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

Ecosystems Chapter, Kenya

Final Document

Brian Harding
Tahia Devisscher

October 2009

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1. ECOSYSTEMS AND ECOSYSTEM SERVICES IN KENYA

This section describes first the ecosystem and ecosystem services in Kenya and then explains briefly the value of ecosystems for Kenya's economy and population well-being.

1.1 Mapping Ecosystems in Kenya

The topography of Kenya rises from a low coastal plain on the Indian Ocean to more than 3,000 meters in the center of the country. Moreover, the total annual rainfall varies significantly across the country. It ranges from 200-400 millimeters in northern and eastern Kenya to more than 1,600 millimeters in western and central Kenya (WRI, 2007). The physiography and the high variability of rainfall throughout the seasons, between years, and across space allows for diverse ecosystems in the country that range from coral reefs and mangroves along the Indian Ocean coast to arid shrub land in the north, to dense mountain forests, and to the shores and waters of Lakes Victoria and Turkana. According to UNEP (2001), and the World Resources Institute (2003b), Kenya has the following ecosystem types (see Figure 1 below): bush- and woodlands, savannah and grasslands (70 %); cropland or agroecosystems and natural vegetation mosaic (20 %); sparse or barren vegetation, snow or ice (6 %); wetlands and water bodies (2 %), urban ecosystems (0.2%); and densely forested areas (1.7 %).

MAJOR ECOSYSTEM TYPES
- Forest
- Bush- and woodland
- Cropland
- Savanna and grassland
- Bare areas
- Urban areas
- Water bodies

Note: Forest is the aggregate of two categories in the *Africover* legend (closed and multilayered trees). Bushland and woodland combine various *Africover* classes such as open trees, thickets, and shrublands. Savannas are grasslands with shrubs or sparse trees. Bare areas include areas covered by rocks or rock fragments.
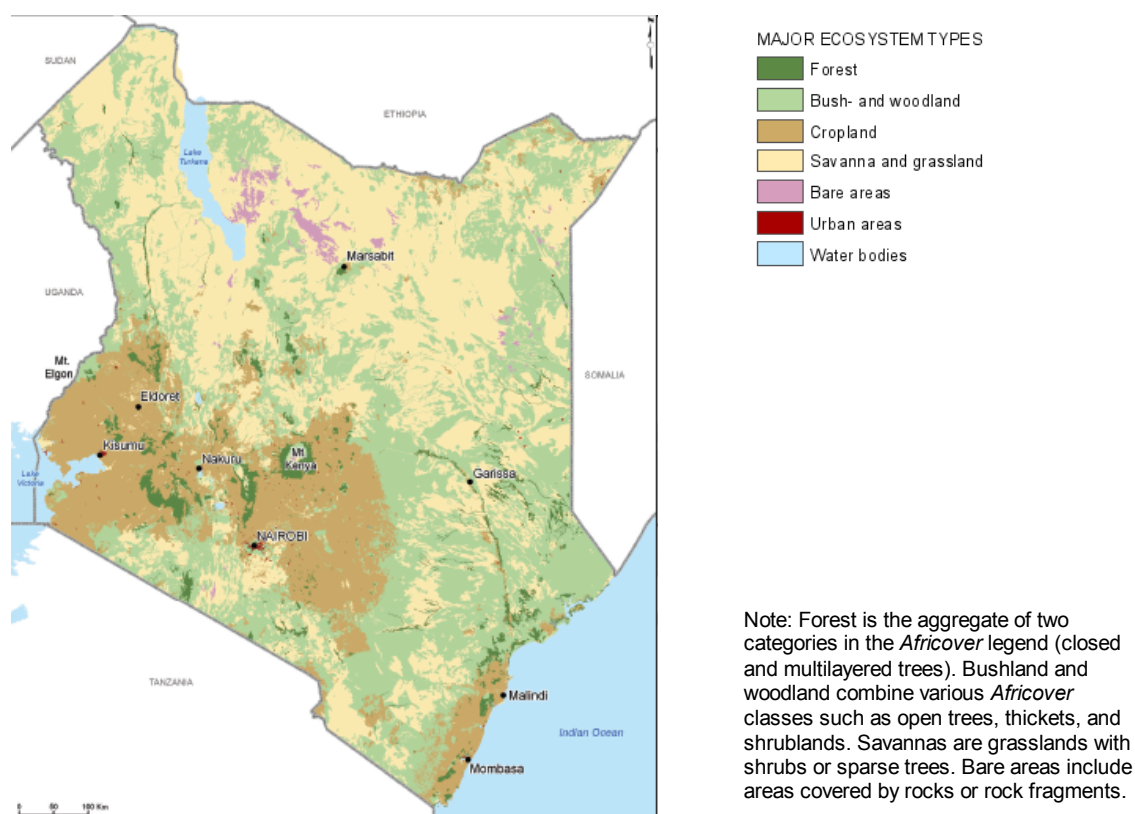
Figure 1. Major ecosystems types of Kenya, 1995-2000

Sources: Cities (SoK and ILRI 2000), water bodies (FAO 2000), and major ecosystem types (FAO 2000). Nature's Benefits in Kenya, WRI 2007.

A glance at the vegetation cover in Kenya: A narrow belt of forest follows the coast and extends inland for about 30 km; mangroves grow along the inter-tidal coastal zones, estuaries and creeks (FAO 2003). Grassland, tropical dry woodlands and mixed evergreen forest expand to the southeast, while evergreen forest covers the southwest at higher altitudes of the Kenya highlands (FAO 2003). These highlands are cut across by the Great Rift Valley, which runs from north to south in two branches. Mt. Kenya, the country's highest mountain, is located in the eastern section of the Rift Valley (United States Library of Congress 2005). The central upland plateau consists of some grassland and semi-deciduous and tropical moist montane forest at an elevation of 1,200–2,000 m (FAO 2003). Croplands stretch from the high rainfall areas in the highlands to more marginal cropping areas often classified as agropastoral, where the major land use is some cropping mixed with livestock raising, due to scarce and erratic rainfall (WRI 2007). Most of the inland region of the country comprises of semi-arid, bush-covered plains, while in the northwest there are high-lying scrublands.

Box 1. Ecoregions of East Africa

According to an ecoregion classification system developed by the World Wildlife Fund (Olson et al. 2001), Kenya has seven predominant terrestrial ecoregions. These ecoregions are listed below along with the provinces in which they are located.

• Masai xeric grasslands and shrublands: mainly Eastern Province and small portion of Rift Valley Province

• Somali Acacia-Commiphora bushlands and thickets: North Eastern Province

• Northern Zanzibar-Inhambane coastal forest mosaic: Coast Province

• Victoria Basin forest-savannah mosaic: Nyanza Province

• Southern Acacia-Commiphora bushlands and thickets: Nyanza and Rift Valley provinces

• East African montane forests: Rift Valley, Western provinces

• Northern Acacia-Commiphora bushlands and thickets: Coast, Central,

Eastern, and Rift Valley provinces

(IISD and UNEP 2005)

Forests

Kenya's tree cover falls under various classes such as forests, woodlands, bushlands, and wooded grasslands. Each class reflects different tree densities and vegetation communities. Tree-covered landscapes also include agroecosystems, where farmers grow both agricultural crops and trees. Figures 8 and 9 delineate forests, tree cover, plantations, and areas where farmers have planted woodlots on farmland. Areas where the vegetation consists of densely spaced trees are generally designated as forests. Most of Kenya's closed forests, where tree canopy covers a high proportion of land surface, fall under government jurisdiction (i.e., as gazetted forest reserves). Extraction of forest products from these reserves is highly regulated or illegal (WRI 2007).

The inventory of the Kenya Indigenous Forest Conservation Programme (Wass 1995) estimated Kenya's closed forest cover to be 1.4 million ha in 1990s, about 2.5 % of the total land area. A different assessment of Kenya's forests, based on satellite imagery and a different definition for closed forests, estimated Kenya's closed forest cover to be 984,000 ha in 1995, equivalent to 1.7 % of the country's total area (UNEP 2001). Most of Kenya's closed canopy forests cover is located in high rainfall zones: in mountain ranges such as Mount Kenya, Aberdares, Mount Elgon, and Mau Escarpment in the country's interior, and areas along the Indian Ocean. In the highlands, closed forests are surrounded by areas with high population densities and intensive agricultural production. Across rangeland areas, closed forests grow primarily in mountain ranges and along permanent and seasonal rivers. The largest closed natural forest areas are west of Nakuru (on the slopes of the Mau Escarpment), north of Nairobi (Aberdare Range), and in Mount Kenya (WRI 2007).

Figure 2 identifies vegetation communities that are classified as forests using Africover[1] categories on a national scale for the year 2000 (FAO 2000). The map highlights natural and semi-natural forested landscapes such as closed canopy forests and other forest types with more open crown cover; it does not include forest plantations or trees on cultivated landscapes. The map shows that the Districts between Garissa and the Indian Ocean coast include large areas of open forest types. It is also possible to see that significant gallery forests follow permanent rivers, for example southwest of Lake Turkana (Turkwell River) and south of Garissa (Tana River). Moreover, large tree-covered seasonal wetlands are prominent in the southeastern rangelands.

Note: Forests have the greatest density of trees and the highest volume of wood per square kilometer (i.e. forests must exceed a minimum threshold in tree cover and a minimum height in the woody vegetation).
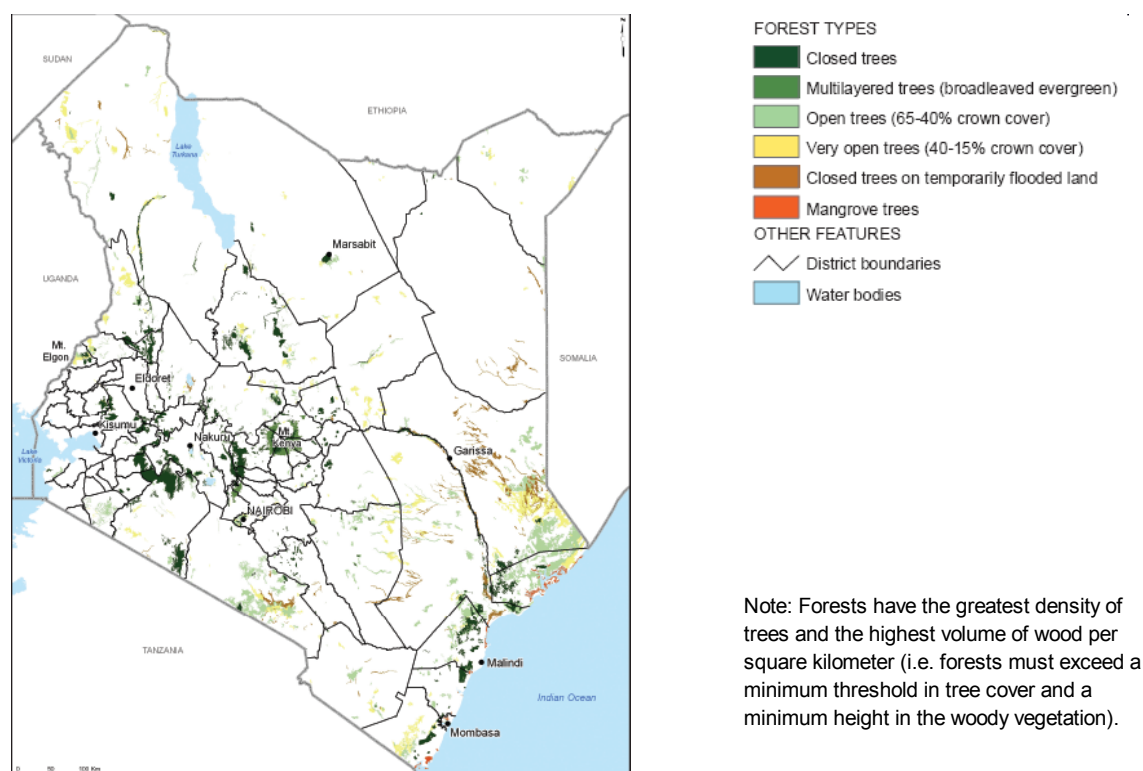
Figure 2. Forested areas in Kenya, 2000 Sources: Administrative boundaries (CBS 2003), cities (SoK and ILRI 2000) and water bodies and forest types (FAO 2000). Nature's Benefits in Kenya, WRI 2007.

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[1]   The Africover project is funded by the Food and Agriculture Organization of the United Nations, and has established a digital georeferenced database on land cover for the whole Africa. The East Africa module is the first operational component of the Africover project and it has been operational from 1995 to 2002.

Figure 3 portrays tree cover density on a continuous scale from 0 to 100 %. It is derived from satellite imagery estimating woody vegetation within grid cells of 500 meters by 500 meters. Such an approach avoids the problem presented by the traditional classification scheme in Figure 8 (i.e., closed versus open canopy forest), which sets a threshold of tree cover for each forest class. As a result, Figure 9 highlights the importance of trees that fall below the minimum tree or canopy cover thresholds including both trees on cultivated and managed landscapes (i.e. in croplands) but also on natural and semi-natural landscapes (i.e., woodlands, bushlands, and wooded grasslands) (WRI 2007). Agricultural land can have a high percentage of tree cover as reflected in the varying tree density in high-rainfall croplands, for example in the Central Province.
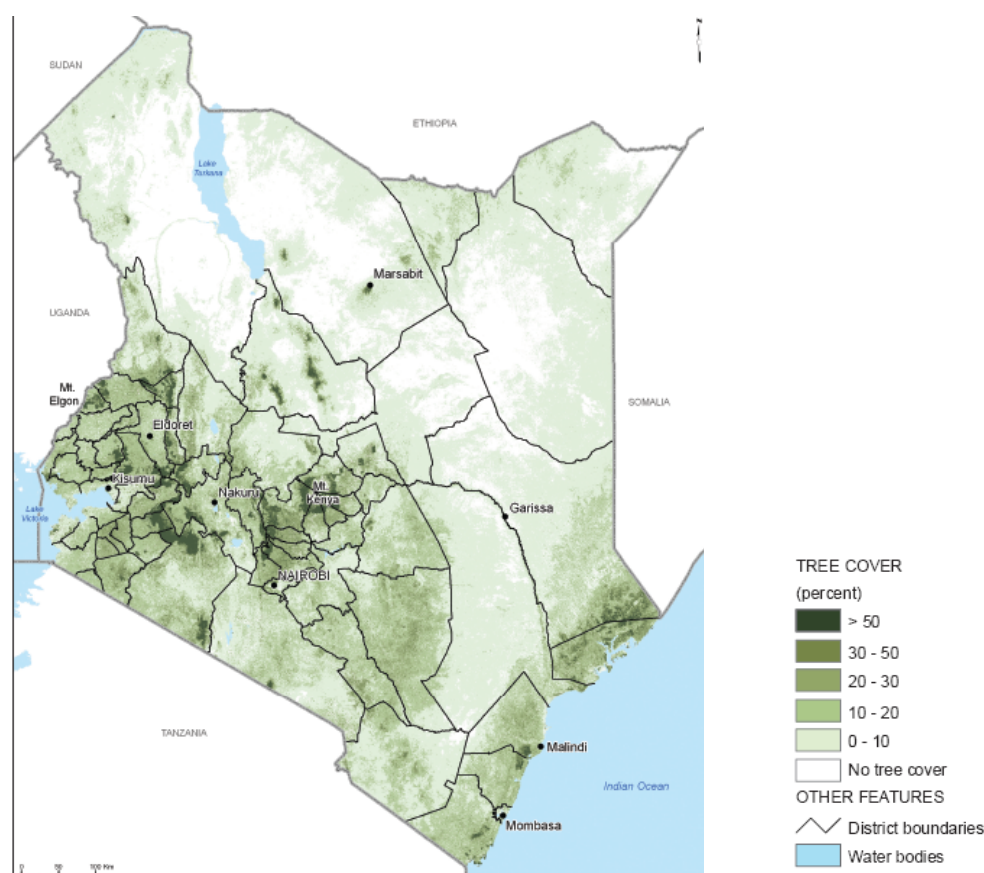

Figure 3. Tree cover in Kenya, 2000

Sources: Administrative boundaries (CBS 2003), cities (SoK and ILRI 2000), water bodies (FAO 2000), and percent tree cover (Hansen et al. 2003). Nature's Benefits in Kenya, WRI 2007.

Generally, most of the closed and open forest areas of Figure 2 coincide with higher tree densities in Figure 3. The rough resolution of the satellite data used for Figure 3 results in a map with fewer small features (e.g., trees in wetlands) or linear features (e.g., forests along riverbanks). However, Figure 3 reflects the varying tree density in high-rainfall croplands, such as the highlands. Considering both maps, it is possible to realize that closed canopy forests do not contain most of Kenya's woody biomass. Instead, woodlands, bushlands, and wooded grasslands combined have a higher total volume of woody biomass due to their

large size, despite the lower tree density and volume per area compared to the small remnants of closed forests (WRI 2007).

Wildlife

Large part of Kenya's wildlife lives in the grassland, savanna, shrubland, and woodland ecosystems. The densities of wild grazing animals in Kenya's rangeland Districts vary across the country (see Figure 4). In Kenya, wildlife is not found only in protected areas, as species also migrate across private and communally held lands and even across international borders. The highest wildlife densities are in Narok and Kajiado Districts, close to the Tanzania border, and in Laikipia District, just north of Mount Kenya. Western et. al, (2006), estimated that 25% of wildlife was to be found in Maasai Mara National Reserve with just 10% in all national parks.

In these Districts, large herds of many different species congregate, especially in areas close to some of Kenya's national parks and reserves, including Masai Mara National Reserve, Amboseli National Park, and Nairobi National Park. Wild grazing animals can also be found throughout the northeastern rangelands, but at lower densities (WRI 2007). It is important to note that, along with wild grazing animals, most of Kenya's rangelands have livestock. In a number of locations in Narok, Kajiado, and Laikipia Districts, high wildlife and livestock densities coincide.

Note: Species numbers are aggregated (using the *tropical livestock unit* which is equivalent to an animal weight of 250 kilograms) to squares of 5 kilometers by 5 kilometers and then averaged by square kilometer. The wildlife counts include 21 different large grazing animals that can be observed during low- altitude flights.
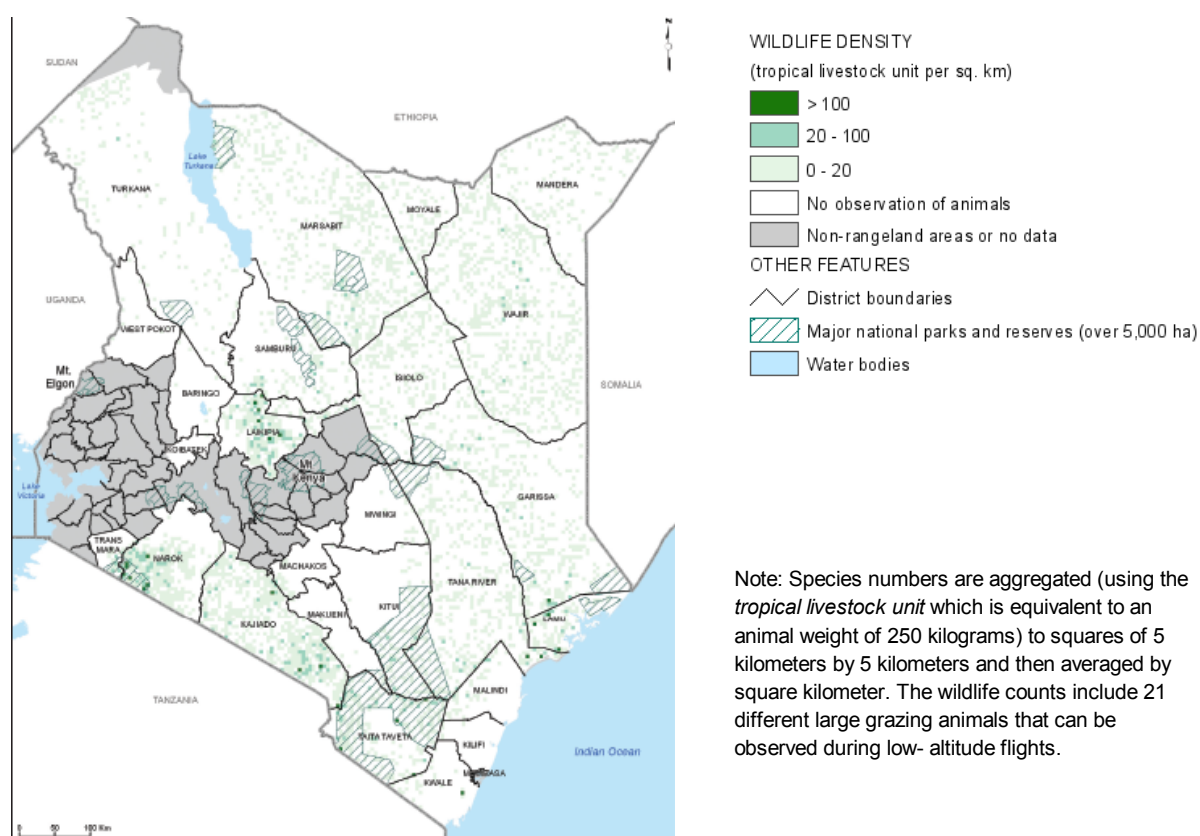
Figure 4. Wildlife density in the rangelands, 1994-1996

Sources: Administrative boundaries (CBS 2003), water bodies (FAO 2000), parks and reserves (IUCN and UNEP/WCMC 2006), and 1994-96 wildlife density (ILRI calculation based on DRSRS 2003; Grunblatt et al. 1995; Grunblatt et al. 1996). Nature's Benefits in Kenya, WRI 2007.

Population and Ecosystems

Most Kenyans inhabit the most productive agricultural lands or live along the coast of Lake Victoria and the Indian Ocean (see Figure 5). The areas around Nairobi as well as the central highlands support the highest population densities with more than 600 people per square kilometer. Similar densities occur in the western part of the country, mainly northwest of Kisumu and in the three Districts of the southern shores of Lake Victoria. Pockets of high population density can also be found along the Indian Ocean coast, primarily around Mombasa. Only 24 % of Kenyans live in the rangeland Districts shown in Figure 5 (WRI 2007).
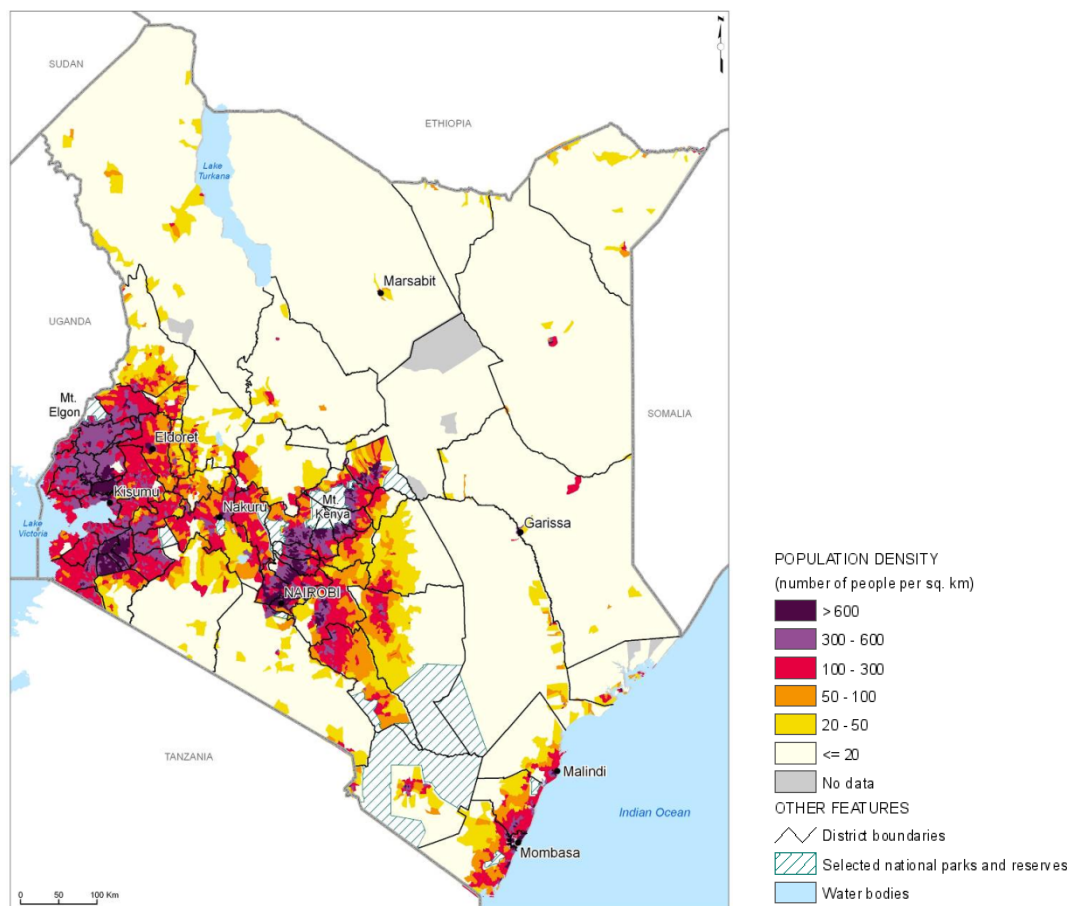

Figure 5. Population Distribution in Kenya, 2002

Sources: Administrative boundaries (CBS 2003), cities (SoK and ILRI 2000), water bodies (FAO 2000), parks and reserves (IUCN and UNEP/WCMC 2006), and 1999 population density (CBS 2002). Nature's Benefits in Kenya, WRI 2007.

Population distribution also reflects the use of ecosystems and ecosystems services by people and industry in Kenya. Ecosystem services vary across the various ecosystem types. The figures above help to map areas where people are using ecosystem services to obtain for example food, fiber, water, and fuel for energy generation. Figures 4 and 5 also show areas that have been restricted to conservation and contribute to maintain biodiversity. Currently, the Kenyan Wildlife Service Web Site lists 31 parks and reserves across the country. Next section explores further the value of ecosystem services for the economy and the population well-being in Kenya.

1.2 Value of Ecosystem Services in Kenya

Ecosystem and ecosystem services play a significant role in Kenya's economy, people's livelihoods, and human well-being. About 80% of Kenyans base their livelihoods on agricultural activities (RoK 2006, CBS 2005). In 2004, the agriculture sector contributed 26% of gross domestic product, or 53% if indirect links to other sectors are accounted. The sector also covered 60% of total export earnings, 45% of government revenue, and 62% of jobs in the formal economy. In addition to agriculture, nature-based tourism, fishing, timber and charcoal production are other important sources of income in the country.

A review carried out by UNEP and IISD (2005) identified four critically stressed ecosystem services in Kenya (based on the Millennium Assessment categorization of ecosystem services, see section I): maintenance of biodiversity; food provision; water supply, purification and regulation; and energy resources. This section will describe each one of these ecosystem services, while the next section will focus on their sensitivity to climate and vulnerability to current stresses.

Maintenance of biodiversity

The relationship between biodiversity and ecosystem services is complex. Species perform different services for ecosystems, and changes in biodiversity affect the way ecosystem function (Loreau, Naeem and Inchausti 2002). The importance of the composition of the species for an ecosystem function is determined by how much a loss in the ecosystem service is experienced when one or more of the species is lost (UNEP and IISD 2005).

Due to its physiography, Kenya supports abundant and varied wildlife of both scientific and economic value. Among known species, Kenya has 6,506 higher plant; 359 mammal; 344 breeding bird; 261 reptile; 63 amphibian; and 314 fish species (World Resources Institute 2003). Furthermore, it harbors eight mangrove and nine seagrass species, and 54 genera of scleractinia coral (World Resources Institute 2003).

Forests and rangelands are habitat for a large portion of the country's biodiversity: coastal forest communities harbor species with high level of endemism, and closed forests harbor 40% of large animals, 30% of birds, and 35% of butterflies (United Nations Office for the Coordination of Humanitarian Affairs 2000). The Kenyan Wildlife Service Web Site lists 31 parks and reserves across the country, but the World Resources Institute (2003a) estimates that Kenya has 336 protected areas concentrated in the Rift Valley, Eastern, Central and Coastal provinces, covering around 12% of the total territory (FAO Forestry Department 2003b, WRI 2003a). Furthermore, Kenya protects 4 Ramsar wetlands of international importance (including Lakes Nakuru and Naivasha in the Rift Valley Province) covering 488 Km^2, 6 Biosphere reserves, and 14 marine or littoral protected areas (World Resources Institute 2003). The country also has 3 World Heritage Convention reserves, including one near Lake Turkana in Eastern Province and one in Central Province (World Resources Institute 2003a; UNEP 2004).

Some economic sectors in Kenya are particularly exposed to risk linked to deteriorating biodiversity and ecosystem services, primarily those that rely directly on the availability of natural products (e.g. fisheries and forestry), healthy function ecosystems (e.g. agriculture, biofuels, food and beverages), or services derived from them (e.g. water utilities,

hydropower, tourism) (UNEP 2008). Section III will describe in further detail the implications of deteriorating biodiversity and ecosystem services on human well-being and economies in the country.

Kenya's forests have several wood and non-wood forest products (NWFP) that contribute to the economy and livelihoods of the country. Forest products include timber, woodfuel and charcoal, fodder plants, medicinal plants (e.g., *Warburgia salutaris*), dyes (*Bixa orellana*), and other non-wood forest products such as tannins, essential oils and beeswax (FAO Forestry Department 2003). In 2004, the forest sector contributed about US$ 141 million to the national economy, about 1.3 % of Kenya's gross domestic product (CBS 2004). However, this number does not fully reflect the forest sector's economic contribution, as it does not account for other significant contributions, such as the value of energy produced from wood, and the value of various NWFP (WRI 2007). Contributions to fuel from woodfuel and charcoal will be discussed later in this section (see section on fuel provision). Most non-wood forest products are derived from the western, montane, coastal and mangrove forests (UNEP and IISD 2005). In 2005, more than 2.9 million people lived adjacent to forests. Near Mt. Kenya, 10% of the population collects NWFP, and Mau, Arabuko Sokoke and Kakamega forests are basic livelihoods commonly used for small-scale hunting, grazing and beekeeping (FAO Forestry Department 2003). Wood-carving is another important revenue stream for the country. Wood-carving is estimated to financially support an estimated of 400,000 dependents, among them 60,000 full-time wood carvers. Although wood sculptures consume less than 1% of Kenya's annual wood harvest (FAO 2005), this activity generates export earnings of around US$ 23 million per year (WRI 2007). Despite this, it is not included in the economic analysis of the forest sector, as most of the NWFP mentioned above.

A decade ago a study was carried out to review the state of knowledge on the economic value of Kenya's environmental resources, and on the consequent economic costs of environmental degradation to Kenya (see Emerton et al. 1998). The table below, which is adapted from this report, presents estimates of forest values, which are drawn from a number of sources, including government statistics. Most refer to the period 1992-1997, and are expressed in 1996 prices:

Table 1. The economic benefits and costs of Kenya's forests

THE ECONOMIC BENEFITS OF KENYA'S FORESTS
To the national economy:
Contribution to GDP US$ 4 million per year
Foreign exchange earnings US$ 0.22 million per year
For forest-adjacent households:
Kenya indigenous forests US$ 94 million per year
Aberdares forest   US$ 165/hold/year
Arabuko Sokoke forest   US$ 135/hold/year
Kakamega forest   US$ 160/hold/year
Mau forest   US$ 350/hold/year
Mount Kenya forest   US$ 212/hold/year
Oldonyo Orok forest   US$ 100/hold/year
To commercial and industrial firms:
Formal sector industry   US$ 2 million per year
Indigenous timber, Kenya   US$ 7.3 million per year
Indigenous timber, Kakamega forest   US$ 1.2 million per year
Indigenous timber, Mau and Trans Mara forests   US$ 0.3 million per year

To tourists:

Forests in National Parks and Reserves	US$ 34.7 million per year
Mount Kenya forest	US$ 0.3 million per year

Watershed catchment protection values:

South West Mau, Ol Pusimoru, Trans Mara	US$ 0.12 million per year
Mount Kenya	US$ 20.4 million per year
Aberdares	US$ 7.4 million per year
Mount Elgon	US$ 3.7 million per year
Nandi	US$ 1.6 million per year
Cherangani	US$ 0.4 million per year
Loita Hills	US$ 2.1 million per year

Agroforestry values:

Fuelwood and crop productivity	US$ 330/ha/year
Fuelwood	US$ 0.60/ha/year
Timber	US$ 23/ha/year
Saved chemical inputs	US$ 9/ha/year
Dairy	US$ 144/cow/year

THE ECONOMIC COSTS OF KENYA'S FORESTS

To the Forest Department:

Development and recurrent expenditure	US$ 1.2 million per year

To local households:

Animal damage around Shimba Hills National Park	US$ 0.45 million per year
Animal damage around Mount Kenya Forest	US$ 1.04 million per year
Opportunity costs of agriculture foregone, all Kenya's forests	US$ 307 million per year
Opportunity costs of agriculture foregone, Mount Kenya forest	US$ 72 million per year

Another important economic activity that is highly based on Kenya's natural endowment and rich wildlife is tourism. The tourism industry accounts for approximately 19% of Kenya's GDP, and is the second largest foreign exchange earner (Association for Strengthening Agricultural Research in Eastern and Central Africa 2002). Tourism is identified as one of the top priorities in national development plans (MoPND et al. 2005). In 2000, Kenya received 552.8 thousand non-African tourists and 201.6 thousand African tourists visiting natural parks. Figure 5 shows the number of visitors to parks and game reserves in Kenya over the past decade. The income from nature tourism in 2000 reached US$ 178.2 million from non-African tourists, US$ 65 million from African tourists, and US$ 7.5 million US$ form domestic visitors (WTO 2001, KPMG 2002). Consolidated tourism earnings expanded from Kshs. 56.2 billion in 2006 to about Kshs. 65.4 billion in 2007 (Figure 6), reflecting an 11.6% growth, however this was severely disrupted by internal conflict in 2008.
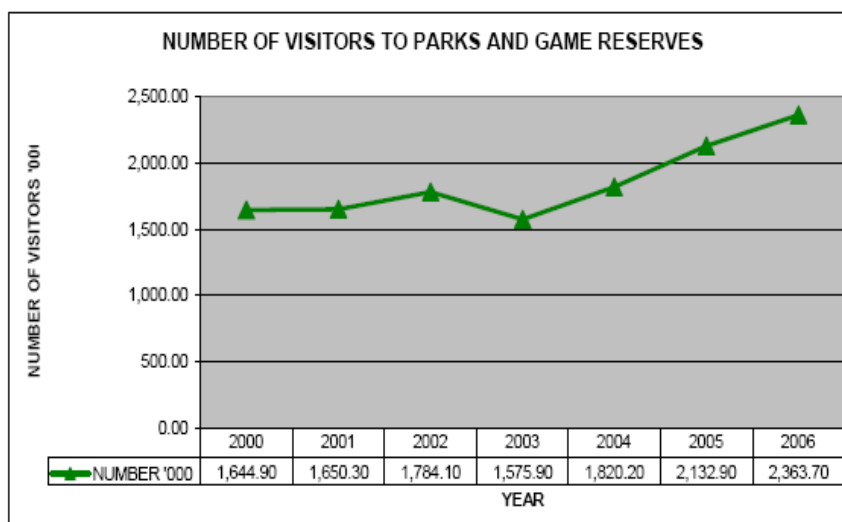
Figure 5. Number of visitors to parks and game reserves in Kenya 2000-2007

Figure 6. Tourism earnings in Kenya 2000-2007

Food and fibre provision

Sustainable supply of food for humans and livestock is a critical ecosystem service for the population well-being in Kenya. For agriculture to succeed, natural factors such as soil fertility, soil moisture, adequate climate conditions, and rich diversity of plant species are critical, even if these factors can be influenced by technology.

About 80 % of Kenya is arid or semi-arid land and 33% (equivalent to 5.2 million ha or around half of the 10 million ha potentially cultivable) was cultivated in 2005 (FAO Land and Water Development Division 2005). The western plateau (17% of the country) has high potential for agriculture and supports about 75% of the population (FAO Land and Water Development Division 2005).

Most food in Kenya is produced by small-holder subsistence farmers, which make up around 80% of the active agricultural population in the country (FAO Land and Water Development Division 2005). Cattle breeding is one of the most important livelihoods of the populations living in arid and semi-arid areas including beef, sheep, goats and camels (FAO Land and Water Development Division 2005). Between 50 to 60 % of beef production in Kenya comes from small-holder farmers who own 80 % of cattle. Fishing represents another source of food and income for Kenyans. Although only 8 % of the population lives within 100 km of the coast, the fishing industry including aquaculture, employed 59,565 people in 2003 and reached up to US$ 49,684 thousand in trade in 2005 (WRI 2007a).

Despite 80 % of the country is arid or semi-arid, rain-fed agriculture dominates, increasing the vulnerability of the sector to climate variability and change, and the risks to food security (FAO Land and Water Development Division 2005). In 2000, for instance, drought affected large numbers of livestock in Kenya and US$10.5 million were needed in emergency assistance to recover livestock production (FAO 2000). Current stresses to food production such us low soil suitability (e.g. in the north in Rift Valley, Eastern and North Eastern provinces and parts of Western and Nyanza provinces) and water scarcity (FAO 2005) are exacerbated by changes in the climate. The climate-sensitivity and vulnerability to current stresses by ecosystems in Kenya will be discussed in more detail in section II.

Water supply, purification, and regulation

Ecosystems play a key role in providing clean freshwater and regulating the flow of water. The effectiveness of ecosystems to provide these services is largely shaped by the quality of the country's hydrological system.

Kenya has five main drainage basins: Lake Victoria basin (8 % of the country); the Rift Valley and inland lakes basin (22.5 %); the Athi River and coast basin covering (11.5 %); the Tana River basin covering (21.7 %); and the Ewaso Ng'iro basin covering 36.3 % (FAO Land and Water Development Division 2005). Most lakes in Kenya are saline except for Lakes Victoria, Naivasha and Baringo (FAO Land and Water Development Division 2005). Furthermore, Kenya has a number of rivers, including the Umba, Mara, Pangani, Soi, Malaba, Malakisi, Omo, Daua and the Nile (FAO Land and Water Development Division 2005).

Including inflows from other countries, Kenya receives on average 30 km^3 of renewable water resources, which is equivalent to roughly 947 m^3 per person (World Resources Institute 2007b). Approximately 10 km^3 of river water flows into the country annually (World Resources Institute 2007b), thus its total internal renewable water resources are 20 km^3 (633 cu m per capita), comprising 17 km^3 of surface water, and 3 km^3 of groundwater recharge (World Resources Institute 2007b).

In terms of distribution of water withdrawal, agriculture accounts for 64 %, followed by domestic use at 30%, and industrial use of 4% (FAO AQUASTAT 2005). These withdrawals

represent 7.6% of internal renewable water resources, suggesting potential for Kenya's water resources to meet higher demand (FAO AQUASTAT 2005).

Nevertheless, the deteriorating capacity of Kenya's watersheds to capture, store and release water, threatens the water availability in the country. It is estimated that out of Kenya's 164 sub-basins with perennial river flows, 90 will face surface water deficit by 2010 and already in 2005 around 33 sub-basins without perennial river flow had noticeable water shortage (FAO Land and Water Development Division 2005). For this reason, the Development Plan 2002–2008 considers Kenya a water-scarce country. In addition to watershed deterioration problems, there is inconsistent and poor distribution of water across the country. In 2004, for example, about 49% of the households had no access to safe drinking water and 57% had no access to improved sanitation (WHO 2006).

Despite covering only 2% of Kenya's territory, closed forests provide a disproportionately large ecosystem service in terms of climate regulation and water catchment for the country water flow both directly and indirectly (United Nations Office for the Coordination of Humanitarian Affairs 2000). The close canopy moist montane forests in Kenya, constituting about three quarters of the total native forest in Kenya, provide much of the nation's water (FAO Forestry Department 2003). Yet, close forests in water catchments are stressed and their deterioration has increased risk of both floods in the rainy season and drought in the dry season. Shortages of water in Nairobi city are generally linked to the degradation of forests in the Mount Kenya and Aberdare range (UNEP and IISD 2005).

Fuel Provision

Charcoal and woodfuel are still the dominant fuel in Kenya. In 2006, biomass (woodfuel, wood for charcoal, industrial wood, wood wastes, and farm residues) was the main source of energy for about 82% of urban and 34% of rural households (IEA 2009). In 2006, woodfuel and charcoal accounted for 73% of total energy supply in the country (IEA 2009).

Estimates of the economic value of Kenya's charcoal production for 2000 range from about US$ 250 to US$ 457 million depending on volume and price (ESDA 2005). According to the most recent National Charcoal Survey 2005, over 2.5 million Kenyans are supported by the charcoal industry. Charcoal production or trade is carried out in almost all of Kenya's Districts. Charcoal producers capture only a small percentage of the revenues because the price at the point of production is significantly lower (around 3 times) than the retail price (ESDA 2005).

Most Kenyans rely on wooded ecosystems to provide them with either firewood or charcoal. Of all the wood supplied by wooded ecosystems in the country, Kenyans use some 80 to 90% for energy purposes (FAO 2005). The remaining 10 to 20 % is used for timber, posts, and poles. As demand for charcoal is expected to grow in the near future (MoE 2002) and forest area from which woodfuel is gathered declines, it is expected that woodfuel will become increasingly scarce.

According to the World Resources Institute (2003b), from 1990 to 2000 natural forest area in Kenya decreased by 5% and total forest area by 3%. Despite significant areas of tree plantations being established in the 1970s and 1980s, the area planted declined in the1990s (FAO 2000b). In recent years, tree planting has increased in farmland areas, as individual farmers plant wood for their own needs, while in larger operations, farmers plant wood for

commercial purposes (UNEP and IISD 2005). Despite the amount of trees that have been planted over the past years, the annual change rate in Kenya's total forested area for 2000-2005 was negative with a percentage of change equivalent to -0.3% (FAO 2006).

Based on the household and charcoal surveys, it is estimated that at least 30 to 50% of Kenya's wood supply comes from farms and settlements that are mainly used for energy purposes. In Kenya, agroforestry is the primary source of firewood. Private lands, either farmland or rangeland, are the major source of wood for charcoal. Figure 7 highlights where farm forestry and the associated woodlots are located. The map also shows plantations, which are a minor supplier of wood for energy, as the majority of wood harvested in plantations is for timber and poles (Wass 2000).

Figure 7. Tree plantations and woodlots in cropland, 2000

Sources: Administrative boundaries (CBS 2003), water bodies and cropland areas (FAO 2000), parks and reserves (IUCN and UNEP/WCMC 2006), and share of woodlots in croplands (WRI calculation based on ICRAF and DRSRS 2001). Nature's Benefits in Kenya, WRI 2007.

Note1: The map combines detailed crop information (including the presence of woodlots) from 5,747 aerial photos for a growing season in 1997, each providing a sample point of detailed crop information. These samples are averaged to spatial units (polygons) of croplands from Kenya's most recent land cover map (FAO 2000).

Note 2:The forest plantations shown in Figure 11 are over-represented. All land intended to be forest plantations according to the 1994 Kenya Forestry Master Plan are shown on the map as plantations, even if significant areas were not replanted with trees. The total plantation area on Figure 11 is 127,000 ha, close to the estimate that should be under forest plantations. However, a 1999 assessment indicated that of the 120,000 hectares that are supposed to be used as forest plantations according to the Kenya Forestry Master Plan, only 78,000 hectares were sufficiently stocked with trees.

Looking at the proportion of croplands covered by woodlots, it is possible to note that areas with higher percentages of woodlots concentrate in the foothills of the Aberdare Range and Mount Kenya, and in most communities of Central Kisii, Nyamira, and Buret Districts. A relatively large area of the upper parts of Maragua and Muranga Districts is covered by cropland where woodlots cover more than 12 % of the land. A factor influencing the spatial distribution of woodlots is the proximity to rural and urban areas with dense population, as

well as to other centres of high wood demand (e.g. tea production). The share of woodlots is much lower in the western parts of the country. Moreover, farmers do not plant woodlots in the more marginal cropping areas with lower rainfall, such as Makueni, Kitui, Mbeere, or Tharaka Districts. Plantations cover only a small percentage of the map area. The majority of plantations are government owned. Major plantations are in the Rift Valley (e.g., Uasin Gishu, Keiyo, Koibatek and Nakuru Districts) and in the central part of the country (e.g., where Thika, Kiambu, and Nyandarua Districts border each other) (WRI 2007).

2. VULNERABILITY OF ECOSYSTEMS IN KENYA

This section identifies and analyses patterns of change affecting ecosystems and causing trade-offs between ecosystem services in Kenya. It recognizes current exposure of ecosystems to stresses and the associated effects on ecosystems services.

Kenya is endowed with a variety of habitats and ecological systems including wildlife. forests, lakes and rivers, wetlands, farmlands, vegetation, marine life forms and other micro-organisms. Biological diversity is crucial for ecological stability including regulation of climate, economic development, recreation, medicinal use, socio-cultural use and scientific advancement, protection of ecosystems and biodiversity especially plants. The degree of vulnerability varies from place to place because of the way the physical and social factors of vulnerability inherently combine in a given area to produce a unique degree of vulnerability over the region. In general the natural resources in Kenya are and will continue to be the most vulnerable especially in arid and semi-arid lands (ASAL) areas.

The Ministry of Environment and Mineral Resources outlines the following key areas as being drivers of vulnerability in Kenya:

The factors associated with maximum vulnerability of ecosystems in Kenya are:

- A high population growth rate in the high potential areas
- High rate of migration from rural to urban areas
- Most of the natural resources are in ASAL areas
- Majority of the wildlife is found outside protected areas
- A current hydrological and climatic regime that is marginal for agricultural and livestock.
- Highly seasonal hydrology due to seasonal precipitation.
- High rates of sedimentation leading to reduction of reservoir storage.
- Topography and land use practices that promote soil erosion and flash floods conditions.
- Sea level rise.
- Lack of variety of climatic conditions across the country leading to inability to relocate activities in response to climate change.

On the other hand, the social characteristics that increase vulnerability of ecosystem include:

- Poverty and low-income levels.
- In adequate natural resources control infrastructure.
- Maintenance and deterioration of existing infrastructure.
- In adequate human capital skills for system planning and management.
- Few appropriate and empowered institutions.
- In appropriate land use planning and management.
- High population densities and other factors that in habit human movement.
- Increased demand for natural resources due to rapid population growth.
- Unwillingness to live with some risks as tradeoffs against more goods and services.

It is not possible that all of these areas can be fully analyzed within the confines of this study, however a number of areas are dealt with below.

2.1 Freshwater Shortage

Kenya is regarded as a water stressed country. It is estimated that only 15% of the available fresh water has been developed. Water resources are constantly vulnerable in Kenya principally due to mismanagement, overexploitation and forest clearance (MEMR 2009). Seasonal rainfall in Kenya mostly occurs during the March-April-May (Long Rains) and September/October-November-December (Short Rains,) as the inter-tropical convergence zone (ITCZ) migrates through the equator from south to north, and vice versa. The Long Rains are more abundant, but the Short Rains tend to more variable. Periodicity of seasonal rainfall exhibits general decreasing trend, in particular for arid and semi-arid areas. However, some areas (e.g. Lamu) do indicate increasing trend during the Short Rains season. This extreme variability of precipitation has knock on effects for ecosystems and human populations (MEMR 2009).

Floods have affected some parts of North Eastern, Western, Nyanza, and Coast Provinces damaging properties worth millions of shillings and loss of lives. Flooding affects many districts in Kenya including, Garissa, Mandera, Wajir in the north, Kilifi on the coast, and Tana River (Second National Comm., Unpub.). Flooding can be compounded by the presence or absence of El Nino and La Nina. Kenya experienced significant problems during the 1997/8 El Nino, which resulted in extreme weather events. Although El Nino is a natural phenomenon, with quite an obvious cyclical pattern, Kenya is not well prepared to mitigate their impacts (MEMR 2009).

Key hydrological zones are affected by the variability in rainfall. For example, the three most important wetland ecosystems for biodiversity conservation and tourism fall within the arid and semi arid region. Lake Nakuru and Bogoria are saline while Naivasha is a fresh water lake. These wetlands are found in areas of low precipitation (<700mm annually) and high temperatures and have high levels of evaporation rates resulting in lake level fluctuations. Problems with these systems are further aggravated by land use changes that are occurring in their catchments leading to diminished river flows into the lakes.

River systems are considered vulnerable from a variety of factors. For example, the Mara River, which supports the Maasai Mara Game Reserve, has its source within the Mau Forest Complex which is currently under threat from illegal exploitation.

Dry lands are already under extreme stress from various activities including conversion to agriculture, introduction of invasive species, alteration of regimes and pollution. In addition, drought is a recurrent phenomenon that affects large areas and numbers of people living in dry lands in the country. There are 36 arid and semi arid districts covering about 80% of Kenya's total area. Of late there has been an increase in the number of districts which experience drought. The effect of 2003 – 2006 droughts in arid and semi arid districts led to loss of livestock of up to 90%. Child malnutrition rose up to 50% and 11 million people received food relief. The worst emergency in recent years have affected central, eastern, rift valley, coast and north-eastern provinces. The 1999-2000 drought saw a 40% drop in hydropower generation. The 2009 drought has also lead to recurrent energy rationing in Kenya. Table 2 lists some of the droughts experienced in Kenya.

Table 2. Some of the droughts experienced in Kenya

Year	Area Coverage	People Affected
1971	Widespread	150,000
1975	Widespread	16,000
1977	Widespread	20,000
1980	Widespread	40,000
1983/4	Widespread	200,000
1985/6	Widespread	1.41 million
1999/2000	Widespread	4.4 million

2.2 Land Degradation and Terrestrial Biodiversity Loss

Biophysical processes such as landslides and erosion have always played a part in land degradation in Kenya. Landslides occur during prolonged down pour of rain on the Kenyan highlands when the earth material becomes over saturated with water.

Ice melting is another problem affecting land and mountain ecosystems In Kenya. Available evidence shows that Mount Kenya has lost about 92% of her ice in the past 100 years. Not only Mount Kenya which is losing her ice, also Mount Kilimanjaro has lost similar or more amount of ice over the past 100 years. The causes for the melting of the ice includes changes in rainfall patterns, temperature and humidity increases, increased exposure to sunlight and human activities. These mountain regions are some of the most vulnerable and obvious in East Africa. The flora, notably the Alpine vegetation, found on these ranges is restricted in distribution, normally near the base of the mountains (IPCC, 1990). These vegetative systems are generally sensitive to genetic and environmental stresses and possible extinction.

Moreover, habitat loss and degradation from ongoing smallholder agriculture; wood plantations; selective cutting and clear-cutting; wood extraction; infrastructure development; and introduced pathogens/parasites affect the sub-tropical and tropical moist montane forest (IUCN 2005 in FAO Forestry Department 2003). Habitat loss and degradation also occurs from mining extraction. Animals face ongoing threats from wildfire, natural disasters and from human disturbance, particularly tourism and civil unrest (IUCN 2005 in FAO Forestry Department 2003).

Kenyan wildlife is in a strong decline. The Mara ecosystem, for example, had a 50% reduction in wildlife numbers between 1970 and 1990. It is believed this is due to the expansion of subsistence and commercial agriculture in wetter areas, the expansion of settlements, increased fencing, changes in fire management systems, drought and increased poaching (ILRI 2004). A compilation of over 270 wildlife counts of Kenya's wildlife population by Western et al. (2009) for a 30 year period has revealed that there has been a sharp decline in populations in national parks and reserves, which is attributed to human induced change. Bird populations also have declined as result of logging and extreme forest degradation through charcoal burning.

2.3 Coastal Degradation and Marine Biodiversity Loss

Coral reefs and mangrove forests fringe the Kenyan Coast. They are important ecosystems as they act as sediment traps, are natural breakwaters protecting coastlines from erosion during storms, are breeding grounds for fishes, habitats for rare fauna and nurseries for commercially valuable fish and crustacean (Ellison 1994; IPPC 1990). These ecosystems are currently threatened by activities such as fishing and development of infrastructure such as ports, residential buildings, tourism and industries. Impacts arising from these activities include coral reed destruction, beach erosion and deforestation of the mangroves, which puts in jeopardy their protective functions. Coral reefs near Malindi are also being damaged by excessive siltation (UNESCO 2009, Ibe and Awosika 1991).

The Kenya Coastline is listed among Africa's 5 most vulnerable areas to sea level rise and is also among the 27 most vulnerable globally (Imbamba 1991). The impacts of a sea level rise will include the following: lowland inundation and wetland displacement; shoreline erosion; salt water intrusion into estuaries and freshwater aquifers; altered tidal range in rivers and bays, changes in sediment patterns, and decreased light penetration to benthic organisms (Ellison 1994).

3. IMPLICATIONS OF CLIMATE CHANGE EFFECTS ON ECOSYSTEM SERVICES IN KENYA

This section will continue to expand on how climate change will affect ecosystems in Kenya under the two possible future development pathways: the "Business as Usual" pathway and the "Vision" pathway.

The Business as Usual pathway will see a continuation of current trends, while the Vision pathway will see the goals and targets of different strategies and initiatives developed for the sustainable development and stability in Kenya.

It is clearly acknowledged that climate change will compound some of the problems that exist in this country, but it is positive to see that many levels of the Kenyan government have developed a strong interest in addressing some of these issues (MEMR 2009).

3.1 Climate Change in Kenya

Observed climate trends

As outlined in the regional overview, it is difficult to know what will happen directly to Kenya and the ecosystems and ecosystem services, which are recorded there due to the impacts of climate change. Rainfall patterns have been inconsistent as is the case in many places in East Africa and this makes clear scenario development, even under current conditions more difficult. Kenya has always been affected by natural, weather related disasters, including droughts and floods that cause disease, death and jeopardize livelihoods (see section 2). However, it expected that such extremes could potentially increase and exacerbate current vulnerability (UNEP 2007).

Climate Projections

It has been noted that GCM's indicate that a warming of 2-5% is likely by 2050 in this region; however downscaling to a level where we can be fully sure what will happen to ecosystems is extremely difficult. This has been outlined clearly by Berry (2009). Although it is acknowledged that since the closing date for submissions to the AR4, wide-ranging surveys have been conducted and analysis suggest that ecological changes in the phenology and distribution of plants and animals are occurring in all well-studied freshwater, and terrestrial groups (UNEP 2009), there is clearly a need for further studies in this area in Kenya.

Documenting the effects of climate change on ecosystems at global scales has consistently challenged the IPCC, mainly because of the scarcity of peer-reviewed research findings from Africa (UNEP, 2009). Kenya offers similar challenges in this area and it is recognized that there is a critical need for governments to improve support to assisting climate change adaptation strategies.

It has been noted that the mean annual temperature in Kenya has increased since 1960 by 1°C. There is a projected increase in temperature by 2060 to 2.8°C and by 2100, temperatures could increase by up to 4°C (UNEP, 2009). Such increases will have serious impacts on diverse aspects of climate vulnerable sectors in Kenya (NEMR 2009).

Predicting precipitation change at a downscaled level has proved to be difficult. Kenya traditionally experiences two rainfall seasons. March-May is considered to be the long rainfall season whilst October – December is the short rain season. In 2009, the "long rains" did not arrive as expected and have exacerbated the existing lack of rainfall in the country. However, if the projections outlined in Hulme (2001) are used, it is likely that there will be dramatic changes to rainfall patterns in Kenya.

3.2 Socio-economic Futures

Business as Usual Pathway

The A2 scenario used in the Business as Usual pathway assumes medium economic development, low per capita incomes, and weak globalization. This scenario would see Kenya remaining a strongly agricultural economy, heavily dependent on cash crops. There may be a decrease in earnings from agriculture, particularly in the area of livestock production. It could also indicate further conflict over natural resources, especially in arid areas. This could also see rapid population expansion above predicted levels due to reduced financial resources available in the country. It would also mean a continuation of low education and high illiteracy rates in Kenya, which would also compound poverty issues and subsequently pressure on natural ecosystems. These increased levels of poverty would increase the number of the population who earn less than US$1/day.

Vision Pathway

The Vision pathway relates heavily to goals set out under Kenya's Vision 2030 document. After a disappointing performance in the 1990s, Kenya's economy has now resumed the path to growth, having achieved a GDP annual growth rate of 6.1% in 2006 compared to 0.6% in 2002. It is hoped that sustained economic growth, that ensures that its benefits are widely distributed to the population and with resulting sustainable development is the aim of the Kenya's Vision 2030 plans.

Kenya's Vision 2030, through its economic pillar aims to improve the prosperity of all Kenyans through an economic development programme, covering all the regions of Kenya, and aiming to achieve an average Gross Domestic Product (GDP) growth rate of 10% per annum beginning in 2012.

Kenya aims to be a nation that has a clean, secure and sustainable environment by 2030. The goals that have been set out for 2012 are: (i) to increase forest cover from less than 3% at present to 4%; and (ii) to lessen by half all environment-related diseases. Kenya will also enhance disaster preparedness in all disaster-prone areas and improve the capacity for adaptation to global climatic change under this scenario.

Specific strategies have been outlined to promote environmental conservation in order to provide better support to the economic pillar flagship projects and for the purposes of achieving the Millennium Development Goals (MDGs); improving pollution and waste management through the design and application of economic incentives.

3.3 Implications of Climate Change Effects on Ecosystems and Ecosystem Services

This section gives a brief analysis of the likely implications associated to possible effects of future climate change on vulnerable ecosystems and ecosystems services considering two possible future development pathways for Kenya (see section 3.2). Each pathway assumes different patterns of socio-economic change for the future, which translates into different factors/drivers of change that will shape future socio-economic conditions, vulnerabilities, and impacts of climate change. The idea of this section is to look at implications for human well-being, economic growth, and social-ecological resilience (all key elements for adaptation capacity in the region). Two main themes have been selected for this section based on the information provided in sections 1.2 and 2: water resources, biodiversity and tourism.

3.3.1 Water Resources

Kenya is classified as water deficit country and generally suffers from the twin problem of cyclic droughts and floods from time to time (NEMR 2009).

Climate change will exacerbate water shortages in many water scarce areas. Climate change is projected to substantially reduce available water in many of the water scarce areas however increases in precipitation are expected in other parts of the country (NEMR 2009).

Changes in hydrology and demand in Kenya have implications on water supply, flood risk, power generation, navigation, pollution control, recreation, habitats and ecosystem services and agriculture (NEMR 2009).

A wide range of adaptation techniques have been developed and applied to water use in all sectors. Rehabilitation of water catchment areas, construction dams and pans in drylands, drilling of boreholes, improvement of sanitation and implementation of policy and strategies on improvement at all levels.

Business as Usual Pathway

Under a Business as Usual pathway Kenya would continue to be a water scarce country. Poor governance structures would not allow for adequate implementation of water management policies. Water borne diseases would increase nationally. Urban and rural water infrastructure would continue to need improvement.

Water conservation would continue to be a problem and integration of new technologies such as harvesting would not be taken up. Forest degradation in all areas would influence watershed management, thus leading to further soil erosion. Water that is delivered would become more expensive under this scenario.

Higher demand on water supply from an increasing population will lead to a depletion in the resource. This may be offset by higher rainfall in the north, but may also lead to unexpected flooding events. Disaster risk reduction would not be fully integrated into policy and this would lead to a lack of early warning systems for flood and drought.

Vision Pathway

Kenya is a water scarce country. The economic and social developments anticipated by Vision 2030 will require more high quality water supplies than at present. The country, therefore, aims to conserve water sources and start new ways of harvesting and using rain and underground water. The 2030 vision for water and sanitation is to ensure that improved water and sanitation are available and accessible to all.

The goal for 2012 is to increase both access to safe water and sanitation in both rural and urban areas beyond present levels. To promote agricultural productivity, the area under irrigation and drainage will increase from 140,000 to 300,000 hectares. Specific strategies will be introduced to raise the standards of the country's overall water, resource management, storage and harvesting capability. Kenya will rehabilitate her hydro-meteorological data gathering network, construct multipurpose dams (on Nzoia and Nyando Rivers and other smaller dams), and also construct water and sanitation facilities to support industries and a growing urban population.

This would also give the opportunity to rehabilitate water supply to the coast, expand urban water supplies and sanitation facilities and improve irrigation schemes nationwide.

3.3.2 Biodiversity and Tourism

Tourism is an important sector that contributes significantly to Kenya's GDP. However, in 2008, the tourism sector in Kenya recorded one of its worst performances ever in real terms, mainly caused by the post election crisis and the subsequent travel bans from the source markets. Tourism earnings decreased by 19.2% from Ksh 65.2 billion in 2007 to Ksh 52.7 billion in 2008. The volume of international arrivals declined by 33.8% in 2008 to 1.2 million from 1.8 million attained in 2007. Others factors that impacted negatively on the sector included the high cost of jet fuel, the global financial meltdown and rise in commodity prices and exchange rate fluctuations that occurred in 2008. Visitors to the Game Parks and Reserves decreased from about 2.5 million in 2007 to 1.633 million in 2008 representing a 34.5% drop. This shows that Kenya's reliance on this sector

Business as Usual Pathway

Under the Business as Usual pathway, Kenya's tourism would suffer a number of negative setbacks, due to a direct impact on habitats and biodiversity, further encroachment on protected areas, habitat fragmentation and a lack of tourist consumer confidence in visiting Kenya as a safe destination. However, it is likely that this sector would continue to expand in the coming years

Species loss and ecosystem degradation are inextricably linked to human well-being, and unless we take urgent remedial action, "normal service" – in the sense of being able to enjoy the benefits that our environment affords us – may never be resumed (TEEB 2008). Under a mosaic pathway, it is certain that the high levels of wildlife that is being lost would continue.

Vision Pathway

Tourism will be a leading sector in achieving the goals of the Vision 2030. Kenya aims to be among the top 10 long-haul tourist destinations in the world offering a high-end, diverse, and distinctive visitor experience that few of her competitors can offer.

Under this pathway, nature based tourism would continue to expand. An expanding national economic sector would also contribute to more Kenyans visiting and utilizing national parks and undertaking nature based activities. Promotion and expansion of schemes such as that outlined in the Vision 2030 of securing the wildlife corridors and migratory routes could enhance Kenya's international reputation for seeing African wildlife.

This would involve an integration of policies on tourism, nature based tourism and conservation within the Kenyan development policy agenda. This would also see tourism's GDP contribution becoming more than KShs. 200 billion due to an increase in international visitors from 1.6 million in 2006 to 3 million by 2012. It is expected that tourists average spend per visit would increase from the present KShs.40,000 to at least KShs.70,000. This would also make more money available to reducing ecosystem vulnerability and improving facilities in all under-utilised parks. It is aimed that by 2012, Kenya would be able to "fully protect" all wildlife ecosystems.

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