Review of the Economic Impacts of Climate Change in Kenya, Rwanda and Burundi

Ecosystems Chapter, Regional

Final Document

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1. REGIONAL OVERVIEW: EAST AFRICA

This section gives a brief explanation of the value of ecosystems services for human well-being and describes main ecosystems and ecosystem services in East Africa.

1.1 Ecosystem Services Value for Human Well-being

Multiple mechanisms link ecosystem services to human well-being. The same is valid for the causal connections between ecosystem changes and changes in socio-economic systems. These relations are not uniform, as socio-ecological systems are dynamic and non-linear, and ecosystem services do not operate in isolation, but interact with one another in complex, often unpredictable ways. This sub-section will focus on the value of ecosystems and ecosystem services for human well being in the region of East Africa, without analyzing the causal connections between ecosystem change and changes in well-being. Such analysis will be carried out later on in this document, when looking at changes in ecosystems due to climate change and other stresses, and the possible implications for socio-economic systems in Kenya, Rwanda, and Burundi.

Overall, human activities and live on earth benefit from a series of inter-linked ecosystem services. According to the Millenium Assesment (2005), the range of ecosystem services enjoyed by humans can be divided into four main categories (see Figure 1 below):

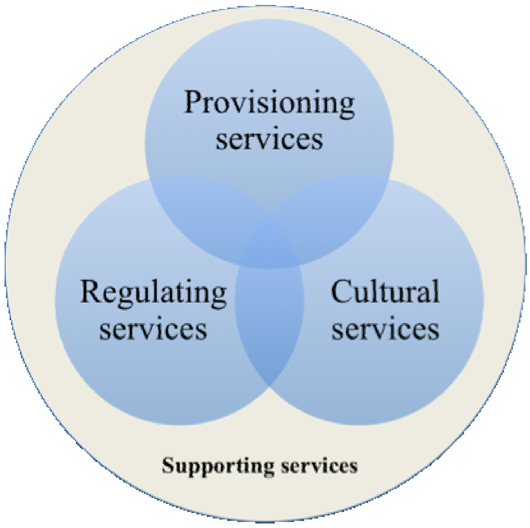


Figure 1. Ecosystem services categories.
Adapted from the MA (2005).

- ***Provisioning services: Products obtained from ecosystems***

Include the production of basic goods such as crops, livestock, water for drinking and irrigation, fodder, timber, biomass fuels, fibers such as cotton and wool; and wild plants and animals used as sources of foods, hides, building materials, and medicines.

- ***Regulating services: Benefits obtained from regulation of ecosystem processes***

Involve benefits obtained as ecosystem processes affect the physical and biological environment around them; these include flood protection, coastal protection, regulation of air and water quality, regulation of water flow, absorption of wastes, absorption of carbon dioxide, control of disease vectors, and regulation of climate.

- ***Cultural services: Non-material benefits obtained from ecosystems***

Encompass the non-material benefits that people derive from ecosystems through spiritual enrichment, recreation, tourism, outdoors-related sports, education, and aesthetic enjoyment. These services also include societies whose cultural identities are tied closely to particular habitats or wildlife.

- ***Supporting services: Services necessary for the production of all other ecosystem services***

These services are necessary for the production and maintenance of the three other categories of ecosystem services. Examples are nutrient cycling, production of atmospheric oxygen, soil formation, and primary production of biomass through plant photosynthesis.

Largely, people's livelihoods and economies depend on a reliable flow and interaction of multiple ecosystem services. It is difficult to draw direct and indirect links between ecosystem services and human well-being given the complexity of the relationships between ecological and socio-economic systems. The dependence of people on ecosystem services is often more apparent in rural communities where lives are directly affected by the availability of resources such as food, medicinal plants and firewood, or the changes in ecosystem processes. Urban communities may be partly buffered from changes in ecosystem services, for example by water treatment plants performing the water cleaning services that healthy rivers provide (SAfMA 2004). Duraiappah (2002) suggest the following links between ecosystem services (the categories provided by the MA) and human-well-being (UNEP and IISD 2005), see Figure 2 below:

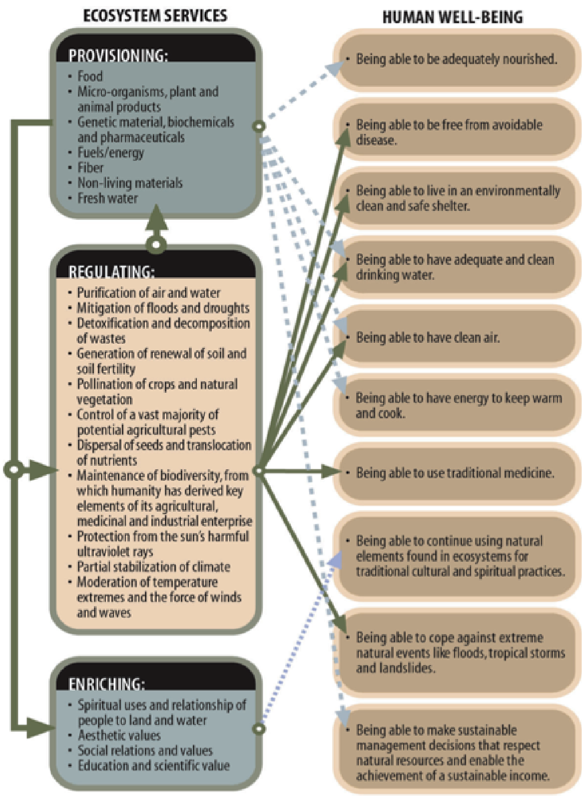


Figure 2. Links between ecosystem services and human well-being.
Source: Duraiappah 2002, UNEP and IISD 2005.

This framework uses a broaden definition of human well-being that considers not only the traditional constituent of material wealth (economic growth and livelihood), but also other constituents such as the ability to be adequately nourished; the ability to have access to freshwater; and the ability to have access to energy to keep warm and to cook, among others (Duraiappah 2004). The Millennium Assessment considers also constituents of human well-being such as basic material for good life, freedom of choice, health, equity, social security, economic security, environmental security, and social relations (MA 2003).

Furthermore, meeting the Millennium Development Goals (MDGs) requires substantial attention on several issues directly related to ecosystem services. Several targets set under the 8 MDGs are closely related to the services provided by ecosystems. For instance, meeting target 2, "halt, between 1990 and 2015, the proportion of people which suffer from hunger", would not be possible without considering all food that is ultimately provided by ecosystems, as a direct service, or through the use of other services such as water or nutrient cycling. In East Africa, a significant portion of nutrition, particularly in poor rural households, is provided by semi-natural ecosystems, and is not accounted for in formal agricultural statistics. Similarly, target 5, "reduce by two-thirds, between 1990 and 2015, the under-five mortality rate", is highly sensitive to ecosystem services that regulate, purify and provide water. One of the main causes of child mortality in East Africa is disease associated with poor sanitation and unsafe water source. Water-related ecosystem services are also fundamental for the achievement of target 10, "halve by 2015 the proportion of people without sustainable access to safe drinking water" (SAfMA 2004).

Box 1. Human well-being in East Africa

Meeting the MDGs is crucial for the population well-being and poverty reduction in the region. The countries in East Africa are amongst the least developed in the world. Indicators such as the Human Development Index (HDI) show that the people in this region are among the most disadvantaged worldwide. In 2001, countries in East Africa were in UNDP's low human development category, with Burundi rate being the lowest among the region (HDI value 0.34, rank 171), and Kenya the highest (HDI value 0.49, rank 146) (SAfMA 2004).

In addition, when different indicators for sustainable development were compared for countries in the southern Africa as part of the Southern African Millennium Ecosystem Assessment (SAfMA 2004), the highest correlation (44%) was found between the Environmental Sustainability Index and the Well-being Index. This high correlation denotes that human well-being is related, substantially but not exclusively, to the state of ecosystems. Figure 3 below shows the comparison of three indicators of sustainable development, the Environmental Sustainability Index (ESI) (World Economic Forum et al. 2002), the IUCN-sponsored Well-being Index (WI) (Prescott-Allen 2001), and the Ecological Footprint (Wackernagel et al. 2002), for the countries of Southern Africa. Overall, it is possible to observe that there is a close relation between the ESI and the WI.

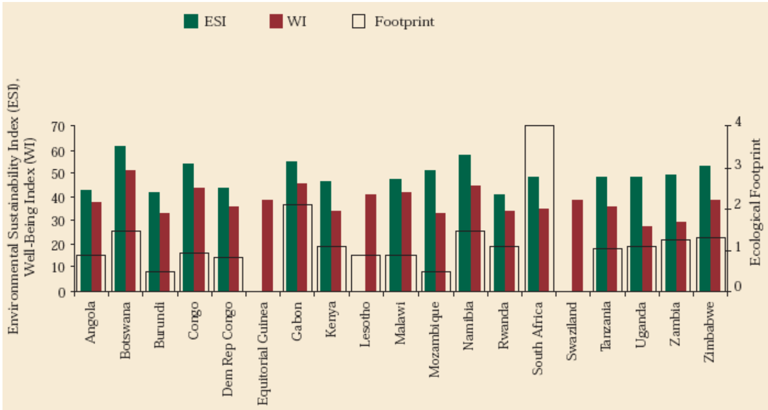


Figure 3. Comparison of ESI, WI, and the Ecological Footprint for countries in southern Africa. Source: SAfMA 2004.

Note: ESI: Measure of overall progress towards environmental sustainability, based 20 core indicators and 68 underlying variables. WI: Average of Human Well-being Index and Ecosystem Well-being Index. Ecological Footprint: Sum of cropland, grazing, forest, fishing, energy and built-up land footprints.

Despite human well-being (including the achievement of MDGs) depend on multiple ecosystem services, there are drivers of change and trade-offs that can be disruptive and increase the pressure on ecosystem services and resources causing social conflict, displacements, economic losses, and threatening human well-being. Sections II and III will discuss the drivers of change and the implications of ecosystem change for socio-economic systems in more detail.

1.2 Ecosystems and Ecosystem Services in the Region

Based on the MA categories for ecosystem services and the links to human well-being suggested by Duraiappah (2002), the scoping study prepared by the International Institute for Sustainable Development for the United Nations Environment Programme reviewed the ecosystem services for Kenya, Rwanda, Tanzania and Uganda and identified four critically stressed ecosystem services that need immediate attention: maintenance of biodiversity; food and fiber provision; water supply, purification and regulation; and fuel provision. This section gives a brief overview of the ecosystems and ecosystem services in East Africa paying special attention to the ones identified as critical for the region. The overview is largely based on the study carried out under the Southern African Millennium Assessment (SAfMA), published in 2004 (see Box 2), and last updated data obtained from the World Resources Institute Earthtrend Database, the United Nations Food and Agriculture Organization Statistics Database, and the International Energy Agency Country Statistics.

Box 2. The Southern African Millennium Assessment (SAfMA)
The Millennium Ecosystem Assessment (MA) was a four-year international effort to assess the capacity of ecosystems to provide the services needed to support human well-being and life on earth. The Southern African Millennium Assessment (SAfMA) assessed several key services provided by ecosystems in southern Africa, and their impacts on the lives of the region's people.

The southern Africa region consists of the nineteen countries on mainland Africa that lie entirely or partially south of the equator (see Figure 4). SAfMA was designed at three 'nested' scales: the region; two major drainage basins within the region; and five local government areas within the basins.

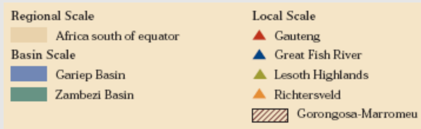


Figure 4. Countries covered by the SAfMA. Source: SAfMA 2004.

According to the SAfMA (2004), using the highest level of ecosystem classification the groups of ecological communities in Southern Africa can be classified into eight 'biomes': forest, savanna, grassland, arid shrublands, desert, fynbos, wetlands and lakes (see Figure 5).

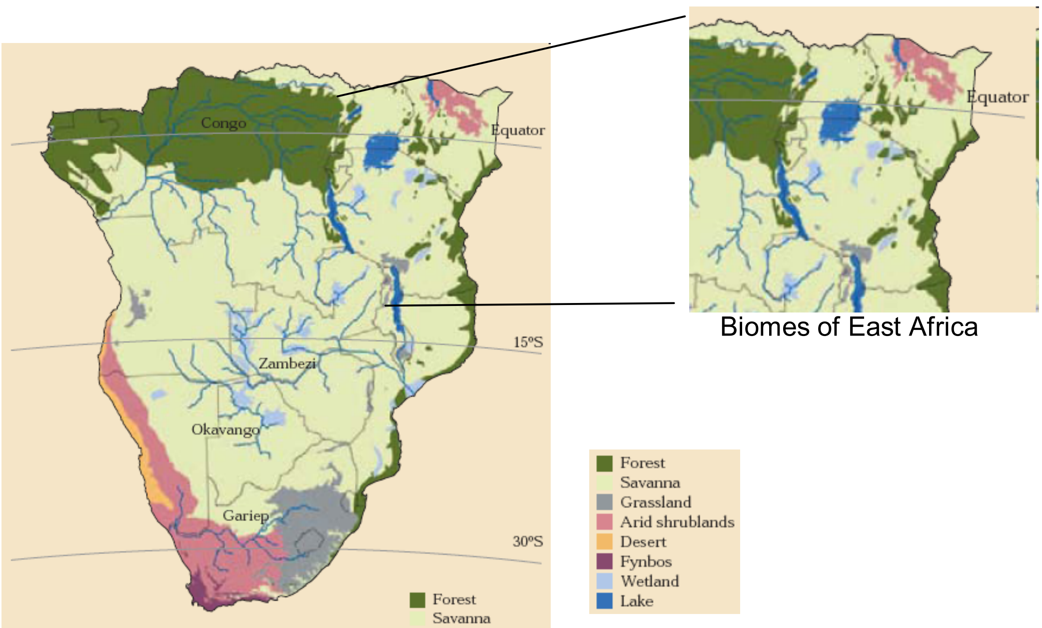


Figure 5. The biomes of Southern Africa.

Table 1 below shows the sub-biomes, soil and geological characteristics for each biome of the region. Over time, landscape in Southern Africa has been shaped and transformed by humans for settlements and crop agriculture. According to the SAfMA (2004) the transformed area was small before the colonial period starting in 1600. The final column of the table below refers to the percentage of the pre-colonial area that remains untransformed by cultivation or urbanization in 2000 (based on GLC 2000 estimates). The high percentages suggest that there have not been substantial changes in the untransformed areas over time.

Table 1. Main ecosystems of southern Africa based on a reclassification of the WWF Terrestrial Ecoregions[1]

Biome	Sub-biome	Soil-geology	% 1600-2000
Forest	Lowland (rain) forest	General infertile Fertile but steep	93 78
Savanna	Broadleaf (Miombo) Mopane Fineleaf (Acacia)	Infertile, sandy Fertile, loamy, clavely	90 77 84
Grassland	Montane grassland	Fertile or infertile	69
Arid shrubland	Non-succulent Succulent	Fertile, often calcareous	99 100
Desert	Namib	Sandy or gravelly	100
Fynbos	Fynbos	Generally infertile	87
Wetland	Permanent wetland Seasonal Estuaries and mangroves Inland water and coastal waterways	Organic (peaty) Often cracking clays Saline, organic	89 89 95 95 100

Source: SAfMA 2004.
[1] Olson et al. 2001.

Forests

Most of Southern Africa has some percentage of tree (woody plants taller than 2.5 m) cover. On the one hand, the Food and Agriculture Organisation of the United Nations (FAO) defines forests as all areas with more than 10% woody cover (FAO 2001). On the other hand, forest professionals in the region usually classify forests as areas with greater than 60% canopy cover, woodlands as areas with 40 - 60% canopy cover, and open savannas as areas with 5 - 40% crown cover (Scholes 2004). Indeed, much of the disagreement in forest cover stems from how much of the savanna component is included in 'forest'. In some cases, the category woodlands can be included in the category of savannas. Table 2 below compares the total area classified as forest and woodland in Southern Africa based on four satellite-derived land-cover products undertaken for the 1990s at the regional-scale: IGBP GLCCD, MODLAND, GLC2000, and SADC landcover. The last column presents FAO forest statistics for 2000 based on a threshold of 10% minimum crown cover to define forest (FAO 2001).

The Global Land Cover 2000 (GLC 2000) uses 1 km resolution vegetation data, and is visually interpreted. The GLCCD product is the latest version of the IGBP land-cover dataset, based on 1.1 km resolution NOAAAVHRR data and an automated decision rule. The MODIS land-cover product (MODLAND) includes a 500 m tree cover percentage layer. The SADC land-cover map is constructed from high-resolution data, interpreted by local experts, and should therefore be the most accurate, for the countries that it covers. For the area covered, the SADC landcover provides a total estimate that is almost three times higher than the ModLand estimate, and about 25% higher than the submissions to FAO.

Table 2. Forest cover in Southern Africa

Country	GLCCD IGBP		MODLAND		GLC 2000 Africa		SAD LC		FAO Statistics 2000	
	1000 km^2	%	1000 km^2	%	1000 km^2	%	1000 km^2	%	Total 1000 km^2	%
Burundi	7	25	6	23	5	19			1.98	6
Kenya	157	27	67	11	65	11			35.82	6
Rwanda	6	24	8	30	4	15			3.44	18
Tanzania	278	29	179	19	296	31	470	50	373.1	41
Uganda	92	38	126	52	88	36			40.5	19

Adapted from SAfMA 2004, and FRA 2000 (FAO 2001).

Notes: FAO Global Forest Resources Assessment 2000 (http://www.fao.org/forestry). The Forest Resources Assessment 2005 adopted a threshold of 10% minimum crown cover to define forest. Total forest includes both natural forests and forest plantations, but excludes trees established primarily for agricultural production (e.g. orchards).

Comparing the last FAO Global Forest Resources Assessment 2005 (FRA 2005) with the FAO Global Forest Resources Assessment 2000 (FRA 2000), it is possible to identify annual change rates for the countries. While Burundi shows a significant reduction in forest cover (around 23% over the five years at an annual change rate of -5.2%), Rwanda has increased its forested area over the past years (40% over the five years, and at an annual rate of 6.9%) (see Table 3 below). The drivers behind this change will be discussed in detail in the section II of this document. According to the FRA 2005, the country with the largest forested area in East Africa is Tanzania, and the country with less forest cover is Burundi. The total area with forest cover in East Africa is about 43 million ha, equivalent to approx. 28% of the combined area of the five countries listed in the table below.

Table 3. Changes in the forest area in East Africa

Country	Forested area 1000 km^2	%	Annual change rate 2000-2005 FAO FRA
Burundi	1.52	5.9	-5.2
Kenya	35.22	6.2	-0.3
Rwanda	4.8	19.5	6.9
Tanzania	352.5	39.9	-1.1
Uganda	36.27	18.4	-2.2
Total	430.31		

Adapted from the FAO Global Forest Resources Assessment 2005 and 2000.

Protected areas

Recent conservation approaches attempt to identify areas of high biodiversity value (in terms of richness, endemism, threat, biodiversity representation, complementarity to existing protected areas, or other value), whose conservation would both preserve a large number of species and maintain general ecosystem health. Variations of sophisticated systematic conservation planning techniques have been locally developed and applied on a regional scale (e.g. Cowling & Pressey 2003). In Africa, many of these high biodiversity value areas are densely populated, creating a potential challenge for conservation and trade-off of ecosystem services. Table 4 below shows estimtes of protected areas per country in the East Africa for 2003 obtained from the World Resources Institue Database[1]. Both Tanzania and Uganda have more than a quarter of their territory under protection, while Kenya has mre than 10% under protection, and Burundi and Rwanda less than 10%. Among all the countries, Kenya has the largest number of Biospehre reserves and Ramsar wetland sites, while Tanzania has the largest number of World Heritage sites in the region.

Table 4. Protected areas in countries of East Africa, 2003

	Area of national parks, nature reserves and protected landscapes (IUCN I-V)[2]		Areas managed for sustainable use and areas not classified by IUCN (IUCN VI and other)[3]		All protected areas as % of total area	Marine and litoral protected areas (IUCN - VI)	Biosphere reserves[4]	Ramsar wetland sites[5]	World heritage sites[6]
	1000 km^2	%	1000 km^2	%	%	1000 km^2	No	No	No
Burundi	1	5.3	0	0	5.4		0	1	0
Kenya	35	6.0	37	6.3	12.3	4	6	4	2
Rwanda	2	7.4	0	0	7.7		1	N	0
Tanzania	138	14.6	236	25	39.6	1	3	3	4
Uganda	18	7.3	47	19.3	26.4		1	1	2

Source: www.earthtrends.wri.org

2 Marine protected areas are excluded. Additionally, about 15% of sites are excluded as they do not yet have area data.

3 Marine protected areas are excluded. Additionally, about 30% of sites are excluded as they do not yet have area data.

4 Areas internationally recognized under the Man and the Biosphere Programme of UNESCO. Available online at www.unesco.rog/mab

5 Wetlands of international importance. Available online at http://ramsar.org

6 Areas of outstanding natural or cultural value. Only sites of natural value listed here. Available online at http://whc.unesco.org

N Countries not signatory to the convention.

Hotspot approaches such as used by Conservation International aim to highlight areas with high concentrations of endemic species that are undergoing dramatic loss of habitat (Myers et al. 2000). The WWF Global 200 identifies areas that can be considered representative examples of all ecosystems and emphasizes biodiversity features that were in place before major human impacts. The hotspots analyses carried out by Conservation International highlight areas of high endemic value that are undergoing high rates of loss. A complementary approach to the hotspot analysis is to identify the remaining areas in each biome that are least impacted by human activity (Sanderson et al. 2002). Figure 6 below illustrates both approaches (a) WWF Global 200, b) remaining least impacted areas. The figure shows areas that have been proposed as priorities for conservation in Southern Africa.

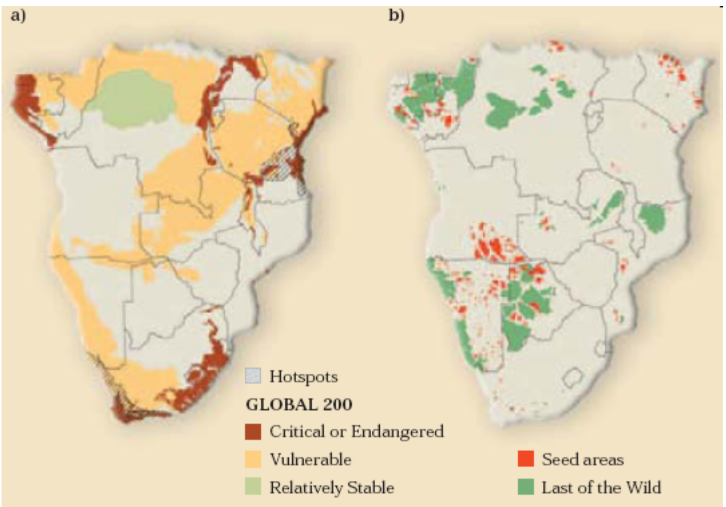


Figure 6. Priority areas for conservation in Southern Africa. Source: SAfMA 2004.

Note: The Last of the Wild areas indicate the ten largest contiguous areas in each biome, which fall within the 10% least impacted (wildest) areas on earth. Seed areas indicate the 1% wildest areas in each biome, regardless of size.

Woodfuel and charcoal

In East Africa, most countries have relatively small industrial energy sectors, and traditional biomass fuels make up a large proportion of the total energy supply (see Kenya and Tanzania examples in Table 5 below). Even where electricity is provided, paraffin, liquid petroleum gas or coal are available as substitutes. Non-traditional biomass fuels are less affordable, or in some cases an open fire is preferred for cooking and domestic space heating (SAfMA 2004). In 2006, biomass represented 73% of the total energy supply in Kenya, followed by crude oil and petroleum products (both imported) and geothermal energy (domestic production) (IEA 2009). In Tanzania, biomass made up almost 91% of the energy supply in 2006, followed from far away by petroleum products (imported) (IEA 2009).

Table 5. Biomass contribution to the energy supply of Kenya and Tanzania in 2006.

Country	TPES	TPES per capita	Biomass	Electricity access[1]
	Mtoe	Toe per capita	%	% Population
Kenya	17.95	0.49	73	8
Tanzania	20.80	0.53	91	11

Sources: IEA country statistics 2009.
[1] World Resources Institute 2000 (http://earthtrends.wri.org/)
Note: TPES=Total primary Energy Supply, toe= Tons of oil equivalent, Mtoe= Million of Tons equivalent.

According to the SAfMA (2004), charcoal is the preferred fuel in urban areas, while wood tends to be used when the wood source is close to the place of consumption, i.e. mostly in rural locations. Charcoal has about twice the energy content per unit mass of compared to that of wood, but the cost of woodfuel when consumed locally is cheaper. Nevertheless, transporting woodfuel from where it grows to where it is consumed increases the total fuel cost, making charcoal a more viable economic option in most large urban centres. A further reason why charcoal is preferred in urban areas is that it is relatively clean-burning. Health impacts of charcoal have been estimated to be four times lower than those of wood (IEA 2002).

Water

There are five broad categories of water use in southern Africa: domestic consumption (including home gardens), industry (including mining and coal-fired electricity generation), hydroelectric power generation (for example in Kenya and Tanzania), irrigated agriculture and the maintenance of aquatic ecosystems. In addition, river ecosystems process and dilute wastes, help with flood control, and provide for recreation, aesthetic satisfaction and religious rituals. Table 6 below shows the contribution of hydro-electricity to the total electricity generated in Kenya and Tanzania. In both countries water resources play a main role in the electricity supply, contributing about 50% to the total production. Table 6 also shows the potential and exploited irrigation in the countries of the region. All countries are using less than the 10% irrigation potential, with exception of Kenya, which has reached almost 20% of the irrigation potential. Considering that the area used for irrigation is in fact the area equipped for irrigation and not necessarily the area that is actually irrigated, the exploited capacity portrayed in this table can be expected to be even lower.

Table 6. Water withdrawals in East Africa, available data for period 1998-2002[1]

Country	Hydro-electricity[2]		Irrigation			Water withdrawals						
	GWh*	%	Potential 1000 ha	Total 1000 ha	Exploited %	Irrigated agriculture		Domestic		Industrial		Total withdrawal
						km^3 p.a.	%	km^3 p.a.	%	km^3 p.a.	%	% internal water resources[3]
Burundi			215	21.4	9	0.22	77	0.04	17	0.01	6	2.9
Kenya	3278	50	539	103	19	1.01	64	0.47	30	0.01	6	7.6
Rwanda			165	8.5	5	0.1	68	0.04	24	0.01	8	1.6
Uganda			90	9.15	10	0.12	40	0.13	44	0.05	16	0.8
Tanzania	1436	50	2132	184	9	4.6	89.3	0.52	10.1	0.02	0.4	6.2

Sources:
1 FAO AQUASTAT, most recent values of period 1998-2002 (http://www.fao.org/ag/agl/aglw/aquastat/dbase/index.stm)
2 IEA Country Statistics, 2006. Percentage = contribution to the total electricity production in the country.
3 WRI Earthtrends Database, 2000 (www.earthtrends.wri.org)

Notes: toe: Metric Tons of Oil Equivalent; Percentage data reflect contribution to total national energy supply
* Includes production from pumped storage plants.

In relation to water withdrawal, irrigation for agriculture represents the largest category of water use in the region (from 40% in Uganda to 90% in Tanzania), followed by domestic use (from 10% in Tanzania, to 44% in Uganda). The industrial sector uses by far the least water resources in the region (from 0.4% in Tanzania to 16% in Uganda), using from 3 times (Uganda) to almost 90 times (Tanzania) less water than the agricultural sector, depending the country. Moreover, al countries use less than the 10% of their internal water resources, suggesting potential in the region to meet higher water demands.

Last but not least, suitable water supply is recognized as a fundamental need and human right, and has significant health and economic implications for households and individuals. Access to safe water in East Africa has improved over the past decades. All countries have increased access to improved water source from 1990 to 2004: Burundi from 69% to 79%; Kenya from 41% to 61%; Rwanda from 59% to 74%; Tanzania from 46% to 62%; and Uganda from 44% to 60% (WHO 2006). In general, urban communities in East Africa have better access to drinking water than rural communities (WHO 2006). Despite access to improved water source has ameliorated, access to improved sanitation has not changed over the last years, reaching only less than the half of the population in all the countries of the region in 2004: Burundi (36%); Kenya (43%); Rwanda (42%); Tanzania 947%); and Uganda (43%) (WHO 2006). Lack of access to improved water source and sanitation has serious implications for human health in the region, especially for children. The most common water-borne diseases that affect the population and in particular children in the region are diarrhea, intestinal worms, trachoma, schistosomiasis (biharzia) and cholera, as well as vector-borne diseases that are highly water-sensitive such as malaria (WHO 2004).

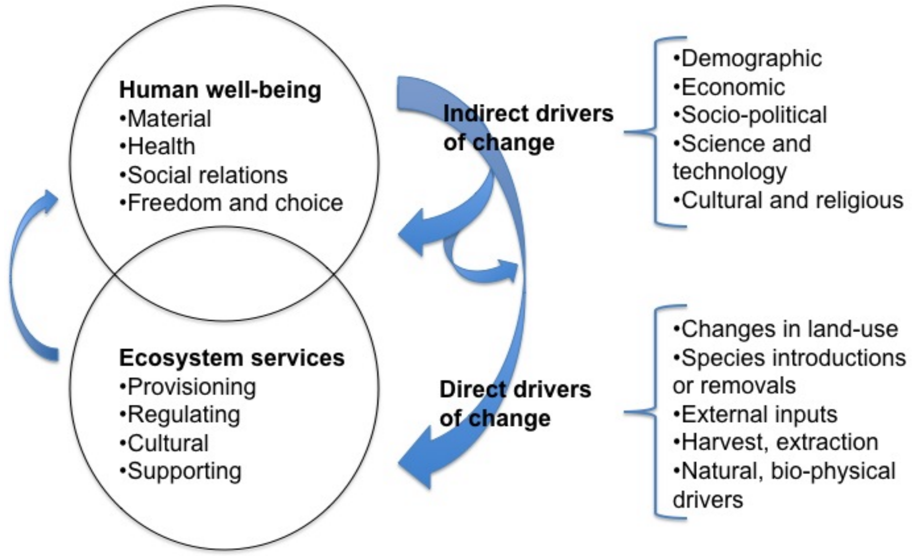
The second part of this section describes in more detail the ecosystems and ecosystem services of Kenya, Burundi, and Rwanda. Section II analyses the current and future changes that affect ecosystems an ecosystem services in the region, followed by section III that explains the implications of these changes for the economies of the region and the well-being of its population.

2. VULNERABILITY OF ECOSYSTEMS IN EAST AFRICA

This section identifies and analyses patterns of change affecting ecosystems and causing trade-offs between ecosystem services in East Africa. Recognizing current exposure of ecosystems to stresses and the associated effects on ecosystems services, it then depicts the susceptibility of stressed ecosystems to climate-related drivers of change. In addition, Annex I summarizes the geographical distribution of main issues related to ecosystem degradation and changes in ecosystem services in East Africa.

2.1 Current Stresses on Ecosystems in the Region

Ecosystems interact with one another in complex ways. Human intervention and dominant patterns of demographic, social and economic change can affect the interaction between ecosystems and thus affect multiple ecosystem services directly and indirectly. In turn, changes in ecosystems and ecosystem services can lead to changes in human well-being (see Figure 7). The Millennium Ecosystem Assessment highlights two specific policy-relevant interactions among ecosystem services: synergisms and tradeoffs.



Adapted from SAfMA 2004.

Figure 7. Drivers of change and interactions between ecosystem services and human well-being

Trade-offs in ecosystem services occur when the provision of one ecosystem service is reduced as a consequence of increased use of another ecosystem service. For example, trade-offs may arise from management choices made by humans, which can change the type, magnitude and relative mix of services provided by one ecosystem, and as a consequence affect the functioning of other ecosystem services. For instance, human exploitation of ecosystem services for the production of consumptive goods (e.g. provisioning ecosystem services for food or energy resources) can reduce the long-term quality of regulating and/or supporting ecosystem services (e.g. renewal of soil and soil fertility, maintenance of biodiversity, water regulation). In some instances, trade-offs can be a consequence of planned actions; in others, trade-offs may be unpredictable (Swallow et al. 2009).

In contrast, synergism is defined in the context of the provision of ecosystem services as a situation in which “the combined effect of several forces operating on ecosystem services is greater than the sum of their separate effects" (adapted from Begon et al. 1996 in MA 2005). Following this line, a synergism occurs when ecosystem services interact with one another in a multiplicative way with positive or negative effects on human-well-being (MA 2005).

Three are the main issues in the region related to changes in ecosystems and trade-offs between ecosystem services that affect human well-being: freshwater shortage, degradation of ecosystems and biodiversity loss, and depletion of fisheries (see Payet and Obura 2004; SAfMA 2004). This section analyzes the drivers of change, trade-offs and consequences associated to each issue. Annex I portrays the geographical distribution of main issues related to ecosystem degradation and changes in ecosystem services in four countries of the region.

2.1.1 Freshwater Shortage

The annual rainfall pattern in the region is seasonal, and annual variability of rainfall is very high. The Inter-Tropical Convergence Zone results in two rainy seasons separated by longer dry seasons each year. The resulting climate is described as semiarid to arid tropical (Payet and Obura 2004). Moreover, the ratio of rainfall to evapotranspiration in the region in among the lowest worldwide. According to the SAfMA (2004), the region has experienced decade-long cyclical periods of wetness and dryness partly associated with the ENSO phenomenon.

Due to relative low rainfall across the region and limited water storage capacity, annual internal renewable water resources per capita for Kenya, Burundi, Rwanda, Tanzania, and Uganda are low, averaging in 2007 about 1,250 m^3 per person, as compared to over 44,820 m^3 in South America (AQUASTAT 2007). As mentioned in section 1, water in the region is used for multiple purposes, the most important being agriculture (irrigation), followed by urban consumption, tourism, industry and hydropower (damming). In most of the countries, more than 50% of the population does not have direct access to potable water (see section 1).

Water resources and scarcity are distributed unevenly across the region. Table 7 below shows water resources availability per capita in 5 countries of the region for 2007 and estimates for 2030. Data cover surface water and groundwater, as well as flows between countries. According to the United Nations, the threshold for water stress resulting in disruptive water shortages (shown in yellow) is estimated at 1700 m3 per capita per year, while water availability below 1000 m3 per capita per year (shown in red) leads to more serious challenges related to human health, food production and economic development.

Table 7. Water resources availability per capita in East Africa

Country	Internal renewable water resources (Km3)	Water per person 2007 (m3 per capita)	Water per person 2030 (m3 per capita)
Burundi	10.1	442.2	264
Kenya	20.7	938.6	734
Rwanda	9.5	550.7	387
Tanzania	84.0	2291.2	1599
Uganda	39.0	2132.8	1032

Sources: FAO AQUASTAT 2007.

Note: Data reflect national averages; completeness and accuracy of data varies between countries. Data represent average annual freshwater resources (actual supply varies from year to year).

All five countries listed in the table below show future water stress. In Kenya, Burundi, and Rwanda, water supply falls already below the scarcity level of 1000 m3 per capita per year, and the situation seems to worsen in the coming decades. Also Tanzania and Uganda show future water supply stress, despite the level at present is above 1000 m3 per person.

One of the main reasons for future water supply stress is increased demand. This is caused on the one hand by population growth, and on the other hand by a change in consumption patterns as living standards rise, resulting in increased water consumption per person (e.g. increasing water use for larger or more intensive agricultural systems and growing urban centers). Land-use change and shifting rainfall are also expected to increase scarcity of water resources with implications for food security, economic growth, health, and social stability. Future scenarios and possible impacts will be discussed in further detail in the next sections of this document. However, it is important to recognize that population in the region is already vulnerable to water shortage. A clear example of this are the effects caused by the prolonged drought in Kenya this year 2009. Severe drought has led to a serious water shortage across the country resulting in months-long water rationing in major towns (Nairobi, Mombasa, Kisumu and Eldoret), shut down of the Ndakaini Dam, which supplies 80% of Nairobi's water, and shut down of key hydro-electricity power plants at Masinga and Kiambere due to inadequate water level for electricity generation. While water shortage in major settlements compromises safe water and sanitation services raising fears of possible disease outbreaks, in rural areas such as the Rift Valley Province and Central Kenya it compromises food security. People and cattle are dying from drought-related causes. The economy in general is highly susceptible to water shortage, as it may lead to increasing food prices and general inflation (Emase 2009).

While the table above focuses on absolute quantity of water supply, an issue that is not reflected in the analysis is water quality, which adds to the problem of water availability. The most significant issues with water quality in the region are suspended solids (sediment), and solid wastes, although organic pollution (sewage) from growing urban centers is also an increasing problem. Sedimentation problems and high volumes of human waste can be found, for example, in the River Lumi in Kenya, where discharges of suspended solids were estimated to be about 300,000 Tons per year in 1998 (Musyoki and Mwandotto 1999). Moreover, anoxic conditions due to sedimentation overloads have been observed in lakes of the region such as Lake Jipe (Kenya) and Lake Victoria (Kenya, Tanzania, Uganda). Solid wastes are also a problem, given that most of the countries lack waste collection and disposal systems and waste is often found scattered throughout cities and village areas (Van der Elst and Salm 1998).

In summary, water shortage is a current concern for the population in the region, and this issue can be expected to worsen in the future due to increasing demand, land-use change and shifting rainfall patterns. Moreover, positive feedbacks between increasing water pollution and decreasing freshwater supply may rapidly raise the importance of water quality in the region (Payet and Obura 2004). Box 1 gives an example of ecosystems trade-offs between land-use change and production patterns and regulating and supporting ecosystems associated with water availability and quality.

Box 1. Case study: Analyzing tradeoffs and synergies between ecosystem service sin the Lake Victoria basin of East Africa

Lake Victoria is a crucial ecosystem for over 25 million people in Kenya, Uganda, Tanzania, Rwanda and Burundi who live in the basin, and for the greater Nile river system downstream of the lake. The lake is a major economic resource for East Africa, providing fish to a multi-million dollar export industry and local consumers. Lake Victoria is also a major biodiversity reserve. Wetlands filter sediment and nutrients from entering the lake, provide habitat for fish breeding, and generate building materials, fuelwood and fodder for a large rural population (Swallow et al. 2003). In addition, the Lake provides hydroelectric power and inland water transport and supports a range of industries in the trade, tourism, and wildlife sectors. In the basin, local population mainly depends on extensive rainfed agriculture for domestic and commercial purposes.

Ecosystem management in the Lake Victoria basin has been highly extractive for most of the last 60 years, with the 1990s being a period of marked decline in food production, economic growth, and poverty levels. In 2004, the Lake Victoria basin was judged to be one of Africa's worst 'hunger hot spots' by the InterAcademy Council (2004). Moreover, severe erosion in parts of the catchment increased sediment deposition in waterways and the lake, causing serious environmental degradation. The lake is now considered to be eutrophic, with fluctuating water levels, high phosphorus and sediment loads, recurrent invasions of water hyacinth, proliferation of blue-green algae, and record rates of fish species extinction (Scheren et al. 2000; Odada et al. 2004).

According to Barrett and Swallow (2006), the simultaneous degradation of ecosystems and human well-being in the Lake Victoria basin can be explained by the fact that the region is caught in a poverty–environment trap, where many farmers, especially in the low and mid-altitude zones of the basin, appear to be subject to poverty traps of low production, low income, low investment and high environmental degradation. Only few farmers are in a synergistic cycle of higher levels of production, adequate investments in land management, and increasing incomes (Barrett and Swallow 2006).

A study carried out in 2005 by Swallow et al. (2009), evaluates temporal and spatial tradeoffs between provisioning and regulating services in the Nyando and Yala basins of the Lake Victoria catchment. Both basins drain into Lake Victoria from the Kenyan portion of the lake catchment and have their headwaters in the Mau range of forested hills in Western Kenya. The provisioning services considered in the study are agricultural crops, and the regulating service is sediment filtration (water purification) or reduction of sediment yield (Sediment yield per hectare is used as an indicator of an ecosystem dis-service). The second indicator of regulating service is the area of natural vegetation; assuming that natural vegetation tends to provide higher protection of regulating services than do cropping systems.

Calculating median sediment yield and median value of production per hectare, the study characterized each sub-basin of the basins as having higher or lower than average sediment yield, and higher or lower than average value of production per hectare. Each sub-basin was thus identified as belonging to one of the four categories: (1) low revenue and low sediment yield; (2) low revenue and high sediment yield; (3) high revenue and low sediment yield; or (4) high revenue and high sediment yield. High value of production (high revenue)/high sediment yield is used as an indicator of tradeoffs between provisioning and regulating services; high value of production/low sediment yield is taken to indicate synergies between economic development and environmental conservation, and low production/high sediment yield is taken to indicate an environment–poverty trap.

Land use change assessment, based on interpretation of aerial photographs, indicates the dynamic nature of land use in the two Nyando and Yala basins between 1991 and 2006. Results show that Nyando basin was particularly subjected to land use tradeoffs: large loss of forest occurred in the uplands due to increases in the area of maize production, while in the lowlands increase in rice and vegetable production led to loss of intact wetlands. Tree crops are important in both the Yala and Nyando basins, with expansions in tea and mangoes, and contractions in coffee. The area of woodlots and hedgerows appeared to be relatively stable.

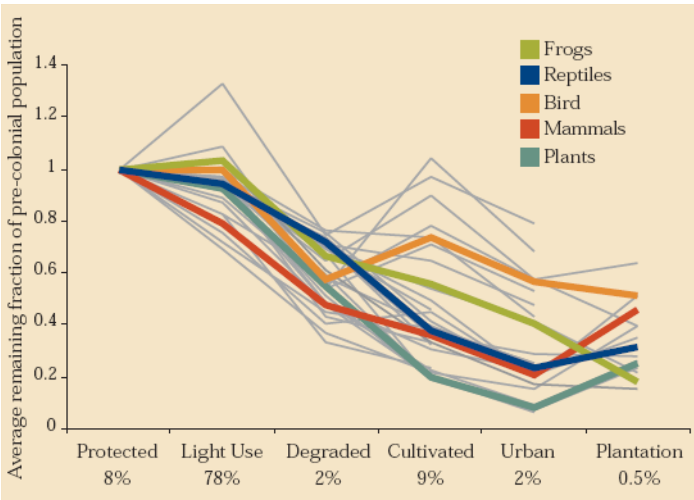
The spatial and temporal analysis of the value of agricultural production shows a clear relationship between altitude and value of production. In both basins, value of production is lowest in the areas near to Lake Victoria and highest in the mid-to-upper altitude areas that are suitable to mixed smallholder agriculture and tea.

The tradeoff analysis shows that between 1997 and 2005, there was a considerable amount of natural vegetation converted to crop production in the Nyando basin, and recent data show that there has recently been a large conversion of wetland into irrigated rice in the Yala basin. The study suggests that in both basins there are locations where tradeoffs between agricultural production and sediment yield predominate and a roughly equal number of locations where synergies predominate. However, results also indicate that increases in sedimentation of waterways can be expected in the Nyando and Yala basins due to land conversion, and thus apparent tradeoffs between value of production and sediment yield within sub-basins. Such sedimentation will be very dependent on rainfall patterns with consequences for phases of flooding and heavy pollution of Lake Victoria (Swallow et al. 2009).

2.1.2 Ecosystems Degradation and Biodiversity Loss

East Africa is characterized by rich, diverse and distinct terrestrial and marine ecosystems. However, modification of habitat due to demographic and socio-economic processes is degrading ecosystems in the region and causing disruption of ecosystem services and biodiversity loss. For example, changes in diet and consumption patterns associated to urbanization processes and population growth (population in southern Africa is projected to nearly double over the next half century, despite the effects of HIV/Aids, SAfMA 2004) will cause changes in land-use and production systems (e.g. by expanding cattle ranching or improving herd productivity to satisfy a increasing demand of animal protein) (SafMA 2004).

Changes in land-use and production systems (e.g. extensification and intensification of agricultural production) have consequences for biodiversity, as land-cover is closely linked to biodiversity change (In Figure 8 below: non-mobile and larger organisms and predators are more affected by human activity than are smaller, non-predatory species.) (SAfMA 2004). Changes in land-use and production systems have also impacts on ecosystem services, as landscapes are modified and resources are (over-) exploited. For example, an increase in long-term stocking of livestock at rates much greater (>200%) than the reference grazing potential become a driver of land degradation, particularly in arid and semi-arid areas characteristic of East Africa (Hoffman & Ashwell 2001, see Box 2). Another consequence can be salinisation and soil erosion, often associated to poor irrigation and cropping practices in marginal lands. Given the age and origin of soils in the region, which makes them inherently low in nutrient, repeated crop harvest without adequate nutrient replenishment (due to for example inadequate infrastructure to deliver fertilizers at affordable costs), can rapidly lead to land degradation (Sanchez 2002). Land degradation can be expected to increase, as population grows, land-use changes, and urbanization processes continue.



Source: SAfMA 2004

Figure 8. The effect of increasing land use intensity on the inferred original Population, Southern Africa.

Note: Estimates, averaged over biomes and functional types, were derived from independent structured interviews with 16 taxon specialists. The x-axis percentages refer to the percentage of southern Africa under the respective land uses. Grey lines show the range of estimates.

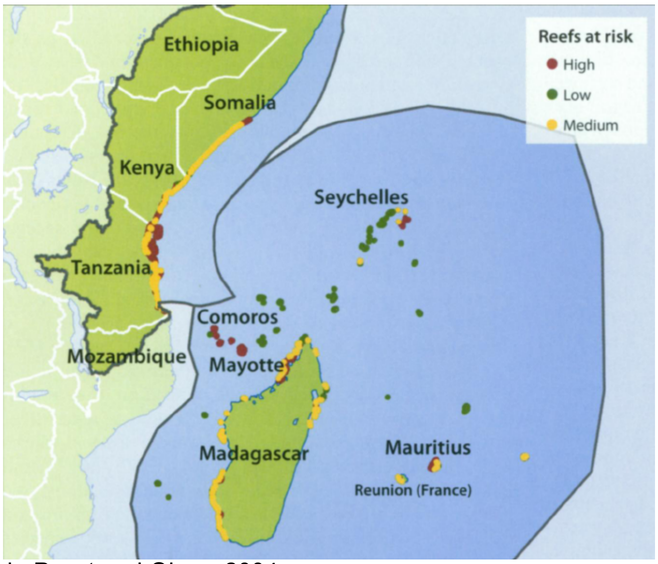
Box 2. Desertification
In the drier parts of Africa, the main processes of ecosystems degradation involve changes to the vegetation cover and composition, or changes to the soil (Hoffman & Ashwell 2001). When dry areas of the region are perceived to be degraded, the ground cover and productivity typically decline, palatable species may be replaced by unpalatable species, a greater fraction of rainfall is converted to storm-flow, and the sediment yield per unit area increases. The main driver of this process known as desertification, is thought to be long-term herbivory (generally domestic livestock) at levels greater than the productive potential that the landscape can support. Reich et al. (2001) estimate that approximately half of the sub-humid and semiarid parts of the region are at moderate to high risk of desertification. Source: SAfMA 2004

Changes in land use have also caused a chronic loss of natural forest within river basins in all the countries of the region. Average annual rates of deforestation 2000 to 2005 range from 0.3% in Kenya, to 1.1% in Tanzania, and 5.2% in Burundi (FRA 2005). In just 30 years, natural forest on the southern slopes of Mount Kilimanjaro has decreased 41 Km^2 due to expansion of cultivation (Yanda and Shishira 2001). Dam projects have also affected riverine forests as a result of decreasing river flows in many areas, such as the Pangani River and Delta in Tanzania. Degradation of natural closed forests does not only modify habitat and impact wildlife, but also climate regulation and water storage capacity. Stress and deterioration of closed forests can increase risk of floods in the rainy season and drought in the dry season. For example, shortages of water in Nairobi city (see section 2.1.1 above) are likely linked to the degradation of forests in the Mount Kenya and Aberdare range (UNEP and IISD 2005).

Another issue affecting forests is sedimentation. Sedimentation processes along the Kikuletwa River in Tanzania have converted humid and wet regions into fragmented forest areas. This has resulted in the migration of several species of wildlife, including river crocodiles. Freshwater fisheries are also affected by high sedimentation levels (Payet and Obura 2004). Around Lake Victoria, rising agriculture and human settlement in the catchments increased the flow of silt, nutrients, and pollutants into the lake, causing euthrophication problems and the expansion of blue-green algae and water hyacinth. Oxygen deprived areas developed over sections of the lake floor. As a result, the diverse fishery changed into one based only on three species, two of which were introduced (Balirwa et al. 2003).

In addition to forests, wetlands in East Africa (including mangroves) support a range of ecosystem services, harboring over 654 associated species, such as mollusks, crustaceans, echinoderms, and fish (Payet and Obura 2004). Wetlands, including mangroves, are also an important source of food and materials. Local people make use of the provisioning ecosystem services for cooking, construction, medicinal purposes, and fodder. However, the multiple and excessive use of ecosystem services and extraction of goods represents an increasing stress for these ecosystems. In Tanzania, for example, over-exploitation of mangrove services in the Ruvu-Wami basin has lead to the destruction of 10-16% of the total mangrove cover by 1995 (World Bank and DANIDA 1995).

Similar to wetlands and forests, coral reefs are habitat of a large number of species and are stressed as a result of human activities. In the case of coral reefs, degradation is compounded by the recent effects of the 1998 Indian Ocean bleaching event (Linden and Sporrong 1999). Coral reefs in the region are affected by high sedimentation levels from the rivers, pollution from agriculture and industries, sewage and solid-waste discharges along the coast, pollution from commercial port operations, use of poison fisheries, coral dynamite blasting, reclamation, and coral mining (Payet and Obura 2004). In 1998, for example, an estimated 80,000 Tons of corals were mined for the production of lime in Lindi and Mtwara in Tanzania (UNEP 2001). The 1998 Map-Based Indicator of Threats to the World's Coral Reefs indicated that at least at least 25% of the coral reefs in the Indian Ocean Islands are at high risk of degradation from human activities (mainly in the Comoros), 29% at medium risk (mainly Madagascar and Mauritius), and 46% at low risk (mainly in the Seychelles) (Bryant et al. 1998) (see Figure 9).



Source: GIWA 2003, in Payet and Obura 2004.

Figure 9. Indicator-based map of reefs at risk in the Indian Ocean.

Fundamental changes in the structure of reef habitats may have consequences for a wide range of species in the long term, due to declines in availability of prey resources and loss of refugia (Jones et al. 2004). Moreover, degradation of reef habitats has the potential to affect coral reef fishes targeted by artisanal reef and reef-related fisheries (Pratchett et al. 2008). This in turn, affects local communities and economies that depend on these fisheries (see section 2.2.3)

In summary, land-use change, modification of habitats, and over-exploitation of natural in the region is contributing to the disruption of ecosystems services and degradation of ecosystems, as well as loss of biodiversity. This consequently has implications for local livelihoods, food security, social stability (i.e. disrupted if multiple users compete for scarce resources, or if migration processes take place), and different sectors that depend directly or indirectly on biodiversity, ecosystems and ecosystem services, such as tourism, fisheries, energy, and water provision. Increasing population pressure and high poverty levels may exacerbate this process. The next section of this document will discuss in further detail the implications of changes in ecosystems services for human well-being and socio-economic development.

2.2.3 Depletion of Fisheries

Fisheries are one of the most critical transboundary issues in the region. Over-exploitation of freshwater and marine fisheries is affecting productivity and stressing systems that largely depend on fishing activities. For example, diminishing catches of freshwater fish have been documented in the Nyumba ya Mungu reservoir in Tanzania, decreasing from 28,000 Tons in 1970 to 3,500 Tons in 1996 (Inter-consult ltd and Norplan A.S. 1996). As a result, fishermen are moving from historically preferred fisheries into new and remote fishing grounds, exploiting new species of fish that previously were not economically viable or culturally desirable. Stress on fisheries can be expected to worsen, given that population in the region is projected to increase over the next three decades and a ceiling appears to have been reached in the quantity of fish that can be harvested (Cinner et al. 2009).

Reef fisheries are particularly stressed as a result of anthropogenic activities and natural disturbances. Fishing has a number of direct and indirect effects on reef communities such as reduction in species diversity, alteration in the size structure of target species, and cascading effects on reef fish species composition, biomass and density (Ohman et al. 1997; Jennings and Kaiser 1998). The combination of these effects can compromise the ecosystems' resilience, with detrimental consequences for long-term sustainability of coral reef ecosystems (Cinner et al. 2009). Kenyan reefs, for example, support a density of fishermen of 10-15 ha-l, almost twice the density considered to be sustainable (7 ha-l) (McClanahan et al. 1997). This does not only show that reef fisheries in Kenya are over-exploited, but that a collapse in the reef ecosystem could have a large impact on both domestic and foreign earning in fisheries, as well as on food availability for local communities (Hara 2001). Moreover, fishing gear can cause high levels of physical damage to coral colonies affecting the health of reef ecosystems (Lewis 1997). In Kenya, beach seines and spear guns, both used at present, have been reported to be the most destructive fishing gear types used in reef lagoons (McClanahan and Mangi 2001).

In addition to anthropogenic impacts, natural disturbances also play a role in damaging reef ecosystems. For example, the 1998 Indian Ocean coral bleaching event reduced coral cover in most areas of Kenya by 50 to 90% (McClanahan et al. 2001). Despite not all fishes targeted by fishers were susceptible to the immediate effects of coral bleaching and mortality, loss of habitat structure following coral mortality can be expected to affect up to almost 60% of targeted species (Cinner et al 2009), with serious implications for fishing communities and fisheries earnings.

In summary, over-fishing is stressing marine and freshwater fisheries in the region, reducing productivity and affecting communities that highly depend on fishing activities. Reef fisheries are particularly stressed. Reef fisheries are not only affected by over-fishing, but also by changes to the structure and health of reef ecosystems caused by human activities and natural disturbances.

2.2 Ecosystems Susceptibility to Climate-related Drivers of Change

The previous section focused mainly on human intervention and dominant patterns of demographic, social and economic change that affect ecosystems and cause trade-offs between ecosystem services in the region. The analysis identified three main issues in the region related to changes and trade-offs in ecosystem services that affect human well-being: freshwater shortage, degradation of ecosystems and biodiversity loss (associated to habitat modification and land degradation), and depletion of fisheries. From the analysis, it is possible to identify four main drivers of change associated to human activities and development processes: increasing water demand, land-use change, changes in production systems, over-exploitation of natural resources. Likewise, the analysis suggests that the following ecosystems are suffering a high level of stress: freshwater bodies, forest and wetlands (including mangroves), arid and semi-arid ecosystems, and coral reefs.

Recognizing current exposure of ecosystems to stresses and the associated effects on ecosystems services (see Table 8, based on the analysis in section 2.1), Table x below highlights the effects of climate-related drivers of change such as rainfall pattern, temperature, and natural events and climatic extremes, to stressed ecosystems, thus indicating their susceptibility to climatic factors.

Table 8. Effects on stressed ecosystems caused by anthropogenic and climate-related drivers if change

	Anthropogenic drivers				**Climate-related drivers**		
Stressed ecosystems	Water-use and pollution	Land-use change	Change in production systems	Over-exploitation of resources	Erratic or changing rainfall pattern	Changing temperature	Natural events/extremes (e.g. drought, floods, etc.)
Freshwater reserves	Water scarcity for consumption and production Disruption of hydrological cycle and water flows.	Increasing sedimentation loads Water shortage Habitat modification.	Pollution of river and lake systems.	Water shortage for consumption and production of goods and energy.	Low rainfall can stress further freshwater reserves, if limited/affected water storage capacity and high water pollution. This can lead to prolonged water shortages.	Increase in evapotranspira-tion can affect water supply, particularly when level of water supply is already low and stressed.	Severe and prolonged droughts affect water availability.
Forests and wetlands		Habitat modificationbiodiversity loss, degradation of all ecosystem services, disruption of water regulation, purification, and storage capacity.	Habitat modification and biodiversity loss.	Destruction of the ecosystems, disruption of regulating and supporting ecosystem services, disruption of provisional services in the long-term.	Changes in rainfall pattern affect water regulation, vegetation cover, and species composition. If forests and/or wetlands are degraded, changes in rainfall pattern can lead to floods and/or droughts.	Changes in temperature can affect hydrologic cycle and water regulation services, leading to changes in vegetation cover.	Severe floods and droughts can modify habitat, affect regeneration, and change species composition.
Arid and semiarid ecosystems	Soil erosion and/or salinisa-tion.	Soil erosion, salinisation, desertification.	Land degradation or enhancement.	Soil erosion, desertification.	Changes in rainfall pattern and intensity affect water availability, soil quality and conditions for production. Low rainfall or heavy rainfall can lead to degradation of land and production systems.	Higher evapotranspiration can reduce water availability in these ecosystems, and affect production systems.	Severe droughts and floods can lead to land degradation and desertification.
Coral reefs	Degradation of ecosystem health, habitat modifica-tion.	Increasing sedimentation loads, habitat modification.	Degradation of reefs health.	Reduction of reef fisheries. Reduction of species diversity and alteration of species composition.		Thermal stress can transform reef communities, with cascading effects on reef fisheries.	Acute warm water events cause bleaching and mortality of corals.

Adapted from McClanahan 2009, Cinner et al. 2009, SafMA 2004, Payet and Obura 2004.

Considering the effects that climate-related drivers of change can have on ecosystems (Table 8), it is possible to state that ecosystems are highly suceptible to climatic factors, particularly when ecosystems are already/also stressed by multiple anthropogenic factors. This means that changes in climate (e.g. in the rainfall pattern, in temperature, in the frequency of climatic extremes) can have significant impacts on stressed ecosystems, exacerbating the degradation caused by anthropogenic factors, disrupting ecosystem services even further, and causing serious damage to livelihoods and economies that highly depend on these services to operate. The next section will analyze in further detail the implications of climate change for ecosystem services and the consequences for different sectors in the region.

3. IMPLICATIONS OF CLIMATE CHANGE EFFECTS ON ECOSYSTEM SERVICES IN EAST AFRICA

Section III analyses the effects of climate change on ecosystem services at the regional level and the implications for human well-being and economic development considering two possible future development pathways: the “Mosaic” pathway and the “Vision” pathway. The first pathway is an extrapolation of current trends, while the second encompasses goals and targets defined by different strategies and initiatives developed for the sustainable development and stability of the region.

3.1. Climate Change and Socio-economic Futures

This section reviews the observed climate trends in the region, as well as estimated climate projections for different SRES scenarios[1]. It then describes the socio-economic pathways considered in the analysis of the effects of climate change on ecosystem services and the implications for human well-being and economic development in the region.

3.1.1 Climate Change in the Region

Observed climate trends

Complex maritime and terrestrial interactions, as well as topographic variations, produce a variety of climates across the region (Christensen et al. 2007).

Observed temperatures have indicated a greater warming trend since the 1960s. Overall Africa has warmed 0.7 °C (IPCC 2001) over the past century. Although these trends seem to be consistent over the region, the changes are not always uniform, as weather stations located close to the coast or to major inland lakes in East Africa have shown decreasing trends in temperature (King’uyu et al. 2000).

In terms of precipitation, rainfall exhibits notable spatial and temporal variability (Hulme et al., 2005. Rainfall patterns are typically seasonal, and annual variability of rainfall is high (SAfMA 2004). Multi-decadal variability plays also an important role. Southern (Sub-saharan) Africa experiences decade-long cyclical periods of wetness and dryness partly associated with the ENSO phenomenon (SAfMA 2004). Over the past decades, East Africa has been experiencing an intensifying dipole rainfall pattern on the decadal time-scale. The dipole is characterized by increasing rainfall over the northern area and declining rainfall over the southern area (Schreck and Semazzi 2004).

Changes in extreme events such as droughts and floods have also affected the region. Recurrent floods and droughts in some countries are linked with ENSO events. At the regional level, there were intense and widespread droughts in 1983-4, 1992 (Chenje & Johnson 1996), and 2002.

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[1] The IPCC Third Assessment Report (TAR) published the Special Report on Emissions Scenarios (SRES) in 2000 (Nakićenović et al, 2000). The SRES scenarios span the 21st century and project emissions for the major greenhouse gases, ozone precursor gases (CO, CH4, NOx, NMVOC’s), and sulfate aerosol emissions, as well as land use changes. Such emissions drive climate change as well as atmospheric chemistry over the next century.

Climate Projections

Overall Africa, General Circulation Models (GCMs) agree that under all SRES scenarios annual mean surface air temperature will increase between 2 to 5°C by 2050compared to 1990 (IPCC 2001). The warming is likely to be greater in the interior, and less near the oceans (see example in Figure 10). Combining simple climate model estimates of the global mean annual temperature response to four combinations of GHG forcing/climate sensitivity with regional patterns of seasonal temperature and precipitation change obtained from 10 GCM simulations for the end of the 21st century relative to 1961-1990, Hulme et al. (IPCC 2001) estimate future annual warming across Africa from 0.2°C per decade (B1—low scenario) to more than 0.5°C per decade (A2—high scenario). Again, this warming is greatest over the interior of semi-arid margins of the Sahara and central southern Africa. Using 20 GCMs and the SRESA1, Christensen et al. (2007) estimated annual mean temperature to increase between 3 and 4°C for the period 2080-2099 compared to the period 1980-1999, again with less warming in coastal areas. Regional Climate Model (RCM) experiments generally give smaller temperature increases (Kamga et al. 2005). Using the HadRM3H RCM with the SRESA2, Hudson and Jones (2002) estimated for the 2080s a 3.7°C increase in summer (December to February) mean surface air temperature and a 4°C increase in winter (June to August) for southern Africa.

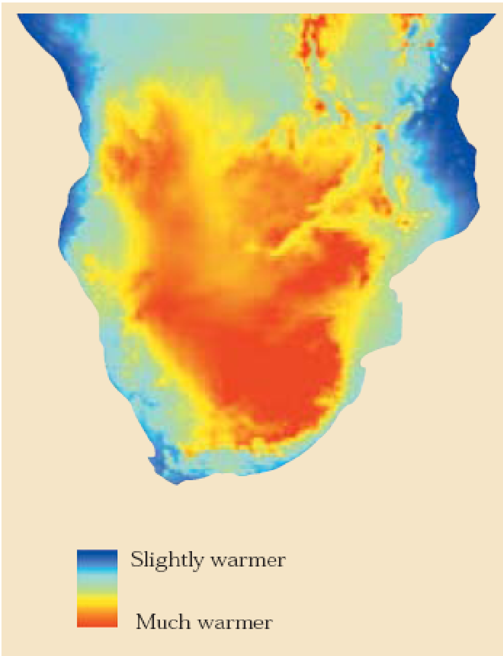


Figure 10. HADCM3 climate model projections of changes in temperature for 2050 relative to mean conditions over the period 1961 to 1990, under the IPCC SRES A2 (high emissions) scenario.

Source: Interpolated by G. Hughes, National Botanical Institute, South Africa. SAfMA 2004.

Precipitation projections are generally less consistent with large inter-model ranges for seasonal mean rainfall responses. Figure 11 below illustrates the extent of intermodel differences for East Africa showing future modelled changes in the context of observed trends.

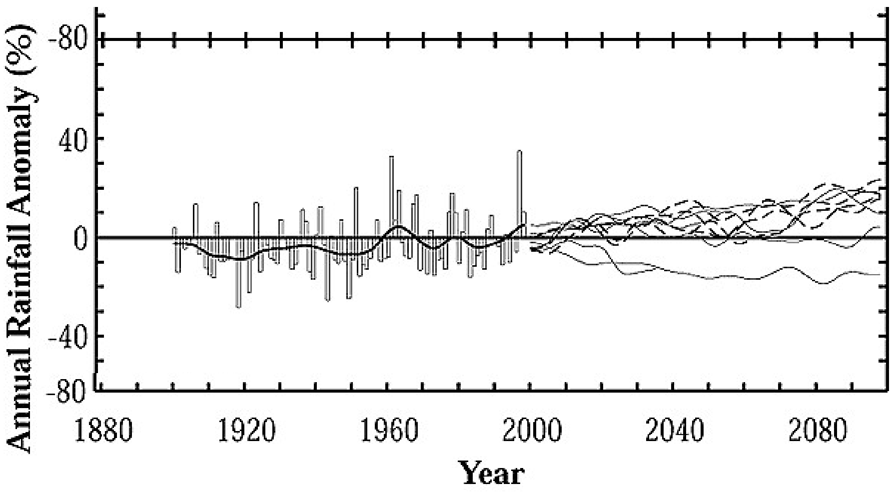


Figure 11. Observed annual rainfall anomalies for East Africa, 1900-1998, and model-simulated anomalies for 2000-2099.

Note: Model anomalies are for 10 model simulations derived from seven DDC GCM experiments; the four HadCM2 simulations are the dashed curves. All anomalies are expressed with respect to observed or model-simulated 1961-1990 average rainfall. Model curves are extracted directly from GCM experiments, and results are not scaled to SRES scenarios (Hulme et al., 2001).Source: IPCC 2001.

According to Hudson and Jones (2002), the largest changes in rainfall in East Africa occur during the austral winter with a decrease in rainfall, and in summer with an increase in rainfall (December to February). Hulme et al. (IPCC 2001), suggest that under lowest warming scenarios, parts of equatorial East Africa will likely experience 5-20% increased rainfall from December-February (summer) and 5-10% decreased rainfall from June-August (winter) by 2050. Under the most rapid global warming scenario, Hulme et al. (IPCC 2001) estimate that by 2050 parts of East Africa will experience increases in summer rainfall of even 50-100%, with decreases in winter. Moreover, using RCMs, Tadross et al. (2005b), estimate a decrease in early summer (October to December) rainfall and an increase in late summer (January to March) rainfall over the eastern parts of southern Africa.

As with rainfall, the uncertainty related to net drying of the soil is high. The majority of GCMs indicate a net drying on the western two-thirds of the African subcontinent, south of about 10°S, and net wetting on the eastern and northern edges. The magnitudes of the drying and wetting are both less than about 15% of the current mean (see example in Figure 12). Uncertainties make it also difficult to estimate future runoff, especially in arid and semi-arid regions where small changes in precipitation can lead to dramatic changes in the runoff process (Fekete et al. 2004).

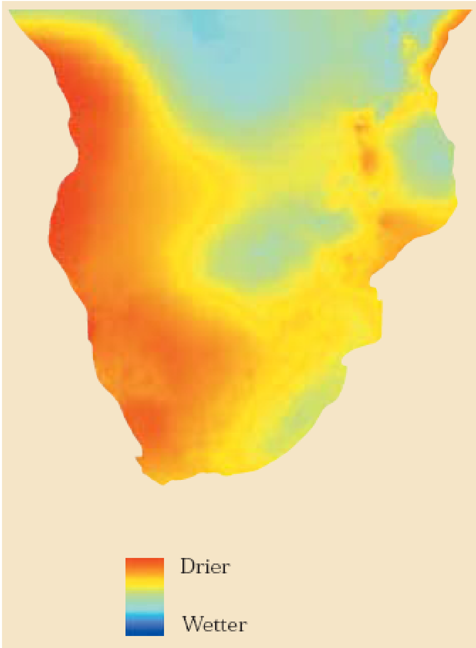


Figure 12. HADCM3 climate model projections of changes in precipitation for 2050 relative to mean conditions over the 1961 to 1990 period, under the IPCC SRES A2 (high emissions) scenario.

Source: Interpolated by G. Hughes, National Botanical Institute, South Africa. SAfMA 2004.

Finally, warming temperatures are projected to cause more frequent and more intense extreme weather events, such as heavy rain storms, flooding, fires, hurricanes, tropical storms (IPCC, 2001). This may be associated to more frequent and intense ENSO events that are expected to occur in the region due to climate change (Wara et al. 2005).

3.1.2 Socio-economic Futures

This section considers two possible future development pathways for the region: the "Mosaic" pathway and the "Vision" pathway. Each pathway involves major driving forces behind human development including economic, demographic, social and technological change. It is important to consider these drivers, as they play an important role in energy consumption, land use patterns and emissions. Moreover, considering different development scenarios in the analysis helps understanding better the effects of climate change on ecosystem services in a particular future state. Even more, assessing the effects of climate change without considering a larger range of driving forces would disregard the fact that future effects of climate change are strongly influenced by socio-economic change and would generate a wrong idea of possible future vulnerabilities. It is also important to consider that future socio-economic scenarios will result in a change in vulnerability or exposure, even in the absence of future climate change.

The Mosaic pathway

The Mosaic pathway is basically an extrapolation of current patterns of demographic, economic and social change. Two socio-economic scenarios were considered in the building of this pathway: the SRES A2 scenario of the IPCC Third Assessment Report (2000) and the African Patchwork scenario of the Regional Assessment of

Ecosystem Services in Southern Africa (2004). These two scenarios were considered because the assumptions on which they are based correspond to extrapolation of socio-economic trends observed in the region and write to a scenario where development efforts are mismanaged, cooperation efforts are weak, and human well-being is not well addressed.

The SRES A2 for the region:

Following the IPCC Third Assessment Report (TAR), the Special Report on Emissions Scenarios (SRES) framework has increasingly become a reference document for modeling the human dimensions component of impacts assessment (Gewin 2002). The A2 scenario used in the Mosaic pathway assumes medium economic development, low per capita incomes, and weak globalization. It is more prone to clashes between cultures and ideas, and places a high priority on regionalisation. Population growth in A2 is high because of the reduced financial resources available to address human welfare, child and reproductive health and education (Gaffin et al. 2004). This scenario also considers poverty levels will increase, assuming calculations that estimate that sub-Saharan share of the global total of those earning below US$1/day will rise sharply from 24% in 2007 to 41% by 2015 (UNDP 2005).

In the SRES A2 the relatively higher fertility rates are assumed to correlate with higher mortality rates and so this scenario uses the IIASA "slow demographic transition" population projections. The downscaled projections for SRES A2 were generated by the Center for Climate Systems Research (CCSR) at Columbia University and are based on population projections realized by IIASA in 1996 and published in Lutz (1996). Figure 13 below shows the SRES A2 population projections for East Africa (considering Burundi, Kenya, Rwanda, Tanzania, and Uganda). By 2030, under SRES A2 the population in East Africa is estimated to reach around 214 million people, one and a half times the current population.

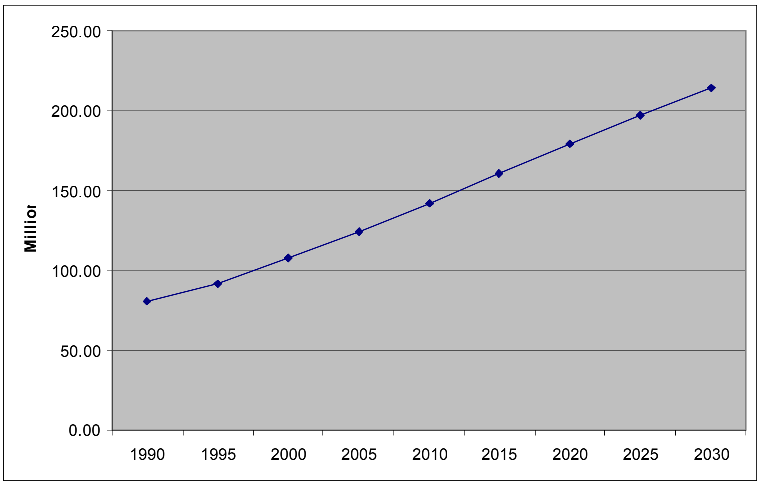


Figure 13. Population projections for East Africa under the Mosaic pathway (in Millions)

Adapted from downscaled of regional population projections to country-level for the SRES A2 scenario, CCSR 2004.

The medium economic growth for SRES A2 has been downscaled by CCSR from the UN database GDP series list entitled "GDP at market prices, current US$ (for 1990) (World Bank estimates)". This data derives from the World Bank's Development Indicator Reports. Figure 14 below illustrates the economic growth estimated for East

Africa under SRES A2. By 2030, the GDP for East Africa under this scenario is expected to be around 129,500 million US$, about three times the current GDP.

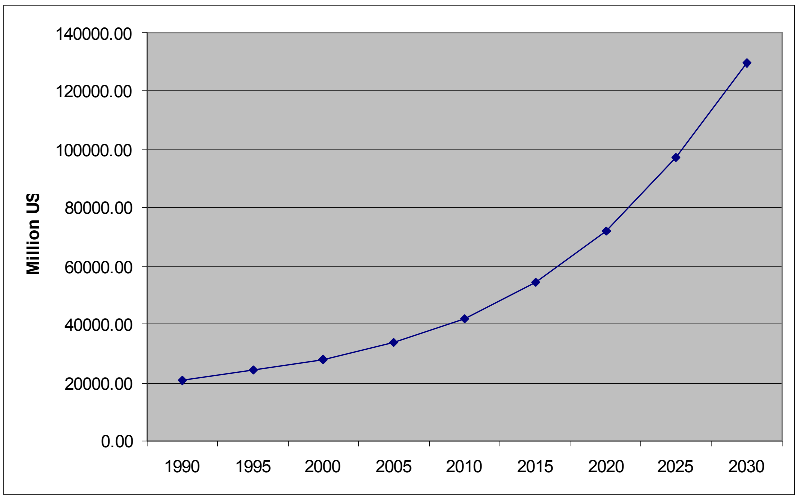


Figure 14. GDP projections for East Africa under the Mosaic pathway (in Million of US$)

Adapted from downscaled of regional GDP projections to country-level for the SRES A2 scenario, CCSR 2004.

The African Patchwork scenario for the region:

The other socio-economic scenario considered for the Mosaic pathway is the African Patchwork scenario of the SAfMA (2004). This scenario considers a region where, despite improvements in democracy and good governance in some countries, general limited state effectiveness, economic mismanagement and conflict prevent the region from improving the well-being of its population. There is a lack of environmental regulation and enforcement, regional food security does not improve, and most countries are unable to ensure the provision of reliable, safe water or modern energy sources. This results in high mortality from malnutrition and waterborne diseases aggravated by the high incidence of HIV/AIDS. Improvements in agricultural productivity are not sufficient leading to expansion of agricultural land in marginal areas and large-scale conversion of woodlands to crops. Large-scale deforestation for charcoal production also threatens woodlands. The rural population relies heavily on a declining natural resource base for their subsistence, and many people migrate to cities, where they remain impoverished. Rural people with access to land and resources are highly self-reliant and locally organized. Protected areas are encroached affecting biodiversity, biomass fuel, and freshwater.

The Vision pathway

The Vision pathway is based on the assumption that a combination of initiatives and strategies designed for the improvement of governance and security in the region has been successfully implemented, contributing to economic growth, cooperation and human well-being in the region. This pathway suggests the African Partnership scenario of the SAfMA (2004), which is based on the successful adoption and implementation of regional initiatives. A summary of regional initiatives aimed to improve environmental management and food security for sustainable development in the region is provided in Annex II.

The African Partnership scenario for the region:

The African Partnership scenario assumes that interventions occur at the regional, national and local level, making use of strong governance structures and the financial resources of the region. Regional food security improves due to intensification of agriculture, using highly selected seeds, irrigation systems, and fertilizers. This improves productivity and leads to high economic and population growth. Rising wealth accelerates a change in diet towards meat products. Increasingly wealthy and urbanised population rise energy demand that is partially met by hydropower, while in rural areas woodfuel remains an important energy source. Nature-based tourism greatly expands due to reduced pressure for land and the development of an extensive system of state, private and community protected areas (SAfMA 2004).

A strong linkage to the global economy marginalizes small growers and affects agricultural diversity. Moreover, in a first stage, increased population and industrial and agricultural development impacts negatively biodiversity, freshwater, biomass fuel and air quality. Over time, impacts stabilize, as effective institutions develop to regulate resource use. Investment in agricultural research and extension helps improving land management practices and food security. Good land management practices outside of protected areas contribute to the maintenance of soil quality and biodiversity in the region. Nevertheless, water purification costs increase due to higher contaminant loads, contributing to rising price of water. The establishment of regionally integrated, representative water management and environmental monitoring institutions, with strongly developed mechanisms for conflict mediation, become central to the maintenance of environmental health, economic growth, as well as peace and security in the region.

3.2 Effects on Ecosystems and Ecosystem Services and Implications for Human Well-being and Economic Development

The first part of this section analyses the effects of possible climate risks associated to future climate change on vulnerable ecosystems and ecosystems services, and the implications for human well-being and economic development in East Africa. The idea of this section is to focus only on ecosystems that are highly vulnerable and climate-sensitive (see section 2) and key effects that may have serious implications for human well-being, economic growth, and social-ecological resilience (all key elements for adaptation capacity in the region), and not to provide an exhaustive analysis of all the effects that climate change may pose to every ecosystem service in the region. The first part of this section considers current vulnerability of ecosystems (shaped by patterns of socio-economic change, see section 2) and sensitivity to climate but does not consider socio-economic factors that may stress ecosystems and ecosystems services in the future. The second part of this section gives a brief analysis of the likely implications associated to the identified effects on ecosystem services considering two possible future development pathways (see section 3.1.2). This second analysis considers different socio-economic factors that may shape future vulnerabilities and impacts of climate change. Trade-offs and synergies between ecosystem services caused by multiple factors (including climate risks) are only assessed in few cases.

3.2.1 Effects of Climate Change on Ecosystems and Ecosystem Services

Section 3.1.1 reviewed briefly climate trends and projections for the region. Based on the available climate information generated with models and using different scenarios, it is possible to assume the following climate risks for East Africa: higher temperature (including temperature extremes); shifting rainfall and higher inter-annual variability; rainfall deficit (dryness and prolonged dry periods); heavy rainfall (high rainfall intensity, floods); changes in frequency and intensity of the ENSO event (which reinforces the climate risks listed above); sea-level rise and higher frequency of hurricanes. These climate risks may have direct and indirect effects on ecosystems and ecosystem services in the region. Figure 14 below shows some of the key effects and the associated implications for human well-being and economic development in the region.

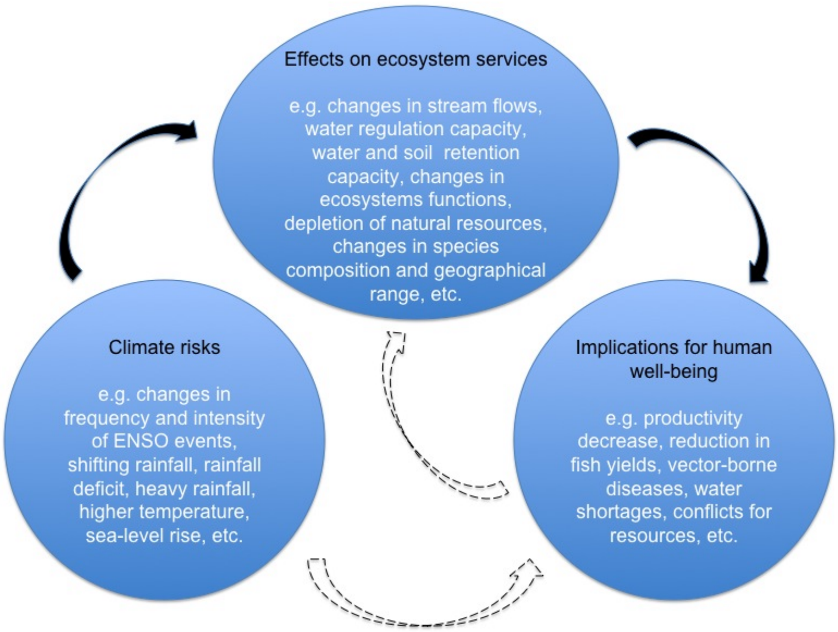


Figure 14. Diagram climate risks, effects, and implications

Climate hazards associated to future climate change in the country (Figure 14 above) will impact ecosystem services in complex ways. This section focuses on the effects that change in climate may have on ecosystem services. Climate hazards may impact multiple ecosystem services intensifying synergies and trade-offs among ecosystem services, with positive and negative effects on human well-being. However, for this analysis only the effects on 1) regulation and provisioning of water resources, 2) formation of quality soil and supporting primary production, and 3) maintenance of biodiversity will be considered. These effects may have large implications for human well-being, economic growth, and social-ecological resilience. The following gives a brief explanation for each one of these effects.

Climate change and the effects on regulation and provisioning of water resources

The effects of climate change on water resources across Africa are not uniform. For East Africa, an analysis of six climate models (HadCM3, ECHAM4-OPYC, CSIRO-Mk2, CGCM2, GFDL_r30 and CCSR/NIES2) and the SRES scenarios (Arnell 2004) shows a likely reduction rather than an increase in water stress (Arnell 2006). Clearly these estimations are at macro-scales and may camouflage a range of complex hydrological interactions and local-scale differences (IPCC 2007). Reductions in water stress can be mainly explained by projected rainfall increase during summer (wet season) (see section 3.1.1). Having said so, it is important to note that similar studies (Hulme et al. 2001, see section 3.1.1) also indicate a decrease in precipitation during winter time (dry period) and that warm sea surface temperatures may lead to increased droughts in equatorial and subtropical Eastern Africa (Funk et al. 2005).

Moreover, temperature in the region is expected to increase and this will have an effect on the balance between input (rainfall) and losses (evaporation from water bodies and soils, and transpiration through plants). Rising temperature increases losses by raising evaporation rates by about 5% per ºC increase. This will be offset, to an uncertain degree, by the reduced transpiration rates of plants under increased atmospheric CO_2 concentrations.

Combining the information above it can be expected that already wet areas are likely to remain approximately the same or become slightly wetter, while dry areas will face the combined impact of reduced rainfall in winter and increased evaporation throughout the year (SAfMA 2004). Figure 15 below shows the relative change in water demand per discharge in 2025 compared to 1985 accounting for change in climate only (not considering future socio-economic changes). From the Figure x below, it is possible to see that not all areas in East Africa will become wetter due to climate change. This is mainly due to the factors explained above. All in all, it is also important to consider that climate change is projected to cause more frequent and intense ENSO events, leading to widespread drought in some areas and widespread flooding in others (Wara et al. 2005).

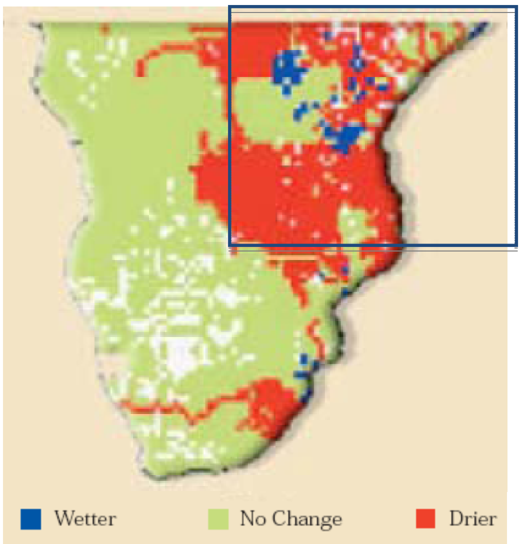


Figure 15. Relative change in water demand per discharge in the region

Source: Vörösmarty et al. 2000.

Note: These scenarios were produced using the Water Balance Model and the Canadian Climate Center general circulation model (CGCM1). A threshold of +-20% was used to highlight areas of substantial change.

Moreover, changes in climate are greatly amplified in the hydrological system, as river flow, water level of inland waterbodies, and the recharge of groundwater are highly sensitive to changes in water balance (see section 2.2) (McCarthy et al. 2001).

In 1997, floods and high rainfall, triggered by an El Niño event in eastern Africa, resulted in a surface rise of 1.7 meters in Lake Victoria (Lovett *et al*. 2005). Using ten scenarios derived by using five climate models (CSIRO2, HadCM3, CGCM2, ECHAM and PCM) in combination with two different emissions scenarios, Strzepek and McCluskey (2006) arrived at the following conclusions regarding impacts of climate change on stream flow in Africa: the possible range of climate-change impacts on streamflow in 2050 is from a decrease of 15% in streamflow to an increase of 5% above the 1961-1990 baseline; while for 2100, the range is from a decrease of 19% to an increase of 14%. A reduction in stream flow is particularly expected during the dry season. For example, a study carried out in Tanzania (VPO-URT 2003), has estimated that high temperatures and less rainfall during already dry months in the Tanzanian river catchments could affect the annual flow to the River Pangani by reductions of 6-9% and to the River Ruvu by 10%.

Climate change and the effects on formation of quality soil and supporting primary production

Recent assessments using the FAO/IIASA Agro- Ecological Zones model (AEZ) in combination with IIASA's world food system or Basic Linked System (BSL), as well as climate variables from five different GCMs under four SRES emissions scenarios, show that by the 2080s, the area of arid and semi-arid land in Africa could increase by 5-8% (60-90 million hectares).

The same assessment has estimated that by 2080 climate change may cause a significant decrease in suitable rain-fed land extent and production potential for cereals. Agoumi (2003) has indicated that climate change will exacerbate erosion and deficiencies in yields from rain-fed agriculture of up to 50% during the 2000-2020 period.

Changes in mountain ecosystems and grasslands are also likely to be exacerbated by climate change. These systems are already vulnerable to significant stresses from changes in land-use and over-exploitation of natural resources, aspects of which are likely to be linked to complex climate-land interactions and which may continue under climate change (IPCC 2007).

Climate change and maintenance of biodiversity

Changes in rainfall and temperature induced by climate change are likely to result in changes in plant and animal species composition and diversity, and shifts of species range (UNEP 2004). Species composition and diversity is expected to change due to individual species response to climate change conditions (Erasmus et al. 2002). Historically, climate change has lead to remarkable shifts in the geographical distributions of species and ecosystems in order for species to adapt (Malcolm et al. 2002). Plant and animals species will migrate or shift in order to find suitable habitats requirements (i.e., water and nutrient availability); this may mean that in some locations the geographical range of suitable habitats will shift outside protected area boundaries.

Shifts in species range and through ecosystems could have profound impacts on species population size and could lead to numerous localized extinctions. This relationship could be exacerbated if climate change restricts the range of a species to just a few key sites and an extreme weather event occurs, thus driving up extinction rates even further (Erasmus et al. 2002). Assessment of species sensitivity to climate change of African mammals[2] (Thuiller et al. 2006) assuming no migration of species, estimated that 10-15% of the species will fall within the IUCN Critically Endangered or Extinct categories by 2050, increasing to 25-40% of species by 2080. Assuming non-constrained migration, the results were less extreme, with these proportions dropping to approximately 10-20% by 2080.

Nonetheless, it is important to bear in mind that species ranges will probably not shift in cohesive and intact units and are likely to become more fragmented as they shift in response to changing climate (Channel and Lomolino 2000). Moreover, destruction of habitats and the transforming existing communities could easily disrupt the connectedness among species and increase the difficulties for migrating. In addition, climate change has the potential to alter migratory routes (and timings) of species that use both seasonal wetlands (e.g., migratory birds) and track seasonal changes in vegetation (e.g., herbivores) (Thirgood et al. 2004). Studies carried out in South Africa's Krueger National Park (Erasmus et al. 2002) indicate that in fact, up to 66% of species may be lost due to predicted range shifts caused by climate change.

Furthermore, if some plant species are not able to respond to climate change, the result could be large changes in ecosystem composition and function and increased vulnerability of ecosystems to natural and anthropogenic disturbance, resulting in species diversity reductions (Malcolm et al. 2002). Deciduous and semi-deciduous closed canopy forests are very sensitive to small decreases in the amount of precipitation that plants receive during the growing season (Hély et al. 2006). Also grass and shrub savannahs are shown to be highly sensitive to short-term availability of water (Vanacker et al. 2005). Shrub and grassland vegetation types generally have root systems that are shallow and dense; these plants draw their moisture from water that is available in upper soil layers and growth in these species depends highly on the timing, intensity and duration of rainfall. Changes in rainfall pattern due to climate change can then affect deciduous and semi-deciduous closed canopy forests and grass and shrub savannahs. If these ecosystems can not adapt and/or shift, it is probable that they will undergo large changes in their composition and ecosystem services they provide, such as the maintenance of biodiversity.

3.2.2 Implications of Climate Change Effects on Ecosystems and Ecosystem Services

The negative effects of climate change on ecosystems and ecosystem services in the region are compounded by many factors, including widespread poverty, human diseases, and high population growth and density, which is estimated to increase the demand for food, water, and land within the next decades. In the previous section key effects of climate change on ecosystems and ecosystem services were described (see Figure 14). This section focuses on the implications for human well-being and economic development associated to the analyzed effects on ecosystem services (section 3.2.1) considering two development pathways for East Africa: the "Mosaic" pathway and the "Vision" pathway (see section 3.1.2). Each pathway assumes different patterns of socio-economic change for the future, which translates into different factors/drivers of change that will shape future conditions and vulnerabilities. This also considers the potential of climate change to disrupt and potentially reverse progress made in improving the socio-economic well-being of East Africans. In short, each pathway explores future risks and opportunities building upon the effects on ecosystem services discussed in the previous section. Two main

[2] Conducted in 141 national parks in sub-Saharan Africa using SRES A2 and B2 emissions scenarios with the HadCM3 GCM, applying a simple IUCN Red List assessment of potential range loss (Thuiller et al. 2006).

implications have been selected for this analysis due to their close relation to ecosystems and ecosystem services considered in section 3.2.1: agriculture and food security; biodiversity and tourism.

Agriculture and food security

East Africa depends heavily on rain-fed agriculture making rural livelihoods and food security highly vulnerable to climate risks (IPCC 2001). Furthermore, agriculture contributes 40% of the region's GDP and provides a living for 80% of its population (IFPRI 2004). Changes caused by climate on ecosystems and ecosystem services that support agricultural activities and future socio-economic development pathways can determine the possible impacts on agriculture and food security in the region.

As discussed in the previous section, climate change and variability have the potential to cause changes in the regulation and provisioning of water resources, and formation of quality soil and supporting primary production. These ecosystem services are key for agriculture and changes in the way they function and interact can lead to decrease in productivity. For instance, changes in seasonality of rainfall, onset of rain days, variability of dry spells and intensity of rainfalls can affect water provisioning services during growing period and lead to decrease in productivity and even loss of production. Changes in climate may also affect water regulation services with negative impacts on agriculture. In Tanzania, for example, rivers have reduced flow due to declining regional rainfall and disrupted water regulation services, which has had ecological and economic impacts such as water shortages, lowered agricultural production, and increased fungal and insect infestations (Orindi and Murray 2005).

Moreover, impact assessments of climate change on agriculture based on various climate models and SRES emissions scenarios indicate that certain agricultural areas in the region may become less suitable for rain-fed agriculture and production of long-cycle crops such as cereals (Funk et al. 2005, see section 3.2.1). Local scale assessments, for example, have shown that southern Africa would be likely to experience notable reductions in maize production under possible increased ENSO conditions (Stige et al. 2006). This is not only due to (extreme) climate conditions, but to loss of soil quality caused by wind/water erosion and land degradation (Thornton et al. 2006).

Loss of soil quality and deficit of water resources and subsequent impacts on agriculture are linked to changes in ecosystem services caused not only by climate change, but also by socio-economic drivers and other natural forces. Both development pathways below explore further these interactions and explore possible futures for the region.

Under the "Mosaic" pathway

Under the Mosaic pathway progressive failure of the 'safety net' provided by ecosystems and ecosystem services will increase vulnerability. Large parts of the region would continue to suffer from worsening food production deficits and widespread food shortages. Population would continue producing long-cycle crops but low crop yields would impact food supply and livestock. Tea and other cash crops would be seriously affected with large impacts on the regional economy (see Box 3).

Decreasing yields may lead to intensive use of land increasing degradation that may influence micro-climates and result in further desertification in marginal lands. Food production deficits may lead to illegal migration to areas of relatively greater food availability, and escalating conflict between increasingly polarised communities. Poor nutrition would allow the HIV/AIDS pandemic to affect rural labour and drain rural assets, further impacting agricultural development already affected by declining soil fertility, increased desertification, water shortage (see Figure 16) and failed extension services.

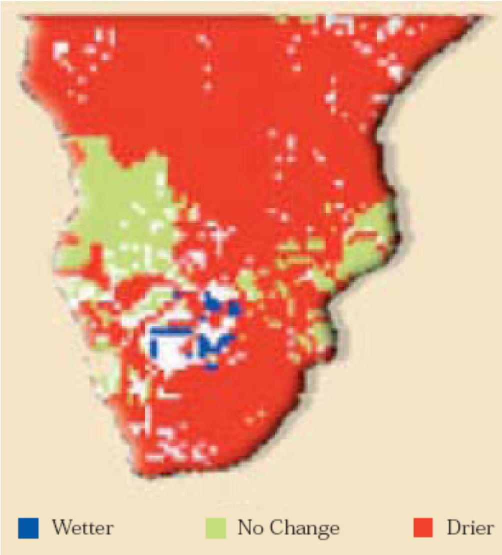


Figure 16. Relative change in water demand per discharge in 2025 compared to 1985 accounting for effects of change in climate and change, population growth and economic development.

Source: Vörösmarty *et al.* 2000.

Note: These scenarios were produced using the Water Balance Model and the Canadian Climate Center general circulation model (CGCM1). A threshold of +-20% was used to highlight areas of substantial change.

Fragmented, vulnerable communities and the lack of institutions able to offer protection and support to the smallholder farmer and enforce environmental protection at the regional level will lead to an increasingly poverty-stricken region. The combination of all factors discussed above exacerbated by climate change would profoundly impact all components needed for food security in the region: availability of food, adequate purchasing and/or relational power to access food, and the acquisition of nutrients from the available food.

The region would become increasingly dependent on food aid, with a large number of children suffering from malnutrition. Per capita food supply will be among the lowest relative to the rest of the developing world. However, deteriorating infrastructure, corruption, conflict and the weakness of national and regional governance institutions would hamstring its distribution to the local level.

Adapted from SAfMA 2004 with additional information from: WWF 2006, Jones & Thornton 2003, Rosegrant et al. 2001, FAO 1993. IPCC 2007.

Box 3. Future vulnerabilities under the Mosaic pathway
Changes in climate, associated effects on ecosystem services and ecosystems health, poverty, lack of technology and sustainable land use management, and poor diversification may increase the vulnerability of key cash crops upon which the economy of the region depends. If areas of land that support tea cultivation in Kenya and Rwanda, coffee in Burundi and Rwanda become largely unusable, this would have far-reaching impacts on the economy of the region because tea exports account for roughly 25% of Kenya's export earnings, coffee exports account for 90% of Burundi's export earnings, coffee exports account for 24% and tea exports for 35% of Rwanda's export earnings (assuming no changes in percentages of 2005 for Kenya and Burundi, and 2003 for Rwanda).

Under the "Vision" pathway

Under the Vision pathway stronger governance and improved regional environmental regulations and initiatives in combination with investment in infrastructure and technology, research and extension, seems to improve production deficit issues in the region, particularly through intensification of crop production and moderate expansion of cultivated land. Despite food security issues are still present in some areas, overall access to markets and purchasing power has improved. The nations would be able to afford food imports to offset the occasional deficits caused by extreme climatic events. Using more cohesive alliances through the implementation of the CAADP, FAFS and PANI (see Annex II), the region has more bargaining power in World Trade Organisation negotiations and lead to world trade policies that nurture southeastern Africa's markets. Economic growth in the industrial, mining and service sectors, together with successful commercial cash crop production, would promote export trade, foreign investment and increased regional wealth.

Establishment of regional-level institutions for the surveillance of environmental conditions (monitoring, early warning system, etc) and implementation of initiatives such as the IGAD Strategy and NEPAD Action Plan for Environment (see Annex II) improves the management of natural resources in the region and prevents large negative changes on ecosystem services and ecosystem health. As a result, ecosystems become more resilient to stresses and climate change has less effect on the economy and food security.

Sustainable agriculture and food security under this scenario will be dependent on sustained investments by national governments in infrastructure, health and education, basic requirements for empowering communities to break the vulnerability cycle. Moreover, while agriculture is a key source of livelihood in Africa, off-farm incomes in this scenario would increase in some areas reaching up to 60 to 80% of total incomes in some cases. This will make the economy of the region less vulnerable to climatic risks.

Adapted from SAfMA 2004 with additional information from Bryceson 2002, UNEP 2003, IGAD, NEPAD 2008, IPCC 2007.

Biodiversity and tourism

The economic benefits of tourism in Africa, which according to 2004 statistics accounts for 3% of worldwide tourism, may change with climate change (World Tourism Organization 2005). This risk holds also for East Africa.

Despite very few assessments of projected impacts of climate change on tourism are available, it is reasonable to expect an impact on tourism due to decreases in species diversity and ecosystems (habitat) degradation. It is also probable to expect a reduction in tourism given more frequent extreme events such a floods and droughts. Climate change is a factor affecting popular tourist destinations, as well as habitats and ecosystem services that maintain biodiversity. A clear example is the effect that coral reef bleaching as a result of climate change may have on tourism (McLeman and Smit 2004). Climate change could also lead to a shift of centres of tourist activity, for example if ecosystems shift and/or plant and species migrate to find more suitable habitats (i.e. a shift from lowland to highland tourism could occur, Hamilton et al. 2005). However, climate change is not the only factor affecting biodiversity and habitats, and socio-economic drivers can also have a large role to play in the degradation and/or protection of nature and biodiversity with implications for the tourism sector in the region. Both development pathways below explore further these interactions and explore possible futures for the region.

Under the "Mosaic" pathway

The Mosaic pathway holds a number of negatives for nature-based tourism, the main ones being the deterioration of habitats with negative impacts on biodiversity (due to encroachment on protected areas, fragmentation, and changes in ecosystem composition and function), perception of risks to health and security among foreign visitors (due to extreme events and related diseases and due to lack of disaster risk reduction strategies), and the slow growth of the domestic market (lack of infrastructure, access, etc.).

Despite this, nature-based tourism is likely to grow at double the rate projected for the general economy under this scenario. At this growth rate, nature-based tourism would not reach the absorptive capacity of the protected area service by 2025, but would nevertheless be an important economic sector overall.

Adapted from SAfMA 2004 with additional information from WWF 2006, IPCC 2007.

Under the "Vision" pathway

Economic growth under the Partnership Scenario is projected to be higher, as well as the contribution by tourism (all types) to the economy of the region. Assuming that nature-based tourism continues to constitute half the total tourism revenue, it would be by far the largest sector directly based on ecosystem services.

For this scenario to be accomplished, the policy priority given to nature-based tourism, and the scenic beauty, biodiversity and environmental qualities that strengthen it would need to equal the priority given to industrial and agricultural development. Moreover, strategies such as the NEPAD Action Plan for Environment Initiative (see Annex II) would have to be successfully implemented to improve protection and conservation measures, introduce integrated natural resources management, reforestation and ecological monitoring systems. Last but not least, future designations of protected areas in the region would need to be developed including projections of future climate change and corresponding changes in the geographic range of plant and animal species to ensure adequate protection and migration processes.

Adapted from SAfMA 2004 with additional information from UNEP 2003, WWF 2006.

4. ECOSYSTEM-BASED APPROACHES FOR ADAPTATION

Section 1 exposed how ecosystems and ecosystem services play a vital role for human well-being. Section 2 identified patterns of change stressing ecosystems and influencing their vulnerability. That section also analyzed the climate-sensitivity of most vulnerable ecosystems in the region. Section 3 explored the effects of climate change on ecosystem services and the possible implications for human well-being and development given two possible future pathways. This section shifts focus from climate change impacts on ecosystems and services to exploring the role and value of ecosystem-based approaches for adaptation, considering the analysis carried out in previous sections.

Ecosystem-based approaches deliver significant value for adaptation. Previous sections portray how ecosystem services can contribute to the reduction of climate risks by acting as buffers to extreme events. Ecosystem services can also maintain biodiversity and diverse landscapes to support productivity and livelihoods under changing climate conditions (CBD 2009). Hence, taking advantage of and enhancing services provided by ecosystems can increase the effectiveness of adaptation and reduce climate risks.

Furthermore, it has been discussed in previous sections that ecosystem services underpin development, provide multiple benefits for human well-being and are fundamental for the existence of life on earth. Particularly, poor and/or rural communities depend upon natural resources and ecosystem services most directly for their basic needs and livelihoods and therefore are highly vulnerable to ecosystem degradation (see section 2). Thus, enhancing the health and resilience of ecosystems enables both people and nature to better cope with existing and future pressures, including climate variability as well as climate change (CAN 2009). In this sense, increasing ecosystem resilience and functioning, and reducing socio-economic vulnerability is not only a robust response to an uncertain, changing climate, but is also an approach that is closely aligned with development goals and poverty alleviation (CAN 2009).

The ecosystem-based adaptation approach is based on the concept of social-ecological resilience and could be understood as the integration of sustainable management of ecosystems in order to shape changes in social-ecological systems that contribute to sustain the supply and availability of ecosystem services by society, and the maintenance of ecological integrity and human well-being in a world dominated by uncertainty and change (adapted from CBD 2009, Chapin et al. 2009). The adoption of this approach may lead to adapting to climate change and other future patterns of change while generating multiple environmental and societal benefits (win-win benefits) and reducing trade-offs. Indeed, the approach of ecosystem-based adaptation can be applied at a range of spatial scales and yield win-win benefits over short- and longer-time scales. The adoption of this approach is not only consistent with the precautionary approach, but can also lower risks of mal-adaptation. Besides, given that ecosystem-based adaptation is more accessible to rural and/or vulnerable communities than measures based on hard engineering, the adoption of this approach can be more cost-effective (CBD 2009, CAN 2009).

Furthermore, the approach of ecosystem-based adaptation is closely connected to community-based adaptation and valuing traditional knowledge. Given that local communities and indigenous peoples hold unique knowledge linked to how they live within, interact with and manage ecosystems, they play a vital role in integrating sustainable management of natural resources to support global climate resilience. Thus, the approach of ecosystem-based adaptation is especially significant to communities and peoples directly dependent on natural resources and ecosystem services for their livelihoods (CAN 2009).

In addition, this approach considers adaptation actions that include technology transfer, risk reduction and management, social and institutional learning, knowledge management, and institutional arrangements (CAN 2009), as all these actions shape changes in social-ecological systems. Lastly, analysis in previous sections show that ecosystems and the services they provide influence different sectors (e.g. water, energy, agriculture, tourism, etc.), thus ecosystem-based approaches for adaptation could be considered a cross-cutting theme.

4.1 Case Studies for Consideration of Ecosystem-based Approaches for Adaptation

This section will describe some case studies that could serve as a basis to explore further the adoption of ecosystem-based approaches for adaptation. Some examples of ecosystem-based approaches for adaptation are: the maintenance and restoration of "natural" or "green" infrastructure such as mangroves, coral reefs and watershed vegetation as buffer zones that reduce climate risks (e.g. the use of coastal ecosystems to reduce risk of flooding and erosion from storm surges and sea-level rise); the maintenance of agricultural landscapes to support productivity and avoid soil erosion under changing conditions (e.g. introduction of agro forestry and soil conservation practices in the upstream areas of water catchments to avoid soil erosion, siltation, and large changes in hydrological regime) (CBD 2009).

While adopting this approach is cost-effective and locally appropriate, it also contributes to reducing biodiversity loss and maintaining or enhancing ecosystem services that support livelihoods and economic activities (e.g. fish spawning and nurseries in protected mangroves and tourism in sustainable managed coastal areas). Thus, this approach can serve multiple purposes and provide multiple benefits (e.g. conservation of tropical forests supports a range of products critical for poor communities, protects against erosion, contributes to mitigation through both maintaining and increasing carbon storage, increases water storage capacity, provides woodfuel, maintains biodiversity and offers renewable raw materials and shelter) (CAN 2009). Given the above, this approach is not only of high value for adaptation, but is aligned with local needs, capabilities, and development objectives.

Incorporating and valuing ecosystems for adaptation can help deliver no regret and multiple benefits related to avoiding mal-adaptation, protecting natural resource base of vulnerable communities, and maintaining social-ecological resilience to future climate change. It is a proactive and enduring way of building adaptive capacity. However, effectively valuing the total economic value[3] and role of ecosystems (both carrying out economic valuation studies and implementing policy that reflects broad ecosystem values) is highly complex and requires coordinated efforts within and between local, national, and international institutions.

Despite the rich biodiversity in East Africa and the high dependence of livelihoods and economic activities on ecosystem services, there is a lack of data quantifying the costs or economic value of ecosystem services. For example, there are 33 carbon forestry initiatives in the region, but only few are quantifying the value of emission

[3] Instead of focusing only on direct commercial value, the concept of total economic value of ecosystems encompasses the subsistence and non-market values, ecological functions and services and non-use benefits of ecosystem services (such as cultural value, aesthetic value, etc.). This approach presents a more complete picture of the economic importance of ecosystems and demonstrates the wide-raging economic costs associated with their degradation (IUCN 2005).

reduction services and none are currently making payments (CGIAR 2008). This section takes a first step in valuing and costing the management of some ecosystem services that could be highly valuable for adaptation based on review of existing valuation studies. Nevertheless, further research on this subject is required that integrates into the valuation analysis different climate change scenarios, as existing studies consider only future socio-economic scenarios and infrastructure developments.

The four case studies considered for the application of ecosystem-based approaches for climate adaptation are:

- Value of ecosystem services in the Tana River catchment, Kenya, to avoid production, water and livelihoods losses and benefit from green water management (*Tahia Devisscher*)
- Costs of Rugezi wetlands degradation, Rwanda, to value ecosystem services for local livelihoods and energy generation (*Tahia Devisscher*)
- Costs of protecting the Mau Complex, Kenya, to avoid water and energy shortages downstream (*Brian Harding*)
- Costs of conserving the Masai Mara reserve, Kenya, to maintain biodiversity and enhance tourism (*African Conservation Centre,* separate document).

4.2 Valuation of Ecosystem Services in the Tana River Catchment, Kenya

The Tana River has a length of some 1,000 km, rising in the Aberdare and Mount Kenya ranges of central Kenya and running through the arid and semi-arid lands in the eastern part of the country to enter the Indian Ocean through a Delta that covers approximately 1,300 km^2. The Tana's catchment covers a total area of 100,000 km^2, and has a population of more than 4 million people (IUCN 2005). Population density is higher in the upper Tana areas (see Figure 17).

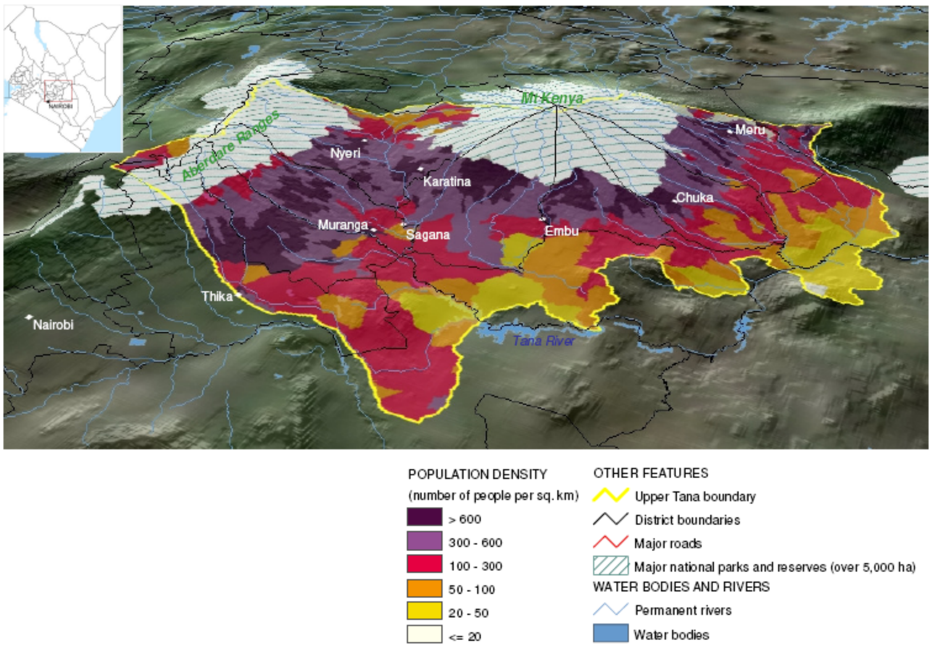


Figure 17. Upper Tana Population Density, 1999

Source: International Livestock Research Institute (ILRI), 2008

The Tana River is the only permanent river in this dry region and represents a vital water resource for all sectors of the population. It is estimated that over a million people depend on the river's flooding regime for their livelihoods, including an additional 800,000 nomadic and semi-nomadic pastoralists as well as seasonal fisherfolk and fish traders (fisheries are the main livelihood for more than 50,000 people with freshwater catch of up to 500 tonnes a year, CADP 1991). About 115,000 farmers practice flood recession and riverbank farming around the Tana. The land area around the river is the only one in the region suitable for arable agriculture. The crop production of farmers depends both on floodwater for irrigation, and on the depositions of fertile sediments that the floods bring. Moreover, almost 2.5 million livestock, including over a million cattle, rely on the downstream floodplain grasslands and water bodies for dry season pasture and water. With no other permanent water sources in the region, the Tana River represent the only safety buffer in case of emergency and drought. Already now, dry season pasture and watering points are limited to the area that is directly adjacent to the river (IUCN 2005).

Water resources from the Tana River are also fundamental for consumption and hydropower. Around 70-80% of the water consumed in Nairobi comes from the Ndakaini reservoir in the upper Tana, with the balance coming from the Sasumua and Ruiru reservoirs and from wells beneath or near Nairobi. Figure 18 shows communities in the upper Tana area where the majority of households rely on surface water for drinking water. The Tana River is also heavily exploited for hydropower. To date, five major reservoirs have been built on the upper reaches of the Tana. Together, these hydropower plants provide nearly three quarters of Kenya's electricity requirements (IUCN 2005).

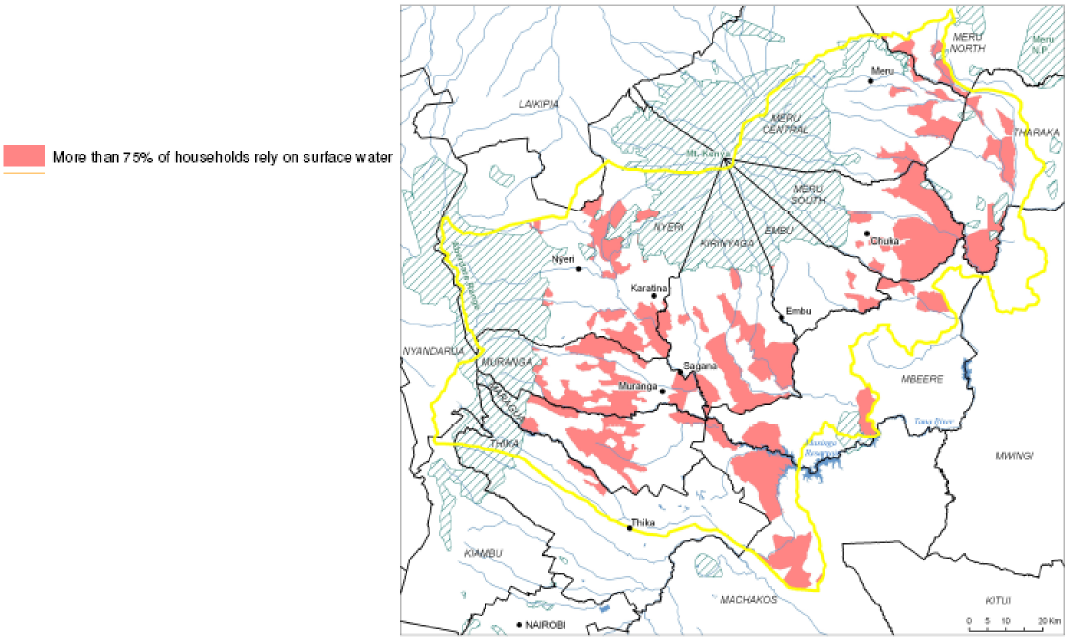


Figure 18. Upper Tana: Communities where Majority of Households Rely on Surface Water for Drinking Water

Source: International Livestock Research Institute (ILRI), 2008

Furthermore, the Tana River region contains unique species and habitats that are endemic to East Africa. Six protected areas are located within the river and delta area, including some of the few remaining riverine forests which support at least four endemic plant species, three of the four primates that are endemic to Kenya and two endemic bird species. In addition, savannahs and grasslands contain populations of large mammals that are key for nature-tourism in the country. In addition to supporting tourism, forests and wildlife are also used by local communities. Approximately a third of local populations in the Tana catchment regularly hunt, and rely on natural forests for energy fuel, construction materials, medicines, boat building materials, and food (Emerton 1994).

Issues and current vulnerability

Currently, electricity demand in Kenya is not met by supply. Demand is increasing at an average of 5% since the 1990s and forecasts estimate demand to triple over the next two decades (Govt of Kenya 2006). As a result, power generation capacity will most likely have to increase. Based on this rationale, a new hydropower scheme, the Mutonga-Grand Falls dam, has recently been proposed for construction on the Tana River below the five existing reservoirs.

To date, dam construction in the Tana River has caused a major influence on the river's downstream flow and physical characteristics, most notably through regulating waterflow and decreasing the frequency and magnitude of flooding (IUCN 2005). Dam-related changes in river hydrology have reduced the area and longevity of flood-supported wetlands and mangrove areas, as well as affeteced fish populations and diversity in the main river channel. In particular, forest and grassland areas have been heavily impacted by dam construction, leading to changes in wildlife and plant species composition and numbers (Duthie 1994). Changes in waterflow and siltation have also affected coastal and marine ecosystems at the river mouth, particularly mangroves and coral reefs near the Kiunga Marina National Reserve (Abuodha and Kairo 2001). UNEP (2006) claims that sediment input into the Indian Ocean has been reduced by 50% after construction of the Tana reservoirs.

If proposed Mutonga-Grand Falls dam is built, there would be no appreciable addition to the river flow except in extreme events occurring every 5 and 10 years. This would effectively end the regular biannual floods downstream, cut off most of the floodplain from water, and significantly lower the local water table. Moreover, reservoir construction would reduce the sediment loads transported down-river, and stabilisation and regulation of waterflow would lead to deepening of the river channel limiting meander and oxbow formation (IUCN 2005). As a result, it is very likely that after construction of the Mutonga-Grand Falls scheme, cropping will be limited to riverbanks only (Quan 1994). Moreover, it is thought that additional dam construction will rapidly exacerbate decline in fishing area and catch (Mavuti 1997). Also, changes in downstream ecosystems and biodiversity would be exacerbated.

If changes in climate are added to the equation, it could be expected that changes in river hydrology would be even more severe causing serious implications for both socio-economic and natural systems in the Tana River catchment. For example, if precipitation decreases during dry periods and these periods become longer, water stress would affect not only hydropower and urban consumption, but also crop production, ecosystem functions, and biodiversity, as well as livelihoods that depend on these. If rain intensity increases, soil erosion may become an issue, as well as siltation of reservoirs. Further research on the effects of climate change on the river hydrology and associated implications is needed.

Similar to energy demand, water demand in the Tana River catchment is projected to increase over the next two decades. Population of Nairobi is growing at 6% annually and industrial water demand is projected to grow from some 220,000 to more than 280,000 m^3/day between 2000 and 2010 (UN water 2006). At present, the Nairobi Water Company is unable to meet daily water demand during dry season, with shortfalls of even 20% (as in 2006). The company estimates an annual increase of 3-5% in water demand, so un-met demand will continue to be a serious issue in the future, unless measures are taken (Hoff et al. 2007).

Changing climate and more frequent extreme events are a huge risk for hydropower industry. For instance, during the 1999-2000 drought, hydropower generation fell by 41% with monthly losses estimated at $68 million and lost industrial production of $1.4 billion. High intensity rain could lead to floods, soil erosion and siltation that would further affect hydropower generation causing loss of reservoir storage capacity and turbine damage. Effects of climate change on river hydrology and implications for hydropower and water consumption need further research.

Given the local importance of the Tana River catchment for economic development, human well-being, and maintenance of biodiversity (see above), it can be assumed that the ecological integrity of its ecosystems and the services they provide play a significant role in the adaptive capacity of social-ecological systems in the catchment to best cope with changing conditions, including changes in climate. The studies below provide an idea of the value of ecosystem services in changing conditions. The first study values the costs of degraded ecosystem services downstream Tana River. The second study values the avoided losses from and additional benefits of applying sustainable management of ecosystem services in the upper Tana River. Both studies consider business as usual scenario as reference and do not account for possible changes in climate and associated implications. To assess full economic costs of implementing ecosystem-based adaptation, it would be necessary to include in the analysis the costs associated to management options and built capacity to avoid marginal costs of negative impacts caused/exacerbated by climate change. Nevertheless, findings below provide a basis to explore further the role of ecosystem services for adaptation and the costs of implementing an ecosystem-based approach.

Valuing downstream flood loss and ecosystem degradation

The study carried out by Emerton (1994) values the costs of flood loss and ecosystems degradation in the floodplains of the Tana River catchment caused by dam construction (see effects of hydrological changes above). The valuation calculates losses in terms of production (livestock and agriculture in the floodplain), fisheries (commercial and subsistence), and livelihoods (hunting, forest and mangrove utilization, water supply). All of these activities are closely related to ecosystem services such as water regulation and storage capacity, maintenance of soil quality (retention of sediments), maintenance of biodiversity, provisioning of water resources, etc. Therefore, it could be assumed that the losses estimated in the study are a valuation of the services that ecosystems provide in the downstream area of the catchment.

The study estimated total losses caused by already existing dams on downstream systems to reach up to $27 million. The median of the incremental costs of building an additional dam (Mutonga-Grand Falls) was calculated at $20 million. If climate change would be considered in the valuation, this incremental cost would most likely be even higher, as water would become an even more serious stress factor in the floodplain, particularly if dry periods become longer. Moreover, water intensity increase in wet periods would probably lead to higher erosion rates and sedimentation of dams, with consequences on stream flows and maintenance costs of reservoirs.

Emerton (1994) also pointed out that economic losses are closely linked to social and cultural costs related to the loss of traditional livelihoods, social change and increasing conflict over scarce resources. The study estimated that changes in Tana’s flood regime affected more than 1 million people by 1994, particularly highly vulnerable nomadic and semi-nomadic pastoralists, who have carried the burden of almost half of the downstream economic losses associated to dam construction.

Estimating costs of implementing green water management in the upstream area of the Tana River and valuing avoided losses in water revenues

The study carried out by Hoff et al. (2007) evaluates the costs associated to implementing green water management (GWM) practices to increase water productivity by reducing unproductive evaporation losses, storm runoff, and soil erosion, and increasing water storage in soils and aquifers. As it is possible to note, GWM uses an ecosystem-based approach, as it contributes to maintain/enhance the services provided by ecosystems that support ecological integrity, livelihoods, human well-being and economic activities (multiple benefits). Some ecosystem services related to green water management include water regulation, groundwater recharge, protection from landslides, floods and siltation, maintenance of water quality, carbon sequestration, and climate regulation.

Financial valuation of ecosystem services for GWM is difficult, however this study tried to estimate avoided losses in terms of water revenues from implementing three specific green water management practices: permanent vegetative contour strips, mulching, and tied ridges. Scenarios considering each practice were developed. The reference scenario is a business as usual scenario, where none of these practices are implemented. All scenarios base their assumption for socio-economic futures on extrapolation of current trends in terms of siltation rates, growth of water supply and demand, reservoir storage capacity, etc.

Before calculating avoided losses of water revenues from implementing GWM practices, the study estimated the total revenues from water resources averaged over two years (a dry year and a wet year) considering hydropower production, irrigation, and urban consumption. Revenues reached around $80 million, mainly from hydropower and irrigation. Water benefits are certainly higher, but benefits to livelihoods, rural consumption, biodiversity, landscape maintenance, among others, were not considered in the valuation of water revenues.

Hydrological changes of implementing the specific GWM practices were evaluated using WOSOFT and SWAT models (Kauffman et al. 2007). Assuming application of these practices on all cropland across the upper Tana River catchment, the study estimated that by 2030 contour strips would reduce erosion by 40%, mulch by 58% and tied ridges by 65%. Compared to the baseline where soil erosion would result in a reservoir storage capacity of 40% by 2030, the GWM practices would result in a capacity reduction of 32%, 28%, and 27% respectively (Hoff et al. 2007).

In terms of avoided losses of water revenues, the comparison between the reference baseline for 2030 and the three GWM practice scenarios for 2030 indicates that both mulching and tied ridges would contribute to decrease un-met water demand by 33% each, while increasing hydropower generation by around 5%. According to the study, each of both practices would contribute to an increase of total water revenues by $14 million per year. Contour strips are also estimated to increase water revenue by $6 million.

Lastly, the study estimates the costs of implementing such GWM practices. The above estimates consider implementation of the GWM across all cropland in the upper Tana. The study suggests that implementing 20% of the area would result in about 50% of the estimated gains. Assuming that the total area under coffee and tea in the upper Tana (394,200 ha) would adopt GWM, the study calculated implementation costs of about $42 million for contour strips, $20 million for tied ridges, and $10 million for mulching (total of $72 million). Considering only 20% adoption of GWM, the study estimated implementation costs of $8.5% for contour strips, $4 million for tied ridges, and $2 million for mulch (totalling about $14.5 million). For the 100% adoption the study calculated annual operational costs between $10-42 million, generally greater than the water revenues. In the case of 20% adoption, annual costs would range between $2-8.5 million, against annual water revenues of $3-7 million. Again, these calculations do not take into account other water-related benefits that can come from implementing GWM practices in the region such as reduction of maintenance costs of reservoirs, and costs associated to malnutrition, migration, and conflicts over scarce water resources (Agwata 2005).

Box 4. Who benefits of enhanced ecosystem services and the implementation of GWM practices? Applicability of a payment for ecosystem services approach for social-ecological resilience.

A question beyond the valuation of ecosystem services is to whom do the benefits accrue? This needs a link between the services and the users, as well as the sellers who would be implementing practices to support social-ecological resilience. A payment for ecosystem services approach could be applicable, as it would not only consider sustainable management of ecosystem services, but also good governance, institutional learning and (re-) arrangement, and capacity building.

One possibility is a debt-for-nature swap that could be attractive for the Government of Kenya as a way to retire national debt in change of implementing sustainable ecosystem management practices (through the Kenya Forest service, or through schemes agreed with upper Tana farmer communities).

Another option is the introduction and implementation of a Green Water Credits (GWC) scheme. Upstream farmers and commercial irrigators would be the sellers of GWCs as they would implement the GWP practices, while the energy companies and downstream irrigators could be the buyers, as they would directly benefit from the implementation of GWM practices upstream. Microfinance could be an appropriate financial instrument for coordination, as it could remain community-based and therefore more likely to be a trusted mechanism. A bank with experience in microfinance could be appointed to establish the GWC contracts, manage the fund and make the payments.

4.3 Economic Losses Associated with Degradation of Ecosystem Services in the Rugezi wetlands, Rwanda

The Rugezi wetlands sit in the highlands of the Northern Province of Rwanda. The total area of the wetlands is 6,735 hectares. Dominant topographical characteristics include rolling hills, wetland lowlands, and a climate of 16-17 °C. The upland hills typically have slopes between 35-60%, fragile soils, and extensive erosion. Land cover surrounding the wetlands consists of shrub plantation and rain-fed herbaceous crop. A small percentage of forest plantations exist, mostly of invasive *Eucalyptus*, *Pinus*, or Cypress species (Musahara 2004). The Rugezi wetlands became part of the Ramsar convention in 2001, officially designating it as a wetland of international importance.

Rugezi is made up of two big valleys. The main valley measures 26 km by 3 km and the second one known as Kamiranzovu measures 9 km by 2.5 km. The waters from the two valleys meet at an altitude of 2,050 m and run into Lake Bulera, about 200 m downstream. Lake Bulera (or Burera) and Ruhondo (see Figure 19) are Rwanda's two deepest lakes and play a fundamental role in national hydropower production. Lake Bulera occupies 5,280 hectares, with a maximum depth of 174 meters, and Lake Ruhondo occupies 2,610 hectares, with a maximum depth of 68 meters. In the last decade, water levels in Lake Bulera dropped 4 meters and levels in Lake Ruhondo dropped 1 meter (REMA 2006). Experts cite overall precipitation changes and decades of anthropogenic stress in Rugezi as causes for these reductions (Hategekimana et al. 2007).

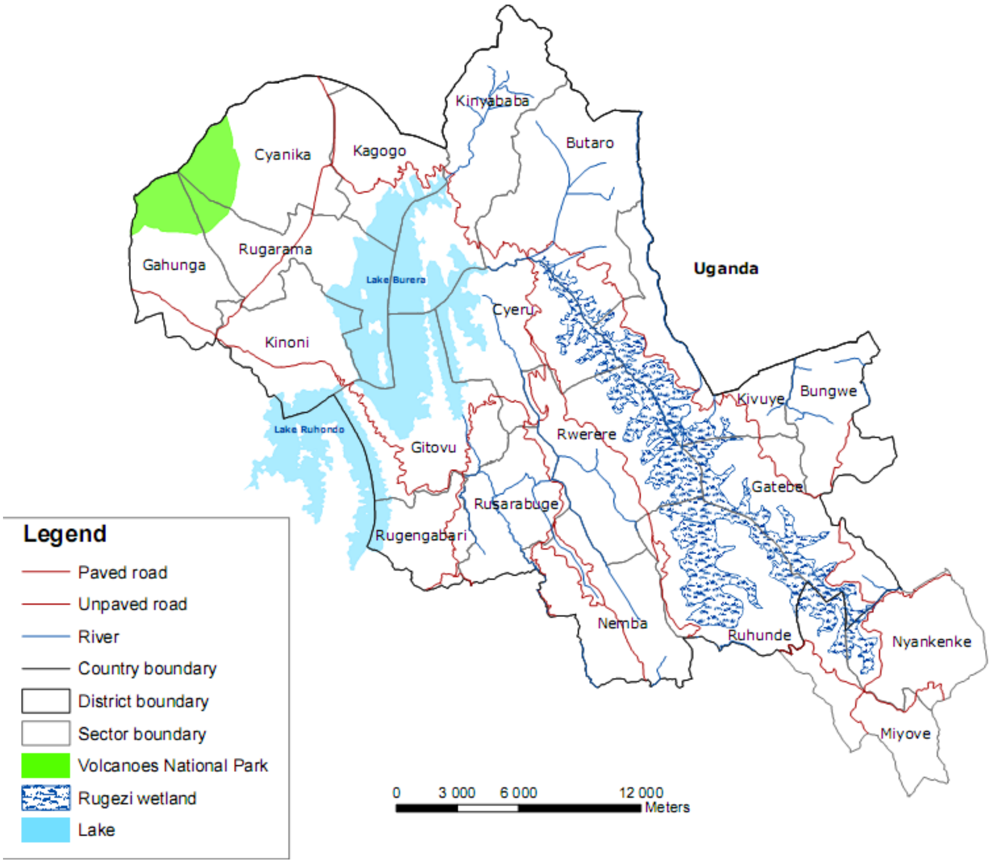


Figure 19. Rugezi Watershed

Source: Republic o Rwanda, 2004

Issues in the Rugezi Wetlands

In general, the northern part of Rugezi is severely degraded, while the southern sections are still in 'good state' (see Figure 20) (Hategekimana et al. 2007). Rugezi's principle ecological issue is a declining water storage capacity caused by anthropogenic uses. Agriculture, drainage projects, poor land management practices, and population density greatly contribute to erosion, vegetation changes, and soil changes. These factors directly affect turbidity of water, water flow rates, runoff, vegetation filtration potential, soil absorption potential, storm peaks, and weather buffering capacity of the wetland. Downstream, the outflow of the affected wetland carries high sediment loads and demonstrates an altered flow pattern (Willets 2008).

Recent drainage also permitted greater community access to the wetland for agriculture, leading to increases in cultivation, and a wetland-dependent agricultural economy.

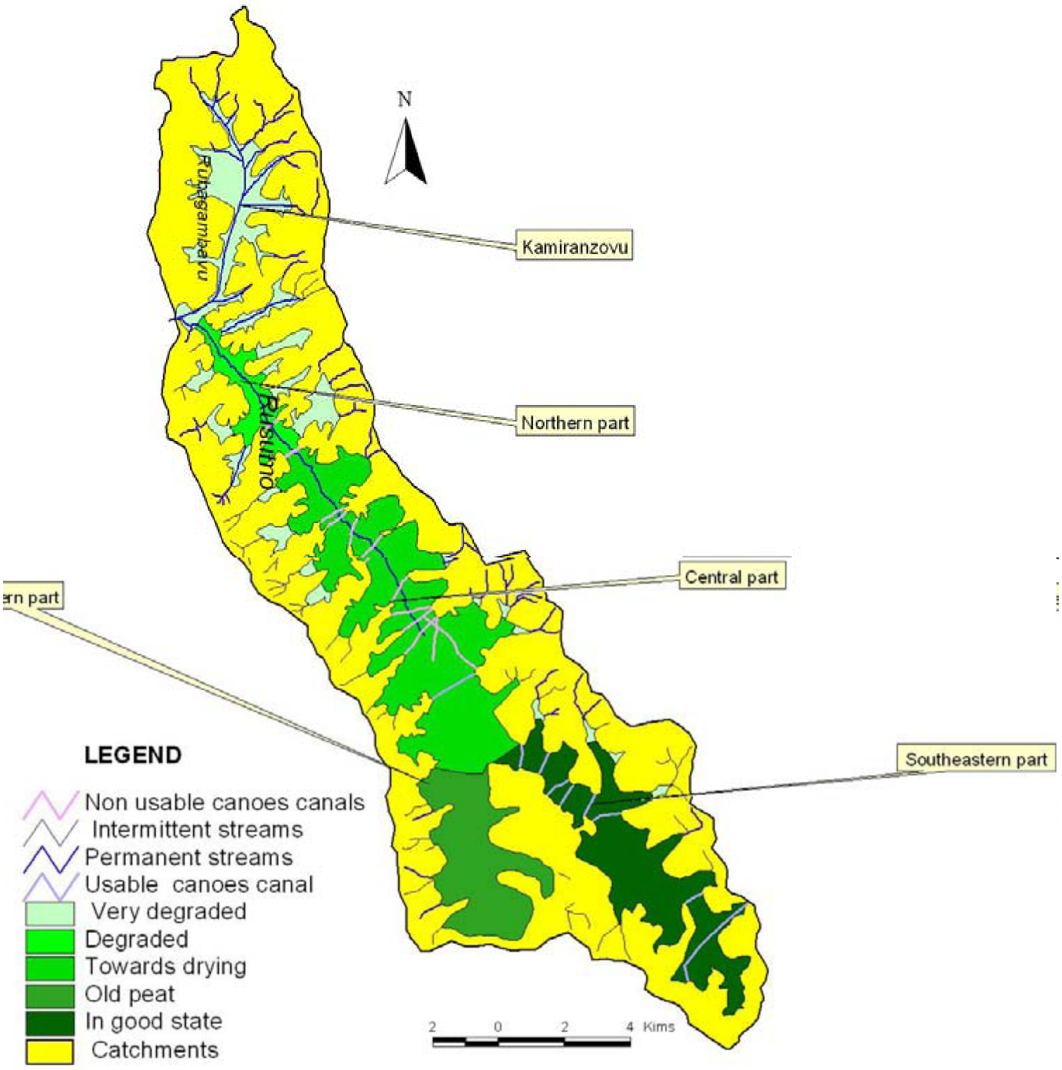


Figure 20. Degradation in Rugezi Wetlands

Source: Hategekimana et al. 2007

Over the past century, various economic activities have damaged the wetland ecosystem. Up until 2001, Rwanda's Ministry of Agriculture supported wetland drainage for socio-economic purposes. Over the last decade, several international organizations tried and failed to re-engineer wetland canals and improve agricultural development of the marsh. General declines in water flows also motivated the hydroelectric utility to intervene in environmental engineering. In efforts to improve flow to the lakes and increase flows to the hydroelectric turbines, the electric utility drained large sections of the wetland. These actions lead only to even greater reductions in the water table (Hategekimana et al. 2007). As result of these poor policies and planning measures, Rugezi now suffers serious ecological and socio-economic problems (Willets 2008).

Moreover, the Rugezi watershed supplies Rwanda with 90% of its total electricity through two main hydropower stations, the Ntaruka and Mukungwa stations located in the Rugezi watershed (Uwizeye and Hammill 2007). Current stations operate at only 30-50% efficiency for various reasons (UNDP 2007). The urban population in Kigali uses around 60% of the total electricity generated in Rugezi. In the last few years, water shortages have caused an energy crisis. This has increased the number of concerned stakeholders involved in Rugezi's watershed management. Various government ministries as well as the electric utility company are now critically aware of wetland mismanagement and climate change risks.

Box 5. A conflict for the value of ecosystem services in the Rugezi Wetland
The wetland currently has two uses: it is a community resource and a source for national energy development. Upstream wetland inhabitants desire improved water quality and quantity. Downstream utility stations and national electricity consumers want increased water flows from Rugezi. Both objectives would benefit from proper, natural, wetland management. However, upstream users have no income or livelihood alternatives than to use the wetland for agricultural or handcraft purposes. The electric utility company also sees no other option than to support agricultural prohibition and immediate, extensive rehabilitation. The immediate needs of the local community are incongruous to the immediate national energy needs (Willets 2008).

Valuing the costs of ecosystem services degradation

A major effect of the Rugezi wetlands degradation, which is linked to national economic loss, is the decrease in water levels and consequently the energy crisis mentioned above. Since the beginning of year 2000, water levels of the two lakes that supply Ntaruka and Mukura hydropower stations have been declining due to reduced water flows from the main source. A study by Helpage Rwanda (2004) found that the average water flows have been reduced to 50% of the average level from 1957-1970. In 2005, the lakes reached the lowest level.

Electricity shortage has resulted in load shedding, for which the power company switches off power to customers. Frequent power shortages has resulted in individuals and industries purchasing their own generators, which has led to an increase in production costs and contributed to consumer good price increase (PIE/REMA 2007).

Moreover, as a result of power shortage, electricity bill has hiked from 48 Rwandan francs to 120 per unit of power consumption, an increase of 250%. In order to meet the energy demand, the electric utility company has purchased a number of diesel powered generators. By the end of 2006, the company's costs for diesel were estimated at about US$ 65,000 per day (EIU 2006).

In addition to economic consequences for the energy sector, the degradation of the Rugezi wetlands has negatively impacted local communities that depend on the ecosystems services the wetlands provide. Degradation affected their food sources, fishing, transport system, and building/handicraft materials.

It is difficult to evaluate the economic losses due to the degradation of Rugezi for the local communities. Ecosystem services are lost and consequences are complex and have not been quantified. However, a study carried out by PIE/REMA (2007), has obtained data from the field that show what the local communities have lost due to degradation of the wetlands. Data in the field were collected referring to 'before' and 'after' 1990s (period before and after the severe degradation).

The results of the study show that there are several households depending on the Rugezi even though their farms are not located in the valley. Around 50% of the households indicated that agriculture (including livestock keeping) is the main livelihood and reason to stay in and around the valley. Other activities are also important and can bring substantial incomes to the household, such as fishing and weaving. Wild goods are also considered sources of incomes and livelihoods to local people.

However, after severe degradation wild goods have become less important for local communities given the diminishing value of incomes that are obtained from them. Before severe degradation wild fruits, wild animals and wild fish were available in large quantities, but after degradation these wild goods have become scarce (wild fruits reduced in 85%, wild animals in 100%, wild fish in 98%) and thus, do not contribute to the income of local communities in the same way they used to. A clear example is how fishing activities have lost value. Before the severe degradation of the Rugezi wetlands, local fishermen used to catch enough fish for local consumption and export to Tanzania. According to Hategikamana (2005), some fishermen were even able to buy livestock from fishing. Before severe degradation, almost 13 tones of fish were traded in a single local community annually. After degradation, the quantity dropped to 0.3 tones.

Findings are consistently similar for other types of resources and services. A decline of resources and ecosystem services provided by the wetlands has also caused changes in activities such as pottery, agriculture, and water transportation.

Boat transportation from and to different market places in the region was very important before Rugezi degradation. Before there were about 20 small ports in the region, where travellers could find boats to travel. This contributed to the income of boat owners (up to Rwf 1,000 per day) and their associations, and also to the transportation and commercialisation of main food, cash crops, and building materials. After the severe degradation, boat transportation is limited and is only practised in the southern part of the wetland. Passengers have dropped from an average of 3,468 a year to 81 causing serious problems in terms of access to markets and increase of goods prices. Economic losses for the communities in terms of lost transport opportunities have not been quantified.

Pottery activities, once part of the main economic activities in the region, have also been seriously affected by the degradation of Rugezi. Clay has become scarce and pottery activities have been totally prohibited in some areas of Rugezi. Natural fertilizer has also become scarce, as well as material for weaving and building. For example, use of reeds for furniture or hunting implements is no longer practiced. Scarce resources result in price increases. For example, prices for weaved mats, which are used by local people, have increased by 300% over the past decade. This has important welfare implications for the local populations in the region, both for producers and consumers.

Another effect of the degradation of ecosystem services in Rugezi is that in the past decade local communities have experienced damages from floods, resulting in losses of houses, livestock and lives. Also some rivers have dried up in some places, increasing the distance to travel between houses to where households fetch water for daily activities.

The results obtained by PIE/REMA (2007) suggest that the degradation of Rugezi wetlands has devastating effects on livelihoods and way of life of the communities in the area. It shows how degradation, in a matter of decades, can affect individuals, households, communities, the economy and beyond. Despite these effects have not been quantified in monetary terms, it helps understanding the value of ecosystem services for local livelihoods and economic activities. If ecosystem services are degraded, local communities that depend on them become even more vulnerable to changes in the future, whether these are socio-economic in nature or are related to changes in climate.

4.4 Valuation of Ecosystem Services in the Mau Forest Complex, Kenya

The Mau forest Complex is one of the five major water towers for Kenya. The forest is situated at 0o 30'South, 35o 20'East, and in Rift Valley Province and spans across the four districts of Narok, Nakuru, Bomet and Trans-Mara. Mau Forest Complex is divided into five units: the Eastern Mau, Western Mau, South Western Mau, Transmara and Ol Posimoru (Raini & Kariuki 2007). Collectively this makes up the largest closed canopy forest ecosystem in Kenya covering about 244,000 hectares The Eburru forest, composed of indigenous tree species covers an area of 8,736 hectares while the Dondori forest covers an area of 6,956 hectares.

The Mau Forest Complex forms part of the upper catchments of the majority of major rivers on the west side of the Rift Valley, including Nzoia, Yala, Nyando, Sondu, Mara, Ewaso Ngiro (south), Makalia, Naishi, Nderit, Njoro, Molo and Kerio (Lambrechts 2009). These rivers supply some of the largest lakes in Kenya including Turkana, Victoria, Nakuru, Natron and Baringo.

The Mau watershed provides environmental services essential for crop production by supporting river flow, favourable climate as well as medicinal plants, firewood and grazing (Raini & Kariuki 2007). Other services noted include river flow regulation, flood mitigation, water storage, reduced soil erosion, and water purification (Lambrechts 2009). These ecosystem services contribute significantly to key economic sectors including agriculture, tourism and supply of water to urban and rural areas. Millions of people depend on the 12 rivers that flow from this large ecosystem - including hundreds of thousands employed in the tea, tourism, energy and livestock industries (KWS 2008)

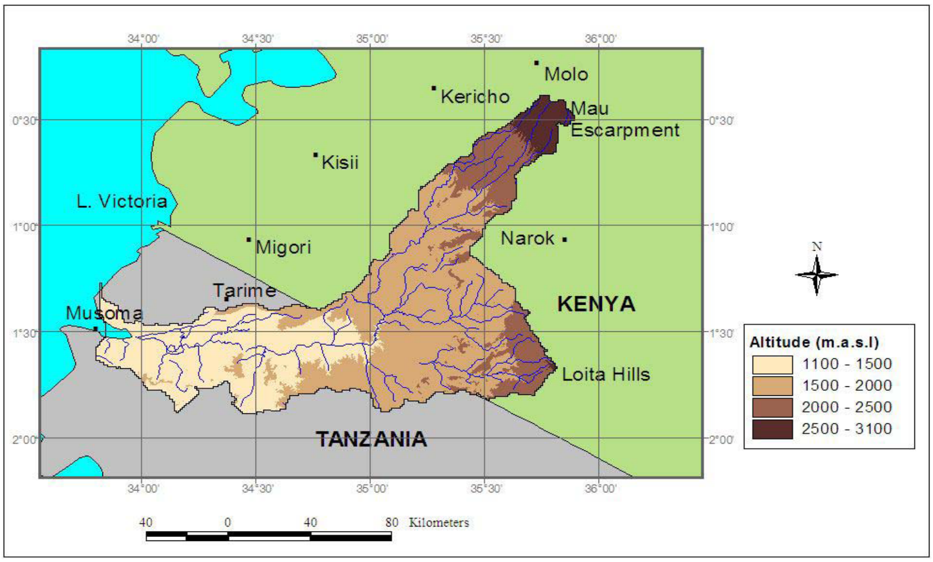


Figure 21. The location of the Mau Forest Complex in Kenya. Source: Mati, et al, 2005

Altitude plays an important role in influencing climate, vegetation and wildlife. The variability in altitude has major implications on socio-economic and ecological services. For example, mean annual rainfall ranges between 1,000mm to 1,750mm on the Mau hills to 300-800mm on the plateau in the South. The northern and western parts of the Mara River basin are wettest, recording 1,200mm to 1,800mm per annum.

Biodiversity of the Mau Forest Complex

Vegetation in the forest has traditionally been composed of bamboo interspersed with stands of *Olea capensis*, *Prunus Africana, Albizia gummifera* and *Podocarpus latifolius.*

The forest had a rich birdlife making it attain Important Birds Area (IBA) status. Forty-nine of Kenya's 67 Afro tropical Highland bird species were known to occur in the Mau Forest Complex as confirmed by records obtained during the World Bird Watch 1999. These included Grey Throated Barbet *Gymnobucco bonapartei, Luhders* Bush Shrike *Laniarius leuhderi,* Equatorial Akalat *Sheppardia aequatorialis,* the Red Chested Owlet *Glaucidium tephronotum,* Banded Prinia *Prinia bairdii* and Black Faced Rufous Warbler *Bathmocercus cerviniventris.* Others are the Verreaux Eagle *Aquila verreauxii*, Amani Sunbird *Anthreptes pallidigaster* and Taita Thrush *Turdus helleri*, Hartlaub's Turacco *Turaco hartlaubi*, the Restricted Range Hunter's Cisticola *Cisticola hunteri* and Jackson's Francolin *Francolinus jacksoni*.

The southern forests of the Mau Complex host ungulates such as the Bongo and the yellow-backed Duiker; carnivores, including the Golden Cat and the Leopard; and the forest elephant (UNEP 2006).

Tourism

The Eastern Mau supports key economic sectors in terms of tourism and wildlife in Lake Nakuru, Masai Mara, Serengeti and Lake Baringo. It provides an important source of water for domestic, industrial, conservation and farming needs. Several rivers and streams supplying fresh water to areas of high biodiversity importance originate from this forest. The Mara River, which originates on the western flank of the Mau escarpment flows through the Mara-Serengeti ecosystem before discharging into Lake Victoria. Streams originating in the Eburru basin flow into Lakes Nakuru and Naivasha, which are designated as Ramsar and UNESCO World Heritage sites. The Ewaso Ng'iro River drains into Lake Natron at the border of Kenya and Tanzania, which is the only regular breeding site for flamingoes while Molo River feeds Lake Baringo.

It is certain that the rivers flowing from the Mau Complex are immensely important in contributing to the Kenyan tourist industry, including Maasai Mara National Reserve and Lake Nakuru National Park. Revenue from these parks generated 650 million Kenya Shillings (ksh) and Ksh 513 million in 2007 (Lambrechts 2009).

The rivers that run from the forest also play important ecological function in supplying water to areas where tourism potential is particularly high, including Kakamega, South Turkana National Reserve, Lake Baringo and Lake Natron. These areas are also remarkable for their high levels of biodiversity, including of bird species. Other noted IBA's include that of Kusa Swamp (near Nyando River), Mara Bay and Masirori Swamp (Lambrechts 2009).

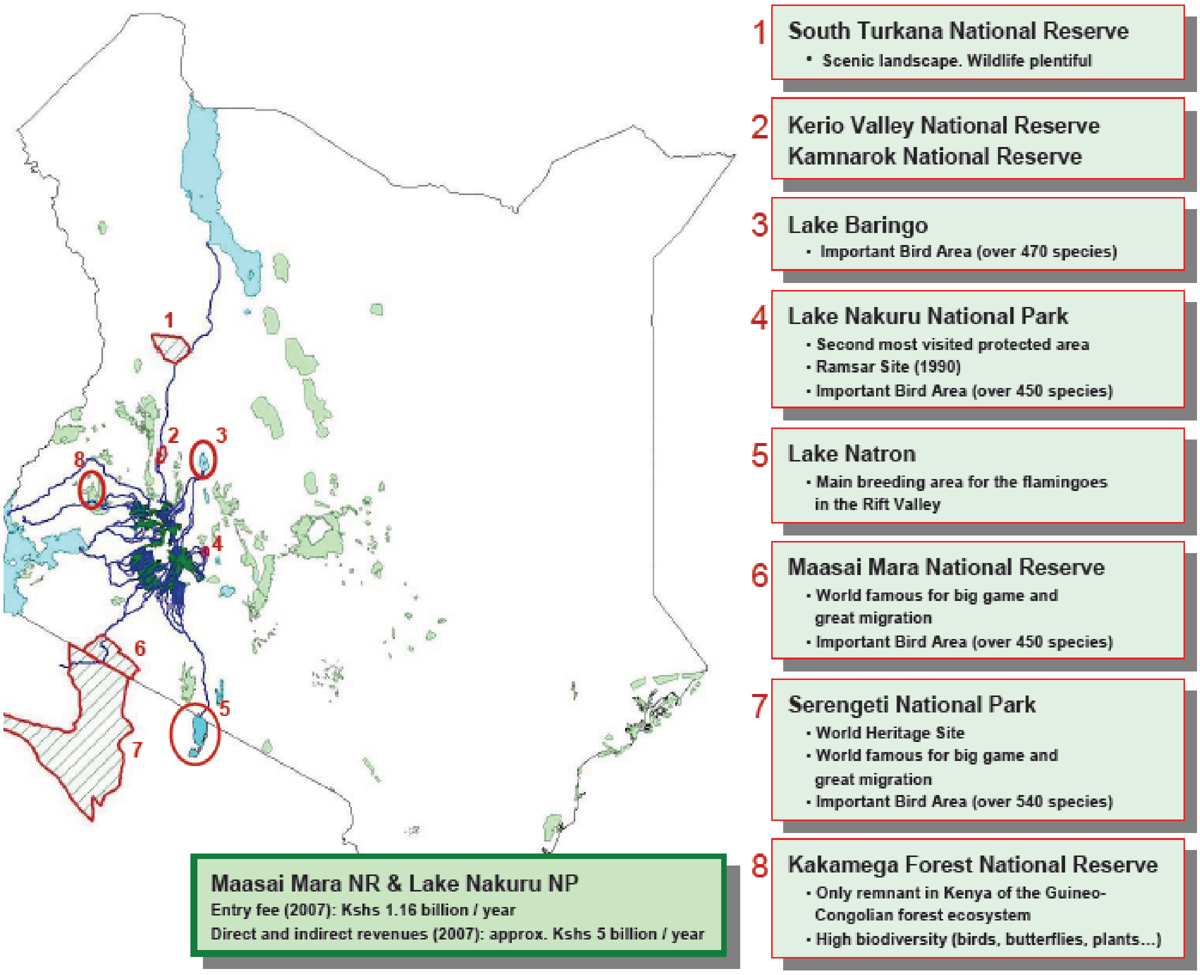


Figure 22. A Review of Mau Forest Complex and it's impact on tourism and potential tourism locations in Kenya

Source: UNEP, 2008

Energy

Power cuts and electricity rationing in Kenya during July, August and September 2009 were widely reported in media globally It was clearly outlined that Kenya's energy supply was intrinsically connected to a healthy environment and a favourable climate. It was estimated that this could be a potential loss of $100million per month (BBC 2009).

Hydropower plants generate over 57% of Kenya's total electricity output. The potential of hydropower generation on rivers arising from the Mau Complex has been estimated at 535 megawatts, which would amount to 41% of total current production (Lambrechts 2009).

Large scale hydropower plants have been recently been completed as part of the Sondu-Miriu Hydropower Scheme with an electricity generation capacity of 60MW and the Sang'oro Hydropower Scheme is currently underway and will generate 21.4MV. These projects have seen huge external investment of just under $300 million.

Proposed electricity generation projections include that of the Magwagwa Multipurpose Dam Scheme which aims to generate 94.6MW. The total capacity of the hydropower projects proposed and under construction is 189MV (Lambrechts 2009).

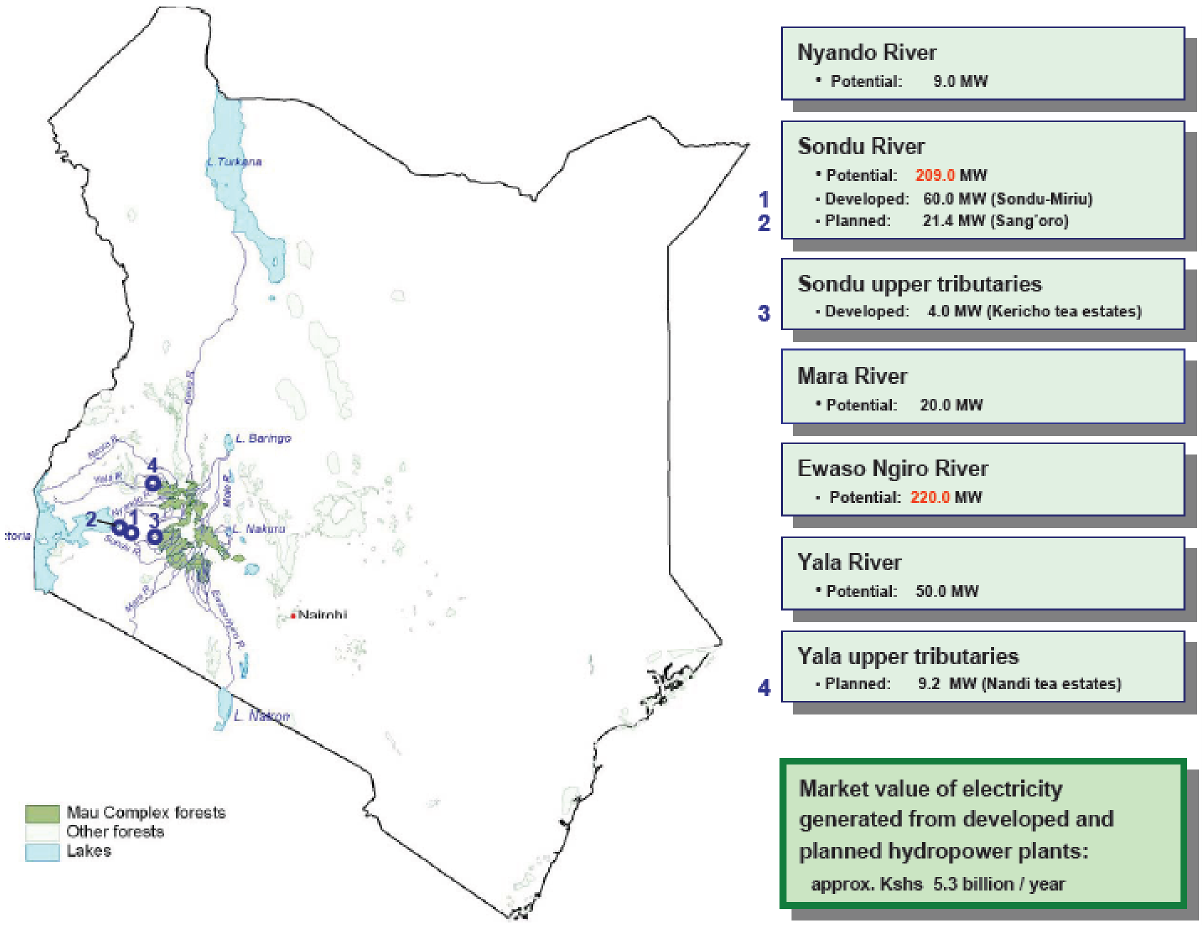


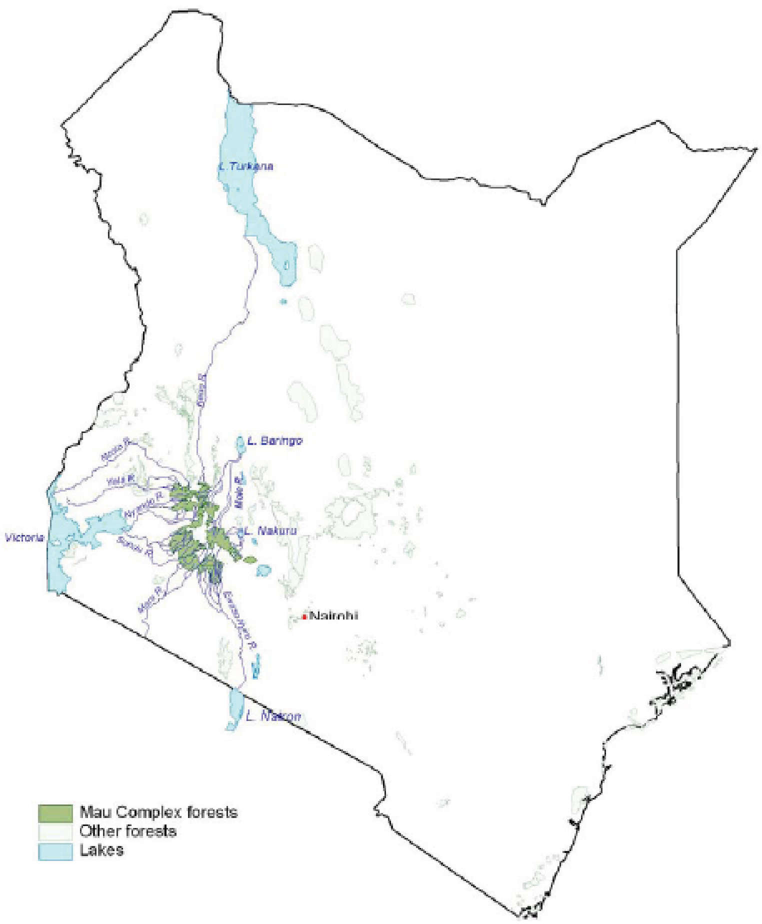
Figure 23. Hydro-electrical power and potential of the Mau Forest Complex in Kenya

Source: UNEP, 2008

Water Supply

Figure 24 demonstrates the immense importance of the hydrological network that the Mau Forest Complex supports. It is clear that there is also a large geographical area cover by the basin. The rivers that flow from the Mau Forest Complex cross 478 sub-locations where the total population is estimated at over 5.5 million. There is clearly a great reliance on healthy flow of clean water arising from the Mau Forest.

Many urban areas in Western Kenya and the Rift Valley's principle water supplies originate in the Mau Forest. These towns include Eldama Ravine, Kericho, Molo, Narok, Nakuru and Njoro (Lambrechts 2009).



The Mau Complex forms the upper catchments of all (but one) main rivers west of the Rift Valley, including:

- Nzoia River (➔ Lake Victoria)
- Yala River (➔ Lake Victoria)
- Nyando River (➔ Lake Victoria)
- Sondu River (➔ Lake Victoria)
- Mara River (➔ Lake Victoria)
- Kerio River (➔ Lake Turkana)
- Molo River (➔ Lake Baringo)
- Ewaso Nyiro River (➔ Lake Natron)
- Njoro River (➔ Lake Nakuru)
- Nderit River (➔ Lake Nakuru)
- Makalia River (➔ Lake Nakuru)
- Naishi River (➔ Lake Nakuru)

It feeds major lakes, including:

- Lake Victoria
- Lake Turkana
- Lake Baringo
- Lake Nakuru
- Lake Natron

of which three are cross-boundary:

- Lake Victoria (Nile River Basin)
- Lake Turkana (Kenya / Ethiopia)
- Lake Natron (Tanzania / Kenya)

Figure 24. Hydrological system of the Mau Forest Complex in Kenya

Source: UNEP, 2008

Vulnerability of the Mau Forest Complex

The entire catchment is a closed basin that's physical and ecological processes are interlinked and interdependent. Human induced factors have threatened and disrupted ecological integrity of the area. Key among these factors are illegal excisions, land subdivision, degradation of water catchment areas through logging, systematic removal of trees by those allocated land on forest land, pollution, inappropriate farming practices such as farming on river banks, quarrying on riversbeds, overharvesting of natural resources such as sand, fuelwood, medicinal plants and wildlife products (Raini & Kariuki 2007) But logging for charcoal and timber, antiquated farming techniques, and illegal settlements continue to threaten the forests and rivers alike (KWS 2008).

Over the last decade, the forests of the Mau Complex have been heavily impacted by official forest excisions, in particular in 2001, as well as by illegal, irregular and unplanned settlements. Eastern Mau Forest Reserve and South West Mau Forest are considered the most affected areas (Raini & Kariuki 2007)

Though most of Kenya's forests have been decimated by degradation among other factors, the Mau Complex forests cover, and in particular that of the Maasai Mau Forest has been the most affected, and has receded drastically over time. The major cause of the forest loss was encroachment.

Valuation of the Mau Forest Complex

During the drought of 2009, there was many estimates of the value of the Mau Forest Complex to Kenya. However, there have been limited attempts to value Ecosystem services supply associated with the Mau in reality. Kenyan national newspapers have even suggested a figure of USD 300 million annually for the entire Mau Forest Complex.

Although it is clear that an insufficient number of studies have been undertaken, it does not diminish the value of the Mau Forest Complex and the ecosystems services, which it provides. Current exploitation of resources within the forest, notably for charcoal production generates income for inhabitants and forest resource users, however this may be having a greater economic cost nationally. This makes the economics of protecting the forest more difficult. There may be added cost for resettlement of current residents of the forest to other locations.

The hydrological power plants, the Megawattage (MW) being produced and the trade in electricity could act as the greatest economic incentive for protection of the forest and its catchment area. As Lambrechts (2009) highlights, if all of the potential electricity was generated from the Mau Forest Complex (i.e 180 MW), the sale value of the average energy production on these sites will be in the range of KSH 10 billion per annum. Of course, it is acknowledge that the hydropower capacity is heavily linked to conservation of the forest.

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SECTION 4: Case Studies for Consideration of Ecosystem-based Approaches for Adaptation

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ANNEXES

ANNEX I. Geographical Distribution of Main Issues Related to Ecosystem Degradation and Changes in Ecosystem Services in East Africa

	Ecosystems degradation and biodiversity loss	Degradation of ecosystems and production systems (agriculture and fiheries)	Water shortage and pollution
KENYA			
Central Province	Unsustainable water use, over-grazing, land degradation, and desertification. Illegal hunting, large-scale logging in the indigenous forest surrounding Mount Kenya	Severe soil degradation	Uneven water distribution and unsustainable use, conflicts between irrigation, livestock, wildlife, and environmental conservation
Coast	High number of threatened species, deforestation for woodfuel, forest fragmentation, unsustainable water use, over-grazing, land degradation and desertification.	Drought, severe soil degradation. Marine fish production decline	Uneven water distribution and unsustainable use, conflicts between irrigation, livestock, wildlife, and environmental conservation
Eastern	Heavy grazing, soil degradation, reduction of large wild mammals population. Large-scale logging in the indigenous forest surrounding Mount Kenya.	Drought and loss of large number of livestock, soil degradation	Severe water scarcity
North Eastern	Habitat degradation due to grazing and woodfuel colllection. Deforestation for woodfuel.	Drought and loss of large number of livestock	Water pollution, eutrophication of Lake Victoria
Nyanza	Deforestation and fragmentation of forests, loss of corridors between protected areas, unsustanable wildlife management. Deforestation for woodfuel.	Severe soil degradation, fish production has declined in Lake Victoria basin	Severe water scarcity
Rift Valley	Habitat transformation, wood cutting of savannah vegetation for charcoal production, loss of corridors between protected areas, unsustainable wildlife management, unsustainable water use, over-grazing, desertification	Severe soil degradation, drought and loss of large number of livestock	Severe water scarcity, water quality degradation due to increased use of fertilizers and pesticides
Western	High population growth and rapid land-use convertion	Severe soil degradation, fish production has declined in Lake Victoria basin	Eutrophication of Lake Victoria
RWANDA			
Butare	Mora than half of wetlands are cultivated	Low food production due to acidic soils	
Byumba	Degradation of Akagera National Park	Decline in protein production	
Cyangugu	Almost all wetlands are cultivated, degradation of Nyungwe National Park	Decline in protein production	
Gikongoro	Almost all wetlands cultivated	Limited food production due to acidic soils	Occasional drought and rain deficit affects water supply
Gisenyi	Degradation of Gishwati forest and Mutara Reserve. Almost all wetlands are cultivated	Decline in protein production, deteriorating fish yields in the Nyabarongo River	
Gitarama	Almost all wetlands are cultivated	Decline in protein production, decline in sweet potato production, deteriorating fish yields in the Nyabarongo River	

Kibungo	Degradation of Akagera National Park	Decline in protein production, deteriorating fish yields in the Kagera River	Occasional drought and rain deficit. Lake Mugesera regions have severly decreased and degraded wetlands
Kibuye	Almost all wetlands are cultivated, degradation of Mukura forest.	Food production stressed in high altitude districts due to heavy rainfall and erosion during the growing season	
Ruhengeri	More than half of wetlands are cultivated, degradation of Volcanoes National Parks	Decline in protein production, soil exhaustion, deteriorating fish yields in the Nyabarongo River	
Kigali-Ngali		Decline in protein production, deteriorating fish yields in the Nyabarongo River and Lakes Cyohoha and Rwero	Occasional drought and rain deficit. Lakes Cyohoha, Bugesera, and Rweru have severly decreased and degraded wetlands, Gashora marsh was drained for food emergency in 2000.
Umutara		Decline in protein production, degradation of pastures	Occasional drought and rain deficit
TANZANIA			
Arusha	Deforestation and land degradation	High risk of desertification and localized land degradation, over-stocking of cattle	Water shortages and drought, water quality problems
Dar es Salaam		Deteriorating fish catch	Water pollution
Dodoma	Deforestation and land degradation	High risk of desertification and localized land degradation	Water shortages and drought
Iringa	Deforestation	Low produciton due to acidic soil	Water shortages and drought
Kagera	Refugees cutting trees for fuelwood and construction		Water shortages and drought, water quality problems
Kigoma	Refugees cutting trees for fuelwood and construction	Deteriorating fish catch	Water shortages and drought, water quality problems
Kilimanjaro		Soil degradation	Water shortages and drought, water quality problems
Lindi	Deforestation and soil degradation. Degradation of Miombo woodland	Soil degradation	
Mara		Over-stocking of cattle, soil degradation	Water quality problems
Mbeya		Low produciton due to acidic soil	Water shortages and drought
Morogoro	Deforestation. Degradation of Miombo woodland degradation	Low produciton due to acidic soil	Flooding
Mwanza		High risk of desertification and severe localized land degradation, over-stocking of cattle	Water quality problems
Pwani	Degradation of Pugu and Kazimzumbwe Forest Reserves due to population growth. Mangrove and wetland conversion, especially Rufiji River forests, woodland and wetlands. Degradation of Miombo woodland degradation.	Soild degradation	
Rukwa		Fish catch deteriorating	Water quality problems
Shinyanga	Land degradation	High risk of desertification and localized land degradation	
Tabora	Land degradation	High risk of desertification and localized land degradation	

Tanga	Forest Reserve encroachment and deforestation, soil degradation	Soil degradation	Flooding, water quality problems
UGANDA			
Central Region	Mukono district has the most degraded high tropical forest. Forest habitats mostly replaced by savannah, farmland, and pasture. Remaining forests patches within protected areas are fragmented, tree cut for woodfuel, timber and construction materials. High deforestation rates in Rakai, Masaka, Mpigi, Kampala and Mukono districts; wood deficit in many districts.	Severe soil degradation in Rakai, Mubende, Kiboga, Luwero, and Mukono. Soil fertility stress in Kalangala. Drought affects livestock production in Kiboga.	Groundwater supply is lowest in Kalangala, Kiboga, Luwero/Nakasongola, Masaka/ Sembabule, Mpigi, Mubende, Mukono and Rakai districts. Loss of 40.8% of original wetland area. Water pollution is a considerable problem in Kampala. Freshwater purification is stressed from wetland degradation in Kampala, Masaka, Mpigi, Mukono and Rakai.
Eastern Region	Forest habitats mostly replaced by savannah, farmland, and pasture. Remaining forests patches within protected areas are fragmented, tree cut for woodfuel, timber and construction materials. Notable biodiversity loss in Kapchorwa and Mbale Districts. High deforestation in Jinja, Iganga, Busia, Soroti; wood deficit in Mbale, Bugiri, Jinja and Mayuge districts.	High proportion of degraded lands in Mbale district, severe soil degradation in Iganga, Tororo and Mbale, Kamuli, Soroti, Pallisa, Kumi and Kapchorwa.	Wetland conversion in Iganga/Bugiri, Jinja, Kamuli, Kapchorwa, Kumi, Mbale, Pallisa, Soroti/Katakwi and Tororo/Busia districts. Location of 73.8% of Uganda's converted wetland areas. Freshwater purification is stressed from wetland degradation in Iganga, Jinja and Pallisa. Water regulation is stressed in the Northern and Eastern regions, which are affected by droughts and floods.
Northen Region	Biodiversity threatened by agricultural and herding activities. Habitat fragmentation, deforesation, uncontrolled wild fires. Pronounced wildlife poaching. Unsustainable water use. Over-grazing by livestosck, land degradation and desertification. Notable biodiversity loss in Nebbi district. Wood deficit in Arua district.	Severe soil degradation in Moroto, Kotido, Lira, Apac and Moroto. Soil and soil fertility stressed in Nebbi. Drought affects livestock production in Kotido and Moroto.	Region is affected by recurring droughts and floods suggesting that water regulation is stressed.
Western Region	Habitat fragmentation. Unsustainable wildlife poaching and hunting. Unsustainable woodfuel collection. Vulnerable populations of large mammals. Deforestation is highest around the southwestern Bugoma, Budongo, and Kagombe forets in Masindi and Hoima districts. Biodiversity loss from deforestation is a problem in Bundibugyo, Bushenyi, Kabale, Kabarole, Kisoro, Mbarara and Rukungiri districts. Wood deficit in many districts.	High proportion of degraded lands in Kabale and Kisoro districts. Soil fertility stressed in Ntungamo. Severe soil degradation in Kisoro, Kabale, Rukungiri, Bushenyi, Mbarara, Kabarole, Kibaale and Hoima.	Water pollution problem in Kasese district. Freshwater purification is stressed from wetland degradation in Kabale.

Adapted from UNEP and IISD 2005.

ANNEX II. Regional Initiatives

NEPAD Action Plan for Environment Initiative (UNEP 2003)

The main objective of the NEPAD Environmental Action Plan is to improve environmental conditions in Africa in order to contribute to the achievement of economic growth and poverty eradication. The Framework for the Action Plan was agreed in 2002 at the Global Ministerial Environment Forum. The Action Plan is organized in clusters of programmatic and project activities to be implemented over an initial period of 10 years. The Environmental Action Plan also plans to complement on-going AMCEN activities; the plan is reviewed by AMCEN on a regular basis (UNEP 2003).

The programmatic areas of the Environmental Action Plan involve: combating land degradation, drought and desertification, protecting wetlands, preventing and managing invasive species, conserving marine and coastal resources, cross-border conservation of natural resources (freshwater, biodiversity, forests), combating climate change, and cross-cutting issues such as health and the environment, transfer of environmentally sound technologies, and early warning systems. Priority measures to be taken under the NEPAD are: sustainable land use (agroforestry and soil conservation); integrated management of water resources; development of new and renewable energy resources; sustainable use of rangelands; integrated natural resources management, reforestation and ecological monitoring; development of sustainable agriculture and enhanced productivity; capacity building activities including pilot projects; facilitation of the adaptation of sound technology and good practices; support to decentralization processes to strengthen rural community systems; technical and scientific cooperation; and information exchange (UNEP 2003).

Some key targets of the action plan include: review of legislation and practices which impact on wetlands in at least 30% of countries in each sub-region, establishment of Technical Wetlands Networks in all sub-regions of Africa, target interventions grouped in thematic clusters to support sustainable development of coastal resources, identify ecosystems, regions and people most vulnerable to climate change, develop adaptation strategies for the identified exposure units, support capacity building for adaptation and institutional learning, integrate national adaptation strategies into national sustainable development planning, and increase access to sustainable, reliable and affordable commercial energy supply from 10 to 35% in the next 20 years (UNEP 2003).

IGAD (InterGovernmental Authority on development) Environment and Natural Resources Strategy

The IGAD Environment and Natural Resources Strategy launched in 2007 derives directly from the 2003 IGAD Strategy and its accompanying Implementation Plan (2004-2008). The overall goal of the IGAD Environment and Natural Resources Strategy is to assist and complement the efforts of the region in environment and natural resources management. To achieve this goal, the strategy aims at four strategic objectives for the region: 1) improve environmental and natural resources governance, 2) develop information required for sound environmental and natural resources management, 3) enhance capacity for improved environmental and natural resources management, 4) enhance the capability for environmental and natural resources research and development. The outcomes of the IGAD Strategy will be constantly monitored and a detailed environmental impact of the Strategy will be carried out in 10 years time bearing in mind that generally improvements in ecological conditions take much longer time to register. Expected outcomes of the Strategy are listed in the Table 9 below.

Table 9. Expected outcomes of the IGAD Environment and Natural Resources Strategy

Strategic Objective 1
Process of harmonizing environment and natural resources policies supported and led. Awareness promoted and process of developing appropriate strategies and concepts in transboundary resources management supported and guided. Member states assisted to comply with the provisions of, and benefit from, the international instruments.
Strategic Objective 2
Environmental and natural resources information provided at the regional level. Timely exchange of environmental and natural resources information promoted.
Strategic Objective 3
Capacity in the use of environmental assessments, crucial for promoting regional cooperation built. Suitable incentives and disincentives measures to complement regulatory enforcement identified. More focused forum targeting the environment and natural resources of civil society organisations and non-state actors established.
Strategic Objective 4
Research agendas identified and the creation of linkages and networks in the area of environment and natural resources management facilitated. Capacity of the member states for accessing potential incremental financial resources built.

Adapted from IGAD.

Comprehensive Africa Agriculture Development Programme (CAADP)

The Comprehensive Africa Agriculture Development Programme (CAADP) has been endorsed by African Heads of State and Governments as a vision for the restoration of agricultural growth, food security, and rural development in Africa. The main objective of the CAADP strategic framework is to guide country development efforts and partnerships in the agricultural sector, stimulating agriculture-led development that eliminates hunger and reduces poverty and food insecurity (NEPAD-CAADP/FAFS 2008). Based on the guidance of the CAADP, the NEPAD vision holds that by 2015 Africa should:

- Attain food security
- Improve agricultural productivity to attain a 6% annual growth rate
- Develop dynamic regional and sub-regional agricultural markets
- Integrate farmers into a market economy
- Achieve a more equitable distribution of wealth

The CAADP directs investment to four mutually reinforcing and interlinked pillars that aim at: 1) extending the area under sustainable land management and reliable water control systems; 2) improving rural infrastructure and trade-related capacities for market access; 3) increasing food supply, reducing hunger and malnutrition, and improving responses to food emergency crises; and 4) improving agriculture research, technology dissemination and adoption. Some clear basic targets of Pillar 1 to operationalise the CAADP concept as framework are: achieve at least 6% growth in agriculture productivity; reach 10% public expenditure budget into agriculture.

CAADP Pillar III draws together the central elements of the CAADP vision to ensure that growing agricultural productivity, well-integrated markets and expanded purchasing power of vulnerable groups combine to eradicate hunger, malnutrition and poverty. The Framework for African Food Security (FAFS) has been established to meet the objectives of CAADP Pillar III and the broader African development agenda. The purpose of the FAFS is to guide and assist stakeholders in Africa to address the food security challenges in the region, particularly: 1) inadequate food supply, 2) widespread and persistent hunger and malnutrition, and 3) inadequate management of food crises (NEPAD-CAADP/FAFS 2008).

In general, the CAADP and FAFS frameworks consider three types of responses under each of the three Pillar III action areas (increasing food supply, reducing hunger and malnutrition, and improving responses to food emergency crises): 1) immediate responses that yield impacts within 1-2 years; 2) medium term responses that generate impacts within 3-5 years; and 3) long term responses that produce impacts within 6-10 years. Table 10 below provides some examples for each one of these types of responses:

Table 10. Intervention examples for each type of responses under Pillar III action areas

Immediate responses that yield impacts within 1-2 years
Preserve and enhance the productivity of key staples and commodities while accelerating the distribution of new varieties of food staples, particularly drought-resistant, long-duration crops Promotion of crop-livestock integration; targeted subsidies as temporary measures to promote technology and raise productive capacity Technical support to farmers in the setting up and management of small animal production enterprises Scaling up of successful integrated natural resource management technologies
Medium term responses that generate impacts within 3-5 years
Increased investment in research and extension on key food staples and quality nutritious foods Investment in small- and large-scale irrigation infrastructure Promotion of low-cost and sustainable production technologies for quality and nutritious foods Removal of policy uncertainties to private trade in food staples
Long term responses that produce impacts within 6-10 years
Capacity development in biotechnology and other modern methods to increase agricultural productivity Improve and enforce land tenure arrangements Investment to strengthen organizational capacities of farmers to access technologies, markets and training Development of management systems that are accessible to the poor to enhance their food and nutrition security

Adapted from NEPAD-CAADP/FAFS 2008

Pan-African Nutrition Initiative (PANI)

The Pan-African Nutrition Initiative (PANI) is dedicated to catalyzing multi-sectoral collaboration, facilitating capacity building, mobilizing resources and promoting the use of a Nutrition Lens to mainstream nutrition in investment planning. To do so, the initiative aims at identifying opportunities to integrate nutrition initiatives across multiple sectors, defining optimal nutrition inputs from each sector, and reviewing the potential impacts of proposed projects. This initiative goes in hand with the African Regional Nutrition Strategy (ARNS) for 2002-2015 that was endorsed by the AU Ministers of Health. The PANI represents a renewed commitment to the improvement of the nutrition situation in Africa and to the achievement of the MDGs (NEPAD-CAADP/FAFS 2008).