International Union of Forest Research Organizations

Climate Change Impacts on African Forests and People

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Occasional Paper No. 23 -	Forest Agencies' Early Adaptations to Climate Change

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Executive Summary

African populations are widely expected to face particularly high impacts of climate change, as a result of three conflating factors: higher than the global average degree of change, particularly high levels of direct forest-dependency in African populations, and a low degree of adaptive capacity due to widespread poverty. These factors make it particularly important that forests in Africa are managed carefuly, with appropriate consideration of the possible effects of climate change.

The IPCC expects the increase in average temperatures in Africa to be substantially higher than the global average change, which may place severe pressures on the ability of forest ecosystems to continue to supply essential ecosystem services. Precipitation expectations are more uncertain and varied, with rises projected for some regions and falls for others. Accurate climate forecasting in Africa is severely hampered by a poor network of maintained climate monitoring stations, both historical and present.

Forests in Africa have been used by humans for many thousands of years, and still supply much food, medicine and energy to local populations. In some areas forests once thought to be completely virgin have been found in fact to be in recovery from shifting agriculture from hundreds of years in the past. Although this shows that recovery is possible, it is also true that clearing for small-scale agriculture is the greatest cause of African deforestation. High levels of forest-dependency among rural people make sustainable forest management a vital necessity for human wellbeing. Planning and implementation of forest policies are often restricted through incomplete or inaccurate forest statistics and an over-reliance on secondary information sources. Forest governance must in many places be improved, with a recognition that forest policies must be broadly supported by local people if they are to be effective.

Africa has experienced much environmental change in the past, and many communities have developed indigenous coping strategies. These strategies may however be inadequate to deal with the speed and scale of projected climate change. Poverty adds to anthropogenic pressures on forests; this is particularly apparent in the need for fuelwood, charcoal and the expansion of agricultural land.

Based on this report and the expert opinion of the African contributors, the thematic policy workshop on 3–4 December 2009 in Vienna, Austria and subsequent discussions developed the following key messages:

1) *Although climate-change projections for Africa are highly variable, the average increase in temperature on the continent is likely to be higher than the average increase globally. There is a significant risk that the adaptive capacity of many African forest ecosystems to provide vital goods and ecosystem services will be exceeded.*

2) *People in Africa are disproportionately dependent on forest goods and services and therefore are particularly vulnerable to the impacts of climate change. Individuals, societies and institutions should be aware of the likely*

impacts of climate change on forests and forest-dependent people and put strategies in place to adapt to them.

3) *Improving the adaptive capacity of forest-dependent communities is important in order to reduce their vulnerability to the effects of climate change. Participatory approaches should be used to obtain a better understanding of local knowledge and perceptions of climatic change and to raise awareness about vulnerabilities and related adaptation measures. Moreover, there is a need to develop and reorient educational systems and programmes.*

4) *Climate change is adding to a range of other pressures – such as agricultural expansion and the over-use of forests – on forest ecosystems in Africa, some of which are currently more pressing than climate change. Measures that reduce non-climatic pressures can help reduce the overall vulnerability of forest ecosystems. Such measures, including forest restoration and rehabilitation, can be implemented in an integrated manner as part of sustainable forest management.*

5) *The development and implementation of adaptation measures as part of sustainable forest management need to be underpinned by new modes of governance that are sensitive to context, take a broad view of community needs, and respond quickly to policy learning. Governance that enables effective stakeholder and community participation, transparent and accountable decision-making, secure land ownership and tenure, and the equitable sharing of benefits and responsibilities needs to be promoted.*

6) *Climate-change adaptation planning in Africa is hampered by a lack of information about current and future climate-related impacts and vulnerabilities. Reliable projections of regional and local impacts require investments in research and monitoring infrastructure and increased support for early-warning systems and preparedness measures.*

7) *Forests can play an important role in achieving broader climate-change adaptation goals but may be threatened by impacts from other sectors. Strategies for adapting forests to climate change should be coordinated with those of other sectors and integrated into national and regional development programmes and strategies.*

Contents

List of figures and tables

1. Introduction

Forests cover nearly one-third of the earth's surface and hold the majority of its terrestrial species. They also account for almost half the terrestrial carbon pool (Fischlin et al 2007) and thus play a significant role in regulating the earth's climate. Tropical forests are particularly important in the global carbon budget because it has been estimated that they may contain as much carbon in their vegetation and soils as temperate and boreal forests combined (Brown 1996).

Climatic changes have been attributed to the increased liberation of greenhouse gases into the atmosphere. These gases include Carbon dioxide (CO_2), Methane, Nitrous oxide, Chlorofluorocarbons (CFC) and Sulphur hexaflouride. Since the start of the industrial revolution, the emission of greenhouse gases has greatly increased, which may be attributed to the combustion of fossil fuels and tropical deforestation. The concentration of CO_2 in the atmosphere has increased substantially since the middle of the 19th century, contributing to an increase in average global temperature of 0.74 ± 0.18 °C over the past 100 years (IPCC 2007).

Climatic change has negative impacts on rural zones as it affects all aspects of human existence and food security, particularly through the impacts on ecosystems (de Haen 2008). Forest loss and degradation is responsible for the release of more carbon to the atmosphere than any other source in central Africa (73% of total carbon is released through land use changes) (Gaston et al 1998). According to Food and Agriculture Organization's Global Forest Resources Assessment 2005 (FAO 2006), Africa in 2005 had over 635 million hectares of forest, covering 21.4% of the land area. This forest area is estimated to contain over 100 Gt (billion tonnes) of carbon (including in soils) which is equivalent to around 160 tonnes of carbon per hectare. In the period 2000–05 an average of 4 million hectares were lost per year (FAO 2009), mainly due to conversion of forestland to small-scale permanent agriculture. FAO (2006) estimates that carbon stocks in living biomass in African forests decreased by 1.4 Gt as a result. The Intergovernmental Panel on Climate Change (IPCC) estimates that deforestation, forest degradation and other land use change contribute 17.4% of global anthropogenic annual greenhouse gas (GHG) emissions, mainly in tropical developing countries (Barker et al 2007). Nabuurs et al (2007) estimate that deforestation was responsible for 5.8 Gt of carbon dioxide equivalent (CO_2-e) emissions per year throughout the 1990s. Most deforestation is caused by the expansion of agriculture and urban and infrastructure development.

The world's climate system and forest ecosystems are inextricably linked and as a consequence changes in either one of these systems inevitably trigger a feedback in the other. The climate significantly determines vegetation patterns globally and thus influences the distribution, structure and ecology of forests. Conversely, forest ecosystems play crucial roles in climate regulation through bio-physical and chemical processes that control fluxes of energy, water and atmospheric constituents. Changes in climate alter the configuration of forest ecosystems, and result in drastic upheavals in their composition, distribution and productivity (Ravindranath et al 2006). These effects, induced by climate change, will aggravate the existing stresses that derive from non-climate factors. In turn, this will have fundamental impacts on the viability of the livelihoods of millions of forest-dependent people in Africa.

Need for this report

The International Union of Forest Research Organisations (IUFRO) published in April 2009 the global assessment report on the ‘Adaptation of Forests and People to Climate Change’ (Seppälä et al 2009a). That report presents the state of information regarding the impacts of climate change on forests, the socio-economic implications and the options for adaptation. However, given the global scope of the assessment and the limited time available, it was not possible to systematically analyse and compile information for particular geographical regions. Although climate change is a global phenomenon, the particular impacts of change and the appropriate adaptive responses are local, and hence there is a need for adaptation reports to be tailored to regional areas. Many studies have been undertaken on forest policies, management planning and practices to help forests adapt to climate change, but recommendations generated from those studies are often generic and mostly based on case studies from temperate countries.

International deliberations on forests and climate change to date have focused mainly on mitigation, giving less attention to the vital need for adaptation. Climate change has had considerable effects on forest ecosystems over time and will have increasing effects on them in the future. This will in turn have an impact on forest goods and services with impacts for society, particularly forest dependent people. The forest-dependent poor such as the pygmies of the central African region, who often depend directly on forests for their livelihoods and for meeting domestic energy, food and health needs, will be most vulnerable to such stresses. Climatic change also has great effects on rural zones which are the principal areas of food supply, thus threatening food security and human life.

Africa covers 20.4% of the earth’s land area and contains 14.8% of the global population and 16%of the world’s forests. Nevertheless, there appears to be a shortage of Africa-specific climate change research, and a lack of sufficient African input into global discussions. This is despite the fact that Africa is expected to face particularly high impacts from climate change (Collier et al 2008; de Haen 2008). While some countries have a body of available published and grey scientific literature, adaptation planning is hampered by a lack of information in many others (Kigenyi et al 2002).

During the period between 1993 and 2002 it was reported that over 136,000,000 people died or were affected by climate-induced disasters in Africa as a whole (Osman-Elasha et al 2006a), indicating that traditional adaptation measures may not be sufficient to face climate change (Tarhule and Lamb 2003; Willems 2005). New methods of adaptation are required to face the current climate change challenges.

This report provides the scientific background for the policy brief entitled "Making African Forests Fit for Climate Change – A regional view of climate-change impacts on forests and people, and options for adaptation"[1]. We hope to help in the development of sustainable forest management practices and policies, which are essential for reducing the vulnerability of forests to climate change. This report also serves to showcase the science that is being done in Africa, and may help bring it to a wider audience. We also highlight those areas (thematic and geographical) where further research is urgently required.

Structure of this report

This report follows a similar structure to the recently published report 'Adaptation of Forests and People to Climate Change' (Seppälä et al 2009a), and extracts and develops Africa-specific material from that report. Further detailed information is derived from a pan-African group of scientists specially convened for this report, and searches of both peer-reviewed and 'grey' scientific and policy literature. Background documents to this report include Kigenyi et al (2002), Osman-Elasha et al (2006a), Gutiérrez et al (2006), IPCC (2007), Eastaugh (2008), and Katerere et al (2009).

172 of the 362 references cited in this report are from reviewed scientific journals (Table 1). Although this represents a solid body of evidence for the discussion and conclusions of this report, over 50% of the citations here were drawn from the 'grey' literature, in particular from NGO or Intergovernmental reports. This does not necessarily diminish the validity of the information, but care must be taken that citing grey literature does not simply propagate unfounded assumptions or out of date paradigms. All references cited in this document were examined in the original, except where these were unavailable to the editor and are noted here as 'cited in' a verified reference.

Table 1. Reference sources

SOURCE	NUMBER
Journal	172
Government/Intergovernmental	63
NGO report	46
Theses, Conference proceedings and Technical reports	38
Books from commercial publishing houses	25
Corporate	6
Other	12
TOTAL	362

Biome classifications

The Global Assessment Report divides forests into four major biome groups: boreal, temperate, subtropical and tropical. Boreal forests are not found

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[1] The policy brief is available for download at the GFEP webpage www.iufro.org/science/gfep/

in Africa, and temperate and subtropical forests are only found in small parts of South Africa (Gibbs-Russell 1987, cited in Seppälä et al 2009a) and will not be considered in this report in any great detail. Note that the southern African subtropical steppe areas are not classified as true forests (Seppälä et al 2009a). This report will follow the scheme used by the Forestry Research Network for Sub-Saharan Africa (FORNESSA) and the International Union of Forest Research Organisations' Special Programme for Developing Countries in Blay et al (2004) and broadly divide tropical forests into 'humid', 'sub-humid' and 'dry' sub-classes. Blay et al (2004) base their classification on an Aridity Index, which is a simple measure of annual precipitation divided by evapotranspiration. An aridity index greater than 1.0 is humid, between 0.5 and 1.0 is sub-humid, and less than 0.5 is dry. Figure 1 is a fine-scale rendition of aridity index across Africa.

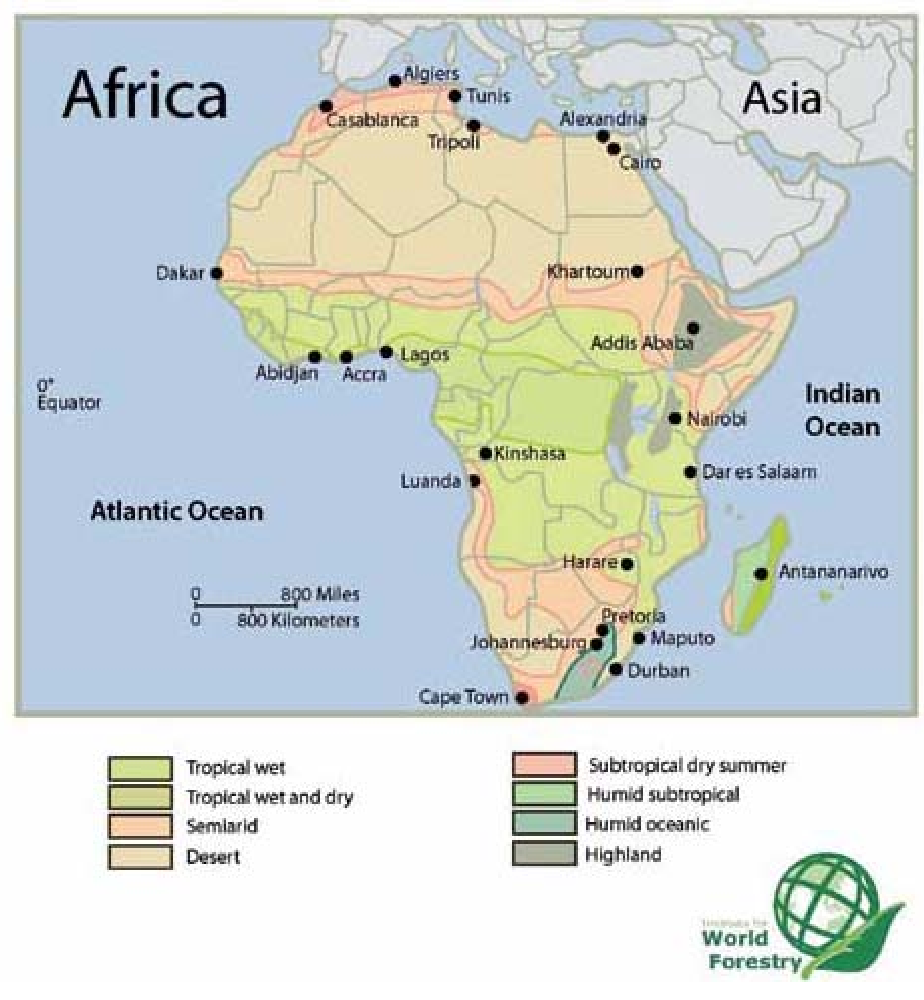


Figure 1. Main climate zones of Africa (developed by the Institute for World Forestry, Johann Heinrich von Thünen-Institut, Hamburg, Germany 2010).

Climate change and sustainable development

In developing countries, climate change issues must be looked at with regard to the need for sustainable development. This is not only a political prerogative, but also goes to the practicality of any mitigation or adaptation actions. Actions and policies driven by climate change in developed countries may not be affordable in developing nations, or may have unacceptable social impacts, or may simply be unworkable. This is not to say that developing countries cannot play their part in mitigation, or that adaptation is impossible. It is however vital that adaptation and development are seen as complementary, rather than as opposing goals (Peach-Brown 2009). Development is vital to increase the adaptive capacity of African societies to climate change, and in that context many past and ongoing sustainable development or forest rehabilitation projects may justifiably be seen as supporting climate change adaptation.

Sustainable development was defined by the Brundtland report as "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs" (WCED 1987). This goal will be unobtainable without considering the impacts of climate change, and actively supporting reduced vulnerability in developing communities (Osman Elasha 2009).

Africa is the world's lowest consumer of energy. Despite the continent having about 15% of the world's population and producing 7% of the world's commercial energy, it consumes only 3%, with more than half of its production being exported (Davidson and Sokona 2002). The average electricity consumption is the lowest in the world – about 578kWh/yr compared to a world average of 2752 kW/year (IEA 2009). This low energy usage is a pointer to the relative lack of economic development of many African communities, which has direct implication for their vulnerability to climate change and to their reliance on local natural resources. Sub-Saharan Africa is heavily dependent on biomass energy for household cooking and other heating needs, with wood fuels accounting for over 80% of primary energy demand (Table 2).

Table 2. Electricity consumption (Adapted from Davidson and Mehlwana n.d.)

Country	Rural Population % 2001	Rural Electricity Access %	GDP/ Capita US$	Biomass as % of total 2001
Botswana	51	8	3 100	-
Ethiopia	84	0.7	100	93
Kenya	66	1.7	350	78
Mauritius	58	100	3 830	-
South Africa	42	49	1 960	17
Tanzania	67	1.0	270	92
Uganda	86	1.0	260	95
Zambia	60	2.0	320	78
Zimbabwe	64	19	480	67

African forests

African forests are extremely diverse, as would be expected in a continent that spans 72 degrees of latitude and ranges in elevation from zero to 5895 metres above sea level. Africa's tropical forests have been estimated to harbour 12 000 forest plant species, of which perhaps 6 400 (Beentje et al 1994 cited in Poorter et al 2004) to 7 500 (Burgess and Clarke 2000) are endemic. Three African nations are among the world's 17 countries with 'mega-biodiversity', and four forested areas are recognized as biodiversity hotspots: the Guinean Forest, the Eastern Arc Mountain Forests, Madagascar and the Mediterranean Basin Forests (Fazey et al 2005, based on data from Conservation International 2000).

White (1983) classified African vegetation into 20 phytochoria (floristic regions), these being either regional or archipelagan centres of endemism or extreme floristic impoverishment, or transitional zones. Figure 2 shows the geographic distribution of these regions, and Table 3 gives a brief description of each. Linder et al (2005) re-examined White (1983) in the light of new data and analysis methods and recommended some adjustments, but White's (1983) classification is still commonly used.

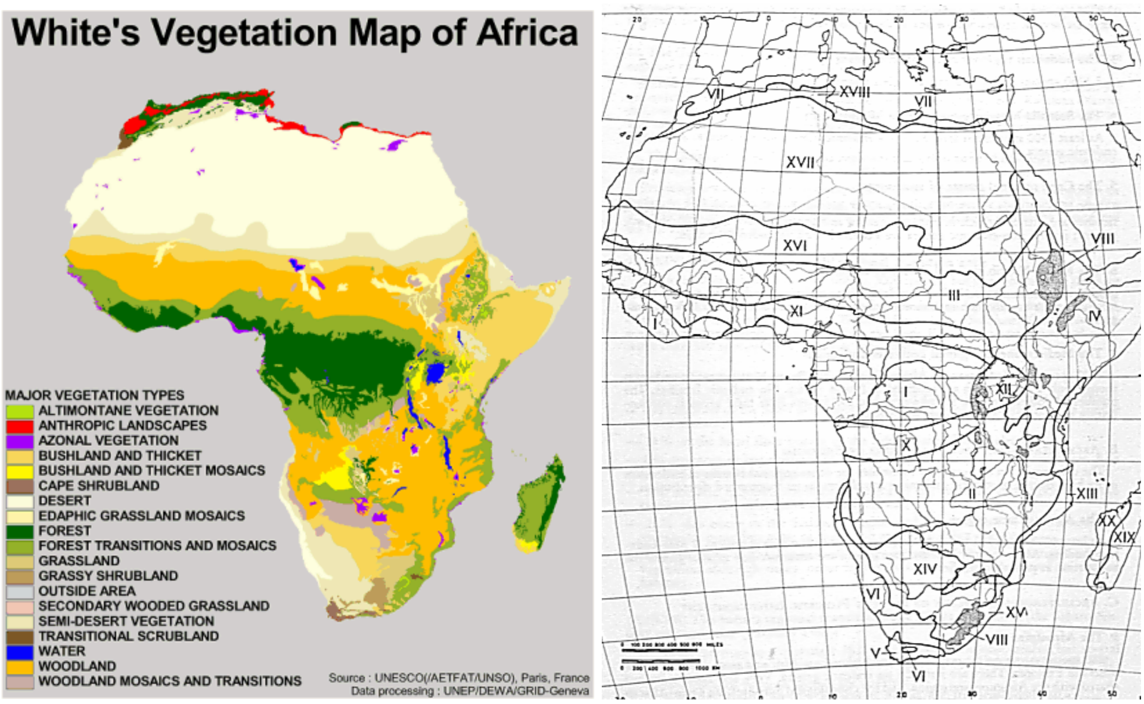


Figure 2. African phytochoria (after White 1983).

Table 3. African Phytochoria (Adapted from White (1983), Kigenyi et al (2002) and TroFFCA (n.d.)

Phytochorion	Extent/Distribution	Description	Threats
I. Guinea-Congolian	From Moist forest in Guinea through South Western Ghana and moist forests in Nigeria to the Congolian forests in Central Africa	Lowland rainforest and swamp forest with very diverse endemic flora including *Chlorophora*, *Holoptelea*, *Uapaca*, *Musanga* and *Elaeis guineensis* (oil palm)	

		Montane rainforest and grassland (above 1000 m altitude) with *Olea hochstetteri, Podocarpus* and *Ilex spp.*	
II. Zambesian	Largest major phytochorion after Sahara. From central and southern Tanzania, much of Zambia, Zimbabwe, south central Angola, Namibia, Caprivi strip, northern Botswana, central Mozambique and South Africa (Mpumulanga region).	Contains richest and most diverse flora in Africa. Dominated by Miombo woodland. Dry evergreen forest with around 1200mm rainfall. Dry deciduous forest and scrub 600-900 mm rainfall. Swamp/riparian forest. Mopane woodland.	Cultivation Charcoal burning Overgrazing Resettlement
III. Sudanian	Northern Uganda above Lake Victoria mosaic. Sudan south of Jabel Mara to Foothills of Ethiopian Highlands. Southern Mali, all the rest of Burkina and northern Ghana	Woodlands with patches of swamp forest. Outlier Guinea-Congolian affinities in extreme south-western Sudan. Rising to montane areas of southern Sudan bordering Uganda where forests exist. Woodland and dry forest, with *Celtis integrifolia*, *Hymenocardia acida, Lannea, Prosopis africana, Mytragyna inermis*, etc.	Cultivation Grazing Fires
IV. Somalia-Masai	Large areas of east Africa mainland. Eastern and southern Ethiopia (except mountains). Somalia, southeast Sudan. Northeast Uganda. Kenya, between the Highlands and the coastal belt. Dryland areas of north and central Tanzania south of the Great Ruaha River valley.	Mostly deciduous bushland dominated by *Acacia* and *Commiphora spp*. High rate of endemism (50%). High fauna population.	Over-grazing (both domestic and wildlife) Charcoal burning Increasing human population Extension of agricultural frontiers
V. Cape			
VI. Karoo-Namib			
VII. Mediterranean			
VIII. Afromontane	On all mountains and high-altitude sites.	Most are national parks and forest reserves. Over 4000 species, with 300 endemics.	Surrounded by high population densities Fragmentation Timber/firewood exploitation Conversion to agricultural and forest plantations
IX. Afroalpine			
X.Guinea-Congolia/ Zambesia			
XI.Guinea-Congolia/ Sudania	Central & south-eastern Ghana	Mosaic of dry, peripheral, semi-evergreen rainforest	

		and woodland or secondary grassland	
XII. Lake Victoria	Uganda south of the Nile. Western Kenya. North western Tanzania	Lowland forests with affinities to 5 distinct flora converging from other centres of endemism – Guinea-Congolan spp. Dominant. Transitional lowland forests (Kakamega with afromontane spp.). Swamp forests (Sango bay and Minziro).	Agriculture (since 400 BC) Timber harvesting Urbanisation and industrialisation Human population Agricultural encroachment Charcoal burning
XIII. Zanzibar-Inhambane	Coastal belt 1° N to Limpopo 25° S	Lowland moist forest (lower parts of eastern highlands of Tanzania, coastal Mozambique and Malawi and Zambia). Mangroves – confined in coastal zone from Somalia to Mozambique. Isolated on the Red Sea coast of Djibouti and Eritrea. Undifferentiated forests on wet and dry sites in Kenya and northern Tanzania.	Cultivation Fisheries and tourism Infrastructure development Charcoal burning
XIV. Kalahari-Highveld			
XV. Tongaland-Pondoland			
XVI. Sahel	Central Mali and northern Burkina	Semi-desert grassland and thorny shrubland (north) to wooded grassland and bushland (south), with *Acacia spp., Commiphora africana, Balanites aegyptiaca, Euphorbiaceae*, and abundant dryland taxa	
XVII. Sahara	Northern Mali	Certain plants characteristic of wadis (e.g. *Tamarix*) and of shady, rocky, gravelly or saline faces (e.g. C*ornulaca, Calligonum, Fagonia*)	
XVIII. Mediterranean/ Sahara			
XIX. East Malagasy			
XX. West Malagasy			

The reliability of forest statistics for Africa is limited due in part to the difficulty of collecting information and the often inconsistent reporting formats and definitions used by different countries. The Food and Agriculture Organisation (FAO) collates figures reported by national organizations, and an overview of the extent of African forests is given inTable 4.

Table 4. African forest statistics (adapted from FAO 2006)

Country/area	Land area					Inland water	Total area
	Forest		Other wooded land	Other land			
				Total	with tree cover		
	1000 ha	%of land	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha
Angola	59 104	47.4	-	65 566	-	0	124 670
Botswana	11 943	21.1	34 791	9 939	-	1 500	58 173
British Indian Ocean Territory	3	32.5	0	5	-	0	8
Comoros	5	2.9	-	180	-	n.s.	186
Kenya	3 522	6.2	34 920	18 472	10 320	1 123	58 037
Lesotho	8	0.3	31	2 996	-	-	3 035
Madagascar	12 838	22.1	17 054	28 262	-	550	58 704
Malawi	3 402	36.2	-	6 006	7	2 440	11 848
Mauritius	37	18.2	15	151	-	1	204
Mayotte	5	14.7	-	32	-	0	37
Mozambique	19 262	24.6	40 919	18 228	-	1 750	80 159
Namibia	7 661	9.3	8 473	66 195	-	100	82 429
Réunion	84	33.6	55	111	18	1	251
Seychelles	40	88.9	-	5	-	0	45
South Africa	9 203	7.6	21 409	90 835	-	462	121 909
Swaziland	541	31.5	289	890	-	16	1 736
Uganda	3 627	18.4	1 150	14 933	-	4 394	24 104
United Republic of Tanzania	35 257	39.9	4 756	48 346	-	6 150	94 509
Zambia	42 452	57.1	3 161	28 726	-	922	75 261
Zimbabwe	17 540	45.3	-	21 145	-	390	39 075
Total Eastern and Southern Africa	226 534	27.8	167 023	421 024	10 345	19 799	834 380
Algeria	2 277	1.0	1 595	234 302	-	-	238 174
Burkina Faso	6 794	29.0	7 427	9 178	-	4 000	27 400
Chad	11 921	9.5	9 152	104 847	-	2 480	128 400
Djibouti	6	0.2	220	2 092	-	2	2 320
Egypt	67	0.1	20	99 458	-	600	100 145
Eritrea	1 554	15.4	7 257	1 289	-	1 660	11 760
Ethiopia	13 000	11.9	44 650	51 981	-	799	110 430

Libyan Arab Jamahiriya	217	0.1	330	175 407	-	0	175 954
Mali	12 572	10.3	16 532	92 916	-	2 000	124 019
Mauritania	267	0.3	3 110	99 145	-	30	102 552
Morocco	4 364	9.8	406	39 860	-	25	44 655
Niger	1 266	1.0	3 740	121 664	8 000	30	126 700
Somalia	7 131	11.4	-	55 603	-	1 032	63 766
Sudan	67 546	28.4	-	170 054	-	12 981	250 581
Tunisia	1 056	6.8	170	14 310	2 207	825	16 361
Western Sahara	1 011	3.8	-	25 589	-	-	26 600
Total Northern Africa	**131 048**	**8.6**	**94 609**	**1 297 696**	**10 207**	**26 464**	**1 549 817**
Benin	2 351	21.3	3 959	4 752	-	200	11 262
Burundi	152	5.9	722	1 694	-	215	2 783
Cameroon	21 245	45.6	14 758	10 537	-	1 004	47 544
Cape Verde	84	20.7	-	319	-	0	403
Central African Republic	22 755	36.5	10 122	29 421	-	-	62 298
Congo	22 471	65.8	10 547	1 132	-	50	34 200
Côte d'Ivoire	10 405	32.7	2 626	18 769	379	446	32 246
Democratic Republic of the Congo	133 610	58.9	83 277	9 819	-	7 781	234 486
Equatorial Guinea	1 632	58.2	31	1 142	-	0	2 805
Gabon	21 775	84.5	-	3 992	-	1 000	26 767
Gambia	471	41.7	125	534	-	0	1 130
Ghana	5 517	24.2	0	17 237	-	1 100	23 854
Guinea	6 724	27.4	5 850	11 998	-	14	24 586
Guinea-Bissau	2 072	73.7	236	505	-	800	3 612
Liberia	3 154	32.7	0	6 478	179	1 505	11 137
Nigeria	11 089	12.2	5 495	74 493	220	1 300	92 377
Rwanda	480	19.5	61	1 926	-	167	2 634
Saint Helena	2	6.5	0	29	-	0	31
Sao Tome and Principe	27	28.4	29	40	10	0	96
Senegal	8 673	45.0	5 001	5 579	-	419	19 672
Sierra Leone	2 754	38.5	384	4 024	-	12	7 174
Togo	386	7.1	1 246	3 807	-	240	5 679
Total Western and Central Africa	**277 829**	**44.1**	**144 468**	**208 227**	**788**	**16 253**	**646 776**
Total Africa	**635 412**	**21.4**	**406 100**	**1 926 946**	**21 339**	**62 516**	**3 030 974**

Humid forests

Tropical humid forests occur approximately between latitudes 10^oN and 10^oS and constitute almost 25% of the total area of global forests. FAO (1993) defines tropical moist forests to include wet, moist evergreen and moist semi-deciduous forests, woodlands and tree savannas in regions where mean annual rainfall is over 1000 mm. Tropical moist forests include all forests within the humid tropics where annual rainfall exceeds the amount of water lost through evaporation and transpiration. There are about 70 countries located within the humid tropical forest region worldwide, including 31 in Africa.

The African humid forest zone covers about 256 million hectares of sub-Saharan Africa. The zone is characterized by an annual rainfall of 1400 mm to more than 4000 mm. The length of the growing period (Pardey et al 2007) ranges between 271 and 365 days per year. The zone largely encompasses locations in West Africa (48 million ha) and Central Africa (202 million ha). The soils in this zone have low cation exchange capacity and are of generally low fertility. The rainforest of the Congo basin (Figure 3) which contains about 91% of Africa's remaining rainforests occurs in this zone (IITA 2000). This region is identified as an important global centre of biodiversity and endemism. As a result of human-induced disturbances, the current forest is composed of a mosaic of different land use types, patches of secondary forest and fallow vegetation, and small remnants of primary vegetation (Jagtap and Chan 2000).

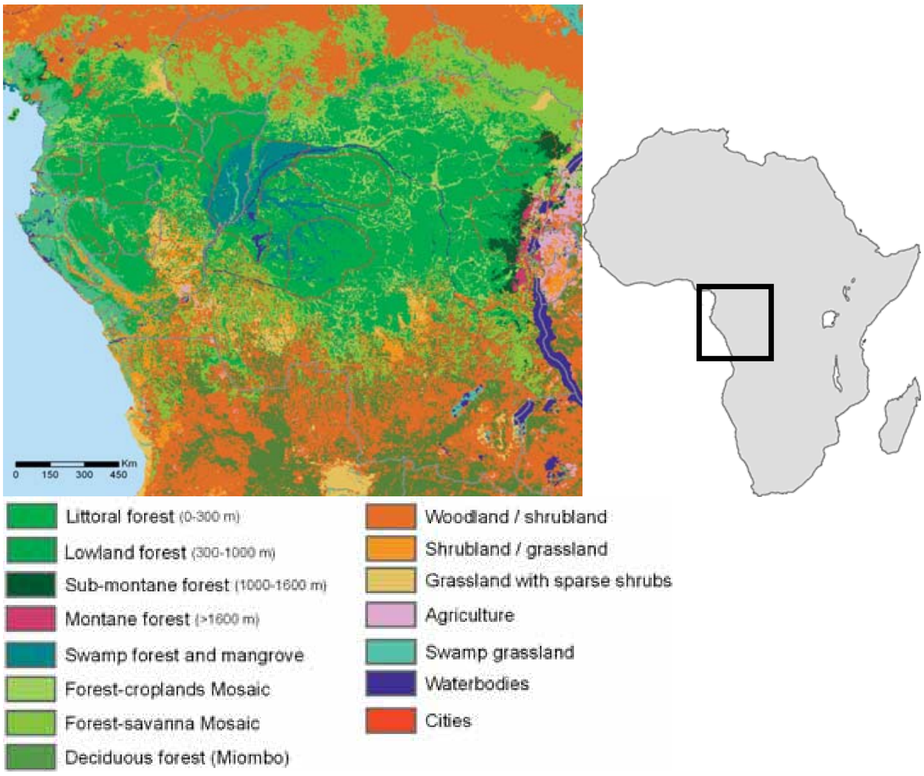


Figure 3. The forests of Central Africa (CBFP 2006).

The forests of the Congo Basin constitute the second largest area of dense tropical rainforest in the world after the Amazonian rainforests. The Congo Basin is a mosaic of moist tropical upland and swamp forests, parts of each type being protected areas, under logging concessions, or used for subsistence agriculture. Congo Basin forests stretch from the coast of the Gulf of Guinea in the west to the mountains of the Albertine Rift in the east and cover about seven degrees of latitude on either side of the equator. They are mostly within the Guinea-Congo forest structure, where they constitute over 80% of the total area. They also include the Afromontane forests found in the west of Cameroon and the east of the Democratic Republic of Congo. According to the CBFP (2006) these forests cover approximately 200 million hectares; however estimates of their area vary considerably.

Along the Atlantic coast there is an irregular strip of evergreen forests including clumps of hyper humid forests in northeastern Gabon and western Cameroon, which receive more than 3000–3500 mm of precipitation annually. Approximately 100–200 km from the coast on the mountain ranges (Monte Alén, Monts de Cristal, Monts Doudou, etc.), there is also an irregular strip of forests that are rich in Caesalpinids (flowering legumes) and, above an altitude of 650 m, have submontane characteristics. Towards the north, this strip mixes with the submontane and montane forests of Mount Cameroon and the highlands of western Cameroon. Further to the east, most of the terra firma forests of the Congo Basin consist of a mosaic of evergreen and semi-evergreen formations, which are generally less rich in species. Among these formations are the monodominant forests, of which the best known and most extensive are *Gilbertiodendron dewevrei*. In the center of the Congo Basin there are 22 million hectares of swamp forests or floodplain forests that exhibit less diversity, but a substantial degree of plant endemism. In eastern Gabon and northern Republic of Congo, there are also vast open-canopy *Marantaceae* forests. In the east of the Congo Basin, the land rises to the mountains of the Albertine Rift with submontane forests between 1000 and 1650 m and montane forests between 1650 and 3000–3400 m. The northern and southern fringes of the forest block consist of semi-deciduous forests that give way to a mosaic of savannahs and gallery forests, less rich from a botanical point of view, but supporting high populations of large mammals.

The rainforests of West Africa, also known as Upper Guinean forests, cover about 10.9 million hectares, and stretch from Senegal to Togo. They are separated from the rest of Africa’s rainforests by the Dahomey gap. The Upper Guinean forests have been designated as one of the global biodiversity hotspots (Myers et al 2000) and are known to contain a large number of species of both fauna and flora. This forest zone straddles nine West African countries aligned along the coast. It is estimated that the West African rainforest zone contains 2800 vascular forest plants species, of which 650 are endemic, and 400 species considered rare (Poorter et al 2004).

Sub-humid forests

Mean annual rainfall ranges from 200 mm to 800 mm in the sub-humid forest zone in Africa. The zone has a growing season of 151– 270 days. It stretches in a band across West and Central Africa and includes coastal lowlands in eastern and southern Africa. The sub-humid zones of eastern and southern Africa are climatically more favourable for agricultural production than in West Africa (Jagtap and Chan 2000).

Dry forests

Africa has large areas of arid land (Table 5), some of which supports forest ecosystems vital to the livelihood of millions of people. Dry forests are characterised by an aridity index of less than 0.5; i.e. where annual evapotranspiration is at least double the annual rainfall. These are usually areas with an extended dry season, with all precipitation concentrated into a limited time. Fire and drought are important ecosystem processes in these environments, and changes in fire frequency can have fundamental effects on the biomes (Swaine 1992).

Table 5. Area (1000 km^2) per aridity zone by sub-region for Africa (adapted from Kigomo 2003)

	Hyper-arid		Arid		Semi-arid		Dry Sub-humid		Total
Sub-region		%		%		%		%	
Northern Africa	4 736	81	640	11	410	7	43	0	5 829
Western Africa	2 363	33	1 465	20	1 278	18	514	7	5 620
Central Africa	0	0	6	0	66	2	144	4	216
Eastern Africa	878	14	1 670	27	1 768	28	767	12	5 083
Southern Africa	96	2	823	13	2 579	42	924	15	4 422
Africa Total	8 072	27	4 604	16	6 100	21	2 392	8	21 170

Biomass production in dry forest is relatively low, which underlines the importance of assuring sustainable usage and successful regeneration (Johannson and Kaarakka 1992). In some areas the persistence of forests depends on rigid controls over allowable wood removals (Lieberman and Li 1992).

The southern African forests are generally classified as dry-land tropical forests, commonly known as ‘Miombo Woodlands’. There are patches of temperate and sub-tropical forests in South Africa, but their occurrences are insignificant. Miombo woodland is one of the most extensive dry forest vegetation types in Africa, occurring in seven countries in eastern, central and southern Africa: Angola, Malawi, Mozambique, Tanzania, Democratic Republic of Congo, Zambia and Zimbabwe (White 1983). They occupy an area of about 2.7 million square kilometres, almost equal to the combined land area of Mozambique, Malawi, Zimbabwe, Tanzania and Zambia.

The miombo ecozone largely coincides with the flat to gently undulating African (early tertiary) and post-African I (Miocene) planation surfaces that form the Central African plateau. These woodlands constitute the largest more-or-less contiguous block of deciduous tropical woodlands and dry forests in the world. The natural range for miombo is from 5° to 25° latitude south (Campbell 1996). Its extent is limited to the unimodal rainfall belt in areas whose rainfall ranges between 750 mm to 1400 mm falling between altitudes of 500 and 1500 m above sea level. A lack of frost tolerance probably explains the southern limit and the altitudinal limit of approximately 2000 m (Huntley 1982 cited in Lowore 1991).

Miombo woodland is dominated by the legume family *Caesalpiniaceae* with the most important tree species being those of *Brachystygia*, either alone or with *Julbernardia*, and *Isoberlinia* (White 1983; Malambo and Syampungani 2008). Dominant trees have short, slender boles and a flat-topped or umbrella shaped crown. Mature, relatively undisturbed stands typically comprise of a 10–20 m high single storey, partly closed canopy, a discontinuous understory of broad-leafed shrubs and a continuous herbaceous layer of forbs, small sedges and grasses (Campbell 1996).

White (1983) classified miombo woodland into wet and dry types. Wet miombo is centred on eastern Angola, northern Zambia, south western Tanzania and central Malawi in areas receiving more than 1000 mm rainfall per annum. In wet miombo canopy height is usually greater than 15 m, reflecting the generally deeper and moister soils which create favourable conditions for growth. The vegetation is floristically rich and includes nearly all characteristic miombo species. Dry miombo occurs in Zimbabwe, central Tanzania, and the southern areas of Mozambique, Malawi and Zambia, in areas receiving less than 1000 mm of rain annually. Canopy height in dry miombo is less than 15 m and the vegetation is less diverse. Many of the dominant canopy tree species of the wet miombo are either absent or local in occurrence.

Interspersed within the woodlands are broad, grassy depressions called dambos. In these depressions seasonally waterlogged bottomlands can cover up to 40% of the landscape in some areas (Whitlow 1989). Dambos are important sites for cultivation and livestock grazing. The woodlands are very important to the livelihoods of about 39 million people in these countries providing products such as food, fibre, fuelwood and charcoal.

Importance of forests in Africa

Importance of forests in general

Forests are indispensable for human wellbeing as they provide a broad range of products, services and functions. They are important for environmental equilibrium as they regulate local climate (rainfall), stabilize temperatures, and are a vital source of energy. Forest ecosystems provide essential services that are critical to the mitigation of the effects of climate change, land degradation, conservation of wetlands, coastal areas and freshwater systems (Zaikowski 2007). As indicated by FAO (2006), the primary functions of forests globally include production (34.1% of area), protection of soil and water (9.3%), conservation of biodiversity (11.2%), multiple purposes (33.8%), and other unknown functions (7.8%). Forest-dependent communities may however have varying perceptions about the value of forests, which may differ from the perceptions of broader national society or the international community.

It is estimated that 348 million hectares of forests around the world are managed for protection purposes (FAO 2006). Accounting for about 80% of global land-based above-ground carbon stocks, forests play crucial roles in the global carbon cycle (Baccini et al 2008). It is estimated that forests in tropical regions constitute a carbon sink of around 1.3 Pg per year (Pg = 10^{15}g) (Lewis et al 2009).

Examples specific to Africa

Africa’s forest area is estimated to be 635 million hectares, corresponding to about 16% of global forest area (FAO 2009). In sub-Saharan Africa these forest resources are crucial national assets providing diverse goods and services and are treasured for their immense contribution to people’s livelihood and economic development. They provide ecological benefits including protection of watersheds, soils, hills and sanctuaries, and serve as habitat for a myriad species of flora and fauna. Local communities have a high dependence on forest areas for farmland, foraging, food, hunting for meat, fodder, fuelwood, building materials, herbal medicines, and household items. In addition, forest fringe communities derive intangible benefits from the forests, including their values as cultural symbols, ritual artefacts and sacred sites. These forests are particularly important to the poor, serving as a ‘safety net’ and providing emergency sustenance during crop failure, economic crisis and in conflict situations. Around 70–80% of Africans rely on traditional medicines, mostly derived from plants (Cunningham 1993). Healthy forests are vital to achieving progress towards the Millennium Development Goals (Cropper 2006).

Nkem et al (2008a) surveyed local populations in West Africa to determine what people thought were the most important contributions of forests to local societies (Table 6). Fodder supplies, non-timber forest products and traditional medicines were considered the most important products, along with ecosystem services (water supply protection).

Table 6. Forest importance ranking example from Burkina Faso (adapted from Nkem et al 2008a)

	Criteria (1–3)				
Sectors	1	2	3	Total	Googs and Services
Livestock fodder	4	5	5	14	Fodder resource during dry season
Water	4	5	5	14	Basins and rivers protection
Energy	5	3	5	13	Fuel wood
Health	5	4	5	14	Drugs for traditional medicine
Blodlversity conversation	4	5	4	13	Fauna an flora
Human nutrition	4	4	5	13	Fruits, seed, beans and some tree leaves, roots, and bark
Non-timber forest products	5	4	5	14	Forest products
Agriculture	2	5	5	12	Fight against erosion, soil conversation
Fibres/wood	4	1	4	9	Handicraft wood, mats
Culture	3	1	3	7	Habitat, rites, customs

Scores from 1 = very low to 5 = extremely high contribution to a particular criteria

Dry forests and woodlands may provide between one sixth and one quarter of the total income stream to poor African communities (Shackleton et al 2007). Forests are used broadly in 3 ways: to supply basic needs, to allow scarce cash resources to be preserved and as a buffer in hard times. 80% of rural households use fuelwood as their primary energy source. Poor rural households rely on environmental resources for around 40% of their income in Zimbabwe (Cavendish 2000) and Ethiopia (Mamo et al 2007). Miombo woodlands in particular are very important to the livelihoods of over 39 million people in the countries of the region. In addition, woodlands have a service role in controlling soil erosion, providing shade, modifying hydrological cycles and maintaining soil fertility. Religious and cultural customs which relate to designated woodland areas and certain species are vital to the spiritual well-being and effective functioning of rural communities.

Timber and other forest products

Wood and non-wood forest products from African forests are highly valued in view of their great impact on the socio-economic development of most African countries (FAO 2007). Arnold and Townson (1998) estimate that perhaps 15 million people in sub-Saharan Africa derive at least part of their income from forest product activities. Often it is the poorest groups in a community that are most dependent on the forest.

Revenues from the forest sector are key components of African economies. It is estimated that on average, forests account for 6% of Africa's GDP (NEPAD 2003). The contribution of the forest products sector to Africa's GDP was 1.5% in 2000; in monetary terms this amounts to about US$7.7 billion (FAO 2007). Exports of timber products contribute more than 60% of GDP in Central and Western Africa. In Ghana, the forest sector contributes about 6% of GDP, while in Uganda this figure is as high as 23% (Kigenyi et al 2002). These statistics should be read with some caution, as different reports may be based on different definitions. FAO (2007) also note the difficulties in estimating socio-economic forest statistics in Africa due to the high contribution of the informal sector.

The area allocated to logging in central Africa has increased significantly over the last few decades. For the region as a whole, it amounted to 49.4 million ha in 2004, equivalent to 36% of the total area of production forests and 27 % of the total area of dense rainforests. In Equatorial Guinea, Gabon, the Central African Republic (CAR) and the Republic of Congo, 77–93% of the production forests have been allocated to logging. In the Democratic Republic of Congo (DRC), these allocations only cover 18% of the production forests due to the fact that many logging permits were cancelled in 2003. At the same time, production has also risen considerably: it reached 8.5 million m^3 for the region as a whole in 2004. In terms of production, Gabon leads, followed by Cameroon and the Republic of Congo. On average, 35% of production is exported as logs. In Equatorial Guinea this proportion rises to 85%, but in Cameroon it is only 6% following the severe legal restrictions on log exports l. In terms of absolute volume, Gabon remains the main exporter of logs. On average, 19% of Central African timber production is exported after it has undergone first-stage processing. This percentage is lowest in Equatorial Guinea (5%) and highest in Cameroon (32%). These figures are taken from Congo Basin Forest Partnership statistics (Table 7), which may not exactly match other reports such as the International Tropical Timber Organisation's annual evaluation (ITTO 2006) or the Food and Agriculture Organisation's 'State of the Forests' report (Table 8). In some cases the differences between these three sources are quite substantial, with for example Cameroon's annual timber production being variously reported as 2375 thousand m^3, 1750 thousand m^3 or 3211 m^3.

Table 7. Statistics on industrial logging in Central Africa (adapted from CBFP 2006)

Country	**Total area of forests**	**Area of production forests**		**Areas allocated to timber production in 2004**		**Production**	**Log exports**		**Transborder exports**	
	ha	ha	%	ha	%	m3	m3	%	m3	%
Cameroon	19,639,000	12,000,000	61	5,400,000	45	2,375,000	141,000	6	758,000	32
Eq. Guinea	1,900,000	1,500,000	79	1,400,000	93	513,000	438,293	85	27,000	5
Gabon	22,069,999	17,000,000	77	13,800,000	80	3,700,000	1,517,000	41	515,000	14
CAR	6,250,000	3,500,000	56	3,000,000	86	570,000	194,000	34	57,000	10
Republic of Congo	22,263,000	13,000,000	58	10,000,000	77	1,300,000	659,000	50	284,000	22
DRC	108,339,000	90,000,000	83	16,000,000	18	90,000	58,000	64	15,000	17
Central Africa	**180,460,999**	**137,000,000**	**76**	**49,400,000**	**36**	**8,548,000**	**3,007,293**	**35**	**1,656,000**	**19**

Table 8. Removals of wood products 1990–2005 (adapted from FAO 2006)

Country/area	1990	2000	2005			
	Total	Total	Total	Industrial roundwood	Wood fuel	% of growing stock
	1000 m^3 o.b.	1000 m^3 o.b.	1000 m^3 o.b.	1000 m^3 o.b.	1000 m^3 o.b.	
Angola	3,668	4,905	5,196	1,283	3,913	0.2
Botswana	792	851	881	132	749	0.4
British Indian Ocean Territory	-	-	-	-	-	-
Comoros	168	193	206	9	197	15.3
Kenya	21,385	24,900	26,658	2,402	24,256	9.5
Lesotho	1,771	2,227	2,455	-	2,455	-
Madagascar	7,246	9,973	7,031	598	6,433	0.3
Malawi	6,348	6,297	6,272	655	5,617	1.7
Mauritius	27	18	14	8	6	0.5
Mayotte	-	-	-	-	-	-
Mozambique	18,174	20,744	22,029	1,732	20,297	4.4
Namibia	-	-	-	-	-	-
Réunion	-	-	8	6	2	-
Seychelles	10	12	13	10	3	0.4
South Africa	15,521	17,000	17,741	17,491	250	2.8
Swaziland	1,814	1,024	1,024	380	644	5.3
Uganda	35,909	42,936	46,449	4,408	42,041	29.8
United Republic of Tanzania	23,846	26,637	28,033	2,833	25,200	2.2
Zambia	8,073	9,259	9,851	1,053	8,798	0.8
Zimbabwe	8,552	10,519	11,566	1,185	10,381	1.9
Total Eastern and Southern Africa						
Algeria	165	184	195	150	45	0.1
Burkina Faso	6,339	7,248	7,338	5	7,333	3.1
Chad	3,931	4,168	4,292	204	4,088	2.0
Djibouti	-	-	-	-	-	-
Egypt	-	-	240	120	120	3.0
Eritrea	-	2,551	2,551	2	2,549	-
Ethiopia	85,841	103,188	111,861	2,982	108,879	39.3
Libyan Arab Jamahiriya	-	-	-	-	-	-
Mali	4,961	5,911	6,386	507	5,879	3.3
Mauritania	1,097	1,651	-	-	-	-
Morocco	1,012	897	949	491	458	0.5
Niger	9,544	12,151	12,473	594	11,879	95.9
Somalia	7,437	10,703	12,334	132	12,202	7.9
Sudan	20,684	21,715	22,230	2,716	19,514	2.4
Tunisia	208	236	274	223	51	1.0
Western Sahara	14	23	23	12	10	0.1
Total Northern Africa						

Benin	-	-	-	-	-	-
Burundi	6,721	8,217	9,693	383	9,310	-
Cameroon	14,861	17,989	19,772	3,211	16,561	1.5
Cape Verde	-	-	-	-	-	-
Central African Republic	4,054	3,566	3,566	1,108	2,458	0.1
Congo	2,059	2,424	2,767	1,450	1,317	0.1
Côte d'Ivoire	8,826	12,137	12,545	2,175	10,370	0.5
Democratic Republic of the Congo	54,922	78,791	82,994	4,199	78,795	0.3
Equatorial Guinea	714	933	933	419	514	0.9
Gabon	2,198	3,550	4,227	3,600	627	0.1
Gambia	602	783	873	154	718	5.0
Ghana	16,078	24,999	29,458	1,205	28,253	9.2
Guinea	11,412	13,179	14,001	748	13,253	2.7
Guinea-Bissau	1,110	1,309	1,417	32	1,385	2.8
Liberia	5,048	5,610	5,918	-	5,918	1.2
Nigeria	63,756	79,002	86,627	13,916	72,711	6.3
Rwanda	3,114	7,789	10,429	226	10,203	11.9
Saint Helena	-	-	-	-	-	-
Sao Tome and Principe	10	10	10	10	-	0.2
Senegal	4,696	5,131	5,110	10	5,100	1.6
Sierra Leone	5,534	6,212	6,551	137	6,414	-
Togo	-	7,054	6,332	3,320	3,012	-
Total Western and Central Africa						
Total Africa						

From an international perspective Africa's contribution to the global timber market is relatively small, and has changed little over the past several decades (FAOSTAT 2008; Seppälä et al 2009a). Africa as a whole produces around 55 million cubic metres of wood products per year, for a projected producer surplus of around 97 billion US$ (net present value) over the period 2000–2150 (Daigneault et al 2008). Economic estimates indicate that the timber output in the African region could increase as a result of climate change by 5–14%, in the period 2000–2050 and by a further 17–31% in the period 2050–2100 (Sohngen et al 2001).

Forests supply a major percentage of energy needs in many African countries (Amous 1999). It has been found that about 90% of the wood removals in Africa are used for fuel, in contrast to less than 40% in the world at large (FAO 2007), and 70% of the population of Eastern and Southern Africa depend on wood energy (Kigenyi et al 2002). Trade in charcoal is a major income source for many households (Kambewa et al 2007). The number of people directly relying on traditional wood energy is projected to rise from 583 million in 2000 to 823 million in 2030, which may place severe stresses on the resource (Nampinga 2008). In many countries in Africa woodfuels are unsustainably produced from forests and woodlands and contribute substantially to deforestation and degradation and CO_2 emissions. In Ghana annual woodfuel extraction (estimated at 16 million m^3) is about four times as much as timber extraction (3.7 million m^3). Woodfuel extraction accounts for about 68% of the annual 65 000 hectares of forest cover loss in Ghana per year (FAO 2006). Modelling by von Maltitz and Scholes (1995) identified a number of regions in South Africa where fuelwood consumption was likely to be unsustainable. Ardayfio-Schandorf (1996) gives a number of examples of regions facing fuelwood deficits, including the Sudan Sahel, Madagascar, urban centres such as Yaounde, Brazzaville and Kinshasa and small mountainous southern countries such as Malawi and Swaziland.

Another significant benefit to many households is the collection and trade of non-timber forest products (NTFPs). There is considerable economic contribution from the production and sale of gums and resins, medicinal plants, honey and beeswax, bush-meat etc. (Sunderland et al 1998), and the small-scale trade in forest products (Shackleton et al 2007). Sudan, the world's leading producer of gums and resins, controls from 50% (Chikamai et al 2009) to 80% (Abdel Nour 1997) of global production. In 2003, the annual export trade in medicinal plants was estimated to be about US$60 million and US$4.4 million in South Africa and Zambia respectively (FAO 2003d). Medicinal plants provide foreign exchange of about US$2.9 million annually for Cameroon (Zaikowski 2007). Table 9 presents some main traded NTFPs in Africa. Although any individual NTFP is usually economically less significant than timber, cumulatively NTFPs can contribute more value per hectare than timber (depending on the region). In Ghana trade in 10 species of NTFP is approximately US$89 million. If we include bushmeat as a NTFP this value is significantly increased to over US$400 million (Ntiamoah-Baidu 1997, cited in Atmadja 2004). An estimated one million ton of bushmeat is consumed in the Congo basin, and such hunting provides 30–80% of the protein in forest communities' diets (FAO 2004).

Table 9. Main NTFPs traded in some sub-Saharan African countries. Adapted and modified from FAO (2001)

Sub-region	Main NTFP	Available national statistics
Eastern Africa	Exudates, medicinal plants, bee products	Eritrea: Export 9 tonnes of *Acacia Senegal* (gum Arabic) and 543 tonnes of *Boswellia papyrifera* (clibanum) in 1997 Ethiopia: 20 000 tonnes/annum honey production in 1976–1983 and annual production of gum arabic of 375 tonnes in 1988–1994 Tanzania: Export of 756 tonnes of *Cinchona spp* bark worth US$258 000 in 1991
Western Africa	Edible plants, medicinal bushmeat, fodder	Burkina Faso: Annual export of 14 200 tonnes of Shea butter worth US$2.4 million in 1984–1990 Guinea: Annual use of more than 100 million chewing sticks (*Lophira lanceolata)* Ghana: Annual bushmeat trade estimated $350 million Liberia: Annual use of 100 000 tonnes of bushmeat for subsistence purposes
Central Africa	Edible plants, medicinal plants, bush meat, rattan	Cameroon: Annual export of 600 tonnes of *Gnetum spp* leaves worth US$2.9 million Rwanda: Annual honey production of 23 000 tonnes in 1998
Southern Africa	Edible plants, medicinal bee products, fodder	Namibia: annual export of *Harpagolum prcumbens* (devils claw) valued at US$1.5–2 million in 1998 Zambia: Honey production of 90 tonnes and beeswax production of 29 tonnes valued at US$170 000 and US$74 000 respectively, in 1992

The value of non-timber forest products is complex and difficult to precisely determine (Adepoju and Salau 2007), although undoubtedly important (Falconer 1990). In some cases the prevalence of NTFPs may be significantly under-reported and given insufficient attention by policy-makers and managers (Nkem et al 2007b; Shackleton 2009), although the FAO does try to determine statistics on the production of various classes of NTFPs (Table 10). NTFPs are particularly important to rural communities in terms of food and nutritional requirements, medicines, fodder for livestock and related domestic requirements. The demand for a number of NTFPs, especially those for food and medicines, is increasing in urban centers and cities as people from rural communities migrate but still desire to use these commodities. Gradually, influence spills over to other communities in the cities thereby increasing the markets. The use of *Dacryodes edulis* and *Gnetum* s*pp.* from Central Africa for Africans in Europe and of *Catha edulis* for Somalis in the diaspora has been mentioned (Chikamai and Tchatat 2005). By 1998 an estimated 105 tonnes of “bush plums” (*Dacryodes edulis*) and 100 tonnes of “eru” (*Gnetum africanum* and *G. buchholzianum)* had been exported from Central African countries to Africans living in France and Belgium (Tabuna 1999).

Indigenous fruits in central Africa are obtained from two distinct ecosystems; dry savannah and humid forests. Important fruits from the dry savannah include *Vitellaria paradoxa, Parkia biglobosa, Sclerocarya birrea, Tamarindus indica* and *Ziziphus mauritania*. Those from the humid forests are *Irvingia* species, *Garcinia cola, Baillonella toxisperma* and *Coula edulis*. They are important both for the subsistence requirements to supplement nutrition and also sold as a source of income. Among the forest vegetables are *Gnetum africanum* and *G. bulccozianum* from the humid zones of Central Africa. Additionally, there are some forest plants whose roots are important as spice or condiment. They include *Mondia whytei* from Central Africa (see Table 11).

Medicinal plants are other important NTFPs from forests and woodlands. There are clear regional specificities for West and Central Africa (mostly from the humid forests) and Eastern and Southern Africa (mostly from Savannah woodlands and forests). Forests are also important for beekeeping in providing nectar and pollen for honey and bees wax production. At the same time, bees are important pollinators for some species.

NTFPs provide both social and economic benefits to the livelihoods of rural communities. At the subsistence level, NTFPs normally address livelihood strategies such as the secure provision of food, health care needs, concerns to reduce risk factors etc. The demand for these types of services from the forest is normally modest and is unlikely to constitute serious threats to sustainablility (Chikamai and Tchatat 2005). Commercialisation of medicinal plants was however observed to often impact negatively on the availability of forest and woodland resources, since most of them are obtained from the wild and the plant parts removed (roots and bark) are sometimes essential for the survival of the plants. Examples of this problem include *Prunus africana* and *Pausinystalia jolimbe* from Cameroon (Cunningham and Mbenkum 1993; Chikamai and Tchatat 2005).

Table 10. Recorded production of non-timber forest products (adapted from FAO 2006)

Country/area	Plant products								Animal products							
	Food	Fodder	Raw material for medicine and aromatic products	Raw material for colourants and dyes	Raw material for utensils, crafts & construction	Ornamental plants	Exudates	Other plant products	Living animals	Hides, skins and trophies	Wild honey and beeswax	Bush meat	Raw material for medicine and aromatic products	Raw material for colourants and dyes	Other edible animal products	Other non-edible animal products
	(t)	**(t)**	**(t)**	**(t)**	**(t)**	**(t)**	**(t)**	**(t)**	**(units)**	**(units)**	**(t)**	**(t)**	**(t)**	**(t)**	**(t)**	**(t)**
Angola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Botswana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
British Indian	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Comoros	151	-	-	-	-	14	-	-	-	-	6	-	-	-	-	-
Kenya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lesotho	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Madagascar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malawi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mauritius	11.00	308.00	-	-	96	-	-	160	8.000	350	93	-	-	-	40	-
Mayotte	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mozambique	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Namibia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Réunion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seychelles	-	-	-	44	-	-	-	-	-	-	-	-	-	-	-	-
South Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swaziland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uganda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
United	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zambia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zimbabwe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Eastern																
Algeria	-	-	-	-	-	-	-	-	-	-	2.000	-	-	-	-	-
Burkina Faso	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chad	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Djibouti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Egypt	50.00	10.200	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eritrea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethiopia	-	-	-	-	-	-	6.55	-	-	-	-	-	-	-	-	-
Libyan Arab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mali	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mauritania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Morocco	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Niger	-	-	-	-	4.079	-	5.00	-	-	-	-	-	-	-	-	-
Somalia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sudan	-	-	-	-	-	-	-	-	663.71	1.388.5	-	66	-	-	-	-
Tunisia	-	420.00	20.00	-	-	-	-	11.01	-	-	80	20	-	-	39	-
Western	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																
Benin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burundi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cameroon	21.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cape Verde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Central African	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Congo	1.426	-	-	-	95.34	-	-	-	8.000	-	12.50	75	-	-	-	-
Côte d'Ivoire	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Democratic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equatorial	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gabon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gambia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ghana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guinea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guinea-Bissau	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Liberia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nigeria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rwanda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saint Helena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sao Tome and	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Senegal	5.000	-	400	10	205	-	1.20	-	725.00	-	900	90	-	-	-	-
Sierra Leone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Togo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Western																
Total Africa																

Table 11. Important NTFP's in the Congo Basin (Tabuna 1999)

Espèces	Famille	Nom vernaculaire	Nom commercial	Statut	Partie vendue
Abellmoschus esculentus (L.) Moench	Malvaceae	*dongo dongo* (CK, CB)	*gombo*	Cultivée	fruit
Afrostyrax lepidophyllus Mildbraed	Styracaceae	*omi* (C)	*omi*	Spontanée	écorce
Aframomum sp	Zingiberaceae	*m'bongo* (C), Nzo za nungu (CB)	*maniguette*	spontanée	fruit sec et frais
Amaranthus hybridus L.	Amaranthaceae	*bitekuteku* (CK), badi (CB)	*bitekuteku*	cultivée	feuilles
Ananas comosus (L.) Merr	Bromeliaceae	ananas (CK, CB, G, C, CA)	*ananas*	mixte *	fruit
Arachis hypogea L.	Fabaceae	*nguba* (CK, CB) arachide (C)	*arachide*	cultivée	graine
Artocarpus communis Forst	Moraceae	Jacq fruit	*Jacq fruit*	mixte	fruit
Basella alba L.	Basellaceae	épinard	*épinard*	cultivée	feuille
Cajanus cajan (L.) Millsp	Fabaceae	*petit haricot* (C)	*petit haricot*	cultivée	graine
Capsicum annuum L.	Solanaceae	*pilipili* (CK), pidi pidi (CB), piment	*pili pili et piment*	cultivée	fruit
Carica papaya L.	Caricaceae	papaye (C, CK, CB, G, CA)	*papaye*	cultivée	fruit
Cola nitida A. Chev.	Sterculiaceae	*makazu* (CK, CB), noix de cola (C, CA)	*kola ou noix de cola*	mixte	graine
Colocasia esculenta (L.) Schott	Araceae	*taro* (CK, CB, CA, C, G)	*taro*	cultivée	tubercule
Cucurbita maxima Duch	Curcubitaceae	*m'bika* (CK, CB) graine de courge (C)	*graine de courge*	cultivée	graine
Corchorus olitorius Per ex DC	Tiliaceae	*dongo dongo ya makasa* (CK, CB)	*gombo*	cultivée	feuille
Cympobogon citratus (DC) STAPF	Poaceae	citronnelle (C, CK, CB, CA, G)	*citronnelle*	cultivée	feuille sèche
Dacryodes edulis (G. Don) Lam.	Burseraceae	*safou* (C, CK, CB, G, CA)	*safou*	mixte	fruit
Elaeis guineensis Jacq	Arecaceae	*m'bila* (CK, CB), noix de palme (C, G)	*noix de palme*	mixte	fruit, boisson, huile
Garcinia kola Haeckel	Clusiaceae	*petit cola* (C), *démarreur* (C)	*petit cola*	spontanée	graine
Gnetum sp	Gnetaceae	*fumbua* (CK, CB), *okok* (C), *koko* (CB, CA)	*fumbua*	spontanée	feuille
Hibiscus sabdariffa L.	Malvaceae	*ngai ngai* (CK, CB)	*ngai ngai*	cultivée	feuille
Hua gabonii Pierre	Stryracaceae	*omi* (C)	*omi*	spontanée	fruit sec
Ipomoea batatas (L.) Lam	Convolvulaceae	*m'bala* (CK, CB), patate douce (C, CA,)	*patate douce*	cultivée	tubercule
Ipomoea sp	Convolvulaceae	*matembele banki* (CK)	*matembele banki*	cultivée	feuille
Irvingia gabonensis Baillon	Irvingiaceae	*sioko*, (C)	*sioko, mango*	spontanée	graine
Landolphia sp	Apocynaceae	*malombo* (C)	*malombo*	spontanée	fruit
Lippia adoensis Hochst	Verbenaceae	*bulukutu* (C)	*bulukutu*	spontanée	feuille sèche
Luffa cylindrica M. Roem	Cucurbitaceae	*liniuka* (CK), nsania (C)	*éponge végétale*	cultivée	fruit sec
Mangifera indica L.	Anacardiaceae	*mangolo* (CK)	*mangue*	cultivée	fruit
Manihot utilissima Pohl	Euphorbiaceae	*saka saka* (CB), pondu (CK)	*saka-saka*	mixte	feuille
Mondia whitei Skells	Periplocaceae	*mundjodjo* (CB)	*mundjondjo*	spontanée	racine
Monodora miristica L.	Annonaceae	*pèpè* (C)	*pepe*	spontanée	graine
Monodora tenuifolia Benth	Annonaceae	*pèpè* (C)	*pepe*	spontanée	graine
Musa sp	Musaceae	banane	*banane*	cultivée	fruit
Ocimum gratissimum (L.) Forsk	Labiaceae	*mantsusu* (CB), *lumbalumba* (CK)	*lumbalumba*	cultivée	feuille
Persea americana L.	Lauraceae	avocat (C, CA, G, CK, CB)	*avocat*	cultivée	fruit
Ricinodendron heudelotii (Baill) Pax	Euphorbiaceae	*djansan* (C), *dansan* (C)	*djansan*	spontanée	graine
Solanum nigrum L.	Solanaceae	*bilolo* (CK)	*bilolo*	cultivée	feuille
Saccharum officinarum L.	Poaceae	*koko* (CK, CB), Canne à sucre (C, G)	*fumbua*	cultivée	tige
Spondias cytherea Sonn.	Anacardiaceae	pomme cythère	*pomme cythère*	cultivée	fruit
Tetrapleura tetraptera Tauba	Mimosaceae	*caroube* (C)	*caroube*	spontanée	feuille
Vernonia sp	Asteraceae	*ndolé* (C)	*ndolé*	cultivée	tubercule
Xanthosoma sagittifolia Schott	Araceae	*macabo* (C), taro (CK, CB)	*macabo*	cultivée	graine
Xylopia aethiopica A. Rich	Annonaceae	*ekolababa* (C)	*ekolababa*	spontanée	fruit (gousse)

C: Cameroun; CA: Centrafrique; CK: Congo Kinshasa; CB: Congo Brazzaville; G: Gabon.

Other economic benefits

Forestry is a significant employer in many rural regions. The formal forest sector in Africa employed 550 000 people in 2000 (FAO 2007). Even though there is scarcity of data on employment in the informal sector, employment in this sector is believed to outweigh that in the formal sector.

Ecotourism is an important industry in some African countries, and is growing rapidly (Le Courrier 2002; Meduna et al 2009). In the Southern African region, Scholes and Biggs (2004) estimated that nature-based tourism provides over 3.6 billion US$ income to national economies, although 2.3 billion US$ of this is in South Africa alone. Although the direct impact of tourism on Gross Domestic Product in Sub-Saharan Africa is only around 2.2%, including the broader indirect impact raises this figure to 6.7% (WTTC 2009).

Ecosystem services

Africa is rich in biodiversity, and is home to about 20% of all known plant species, mammals, and birds in the world, as well as one-sixth of amphibians and reptiles (Siegfried 1989, cited by Desanker 2003; WWF 2006). In particular, the tropical forests in sub-Saharan Africa are noted as centres of unique biodiversity (Cordeiro et al 2007). Three African nations are among the world's 17 countries with 'mega-biodiversity', and four forested areas are recognized as biodiversity hotspots: the Guinean Forest, the Eastern Arc Mountain Forests, Madagascar and the Mediterranean Basin Forests (Fazey et al 2005, based on data from Conservation International 2000). The Congo Basin is the second-largest continuous expanse of tropical rainforest in the world, and accounts for more than 60% of Africa's biodiversity, and Central African forests contain the most intact forest ecosystems left anywhere in Africa. The rainforests of central Africa are significant both for the total number of species found there and for endemic species. Unique to this region, intact forest communities of large mammals are found such as gorillas, bonobos, bongos, mandrills, and forest elephants. Regional centers of biodiversity and endemism include the Cameroon highlands, the western equatorial forests of Cameroon and Gabon, coastal mangroves, the Albertine Rift highlands, and the eastern lowland forests of the Democratic Republic of Congo.

Forests are essential to fresh water management as they are often significant components of the vegetation cover in the upper watersheds of major rivers (Chikamai and Tchatat 2005). Because of high infiltration rates and protective ground cover, they are important in reducing storm flows while improving re-charge of under-ground aquifers as well as reducing the load of nutrients and pollutants entering water bodies. Rapidly expanding poulations are placing additional pressures on water supplies. In Africa the availability of water per person decreased by 2.8 times between 1970 and1995 (Shiklomanov 1998).

Forests also play an important role as a sink for carbon dioxide through the assimilation of carbon during photosynthesis and hence can be used to mitigate global warming if proper mechanisms are put in place. The African old-growth forest sink has been estimated at 0.34 PgC/a (Lewis et al 2009). The rainforest of the Democratic Republic of Congo (DRC) alone is estimated to have about 23.7 Gt carbon (equivalent to 47.4 Gt of biomass) (Baccini et al 2008). The miombo woodlands have great potential to either add to the growing carbon dioxide content of the atmosphere, or help reduce it. In the event that substantial areas of miombo are cleared for cereal crop agriculture, 6–10Pg of carbon could be released, or if the woodlands were managed to maximise carbon storage, a similar amount could be taken up (Scholes 1996). In both cases, about half of the change in carbon stocks occurs in the soil, and the rest in the biomass.

Forests are thus critical for agriculture and food production. They supply timber, wood for energy, construction materials and NTFPs, including food and medicines. Other services include provision of shade, habitat functions, and grazing, cultural and aesthetic values. Forests in the region have sizeable carbon stocks and thus play an important function in global carbon dynamics.

Social services

Besides the tangible benefits of forests discussed above, there are also a wide range of less physical (but still very important) aspects to consider that relate to cultural and aesthetic functions of forests. Barany et al (2001) point out the importance of non-timber forest benefits in the context of the struggle against AIDS, and stress that the forest sector has a vital role to play. Seppälä et al (2009a) discuss the ‘social’ value of old trees, which are often important meeting places in rural areas.

Ghana contains around 2000 sacred groves, ranging in size from single trees to several hundred hectares (Decher 1997). Groves are protected by taboo against fire as well as from exploitation, although sustainable use (including timber harvesting) is permitted. In much of Africa trees are consider to have religious and mystical functions. Tchouamo (1998) and many others (i.e. Decher 1997) have confirmed through research that without such beliefs many tree species would have disappeared from overpopulated or ecologically fragile zones. A comparison of two forest protected areas in Cameroon (Meleta State Forest Reserve) and a sacred forest (Mbing Mekoup) showed that today villagers have fully occupied the state forests but the sacred forest has been fully conserved (Tchouamo 1998). The reasons here are based on historical beliefs which link the latter to refuges of ancestral spirits or places for sacrifices, and strategically as refuges for warriors. The sacred forests have important cultural dimensions as they are reserved only for the initiated of the community for prayers and benediction from the Gods. As tradition demands that each village in the Bamiléké land has a sacred forest their protection is assured collectively or individually and is the pride of every village or quarter. Although in many cases these tribal attitudes are fading (Decher 1997), reinforcement of local community responsibility for forest protection will increase the likelihood of successful forest management.

2. Past and future impacts and vulnerabilities

Climate changes

In the tropics, the primary driver of the general circulation is tropospheric heating, which is achieved mainly through condensation of water vapour in deep convective clouds. North of roughly 9°N the climate is marked by a single wet season peaking in August, and one dry season extending from November to March. Nearer to the equator there are two wet seasons, one peaking in March–April and the other in October–November, separated by two drier seasons; the short dry season in December and a longer from June to September. The southern hemisphere shows a similar pattern to the north, but reversed. Morishima and Akasaka (2010) Studied climate trends over Africa from 1979 to 2007, and found trends or step-changes that varied both geographically and seasonally.

Africa is a continent characterized by a highly variable climate. Some key limitations to knowledge regarding future African climate have been identified by Hulme et al (2001), as the mostly poor representation of the climate variability of El Niño in the global climate models, and the absence in these models of any representation of regional changes in land cover and dust and biomass aerosol loadings. However, climate change models suggest that, in general terms, the climate in Africa will become more variable. Since 1900 mean surface temperature in Africa has increased by only 0.5º, yet by 2100 it could increase by 2–6ºC (Hulme et al 2001).

Future climate is dependant on a host of possible physical, social and economic factors. To address the influences of different possible economic futures, the IPCC (2007) developed a range of possible scenarios whereby the CO_2 content of the atmosphere differs according to various models of global development. Scenarios mentioned in this report are the A1B (low population growth, rapid economic growth, energy sources balanced between fossil and non-fossil sources) and B1 (low population growth, transition to information and services economy, clean technologies).

Temperature trends

Temperature has a very weak latitudinal gradient in the tropics, especially at the surface, and it is precipitation that shows the greatest variability (Brncic et al 2007). From several decades of research, there is now a reasonable scientific understanding of several parts of the African climate system, including southern Africa, the Sahel and to a lesser extent East Africa, although there is still an incomplete understanding of climatic changes in the Central African convective region. Hulme et al (2001) studied African climate patterns from 1900 to 1995, and found increases and decreases in both temperature and precipitation trends, depending on the geographic region (Figure 4). Unganai (1996) found an average daytime temperature rise of 0.8°C in the sixty years prior to 1993, and a fall in precipitation of 10% from 1900.

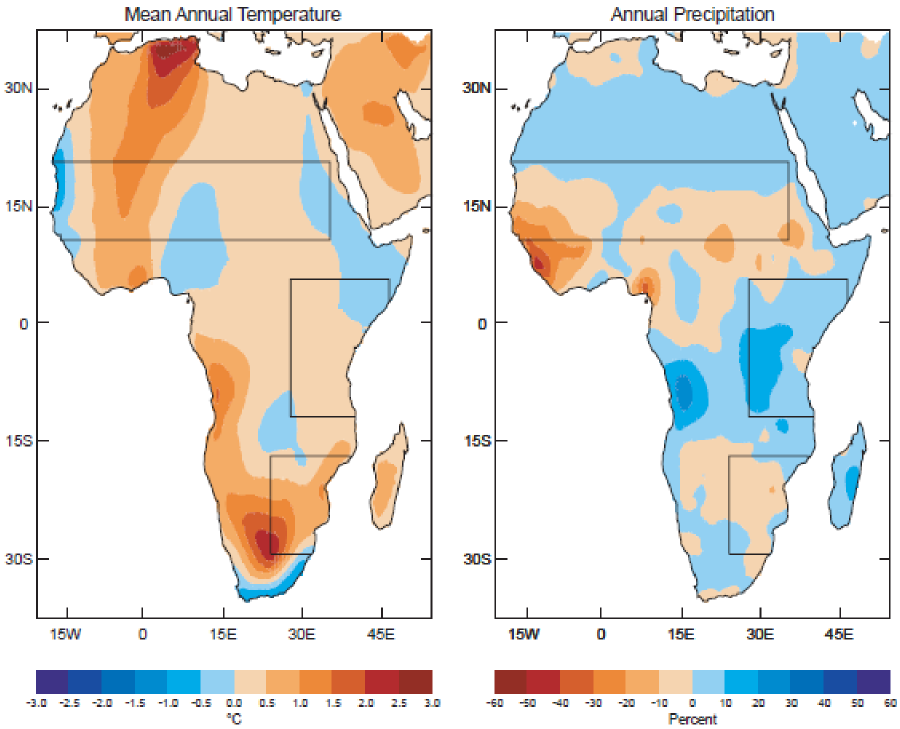


Figure 4. Main linear trends in annual temperature (°C century^{-1}) and annual rainfall (% century^{-1}), calculated over the period 1901–95 from the New et al. (1999, 2000) date set. Date were filtered with a 10-point Gaussian filter before being subject to regression analysis (Hulme et al 2001).

It has been observed that mean annual temperatures in Africa have been rising steadily, and an increase of about 0.5°C was recorded during the 20th century (Hulme et al 2001). Climate models project a median temperature increase of between 3°C and 4°C across the entire continent by the end of this century (Christensen et al 2007). These increases are about 1.5 times the global mean response. The IPCC expects warming to be greater in Africa than the global average, with warming being greatest in the drier, sub-tropical regions (Figure 5). The interior of semi-arid margins of the Sahara and central southern Africa are expected to be the warmest. Global temperatures have increased by over 0.5°C since the nineteenth century, but a relatively higher rate of warming of approximately 0.7°C has been observed during the present century in southern African countries (Desanker et al 2001). Observational records show that this warming occurred at the rate of about 0.05°C per decade with slightly greater warming in the June–November seasons than in December–May (Hulme et al 2001). Maximum temperatures in Libya however showed a downward trend from 1951 to 1999, although minimums increased (El-Kenawy et al 2009), and Christy et al (2009) simialarly found no significant trend in maximum temperatures in Eastern Africa, but a rise in minimums. Kruger and Shongwe (2004) show that most high-value meterological stations in South Africa display warming trends in both maximum and minimum temperatures. These variations show that generalisations at the continental scale must be made with caution.

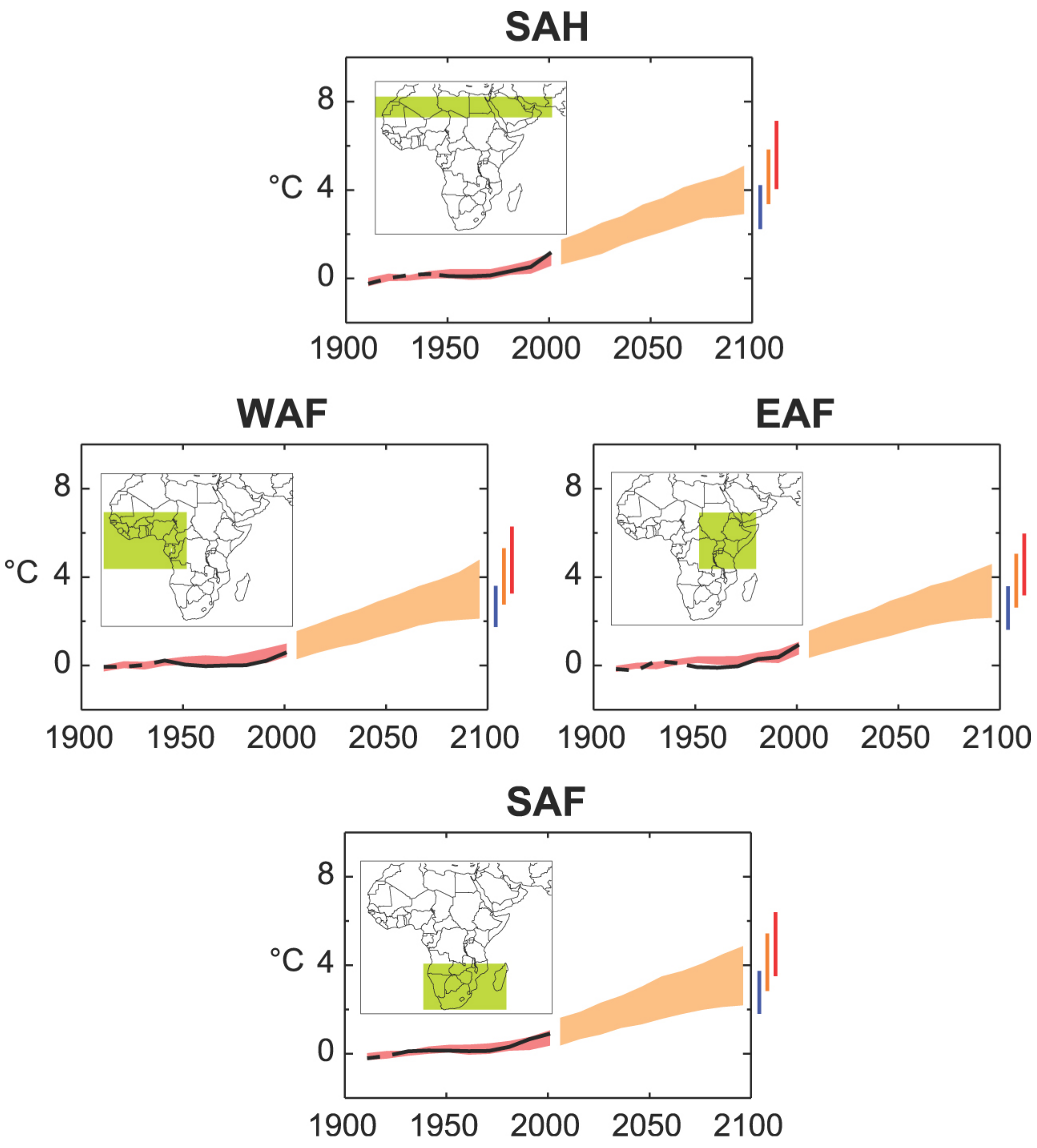


Figure 5. Temperature anomalies with respect to 1901 to 1950 for four African land regions for 1906 to 2005 (black line) and as simulated (red envelope) by MMD models incorporating known forcings; and as projected for 2001 to 2100 by MMD models for the A1B scenario (orange envelope). The bars at the end of the orange envelope represent the range of projected changes for 2091 to 2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). The black line is dashed where observations are present for less than 50% of the area in the decade concerned. Subregions: West Africa (WAF), East Africa (EAF), South Africa (SAF), Saharan Africa (SAH). Climate Change 2007: The Physical Science Basis. Working Group I contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure 11.1. P. 868. Cambridge University Press, Cambridge, UK (Christensen et al 2007).

Preciptitation trends

Rainfall in much of Africa is highly variable from year-to-year and floods and droughts have always occurred from time-to-time. Some of the observed extreme climatic events that occurred in the region include recurrent flooding in some countries in southern and west Africa; even communities located in dry areas have been affected by floods. The years 2000 and 2001 witnessed a huge flooding event in Mozambique, particularly along the Limpopo, Save and Zambezi valleys. In 2000, floods resulted in half a million people made homeless and 700 losing their lives. The floods had a devastating effect on livelihoods, destroying agricultural crops, disrupting electricity supplies and demolishing basic infrastructure such as roads, homes and bridges (Christie and Hanlon 2001). The last twenty years, however, have seen a trend towards reduced rainfall in many southern African countries and, during the early 1990s a number of serious droughts occurred (Funk et al 2008). Droughts in the region are often synonymous with famines. The 1980s witnessed very severe famines associated with the famous drought of 1984–85 that hit sub-Saharan Africa, causing many casualties, and much hardship. In South Africa, natural disasters, including droughts, are predicted to occur more frequently under changed climatic conditions (Dynacon and Wiechers Environmental Consultancy 2000). These repeated drought cycles are reducing the ability of the society to cope with droughts by providing less recovery and preparation time between events (Adger and Brook 2002).

Fauchereau et al (2003) studied precipitation changes in southern Africa and found no trend towards wetter or drier conditions, but a marked increase in rainfall variability. Giannini et al (2008) identified two mechanisms liable to influence changes in African rainfall of the recent past and future; moisture supply mechanism and a stabilization mechanism, and indicated that competition between them in a warming world may explain the uncertainties in projections of African rainfall into the next century.

Rainfall is projected to decrease in western and winter rainfall areas of southern Africa, but to increase in the east (Figure 6). Projections for the Sahel and the Guinea coast are uncertain, as the global climate models are unreliable in this region. Decreased rainfall is projected throughout southern Africa, however increases are expected in eastern Africa while in West Africa decreased rainfall is expected (Eriksen et al 2007). Reduced streamflows and groundwater limitations are already being noticed in parts of Ghana (Gyampoh et al 2008). Run off reductions of 43.7% and 44.1% have been recorded for the River Pra and the River Tano respectively over a 20 year period (Gyau-Boakye and Tumbulto 2006), although the authors attribute this to a combination of climatic and land use issues and increased groundwater extraction.

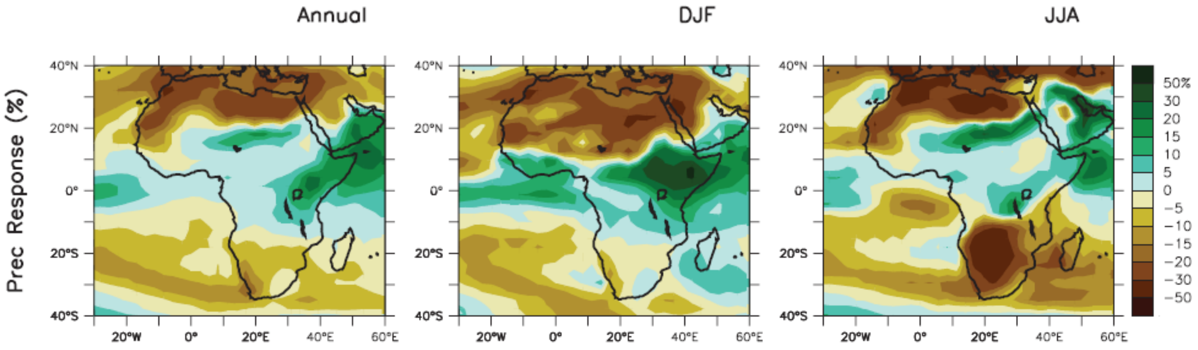


Figure 6. Precipitation changes over Africa from the MMD-A1B simulations. Annual mean, DJF and JJA precipitation change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Climate Change 2007: The Physical Science Basis. Working Group I contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, University Press, Cambridge, UK (Christensen et al 2007).

Drought

Two thirds of Africa is desert or drylands, and desertification has its greatest impact in this continent (Figure 7). Desertification in southern Africa is strongly linked to poverty, since poor people have little choice but to over-exploit the land. Extensive agriculture in the drylands of southern Africa and the heavy dependence of rural people on natural resources for subsistence has largely contributed to land degradation and desertification. This situation may be further aggravated by the impacts of climatic variations, e.g. a decrease in precipitation and increasing temperature.

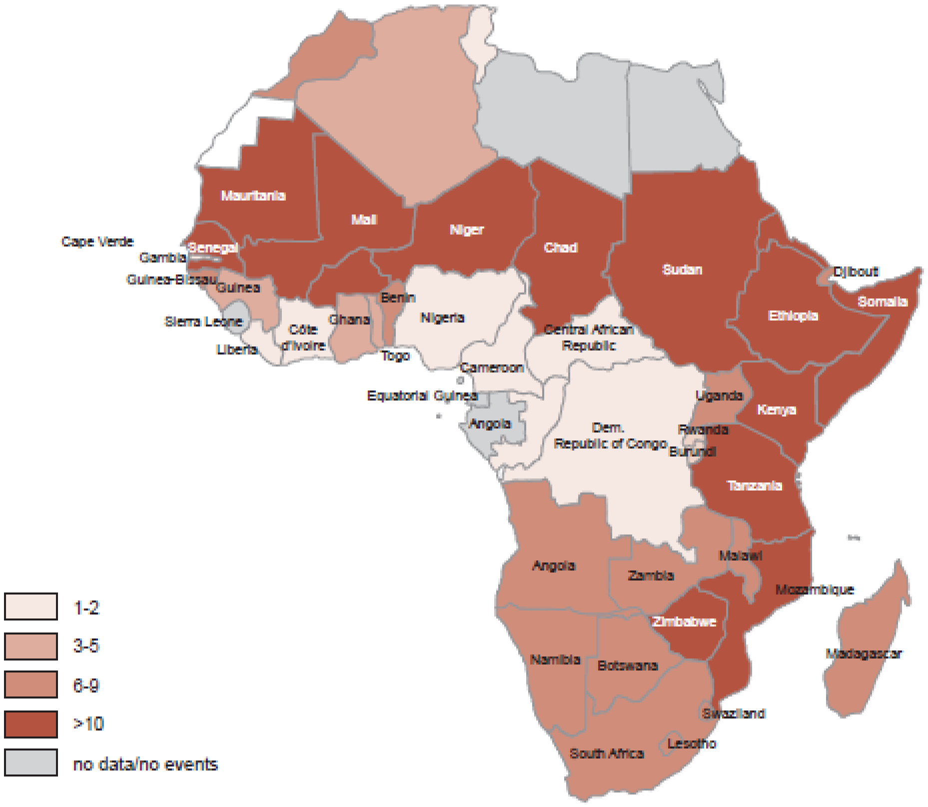


Figure 7. Drought events in Africa 1970 – 2004 (UNECA 2008).

Global Circulation Models predict a 15 to 62% decrease in rainfall over southern Africa in the next 50 years (Hulme et al 2001). However some studies have indicated that these general trends may include hidden variations within the regions and countries, e.g. southern Africa may be drier in general terms, but some countries of the region may become wetter than the average (Hulme et al 2001).

According to Nicholson (2001) the major climatic change that has occurred in Africa in recent times has been a protracted decline in rainfall in the semi-arid regions of West Africa. In parts of the Sahel the reduction was as much as 20 to 40%, although Prince et al (1998) suggest that rainfall use efficiency in the Sahel is actually increasing. There are suggestions that wet-season reliability in Cameroon is decreasing (Peach-Brown 2009), but this does not yet appear to have been formally demonstrated. Parts of Ethiopia that already had insecure water supplies have faced a declining trend since 1997 (Funk et al 2005).

The Sahel represents the southern edge of the Sahara desert, extending at least 4500km from Cape Verde through Senegal, Mauritania, Mali, Burkina Faso, Niger and Chad. The region is characterised by strong climatic variations and an irregular rainfall that ranges between 200mm to 600mm with coefficiency variation ranging from 15 to 30% (Fox and Rockstrom 2003). The Sahel is highly vulnerable to climate change due to its geographic location and the strong dependence of its population on rainfed agriculture. Rainfall variability, land degradation and diversification are some of the factors that make life particularly difficult for the rural communities in this region.

Some models of future climate change suggest precipitation changes that may ultimately lead to a more humid regime in the Sahel and parts of the Sahara (Brooks 2004). This suggestion is based on observations since the late 1990s of an amelioration of the regional climate, and abundant rainfall throughout much of the Sahel and in parts of the Sahara in 2003. Similar results are obtained by Claussen et al (2003), who reported a potential increase of vegetation cover of up to 10% of the Saharan area per decade as a result of increased CO_2 concentrations. Increased CO_2 concentrations trigger increased rainfall which is then sustained through vegetation-atmosphere feedbacks. Maynard et al (2002) also suggested a wetter regime in the Sahel in the future. Liu et al (2002) examined the impact of a one percent increase in atmospheric CO_2 per year for 80 years, using models that produce realistic climatological representations of the present-day Sahara, and found that the Sahara shifts northwards in a number of models. However, slight increases of rainfall are unlikely to reverse the situation since hotter climate means that evapotranspiration will be more intensely exacerbating the already arid conditions.

Modelling and climate projections

Climate projections for Africa are inhibited by a lack of reliable data for much of the continent (IRI 2006b; Osman-Elasha et al 2006b) and an incomplete understanding of the mechanisms that control climate. This lack of knowledge may severely hamper adaptation planning (Amwata et al 2008). The African climate observing system is in a worse state than that of any other populated continent and is deteriorating (Washington et al 2004). Compared to many parts of the world the scientific understanding of the African climate system as a whole is poor, particularly in areas such as the Congo Basin. Some few meteorological centers in Africa are however making efforts to provide information on climate forecast.

Many impact assessment reports and adaptation studies conducted for southern Africa, such as those for the purpose of national communications to the United Nations Framework Convention on Climate Change (UNFCCC), represent so-called ‘first generation’ studies. These provide results that show how different sectors, systems and communities might be impacted by climate change. In these studies, southern African countries depended on generated climate scenarios based on inputs from general circulation models (GCMs), which are generally designed in developed countries. Global GCMs provide coarse climate prediction with low resolution and a very broad scale (300 km^2). The task of developing reliable predictions of future climate change in southern Africa is difficult because of the complexity of the African climate coupled with the lack of accurate baseline data on current climate (needed to feed into models of future climate) (DFID 2004a). While global climate models simulate changes to southern African climate resulting from increased greenhouse gas concentrations, two potentially important drivers of southern African climate variability, namely the El Niño/Southern Oscillation and land cover changes are not well represented in the models (Hulme et al 2001).

GCM-based climate change scenarios are generally consistent in predicting temperature rise across southern Africa, but show considerable uncertainty about both the magnitude and direction of changes in precipitation (IRI 2006). Appropriate use of a range of such scenarios combined with analysis of trends in historic data can contribute to the understanding of future trends and uncertainties that are crucial for long-term planning horizons. The results of these studies suggests that these scenarios could provide important information which can give a good indication of future climate change and that the use of Global Climate Change models could provide for long-term climate risk assessments at a general level (DFID 2004b).

Ghana model projections

In Ghana, which lies south of the Sahel region in the humid forest zone, climate change scenarios constructed for two major forest zones (the semi-deciduous forest and evergreen rainforest) indicated that the projected mean annual rainfall values in the semi-deciduous forest zone will decline by 2.8%, 10.9% and 18.6% in years 2020, 2050 and 2080, respectively. Over the same period, it is projected that the evergreen rainforest forest zone will experience reductions in mean annual rainfall values by 3.1%, 12.1% and 20.2% respectively (EPA 2008). Increases in mean annual temperature of up to 5.4°C and 3.9°C have been projected for the semi- –deciduous and evergreen rainforest zones in Ghana by 2080 (EPA 2008). These forest areas represent the most economic and diverse of all the forest types in Ghana. They are the centres of major timber and non-timber forest resources, and contain valuable genetic materials. Model projections indicate that the average minimum temperature is projected to increase by 2.5°C in the Sudan Savannah, Guinea Savannah and the semi-deciduous Rainforest zones by the year 2100.

For the transition High Forest Zones, the minimum temperature is projected to increase by 3°C and 2°C, respectively, by the year 2100. Projections on rainfall suggest that by the year 2100 the mean annual rainfall would be reduced by 170 mm in the Sudan Savanna Zone, 74 mm in the Guinea Savanna

Zone and 99 mm in the Semi-Deciduous Forest Zone, respectively (EPA 2000). Nicholson (2001) discusses the changing climate conditions in Africa over the past two centuries and records a drying trend in semi-arid areas of West Africa, although she also notes that extended dry periods are not unusual in these areas. In contrast to these expected declines, the High Forest Zone was projected to increase in mean annual rainfall by 1105 mm within the same period (EPA 2000), but later modelling presented by Agyemang-Bonsu (2009) shows rising temperatures and falling precipitation expected for all Ghanaian ecozones (Figures 8, 9).

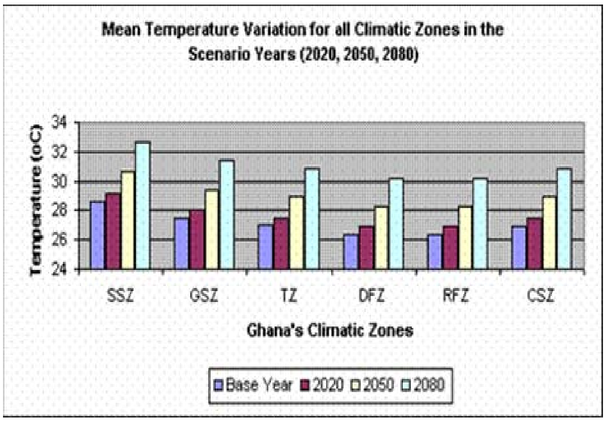


Figure 8. Temperature scenarios for Climatic zones in Ghana (Agyemang-Bonsu (2009).

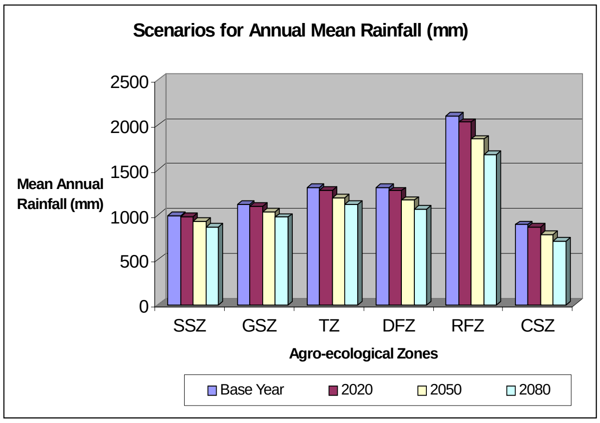


Figure 9. Precipitation scenarios for Ghana (Agyemang-Bonsu (2009).

Impact projections

Climate change impacts for the continent are generally based on predictions from global circulation models. However, these model outputs are often considered limited in their predictions due to the coarse resolution of GCMs. Often, downscaled climate models at finer spatial and temporal resolutions are desired. Nevertheless, outputs from the existing models remain useful, and offer valuable information for managing climate change impacts. Regional climate models are needed to provide fine-scale climate information for impact studies, particularly in areas characterized by a diverse and heterogeneous land surface. Compared to many parts of the world, scientific understanding of the African climate system as a whole is low, and variations in capacity exist among different African regions (Washington et al 2004).

Some efforts are being undertaken, and Regional Circulation Models (RCMs) with a higher resolution (typically 50 km^2) are currently being developed for smaller areas and for shorter time scales (approximately 20 years). These regional models are capable of providing more useful information needed by planners and policy makers. The UK Department for Environment, Food and Rural Affairs (DEFRA) funds the development of the Hadley Centre's Regional Climate Model and the UK Department for International Development (DFID) has supported the development of the PC version of the Hadley Centre's model 'PRECIS' designed for use by local meteorological offices or research institutes. To-date, it has been run for the Indian subcontinent and southern Africa (DFID 2004b).

Delire et al (2008) use the IBIS model (Foley et al 1996) to simulate vegetation cover in Central and West Africa to 2080 with HADCRUT under the IPCC's A1F1 and ECH with the B2 scenario, and find a general reduction over the region (Table 12, Figure 10), with the exception of a slight increase around Lake Chad under the ECHB2 scenario. Wildfire frequency is projected to increase. It must be noted however that due to a lack of data Delire et al (2008) held CO_2 levels constant at 350 ppm in their simulation, and thus ignore any possible CO_2 effects (see Jolly and Haxeltine 1997).

Table12: Area covered by vegetation, average NPP (net primary productivity) and LAI (leaf area index) of vegetation types as simulated by IBIS forced with present-day CRU TS2.1 dataset (control and the ECHB2 and HADA1F climate anomalies for the 2080s (after Delire et al 2008).

Vegetations types	Area			NNP			Total LAI		
	Km²			(kg C m^{-2} yr^{-1}					
	Control	ECH B2	HADA 1F	Control	ECH B2	HADA 1F	Control	ECH B2	HADA 1F
Tropical evergreen forest/woodland	2,12	1,86	1,34	1,06	0,96	0,88	7,85	7,08	6,52
Tropical deciduous forest/woodland	0,96	0,91	0,65	0,91	0,76	0,69	6,7	5,62	5,07
Savanna	1,02	1,26	0,97	0,66	0,65	0,62	5,03	5,33	5,25
Grassland/steppe	1,49	1,81	2,27	0,3	0,32	0,33	2,06	2,26	2,61
Open shrubland	0,42	0,28	0,59	0,06	0,06	0,06	0,76	0,77	0,68
Desert	0,10	0,02	0,32	0,02	0,02	0,01	0,28	037	0,27

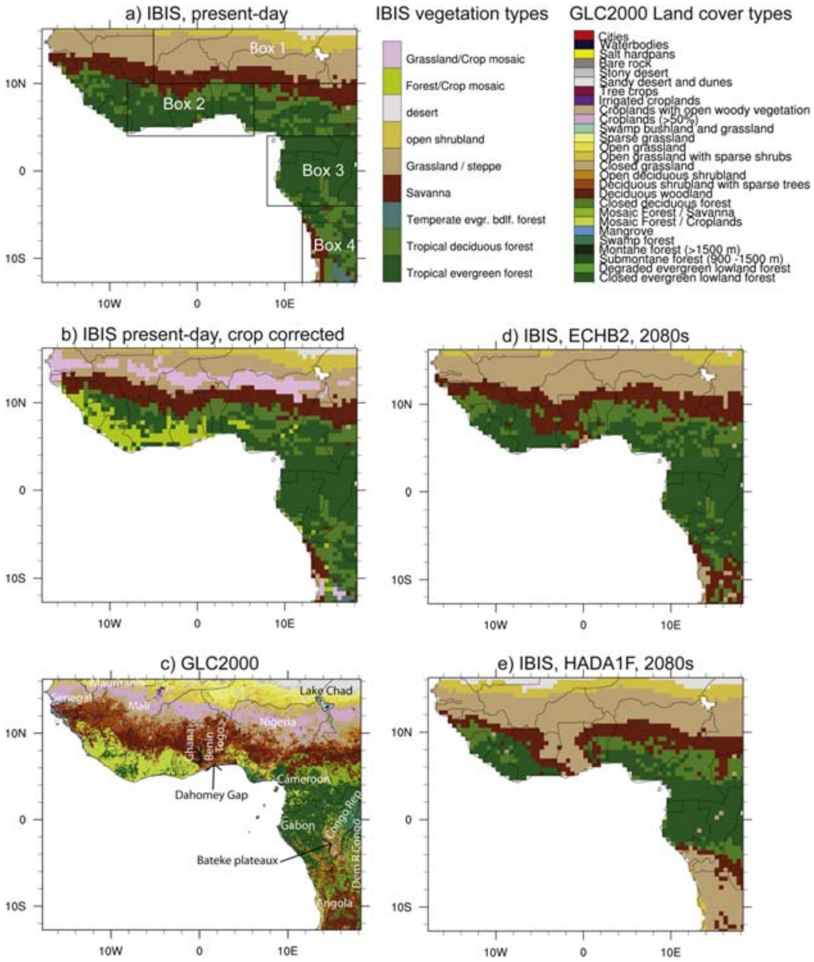


Figure 10. Simulated and observed distribution of vegetation/land cover types a) simulated by IBIS forced with the present-day CRU TS2.1 climate, b) same as a) but corrected by Ramankutty and Foley (1998) cropland dataset c) derived from satellite observations (Global Land Cover 2000–GLC200, Mayaux et al., 2003), d) simulated by IBIS forced with the ECHB2 anomalies for the end of the 21st century, e) simulated by IBIS forced with the HADA1F anomalies for the end of the 21st century. 4 c) (Delire et al 2008)

Climate models often poorly represent some aspects of African climatology: notably the movement of the inter-tropical convergence zone (Hudson and Jones 2002; Wu et al 2003; Richter and Xie 2008) and the historic changes in Sahelian rainfall (Lau et al 2006), and thus regional projections must be taken with caution. Hulme et al (2001) produced climate projections for the African continent for the 21st century at a scale of 5°, but intermodel variability was often wide in many areas. Other downscaling efforts include Hewitson and Crane's (2006) study of precipitation in South Africa and Jones and Thornton's (2000) gridded daily weather software (MARKSIM). Wilby (2007) asserts that Africa's climate science is in its infancy and remains the least developed on the globe, and Giannini et al (2008) concluded that, at this stage, "a detailed downscaled analysis [of African climate] is premature". Nevertheless, these regional climate models are urgently needed to facilitate adaptation planning (Osman-Elasha et al 2006b). According to Ziervogel and Zermoglio (2009) very few regional to sub-regional climate change scenarios based on regional climate models are available for Africa. They argued that the much needed regional climate models and downscaled GCMs are inadequate in Africa, although there are a number of organizations on the continent engaged in climate work.

Differing climate projections and model uncertainties present serious challenges to determining potential changes to the niches of species that are only adapted to particular forest ecosystems. Even though projections on the likely shifts in species distribution and changes in productivity are not available, the implications can be disconcerting. It is known that some key tree species (both timber and non-timber) are endemic to limited forest areas and survive only under those conditions.

Forest responses to climatic and anthropogenic influences

Homo sapiens sapiens is thought to have evolved in Africa, and so the separation between 'natural' and 'man-made' influences is perhaps somewhat moot. This section will briefly examine the formative influences on African forests, and as far as is possible separate those effects that may be attributed to climatic changes over the past century. As found in many other parts of the world, it is often difficult to separate climatic influences on forests from the results of prior anthropogenic influences (Although see Seaquist et al [2009] for a study of human/climate influences in recent vegetation changes in the Sahel). Although structurally many central African rainforests appear pristine, studies have shown that some forests overlie extensive evidence of prehistoric clearance in the form of pottery, charcoal and palm nut layers, or even iron furnaces (White and Oates 1999). Brncic et al (2007) studied historical influences (climatic and cultural) on the composition of Congo rainforest, and found that although Central Equatorial African forests have been resistant to climatic and disturbance events, forest compositions have changed significantly over the past 3300 years in response to climate influences and fire regimes. Close examination of the regeneration requirements of mature trees in such areas reveals that many species are likely to have only regenerated following large-scale disturbance (van Gemerden et al 2003). The composition of modern day forests still often reflects past human activities. Justice et al (2001) make the point that "*one of the most studied 'climax forest' trees in tropical Africa turns out to be a fallow field and savanna colonizer*" and highlight "*the important role that human land-use has and continues to play in shaping the structure and composition of the forest in the region* ".

Palaeographic

African biomes have undergone significant changes over the past 20 000 years, in response to changes in temperature, precipitation, humidity or atmospheric CO_2 content (Olago 2001). The majority of the area presently under forest within the Congo Basin is of relatively recent origin (Maley 1996). During the last global ice age (~20 000–15 000 BP), rainfall declined throughout the region and forests were restricted to remnant patches that constituted refuges for obligate forest species. Only after the ice began to recede (8000 BP) did rainfall increase in the Basin and forest once again invade the savannas and re-dominate the landscape. Prior to and since this time, human foragers have hunted forest wildlife, gathered non-timber forest products, and occasionally felled trees to gather honey. Precise palaeoclimatic records are often lacking in the African tropics but work on palaeolimnology (Street-Perrott et al 2007), pollen profiles (Vincens et al 1999; Scott et al 2008) and carbon isotopes (Gebrekirtos et al 2009) may go some way towards rectifying this lack.

Evidence from high-resolution pollen records from rainforests of Atlantic Equatorial Africa demonstrate fluctuations between mature and secondary forest taxa during the last 4000 years that may have been caused by changes in precipitation. For example, a sedimentary sequence covering the last 1325 years from Lake Kamale´te´ in central Gabon shows an increase in the percentage of some pioneer species and a decrease in mature forest species from approximately 1240 to 450 BP, hypothesized to be related to a decrease in the regional balance of available moisture (Ngomanda et al 2005). At a site in southwestern Cameroon, pollen evidence from a sedimentary sequence at Lake Ossa indicates that the basin contained closed forest from 4770 to 2700 BP, when pioneer tree species increased in abundance. At approximately 1300 BP and after 600 BP mature forest species increased again, though not to the same percentages as prior to 2700 BP. Near Lake Ossa at Barombi Mbo, situated in evergreen rainforest in southwest Cameroon, a similar trend of increasing percentages of pioneer species and a decrease in mature forest species after approximately 3000 BP is seen in the pollen record. Vegetation of Barombi Mbo may have opened up as a response to the same decrease in precipitation reconstructed for Lake Ossa at that time. It is currently unknown however, whether Central Equatorial Africa experienced similar climatic conditions as those in Atlantic Equatorial Africa, or if the lowland Congo basin forest composition responded to climate change with changes in forest composition (Brncic et al 2007). Pietsch et al (2009) have found evidence of rainforest refugia in the Birougou Mountains of Gabon that were persistent throughout the Holocene.

Kröpelin et al (2008) discuss Holocene biome changes in the Sahara, suggesting that changes from tropical forest to dry savannah to desert over the past 6000 years occurred gradually in response to a long-term decline in rainfall, rather than as an abrupt biome change. Other prior modelling (Claussen et al 1999; Liu et al 2007) supported the abrupt change theory, which leads Kröpelin et al (2008) to suggest that the biophysical feedbacks on Saharan climate are relatively weak.

In Central Equatorial Africa, the patterns of prehistoric human activity are difficult to discern due to a small number of research sites, particularly in forested areas. However, from regional archaeological studies, a relative chronology of the technological and political changes that have impacted the region can be constructed. Metallurgy in particular may have been an important driver of forest change. Archaeological data suggests that iron smelting was developed independently in Central Africa as early as 3000–4000 years ago (Maes-Diop 2004). Farmers first began cultivating fields within the forest approximately 10 000 BP and Casey (2005) suggests that oil palms were cultivated in forest areas around 3000 BP, but until the advent of iron tools (2000–700 BP) farmers' ability to clear the forest was limited. Forest farming was a marginal subsistence practice until plantains and bananas (*Musa* spp.) were introduced from Asia.

Bahuchet (1990, cited in Justice et al [2001]) places this around 1000–2000 BP, but Mbida et al (2000) found evidence for banana cultivation and husbandry of goats and/or sheep in the rainforest area of Cameroon around 800 BC, and some evidence from Uganda suggests that bananas may have been present far earlier (Lejju et al 2006). In any case, plantain cultivation spread from the Red Sea to the coast of what is now Ghana. By the 16th or 17th century, agriculture had received a further boost with the introduction of numerous crops from the Americas –maize, beans, peanuts, peppers, okra, cassava, avocado, papaya, squash, cocoyams, *Colocasia esculenta*, water yams *Dioscorea alata*, mango, coconuts and citrus from Asia and breadfruit from Oceania. Iron tools and a range of new crops adapted for cultivation in forests allowed the scale of farmers' impact on the forests to significantly increase (Justice et al 2001).

Carbonized oil palm kernels and the remains of iron furnaces are found throughout the Congo Basin, which points to the long-term occupation of the forest by farmers. Archaeological evidence (Oslisly 1998; White and Oates 1999; Justice et al 2001) coupled with the age of trees that are currently being selectively harvested for timber suggests that the mahogany forests (*Entandrophragma*, *Khaya* and *Guarea* spp.) of southwestern Nigeria, southeastern Cameroon, southwestern Central African Republic, and northern Congo can be traced back to a period about 700–800 ago, when farming became less common in the area, leaving extensive areas of secondary forest and farmland to regenerate. The population of farmers in Gabon also appears to have peaked between 2500 and 1400 years ago (Oslisly 1995 cited in Justice et al 2001), and to have collapsed by 600 years ago.

Historic

Pre-colonial management of natural resources was generally the responsibility of traditional leaders, a practice that worked well in times of low population and limited demand (Kigenyi et al 2002). Colonisation introduced resource control centralisation, although with some differences depending on the colonists in question (Dixon et al 1996). Colonisation accelerated land clearing for agricultural commodities in many forest areas, and afro-montane forests in particular were extensively cleared. Road construction in the 1930s–40s by the colonial governments began to enable access to tracts of forests isolated from navigable rivers, attracting resettlement of people along road lines. This had, and continues to have, a profound impact on the spatial pattern of forest resource use. Infrastructure development and the post World War II economic boom made the decades between the 1930s and the 1960s probably the most significant period of agricultural expansion and associated deforestation in the region in the 20th Century, as old-growth forest was cleared and converted to coffee, oil-palm, rubber, and banana plantations. Post-independence governments retained central control, and in many cases emphasised production values. Timber remains an important component of most national economies.

Until very recently, forest resource exploitation within the Congo Basin was primarily at the household scale, positively influencing forest species, composition, distribution and abundance. Current policy evolution emphasises local control, but this is often difficult to produce in practice. Indigenous peoples of the tropical rainforest belt are very dependent on the forest. Many of them are already today affected by the impacts of environmental change and are struggling to adapt. People who had once lived in a symbiotic relation with the forest in low population numbers (i.e. hunters-gatherers such as the Punan and Kenyah in Borneo and the Baka Pygmies and Bantu in the Congo Basin) see their life style changing. Formerly nomadic peoples are gradually adapting their lives to an agricultural economy and are becoming increasingly semi-sedentary with the creation of farmlands at the expense of the forest (Macchi et al 2008).

Recent

Africa can be seen to be showing the effects of climate change and variability. In parts of the West African sub-region, intense or frequent extreme climate events of droughts or floods, high temperatures and windstorms are apparent (Kalame et al 2008). Some species valuable for NTFPs in Burkina Faso (e.g. *Adansonia digitata*, *Diospyros mespiliformis* and *Anogeissus lelocarpous*) have become locally extinct, which is being attributed to recent recurrent droughts (Idinoba et al 2009).

While deforestation and climate change are separate issues, there are connections that must be considered in any discussion of either problem. Climate change increased pressure on forests, and a loss of forest cover increases atmospheric CO_2 and adds to the negative consequences of climate change. Semazzi and Song (2001) modelled the likely changes in climate that would be caused by deforestation of all African tropical forests, and found that significant rainfall reductions could be expected. African tropical forests are also under threat from population and land-use pressures (Hassan et al 2005). Achard et al (2002) used satellite imagery samples to suggest that humid tropical forests in Africa shrunk by 5 million hectares between 1990 and 1997. ‘Hot spot’ areas in Madagascar and the Ivory Coast showed losses of between 1.1% and 4.7% annually. Brink and Eva (2008) suggest that agricultural land in sub-Saharan Africa has expanded 57% since 1975, at the expense of a forest area decline of 16% and a 5% decline of other native vegetation. The forests and woodlands of southern Africa are currently under intense pressure from anthropogenic demand for land for agricultural production and expansion, firewood and charcoal as energy sources and timber as construction materials for the increased urbanization in the region. This has led to deforestation and degradation of forests in southern Africa.

Forest ecosystems in the West African region are experiencing impacts of climate change (Nicholson 2001; Boko et al 2007; IPCC 2007). These impacts include increased incidence and frequency of forest fires, increased tree mortality, reduced biodiversity and reduced tree stocking (Kalame et al 2009). Kalame et al (2009) discuss the difficulty of tree growth and regeneration, migration and extinction of forest species in some West African countries. The progressive decline of the valuable timber species Iroko (Milicia spp.) is attributed to a combination of factors including over exploitation, extensive damage by the gall forming pest *Phytolyma lata* and poor natural regeneration. Iroko is currently found in low altitude closed forests. Relics of Iroko are also found however at sites of fetish worship or former special cemeteries in Burkina Faso in the Sahel region, indicating that Iroko had a wider distribution than its present range

(Cobbinah et al 2000). Historic changes in precipitation may explain the contraction of Iroko distribution range. Gonzales (2001) notes a significant decline in tree density and tree species richness in the Sudanese, Guinean and Sahelian tree species over the latter half of the 20th century, equating to a biome shift of 500–600 metres per year. This has been linked to declining rainfall, although Seaquist et al (2009) note a greening trend in the Sahel since the 1980s, probably rainfall-driven with minor CO_2 influence. As in many forested environments the most noticeable effects of climate change are often indirect, through altered patterns in fire occurrence or of pest and disease incidence. In tropical Africa the most crucial climate issue for pathogen distribution is seasonal patterns of precipitation, and whilst published literature that directly relates precipitation to insect pest outbreaks is scanty there is strong anecdotal evidence that wet and dry seasons regulate insect population cycles. A comparison of pests and disease problems in plantations and natural forests in West Africa indicates that pests have a greater impact in plantations (Cobbinah et al 2004), and in many cases the trigger for pest population eruption is rainfall or lack of rainfall at a critical stage in the development of the host plant, the pest or its predators. In West Africa outbreaks of the oriental yellow scale insect (*Aonidiella oreantalis*) on neem in the Lake Chad Basin (Chad, Nigeria, Cameroon and Niger), the eucalypt defoliator (*Strepsicrates rhothia*), the variegated grasshopper (*Zonocerus variegatus*) and the tree borer (*Apate monachus*) are linked to periods of low rainfall or prolonged drought (Abdou 2004; Wagner et al 2008). On the other hand high populations of the obeche defoliator (*Anaphe venata*), the *Afrormosia* defoliator (*Lamprosema lateritialis*) and the skeletonizer of *Mansonia* (*Codasa sidae*) are recorded during good rainy seasons (Wagner et al 2008). Population buildup of this second group is somewhat dependant on the availability of abundant and high quality food resources which usually occurs during the wet season. Alteration of the synchrony between forest insect pests and their natural enemies induced by changes in rainfall patterns can also alter insect population patterns. Recent outbreaks of the caterpillar identified as *Achaea catocaloides* in Cameroon and Liberia may be due to a disruption of the balance between the insect and its key natural enemies brought about by low rainfall and changes in the rainfall pattern (Brahima 2009). Other indirect effects on forest biomes are also of concern. Rouget et al (2002) and van Wilgen et al (2001) studied invasive plants in South Africa and found that climate is one of the major determinants in whether particular species may become damaging.

Droughts influence trees and forest vegetation in that trees exhibit various adaptations to short-term water loss (i.e. an El Nino event). Trees may thus experience leaf shedding and a decrease in production of new leaves, leading to a loss of leaf area while lower leaf area facilitates drying of the leaf litter layer, increasing the rate of fire spread (Nepstad et al 2002). Continued water deficit can lead to increased tree mortality, creating gaps in the forest cover. This provides opportunities for light-demanding secondary species to colonize the forest under a short-term drought scenario, but severe drought may lead to an overall loss of forest cover.

Longer dry seasons combined with other disturbances to forest systems make forest ecosystems particularly vulnerable to major forest fires. Evidence of this can already be seen in the northern fringe of the Congo Basin in several recent years (Macchi et al 2008). During the El Niño years of 1983, 1987 and

1997, fires were particularly devastating in the forests surrounding the village of Mambele in southeast Cameroon and Bomassa in N. Congo. Fire has occurred in forest areas where it has not been observed in the past. These El Niño years cause droughts in the forest zone and fires occurred in forests that had not previously burned in the living memory of these peoples (FAO 2007). Although in some cases fires positively influence the establishment of pioneer tree species, repeated annual savannah fires can hinder the expansion of important timber species such as *Aucoumea klaineana* (King et al 1997; Born et al 2008).

The net annual loss of the African forest in the period between 2000 and 2005 has been reported as four million hectares, which was stated as accounting for 55% of the world's total loss in forest area during that period (FAO 2007). Hansen et al (2008) however calculated that Africa was responsible for only 5.4% of global humid forest loss in that period. It is possible that the FAO statement is exagerated, comparing African forest loss for the five year period with the estimated 7.3 million hectares (CBD 2006) of net annual forest loss throughout that time.

The main reason for forest losses have been wildfires which have been especially severe in Angola and in the southern Democratic Republic of Congo and in southern Sudan and the Central African Republic (Macchi et al 2008). Biomass burning is a significant contributing factor to the buildup of CO_2, other trace gasses and aerosols in the atmosphere, and African savannah fires account for around 22% of biomass burnt globally each year (Scholes and Andreae 2000). High demands for fuelwood are also contributing to deforestation (UNECA 2008).

Land use change is a significant contributor to greenhouse gas levels. Figure 11 shows the carbon emissions from a range of African countries. Land use change is responsible for 240 Tg of the 500Tg C produced annually in Africa from 2000 to 2005 (Canadell et al 2009); 90% of the Congo basin's carbon emissions are from deforestation and degradation (Nkem at al 2008b). Deforestation for crop production in Ghana may have reduced soil carbon in Ghana by as much as 33% (Tan et al 2009). The specific contribution of land use change is shown in Figure 12. The carbon cycling response of African ecosystems has been modeled by Cao et al (2001), who found the carbon sequestration in African forests of 0.34 GT per year is offset by the losses from land use change.

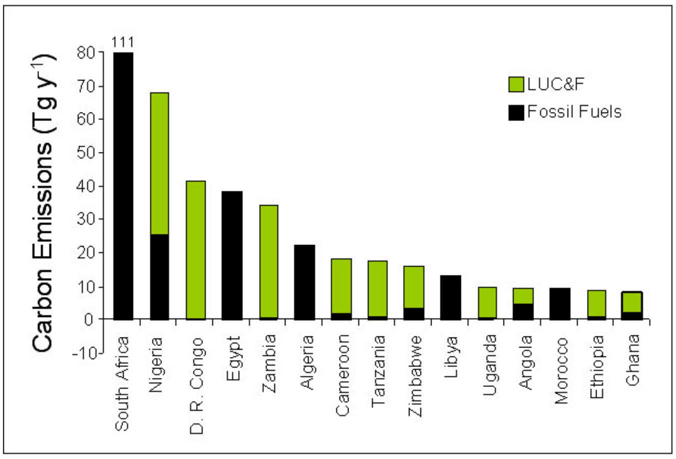


Figure 11. Annual emissions of carbon (Tg C y^{-1}) from the combustion of fossil fuels (FF) and land use change and forestry (LUC&F). Top fifteen African countries averaged for the period 2000-2005 (Canadell et al 2009).

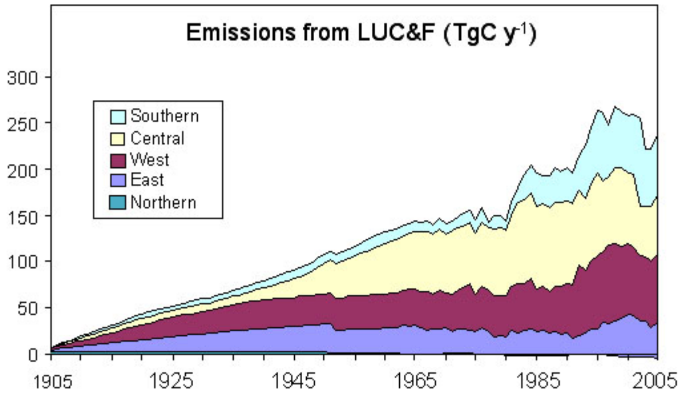


Figure 12. Annual emissions of carbon (Tg C y^{-1}) from changes in land-use change and forestry in four African regions during the period 1900-2005 (Canadell et al 2009).

Climate change and air pollution interact in affecting forests by changes in soil processes, for example, the natural ability of forest soils to take up CH_4 decreases due to N deposition (also affecting tree growth), species composition and distribution, increased plant susceptibility to stressors, increased fuel built-up and fire danger, water resources, recreation value, etc (Bytnerowicz et al 2006). Other factors beside climate which have considerably influenced forest in the Congo basin include the civil war in the DRC and the 50% devaluation of the Central African Franc in 1992. Continued global fluctuations in oil and commodity prices affect all developing countries and thus influence economic activities in the forestry sector and the potential for sustainable resource management.

Future forest environmental impacts and vulnerabilities

Generally benign biome changes are expected for much of sub-Saharan Africa under the IPCC ‘stable’ scenario, but some forest declines and type changes under the ‘growth’ scenario (Fischlin et al 2007, Figure 13). Increases in temperature (to some extent) and an increase in atmospheric CO_2 may accelerate photosynthesis and provide a fertilizing effect to many plants. This is a potentially positive impact of climate change, although the issues are complex and further study is needed (Körner 2000; de Haen 2008). Industrially, an anticipated shift to short-rotation timber plantations increases timber production and producer returns across Africa (Sohngen et al 2001). Nevertheless, a range of negative effects are also likely, particularly if no effort is made at anticipatory adaptation (Dixon et al 1996).

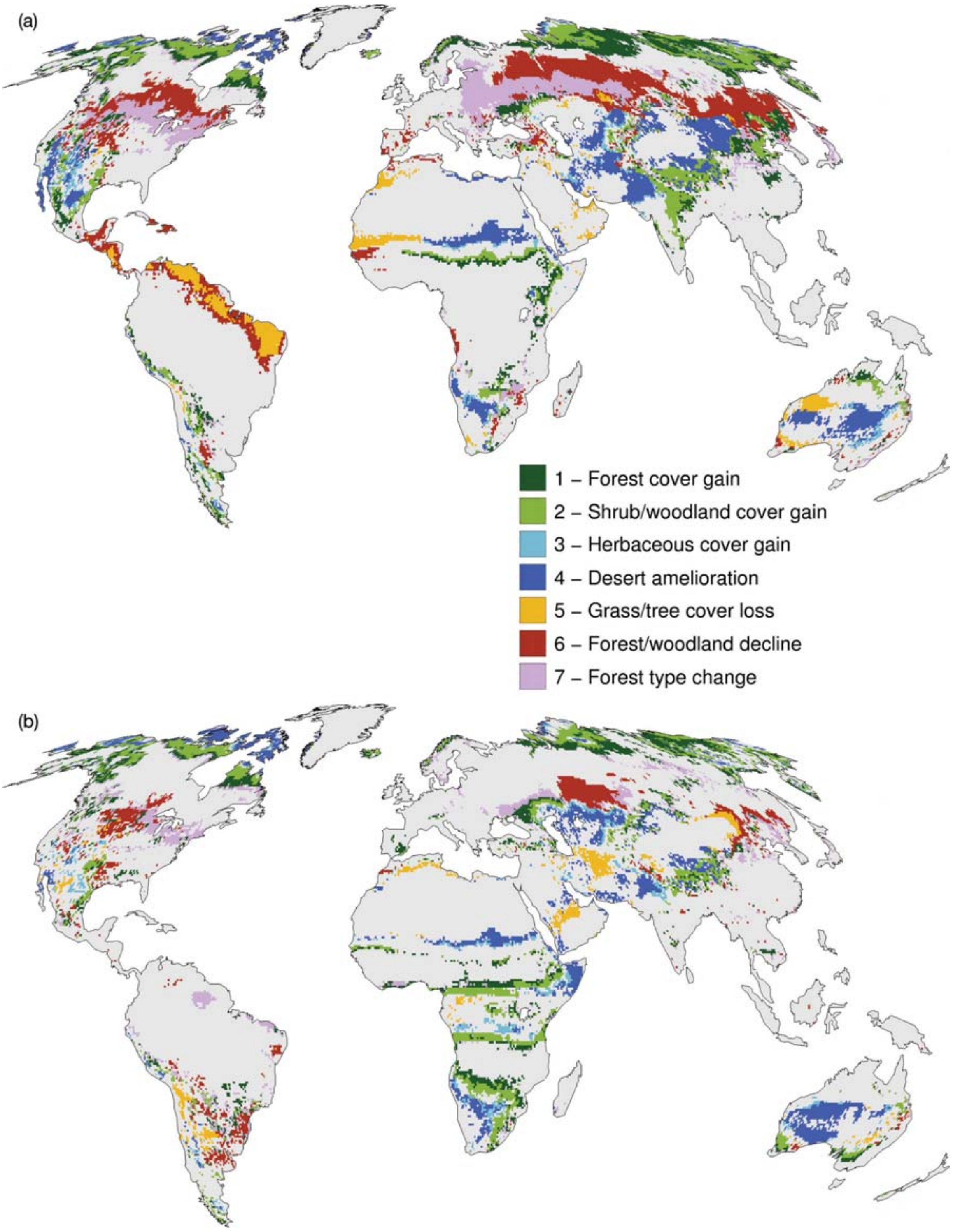


Figure 13. Projected changes in terrestrial ecosystems by 2100 relative to 2000 for two scenarios forcing two climate models: (a) 'growth' scenario cluster, (b) 'stable' scenario cluster. Changes are considered appreciable and are shown only if they exceed 20% of the area of a simulated grid cell. Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure 4.3. P. 238. Cambridge University Press, Cambridge, UK (Christensen et al 2007).

Although climate change and enhanced CO_2 fertilisation may be positive for African forests overall, Dixon et al (1996) estimated that up to 40% of the vegetation in Africa may need to shift its range to avoid extinction or take advantage of new conditions. Using HadCM3 and other models, McLeman and Smit (2005) postulated that by the year 2085, an estimated 5000 African plant species are expected to be negatively impacted as a result of substantial reductions in areas of suitable climate. Modelling by Hély et al (2006) suggests that decidous and semi-decidous forests are very sensitive to relatively minor changes in precipitation, although their results do not predict a change in biome type under IPCC precipitation scenarios.

As the climate changes plants will naturally attempt to adapt by migrating, assuming the landscape is not too fragmented. However, given that most of the land in Africa is inhabited by humans, not all species will be able to migrate. For some regions such as the fynbos, which is at the edge of the continent, there will be limited options for migration (Desanker 2003). According to the Millennium Ecosystem Assessment (2005) climate change can potentially reduce the population viability of many species and alter habitats. Climate change effects will exacerbate stress on forest ecosystems through shifts in species range and modifications in productivity of tree species (UNDP 2004; Boko et al 2007). Some mammal species in Sub-Saharan Africa are projected to become endangered or extinct due to changing climate.

An assessment by UNEP (2002), suggested that by 2050 rainfall in Africa could decline by 5% and become more variable year by year. Due to this interannual variability of rainfall, water availability is already decreasing in southern Africa with disparities between the location of and need for water resources (Johns Hopkins University 1998). For example, some countries such as Namibia, Botswana, southern Zimbabwe and Mozambique and much of South Africa lie in drought prone areas. Scholze et al (2006) modelled 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. Reduction in water quantity will lead further 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 the livelihoods of forest-dependent households in southern Africa. Longer droughts and more severe floods could reduce agricultural yields and thus put further pressure on forest ecosystems to meet the needs of distressed people (Cohen et al 2008; Seppälä et al 2009a). Projected rises in sea levels may cause increased flooding and severely affect mangrove forests (APP 2009). Higher drought frequency threatens biodiversity in southern Africa, and floristic hotspots in Cameroon and Ethiopia could be threatened by rainfall pattern shifts. Upslope dispersal opportunities limited in African tropical forests (McClean et al 2005), adding to the vulnerability of some species. South Africa is expected to face biome shifts (Rutherford et al 1999) and threats to biodiversity. Many of these changes are predicated on altered fire regimes due to reduced precipitation and increased evapotranspiration. A modelling study on 5197 plant species using Hadley Centre climate projections and 3 distribution models shows that the areas of suitable climate for over 80% of African plant species are projected to decrease in size and shift in location to higher altitudes. 25–41% would lose all their area by 2085 (McClean et al 2005). Particularly dramatic changes are modelled in the Guinea-Congolean forest of west and central Africa. Ecosystem services in southern Africa may also be threatened (Scholes and Biggs 2004).

In the absence of grazing, the balance between forests and grassland/savannah biomes is controlled largely by the frequency of fire (Bond et al 2003). Bond and Midgley (2000) suggested that elevated CO_2 levels may encourage forest growth at the expense of grasslands, as higher CO_2 levels may enable trees to recover from fire more quickly, and more rapidly grow to a size where they are less liable to injury from future fires. Bond et al (2003) modelled forest/savannah interactions at different levels of atmospheric CO_2, and found that forests were not present at levels of 180 ppm (as found in the last glacial period), trees were present at low densities with pre-industrial levels of 270 ppm and are most favoured by current levels of 360 ppm. This modelling appears to be consistent with historical evidence. The Sahel and southern Africa are likely to experience more fires under projected future climates, but some models anticipate less in parts of tropical Africa (Goldammer and Price 1998; Scholze et al 2006).

Warmer, drier climates may increase damage from pests such as termites (Langewald et al 2003), and concerns have been raised about the effect on eucalypt diseases in South African plantations (Roux et al 2006). South African plantation fungal pathogens have been bioclimatically modelled by van Staden et al (2004), who found that some pathogens may move into previously free areas and cause significant damage in commercial plantations.

For any species whose continued viability under climate change is of potential concern, a range of issues need to be considered. These include:

- Species range shifts relative to reserve boundaries: net loss/gain of species in Reserves, suitability of Reserves for particular species under changed climae conditions
- Local, regional and global extinctions of species due to the changing conditions
- Migration of invasive alien species and/or pathogens and parasites
- Individualistic species responses in latitudinal and altitudinal directions
- Individualistic species responses to warmer/cooler and drier/moister conditions
- Geographic variation in the magnitude of species responses to the changing conditions
- Species range shifts/losses due to range expansions, contractions and eliminations
- Changes in phenology (the timing of events such as flowering)
- Changes in nutrient cycling and natural resource supply (e.g. water)

- Changes in predator-prey, parasite-host, plant-pollinator and plant-disperser relationships
- Changes in ecosystem services such as pest control, pollination and soil stabilisation
- Ecosystem switches following changes in ecosystem functioning and disturbance regimes
- Pressure from human development
- Human needs

Vulnerability to climate change is influenced by variation related to current climate, geographic heterogeneity and social factors (Eriksen et al 2007). These factors vary significantly across Africa, and so there is differential vulnerability between countries across the continent.

HUMID

Humid tropical Africa includes a number of centres of floral endemism, including mountainous ares in Cameroon and a long series of isolated areas above 2000 m from Ethiopia to South Africa. Climate change is generally held to increase biodiversity risks (Fischlin et al 2007), and montane areas in tropical Africa will logically face relatively higher risks from climatic change due to the lack of migration paths for mountain species (Desanker et al 2001).

Almost all studies on the effects of climate chage on humid biodiversity rely on modelling, although Boko et al (2007) caution against overinterpretation of such models. Dixon et al's (1996) modeling is summarized in Table 13. Climate/species interactions are however complex, and may lead to unexpected results. Hemp (2005) for example demonstrates that forests on Mount Kilimanjaro have *reduced* their upward altitudinal extent in response to climate change, due to altered fire regimes.

Care must also be taken in extrapolating results from other parts of the world to tropical Africa. For example, Andreone et al (2005) reviewed amphibian species in Madagascar, and found that all but two of the species described in the nineteenth century were also found in the past 15 years. This surprising result is at odds with amphibian extinctions documented by Pounds et al (2006) and may suggest that climatic changes in Madagascar have not been overwhelmingly detrimental to amphibian populations, or that their adaptive capacity is underestimated.

Table 13. Current forest ecoregion area and the effect of future climate change on annual extent of forest in Cameroon and Ghana under 4 GCM scenarios (adapted from Dixon et al. 1996)

Nation		GCM scenario (2xCO_2)			
Ecoregion	Current	GISS	OSU	UKMO	GFDL
		(10^6 ha)			
Cameroon					
Evergreen forest	8 021	8 663	8 684	8 181	7 620
Deciduous forest	10 477	11 315	11 734	10 687	9 953
Hilll and montane	1 767	1 908	1 979	1 802	1679
Ghana					
Evergreen forest	-	-	-	-	-
Deciduous forest	9 555	10 319	10 702	9 746	9 077
Hill and montane	480	518	538	490	456

SUB-HUMID

The sub-humid zone is in some respects a ‘transitional’ region between the humid and dry zones. As such it is difficult to make firm generalisations, as at times the influences and impacts on the region will be similar to dry areas, but at other times more humid characteristics will be seen. This adds a further degree of uncertainty and complication, as the results of climate change will depend to a large extent on how annual conditions affect variable ecosystem drivers such as fire or grazing regimes (Sankaran et al 2005; Dube 2009).

DRY

Increased evaporation and desertification are expected in the Sahel, Sudan and Guinea regions (Zhao et al 2005), although as discussed earlier, this is not universally agreed. Modelling of forest area in Zimbabwe showed an expected shift of biomes from subtropical thorn woodland and subtropical dry forest to tropical very dry forest across 17 to 18% of the national land area (Matarira and Mwamuka 1996), although the authors note that this was a very preliminary estimation. Increased erosion may cause siltation of downstream river basins in places such as Mauritania, Niger, Nigeria and Senegal, which may lead to buildups of debris that can engulf riparian forests (UNECA 2008).

Some model results indicate that only 80 000 km^2 of agricultural land in Sub-Saharan Africa with currently severe environmental constraints (out of more than 15.1 million km^2) would improve with climate change, whereas more than 600 000 km^2 currently classified as moderately constrained could move to the class of severe environmental limitations (Fischer et al 2002). The consequences of this would be that the areas of grassland in southern Africa would decline, being replaced either with thorn scrub savannah or seasonal and dry forests. Desert areas may expand northeastwards into larger areas of Botswana. If improvements in plant water use efficiencies (WUE) due to elevated carbon dioxide concentrations in the 2050s of about 560 ppm are also assumed, the simulated vegetation changes are much altered. In this case, seasonal dry forests become the dominant biome in southern Africa. This result implies that, should vegetation in southern Africa respond in this way to elevated carbon dioxide, the gain in WUE tends to modify many of the indirect effects of climate change on plant growth. This conclusion needs further careful examination. Hulme (2001) reported that between about fifteen and twenty per cent of large forests and nature reserves and national parks in southern Africa would experience a change in biome under some climate change scenarios. This percentage increases to between twenty-five and thirty-eight per cent when WUE changes are also modelled.

Future forest socio-economic impacts and vulnerabilities

Africa is one of the world’s regions most vulnerable to climate change because of low adaptive capacity and projected climate change impacts (Boko et al 2007; IPCC 2007). Africa’s vulnerability is exacerbated by the fact that so many Africans depend directly on the natural environment for livelihood support, in addition to the lack of financial, technological and institutional capacity for climate change adaptation (Eriksen et al 2007). Therefore, climate change effects pose substantial challenges to development in the region. There are also however some possible climate change effects that may result in improved conditions (possible CO_2 fertilisation effects, increased rainfall in some areas, expansion of vegetation cover in the Sahel zone etc.).

Extant and projected climate change in Africa has serious implications for forest ecosystems and for the livelihood of forest-dependent people. 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 (Faurés and Santini 2008). The impact of the changes on forestry is exacerbated by the lack of adaptation strategies, which are increasingly limited due to the lack of institutional, economic and financial capacity to support such actions (FAO 1999).

In studies of the impacts on specific sectors, in most cases southern African countries applied impact models such as DSSAT, SPUR2, CLIRUN, and the Holdridge Life Zones Classification, and WATBAL (UNFCCC 2005 and references therein) to vulnerable sectors such as water resources, agriculture, health, coastal zones and forestry. To a lesser extent, socio-economic analyses were also applied. More capacity and work is needed in the region to assess vulnerability and, more importantly, to integrate assessments including economic and cross-sectional analysis of adaptation options at the national scale.

More recent impact and vulnerability studies (e.g. African studies under AIACC project [www.aiaccproject.org]) employed more sophisticated impact models and vulnerability-based assessments. These studies seek to identify the sources of vulnerability (for example, by investigating the ranges of climate variability and the frequencies and magnitudes of extremes with which communities have coped in the past and might be able to cope with in the future), evaluate the risks from climate change, examine the resources (economic, social, and political) presently or potentially available to a community, and finally assess its capacity to adapt to change. They evaluate opportunities for, impediments to, and the effectiveness and costs of adaptation responses. These studies show that local or rural communities are most vulnerable to climate change, and approaches that emphasize a bottom-up approach recognizing local coping strategies and indigenous knowledge and technologies hold the most promise, as these will more easily add to local adaptive capacities. Involving stakeholders in the assessment process is a necessary part of vulnerability studies.

Agyemang-Bonsu (2009) conducted an impact study for Ghana, and concluded that vulnerability to climate change is related to mean poverty levels in the various ecological zones. The study warns that climate change could stall and reverse Ghana's economic development through six key transmission mechanisms:

- Agriculture production and food security
- Water stress and water insecurity
- Rising sea levels and exposure to climate disasters
- Reduction in ecosystem services and loss of biodiversity
- Human health impacts
- Destruction of infrastructure

The vulnerability of forest-based communities is exacerbated by the limited ability of rural, resource-dependent communities to respond to risk in a proactive manner (Davidson et al 2003; Tschakert 2007). Many sources agree that in a bid to fight predicted food crises, the affected population will increasingly depend on available natural resources with an attendant increase of deforestation in search for more farm lands (Bergonzini and Riera 2005). Human activities may limit the potential of forest ecosystems to adapt naturally to climate change.

High population growth rates, especially in rural areas, will raise pressure on agricultural production and natural resources (FAO 2003a). Already, the continent is estimated to be losing 4 million hectares of forest area annually (FAO 2007). The population in Sub-Saharan Africa is projected to double by 2050, increasing annual agricultural consumption by between 2.0–2.8 times (Calzadilla et al 2009). Furthermore, remaining forest ecosystems are likely to experience increased pressure due to increasing global demand for new land for the agro-industry. Brink and Eva (2008) expect an increase in agricultural area, which may be statistically modelled (Kamusoko et al 2009).

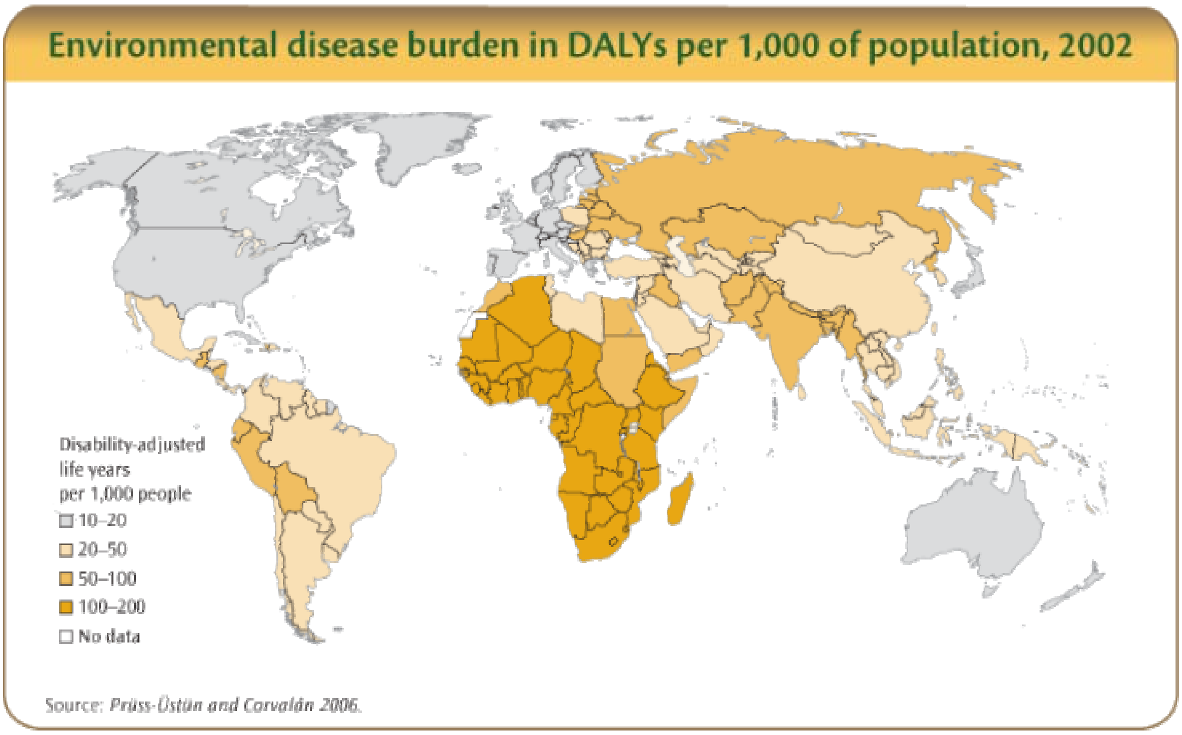
Li et al (2005) studied the hydrological variability of West Africa, and note that consideration of vegetative cover is a necessary input, but Ilstedt et al (2007) note that water infiltration into soil following afforestation is still poorly studied. On the basis of their meta-review they conclude that afforestation increased water infiltration by approximately 200%. Hydrological responses are however not necessarily linear in response to precipitation changes. De Wit and Stankiewicz (2006) use predicted precipitation changes to calculate that surface water supplies will be significantly affected over 25% of Africa by the end of this century, and Delire et al (2008) suggest that this may even be an underestimation due to De Wit and Staniewicz including consideration only of precipitation changes, not temperature. Marginal lands in equatorial central Africa and the eastern Highlands may experience a rise in productivity due to increased rainfall, but these gains may be swallowed by increased population pressure on these areas (Watson et al 1997). Migration (temporarily or permanently) is a common response to environmental pressures, and it must be recognised that if drier areas are placed under further stresses people are likely to move to more heavily forested regions, placing additional burdens on those landscapes.

Climate impacts on biodiversity and ecotourism. Viner and Agnew (1999) have pointed out the potential risks to ecotourism in south and east Africa, particularly raising concerns about the loss (or reduction in abundance) of iconic wildlife species, the lessening of the pleasant climate for tourism and the risks of extreme weather to recreation activities and infrastructure. Mkanda (1996) studied the anticipated effects of climate change on the Nyala antelope in Malawi, and concluded that all ungulates could be highly susceptible to changes in food supply and habit. Fragmentation of ecosystems will also complicate human efforts to assist adaptation (Western 2001).

Non-timber forest products may also be adversely affected. For example, Sudan supplies 80% of the world's gum arabic, produced from *Acacia senegal* and *Acacia seyal*, tapped either from planted or naturally occurring trees (GoS 2003). This product is considered to be one of Sudan's most important exports. Despite projected increased in precipitation in the gum arabic belt, increased evaporation may cause moisture stress and reduce yields. Projections carried out for the GoS (2003) report show a 25% decline in gum arabic production by 2030, and 30% decline by 2060.

From 25% to over 30% of disease in sub-Saharan Africa is associated with environmental factors (Prüss-Üstün and Corvalán 2006) and African people are clearly more vulnerable to environmental disease than those in other parts of the world (Figure 14). Concerns have been raised regarding a possible climate driven rise in cases of diseases such as malaria (Matola et al 1987; Hay et al 2002), Ebola, and Nipha encephalitis (Gonzales at al 2008). Zhou et al (2004) found links between climatic variability and malaria cases in the East African highlands, but they stress that topography, human settlement pattern, land use, and drug resistance are also important factors, and in some areas less than 20% of the recent decadal rise in malaria cases can be explained by climatic influences. Along with AIDS, these diseases may potentially have serious impacts on the forest workforce (FAO 2003c; Anaeto and Emenyonu 2005) and add further pressure to forested ecosystems as sick people return from the cities to their villages (Topouzis and du Guerny 1999; Neves 2008). Other social changes that may be exacerbated by climate change such as conflict (Richards

1996) or psychological damage (van Haaften 2002 cited in Seppälä et al 2009a) may also cause social dislocation and add to pressure on forest biomes.


Environmental disease burden in DALYs per 1,000 of population, 2002

Source: *Prüss-Üstün and Corvalán 2006.*

Figure 14. Environmental disease burden. International Bank for Reconstruction and Development, The World Bank (2008).

3. Adaptation options

The high vulnerability of Africa is attributed to a large extent to its low adaptive capacity, not just the prevailing climate. Sub-Saharan Africa contains the poorest and 33 out of the 49 least developed nations of the world (UN-OHRLLS n.d.) with low per capita GDP, short life expectancy and high infant mortality. Literacy is in the bottom quartile globally and there is a high dependence on the natural resource base. Along with weak governance structures these combine to result in a low capacity for sub-Saharan African governments to respond proactively to change. Terms of trade and aid dependence further complicate matters.

Africa has a low level of expertise in climate science, particularly in prediction at longer time scales, as most predictions are supplied from international centres external to Africa (Washington et al 2004). The region lags behind other regions in terms of availability of detailed scientific knowledge of its climate (Tarhule 2007) and comparatively few resources are allocated to climate at national levels, since climate is seen as a lesser priority compared to other urgent needs.

Needs for capacity building and training have been expressed by a number of African countries in their national communications to the UNFCCC and summarised in the compilation and synthesis reports by the Secretariat. A number of factors have been advanced to explain this very low adaptive capacity: widespread poverty, inequitable land distribution, a high dependence on a deteriorating natural resource base and the ravages of HIV/AIDS (IPCC 1998; Ikeme 2003; Magadza 2003; Thornton et al 2006). Improving adaptive capacity is important in order to reduce vulnerability to climate change. More is needed to be done to enhance the adaptive capacity of institutions, organizations and individuals (Denton et al 2001). The sixth UNFCCC compilation and synthesis report (UNFCCC 2005) highlighted the critical gaps and institutional and human capacity building needs as identified by southern African countries. The most commonly mentioned gaps and needs include:

- Lack of knowledge of climate change issues and the need for more longer term training in vulnerability and adaptation assessment, including for developing national communications, and retention of expertise;
- Need for establishing national climate change committees;
- Need for strengthening national institutions to take on work on developing GCMs at appropriate scales;
- Need for improvement of the institutional framework for implementation of adaptation.

Many southern African country reports highlighted specific constraints and data needs to build capacity related to vulnerability and adaptation components of national communications, such as the lack of country-specific socio-economic scenarios, the deficiencies in data collection, quality control, archiving, retrieval, preparation and analysis of data, and the lack of comprehensive studies on possible adaptation measures and cost-benefit analysis of adaptation options.

Current adaptation measures and policies

According to the FAO’s State of the World’s Forest report (FAO 2007) a majority of African countries have adopted new forest policies and forest laws, and measures are underway in many countries to improve forest law enforcement and governance (FAO 2007). The Yaoundé Declaration of 1999 had led to significant developments in forest management across Central Africa, with a wide range of new protected areas, stricter and better policed logging regulations, fauna management plans and anti-poaching actions. Cooperation between neighbouring states (Cameroon, the Republic of Congo and the Central African Republic) in the creation of protected areas is a feature of the Yaoundé summit’s success. Many African countries produced updated forest legislation in the late 1990s (Kigenyi et al 2002, Table 14). Forest policies in any nation offer an avenue for increasing the resilience of forests and improving forest sustainability (Eastaugh et al 2009).

Table 14. African forest policies (expanded from Alden-Wily and Mbaya 2001; Kigenyi et al 2002)

COUNTRY	FOREST LAWS	FOREST POLICY
Uganda	Forest Act Cap 264 (1964) Amendment in 1998 following Land Act 1998, redefined certain reserves as Local Forest Reserves to be held in trust by District of Lower Local Government Councils.	New Policy in draft 1999-2000

Tanzania	Forest Ordinance Cap 389 (1957) Draft bill for Forest Act 2000	National Forest Policy March 1998
Zanzibar	Forest Resources and Conservation Act 10 (1996)	Forest Policy 1995
Kenya	Forest Act Cap 385 (1962) Draft Forestry Bill 2000	Kenyan Forest Policy 1999
Ethiopia	Forestry Conservation, Development and Utilisation Proclamation 1994	Forest Policy in Draft 1998
Eritrea	Proclamation 192, 1980 New law in draft	
Malawi	Forestry Act 1997	National Forest Policy 1996
Zimbabwe	Revised Forest Act 1996 Communal Lands Forest Produce Act 1987	Forest Policy for Tribal Trust Lands Revised Forest Policy 1968
Zambia	Forestry Act 1999	National Forest Policy 1998
Botswana	Forest Act 1968, ammended 1980	
Namibia	Draft Forest Bill 1998-2000	Draft Forest Policy 1998
South Africa	National Forest Act 1998 Management of State Forest Act 1992 Forestry Laws Rationalization and Amendment Act 1994	National Forestry Action Plan 1997
Mozambique	Forest and Wildlife Act 1999	
Swaziland	Forest Preservation Act 1910 Natural Resources Act 1951 Private Forests Act 1961 New draft planned for 2001	Drafting of new forest policy underway in 2000
Lesotho	Forestry Act 1999	National Forest Policy 1997
Gabon	Law 16/01 of 31 December 2001 on the forestry code	Decree N° 689/PR/MEFEPEPN of August 2004 defining the technical norms of forestry management and sustainable management of registered productive forestry domains
Central African Republic	Law N° 90/003 of 09 June 1990 on the Central African forestry code Forest Code promulgated in 2002	The elaboration of national norms relatives to forestry management plan (May 2001, under revision) Forest management plans jointly applied by the public structure and the logging companies
Republic of Congo	Law 16-2000 of 20 November 2000 on forestry code	National directives relative to the sustainable management of the natural forest of Congo (February 2004)
Democratic Republic of Congo	Law 011/2002 of 29 August 2002 on the forestry code	Ministerial arête N°CAB/MIN/AF.F-E.T/262/2002 of 03 October 2002 fixing the procedures relative to the establishment of sustainable forestry management plan
Cameroon	Law N°94/01 of 20 January 1994 to lay down forestry, wildlife and fisheries regulations	Forest management obligation. 1995, National Forestry Action Programme, later on replaced by the Forest and Environment Sectoral Programme (2003). Land use zoning plan developed for the southern part of the country (Guinean-Congolese forest region)
Equatorial Guinea	LEY 1/1997, sobre el Uso y Manejo de los Bosques (Ley Forestal) 1997	No policy Forest Management Obligation
Ghana	Forest Ordinance Act- 1927 Concession ordinance law – 1939 GoldCoast and Wildlife policy – 1940s Forest and Wildlife policy – 1994 Trees and timber amendment act Forestry development master plan – 1986 Act 547: Timber Resources Management Act, 1997. LI 1649: Timber Resources	Constitution of Forest Reserves Introduction of a system of Timber harvesting rights Timber exports and management of permanent estates. Liquidation of off reserves Regulation of timber trade Strategies for forest and wildlife policy Mainstreaming climate change impacts into policy

	Management Regulations, 1998. Act 671: Timber Resources Management (Amendment) Act, 2002. LI 1721: Timber Resources Management (Amendment) Regulations, 2003. Act 493: The Trees and Timber (Amendment) Act, 1994 (An Act to Amend the Trees and Timber Decree, NRCD 273 of 1974). Act 583: Forest Plantation Development Fund Act, 2000. Act 623: Forest Plantation Development Fund (Amendment) Act, 2002. Act 624: The Forest Protection (Amendment) Act, 2002.	

There is currently little consideration of an overall climate change adaptation strategy for the forestry sector in Sub-Saharan Africa but regional processes such as the Congo Basin Initiative or the African Forest Forum could provide suitable mechanisms for gradually developing a cooperative climate change adaptation strategy. Forest protection is promoted, but is in some instances hindered by a breakdown of traditional authority structures (Maxted 2002). Tree planting is sometimes not enthusiastically supported by farmers due to past disputes with logging companies based on disagreements over land tenure issues. Assessment of forest policies in two West African states, Burkina Faso and Ghana, by Kalame et al (2009) showed that forest policies have yet to incorporate climate change adaptation. They did however find that forest policies in these countries contain elements of risk management practices relevant to the adaptation of forest ecosystems.

The International Institute for Sustainable Development's Community Drought Mitigation Programme is enhancing sustainability in drought-prone areas in Zimbabwe through promoting 'sustainable livelihoods' (Neely et al 2004), harnessing local knowledge, promoting the adoption of adaptation strategies and technologies and advising policy-makers (Agobia 1999). A similar focus on sustainable livelihoods is credited with significantly increasing communities' adaptive capacity to climate change (Osman-Elasha et al 2006a). In Ghana, a National Climate Change adaptation strategy is being developed, and efforts have been initiated to mainstream climate change adaptation and mitigation, as well as REDD+ in the Agriculture, Forestry, and other sectors of national development. Within the forestry sector, plans are afoot to revise the policy to emphasise climate change mitigation more prominently, and management plans for all the 215 forest reserves in the High Forest Zone are being revised to address REDD+ issues.

The commercial development of a viable timber industry is receiving attention in many parts of Africa. Iroko (*Milicia excelsa* and *M. regia*) in West Africa are very valuable native timber species, and are potentially profitable in plantations. Commercial development is however hampered by their susceptibility to *Phytolyma* gall attacks (Cobbinah et al 2001). Native stocks of *Milicia* are declining rapidly, due to *Phytolyma* infestations and unsustainable harvest levels. Ofori and Cobbinah (2007) report on efforts to develop the plantation potential of these species through a management approach that utilises pest resistant genotypes within a silvicultural system that simulates conditions in the natural forests and enhances the activities of natural enemies. Similarly, African Mahogany (*Entandrophragmais* spp., *Khaya* spp.) in West and Central Africa and *Gmelina arborea* in Nigeria are important timber species, and efforts are being made to better understand the factors militating against their success as plantation species (Hall 2008; Opuni-Frimpong et al 2008). Reforestation schemes in West Africa in the 1950s and 60s using neem trees (*Azadirachta Indica*) are considered to have been most successful (OIA and PGA 1992).

Specific plans for adaptation are rare, although some municipal examples exist (i.e. Mukheibir and Ziervogel 2007). A range of ‘local coping strategies’ has been published by the UNFCCC (http://maindb.unfccc.int/public/adaptation) although as of September 2009 only one project was present there under the heading ‘damage to forests’, in Central Asia. No details were available. There is however mention of several projects addressing land degradation in Africa (UNFCCC 2008). In Malawi, it has been suggested that energy-efficient stoves and other forms of domestic energy supplies need to be promoted to reduce the reliance on wood from forests (Jumbe et al 2008). In Ghana, Burkina Faso and Mali governments are supporting programs to adapt forest ecosystems to predicted climates, through means such as reforestation and afforestation efforts and research into resistance and adaption to drought and bushfire (Idinoba et al 2009).

Indigenous knowledge can play an important role in adaptation to climate change (Eastaugh 2008). Indigenous people have survived due to their capacity to adjust to climate uncertainties. The strategies that they have developed have their own strengths and have helped to withstand some of the pressure posed by climate change. Boven and Morohashi (2002) provide examples of using indigenous knowledge to promote sustainable development in (among others) Botswana, Kenya, Senegal, Burkina Faso, Nigeria and Ethiopia. As a consequence of high climatic variability, southern Africa's inhabitants have developed highly effective strategies to cope with drought since the region became semi-arid some four or five thousands of years ago (Andah 1993; Casey 1998). A myriad of indicators such as duration and intensity of hot periods, tree phonological characteristics, animal behaviour, are used to predict duration, intensity and timing of rainfall by communities in Ghana (Cobbinah 2007). Henning (2002) gives the example of the multiple-use Jatropha hedges in Mali, although this was an introduced South American species.

Management for adaptation

In an early review of climate change adaptation possibilities in Africa, Smith and Lenhart (1996) stressed three points in relation to forests: the preservation of diverse seed banks, the reduction of habitat fragmentation and the establishment of dispersal corridors, and the encouragement of diverse and flexible management procedures and policies. Drawing insights from Spittlehouse and Stewart (2003), Kalame et al (2009) made several recommendations for forest management actions to climate change adaptation in West Africa (Table 15).

Table 15: Recommended adaptation actions under changing climate (adapted from Kalame et al 2009)

Topic	Adaptation actions
Gene management	Reassessing conservation and seed banks locations, breeding pest resistant genotypes, determining adaptability and responses of genotypes will be necessary for the genetic diversity and resilience of tree species to climate change
Forest protection	Forest fire and pest management to reduce disturbance, restore destroyed forest and protect trees against diseases
Forest regeneration	Use drought tolerant genotypes, use artificial regeneration and control invasive species
Silvicultural management	Selective removal of poor adapted trees, reduce rotation period, manage forest density, species composition, and forest structure to control the declining and disturbed stands
Forest Operations	Increased logging from disturbed stands, forest carbon management, increase use of wood fuel from forest, and put in place appropriate policies to ease adaptation actions
Non-timber resources	Minimize habitat fragmentation, conserve wildlife, maintain primary forest, and diversity of functional groups
Park and wilderness area management	Plant adapted species, conserve biodiversity and maintain connectivity and employ adaptive management to influence change

Such measures can be implemented as part of sustainable forest management, which is an evolving system of forest practices that aims to ensure that the goods and services derived from forests meet present-day needs while at the same time securing their continued availability and contribution to long-term development (Seppälä et al 2009a). The importance of sustainable forest management as a vital component of climate change adaptation has been stressed at a global level (Seppälä et al 2009a), and African forests are no exception (FAO 2003b; Patosaari 2007). There is evidence that forest management in Africa has been gradually improving (ITTO 2005), although much remains to be done. Concepts such as management plans (Nasi et al 2006), lumber recovery efficiency (Uzowulu et al 2005) and Reduced Impact Logging (Sist 2000; Putz et al 2008) are well understood in developed forestry nations, but need further promotion in much of Africa. Diversifying livelihood sources through varying economic activities (e.g. utilizing forest and veld products as a buffer to climate-induced crop failure from farming in marginal areas [Dube and Sekhwela 2007]) are also a necessity for facing future challenges.

Blay et al (2004) reviewed the progress of a series of rehabilitation projects established across humid, sub-humid and dry regions of Sub-Saharan Africa. Although these case studies were targeted at the rehabilitation of degraded lands rather than specifically at climate change adaptation or mitigation, the lessons learned from these efforts will be equally applicable to similar future community-based adaptation projects. Common themes from the case studies included:

- the need for broad community consultation with all partners and stakeholders
- the importance of secure and well understood land tenure arrangements
- the need to establish and support community participants' management skills
- project objectives must be consistent with communities' needs and constraints
- communities must maintain a sense of ownership and control of the project

Short rotation plantations using fast growing species such as *Gmelina arborea* in Malawi and West Africa or *Acacia mearnsii* in South Africa and Kenya (Evans and Turnbull 2004) reduce risks of maladaption and lessen the risk that catastrophic events will destroy plantations within the life of a rotation (Seppälä et al 2009a). Restoration of *ngitilis* (forest enclosures) in the Shinyanga region of Tanzania has reversed desertification, restored water supplies and provides forest products for local people (Barrow 2002). These are protected through community-based fire management (Nssoko 2004).

Integrated land-use approaches such as agroforestry and silvo-pastural systems can play an important role in improving the resilience of local communities to climate variability. This is particularly important given rapid rural population growth and the resulting added pressure on agricultural production and natural resources (FAO 2003a). Agroforestry projects have shown great potential in many areas, and Franzel et al (2006) suggest that these projects need 'scaling up' to broader, more mainstream adoption. Franzel et al (2006) present some key elements in moving beyond pilot projects to have new innovations in agroforestry more broadly adopted by farmers. These elements include:

- taking a farmer-centred research and extension approach
- providing a range of technical options
- building local institutional capacity
- sharing knowledge and information
- learning from successes and failures
- strategic partnerships and facilitation
- marketing
- germplasm production and distribution systems
- policy options

Agroforestry in Nigeria was studied by Tiku et al (2006), who point out the benefits and encourage landholder participation on economic grounds. Unruh et al (1993) suggested that agroforestry has the potential to offset greenhouse gas emissions in Africa for between 20 and 125 years. In other cases, adaptive actions in agricultural areas have put further pressures on forests (Paavola 2008).

Fire and drought are major impactors on forest ecosystems in southern Africa (Geldenhuys 1994; De Wit and Stankiewicz 2006; Christensen et al 2007; Oluwole et al 2008) and west Africa (Savadogo et al 2007). Bond et al (2005) suggest that the exclusion of fire from humid grasslands and savannahs may allow for the expansion of tropical forests to twice their current extent in some areas.

Augustine et al (2003) pointed out the significance of ungulate grazing on soil nitrogen and phosphorus in nutrient-poor Acacia bushland in Kenya, and Mkanda (1996) stresses that adaptation options such as assisted migration, culling and artificial water supplies may be needed to reduce climate change impacts. Creating avenues of migration for critical plant groups (in either direction of the climatic gradient) might be a useful hedge against destructive changes in climate (Reid et al 2007). Some plant species must be allowed to colonise new areas if they are to survive, and Williams et al (2005) have suggested that dispersal corridors may need to be put into place for Cape proteas (*Protea spp*.). Osman-Elasha et al (2006b) mention the possibility of land use shifts away from agriculture towards ecosystem services in Botswana, and the establishment of seed banks in Ethiopia. Sogbohossou et al (2008) discuss the use of botanical gardens as a preservation tool. Forest restoration measures such as those discussed by Blay et al (2004) have an important role to play in climate change adaptation. Blay et al (2004) concluded from their work that it is important that local communities see restoration works as having a direct bearing on their livelihood through short-term tangible benefits such as forest products. UNECA (2008) report a range of successful restoration and afforestation projects across Africa (Table 16).

Table 16. Successful restoration and afforestation projects (adapted from UNECA 2008)

Country	Achievements/Successes
Chad	Reforested degraded lands.
Madagaskar	Reforested degraded lands.
Democratic Republic of Congo	Afforested and reforested degraded lands and promoted community forestry management practices.
Djibouti	Restoration of the Day forest
Ethiopia	Rehabilitated degraded patches of remnant forest areas through enrichment planting and enclosure. Insituted area enclosure and afforestation programmes. Introduced and disseminated fuel saving stoves and renewable energy.
Ghana	Controlled bushfires in many communities.
Morocco	Afforested four million hectares of land and reforested close to

	530 thousand hectares of degraded land.
South Africa	Promoted community forestry aimed at meeting local social, household and environmental needs and at favouring local economic development.
Togo	Afforested and reforested degraded lands.
Zambia	Established community forests and fruit tree plantations and rehabilitated degraded lands through afforestation programmes.

Brockhaus and Djouti (2008) provide an example of spontaneous adaptation of ecosystems and society in Mali, in response to a drying climate and reduced agricultural pressure due to political instability. The ecological changes involve a shift from water-based (agriculture and fisheries) to forest land. People in the area have adapted through identifying new income-producing activities such as charcoal production or through migration out of the area, the use of forests for livestock fodder or changing grazing patterns. The authors stress however that these are autonomous adaptations, with little or no pre-planning or institutional support. This support must be developed if the newly formed strategies are to be sustainable in the long term. In Burkina Faso, soil and water conservation programmes have been shown to be successful in many villages (Reij et al 2005), but high levels of outside support were required.

Socioeconomic circumstances have a strong bearing on adaptive capacity, and community surveys conducted by Tschakert (2007) identified health, poverty, the threat of hunger, unemployment and poor infrastructure as the leading detrimental issues. In spite of the low adaptive capacity of much of Africa, people have developed traditional adaptation strategies to face climate inter-annual variability and extreme events (Fagan 2000; Nyong et al 2007). Those communities that have faced harsh environmental conditions over prolonged periods have consequently been trying, testing and adopting different types of coping strategies (Mortimore 2003). An unusually persistent drought may increase vulnerability in the short term, but it may also encourage adaptation in the medium to long term. Local peoples have perceived, interacted with, and made use of their environment with its meagre natural resources and changing climatic conditions in what could be seen as practical coping mechanisms. This is particularly true for drought prone areas such as the Lower Shire region of Malawi, which is susceptible to frequent climatic hazards. Farmers in drought-prone areas have been practicing coping strategies and tactics and have developed their own ways of assessing the prospects for favourable household or village seasonal food production (Shipton 1990), although in the long term some short-term coping methods may be counterproductive (Smucker and Wisner 2008). Burkina Faso farmers are preserving useful NWFP species (Idinoba et al 2009), and in Namibia and some parts of Botswana locals have improved their adaptive capacity by using traditional pruning and fertilizing techniques to double tree densities in semi-arid areas. Such methods help in holding soils together and reversing desertification. Similar community-initiated projects in Zimbabwe have been acclaimed successes (ECA 2001).

Other adaptation strategies practised by communities in southern Africa include: reliance on naturally occurring forest and veld products in case of crop failure in climatically marginal agricultural areas (Dube and Sekhwela 2007); decentralization of local governance of resources i.e. the Community Based

Natural Resource Management (CBNRM) approach to promote use of ecosystems goods and services as opposed to reliance on agriculture (in climatically marginal areas for agriculture); and the manipulation of land use leading to land use conversion through for example a shift from pastoralism to game farming in Southern Africa (Smith and Wilson 2002; Nel and Hill 2008) or altered crop or irrigation choices (Seo et al 2008). Buß and Nuppenau (2004) found however that farmer's adaptive responses may in some cases amplify the degrading effects of a worsening climate.

Despite situations of poverty known to be particularly extreme in rural areas in Africa, local populations may play a great role in biodiversity conservation through certain traditional and ancestral practices (which may include taboos, by-laws and sanctions and the recognition of sacred places). This is largely due to local concepts of nature, forest knowledge systems and adaptive natural resource management practices. Mala (2008) found out that in the south of Cameroon, the concepts were based on spiritual, human and natural dimensions with, importantly, the final aim being the search for livelihood. Farmers in the West Region of Cameroon (the Bamilékes and Bamounds) have been able to conserve trees in their farms despite the intensive nature of farming practiced and the lack of land resulting from an increase in population pressure of 2.37% per year (Tchouamo 1998). Meanwhile, the protected areas and plantations of exotic trees created by the state were abandoned and destroyed by fire (Njoukam et al 2008). The farmers made boundaries around their farmlands with various plants species (a mixture of shrubs and trees). Inside the farms and around their homes multipurpose tree species were conserved or planted. For certain species (*Entandrophragma* or *Canarium*) felling permits are required, often following tedious and costly administrative procedures. Similar conditions exist for *Faidherbia albida* and *Vitellaria paradoxa* in the Soudanese zone and *Irvingia gabonensis* in the Guinean zone. Indigenous knowledge on ethno botany has lead to more sustainable management decisions with regards to resource management of species such as *Combretacea* (Bognounou et al 2008).

Generally, structures are currently non-existent for the transfer of indigenous knowledge on adaptation in most countries. There is therefore an urgent need for research into the design and implementation of community-based adaptation strategies. Nevertheless, some land management related adaptation strategies have been adopted by some localities in Ghana in response to complex challenges posed by climate change and environmental degradation (EPA 2008). Traditional knowledge and coping mechanisms such as rationing and reusing water and a return to previous practice of collecting rainwater rather than relying on wells have been observed in drying regions in Ghana (Gyampoh et al 2009). Other community-driven initiatives such as the 'women-made' forests of Kenya and Zimbabwe (Nampinga 2008) and the 'church forests' of Ethiopia (Wassie 2007) deserve further study.

Governance and policies

Appropriate policy and governance arrangements are essential for supporting sustainable forest management and for effectively addressing climate change issues. The need for new governance systems was highlighted by Seppälä et al (2009b). In particular, Seppälä et al (2009a,b) stress the need for new modes of governance that enable meaningful stakeholder participation, provide secure land tenure and forest user rights and sufficient financial incentives. The global report also highlights the importance of inter-sectoral coordination and policy integration. It concludes that policymakers should aim to demonstrate the benefits of adapting forests to climate change through integrated land use at the project level rather than by attempting large-scale transformative changes that almost always fail.

Issues such as land tenure, decentralisation etc. are often poorly managed in developing countries. A better understanding of environmental and human history in Africa may help to prevent misconceptions of prior influences which can result in poor policy (Fairhead and Leach 1995). Stringer (2009) points out the dangers of allowing policy to be driven by orthodoxies rather than evidence, with regard to desertification in Swaziland. The impacts of cross-sectoral policies on forests (Kigenyi et al 2002) should also be considered when discussing forest policy.

Agyemang-Bonsu (2009) points out the variations in poverty levels in Ghana, as determined by the various ecological zones (Table 17). This underlines the need for regional considerations to be taken into account in climate change adaptation studies and policy formulation. Similar policies and external drivers may not lead to similar outcomes in disparate regions (Kull et al 2007).

Table 17. Ecological zones and mean poverty levels in Ghana (adapted from Agyemang-Bonsu 2009)

Eco-climatic Zone	Mean temperature (^{o}C)	Mean Rainfall (mm)	Mean poverty level (%)
Coastal savannah	27.1	750	34.8
Rainforest	26.5	2 250	45.0
Semi-deciduous	26.3	1 605	60.9
Transitional	27.1	1 350	84.4
Guinea savannah	27.1	1 175	93.1
Sudan savannah	28.7	870	90.6

Due to the limited technical understanding of climate in Africa as a whole, and the restricted resource and expertise in handling climate issues, it becomes increasingly essential to raise Africa’s capacity to handle climate variability, increase the resilience and reduce the vulnerability of the continent to climate variability and change (DFID 2004b).

African forests face a range of climatic and non-climatic challenges, and possibilities exist for synergies between existing development and environmental programmes (Cowie et al 2007; OSS and GTZ 2007; Nkem et al 2008c). There is considerable risk however that conflicts may occur between different stakeholders, or even between different international agreements (Eastaugh 2008).

Examples of governance adaptation relevant to forestry include the decentralisation of local governance of resources such as the Community Based Natural Resource Management (CBNRM) approach to promote the use of ecosystems goods and services (Shackleton et al 2002) as opposed to a reliance on agriculture in climatically marginal areas. Some National Communication Reports (e.g. EAD [2002], from Malawi) mentioned the establishment of seed banks that maintain a variety of seed types to preserve biological diversity and provide farmers with an opportunity to diversify their products and tree cover. Soil conservation and well-managed tree plantations are also important (Osman-Elasha 2006b). Roberts (2008) reviewed National Adaptation Programmes of Action (NAPAs) for several African countries, and found a range of projects relevant to forests (Table 18). Although not always specifically targeted to climate change adaptation, these projects aim to improve forest management or increase forest area, and will thus increase the climate change resilience of forest dependant communities. A full collection of NAPAs is available via the UNFCCC at: http://unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php

Table 18. National Adaptation Programmes of Action (Roberts 2008)

Country	Project Title	Principle Implementing Body	Funding a barrier
Benin	Support participatory management of gallery forests.		
	Prevention and control of forest fires: capacity development of riverine communities.		
	Support sustainable management of animal biodiversity.		
	Support community planting.		
	Support sustainable management of energy wood.		
Burkina Faso	Sound management of natural resources, valorising non wood forest products (NWFP) in the East of Burkina		
	Promotion of improved stoves, renewable energies and equipments of substituted energy (auto-cooker, water heater and solar-energy dryer etc.)		
Burundi	Rehabilitation of Degraded Areas	The Forestry Department, National Coordinator, the National Director, INECN, representatives of all stakeholders.	Yes
	Safeguarding the most Vulnerable Natural Environments	INECN, the National Coordinator, representatives from NAPA Committee, the National Environment Commission,	Yes
	Capacity Building to Promote Energy-Wood Saving Techniques	The framework of the Ministry for Land Management, Tourism and	Yes

		Environment. Forestry Department, the National Director.	
	Education to Climate Change Adaptation	INECN, the National Coordinator, department in charge of woodlots, representatives from all stakeholders. A Steering Committee representatives from the NAPA Committee and the National Environment Commission, members of the biodiversity-related activities coordinating body and representatives from institutions responsible for biodiversity.	Yes
Cape Verde	Modernization and diversification of agricultural production for food security improvement.		Yes
Comoros	Defence and Restoration of degraded soils (DRS)	Island Minister of Environment, the Union Ministry in charge of Environment.	Yes
	Reconstitution of the basin slopes	MoE, NGOs, Union Ministry in charge of Environment.	Yes
	Use of non-metallic local materials for the construction of low price housing.	Island Ministry of Environment, with the support of the national laboratory for Public Works, under the coordination of the Union Ministry of Environment.	Yes
Dijbouti	Risk reduction for production systems on the coastal zone through integrative, adaptive and participatory management with community organisations		
	Promote the protection of forest areas at Day and Mabla and introduction of improved stoves		
Eritrea	Encourage Afforestation and Agroforestry through Community Forestry Initiative	MoA and its regional branches.	Yes
	Groundwater Recharging for Irrigation wells	MoA, WRD.	Yes
Ethiopia	Community based carbon sequestration in the Rift Valley system of Ethiopia.	Environmental Protection Authority	Yes
	Promotion of on Farm and Homestead Forestry and Agroforestry in Arid, Semi-Arid and Drysub Humid Parts of Ethiopia.	Ministry of Agriculture and Rural Development (MoRAD)	Yes
Guinea	Promotion of agroforestry		
	Promotion of appropriate technologies in adaptation		
	Promotion of fire management and protection of forests		
Lesotho	Management and Reclamation of Degraded and Eroded Land in the Flood Prone Areas (Pilot project for Western-Lowlands).	The project will be implemented by the Ministry of Forestry and Land Reclamation working closely with Local Government and community organizations.	Yes
Malawi	Restoring forests in the Upper, Middle and Lower Shire Valleys catchments to reduce siltation and the associated water flow problems:	Department of Forestry	No
Mauritania	Substitution of ligneous fuel		Yes
	Institutional reinforcement of the structure responsible for nature conservation		No
	Improvement of knowledge of the resource and its sustainable management.		No
	Fixation of shifting dunes threatening the national socioeconomic infrastructure		Yes
	Participatory reforestation for energy and Agroforestry in the agricultural zones		Yes
	The protection and reinforcement of the dune bar along the coastline in Nouakchott		No
Niger	Mobilization of surface water and exploitation of ground water	Agricultural development departments, water resources services.	Yes
	Development of anti-erosion infrastructures (CES/DRS) for agricultural forestry and	Ministry of Agricultural Development, Ministry of Water Resources and	Yes

	pastoral purposes	Environment, Village Development Committee, CNEDD.	
	Popularization of animal and vegetative species that are most adapted to climatic conditions	Ministry of Agriculture, Ministries of Animal Resources and Environment, Executive Secretariat of the CNEDD.	Yes
Rwanda	Conservation and protection of lands against erosion and floods at district level in vulnerable regions	Project coordination, MINITERE, MININFRA, Districts, Provinces.	Yes
	Increase the capacity of adaptation of villages “Imidugudu” in vulnerable regions through improvement of drinking water and sanitation and alternative energy services and promotion of non-agricultural activities.	Project coordination - MINITERE, - MININFRA, - ELECTROGAZ,	No
	Preparation and implementation of woody combustible substitution national strategy to combat the deforestation and put a brake on erosion due to climate change.	MINITERE, MININFRA, MININTER, ELECTROGAZ, REMA; Research institutes: KIST, IRST, Private sector: Individuals and professional associations, Decentralized structures: Districts and Sectors.	Yes
Sudan	Enhancing resilience to increasing rainfall variability through rangeland rehabilitation and water harvesting in the Butana area of Gedarif State	The description of highest priority projects did not give any implementing body names.	Yes
	Reducing the vulnerability of communities in drought-prone areas of southern Darfur State through improved water harvesting practices		
	Environmental conservation and biodiversity restoration in northern Kordofan State as a coping mechanism for rangeland protection under conditions of increasing climate variability		
	Strategies to adapt to drought-induced water shortages in highly vulnerable areas in Central Equatorial State		
	Enhancing the resilience of water-stressed agricultural systems through agroforestry in River Nile State		
	Rehabilitation of gum arabic belt for poverty reduction, combating desertification and conservation of biodiversity		
	Rehabilitation of gum arabic belt for increase of resilience, diversification of livelihoods and conservation of resources in Alrahad locality		
	Development of social forestry schemes in Sharia, Almalam, Muhagria, Dirbat, Mershing		
	Agro forestry to increase the adaptive capacity to climate changes in west Juba areas.		
Zambia	Management of critical habitats	ZAWA, MTENR Department of Water Affairs (DWA) communities	Yes
	Promote natural regeneration of indigenous forests	Department of Forestry and Communities.	
	Eradication of Invasive Alien Species	Department of forestry and communities	
Tanzania	Climate Change Adaptation through Participatory Reforestation in Kilimanjaro Mountain.	Ministry of Natural resources and Tourism, Ministry of Energy and Minerals, Local Government Authority, Academic and Research Institutions, local communities, Local NGOs/CBOs	Yes
	Community Based Mini-hydro for Economic Diversification as a result of Climate Change in Same District.	Ministry of Energy and Minerals in collaboration with Local Government Authority, Ministry of Natural Resources and Tourism, local communities and NGOs/CBOs.	

Uganda	Community Tree Growing Project	Forestry Resource Research Institute (FORRI) of the National Agricultural Research Organization (NARO). NFA, MWLE, MAAIF, ENR/SWG, NAADS and Department of Information in the President's Office.	Yes
	Indigenous Knowledge (IK) and Natural Resources Management Project	The Ministry of Water, Lands and Environment (Department of Meteorology)	Yes

Some Parties indicated that they had initiated specific institutional frameworks dedicated to climate change activities. Others have set research activities as part of regional networks, e.g. the Botswana Global Change Research Committee affiliated with the International Geosphere–Biosphere Programme (IGBP). Malawi noted the need to set up an institutional framework for undertaking studies on climate change (UNFCCC 2005). Many countries reported research efforts on variability and impacts, and monitoring and adaptation. Some countries in southern Africa indicated that their universities offer post-graduate courses on climate change. In South Africa for example, five universities undertake climate change research and offer specialized training, such as on implementation of Clean Development Mechanism (CDM) projects. South Africa is also funding research on climate change through its National Research Foundation (UNFCCC 2005).

At the institutional level, many countries stressed the critical role that local government units play in the development and implementation of policies and measures to address climate change. Some Parties have established training programmes for local government officials. For example, Botswana assisted its district and metropolitan assemblies to draw up local environmental action plans that contain climate change programmes and projects.

Decentralisation is generally assumed to be a positive force for effective governance, on the assumption that lower levels of government will be more attuned to the wishes of the local population and more easily held democratically accountable (Lawry 1990). Where this accountability fails however, the advantages of decentralisation are not so easily determined (Ribot 2002). In some cases the decentralisation process may be in some ways ‘designed to fail’, as central governments limit the ability of local governments to make independent decisions, or choose local authorities likely to carry out the central government’s wishes. Agrawal and Ribot (1999) studied decentralisation in the forest sector in Senegal and Mali and Ribot et al (2004) report on Senegal and Uganda. These studies find that much of the ‘on paper’ decentralisation is not yet fully applicable in practice. Oyono (2007) finds a similar lack of positive results in central African states, while Brockington (2007) reports on the difficulties of village-based conservation under circumstances of local government corruption. Kigenyi et al (2002) point out the lack of financial resources and management and technical expertise at local levels, a lack of commitment to SFM from local authorities and a lack of integration with district management plans and clear operating frameworks as common inhibiting factors. Brockhaus and Kambire (2009, cited in Seppälä 2009a) are more positive about the potentials of decentralisation in Burkina Faso.

Carbon storage in African woodlands is significant (Unruh et al 1993; Glenday 2008), and increasing interest is being shown in tree plantations under the Clean Development Mechanism Afforestation/Reforestation (CDM-AR) of the Kyoto Protocol. 27% of the world's potential CDM-AR land (based on biophysical suitability and UNFCCC rules) is in sub-Saharan Africa (Zomer et al 2008, Figure 15). Zomer et al (2008) however raise some concerns about food security and local livelihoods if the amount of land under CDM-AR projects were to be significantly increased. Henry et al (2009) express some doubts as to the feasibility of CDM-AR schemes in Kenya, and issues of land tenure (Unruh 2008) must also be debated and settled before CDM-AR projects can become a reality. Nkem et al (2007b) raise concerns about possible incompatibilities of some CDM projects with other essential forest outputs and community needs, while Reyer et al (2009) stress the need for CDM carbon mitigation projects to consider adaption as a core element of their design.

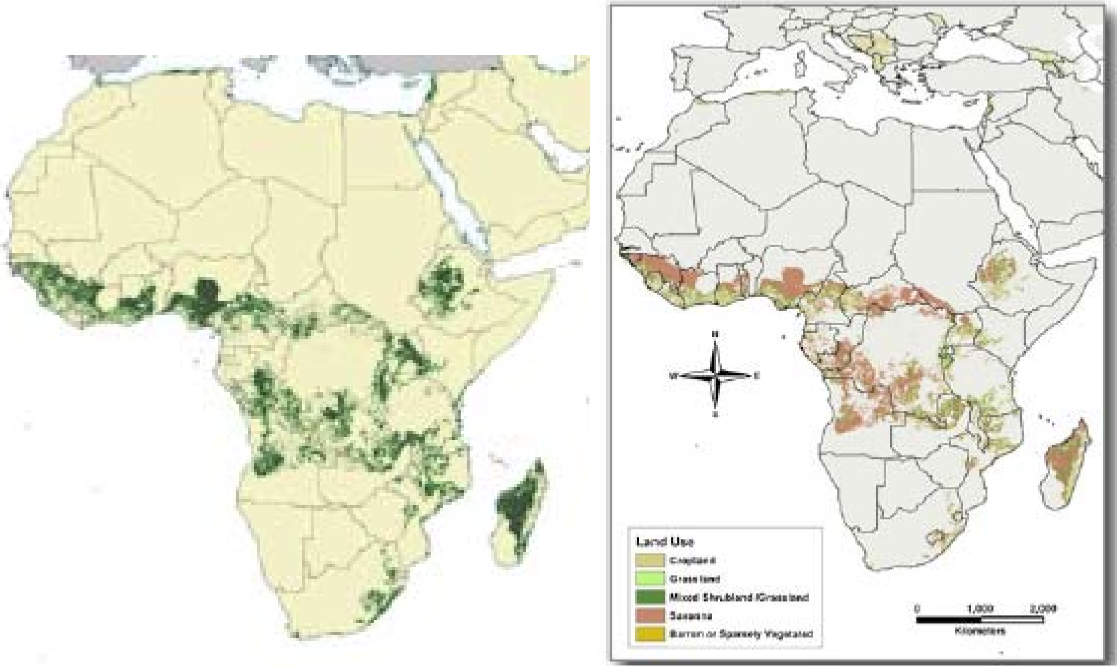


Figure 15. 1st figure – potential CDM-AR land. 2nd figure – current land use in those areas (Zomer et al 2008)

There are also concerns that extensive plantation developments may have deleterious effects on water supplies (Dye and Versfeld 2007). Plantation areas in parts of southern Africa are calculated to reduce available water supplies to streams by 98.6 mm per year. The hydrological impacts of afforestation were also studied by Trabucco et al (2008). Forestry activities have been legally declared a 'stream flow reduction activity' in South Africa (Brown and Woodhouse 2004). Fuller et al (2003) calculate that an increase in forestry in the Limpopo catchment in South Africa to the maximum possible extent (i.e., all areas receiving greater than 650 mm of rainfall per year) would reduce water runoff by around 7–9%, or 20 mm per year. This can lead to friction between forestry and other water users (Brown and Woodhouse 2004, Table 19), which must be carefully managed to prevent conflict.

Table 19. Water requirements for the various water users in the Inkomati for the year 2003 (million m³ / annum) (adapted from Brown and Woodhouse 2004)

Catchments	Komati (North of Swaziland)	Komati (North of Swaziland)	Crocodile	Sabie/ Sand	Total Inkomati WMA %	
Irrigation	21	222	257	65	565	55.7
Urban	2	3	35	22	62	6.3
Rural	4	6	7	4	21	2.1
Mining	-	1	23	0	24	2.4
Afforestation	23	12	42	37	114	11.5
Total Requirements	50	244	364	128	542	
International requirements	-	60	49	0	109	11.0
Transfers	97	-	0	0	97	9.8
Grand Total	147	304	413	128	992	

Effective governance frameworks also need to consider the indirect effects of climate change, for example the conversion of forests to agriculture or biofuel crops (Seppälä et al 2009a). An international initiative that is gaining some traction is Reducing Emissions from Deforestation and Degradation in Developing Countries (REDD). Essentially, REDD aims to provide a financial compensation to countries that are willing and able to reduce emissions from deforestation and forest degradation. Bellassen and Gitz (2008) found that at current carbon prices it may be economic in Cameroon to reserve forests rather than to log and clear them for crop growing, and similar results have been found in Ghana (Osafo 2005). Currently, Ghana is taking the lead role in Africa in preparing a REDD-Readiness Preparation Proposal for submission to the Forest Carbon Partnership Facility (FCPC). Concerns have however been raised about the implications of REDD to the environment and to forest-dependant people (Kowero n.d.; Putz and Redford 2009), REDD may in some cases reverse trends towards decentralised forest management (Phelps et al 2010).

It is important that forests still retain the interest of people, rather than becoming simply a passive income source. Kalame et al (2008) discuss the case in Ghana, where there is a risk of ‘maladaptation’ due to forest protection laws preventing forest-dependant people from harvesting trees on their own land. Mogaka et al (2001) stress the need to maintain an economic benefit from the forest in order to keep community support, and Barrow et al (2002) point out several benefits and risks of forest commercialisation. In line with the idea that local communities should benefit from management, Oyono et al (2009) discussed the distribution of logging taxes in Cameroon, which is done in the ratio of 50% for the state, 40% for local councils and 10% for the village communities.

Forests are better managed where property rights are clear and rules are enforced. Uncertainty of land tenure has been blamed for contribution to deforestation. A lack of recognition of traditional ownership structures and shared or individual rights has reduced the incentive for local communities to plant and protect trees and shifts the responsibility for protecting the asset solely to the State (Banana and Gombya-Ssembaajjwe 2000). If forests have little economic value to local people then institutions and habits of sustainable management are not likely to develop. Unruh (2008) examined land tenure issues in relation to afforestation/reforestation projects, and concluded that there are five prohibitive obstacles:

- The disconnect between customary and statutory land tenure
- Legal pluralism
- Tree plantings being used as a land claim
- The expansion of tree plantings in smallholder agricultural areas
- Difficulties in defining ‘abandoned land’

Kigenyi et al (2002) discuss ‘community use rights’ in Kenya, as a means of ensuring that local communities retain some interest in forests managed by other bodies. The positives of private forest ownership in Tanzania were studied by Ylhäisi (2003), but in other environments the concept of land tenure and forest ‘ownership’ may be foreign to forest inhabitants, and lead to misunderstanding, resentment and conflict (Lewis 2005). Tesema (2008) examine the system of leaseholds in Ethiopia, while Alden-Wily and Mbaya (2001) discuss the benefits of community forestry. Various forms of both traditional and modern land tenure are in existence (Colchester et al 2001), and policymakers must take care that new systems are compatible with community needs and that pre-existing rights are not impinged.

Migration is a common adaptation strategy for communities faced with intolerable environmental change, and pro-active plans should be put into place to cope with the expected movements of large numbers of people (Amwata et al 2008). Liu et al (2008) have pinpointed future hunger hotspots in sub-Saharan Africa, which may help to identify which forest regions are likely to come under greatest pressure.

Training and capacity building in Africa has been reflected in most of the project concepts of the GCOS-RAP for Eastern-Southern and Western-Central Africa (GCOS 2002; GCOS 2004) as a priority consideration. Specifically the following areas are mentioned as urgent:

- Application of the PRECIS (Providing Regional Climates for Impacts Studies) model is important to all countries in the region in planning for adaptation to climate variability and climate change
- Ocean modelling and its applications has been identified as a critical requirement in Africa with provision of university fellowships cited as an effective means of addressing this need
- Database management and the use of national climate data for climate change analyses
- The provision of advanced training to local staff
- Satellite applications for monitoring and change detection
- Estimation techniques to convert the remotely sensed proxy data into measures of weather variables
- Validation and application of the impact models for use in different countries

- Methodologies and tools for climate change monitoring, detection and attribution and suitable methods for developing climate change scenarios
- Methods and tools necessary for vulnerability and adaptation assessment

A number of options and initiatives have been identified to address African resource and capacity gaps in the areas of observations, research and model development, prediction activities, and of the delivery of climate services. Examples include: the AIACC programme, an important element of which was to contribute to capacity-building among African scientists in relation to model development and construction of regional scenarios appropriate to the assessment of impacts and vulnerability in Africa (Brew and Washington 2004), the IRI programme (which set up contracts for the supply of model software and training) and WMO and START which have supported training workshops in climate modelling. It should be noted that research and development spending in general is low in Sub-Saharan Africa, at abut 0.3% of GDP (Gaillard 2008).

Conclusions and way forward

Forests in Africa have evolved along with mankind for many thousands of years. Forests cannot be considered without reference to the past influences and future needs of people. It is unlikely that any forest in Africa has developed without anthropogenic influences at some stage, and thus human influence in itself should not be considered a negative factor in forest development.

A lack of information hampers adaptation planning for Africa. This problem includes a comparatively poor network of climate monitoring stations, incomplete or contradictory forest and forest products statistics, low levels of detail in future modelling and an over-reliance on secondary information sources. Acceptance of orthodoxies not based on current science can lead to poor policy outcomes.

There is a more direct link between forest welfare and human wellbeing in Africa than in many (or most) other regions. Many communities directly rely on forest resources for survival, and widespread poverty reduces adaptive capacity. African communities may be directly affected by threats to ecosystem services.

Synergies are possible between climate adaptation and other policy prerogatives, and there is a clear link between sustainable development of forests and reduced community vulnerability.

Although climate change risk is high, environmental change is not new to Africa and adaptive methods are well developed in some communities. Indigenous knowledge and strengths should be recognised and supported.

Forests must retain the interests of people, and there is a clear need to maintain the economic benefits of forests for communities. Ownership or forest use rights are a vital component of maintaining community support.

The link between forest policy, community wellbeing and energy policy must be explicitly recognised. Fuelwood and charcoal are very large components of many regions’ energy supply, but do not appear to attract much policy attention.

Any policies aimed at climate change adaptation in forests must take a holistic approach, and recognise that the impacts of change will largely be seen through secondary pathways such as changes to fire and pest regimes. Other modes of environmental change must be taken into account, and adaptative solutions must take a broad view of community needs. Secondary social effects of climate change are also important considerations. Migration from adversely effected areas will add to pressures on forests even if those forests face relatively benign climate influences. Increasing needs for agricultural land also adds to pressure on forests.

Based on this report, the above summary and the expert opinion of the African contributors, the thematic policy workshop on 3–4 December 2009 in Vienna, Austria and subsequent discussions developed the following key messages:

1) Although climate-change projections for Africa are highly variable, the average increase in temperature on the continent is likely to be higher than the average increase globally. There is a significant risk that the adaptive capacity of many African forest ecosystems to provide vital goods and ecosystem services will be exceeded.

2) People in Africa are disproportionately dependent on forest goods and services and therefore are particularly vulnerable to the impacts of climate change. Individuals, societies and institutions should be aware of the likely impacts of climate change on forests and forest-dependent people and put strategies in place to adapt to them.

3) Improving the adaptive capacity of forest-dependent communities is important in order to reduce their vulnerability to the effects of climate change. Participatory approaches should be used to obtain a better understanding of local knowledge and perceptions of climatic change and to raise awareness about vulnerabilities and related adaptation measures. Moreover, there is a need to develop and reorient educational systems and programmes.

4) Climate change is adding to a range of other pressures – such as agricultural expansion and the over-use of forests – on forest ecosystems in Africa, some of which are currently more pressing than climate change. Measures that reduce non-climatic pressures can help reduce the overall vulnerability of forest ecosystems. Such measures, including forest restoration and rehabilitation, can be implemented in an integrated manner as part of sustainable forest management.

5) The development and implementation of adaptation measures as part of sustainable forest management need to be underpinned by new modes of governance that are sensitive to context, take a broad view of community needs, and respond quickly to policy learning. Governance that enables effective stakeholder and community participation, transparent and accountable decision-making, secure land ownership and tenure, and the equitable sharing of benefits and responsibilities needs to be promoted.

6) Climate-change adaptation planning in Africa is hampered by a lack of information about current and future climate-related impacts and vulnerabilities. Reliable projections of regional and local impacts require investments in research and monitoring infrastructure and increased support for early warning systems and preparedness measures.

7) Forests can play an important role in achieving broader climate-change adaptation goals but may be threatened by impacts from other sectors. Strategies for adapting forests to climate change should be coordinated with those of other sectors and integrated into national and regional development programmes and strategies.

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References

Abdel Nour HO (1997) Gum Arabic in Sudan: Production and socio-economic aspects. Proceedings of the International Expert Meeting on Medicinal, Culinary and Aromatic Plants in the Near East, 19-21 May 1997, Cairo. Online via http://www.fao.org/docrep/x5402e/x5402e00.htm Accessed 23 January 2010.

Abdou M (2004) Neem decline and scale insects attacks in the Sahel: the state of knowledge and the way forward. In: *Pest Management in Tropical Plantations*, International Workshop Proceedings, Eds. Cobbinah JR, Ofori DA and PP Bosu, University Press, Ghana. Pp. 119-128.

Achard F, Eva HD, Stibig HJ, Mayaux P, Gallego J, Richards T and Malingreau JP (2002) Determination of deforestation rates of the world's humid tropical forests. *Science* vol. 297, pp. 999-1002.

Adepoju AA and Salau AS (2007) Economic valuation of non-timber forest products (NTFPs). MPRA Paper Number 2689, Munich Personal RePEc Archive.

Adger, W. N. and Brook N. (2002), Does global environmental change cause vulnerability to disaster?/CSERGE and Tyndall Centre for Climate Change Research, University of EastAnglia, Norwich, NR4 7TJ, UK. Online at http://www.aiaccproject.org/meetings/Norwich_02/Norwich_CD/APPENDICES/ARTICLES_VULN_ADAPTCAP/EC_VULN_TO_DISASTER.PDF Accessed 10 October 2009.

Agobia CA (1999) *Enhancing sustainable livelihoods in drought prone areas of Mudzi (Makaha Ward) and Gwanda (Gwanda Ward 19): Building on adaptive strategies*. Final Report Project Number 050/19284. International Institute for Sustainable Development Community Drought Mitigation Project, Winnipeg.

Agrawal A and Ribot J (1999) Accountability in decentralization: A framework with South Asian and West African cases. *The Journal of Developing Areas* vol. 33, pp. 473-502.

Agyemang-Bonsu WK (2009) Overview of Ghana's climate change adaptation activities. Paper presented at the National Climate Change Committee Retreat, Koforidua, 10 – 13 September 2009.

Alden-Wily L and Mbaya S (2001) Land, People and Forests in Eastern and Southern Africa at the beginning of the 21st century. The impact of land relations on the role of communities in forest future. IUCN-EARO, Nairobi.

Amous S (1999) The role of wood energy in Africa. *FAO Wood Energy Today for Tomorrow Series*, Food And Agriculture Organisation, Rome. Online at http://www.fao.org/docrep/x2740E/x2740e00.HTM Accessed 1 November 2009.

Amwata D and 20 others (2008) *Climate Change Adaptation in Africa*. Scoping Paper for the Expert Group Meeting on Climate Change Adaptation of the African Ministerial Conference on the Environment. Policy brief.

Anaeto CF and Emenyonu CA (2005) Effect of HIV/AIDS on the agricultural workforce: Implications for sustainable agricultural development. *Journal of Agriculture, Forestry and Social Sciences* vol. 3(1), pp. 151-161.

Andah, B. W. (1993) Identifying early farming traditions of West Africa, in Shaw, T., Sinclair, P., Andah, B. and Okpoko, A. (eds.) *The Archaeology of Africa: Food, Metals and Towns*, London, Routledge, 240-254.

Andreone F, Cadle JE, Cox N, Glaw F, Nussbaum RA, Raxworth CJ, Stuart SN, Vallan D and Vences M (2005) Species review of amphibian extinction risks in Madagascar: conclusions from the global amphibian assessment. *Conservation Biology* vol. 19(6), pp. 1790-1802.

APP (2009). Climate Change: A Call to Action for African Leaders (Policy brief). Africa Progress Panel. Geneva, Switzerland.

Ardayfio-Schandorf E (1996) The fuelwood/energy crisis in Sub-Saharan Africa. In: *Sustaining the Future: Economic, Social and Environmental change in Sub-Saharan Africa* G Benneh, WB Morgan and JI Uitto (eds) United Nations University Press, Tokyo.

Arnold M and Townson I (1998) *Assessing the potential of forest product activities to contribute to rural incomes in Africa*. ODI Natural Resource Perspectives No. 37, Overseas Development Institute, London.

Atmadja S (2004) Bush Meat : Hunting, Trade and Traditions, In : Ghana : North Carolina State University Department of Forestry study tour, North Carolina State University. Online at http://www.ncsu.edu/project/cnrint/GHANA/notebook_Masterfile.pdf Accessed 23 January 2010

Augustine DJ, McNaughton SJ and Frank DA (2003) Feedbacks between soil nutrients and large herbivores in a managed savanna ecosystem. *Ecological Applications* vol. 13(5), pp. 1325-1337.

Banana AY and Gombya-Ssembaajjwe WG (2000) Successful forest management: The importance of security of tenure and rule enforcement in Ugandan forests. In: Gibson CC, McKean MA and Ostrom E (eds) People and Forests: Communities, institutions and governance. Massachusetts Institute of Technology.

Barany M, Hammett AL, Sene A and Amichev B (2001) Non-timber forest benefits and HIV/AIDS in sub-Saharan Africa. *Journal of Forestry* vol. 99(12), pp. 36-41.

Barker T, Bashmakov I, Bernstein L, Bogner JE, Bosch PR, Dave R, Davidson OR, Fisher BS, Gupta S, Halsnæs K, Heij GJ, Kahn Ribeiro S, Kobayashi S, Levine MD, Martino DL, Masera O, Metz B, Meyer LA, Nabuurs GJ, Najam J, Nakicenovic N, Rogner HH, Roy J, Sathaye J, Schock R, Shukla P, Sims REH, Smith P, Tirpak DA, Urge-Vorsatz D, Zhou D (2007) Technical summary. In: Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA (eds) Climate change 2007: mitigation. Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.

Barrow E (2002) Shinyanga, Tanzania: Case study under the UNEP-MNCM Global Partnership on forest Landscape Restoration. United Nations Environment Program.

Baccini A, Laporte N, Goetz SJ, Sun M and Dong H (2008) A first map of tropical Africa's above-ground biomass derived from satellite imagery. *Environmental Research Letters* vol. 3(9).

Bahuchet S (1990) A historical background of cultivated plants in Central Africa. In: Hladik CM, Bahuchet S, de Garine I (eds) Food and nutrition in the African rain forest. UNESCO-MAB, Paris, p 28–30.

Barrow E, Clarke J, Grundy I, Kamugisha-Jones R and Tessema Y (2002): Whose Power? Whose Responsibilities? An Analysis of Stakeholders in Community Involvement in Forest Management in Eastern and Southern Africa. Nairobi, IUCN-EARO.

Beentje HJ, Adams B and Davis SD (1994) Regional Overview: Africa. In: Davis SD, Heywood VH, Hamilton AC (eds) *Centres of plants diversity. A guide and strategy for their conservation*. *Vol 1*, 354 pp.

Bellassen V and Gitz V (2008) Reducing emissions from deforestation and degradation in Cameroon – Assessing cost and benefits. *Ecological Economics* vol. 68(1-2), pp. 336-344.

Bergonzini JC and Riera B (2005) Présentation du bassin du Congo, les forêts tropicales humides. *Le Flamboyant* vol. 59 /60, pp. 9-14.

Blay D, Bonkoungou E, Chamshama SAO and Chikamai B (2004) *Rehabilitation of Degraded Lands in Sub-Saharan Africa: Lessons Learned from Selected Case Studies.* Forestry Research Network for Sub-Saharan Africa and the International Union of Forest Research Organisations' Special Programme for Developing Countries, Vienna, Austria.

Bognounou F, Savadogo P, Thiombiano A, Oden PC, Boussim IJ and Guinko S (2008) Ethnobotany and utility evaluation among four ethnic groups in western Burkina Faso. . In: *International Conference on Traditional Forest Knowledge and Sustainable Forest Management in Africa; Accra, Ghana; 15-17 October 2008*.

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. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. ML Parry, OF Canziani, JP Palutikof, PJ van der Linden and CE Hanson (Eds), Cambridge University Press, Cambridge UK.

Bond WJ and Midgely GF (2000) A proposed CO2 controlled mechanism of woody plant invasion in grasslands and savannas. *Global Change Biology* vol. 6(8), pp. 865-869.

Bond WJ, Midgley GF and Woodward FI (2003) The importance of low atmospheric CO2 and fire in promoting the spread of grasslands and savannas. *Global Change Biology* vol. 9(7), pp. 973-982.

Bond WJ, Woodward FI and Midgely GF (2005) The global distribution of ecosystems in a world without fire. *New Phytologist* vol. 165(2), pp. 525-537.

Born C, Kjellberg F, Chevallier MH, Vignes H, Dikangadissi JT, Sanguie J, Wickings EJ and Hossaert-McKey M (2008) Colonization processes and the maintenance of genetic diversity: insights from a pioneer rainforest tree, *Aucoumea klaineana*. *Proceedings of the Royal Society B* vol. 275, pp. 2171-2179

Boven K and Morohashi J (eds) (2002) *Best Practices using Indigenous Knowledge*. Nuffic, The Hague and UNESCO/MOST, Paris.

Brahima S (2009) Mission report Monrovia January 30th to February 8th 2009, Permanent Interstate Committee for Drought Control in the Sahel. Online at http://www.agrhymet.ne/PDF/RAPPORT_monroviang.pdf Accessed 13 February 2010.

Brink AB and Eva HD (2008) Monitoring 25 years of land cover change dynamics in Africa: A sample based remote sensing approach. *Applied Geography* vol. 29(4), pp. 501-512.

Brncic TM, Willis KJ, Harris DJ and Washington R (2007) Culture or climate? The relative influence of past processes on the composition of the lowland Congo rainforest. *Philosophical Transactions of the Royal Society of London B – Biological Science* vol. 362(1478), pp. 229-242.

Brockhaus M and Djoudi H (2008) Adaptation at the Interface of Forest Ecosystem Goods and Services and Livestock Production Systems in Northern Mali. CIFOR, Bogor, Indonesia.

Brockhaus M and Kambire H (2009) Decentralisation as a window of opportunity? In: Adger WN, Lorenzoni I and O'Brien K (eds) Adapting to Climate Change: Thresholds, Values, Governance. Cambridge University Press, Cambridge.

Brockington D (2007) Devolution, community conservation and forests: On local government performance and Village forest Reserves in Tanzania. *Society and Natural Resources* vol. 20, pp. 835-848.

Brooks N (2004) *Drought in the African Sahel: long-term perspectives and future prospects*. Tyndall Centre Working Paper No. 61

Brown S (1996) Forest influences. *Unasylva* vol. 47.

Brown J and Woodhouse P (2004) *Pioneering Redistributive Regulatory Reform: A Study of Implementation of a Catchment Management Agency for the Inkomati Water Management Area, South Africa.* University of Manchester Centre on Regulation and Competition Working Paper Series No. 89.

Burgess and Clarke (2000) *Coastal Forests of Eastern Africa.* International Union for Conservation of Nature and Natural Resources.

Buß HJ and Nuppenau EA (2004) Climate Change and Optimal Farming Strategies in Semi-Arid Southern Africa. Deutscher Tropentag 2004 Conference on International Agricultural Research for Development, Berlin, October 5-7, 2004. Online at http://www.tropentag.de/2004/abstracts/full/43.pdf Accessed 23 November 2009.

Bytnerowicz A, Omasa K and Paoletti E (2006) Integrated effects of air pollution and climate change on forests: A northern hemisphere perspective. *Environmental Pollution* vol. 147(3), pp. 438-445.

Calzadilla A, Zhu T, Rehdanz K, Tol RSJ and Ringler C (2009) *Economywide Impacts of Climate Change on Agriculture in Sub-Saharan Africa*. International Food Policy Research Institute.

Campbell BM. (Ed) (1996) *The Miombo in Transition: Woodlands and Welfare in Africa*. Centre for International Forestry Research (CIFOR), Bogor, Indonesia

Canadell JG, Raupach MR and Houghton RA (2009) Anthropogenic CO_2 emissions in Africa. *Biogeosciences* vol. 6, pp. 463-468.

Cao M, Zhang Q and Shugart HH (2001) Dynamic responses of African ecosystem carbon cycling to climate change. *Climatic Research* vol. 17(2), pp. 183-193.

Casey J (1998) The ecology of food production in West Africa. In: *Transformations in Africa: Essays on Africa's Later Past*, G Connah (ed). Leicester University Press, London.

Casey J (2005) Holocene occupations of the forest and savanna. In: *African archaeology* AB Stahl (ed). Blackwell Publishing, Oxford, UK.

Cavendish W (2000) Empirical regularities in the poverty-environment relationship of rural households: Evidence from Zimbabwe. *World Development* vol. 28(11), pp. 1979-2003.

CBD (2006) *Global Biodiversty Outlook 2*. Convention for Biological Diversity. Online via http://www.cbd.int/gbo2/

CBFP (2006) *The Forests of the Congo Basin; State of the forest 2006*. Congo Basin Forest Partnership.

Chikamai B, Tchatat M, Tieguhong JC and Ndoye O (2009) Forest Management for Non-Wood Forest Products and Services in Sub-Saharan Africa. *Discovery and Innovation* vol. 21, pp. S50-S59.

Chikamai B and Tchatat M (2005) Forest management for non-wood products and services in Africa. Royal Swedish Academy of Agriculture and Forestry, African Forest Research Network of the African Academy of Sciences and the Food and Agriculture Organisation.

Christensen JH and 16 others (2007) *Regional climate projections*. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M and Miller HL (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.

Christie F and Hanlon J (2001) *Mozambique and the great flood of 2000*. The International African Institute, James Currey and the Indiana University Press.

Christy JR, Norris WB and McNider R (2009) Surface temperature variations in East Africa and possible causes. *Journal of Climate* vol. 22(12), pp. 3342-3356.

Claussen M, Kubatzhi C, Brovkin V and Ganopolski A (1999) Simulation of an abrubt change in Saharan vegetation in the mid-Holocene. *Geophysical Research Letters* vol. 26, pp. 2037-2040.

Claussen M, Brovkin V, Ganopolski, A, Kutzbaki C and Petoukhov V (2003) Climate change in northern Africa: the past is not the future. *Climatic Change* vol. 57, pp. 99-118.

Cobbinah J.R. (2007) Climate change and indigenous adaptive strategies. Paper presented at National Traditional knowledge Working Group meeting, Accra, Ghana, 2-3 August 2007.

Cobbinah JR, Wagner MR, Ofori DA, Agyeman VK and Adu-Bredu S (2000) Sustainable production of Iroko: critical issues, In *Research Advances for the restoration of Iroko*, eds JR Cobbinah and MR Wagner. University Press, Kumasi, pp. 113-118.

Cobbinah JR, Agyeman VK, Ofori DA and Wagner MR (2001) Overview of the Iroko (Milicia excelsa) project: 1986 - 2000. pp. 1-10 In: *Research Advances in Restoration of Iroko as a Commercial Species in West Africa*, JR Cobbinah, and MR Wagner (Eds).

International Tropical Timber Organization. Odum Workshop. Nov 2000. Kumasi, Ghana. 134pp.

Cobbinah JR, Wagner MR, Ofori DA and S Adu-Bredu (2004) Deployment of resistance and tree strategies in the management of pests of tropical plantations. In: *Pest Management in Tropical Plantations*. International Workshop Proceedings, Eds Cobbinah JR, Ofori DA and PP Bosu, University Press 244pp.

Cohen MJ, Tirado C, Aberman N and Thompson B (2008) *Impact of Climate Change and Bioenergy on Nutrition*. International Food Policy Research Institute (IFPRI) and Food and Agriculture Organization of the United Nations.

Colchester M, MacKay F, Griffiths T and Nelson J (2001) A Survey of Indigenous Land Tenure – in Latin America, Sub-Saharan Africa and Asia. Colchester M (ed.) A report for the Food & Agriculture Organisation (FAO).

Collier P, Conway G and Venables T (2008) Climate change and Africa. *Oxford Review of Economic Policy* vol. 24(2), pp. 337-353.

Conservation International 2000, *Megadiversity data tables*, Washington, USA.

Cordeiro NJ, Burgess ND, Dovie DBK, Kaplin BA, Plumptre AJ and Marrs R (2007) Conservation in areas of high population density in sub-Saharan Africa. *Biological Conservation* vol. 134(2), pp. 155-163.

Cowie A, Schneider UA and Montanarella L (2007) Potential synergies between existing multilateral environmental agreements in the implementation of land use, land-use change and forestry activities. *Environmental Science & Policy* vol. 10(4), pp. 335-352.

Cropper A (2006) Why we need Africa's forests. *International Forestry Review* vol. 8(1), pp. 1-3.

Cunningham AB (1993) African medicinal plants: Setting priorities at the interface between conservation and primary healthcare. *People and Plants Working Paper 1*, United Nations Educational, Scientific and Cultural Organisation, Paris.

Cunningham AB and Mbenkum FT (1993) *Sustainability of harvesting Prunus africana bark in Cameroon*. UNESCO, Paris.

Daigneault AJ, Sohngen B and Sedjo R (2008) Exchange rates and the competitiveness of the United States timber sector in a global economy. *Forest Policy and Economics* vol. 10(3), pp. 449-469.

Davidson DJ, Williamson T and Parkins JR (2003) Understanding climate change risk and vulnerability in northern forest-based communities. *Canadian Journal of Forest Research* vol. 33, pp. 2252-2261.

Davidson O and Sokona Y (2002) A new sustainable energy path for African development: Think bigger, act faster. Energy and Development Research Centre, University of Cape Town and Environmental Development Action in the Third World, Senegal.

Davidson O and Mehlwana M (n.d.) Rural energy policy in Africa: Past and future directions. Powerpoint presentation, online at www.e4d.net/euei/Ouagadougou/Davidson-Mehlwana.ppt Accessed 1 November 2009.

Decher J (1997) Conservation, small mammals, and the future of sacred groves in West Africa. *Biodiversity and Conservation* vol. 6, pp. 1007-1026.

De Haen H (2008) Changement climatique et Développement rural ; *Rural 21 Le journal international du développement* vol. 14(2), pp. 8-13.

Delire C, Ngomanda A and Jolly D (2008) Possible impacts of 21st century climate on vegetation in Central and West Africa. *Global and Planetary Change* vol. 64(1-2), pp. 3-15.

Denton F, Sokona Y and Thomas JP (2001) *Climate change and sustainable development strategies in the making: what should West African countries expect*? OECD, Paris.

Desanker PV (2003) *Impact of climate change on life in Africa*. World Wildlife Fund and the Center for African development solutions, Johannesburg, South Africa.

Desanker PV and 14 others (2001) Africa. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ and White KS (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. Cambridge University Press, Cambridge.

De Wit M and Stankiewicz J (2006) Changes in surface water supply across Africa with predicted climate change. *Science* vol 311(5769), p. 1832.

DFID (2004a) *Climate change in Africa*. Key sheet 10, Global and Local Environment Team, Policy Division, Department for International Development, UK.

DFID (2004b) *Adaptation to climate change: The right information can help the poor to cope*. Key sheet 7, Global and Local Environment Team, Policy Division, Department for International Development, UK.

Dixon RK, Perry JA, Vanderklein EL and Hiol-Hiol F (1996) Vulnerability of forest resources to global climate change: case study of Cameroon and Ghana. *Climate Research* vol. 6(2), pp. 127-133.

Dube OP (2009) Linking fire and climate: interactions with land use, vegetation, and soil. *Current Opinion in Environmental Sustainability* vol. 1(2), pp. 161-169.

Dube OP and Sekhwela MBM (2007) Community coping strategies in semiarid Limpopo Basin part of Botswana: enghancing adaptation capacity to climate change. AIACC Working Paper No. 47, Assessment of Impacts and Adaptations to Climate Change. Online at http://www.aiaccproject.org/working_papers/Working%20Papers/AIACC_WP47_Dube.pdf Accessed 07 February 2010.

Dye P and Versfeld D (2007) Managing the hydrological impacts of South African plantation forests: An overview. *Forest Ecology and Management* vol. 251(1-2), pp. 121-128.

Dynacon and Wiechers Environmental Consultancy (2000) *South Africa: Initial National Communication under the United Nations Framework Convention on Climate Change*. Online at http://unfccc.int/resource/docs/natc/zafnc01.pdf Accessed 23 November 2009.

EAD (2002) *Initial National Communication of Malawi*. Ministry of Natural Resources and Environmental Affairs Environmental Affairs Department, Malawi.

Eastaugh C (2008) *Adaptations of forests to climate change: A multidisciplinary review.* IUFRO Occasional Paper Number 21, International Union of Forest Research Organisations, Vienna.

Eastaugh C, Reyer C, Gonzales-Moreno P, Wu J, Biscaia AG and Pentelkina O (2009) *Forest agencies' early adaptations to climate change.* IUFRO Occasional Paper Number 23, International Union of Forest Research Organisations, Vienna.

ECA (2001), State of Environment in Africa / ECA/FSSDD/01/06. United Nations Economic and Social Council.

El-Kenawy AM, Lopez-Moreno JL, Vincente-Serrano SM and Mekld MS (2009) Temperature trends in Libya over the second half of the 20th century. *Theoretical and Applied Climatology* vol. 98, pp. 1-8.

EPA (2000) Ghana's initial national communication on climate change. Environmental Protection Agency, Ghana.

EPA (2008). Report on climate change impacts assessment in Ghana (Under the Netherlands climate change studies assistance programme: NCAP 2).

Eriksen S, O'Brien K, and Rosentrater L. (2007). Climate Change in Eastern and Southern Africa:Impacts, Vulnerability and Adaptation. *Global Environmental Change and Human Security Report 2007.* University of Oslo, Oslo.

Evans J and Turnbull J (2004) Plantation forestry in the Tropics. 3rd Edition. Oxford University Press, Oxford.

Fagan B (2000) *Floods, Famines and Emperors; El Niño and the Fate of Civilizations*, Pimlico, London

Fairhead J and Leach M (1995) False forest history, complicit social analyses: rethinking some West African environmental narratives. *World Developmen*t vol. 23, pp. 1023-1035.

Falconer J (1990) *The major significance of minor forest products: the local use and value of forest in the West African humid forest zone*. Community Forest Note Number 6, Food and Agriculture Organisation, Rome. Online via http://www.fao.org/docrep/t9450e/t9450e00.htm Accessed 23 January 2010.

FAO (1993) The challenge of sustainable forest management: What future for the World's forests? Food and Agriculture Organisation, Rome. Online at http://www.fao.org/docrep/t0829e/t0829e00.HTM Accessed 17 October 2009.

FAO (1999) *The state of food insecurity in the world.* Food and Agriculture Organization, Rome.

FAO (2001) Global Forest Resources Assessment 2000 – Main Report. FAO Forestry Paper No. 140. Food and Agriculture Organization of the United Nations, Rome.

FAO (2003a). Responding to Agricultural and Food Insecurity Challenges Mobilising Africa to Implement Nepad Programes. Conference of ministers of agriculture of the African Union, Maputo, Mozambique. 1-2 July, 2003. Online at http://www.fao.org/DOCREP/MEETING/006/Y9483E/Y9483E00.HTM Accessed 10 October 2009.

FAO (2003b) Sustainable management of tropical forests in central Africa: in search of excellence. FAO Forestry Paper 143. Online at http://www.fao.org/docrep/006/y4853e/y4853e00.htm Accesed 26 August 2009.

FAO (2003c) Forestry outlook study for Africa: regional report – opportunities and challenges towards 2020. FAO Forestry Paper 141. Online at http://www.fao.org/docrep/005/y4521e/y4521e00.HTM Accessed 14 March 2010.

FAO (2003d) Forestry outlook study for Africa: regional report – Subregional report for southern Africa. Online at ftp://ftp.fao.org/docrep/fao/005/y8672e/y8672e00.pdf Accessed 01 May 2010.

FAO (2004) The bushmeat crisis in Africa: Conciliating food security and biodiversity conservation in the continent. Proceedings of the 23rd Regional Conference for Africa, 1-5 March 2004, Johannesburg. Online at http://www.fao.org/docrep/MEETING/007/J1457E.HTM Accessed 11 February 2010.

FAO (2006) Global forest resources assessment 2005. Food and Agriculture Organisation, Rome.

FAO (2007) *State of the World's Forests 2007*. Food and Agriculture Organisation, Rome.

FAO (2009) *State of the World's Forests 2009*. Food and Agriculture Organisation, Rome.

FAOSTAT (2008) Food and Agriculture Organisation of the United Nations. Online via http://faostat.fao.org/site/626/DesktopDefault.aspx Accessed 23 January 2010.

Fauchereau N, Trzaska S, Rouault M and Richard Y (2003) Rainfall variability and changes in Southern Africa during the 20th cantury in the global warming context. *Natural Hazards* vol. 29, pp. 139-154.

Faurés JM and Santini G (2008) Water and the rural poor: Interventions for improving livelihoods in sub-Saharan Africa. *Food and Agriculture Organisation*, Rome.

Fazey I, Fischer J and Lindemayer DB (2005) Who does all the research in conservation biology? *Biodiversity and Conservation* vol. 14, pp. 917-934.

Fischer G, Shah M and van Veltuizen H (2002) *Climate change and agricultural vulnerability*. Report prepared by the International Institute for Applied Systems Analysis as a contribution to the World Summit on Sustainable Development, Johannesburg 2002.

Fischlin A, Midgley GF, Price JT, Leemans R, Gopal B, Turley C, Rounsevell MDA, Dube OP, Tarazona J and Velichko AA (2007) Ecosystems, their properties, goods, and services. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ and Hanson CE (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, Cambridge.

Foley JA, Prentice IC, Ramunkutty N, Levis S, Pollard D, Sitch S and Haxeltine A (1996), An integrated biosphere model of land surface processes, terrestrial carbon balance and vegetation dynamics, *Global Biogeochemical Cycles* vol. 10(4), pp. 603-628.

Fox P and Rockstrom J (2003) Supplemental impact for dry-spell mitigation of rainfed agriculture in the Sahel. *Agricultural Water Management* vol. 61, pp. 29-50.

Franzel S, Denning G, Lillesø-Barnekow J and Mercado Jr A (2006) Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia. In: Garrity DP, Okono A, Grayson M and Parrott S (eds.) *World Agroforestry into the Future*. World Agroforestry Centre (ICRAF), Nairobi.

Fuller L, Garratt JA, Jewitt G and Calder IR (2003) *Water resources planning and modelling tools for the assessment of land use change in the Luvuvhu catchment, South Africa*. In: WATERNET/WARFSA. WARFSA. October 15-17, 2003. Centre for Land Use and Water Resources Research (CLUWRR), Newcastle, UK.

Funk C, Senay G, Asfaw A, Verdin J, Rowland J, Korecha D, Eilerts G, Michaelsen J, Amer S and Choularton R (2005) *Recent drought tendencies in Ethiopia and equatorial.subtropical Eastern Africa*. USAID.

Funk C, Dettinger MD, Michaelson JC, Verdin JP, Brown ME, Barlow M and Hoell A (2008) Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. *Proceedings of the National Academy of Sciences* vol. 105(32) pp. 11081-11086.

Gaillard J (2008) *The characteristics of R&D in developing countries*. UNESCO Institute for Statistics.

Gaston G, Brown S, Lorenzini M, Singh KD (1998) State and change in carbon pools in the forests of tropical Africa. *Global Change Biology* vol*.* 4, pp. 97-114.

GCOS (2002), Regional Action Plan for Eastern and Southern Africa. Global Climate Observing System

GCOS (2004), Regional Action Plan for Western and Central Africa. Global Climate Observing System

Gebrekirstos A, Martin W, Teketay D, Fetene M and Mitlöhner R (2009) Stable carbon isotope ratios in tree rings of co-occurring species from semi-arid tropics in Africa: Patterns and climatic signals*. Global and Planetary Change* vol. 66(3-4), pp. 253-260.

Geldenhuys CJ (1994) Bergwind fires and the location pattern of forest patches in the southern Cape landscape, South Africa. *Journal of Biogeography* vol. 21, pp. 49-62.

Giannini A, Biasutti M, Held IM and Sobel AH (2008) A global perspective on African climate, *Climatic Change* vol. 90, pp. 359-383.

Gibbs-Russell GE (1987) Preliminary floristic analysis of the major biomes in southern Africa. *Bothalia* vol. 17(2), pp. 213.227.

Glenday J (2008) Carbon storage and emissions offset potential in an African dry forest, the Arabuko-Sokoke Forest, Kenya. *Environmental Monitoring and Assessment* vol. 142, pp. 85-95.

Goldammer JG and Price C (1998) Potential impacts of climate change on fire regimes in the tropics based on MAGICC and a GISS GCM-derived lightning model. *Climatic Change* vol. 39(1-2), pp. 273-296.

Gonzales P (2001) Desertification and a shift of forest species in the West African Sahel. Climatic Research vol. 17(2), pp. 217-228.

Gonzales JP, Gouilh MA, Reynes JM and Leroy E (2008) Bat-borne viral diseases. In: Colfer CJ (ed) *Human health and forests: A global overview of issues, practice and policy*. Earthscan, London.

GoS (Government of Sudan) (2003) Sudan's first national communication to the United Nations Framework Convention on Climate Change (UNFCCC). Climate Change Project Higher Council for Environmental and Natural Resources (HCENR), Khatoum.

Gutiérrez M, Appleton A and Carter S (2006) A summary report of the United Nations Framework Convention on Climate Change (UNFCCC) African Regional Workshop on Adaptation. *African Regional Workshop on Adaptation Bulletin* vol 2(1).

Gyampoh BA, Idinoba M and Amisah S (2008) Water scarcity under a changing climate in Ghana: Options for livelihoods adaptation. *Development* vol. 51, pp. 415-417.

Gyampoh BA, Amisah S, Idinoba M and Nkem J (2009) Using traditional knowledge to cope with climate change in rural Ghana. *Unasylva* vol. 60(231/232), pp. 70-74.

Gyau-Boakye, P. and Tumbulto, J. W. (2006) Comparison of rainfall and runoff in the humid south-western and the semiarid northern savannah zone in Ghana. *African Journal of Science and Technology* vol. 7(1), pp. 64-72).

Hall JS (2008) Seed and seedling survival of African Mahogany (Entandrophragma spp.) in the Central African Republic: implications for forest management. *Forest Ecology and Management* vol. 255(2), pp. 292-299.

Hansen MC and 11 others (2008) Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data. *Proceedings of the National Academy of Sciences* vol. 105(27), pp. 9439-9444.

Hassan R, Scholes R and Ash N (eds) (2005) *Ecosystems and human well-being – volume 1: current state and trends*. Island Press, Washington DC.

Hay SI, Cox J, Rogers DJ, Randolph SE, Stern DI, Shanks GD, Myers MF and Snow RW (2002) Climate change and the resurgence of malaria in the East African highlands. *Nature* vol. 415, pp. 905-909.

Hély C, Bremond L, Alleaume S, Smith B, Sykes MT and Guiot J (2006) Sensitivity of African biomes to changes in the precipitation regime. *Global Ecology and Biogeography* vol. 15, pp. 258-270.

Hemp A (2005) Climate change-driven forest fires marginalize the impact of ice cap wasting on Kilimanjaro. *Global Change Biology* vol. 11, pp. 1013-1023.

Henning RK (2002) *Using the indigenous knowledge of Jatropha*. Work Bank IK Notes Number 47.

Henry M, Tittonell P, Manlay RJ, Bernoux M, Albrecht A. and Vanlauwe B. (2009) Biodiversity, carbon stocks and sequestration potential in aboveground biomass in smallholder farming systems of western Kenya. *Agriculture, Ecosystems & Environment* vol. 129(1-3), pp. 238-252.

Hewitson BC and Crane RG (2006) Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa. *International Journal of Climatology* vol. 26(10), pp. 1315-1337.

Hudson DA and Jones RG (2002) Simulations of present day and future climate over southern Africa using HadAM3H. *Hadley Centre Technical Note 38*. UK Meteorological Office.

Hulme M, Doherty R, Ngara T, New M and Lister D (2001) African climate change 1900-2100. *Climatic Research* vol. 17(2), pp. 145-168.

Huntley BJ (1982) Southern African savannes. In: Huntley BJ and Walker BH (eds) Ecology of tropical savannas. Springer-Verlag, Berlin.

Idinoba M, Kalame F, Nkem J, Blay D and Coulibaly Y (2009) Climate change and non-wood forest products: vulnerability and adaptation in West Africa. *Unasylva* vol. 60(231/232), p. 75.

IEA (2009) *Key world energy statistics*. International Energy Agency, Paris.

IITA. (2000). IITA Strategic Plan 2001–2010 supporting document. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Ikeme, J. (2003). ‘Climate change adaptational deficiencies in developing countries: the case of sub-Saharan Africa’. *Mitigation and Adaptation Strategies for Global Change*, 8(1):29-52.

IPCC (1998) The regional impacts of climate change: an assessment of vulnerability. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IRI (2006) A gap analysis for the implementation of the global climate observing system program in Africa. International Research Institute for Climate and Society, New York.

ITTO (/2005) *Status of tropical forest management 2005*. International Tropical Timber Organisation, Yokohama, Japan.

ITTO (2006) Annual review and assessment of the world timber situation. International Tropical Timber Organisation, Yokohama, Japan.

Ilstedt U, Malmer A, Verbeeten E and Murdiyarso D (2007) The effect of afforestation on water infiltration in the tropics: systematic review and meta-analysis. *Forest Ecology and Management* vol. 251, pp. 45-51.

Jagtap SS and Chan AK (2000) Agrometeorological aspects of agriculture in the sub-humid and humid zones of Africa and Asia. *Agricultural and Forest Meteorology* vol. 103(1-2), pp. 59-72.

Johannson SG and Kaarakka VJ (1992) Regeneration of cleared *Acacia zanzibarica* bushland in Kenya. *Journal of Vegetation Science* vol. 3(3), pp. 401-406.

Johns Hopkins University (1998) Solutions for a Water-Short World. Population Report, Vol. XXVI, No. 1, September 1998. Johns Hopkins Population Information Program, Baltimore, Maryland, United States. Online at http://info.k4health.org/pr/m14edsum.shtml Accessed 20 October 2009.

Jones PG and Thornton PK (2000) MarkSim: Software to generate daily weather data for Latin America and Africa. *Agronomy Journal* vol.92(3), pp. 445-453.

Jolly D and Haxeltine A (1997) Effect of low glacial atmospheric CO2 on tropical African montane vegetation. *Science* vol. 276 (5313), pp. 786–788.

Jumbe CBL, Wiyo KA, Njewa E and Msiska FBM (2008) *The role of government, donors, civil society and the private sector in climate change adaptation in Malawi: Scoping Study*. Christian Aid Innovative Fund Africa, Lilingwe, Malawe.

Justice C, Wilkie D, Zhang Q, Brunner J and Donoghue C (2001) Central African forests, carbon and climate change. *Climatic Research* vol. 17(2), pp. 229-246.

Kalame FB, Idinoba M, Brockhaus M and Nkem J (2008) Forest policies and forest resource flow in Burkina Faso, Ghana and Mali: Conflicting or consistent for adaptation to climate change? CIFOR, Bogor, Indonesia.

Kalame FB, Nkem J, IdinobaM and Kanninen M. (2009). Matching national forest policies and management practices for climate change adaptation in Burkina Faso and Ghana Mitigation and Adaptation Strategies for Global Change, vol. 14(2), pp. 135-151.

Kambewa P, Mataya B, Sichinga K and Johnson T (2007) Charcoal, the reality. International Institute for Environment and Development, UK.

Kamusoko C, Aniya M, Adi B and Manjoro M (2009) Rural sustainability under threat in Zimbabwe – Simulation of future land use/cover changes in the Bindura district based on the Markov-cellular automata model. *Applied Geography* vol. 29(3), pp. 435-447.

Katerere Y, Minang P and Vanhanen H (eds) (2009) Making sub-Saharan African forests work for people and nature: Policy approaches in a changing global environment. WFSE(IUFRO), ICRAF, CIFOR and METLA.

Kigenyi F, Gondo P and Mugabe J (2002) *Practice Before Policy: An Analysis of Policy and Institutional Changes Enabling Community Involvement in Forest Management in Eastern and Southern Africa.* IUCN-EARO. Nairobi, Kenya.

Kigomo BN (2003) Forests and woodlands degradation in dryland Africa: A case for urgent global attention. Paper submitted to the XII World Forestry Conference, 2003, Quebec City, Canada.

King J, Moutsinga JB and Doufoulon G (1997) Conversion of anthropogenic savanna to production forest through fire-protection of the forest-savanna edge in Gabon, central Africa. *Forest Ecology and Management* vol. 94(1-3), pp. 233-247.

Kowero G (n.d.) *Getting REDD right for Africa*. Science and Development Network, Online at http://www.scidev.net/en/opinions/getting-redd-right-for-africa.html Accessed 30 September 2009.

Kruger AC and Shongwe S (2004) Temperature trends in South Africa 1960-2003. *International Journal of Climatology* vol. 24, pp. 1929-1945.

Kröpelin S and 14 others (2008) Climate-driven ecosystem succession in the Sahara: The past 6000 years. *Science* vol. 320(5877), pp. 765-768.

Kull CA, Ibrahim CK and Meredith TC (2007) Tropical forest transitions and globalization: Neo-liberalism, migration, tourism, and international conservation agendas. *Society and Natural Resources* vol. 20, pp. 723-737.

Körner C (2000) Biosphere responses to CO_2 enrichment. *Ecological Applications* 10:1590-1619

Langewald J, Mitchell JD, Maniania NK and Kooyman C (2003) Microbial control of termites in Africa. In: *Biological control in IPM system in Africa*, P Neuenschwander, C Borgemeister and J Langewald (eds). CABI Publishing, Cambridge.

Lau KM, Shen SSP, Kim KM, and Wang H (2006) A multimodel study of the twentieth century simulations of Sahel drought from the 1970s to 1990s. *Journal of Geophysical Research* Vol 111, DO7111.

Lawry SW (1990) Tenure Policy Towards Common Property Natural Resources in Sub-Saharan Africa. *Natural Resources Journal* vol. 30, pp. 403-404.

Le Courrier (2002) Developpement durable reportage Cameroun. *Le Courrier* no. 193.

Lejju BJ, Robertshaw P and Taylor D (2006) Africa's earliest bananas? *Journal of Archeological Science* vol. 33(1), pp. 102-113.

Lewis J (2005) Whose forest is it anyway? Mbendjele Yaka pygmies, the Ndoki forest and the wider world. In: Widlok T and Tadesse WG (eds) Property and equality: encapsulation, commercialisation, discrimination. Berghahn Books, New York.

Lewis SL and 32 others (2009) Increasing carbon storage in intact African tropical forests. *Nature* vol. 457, pp. 1003-1007.

Li KY, Coe MT and Ramankutty N (2005) Investigation of hydrological variability in West Africa using land surface models. *Journal of Climate* vol. 18(16), pp. 3173-3188.

Lieberman D and Li M (1992) Seedling recruitment patterns in a tropical dry forest in Ghana. *Journal of Vegetation Science* vol. 3(3), pp. 375-382.

Linder HP, Lovett J, Mutke JM, Barthlott W, Jürgens N, Rebelo T and Küper W (2005) A numerical re-evaluation of the sub-Saharan phytochoria of mainland Africa. *Biologiske Skrifter* vol. 55, pp. 229-252.

Liu J, Fritz S, van Wesenbeeck CFA, Fuchs M, You L, Obersteiner M and Yang H (2008) A spatially explicit assessment of current and future hotspots of hunger in Sub-Saharan Africa in the context of global change. *Global and Planetary Change* vol. 64(3-4), pp. 222-235.

Liu P, Meehl GA and Wu G (2002) Multi-model trends in the Sahara induced by increasing CO_2. *Geophysical Research Letters* vol. 29(18), pp. 28.1-28.4.

Liu Z and 13 others (2007) Simulating the transient evolution and abrupt change of Northern Africa atmosphere-ocean-terrestrial ecosystem in the Holocene. *Quaternary Science Review* vol. 26(13-14), pp. 1818-1837.

Lowore JDK (1991) Coppice regeneration in some Miombo woodlands in Malawi. Master's Thesis for the Forestry Department, Universtiy of Aberdeen.

Macchi M, Oviedo G, Gotheil S, Cross K, Boedhihartono A, Wolfangel C and Howell M (2008) Indigenous and Traditional Peoples and Climate Change, *Issues Paper,* IUCN.

Maes-Diop L-M (2004) Assessment of the dating of ancient relics of ironworking in Africa: main lessons. In: *The origins of iron metallurgy in Africa*, H Bocoum (ed). UNESCO, Paris.

Magadza C (2003) Engaging Africa in adaptation to climate change. In: *Climate change, adaptive capacity and development*, JB Smith, RJT Klein and S Huq (eds). Imperial College Press, London.

Mala WA, Geldenhuys CJ and Prabhu R (2008) Local Conceptualization of Nature, Forest Knowledge Systems and Adaptive Management in Southern Cameroon. Presentation at the International Conference on Traditional Forest Knowledge and Sustainable Forest Management in Africa; Accra, Ghana; 15-17 October 2008.

Malambo FM and Syampungani S (2008) Opportunities and challenges for sustainable management of miombo woodlands: the Zambian perspective. Working Papers of the Finnish Forest Research Institute vol. 98, pp. 125-130.

Maley J (1996) The African rain forest—main characteristics of changes in vegetation and climate from the Upper Cretaceous to the Quaternary. *The Royal Society of Edinburgh Proceedings Section B (Biological Sciences)* 104:31–74

Mamo, G, Sjaastad, E and Vedeld, P 2007, Economic dependence on forest resources: A case from Dendi District, Ethiopia, *Forest Policy and Economics* vol. 9 (8), pp. 916-927.

Matarira CH and Mwamuka FC (1996) Vulnerability of Zimbabwe forests to global climate change. *Climate Research* vol. 6(2), pp. 135-136.

Matola YG, White GB and Magayuka SA (1987) The changed pattern of malaria endemicity and transmission at Amani in the eastern Usambara Mountains, north-eastern Tanzania. *Journal of Tropical Medicine and Hygiene* vol. 90, pp. 127-134.

Maxted J (2002) Environmental entitlements and the rural poor in South Africa. *Journal of Asian and African Studies* vol. 37(3-5), pp. 353-375.

Maynard K, Royer JF and Chauvin F (2002) Impact of greenhouse warming on the West African summer monsoon, *Climate Dynamics* vol. 19, pp. 499-514.

Mbida CM, Van Neer W, Doutrelepont H and Vrydaghs L(2000) Evidence for banana cultivation and animal husbandry during the first millennium BC in the forest of southern Cameroon. *Journal of Archaeological Science* vol. 27(2), pp. 151–162.

McClean CJ, Lovett JC, Kuper W, Hannah L, Sommer JH, Barthlott W, Termansen M, Smith GE, Tokamine S and Taplin JRD (2005) African plant diversity and climate change. *Annals of the Missouri Botanical Garden* vol. 92(2), pp. 139-152.

McLeman R and Smit B (2005) *Assessing the security implications of climate change-related migration*. Human Security and Climate Change: An International Workshop, Oslo June 21-23, 2005.

Meduna AJ, Ogunjinmi AA and Onadeko SA (2009) Biodiversity conservation problems and their implications on ecotourism in Kainji Lake National Park, Nigeria. *Journal of Sustainable Development in Africa* vol. 10(4), pp. 59-73.

Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.

Mkanda FX (1996) Potential impacts of future climate change on nyala *Tragelaphus angasi* in Lengwe National Park, Malawi. *Climate Research* vol. 6(2), pp. 157-164.

Mogaka H, Simons G, Turpie J, Emerton L and Karanja F (2001) *Economic Aspects of Community Involvement in Sustainable Forest anagement in Eastern and Southern Africa.* IUCN — The World Conservation Union, Eastern Africa Regional Office, Nairobi.

Morishima W and Akasaka I (2010) Seasonal trends of rainfall and surface temperature over Southern Africa. *African Study Monographs* suppl 40, pp. 67-76.

Mortimore M (2003) Long-term change in African drylands: Can recent history point towards development pathways? *Oxford Development Studies* vol. 31(4), pp. 503-518.

Mukheibir P and Ziervogel G (2007) Developing a municipal adaptation plan (MAP) for climate change: the city of Cape Town. *Environment and Urbanization* vol. 19, pp. 143-158.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB and Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* vol. 403(6772),pp. 853-858.

Nabuurs GJ and 16 others (2007) Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Nampinga R (2008) Emerging Issues Panel: Gender Perspectives on Climate Change. Commission on the Status of Women, Fifty-second session, New York February 25–March 7, 2008. United Nations.

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

Neely C, Sutherland K and Johnson J (2004) *Do sustainable livelihoods approaches have a positive impact on the rural poor? A look at 12 case studies*. LSP Working Paper 16, Food and Agriculture Organisation, Rome.

Nel E and Hill T (2008) Marginalisation and demographic change in the semi-arid Karoo, South Africa. *Journal of Arid Environments* vol. 72, pp. 2264-2274.

NEPAD (2003) Action plan of the environment initiative of the new partnership for Africa's development (NEPAD). *United Nations Environment Programme*. Online at http://www.economicswebinstitute.org/essays/nepad-environment.pdf Accessed 16 August 2010.

Nepstad DC and 19 others (2002) The effects of partial throughfall exclusion on canopy processes, aboveground production, and biogeochemistry of an Amazon forest. *Journal of Geophysical Research* vol. 107, 8085.

Neves D (2008) The impact of illness and death on migration back to the Eastern Cape. *CSSR Working Paper No. 229*. Centre for Social Science Research, University of Cape Town, South Africa.

Ngomanda A, Chepstow-Lusty A, Makaya M, Schevin P and Maley J (2005) Vegetation changes during the past 1300 years in western equatorial Africa: a high-resolution pollen record from Lake Kamalete, Lope Reserve, Central Gabon. *Holocene* vol. 15(7), pp. 1021–1031.

Nicholson SE (2001) Climatic and environmental change in Africa during the last two centuries. *Climatic Research* vol. 17(2), pp. 123-144.

Njoukam R, Temgoua LF and Peltier R (2008) Dans l'Ouest-Cameroun, les paysans ont préservé les arbres dans leurs champs, pendant que l'Etat laissait brûler ceux qu'il avait plantés dans ses réserves. In : *International IUFRO Conference on Traditional Forest-related Knowledge and Sustainable Forest Management in Africa,* 14-17 October 2008, Accra, Ghana.

Nkem J, Perez C, Santoso H and Idinoba M (2007a) Methodological framework for vulnerability assessment of climate change impacts on forest-based development sectors. CIFOR.

Nkem J, Santoso H, Murdiyarso D, Brockhaus M and Kanninen M (2007b) Using Tropical Forest Ecosystem Goods and Services for Planning Climate Change Adaptation with Implications for Food Security and Poverty Reduction. *SAT eJournal* vol 4(1), pp. 1-23.

Nkem J, Idinoba M, Santoso H, Perez CJ, Forner C, Locatelli B and Kanninen M (2008a) *Prioritisation for Adaptation in Tropical Forest Ecosystems*. Working Paper No. 44. CIFOR, Bogor, Indonesia.

Nkem J, Idinoba M and Sendashonga C 2008b) *Forests for climate change adaptation in the congo basin: Responding to an urgent need with sustainable practices*. CIFOR Environment Brief No. 2. Nov. 2008.

Nkem J, Idinoba M, Brockhaus M, Kalame F and Tas A (2008c) Adaptation to climate change in Africa: Synergies with biodiversity and forests. Tropical Forests and Climate Change Adaptation (TroFCCA) June 2008. CIFOR, Bogor.

Nssoko E (2004) Community-based fire management in the Miombo woodlands: a case study from Bukombe District, Shinyanga, Tanzania. *Aridlands Newsletter* vol. 55, May/June 2004.

Ntiamoah-Baidu, Y. (1997) Sustainable use of bushmeat. A technical report submitted to the Wildlife Division under the Wildlife Development plan, Wildlife division, Accra.

Nyong A, Adesina F and Osman-Elasha B (2007) The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel, *Mitigation and Adaptation Strategies for Global Change* vol. 12, pp. 787-797.

Ofori DA and Cobbinah JR (2007) Integrated approach for conservation and management of genetic resources of Milicia species in West Africa. *Forest Ecology and Management* vol. 238(1-3), pp. 1-6.

OIA and PGA (1992) *Neem: a tree for solving global problems*. Report of an Ad Hoc Panel of the Board of Science and Technology for International Development, National Research Council. Office of International Affairs and Polica and Global Affairs, The National Academies Press, Washington.

Olago DO (2001) Vegetation changes over palaeo-time scales in Africa. *Climatic Research* vol. 17(2), pp. 105-121.

Oluwole FA, Sambo JM and Sikhalazo D (2008) Long-term effects of different burning frequencies on the dry savannah grassland in South Africa. *African Journal of Agricultural Research* vol. 3, pp. 147-153.

Opuni-Frimpong E, Karnosky DF, Storer AJ and Cobbinah JR (2008) Silvicultural systems for plantation mahogany in Africa: influences of canopy shade on tree growth and pest damage. *Forest Ecology and Management* vol. 255, pp. 328-333.

Osafo Y (2005) Reducing greenhouse gas emissions from tropical deforestation: applying compensated reduction in Ghana. In: Moutinho P and Schwartzman s (eds) Tropical deforestation and climate change. Instituto de Pesquisa Ambiantal de Amazonia, Belem, and Environmental Defence, Washington DC.

Oslisly R (1995) The middle Ogooué valley, Gabon: cultural changes and palaeoclimatic implications of the last four millenia. *Azania* 39-40:324–331

Oslisly R (1998) Hommes et milieux a l'Holocene dans la moyenne vallee de l'Ogooue (Gabon). *Bulletin de la Societe prehistorique francaise*, vol. 95(1), pp. 93-105.

Osman Elasha (2009) Climate change impacts, adaptation and links to sustainable development in Africa. *Unasylva* 231/232 vol. 60, pp. 12-16.

Osman-Elasha B, Goutbi N, Spanger-Siegfried E, Dougherty B, Hanafi A Zakiekleen S, Sanjak A, Atti H and Elhassan H (2006a) *Adaptation strategies to increase human resilience against climate variability and change: Lessons from the arid regions of Sudan*. AIACC Working Paper 42, International START Secretariat, Washington DC.

Osman-Elasha B, Medany M, Niang-Diop I, Nyong T, Tabo R and Vogel C (2006b) *Impacts, vulnerability and adaptation to climate change in Africa*. African Workshop on Adaptation Implementation of Decision 1/CP.10 of the UNFCCC Convention. September 21 - 23, 2006, Accra, Ghana. Background paper. UNFCC Secretariat.

OSS and GTZ. 2007. *Climate change adaptation & the fight against desertification*. Introductory Note Number 1. Sahara and Sahel Observatory and Gesellschaft für Technische Zusammenarbeit, Tunis. 28 pp.

Oyono PR (2007) Is decentralization in natural resource management leading to livelihoods improvement and sustainability?: evidence from Central Africa. In: Kelbessa E and De Stoop C (eds.). Participatory forest management (PFM), biodiversity and livelihoods in Africa: proceedings of the International Conference, Addis Ababa, Ethiopia. March 19-21, 2007. pp.19-35

Oyono PR, Cerutti PO and Morrison K (2009) Forest taxation in post-1994 Cameroon: distributional mechanisms and emerging links with poverty alleviation and equity. CIFOR/WRI Working Paper.

Paavola J (2008) Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science & Policy* vol. 11(7), pp. 642-654.

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.

Patosaari P (2007) Climate Change and Forests: Mitigation and Adaptation through Sustainable Forest Management. Presentation to the 60th Annual DPI/NGO Conference “Climate Change: How it Impacts Us All” Roundtable on Coping with Climate Change: Best Land Use Practices. United Nations, New York. September 6, 2007.

Peach-Brown HC (2009) Institutional dynamics and climate change in the Congo Basin Forests of Cameroon: Report of preliminary findings. Centre for International Forestry Research.

Phelps J, Webb EL and Agrawal A (2010) Does REDD+ threaten to recentralize forest governance? *Science* vol. 328, pp. 312-313.

Pietsch SA, Tanga JJ and Ngok-Banak L (2009) The Birougou Mountains: Forested throughout the Holocene. *Geophysical Review Abstracts*, vol. 11.

Poorter L, Bongers F, Kouamé FN and Hawthorne WD (Eds.) (2004) *Biodiversity of West African Forests: An Ecological Atlas of Woody Plant Species*: CABI Publishing, Oxford.

Pounds JA and 13 others (2006) Widespread amphibian extinctions from endemic disease driven by global warming. *Nature* vol. 439, pp. 161-167.

Prince SD, Brown de Colstoun E and Kravitz LL (1998) Evidence from rain-use efficiencies does not indicate extensive Sahelian desertification. *Global Change Biology* vol. 4, pp. 359-374.

Prüss-Üstün A and Corvalán C (2006) *Preventing disease through healthy environments*. World Health Organisation, Geneva.

Putz FE, Sist P, Fredericksen T and Dykstra D (2008) Reduced-impact logging: Challenges and opportunities. *Forest Ecology and Management* vol. 256, pp. 1427-1433.

Putz FE and Redford KH (2009) Dangers of carbon based conservation. Global Environmental Change vol. 19(4), pp. 400-401.

Ravindranath NH, Joshi NV, Sukumar R and Saxena A (2006) Impact of Climate Change on Forests in India. *Current Science* vol. 90(3), pp. 354-361.

Reid H, Sahlén L, MacGregor J and Stage J (2007) *The economic impact of climate change in Namibia; How climate change will affect the contribution of Namibia’s natural resources to its economy*. Environmental Economics Discussion Paper 07-02, International Institute of Environment and Development, London.

Reyer C, Guericke M and Ibisch PL (2009) Climate change mitigation via afforestation, reforestation and deforestation avoidance: and what about adaptation to environmental change? *New Forests* vol. 38(1), pp. 15-34.

Ribot JC (2002) *African decentralisation: local actors, powers and accountability*. Democracy, Governance and Human Rights Paper Number 8, United Nations Research Institute for Social Development, Geneva.

Ribot JC, Agrawal A and Larson A (2004) Recentralizing while Decentralizing: How National Governments Re-appropriate Forest Resources. Paper presented at the Conference on Globalisation and Self-Determination, Yale University, May 14-15, 2004.

Richards P (1996) *Fighting for the rainforest: war, youth and resources in Sierra Leone*. The International African Institute/James Currey/Heinemanne, Oxford.

Richter I and Xie SP (2008) On the origin of equatorial Atlantic biases in coupled general circulation models. *Climate Dynamics* vol. 31, pp. 587-598.

Roberts G (2008) Policies and Instruments for the Adaptation of Forests and the Forest Sector to Impacts of Climate Change as Indicated in United Nations Framework Convention in Climate Change National Reports. *IUFRO Occasional Paper 22*, International Union of Forest Research Organisations, Vienna.

Rouget M, Richardson DM, Nell JL and van Wilgen BW (2002) Commercially important trees as invasive aliens – towards spatially explicit risk assessment at a national scale. *Biological Invasions* vol. 4(4), pp. 397-412.

Roux J, Mthalane ZL, de Beer ZW, Eisenberg B and Wingfield MJ (2006) Quambalaria leaf and shoot blight on Eucalyptus nitens in South Africa. *Australasian Plant Pathology* vol. 35(4), pp. 427-433.

Rutherford MC, Powrie LW and Schulze RE (1999) Climate change in conservation areas of South Africa and its potential impact on floristic composition: a first assessment. *Diversity and Distributions* vol. 5(6), pp. 253–262.

Sankaran M and 29 others (2005) Determinants of woody cover in African savannas. *Nature* vol. 438, pp. 846-849.

Savadogo P, Zida D, Sawadogo L, Tiveau D, Tigabu M and Oden PC (2007) Fuel and fire characteristics in savanna-woodland or West Africa in relation to grazing and dominant grass type. *International Journal of Wildland Fire* vol. 16(5), pp. 531-539.

Seaquist JW, Hickler T, Eklundh L, Ardö J and Heumann BW (2009) Disentangling the effects of climate and people on Sahel vegetation dynamics. *Biogeosciences* vol. 6, pp. 469-477.

Seo N, Mendelsohn R, Kurukulasuriya P, Dinah A and Hassan R (2008) *Differential Adaptation Strategies to Climate Change in African Cropland by Agro-Ecological Zones*. World Bank Development Research Group.

Scholes RJ and Biggs R (eds) (2004) Ecosystem services in southern Africa: A regional assessement – A contribution to the Millennium Ecosystem Assessment, prepared by the regional-scale team of the Southern African Millenium Ecosystem Assessment. Council for Scientific and Industrial Research, Pretoria, South Africa.

Scholes M and Andreae MO (2000) Biogenic and Pyrogenic Emissions from Africa and their Impact on the Global Atmosphere. *Ambio* vol. 29(1), pp. 24-29.

Scholes RJ (1996) Miombo woodlands and carbon sequestration. Box 2.3 in The ecology of Miombo woodlands (P. Frost), in *The Miombo in Transition: Woodlands and Welfare in Africa* BM Campbell (ed). Centre for International Forestry Research (CIFOR), Bogor, Indonesia

Scholze M, Knorr R, Arnell NW and Prentice IC (2006) A climate change risk analysis for world ecosystems. *Proceedings of the National Academy of Sciences* vol. 103(35), p. 13116-13120.

Scott L, Holmgren K and Partridge TC (2008) Reconciliation of vegetation and climatic interpretations of pollen profiles and other regional records from the past 60 thousand years in the Savanna Biome of Southern Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology* vol. 257, pp. 198-206.

Semazzi FHM and Song Y (2001) A GCM study of climate change induced by deforestation in Africa. *Climatic Research* vol. 17(2), pp. 169-182.

Seppälä R, Buck A and Katila P (eds) (2009a) *Adaptation of Forests and People to Climate Change – A Global Assessment Report*. IUFRO World Series volume 22, International Union of Forest Research Organisations, Vienna.

Seppälä R, Buck A and Katila P (eds) (2009b) *Policy brief: Making forests fit for climate change*. Ministry for Foreign Affairs of Finland and the International Union of Forest research Organisations, Vienna.

Shackleton C (2009) Will the real custodian of natural resource management please stand up. *South African Journal of Science* vol. 105, pp. 91-93.

Shackleton CM., Shackleton SE, 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* vol. 9(5), pp. 558-577.

Shackleton S, Campbell B, Wollenberg E and Edmunds D (2002) Devolution and community-based natural resource management: creating space for local people to participate and benefit? *Natural Resources Perspectives* vol. 76 March 2002, DFID and ODI.

Shiklomanov IA (1998) *World water resources: A new appraisal and assessment for the 21st century.* UNESCO, Paris.

Shipton P (1990) African famines and food security: anthropological perspectives. *Annual Review of Anthropology* vol. 19, pp. 353-394.

Siegfried, W. R. (1989). Preservation of species in southern African nature reserves. In, Huntley, B. J. (Ed.), Biotic Diversity in Southern Africa: Concepts and Conservation, Oxford University Press, Oxford, UK.

Sist P (2000) Reduced-impact logging in the tropics: Objectives, principles and impacts. *International Forestry Review* vol. 2(1), pp. 3-10.

Smith JB and Lenhart SS (1996) Climate change adaptation policy options. *Climate Research* vol. 6(2), pp. 193-201.

Smith N and Wilson SL (2002) *Changing land use trends in the thicket biome: Pastoralism to game farming*. Terrestrial Ecology Research Unit, University of Port Elizabeth, South Africa.

Smucker TA and Wisner B (2008) Changing household responses to drought in Tharaka, Kenya: vulnerability, persistence and challenge. *Disasters* vol. 32(2), pp. 190-215.

Sogbohossou E, Akpona HA and Sinsin B (2008) Traditional botanical gardens as a tool for preserving plant diversity, indigenous knowledge and last threatened relic forest in northern Benin. In: *International Conference on Traditional Forest Knowledge and Sustainable Forest Management in Africa; Accra, Ghana; 15-17 October 2008*.

Sohngen B, Mendelsohn R and Sedjo R (2001) A global model of climate change impacts on timber markets. *Journal of Agricultural and Resource Economics* vol. 26(2), pp. 326-343.

Spittlehouse DL and Stewart RB (2003) Adaptation to climate change in forest management *BC Journal of Ecosystems and Management* vol. 4(1), pp. 1–11.

Street-Perrott FA, Barker PA, Swain DL, Ficken KJ, Wooller MJ, Olago DO and Huang Y (2007) Late Quaternary changes in ecosystems and carbon cycling on Mt. Kenya, East Africa: a landscape-ecological perspective based on multi-proxy lake-sediment influxes. *Quaternary Science Reviews* vol. 26(13-14), pp. 1838-1860.

Stringer LC (2009) Testing the orthodoxies of land degradation policy in Swaziland. *Land Use Policy* vol. 26(2), pp. 157-168.

Sunderland TCH, Clark LE and Vantomme P (eds) (1998) *Non-wood forest products of Central Africa: Current research issues and prospects for conservation and development*. FAO, Rome. Online at http://www.fao.org/docrep/x2161e/x2161e00.htm Accessed November 23 2009.

Swaine MD (1992) Characteristics of dry forest in West Africa and the influence of fire. Journal of Vegetation *Science* vol. 3(3), pp. 365-374.

Tabuna H (1999) Le Marché des Produits Forestiers Non Ligneux de l.Afrique Centrale en France et en Belgique ; Produits, Acteurs, Circuits de Distribution et Débouchés Actuels, CIFOR occasional paper N 19 ,37p.

Tan Z, Liu S, Tieszen LL and Tachie-Obeng E (2009) Simulated dynamics of carbon stocks driven by changes in land use, management and climate in a tropical moist ecosystem of Ghana**.** *Agriculture, Ecosystems & Environment* vol. 130(3-4), pp. 171-176*.*

Tarhule AA (2007) Climate information for development: An integrated dissemination model. *Africa Development* vol. 32(4), pp. 127-138.

Tarhule A and Lamb PJ (2003) Climate research and seasonal forecasting for West Africans: Perceptions, Dissemination and Use? *Bulletin of the American Meteorological Society* vol. 84(12), pp. 1741-1759.

Tchouamo IR, (1998) La protection de la biodiversité en Aric par des Forets Sacrées. *Le Flamboyant* vol. 46, pp. 18-22.

Tesema T (2008) The Underlying Causes and Mitigation Measures of Deforestation: A Critical Assessment of the Ethiopian Forest Policies and Strategies. Doctoral Dissertation at the University of Natural resources and Applied Life Sciences (BOKU), Vienna.

Thornton PK, Jones PG, Owiyo T, Kruska RL, Herrero M, Kristjanson P, Notenbaert A, Bekele N and Omolo A (2006) Mapping climate vulnerability and poverty in Africa. Report to the Department for International Development, International Livestock Research Unit, Nairobi.

Tiku NE, Agbogo EA and Mbu JE (2006) Analysis of economic benefits of rural communities \' participation in sustainable agroforestry practices in Central Cross River State. *Journal of Agriculture, Forestry and the Social Sciences* vol. 4(2).

Topouzis D and du Guerny J (1999) Sustainable agricultural/rural development and vulnerability to the AIDS epidemic. UNAIDS Best Practice Collection, Geneva. Online at http://data.unaids.org/Publications/IRC-pub01/jc278-fao_en_pdf.pdf Accessed 7 March 2010.

Trabucco A, Zorner RJ, Bossio DA, van Straaten O and Verchot LV (2008) Climate change mitigation through afforestation/reforestation: a global analysis of hydrological impacts with four case studies. *Agriculture, Ecosystems and Environment* vol. 126(1-2), pp. 81-97.

TroFFCA (n.d.) *Forest Ecosystems*. Tropical Forests and Climate Change Adaptations. Online at http://www.cifor.cgiar.org/trofcca/_ref/africa/reginfo/foreco.htm&mn=trofcca_0_1 Accessed 25 September 2009.

Tschakert, P 2007, Views from the vulnerable: Understanding climatic and other stressors in the Sahel. *Global Environmental Change* vol. 17, pp. 381-396.

UN-OHRLLS (n.d.) Least developed countries. United Nations Office of the High Representative for Least Developed Countries, Landlocked Developing Countries and Small Island Developing States. Online at http://www.unohrlls.org/en/ldc/related/62/ Accessed 08 February 2010.

UNDP (2004) *Reducing Disaster Risk: a Challenge for Development*. UNDP Bureau for Crisis Prevention and Recovery, New York. http://www.undp.org/bcpr/disred/documents/publications/rdr/english/rdr_english.pdf

UNECA (2008) *Africa Review Report on Drought and Desertification*. United Nations Economic Commission for Africa, Addis Ababa, Ethiopia.

UNEP (2002), Africa Environmental Outlook: Past, Present and Future Perspectives. United Nations Environment Programme. Online at http://www.unep.org/dewa/Africa/publications/AEO-1/index.htm Accessed 11 October 2009.

UNFCCC (2005) Sixth compilation and synthesis of initial national communications from Parties not included in Annex I to the Convention: addendum, research and systematic observation, FCCC/SBI/2005/18 and addenda. United Nations Framework Convention on Climate Change. Online via http://unfccc.int/national_reports/non-annex_i_natcom/compilation_and_synthesis_reports/items/2709.php Accessed 23 November 2009.

UNFCCC (2008) Database on Local Coping Strategies: Online at www.maindb.unfccc.int/public/adaptation/adaptation Accessed 29 September 2009.

Unganai LS (1996) Historic and future climatic change in Zimbabwe. *Climate Research* vol. 6(2), pp. 137-145.

Unruh JD (2008) Carbon sequestration in Africa: The land tenure problem*. Global Environmental Change* vol. 18(4), pp. 700-707.

Unruh JD, Houghton RA Lefebvre PA (1993) Carbon storage in agroforestry: an estimate for sub-Saharan Africa. *Climate Research* vol. 3, pp. 39-52.

Uzowulo GI, Edet DI, Ajayi S and Idege DA (2005) Lumber recovery efficiency in the Artisanal sector in Cross River State, Nigeria. *Journal of Agriculture, Forestry and the Social Sciences* vol. 3(1).

van Gemerden BS, Olff H, Parren MPE and Bongers F (2003) The pristine rain forest? Remnants of historical human impacts on current tree species composition and diversity. *Journal of Biogeography* vol. 30, pp. 1381–1390.

van Haaften EH (2002) Linking ecology and culture: towards a psychology of environmental degradation. Faculty of Social and Behavioural Sciences. Thesis, Tilburg University, Netherlands.

van Staden V, Erasmus BFN, Roux J, Wingfield MJ and van Jaarsveld AS (2004) Modeling the spatial distribution of two important South African plantation forestry pathogens. *Forest Ecology and Management* vol. 187, pp. 61-73.

van Wilgen BW, Richardson DM, le Maitre DC, Marais C and Magadlele D (2001) The economic consequences of alien plant invasions: examples of impacts and approaches to sustainable management in South Africa. *Environment, Development and Sustainability* vol. 3(2), pp. 145-168.

Vincens A and 12 others (1999) Equatorial Africa during the last 4000 years BP and inheritance on the modern landscapes. *Journal of Biogeography* vol. 26, pp. 879-885.

Viner D and Agnew M (1999) *Climate Change and its Impacts on Tourism*. Report prepared for WWF-UK, Climatic Research Unit, University of East Anglia, Norwich.

von Maltitz GP and Scholes RJ (1995) Burning of fuelwood in South Africa: when is it sustainable? *Environmental Monitoring and Assessment* vol. 38, pp 243-251.

Wagner MR, Cobbinah JR and Bosu PP (2008) *Forest Entomology in West Tropical Africa: Forests Insects of Ghana*. Springer, Netherlands.

Washington R, Harrison M and Conway D (2004) African climate report: *UK Department for Environment Food and Rural Affairs*, *Department for International Development.* United Kingdom.

Wassie A (2007) Ethiopian church forests: opportunities and challenges for restoration. PhD thesis at the University of Wageningen, Netherlands.

Watson RT, Zinyowera MC, Moss RH and Dokken DJ (eds) (1997) Regional impacts of climatic change: An assessment of vulnerability – Summary for Policymakers. A special report of the Intergovernmental Panel on Climate Change (IPCC) Working Group II. IPCC, Paris.

WCED (1987) *Report of the World Commission in Environment and Development: Our Common Future*. Oxford University Press, Oxford.

Western D (2001) Human-modified ecosystems and future evolution. *Proceedings of the National Academy of Sciences* vol. 98(10), pp. 5458-5465.

White F (1983) *The vegetation of Africa*. UNESCO, Paris.

White LJT and Oates JF (1999) New data on the history of the plateau forest of Okumu, southern Nigeria: an insight into how human disturbance has shaped the African rain forest. *Global Ecology and Biogeography* vol. 8(5), pp. 355–361.

Whitlow R (1989) A review of dambo gullying in south-central Africa. *Zambezia* vol. 16(2), pp. 123-150.

Wilby R (2007) Decadal Climate Forecasting Techniques for adaptation and development planning. Department for International Development, UK.

Willems S (2005) National approaches to adaptation: Some lessons learned from recent OECD and UNFCCC workshops. Organisation for Economic Cooperation and Development, online at http://www.oecd.org/dataoecd/22/16/34878199.pdf Accessed 12 February 2010.

Williams P, Hannah L, Andelman S, Midgley G, Araujo M, Hughes G, Manne L, Martinez-Meyer E and Pearson R (2005) Planning for climate change: identifying minimum-dispersal corridors for the Cape Proteaceae. *Conservation Biology* vol. 19, pp. 1063-1074.

World Bank (2008) Global Monitoring Report 2008: MDGs and the Environment. World Bank, Washington.

WTTC (2009) Travel and tourism economic impact: Sub-Saharan Africa. World Travel and Tourism Council, online at http://www.wttc.org/bin/pdf/original_pdf_file/subsaharanafrica.pdf Accessed 14 February 2010.

Wu Y, Liang XZ and Zhang GJ (2003) Seasonal migration of ITCZ precipitation across the equator: Why can't GCMs simulate it?. *Geophysical Research letters* vol. 30(15), pp. ASC12.1-ASC12.4.

WWF (2006) Climate change impacts on East Africa: a review of the scientific literature. World Wide Fund for Nature, Gland, Switzerland.

Ylhäisi J (2003) Forest privatisation and the role of community in forests and nature protection in Tanzania. *Environmental Science & Policy* vol. 6, pp. 279–290.

Zaikowski L. (2007) Forests and woodlands in Africa. In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). http://www.eoearth.org/article/Forests_and_woodlands_in_Africa Accessed 11 October 2009.

Zhao YX, Wang CY, Wand SL and Tibig L (2005) Impacts of present and future climate variability on agriculture and forestry in the humid and sub-humid tropics. *Climatic Change* vol. 70(1-2), pp. 73-116.

Zhou G, Minakawa N, Githeko AK and Yan G (2004) Association between climate variability and malaria epidemics in the East African highlands. *Proceedings of the National Academy of Sciences* vol. 101, pp. 2375-2380.

Ziervogel G and Zermoglio F (2009) Climate change scenarios and the development of adaptation strategies in Africa: challenges and opportunities..*Climate Research* vol. 40, pp. 133-146.

Zomer RJ, Trabucco A, Bossio DA and Verchot LV (2008) Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. *Agriculture, Ecosystems & Environment* vol. 126(1-2), pp. 67-80.

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to promote global cooperation in forest-related research and to enhance the understanding of the ecological, economic and social aspects of forests and trees; as well as to disseminate scientific knowledge to stakeholders and decision-makers and to contribute to forest policy and on-the-ground forest management.