual rainfall along the Guinea coast during the last 30 years. Also, GBUYIRO (1998) has shown that precipitation decrease in the humid regions of West Africa is by about 10-25% or 2.5% per decade since the beginning of the nineteenth century. These changes in temperature and rainfall will probably alter the environmental conditions to which moist tropical forest trees in Central and West Africa are adapted, and hold potential to expose them to new pests and diseases. FISCHLIN ET AL. (2007) have stated that moist forests that usually experience little climatic seasonality are highly affected by changes in precipitation from global climate change. With a decrease in precipitation, the moist forests could develop into a drought-deciduous type. Furthermore, longer dry seasons caused by climate change combined with other disturbances to forest systems make forest ecosystems particularly vulnerable to major forest fires (IUFRO, 2010).

 

# CHAPTER 4 Vulnerability to and impacts of climate change

Impact of climate change can be defined as the consequences of climate change on natural and human systems. According to IPCC (2007), the key vulnerabilities are associated with many climate-sensitive systems, including, for example, food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets, and modes of oceanic and atmospheric circulation.

## WATER RESOURCES

Water resources are inextricably linked with climate. Therefore, the prospect of global climate change has serious implications for water resources and regional development (Riebsame et al., 1995). An assessment by UNEP (2002), suggested that by 2050, rainfall in Africa could decrease by 5% and become more variable year by year. Scholze et al. (2006) modeled climate change risks, under an anticipated future climate, and found that water runoff was likely to increase in tropical Africa but decrease in West Africa. Projected temperature increases are likely to lead to increased open water and soil-plant evaporation. The dominant impact of global warming as a result of increased potential evapotranspiration and decreased runoff will be a reduction on soil water. In addition, apart from the Congo River, the major rivers of West and Central Africa (e.g. Niger and Senegal) transverse semi-arid and arid lands on their way to the coast. This will enhance the evaporative losses as a result of increased temperatures and, likely, further reducing runoff unless compensated by increased precipitation.

The expected increased variability in precipitation, could result in floods in the moist forest zones of the sub-regions. Flooding, exacerbated by this climate change, often, results in increased contamination of drinking water. In this regard, when water is available, it is often of poor quality, thus, contributing to a range of health problems, including diarrhea, intestinal worms and trachoma. Much of the sufferings from lack of access to safe drinking water and sanitation are borne by the poor who live in degraded environments and are overwhelmingly women and children. Increase in surface water temperature has also been associated with disease transmission. For instance, in 2012, there was extensive flooding in Nigeria due to excessive rainfall, which the Nigerian Meteorological Agency (NIMET) attributed to the delay in the movement of the Inter-Tropical Discontinuity, ITD also known as Inter-Tropical Convergence Zone (ITCZ) (Njoku, 2012).

 

# COASTAL RESOURCES

Sea levels will rise around the globe as a result of global warming (CONWAY, 2009). The primary cause, at least in the near term, is the thermal expansion of the oceans, resulting from rising oceanic temperatures (CONWAY, 2009). This will deliver a rise of about half a meter by the end of the century (MEEHL ET AL., 2007). There is also the threat of polar ice-caps melting, leading to, even, more dramatic sea level rise. The sea level rise associated with climate change would have serious consequences for low-lying coastal areas along the West and Central Africa. The coastal countries of west and central Africa that have low-lying lagoon coasts that are susceptible to erosion and, hence, are threatened by sea level rise are Angola, Cameroon, Gabon, Gambia, Nigeria, Senegal and Sierra Leone. There will be erosion and submergence of lowlands (along the coast of Senegal and Niger Deltas and The Gambia Estuary) and much of the land currently used for agriculture and livestock practices in these areas would be lost leading to socio-economic and socio-cultural problems.

JALLOW ET AL. (1996) report that the capital of Gambia, Banjul, could disappear in 50-60 years through coastal erosion and sea-level rise putting more than 42,000 people at risk. In Ghana, the coastal zone occupies less than 7% of the land area, but contains 25% of the population and, as a result, even relatively small rises could have damaging physical consequences on the economy (CONWAY, 2009). These could include permanent connection of lagoons to sea, penetration of salt water inland, increased coastal erosion, salinization of freshwater lagoons and aquifers, increased depth of water table in coastal areas, destruction of wetlands and associated industries and accelerated loss of the capital Accra (CONWAY, 2009). In Nigeria's Niger Delta, it is estimated that with sea-level rise of one metre, inundation may render more than 15,000 square kilometres of land at risk, while erosion may claim more than 300 square kilometers (AWOSIKA ET AL., 1994). The Lagos region, which consists of large areas of lowland that are very vulnerable to the impacts of climate change and sea-level rise, is generally characterized by low lying areas most of which are below 5 m above sea level. It is expected that considerable physical, ecological and socio-economic losses would be incurred with expected rise in sea level of about 0.5 and 1.0 m.

The intrusion of salt water could also affect lagoon fisheries and aquaculture in Cote d'Ivoire (REPUBLIQUE DE COTE D'IVOIRE, 2000), coastal agriculture (e.g. plantations of oil palm and coconuts in Benin and Cote d'Ivoire, and shallots in Ghana) could risk inundation and soil salinization (Boko et al., 2007). Between 130 and 235 $km^2$ of rice fields (17% and 30% of the existing rice field area) in Guinea could be lost as a result of permanent flooding, depending on the inundation level considered (between 5 and 6 m) by 2050 (REPUBLIQUE DE GUINEE, 2002).

 

Sea level rising will result in the pollution of most of the water resources along the coast by intrusion of sea water, and management of water resources would place greater emphasis on desalination.

## BIODIVERSITY (INCLUDING FORESTRY)

The MTFs in West and Central Africa contribute significantly to biodiversity and human wellbeing. The uses of the rich biodiversity of the forests are consumptive (food, fibre, fuel, shelter, medicinal, wildlife trade, etc.) and non-consumptive (ecosystem services and the economically important tourism industry). These forests, especially those of Central Africa (the Congo Basin forests), are globally important store house of plants and animals. The Congo Basin tropical rain forests account for 60% of Africa's biodiversity and are significant both for total number of species found there and for endemic species (IUFRO, 2010). The protected areas in the Congo Basin forests support the largest populations of African elephants and are home to four of the world's species of great apes and numerous other unique species such as Okapi, Bongo and Congo peacock. The forests also contain at least 12,000 species of plants, numerous species of mammals, birds, reptiles, amphibians, freshwater fish and butterflies (JUSTICE ET AL., 2001). Some of the biodiversity is concentrated in several centres of endemism, such as the Afromontane habitats of Cameroon, the western equatorial forests of Cameroon and Gabon, and eastern lowland forests of the Democratic Republic of Congo.

Climate change is generally believed to increase the risks of biodiversity loss (FISCHLIN ET AL., 2007), and montane areas in tropical Africa will logically face relatively higher risks from climate change due to the lack of migration paths for mountain species (DESANKER ET AL., 2001). These and other biodiversity spots, which are mainly outside protected areas in the sub-regions, are under threat from climate change and vulnerability and other stresses. Montane centres of biodiversity are particularly threatened by increase in temperature because many represent isolated populations with no possibility of vertical or horizontal migration.

The ultimate impact of climate change on biodiversity is to bring about biodiversity loss through species extinction (OKALI, 2010). After, examining the results from various modeling studies, the Fourth Assessment Report of IPCC (2007) confirmed that climate change is a major driver of biodiversity loss in tropical forests and several other ecosystems. It was estimated that on the average 15 to 37% of species will become extinct by 2050, and that climate-induced extinction rates in tropical biodiversity spots are likely to exceed the predicted extinction rates from deforestation by the end of this Century. This is because even quite small changes in temperature and rainfall patterns can have deleterious impacts on the viability of plants and animals. Perhaps one of the biggest losses, wide-spread consequences, will be forests of the sub-regions, particularly along the Congo Basin, driven by logging and increasing aridity.

Changing disturbance regimes will interact with climate change in important ways to control biodiversity, for instance through rapid, discontinuous "ecosystem switches"[2] that are accompanied by drastic species shifts and even species extinction. This is because climate change alters the spatial and temporal patterns of temperature and precipitation. These are the two most fundamental factors determining the distribution and productivity of vegetation, geographical shifts of changes in productivity, and, thus, constitute the most likely impacts of $CO_2$-induced climate change on forest species. Subtle changes in species composition of these rich forests will impact goods and services obtained from biodiversity. The loss in biodiversity will also affect and might exacerbate climate change through a positive feedback mechanism because biodiversity itself has a reciprocal impact on climate change through the central position of plants in modulating global carbon cycle (OKALI, 2010).

Fire has occurred in forest areas where it has not been observed in the past. The predicted climate change to alter the likelihood of increased sizes and frequencies of wildfire in forests (e.g. BROWN ET AL., 2004) and the reported increased wildfire incidents in tropical rain forest zones of the world, especially in deciduous forests where the dry season exceeds 3-4 months (ISICHEI ET AL. 1986; KINNARD AND O'BRIEN 1998), will impact biodiversity through the effects on composition, structure, regeneration and recovery potential of rain forests. This is because the effect of fire on rain forest is devastating (KIO AND NNAOBI, 1983) since fire resistance, as found in savanna tree species, is lacking (KEAY, 1959). MACCHI ET AL. (2008) reported that the main reasons for forest losses have been wildfires, which have been severe, especially in Angola, southern Democratic Republic of Congo and Central African Republic.

FAUSET ET AL. (2012) have reported that over the past two decades, species composition in Ghanaian forests has shifted to favour deciduous, drier forest affiliated, canopy species with intermediate light requirements over wetter-forest affiliated, evergreen shade-tolerant, sub-canopy species in response to drought-induced shifts in the floristic and functional composition of tropical forests in Ghana. These changes have been occurring since the onset of the West African drought in the 1970s, perhaps, linked to increasing sea surface temperatures (DAI, 2011). All the changes will, thus, create additional challenges for forest management in these sub-regions of Africa with consequent impacts on the economic and

[2] 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.

 

social benefits that the societies and individuals derive from the forests and biological diversity in the forest ecosystems.

# AGRICULTURE

Agriculture constitutes a large share of Central and West African economies with a mixture of subsistence and commercial production. For example, in Central Africa it constitutes the primary activity and 58-63% occupation of the people, and practices such as slash and burn shifting cultivation have continued to contribute to forest loss (SONWA ET AL., 2010). Forestry is an important complement to agriculture in many rural areas. One-third of the income in African countries is generated by agriculture. In Cameroon, for example, close to 30% of the GDP comes from agriculture (MOLUA, 2008). Crop production and livestock husbandry account for about half of household income. The agricultural sector is already hampered by its reliance on rain-fed irrigation, poor soil and antiquated technology and farming methods. It is likely to be hit hard as droughts and flooding worsen, temperatures and growing seasons change and farmers and herds are forced off their land (FLESHMAN, 2007). This could create considerable humanitarian and economic challenges in the sub-regions where farming accounts for 70% of employment and is often the engine for national economies - generating export earnings, industrial raw materials and inexpensive food (FLESHMAN, 2007).

An increase in temperature and rainfall is also likely to encourage the proliferation of pests that are detrimental to staple crops. Central and West Africa’s warm, moist conditions are ideal for insects and crop diseases. Insects will multiply and prosper because, during the growing season, some insects could produce several offsprings per female (PIMENTEL, 1993). Rising temperatures will lengthen the breeding season and increase reproductive rate that will in turn, raise the total number of insects attacking crops and subsequently increase crop losses (PIMENTEL, 1993). Also, weeds, which are better adapted than crops, could increase the competition for light, moisture and nutrients leading to increase in crop losses due to weeds and pests (PIMENTEL, 1993). As a consequence of pest increase, there may be substantial rise in the use of agricultural chemicals to control them.

Livestock distribution and productivity could be indirectly influenced via changes in the distribution of vector-borne livestock diseases, such as nagana (trypanosomiasis) and the tick-borne East Coast Fever and Corridor disease (HULME, 1996). Thus, changes in temperature, moisture, carbon dioxide, insect pests, animal and plant diseases and weeds associated with global warming will reduce food production in the moist tropical forest zone.

 

# SETTLEMENTS AND INFRASTRUCTURE

The main challenges that are likely to be faced by populations in these sub-regions will emanate from the effects of extreme events, such as tropical storms, floods, landslides, wind and abnormal sea level rises expected as a result of climate change. Large numbers of people are currently at risk of floods (UNDP, 2004; UNESCO-WWAD, 2006), particularly, in coastal areas where coastal erosion is already destroying infrastructure, housing and tourism facilities (e.g. in residential region of Akpakpa in Benin (NIIASSE ET AL., 2004)). CONWAY (2009) has asserted that floods could become common in Africa, in part, because some regions will experience higher rainfalls, but even in drier regions there is likely to be a higher frequency of more intense downpours which may create flooding. He reported that 2007 saw heavy flooding in both eastern and western Africa and listed the direct and indirect consequences of floods as:

- immediate deaths and injuries from drowning;
- non-specific increases in mortality;
- infectious diseases, e.g. increased malaria;
- exposure to toxic substances;
- damage to property and infrastructure, e.g. roads, railway networks, dams and power generation;
- damage to crops and livestock;
- community breakdowns;
- increased psychological stress; and
- increased demands on health systems and social security.

Communications among human settlements will be seriously disrupted, impeding movement of goods and persons in the sub-regions. Many refuges will not be reached by land resulting in significant depletion of their food and medical supplies and leading to mortalities. Climate change may also lead to industrial relocation, resulting from either sea-level rise in coastal-zone areas or from transitions in agro-ecological zones. Reduced stream flows would cause reductions in hydropower production, leading to negative effects on industrial productivity and also costly relocation of some industrial plants. Many harbors and ports in coastal–zone of the sub-regions will be adversely affected, which will be devastating economically. All these events will likely exacerbate management problems relating to pollution, sanitation, waste disposal, water supply, public health, infrastructure and technologies of production (IPCC, 1996).

 

# HUMAN HEALTH

The IPCC Special Report on Regional Impacts of Climate Change (IPCC, 1998) acknowledges that climate change will have impact on vector-borne diseases. Also, GITHEKO ET AL. (2000) stated that 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 vectors and intermediate hosts and, consequently, the risk of disease transmission. Mosquito species, such as *Anopheles gambiae complex*, *A. funestus*, *A. darling*, *Culex quinquefasciatus* and *Aedes aegypti* are responsible for transmission of most vector-borne diseases, and are sensitive to temperature changes at immature stages in the aquatic environment and as adults (GITHEKO ET AL., 2000). If water temperature rises, the larvae take shorter time to mature (RUEDA ET AL., 1990) and, consequently, there is greater capacity to produce more offsprings during disease transmission period. In warmer climates, the adult female mosquitoes digest blood faster and feed more frequently (GILLIES, 1953), thus, increasing transmission intensity. Similarly, malaria parasites and viruses complete extrinsic incubation within the female mosquito in a shorter time as temperature rises (TURELL, 1989), thereby increasing the proportion of infective vectors (GITHEKO ET AL., 2000). Furthermore, increased precipitation has the potential to increase the number and quality of breeding sites for vectors, such as mosquitoes, ticks and snails, and the density of vegetation, affecting the availability of resting sites. Disease reservoirs in rodents can increase while favorable shelter and food availability lead to population increases, in turn, leading to disease outbreaks (GITHEKO ET AL.; 2000).

The climate of West and Central Africa, like that of other tropical African climate, is favorable to most major vector-borne diseases, including malaria, schistosomiasis, onchocerciasis, trypanosomiasis, filiariasis, leishmaniasis, plague, Rift Valley Fever, yellow fever and tick-borne haemorrhagic fevers (GITHEKO ET AL., 2000). There is also high diversity of vector species complexes that have the potential to redistribute themselves to new climate-driven habitats leading to new disease patterns (GITHEKO ET AL., 2000). Recent studies in Africa have shown that climate change will have direct and indirect impacts on diseases that are endemic in Africa. It is expected that small changes in temperature and precipitation will support malaria epidemics at current altitudinal and latitudinal limits of transmission (LINDSAY AND MARTENS, 1998). Furthermore, flooding could facilitate breeding of malaria vectors and, consequently, malaria transmission (WARSAME ET AL., 1995), epidemics of cholera, a water and food-borne disease, through contamination of public water supplies caused by flood. Unhygienic practices because of water shortage as a result of drought will also facilitate the epidemic of cholera.

Recent data from West Africa indicate that the risk of a new Rift Valley Fever epizootic is increasing in the region (FONTENILLE ET AL., 1995), with significant exposure to the virus among livestock herders and wildlife rangers during the wet season (OLALEYE ET AL., 1996). It is expected that increased precipitation, as a consequence of climate change, could increase the risk of infections in livestock and people because studies on mosquito vectors of the disease in Kenya (mainly *Aedes* and *Culex* species) have clearly linked the risk of outbreak to flooding (LINTHICUM ET AL., 1990). There is a likely increase in plague, a flea-borne disease with rodents as reservoir, because of increase in the population of rodents following heavy rains as a result of abundant food. Increased temperature can also accelerate the development of fleas and the pathogen they carry. Pollution of streams, wells and other sources of rural water supplies by flooding could introduce parasites, such as amoeba and cryptosporidium into drinking water (ALTERHOLF ET AL., 1998).

 

# CHAPTER 5. Knowledge generation and permanent sample plots

Long-term changes in vegetation are best studied by means of permanent sample plots. Changes in flora and fauna in successive seasons through the year and, possibly, in successive years can be followed by setting out permanent sample plots (PSPs). Such plots are clearly marked out by permanent marks and geo-referenced. Records of plant and animal life, and habitat factors are made at regular intervals. Much of what is known about tropical forest dynamics in terms of changes in tropical forest structure, dynamics, productivity and function has come from the long-term monitoring of tropical tree populations within permanent sample plots (LEWIS ET AL., 2004; CHADZON ET AL., 2007). Long-term monitoring allows changes in forest growth, recruitment and mortality rates to be calculated (PHILLIPS ET AL., 1994; SHEIL ET AL., 1995; LEWIS, 2006). Furthermore, by using allometric equations, tree diameter measurements can be converted to biomass and carbon content to ascertain if intact tropical forests are currently a carbon sink, source or neutral, and, hence, how they moderate the rate and magnitude of climate change (LEWIS, 2006).

## STATUS OF CURRENT KNOWLEDGE ON CLIMATE CHANGE AND TROPICAL MOIST FORESTS

Current knowledge indicates that TMFs are being or will be negatively affected by climate change (shifts in species composition and functional groups, reduction in productivity and resilience, impacts on biodiversity, agriculture, human health, water, socio-economic development and livelihoods). In-spite of the above, there are uncertainties about the outcomes of interacting factors (temperature increase, variability in precipitation, extreme events, $CO_2$-fertilization and wildfires), hence, the necessity of generating more knowledge through monitoring climate factors and forest phenology as well as growth and regeneration of the woody species and synthesizing cross-site data sets.

In considering the effects of climate change on TMFs of West and Central Africa, the emphasis should be on examining the effects of changes in climate variables (temperature and precipitation) and carbon dioxide concentrations on the growth of plants. This is because temperature, water availability (determined by precipitation and soil characteristics as well as other meteorological variables) and carbon dioxide concentration are significant in relation to climate change among the many climatic variables that are important for plant growth. This is particularly important because of the predicted increase in atmospheric $CO_2$ in the future, causing future temperature rises and possibly abrupt climatic shifts.

 

The predicted higher temperatures, altered precipitation and higher levels of atmospheric $CO_2$ would adversely affect tropical moist forests in West and Central Africa. Trees are sensitive to climate change which affects soil temperatures and moisture levels and determines the vitality of pests. Forest water regime will be affected by changes in seasonal precipitation, within-season pattern of precipitation and inter-annual variation of precipitation which in turn would affect species composition, growth, productivity, phenology and regeneration in MTFs zones of West and Central Africa. Already, rainfall has declined in West Africa and northern Congo Basin over the past two decades (MALHI AND WRIGHT, 2004). There is a critical threshold of water availability below which tropical forests cannot persist and are replaced by savanna systems (SALZMANN AND HOELZMANN, 2005). These forests are already relatively dry (ca 1,500 mm year$^{-1}$) and may become savanna if the current trends continue, leading to large carbon fluxes to the atmosphere (Lewis, 2005). As these forests get drier, they will be more susceptible to burning caused by either lightening or human actions although they were thought to be immune to wildfires. Furthermore, higher air-temperatures would increase respiration in trees, thereby, reducing forest growth. It will also have an impact on the soil, a vital element in forest ecosystems by increasing soil temperatures, thereby, accelerating decay of soil organic matter, resulting in release of $CO_2$ to the atmosphere and a decrease in carbon/nitrogen ratio.

The impacts of increasing atmospheric $CO_2$ on forests in the sub-region will be complicated by the effects it has on trees besides its alteration of their climate regime. Most plants growing in enhanced $CO_2$ exhibit increased rates of net photosynthesis, the “fertilizing” effects. However, $CO_2$ enrichment also tends to close plant stomata, and, by so doing, reduces transpiration per unit leaf area while still enhancing photosynthesis. There is need to investigate the effects of increased $CO_2$ availability on TMFs, especially on their growth, dynamics and regeneration.

There are also uncertainties on how African tropical moist forest biome and the tree species would respond or are already responding to changes in their physical, chemical and biological environment as a result of climate change and variability. Climate change would likely result in changes in the structure, dynamics and species composition of TMFs in West and Central Africa. Therefore, there is a need to investigate the impacts of climate change on the forests, especially, on individual trees, species composition, functional groups, growth, phenology and regeneration of the forests to generate data and information that would be used for forest-based mitigation and adaptation to climate change. This is important because any small changes in tropical moist forest biome can potentially lead to major global impacts on both the rate and magnitude of climate change and the conservation of biodiversity (LEWIS, 2005).

 

# PERMANENT SAMPLE PLOTS

There is a great paucity of information on permanent sample plots (PSPs) used in the study of vegetation in West and Central Africa in the MTFs. Even where they were established, current information on their geographic locations (latitude and longitude), climatic data and vegetation characteristics are lacking and difficult to access. This is probably because at the time of their establishment, the geographic positioning system technology was not available in most of the West and Central African countries, and there was no follow-up monitoring after establishment. Some of them visited were already either completely deforested or highly degraded. Furthermore, all attempts to get information on PSPs from individual scientists and international organizations working in government departments and ministries of the countries in the sub-regions did not solve this problem.

This leaves the strict nature reserves (SNRs) with existing data as the best option to be used in monitoring climate change impacts in the sub-regions. The PSPs and SNRs, which have been verified in Google Earth to be intact as well as with available data and information (Table 2) along with other SNRs or PSPs to be identified and selected from some representative countries, are suggested for use in monitoring climate change impacts on MTFs of and West and Central Africa. Permanent sample plots established in the reserves would be protected by existing regulations on the reserves in the various countries.

It is recommended that, one hectare PSPs should be established in each of the locations. When established in the SNRs, the PSPs should be geo-referenced and delineated with permanent markers that will not attract too much attention for easy identification or reference in future. A scientist who is currently actively engaged in research and institutionally based should be identified and appointed to collect data and information from the plots for monitoring climate change impacts in TMFs. The data to be collected from the plots should include those on soil properties, species composition (liana, tree and shrub) functional groups, phenology (deciduous or evergreen), tree growth, basal area, height, mortality and recruitment. The soil samples should be collected by sampling five soil cores down to 2 m depth per plot and analyzed for carbon, nutrient distribution with depth, density, texture and ground water level. Tree species should be completely identified, enumerated, diameter at breast (DBH, 1.3 m height) or 50 cm above buttress measured, permanently tagged with a number or name identifying each species and tracked through time. The data collected from the plots will be used in compiling the species composition, functional groups and phenology as well as calculating the basal of the species in each plot.

 

## Table 2. General information on suggested Strict Nature Reserves and Permanent Sample Plots.

| Designation | Country | Eco-region | Area (ha) | Average rainfall (mm) | Altitude (m) | Location |
|---|---|---|---|---|---|---|
| RN Mount Nimba | Guniea/Côte d'Ivoire | Rain forest/woodland savannah | 17,130 | - | 450-1,752 | 7.32° – 7.44° E x 8.2° – 8.3° W |
| RN Yangambi | Democratic Republic of Congo | Moist forest | 73,860 | 1,698 | 374 - 529 | 0.89° N, 24.48° E |
| PEP | Nigeria | Semi-deciduous forest | 2.5 | 1,413 | 286 - 381 | 7.31° N, 4.31° E |
| RN de Takumanda (PEP)1 | Cameroon | Rain forest | - | - | 120 | 6.03° N, 9.16° E |
| | | Montane forest | - | - | 1,200 | 6.19° N, 9.23° E |
| PEP2 | Ghana | Moist semi-deciduous | 0.6 | 1,412 | - | 6.56° N, 2.22° E |
| | | Moist evergreen | 1 | 1,659 | - | 5.35° N, 1.83° E |
| | | Wet evergreen | 1 | 1,733 | - | 4.83° N, 2.1° E |

**Source**: Sunderland  et al. (2003); and Fauset et al. (2012).

 

# Conclusion

The West and Central African TMFs are characterized by annual rainfall of 1,400 mm to 4,000 mm and include moist deciduous and rain forests at low altitudes and Afromontane broadleaved forests at high altitudes (> 900 m elevation). A large fraction of the population who live in rural areas in West and Central Africa depend on the forests for many of their subsistence needs and the export of timber, and non-timber forest products generate income for the countries of West and Central Africa. Climate change scenarios for Africa indicate future warming across Africa ranging from 0.2°C per decade (low scenario) to more than 0.5°C (high scenario). Over this century, this warming trend and changes in precipitation patterns are expected to continue and accompanied by a rise in sea level and increased frequency of extreme events. These climate change patterns will alter environmental conditions to which trees in MTFs of West and Central Africa are adapted, adversely impacting the forests and forest-dependent people.

Current knowledge indicates that the TMFs are being or will be negatively affected by climate change (shifts in species composition and functional groups, reduction in productivity and resilience, impacts on biodiversity, human health, water, agriculture, socio-economic development and livelihoods).

In spite of the above, the characteristics and impacts of climate change on TMFs of West and Central Africa at a regional scale have yet to be determined. There are uncertainties about the outcomes of interacting factors (temperature increase, variability in precipitation, extreme weather events, $CO_2$-fertilization and wildfires) on the moist forests, hence the necessity of generating more knowledge through monitoring climate factors and forest phenology, growth, regeneration, dynamics and synthesizing cross-site data sets.

This requires establishing PSPs in the TMFs of some representative countries across West and Central Africa to generate more accurate data to be used in forest-based mitigation and adaption of climate change through periodic re-sampling and monitoring of the plots. These improved data would include the impact of temperature increase, changes in precipitation and increasing atmospheric $CO_2$ concentration on forest growth, regeneration, species composition, dynamics, biomass, functional groups, phenology as well as more accurate estimates of forest cover, location and rates of change as a result of deforestation, forest degradation and re-growth.

 

# References

Alterholf, T.B., LeChevallier, M.W., Norton, W.D. and Rosen, J.S. 1998. Effects of rainfall on giardia and cryptosporidium. Journal of American Water Works Association 90: 66-80.

Awosika, L.F., French, G.T., Nicholls, R.J. and Ibe, C.E. 1994. The impact of sea level rise on the coastline of Nigeria. In: O'Callahan, J. (ed.). Global Climate Change and the Rising Challenge of the Sea. Proceedings IPCC Workshop at Margarita Island, Venezuela, 9-13 March 1992, pp 123-154 National Oceanic and Atmosphere Administration, Siver Spring, MD, USA.

Bernier, P. and Schoene, D. 2008. Adaptation forests and their management to climate change: an overview (http://www.fao.org/docrep/011/i0670e02.htm, accessed on 14-07-2012)

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R. and Yanda, P. 2007. Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (eds.). Contribution to Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 433-467. Cambridge University Press, Cambridge, UK.

Brown, T.J., Hall, B.L. and Westerling, A.L. 2004. The impact of twenty-first century climate change on wildland fire change danger in the western United States: an applications perspective. Climatic Change 62: 365-388.

Chadzon, R.L. 2003. Tropical forest recovery: Legacies of human impact and natural disturbances. Perspectives in Plant Ecology and Evolutionary System 6: 51-71.

Chadzon, R.L., Letcher, S.G., Breugel, M., van Martinez-Ramos, M., Bongers, F. and Finegan, B. 2007. Rates of change in tree communities of secondary neotropical forests following major disturbances. Philosophical Transactions of the Royal Society of London. B: Biological Sciences 362: 273-289.

Chakravarty, S., Ghosh, S. K., Suresh, C. P., Dey, A. N. and Shukla, G. 2012. Deforestation: Causes, Effects and Control Strategies. In: Akias, O. C. (ed.). , Global Perspectives on Sustainable Forest Management, pp. 3-28. InTech, Crotia.

Chappall, A. and Agnew, C.T. 2004. Modelling climate change in West African Sahel rainfall (1931-1990) as an artifact of changing station locations. International Journal of Climatology 24: 517-554.

 

Conway, G. 2009. The Science of Climate Change in Africa: Impacts and Adaptation. Granthan Institute for Climate Change Discussion Paper No. 1. Imperial College, London.

Dai, A. 2011. Drought under global warming: a review. Wiley Interdisciplinary Review of Climate Change 2: 45-65.

Dai, A., Lamb, P.J., Trenberth, K.E., Hulme, M., Jones, P.D. and Xic, P. 2004. The recent Sahel drought is real. International Journal Climatology 24: 1323-1331.

Desanker, P.V., Magadza, C., Allali, A., Bosalirwa, C., Boko, M., Dieudonne, G., Downing, T.E., Dube, P.O., Githeko, A., Githendu, M., Gonzalez, P., Gwary, D., Jallow, B., Nwafor, J. and Scholes, R. 2001. Africa. In: McCarty, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. (eds.). Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, pp. 487-531. Cambridge University Press, Cambridge.

Elmqvist, T., Wall, M., Berggren, A.L., Blix, L., Fritioff, A. and Rinman, U. 2001. Tropical forest re-organization after cyclone and fire disturbance in Samao: remnant trees as biological legacies. Conservation Ecology 5(2), Art. No. 10 (http://www.botany.hawaii.edu/basch/uhnpscesu/pdfs/sam/Elmqvist2001WS.pdf, accessed on 14-07-2012).

FAO. 1988. An Interim Report on the State of Resources in the Developing Countries. Publication of FAO Forest Resources Division, FAO, Rome.

FAO. 2001. State of the World's Forests 2001. FAO, Rome.

FAO. 2003. Forestry Outlook Study for Africa-African Forests: A View to 2002. African Development Bank, European Commission and the FAO, , Rome.

FAO. 2009. State of World Forests 2009. FAO, Rome.

Fauset, S., Baker, T.R., Lewis, S.I., Feldpausch, T.R., Affum-Baffoe, K., Foli, E.G., Hamer, K.C. and Swaine, M.D. 2012. Drought-induced shifts in floristic and functional composition of tropical forests in Ghana. Ecology Letters 15: 1120-1129 (doi:10.1111/j.1461-0248.2012.01834.x).

Fischlin, A., Midgley, G.F., Price, J.T., Leemans, R., Turley, C., Rounsevell, M.D.A., Dube, O.P., Tarazona, J. and Velichko, A. A. 2007. Ecosystems, their properties, goods and services. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (eds.). Climate Change 2007: Impacts, Adaptation and Vulnerability.

 

Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambrigde.

Fleshman, M. 2007. Climate change: Africa gets ready planning how to deal with higher temperatures, shifting weather. Africa Renewal 21(2): 14.

Fontenille, D., Traore-Lamizana, M., Zeller, H., Mondo, M., Diallo, M. and Gigoutte, J. P. 1995. Short report: Rift Valley Fever in western Africa: isolations from Aedes mosquitoes during an interrepizootic period. American Journal of Tropical Medicine and Hygiene 52: 403-404.

Galindo-Gonzalez, I., Guevara, S. and Sosa, V.J. 2000. Bat and bird generated seed rains at isolated trees in pastures in tropical rain forest. Conservation Biology 14: 1693-1703.

Gbuyiro, S.O. 1998. On Rainfall Variability, Enso and its Relationship with Nigeria Rainfall. M.Sc. Thesis, University of Lagos, Lagos.

Gillies, M.T. 1953. The duration of the gonotrophic cycle in Anopheles gambiae and Anopheles funestus with a note on the efficiency of hand catching. East African Medical Journal 30: 129-135.

Githeko, A.K., Lindsay, S.W., Confalonieri, U.E. and Patz, J.A. 2000. Climate change and vector-borne diseases: a regional analysis. Bulletin of the World Health Organization 78(9): 1136-1147.

Hulme, M. (ed.). 1996. Climate Change in Southern Africa: An Exploration of some Potential Impacts and Implications in the SADC Region. Climatic Research Unit, University of East Anglia, Norwich, United Kingdom.

Hulme, M., Doherty, R., Ngara, T. and New, M. 2005. Global warming and African climate: a re-assessment. In: Pak, S.L. (ed.). Climate Change and Africa, pp. 29-40. Cambridge University Press, Cambridge.

IITA. 2000. IITA Strategic Plan 2001-2010 supporting document. International Institute of Agriculture, Ibadan, Nigeria.

IPCC 1990. Potential impacts of climate change. Report of Working Group 2. Intergovernmental Panel on Climate Change, 1-1 to 2. Geneva: World Meteorological Organization (WMO)/United Nations Environment Programme (UNEP).

IPCC. 1996. Climate Change 1995. Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. In: Watson, R.T., Zinyowera, M.C. and Moss, R.H. (eds.). Cambridge University Press, Cambridge.

 

IPCC. 1998. The Regional Impacts of Climate Change: An Assessment of Vulnerability. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IPCC TAR 2001. Climate Change 2001. Impacts, Adaptation and Vulnerability. IPCC Working Group II. Third Assessment Report. In: McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. (eds.). Cambridge University Press, Cambridge.

IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (eds.). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 7-22. Cambridge University Press, Cambridge, UK.

Isichei, A.O., Ekeleme, F. and Jimoh, B.A. 1986. Changes in a secondary forest in southwestern Nigeria following a ground fire. Journal of Tropical Ecology 2: 249-256.

IUFRO. 2010. Climate Change Impacts on African Forests and People. IUFRO Occasional Paper No. 24. IUFRO Headquarters, Vienna.

Jagtap, S.S. and Chan, A.K. 2000. Agrometeorological aspects of agriculture in the sub-humid and humid zones of

Africa and Asia. Agricultural and Forest Meteorology 103(1 and 2): 59-72.

Jallow, B. P., Barrow, M.K.A. and Leatherman, S.P. 1996. Vulnerability of the coastal zone of Gambia to sea level rise and development of response strategies and adaptation options. Climate Research 6: 165-177.

Justice, C., Wilkie, D., Zhang, Q., Brunner, J. and Donoghue, C. 2001. Central African forests, carbon and climate change. Climate Research 17: 229-246.

Keay, R.W.J. 1959. Outline of Nigerian Vegetation (3rd Edition). Federal Ministry of Information. Printing Division. Lagos.

Kinnard, M. and O’Brien, T. 1998. Letter from Indonesia: forest fires that raged throughout Indonesia are linked to a quirky El Nino. Wildlife Conservation, March/April 1998.

Kio, P.R.O. and Nnaobi, C.H. 1983. An economic analysis of the effects of forest fires - a case study of plantation losses in the 1982/83 dry season in southern Nigeria. Forest Research Institute, Ibadan (unpublished).

Krugger, A.C. and Shongwe, S. 2004. Temperature trends in South Africa 1960-2003. International Journal Climatology 24: 1929-1945.

 

Lewis, S. L. 2006. Tropical forests and the changing earth system. Philosophical Transactions of the Royal Society of London B: Biological Sciences 361: 439-450.

Lewis, S.L., Phillips, O.L., Baker, T.R., Lloyd, J., Malhi, Y., Almeida, S., Higuchi, N., Laurance, W.F., Neill, D.A., Silva, J.N.M., Terborgh, J., Torres Lezama, A, Vazquez-Martinez, R., Brown, S., Chave, J., Kuebler, C., Nunez Vargas, P. and Vinceti, B. 2004. Concerted changes in tropical forest structure and dynamics: evidence from 50 South American long-term plots. Philosophical Transactions of the Royal Society of London. B: Biological Sciences 359: 421-436.

Lindsey, S.W. and Martens, W.J. 1998. Malaria in the African Highlands: past, present and future. Bulletin of the World Health Organization 76: 33-45.

Linthicum, J.K., Bailey, C.L., Tucker, C.J., Mitchell, K.D., Logan, T.M., Davis, F.G., Kamau, C.W., Thande, P.C. and Wagatteh, J.N. 1990. Application of polar-orbiting meteorological satellite data to detect flooding of Rift Valley Fever virus vector mosquito habitats in Kenya. Medical Veterinary Entomology 4: 433-438.

Macchi, M., Oviedo, G., Gotheil, S., Cross, K., Boedhihartono, A., Wolfangel, C. and Howell, M. 2008. Indigenous and Traditional Peoples and Climate Change: Vulnerability and Adaptation. Issues Paper, IUCN, Gland.

Malhi, Y. and Wright, J. 2004. Spatial patterns and recent trends in the climate of tropical forest regions. Philosophical Transaction of Royal Society of London B: Biological Sciences 359: 311-329.

Meehl, G.A., Stocker, T.F., Collins, W., Friedingstein, P., Gaye, A., Gregory, J., Kitoh, A., Knutti, R., Murphy, J., Noda, A., Raper, S., Watterson, I., Weaver, A. and Zhao, Z.C. 2007. Global Climate Projections. In: Solomon, S., Qui, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.I. (eds.). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Molua, E.L. 2008. Turning up the heat on African agriculture: The impact of climate change on Cameroon’s agriculture. African Journal of Agricultural and Resource Economics 2(1): 45-64.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., and Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403(6772): 853-858.

Nasi, R., Cassagne, B. and Billand, A. 2006. Forest management in Central Africa: where are we? International Forest Review 8(1): 14-20.

 

New, M., Hewitson, B., Stephenson, D.B., Tsiga, A., Kruger, A., Manhique, A., Gomez, B., Coelho, C.A.S., Masisi, D.N., Kululanga, E., Mbambalala, E., Adesina, F., Saleh, H., Kanyanga, J., Adosi, J., Bulane, L., Fortunata, L., Mdoka, M. L. and Lajoie, R. 2006. Evidence of trends in daily climate extremes over southern and West Africa. Journal Geophysical Research 111 (D14102.doi:10.1029/2005JD006289).

Niiasse, M., Afouda, A. and Amani, A. (eds.). 2004. Reducing West Africa Vulnerability to Climate Impacts on Water Resources, Wetlands and desertification: Elements for a Regional Strategy for Preparedness and Adaptation. IUCN, Cambridge.

Nicholson, S.E., Some, B. and Kone, B. 2000. Analysis of recent rainfall conditions in West Africa including the rainy season of the 1997 El Nino and 1998 La Nina years. Journal of Climate 13: 2628-2640.

Njoku, J. 2012. 2012 Year of Flood Fury: A disaster foretold, but ignored? Vanguard News, October 03, 2012.

Okali, D. 2010. Many species one planet one future. In: Ofozie, I.E., Awotoye, O.O. and Adewole, M.B. (eds.). Many Species One Planet One Future, pp. 8-21. Proceedings of the 3rd Annual Conference of the Institute of Ecology and Environmental, June 15-17, 2010, Obafemi Awolowo University, Ile-Ife.

Okali, D. 2011. Climate change and African moist forests. In: Chidumayo, E., Okali, D., Kowero, G. and Larwanou, M. (eds.). Climate Change and African Forest and Wildlife Resources, pp. 68-84. African Forestry Forum, Nairobi, Kenya.

Okali, D. and Eyog-Matig, O. 2004. Rain Forest Management for Wood Production in West and Central Africa. A Report Prepared for the Project 'Lessons Learnt on Sustainable Forest Management in Africa'. The African Forest Research Network, Nairobi, Royal Swedish Academy of Agriculture and Forestry, Stockholm, and FAO, Rome.

Olaleye, O.D., Tomori, O., Ladipo, M.A. and Schmitz, H. 1996. Rift Valley Fever in Nigeria: infections and humans. Review of Science Technologies 15: 923-935.

Onochie, C.F.A. 1990. The Dying Forest. The Declining Forest Resources of Nigeria. A Keynote Address Delivered at the Fourth Annual Conference of the Botanical Society of Nigeria, Nsukka, 4-8 March, 1990.

Phillips, O.L., Baker, T.R., Arroyo, L., Higuchi, N., Killeen, T.J., Laurance, W.F., Lewis, S.L., Lloyd, J., Malhi, Y., Monteagudo, A., Neill, D.A., Vargas, P.N., Silva, J.N.M., Terborgh, J., Vasquez  Martinez, R., Alexiades, M., Almeida, S., Brown, S., Chave, J., Comiskey, J.A., Czimczik, C.I., Di Fiori, A., Erwin, T., Kuebler, C., Laurance, S.G., Nascimento, H.E.M., Olivier, J., Palacios, W., Patino, S., Pitman, N.C.A., Quesada, C.A., Saldias, M., Lezama, A.T. and Vinceti, R. 2004. Pattern and process in Amazon tree turnover, 1976-2001. Philosophical Transactions of the Royal Society of London. B: Biological Sciences 359: 381-407.

Pardey, P., James, J., Alston, J., Wood, S., Koo, B., Binenbaum, E., Hurley, T. and Glewwe, P. 2007. Science, Technology and Skills. Instepp International Science and Technology Practice and Policy, University of Minnesota, Minnesota.

Pimentel, D. 1993. Climate changes and food supply. Forum for Applied Research and Public Policy 8(4): 54-60.

Poorter, L., Bongers, F., Kouame, F.N. and Hawthorne, W.D. (eds.). 2004. Biodiversity of West African Forests: An Ecological Atlas of Woody Plant Species. CABI Publishing, Oxford.

Republique de Cote d’Ivoire. 2000. Communication Initiale de la Cote d’Ivoire. Ministere de l’Environnement, de l’Eau et de la Foret, Abidjan.

Republique de Guinee. 2002. Communication Initiale de la Guinee a laConvention Cadre desNations Unies sur les Changements Climatiques. Ministere des Mines, de la Geologie et de l’Environnement, Conakry.

Richards, P.W. 1955. The secondary succession in tropical rain forest. Science Progress 43: 45-57.

Riebsame, W.F. 1995. “Complex river basins”. In: Strzepek, K.M. and Smith, J.B. (eds.). As Climate Changes, International Impacts and Implications, pp. 57-91. Cambridge University Press, Cambridge.

Rueda, L.M., Patel, K.J., Axtell, R.C. and Stinner, R.E. 1990.Temperature dependent development and survival rates of Culex quinquefasciatus and Aedes aegypti (Diptera: Culicidae). Journal of Medical Entomology 27: 892-898.

Salzmann, U. and Hoelzmann, P. 2005. The Dahomey gap: an abrupt climatically induced rain forest fragmentation in West Africa during the late Holocene. Holocene 15: 190-199.

Scholze, M., Knorr, R., Arnell, N.W. and Prentice, I.C. 2006. A climate change risk analysis for world ecosystems. Proceedings of the National Academy of Sciences 103(35): 13116-13120.

Shackleton, C.M., Shackleton, S.E., Buiten, E. and Bird, N. 2007. The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. Forest Policy and Economics 9(5): 558-577.

 

Sheil, D., Burslem, D.F.R.P. and Alder, D. 1995. The interpretation and misinterpretation of mortality rate measures. Journal of Ecology 83: 331-333.

Sommer, A. 1976. Attempt at an assessment of the world's tropical moist forests. Unasylva 28(112-113): 5-24.

Sonwa, D.J., Bele, Y.M., Somorin, O.A. and Nkem, J. 2010. Central Africa is not only carbon stock. Preliminary efforts to promote adaptation to climate change for forest and communities in Congo Basin. Nature and Faune 25(1): 58-63.

Sunderland, T.C.H., Clark, L.E. and Vantomme, P. (eds.). 1998. Non-wood Forest Products of Central Africa: Current Research Issues and Prospects for Conservation and Development. FAO, Rome.

Sunderland, T.C.H., Comiskey, J.A., Besong, S., Mboh, H., Fonwebon, J. and Dione, M.A. 2003. Vegetation assessment of Takamanda Forest Reserve, Cameroon. SI/MAB Series 8: 19-53.

Swaine, M.D. and Hall, J.B. 1983. Early succession on cleared forest land in Ghana. Journal of Ecology 71: 601-628.

Turell, M.J. 1989. Effects of environmental temperature on the vector competence of Aedes fowleii for Rift Valley fever virus. Research in Virology 140: 147-154.

Uhl, C., Clark, K., Clark, H. and Murphy, P. 1981. Early plant succession after cutting and burning in the upper Rio Negro region of the Amazon basin. Journal of Ecology 69: 631-649.

United Nations1992.United Nations Framework Convention on Climate Change. FCCC/INFORMAL/84, GE.05-62220 € 2000705

UNDP 2004. Reducing Disaster risk: A Challenge for Development. UNDP Bureau for Crisis Prevention and Recovery, New York.

UNEP. 2002. Africa Environmental Outlook: Past, Present and Future Perspectives. UNEP, Nairobi (http://www.unep.org/dewar/Africa/publications/AEO-1/index.htm, accessed on18/10/2012

UNESCO-WWAP. 2006. Water : A Shared Responsibility. United Nations World Water Development Report 2. UNESCO, Paris and the United Nations World Water Assessment Programme, Paris.

 

UNFCCC 2008. Report of the Conference of the Parties on its Thirteenth Session, Held in Bali from 3 to 15 December 2007. FCCC/CP/2007/6/Add.1. 14 March 2008. GE.08-61035.

Warsame, M., Wernsdofer, W.H., Huldt, G., and Bjorkman, A. 1995. An epidemic of Plasmodium falciparum malaria in Balcad Somalia, and its causation. Transactions of the Royal Society of Tropical Medicine and Hygiene 98: 142-145.

White, F. 1983. The Vegetation of Africa-a descriptive memoir to accompany the UNESCO/AET/FAT/UNSO vegetation map of Africa. UNESCO, Paris.

WRI. 1996. World Resources: A Guide to the Global Environment, 1996-197. World Resources Institute (WRI)/United Nations Environment Programme/United Nations Development Programme/The World Bank. Oxford University Press, New York.

 

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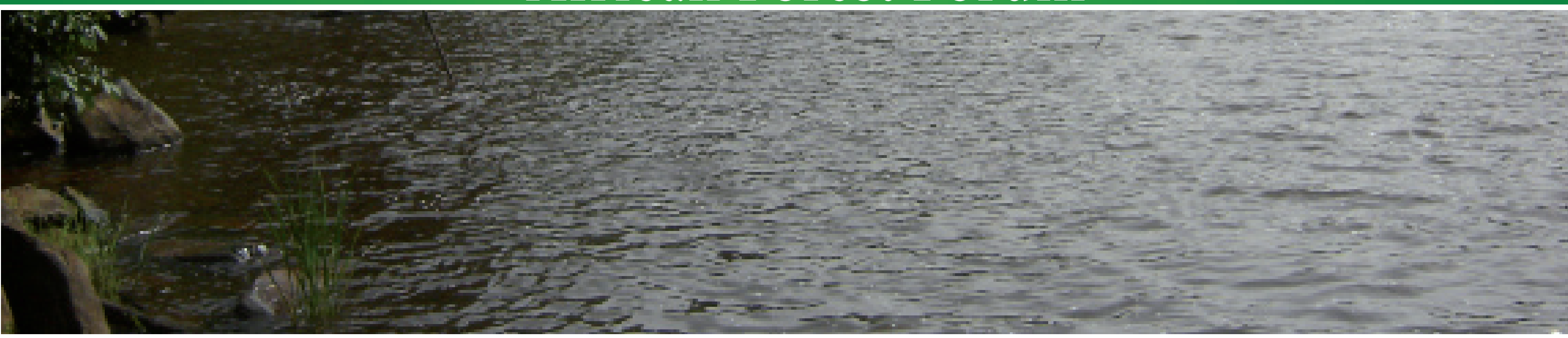

Contact us at:
African Forest Forum
P.O. Box 30677-00100 Nairobi GPO KENYA
Tel: +254 20 722 4203 Fax: +254 20 722 4001
www.afforum.org