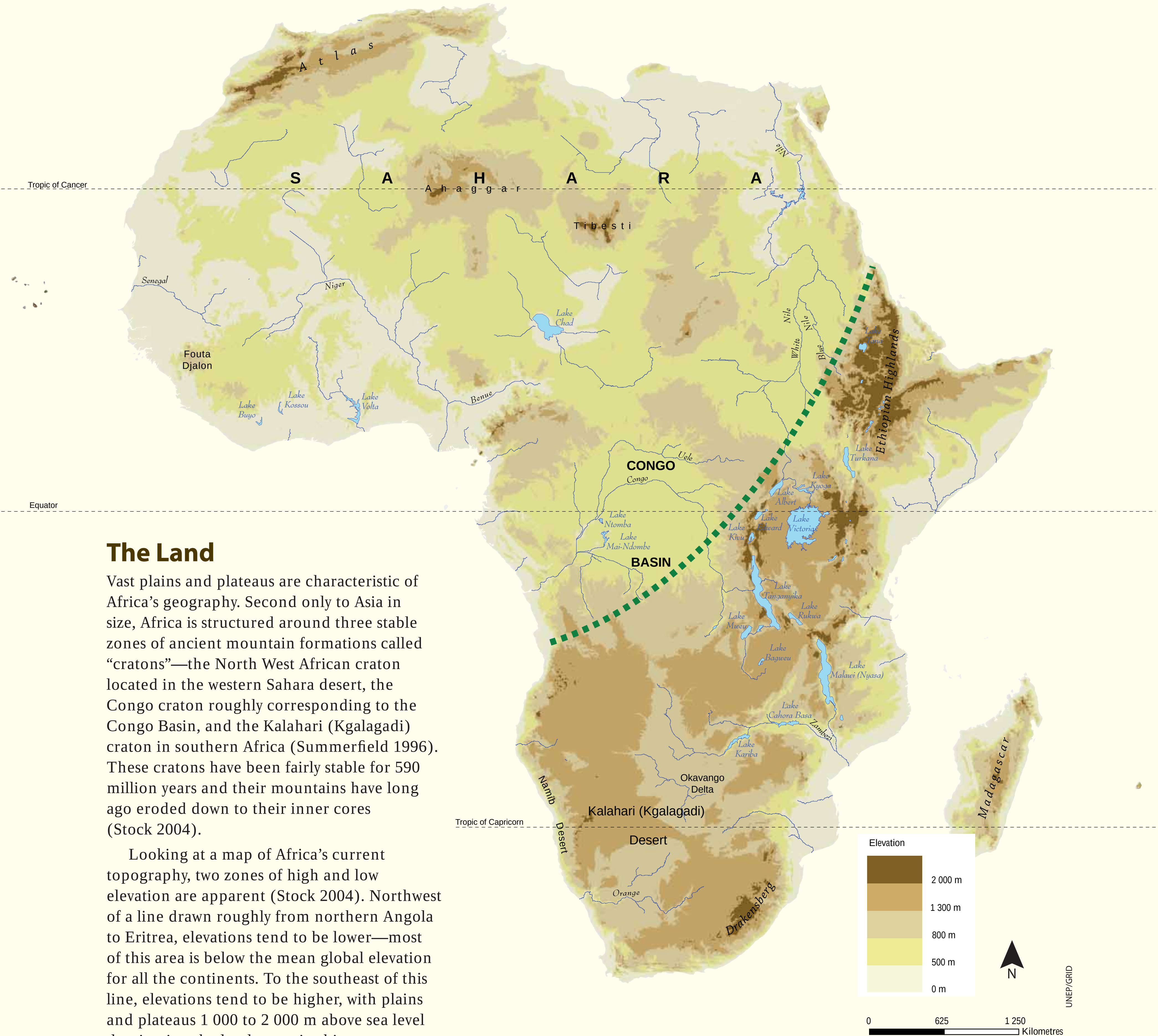
# Chapter 1

## Africa

LMODIS 500m 32-day Composite. NASA 2001, UNEP/GRID Sioux Falls

### Introduction

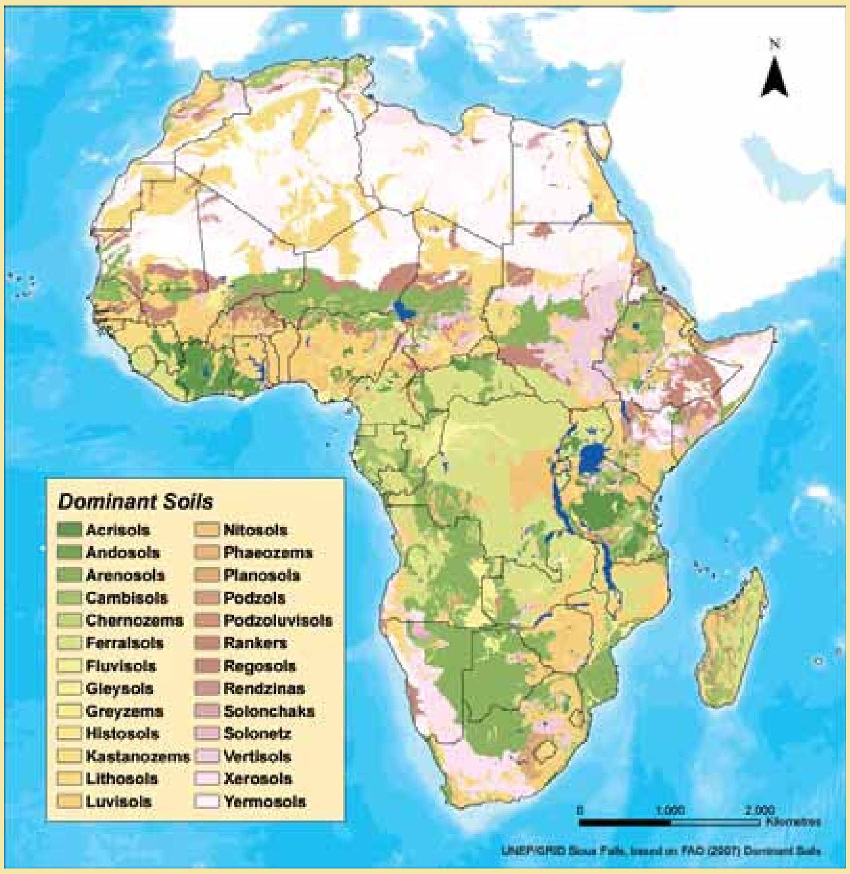
Geography is key to understanding any region of the world. Africa accounts for one-fifth of Earth's total land area. Widely regarded as the site where the human race originated, in 2007 Africa was home to more than 965 million people. The continent's population has undergone great change over time. That changing population has, in turn, altered African landscapes and ecosystems. While environmental change is not new to Africa, the pace of change has accelerated, as it has in many other parts of the world. Examining specific examples of change in Africa can help shed light on the causes of change, the problems engendered, and possible solutions. Earth observations, particularly those made using the tools of satellite remote sensing, are essential to such an endeavour.

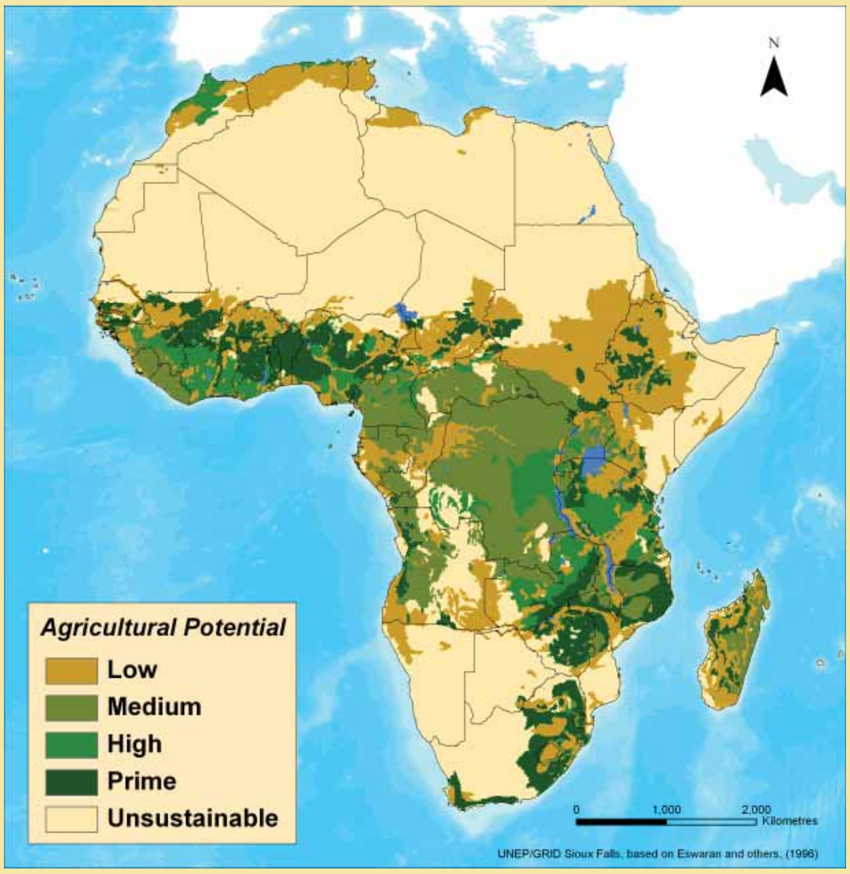



## The Land

Vast plains and plateaus are characteristic of Africa's geography. Second only to Asia in size, Africa is structured around three stable zones of ancient mountain formations called "cratons"—the North West African craton located in the western Sahara desert, the Congo craton roughly corresponding to the Congo Basin, and the Kalahari (Kgalagadi) craton in southern Africa (Summerfield 1996). These cratons have been fairly stable for 590 million years and their mountains have long ago eroded down to their inner cores (Stock 2004).

Looking at a map of Africa's current topography, two zones of high and low elevation are apparent (Stock 2004). Northwest of a line drawn roughly from northern Angola to Eritrea, elevations tend to be lower—most of this area is below the mean global elevation for all the continents. To the southeast of this line, elevations tend to be higher, with plains and plateaus 1 000 to 2 000 m above sea level dominating the landscape; in this zone, most of the land lies above mean global elevation of the continents (Nyblade and Robinson 1994). In a significant respect, everything follows from these land forms—their relief, elevation, latitude, and scale underlie all that is Africa.




## Soils

Arable land is not evenly distributed across Africa. Over half of Africa's land is either desert or is otherwise unsuited to agriculture. A further quarter of Africa's land area can be classified as having only medium to low potential, often requiring extensive management to be farmed sustainably (Eswaran and others 1996). Many soils classified as medium-potential are the characteristic laterite soils which are weathered, leached of minerals and nutrient-poor, requiring significant nutrient inputs for sustainable farming. Shifting cultivation, which uses the burning of natural vegetation to supply the needed nutrients, is the traditional practice in regions where such soil types predominate (Stock 2004). Chernozem soils located in and around the Congo Basin as well as in Sierra Leone and Liberia in western Africa, account for much of this land with moderate agricultural potential (FAO 2007). Along the margins of Africa's deserts, physical characteristics, acidity, alkalinity, salinity, or erosion generally result in soils which are of low agricultural potential and require careful management.

Some soils are ideally suited to agriculture in Africa. Around ten per cent of the farmland in Africa has deep permeable layers, adequate nutrients, and suffers little or no moisture stress (Eswaran and others 1996). Many of these prime agricultural lands are located south of the Sahel in Senegal, Mali, Burkina Faso, Ghana, Togo, Benin, Nigeria, and Chad. Areas of prime agricultural lands can also be found in southern Africa in countries such as Mozambique, Zambia, Zimbabwe, and South Africa. These resilient and productive farmlands are primarily soils designated by the Food and Agriculture Organization (FAO) as "andosols", mostly "mollic andosols" (FAO 2007).

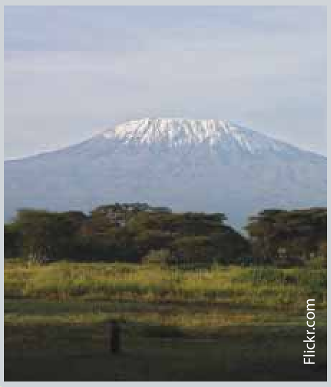
Another seven per cent of Africa's agricultural land requires more management than prime farmland, but nevertheless has high agricultural potential. The majority of these areas have one of four major soil types. Large concentrations of glossic chernozems are found in Cote d'Ivoire, southern Ghana, and United Republic of Tanzania. In Democratic Republic of the Congo and Nigeria there are large areas of humic andosols. A large region of calcic chernozem is found in Zambia, while northern Morocco has a large area of mollic andosol.

## Deserts

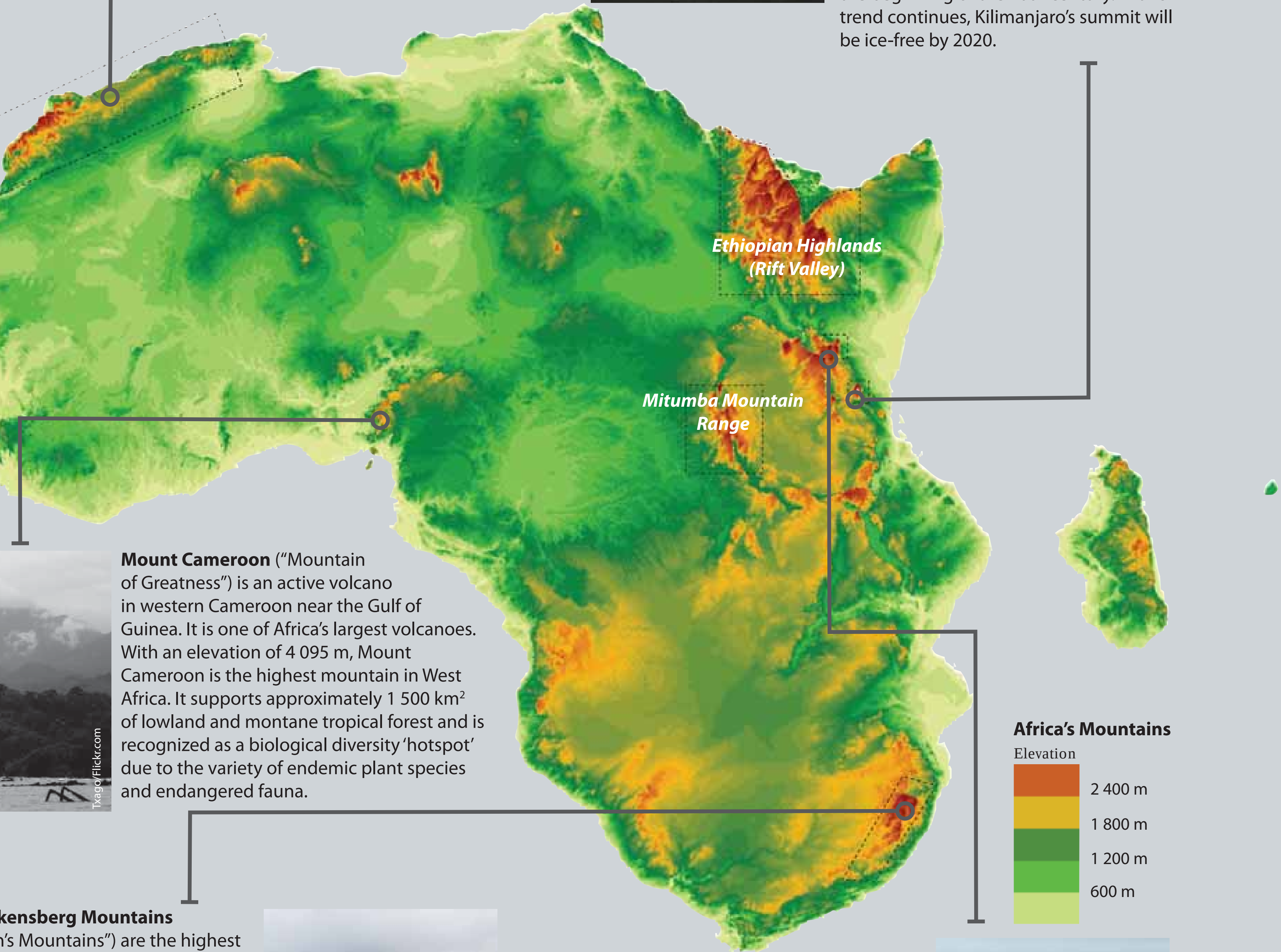
Arid lands cover approximately 60 per cent of Africa. The prominent deserts—the Sahara, the Namib, and the Kalahari (Kgalagadi)—are generally concentrated around the Tropic of Cancer in North Africa and Tropic of Capricorn in southern Africa. Droughts during the past three decades and degradation of land at the margins of the deserts, particularly the Sahara, have raised concerns of expanding desertification (Herrmann and Hutchinson 2005). The full nature of this problem and the degree to which human activities and climate change are contributing to it are still being determined. However, the negative impact that these degraded lands have on the livelihoods of the people who attempt to utilise them is well known (Smith and Koala 1999).

A view across the Namib desert of southwestern Africa

The **Atlas Mountains** are the most northerly of Africa's mountain chains, extending 1 610 km across Morocco, Algeria, and Tunisia. To the north of this mountain chain lie coastlines bordering the Mediterranean Sea and Atlantic Ocean. To the south sprawls the Sahara Desert. The Atlas Mountains were formed by converging African and Eurasian tectonic plates. The region contains some of the world's largest and most diverse mineral resources, most of which remain largely untouched.

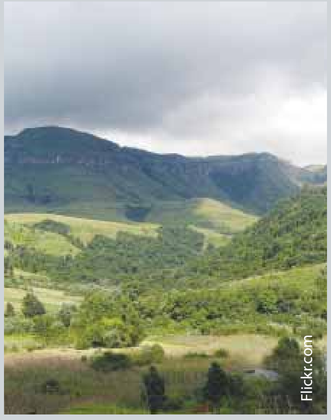

**Mount Kilimanjaro** is a volcano in East Africa. At 5 895 m, Uhuru Point on the mountain's summit is the highest point on the African continent. Kilimanjaro National Park is a World Heritage Site, and together with Kilimanjaro Forest Reserve, is renowned for its natural beauty and biodiversity, including 140 mammal species, many of which are endangered. The glaciers on the top of Kilimanjaro have been disappearing since the beginning of the 20th century. If this trend continues, Kilimanjaro's summit will be ice-free by 2020.





**Mount Cameroon** ("Mountain of Greatness") is an active volcano in western Cameroon near the Gulf of Guinea. It is one of Africa's largest volcanoes. With an elevation of 4 095 m, Mount Cameroon is the highest mountain in West Africa. It supports approximately 1 500 km$^2$ of lowland and montane tropical forest and is recognized as a biological diversity 'hotspot' due to the variety of endemic plant species and endangered fauna.

The **Drakensberg Mountains** ("Dragon's Mountains") are the highest in southern Africa, rising to an elevation of 3 482 m at Thabana Ntlenyana. Geologically, the Drakensberg Mountains are a remnant of the original African plateau. The uKhahlamba, or Drakensberg Park, is a World Heritage site well known for its diversity of habitats. The site protects a high level of endemic and globally threatened species, especially birds and plants.

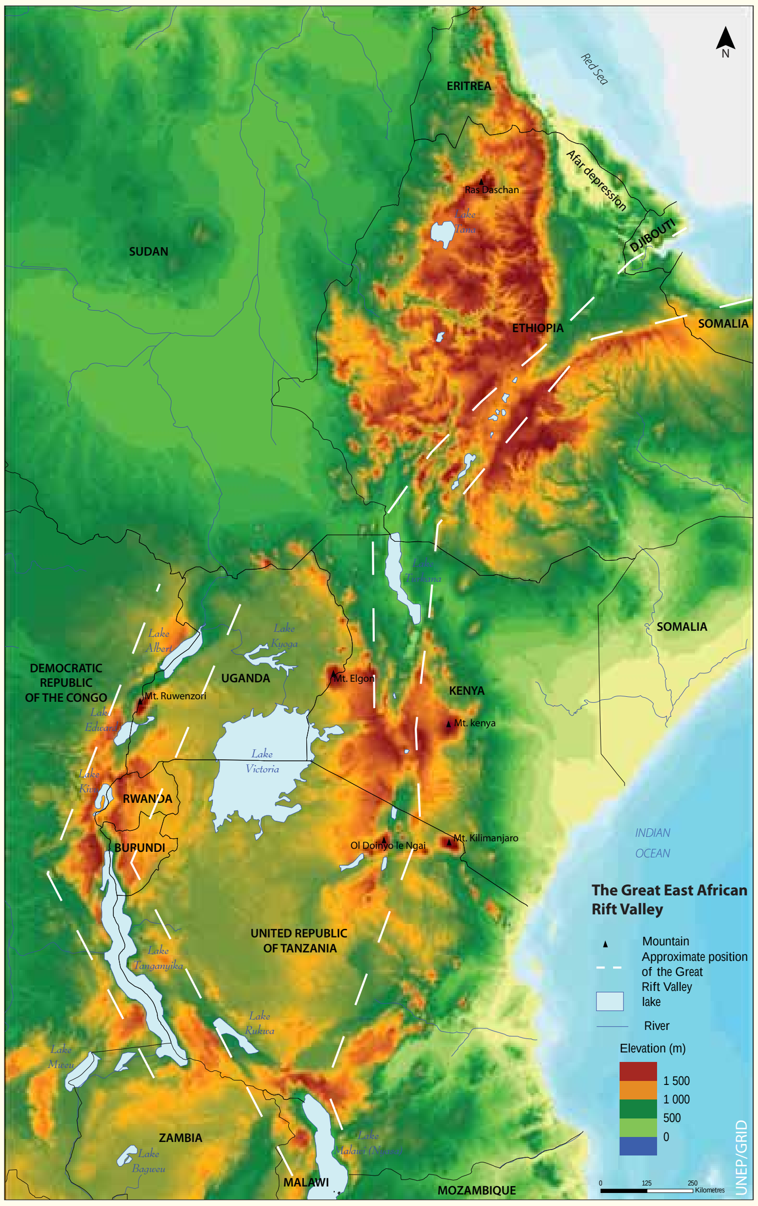



**Mount Kenya**, another World Heritage site, was formed by intermittent volcanic eruptions. At 5 199 m, it is the second highest peak in Africa. The entire mountain is deeply dissected by glacier-carved valleys radiating from the peaks. Approximately 2 000 km$^2$ of forests cover most of Mount Kenya. These forests provide invaluable natural resources and perform important environmental services such as providing the water catchment area of the Tana River, from which more than 50 per cent of Kenya's electricity is generated.


*Other sources: National Geographic 2003; Peakware-World Mountain Encyclopedia 2007., LIMBE Botanical and Zoological Gardens 2002., NASA 2004, NASA 2005, UNESCO n.d.a, UNEP-WCMC 2008.*

## Mountains

Mountains in Africa generally occur as widely scattered exceptions to the plateaus and plains that dominate the landscape (Taylor 1996). At the northwestern edge of the continent are the Atlas Mountains, formed by the collision of the African and Eurasian tectonic plates (Taylor 1996). Extending northeast to southwest, they rise to a maximum height of 4 167 m (CIA 2007a). Across the continent, at its southern edge, the Drakensberg Mountains rise to 3 482 m at their highest point—Thabana Ntlenyana—known in Zulu as uKhahlamba, the "barrier of spears" (CIA 2007a). In East Africa, a number of mountain ranges surround the Eastern and Western Rifts including Kilimanjaro and Mount Meru in the United Republic of Tanzania, as well as Mount Kenya in Kenya, Mount Elgon on the border of Kenya and Uganda, and the Rwenzori Mountains, located on the border of Uganda and the Democratic Republic of the Congo (Taylor 1996). Many of East Africa's mountains are volcanoes created as magma rose through cracks created by the spreading crust (Kious and Tilling 1996).




## The Great Rift Valley

East Africa's Great Rift Valley extends over 5 500 km, from the Somalia-Ethiopia border at the Red Sea, southwest toward Kenya, then south to Mozambique in southern Africa. Near where the Rift Valley crosses the equator it divides into the Eastern and Western Rifts, on either side of Lake Victoria (Nyamweru 1996). The Great Rift Valley—which includes the Mitumba Mountain Range—is one of Africa's best-known geological features. The complex geological processes associated with the Rift Valley are responsible for the creation of several of East Africa's largest lakes as well as much of its topography. The rugged escarpments bordering the Rift Valley are especially dramatic in Kenya and Ethiopia. Guraghe Escarpment in Ethiopia, for example, rises 1 000 m above the Valley floor (Nyamweru 1996). The Rift Valley is the result of spreading, or rifting, between tectonic plates, which, if it continues, may ultimately transform the Horn of Africa into an island in the Indian Ocean (Kious and Tilling 1996).

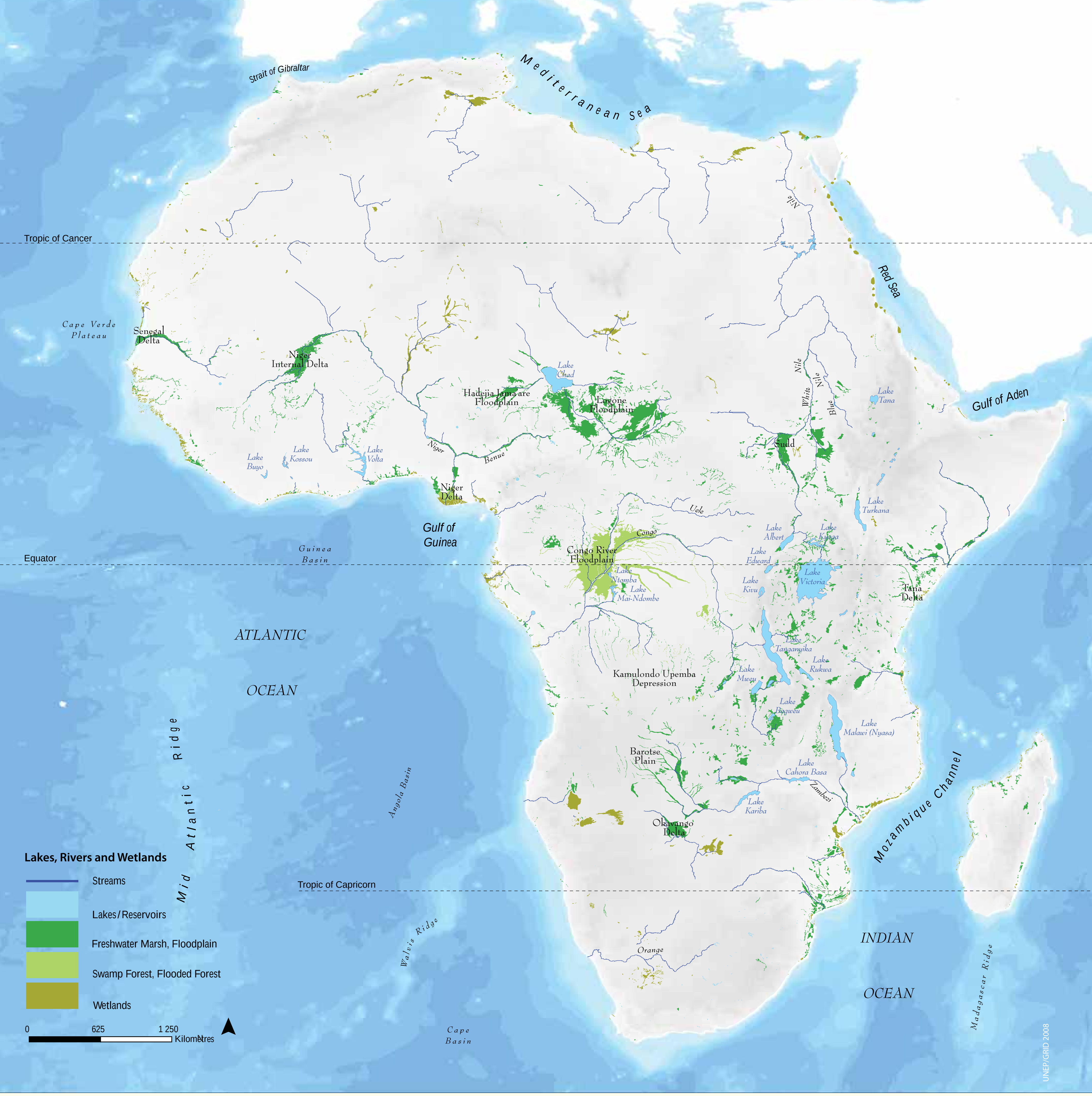
Overlooking the Rift Valley, Kenya

## Coasts

Thirty-nine African countries, including the island nations, border an ocean. The continent's coastline is a mix of diverse ecosystems, including estuaries, deltas, barrier islands, lagoons, wetlands, mangroves, and coral reefs (Watson and others 1997). On the whole, the coastline is relatively straight, with a low-lying coastal belt and narrow continental shelf and few large natural harbours (Orme 1996). The major exceptions are located in West Africa from Senegal to Liberia, where coastal submergence has created deep inlets at the mouths of several rivers (Finkl 2004). This general lack of deep-water ports contributed to Africa's isolation in centuries past (Orme 1996).

The warm ocean currents that bathe Africa's eastern coast create ideal conditions for mangrove and coral reef ecosystems in many places (Orme 1996). In contrast, currents running along the continent's western coast are predominantly cold (Orme 1996). The Benguela Current that runs offshore from Angola, Namibia, and South Africa is a coastal upwelling of nutrient-rich cold water that creates one of the most biologically diverse marine environments in the world (O'Toole and others 2001).

Cape of Good Hope, South Africa




## Water Resources

Africa is the world's second driest continent, after Australia (Revenga and Cassar n.d.). Freshwater is unevenly distributed across countries and regions due in large part to the variability of rainfall in different climatic zones. The countries that use the most water by volume are Egypt, Sudan, Madagascar, South Africa, Morocco, Nigeria, and Mali, but these are not necessarily the most water-rich nations. Egypt, for example, is in a climatic zone of low water availability, but is Africa's largest water consumer (61.7 km$^3$ per year). About 75 per cent of the African population relies on groundwater as its major source of drinking water, especially in northern and southern Africa. However, groundwater represents only about 15 per cent of the continent's total renewable water resources (UN 2006a).

Renewable water resources for the whole of Africa amount to about 3 930 km$^3$. That is less than nine per cent of global renewable water resources (Frenken 2005).

## Rivers

The rivers of Africa are notable for their variety, which follows from the variation of rainfall across the continent—near 0 mm/yr in parts of the Sahara to 9 950 mm/yr near Mount Cameroon (Walling 1996). Many of the rivers in Africa show dramatic seasonal variability and inter-annual variation as well (Walling 1996). More than 1 270 large dams have been built along the continent's many rivers (World Commission on Dams 2001), altering the sedimentation and flooding patterns (Walling 1996). Africa's rivers tend to carry less sediment than rivers on other continents, due primarily to an overall lack of both tectonic activity and steep gradients and rapid water flows needed to transport sediment (Walling 1996).

Historically, Africa's rivers served as transportation arteries, fisheries, and water sources for irrigation for indigenous populations. The Congo, Niger, and other major rivers were also used by colonial Europeans as avenues into the African heartland (Chi-Bonnardel 1973).

Congo River, Democratic Republic of the Congo

Lake Bosumtwi, Ghana

## Lakes

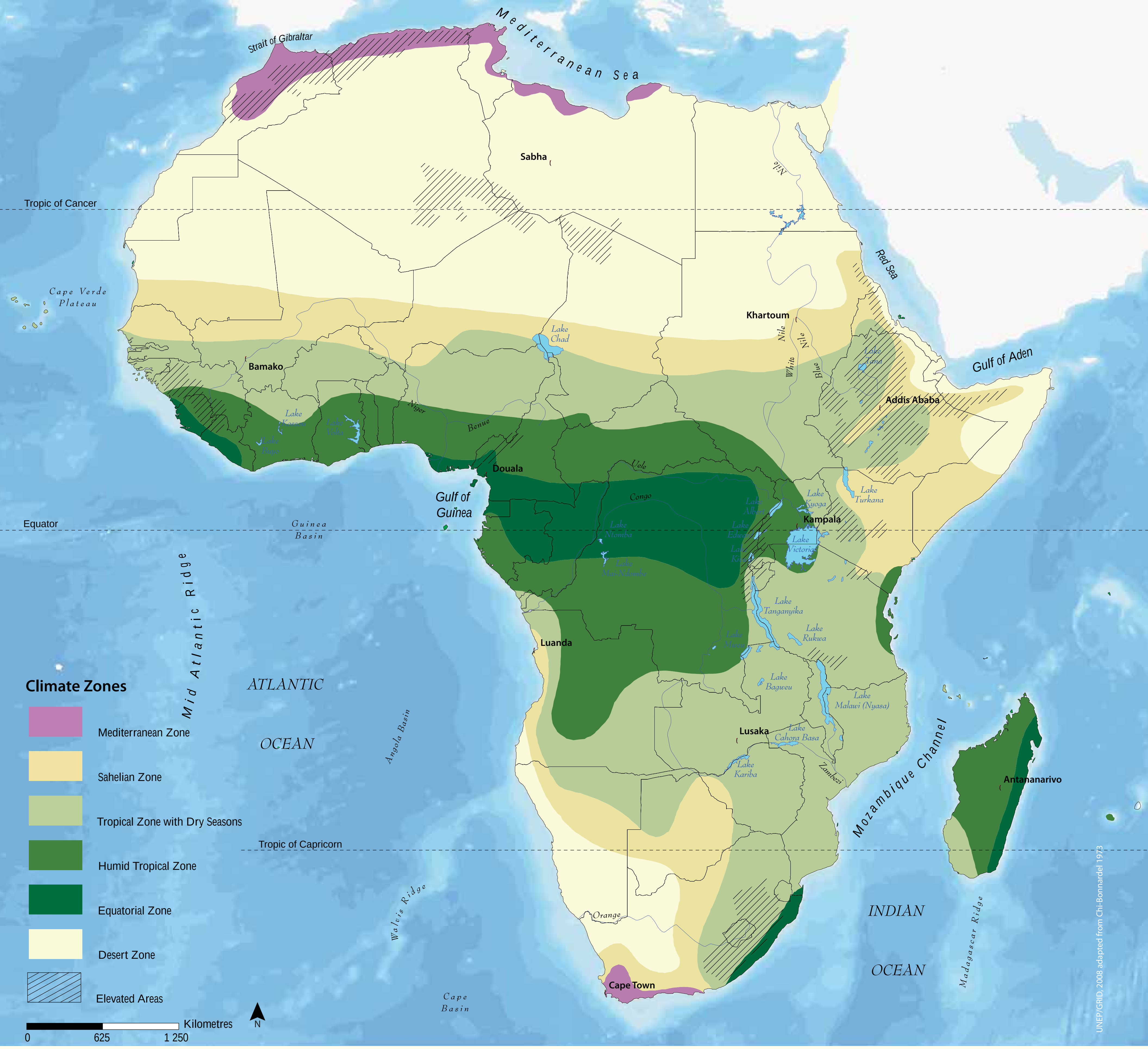
Africa, particularly East Africa, has numerous lakes that support important fisheries which provide livelihoods for millions of people and contribute significantly to the food supply (UNEP 2006c). Among these lakes are Lake Victoria, third largest in the world by area, and Lake Tanganyika, third largest by volume (WM Adams 1996). In addition to Africa's natural lakes, there are many large dams. The 53 largest of these account for 90 per cent of the total amount of water retained in reservoirs on the continent (Frenken 2005).

On a continental scale, Africa is second only to Asia in the global capture of inland fish (FAO 2006). Nile perch (*Lates niloticus*), and cichlids such as tilapia and cyprinids, represent the majority of the catch in Africa's top inland fishing nations, which include Uganda, United Republic of Tanzania, Egypt, Kenya, and Democratic Republic of the Congo (FAO 2006). As with many of Africa's natural resources, its lakes are directly linked to the livelihoods of many of its people and the economic well-being of its countries.

## Wetlands

Wetlands are areas that are regularly saturated by surface water or groundwater such as swamps, bogs, fens, marshes, and estuaries. Wetlands are characterized by a prevalence of vegetation that is adapted for life in saturated soil conditions (EPA 2006). Wetlands are important for the resources they contain and the ecological functions they provide. In Africa, wetlands cover about one per cent of the continent's total surface area, and are found in virtually all countries.

Wattled cranes in the Okavango, Botswana

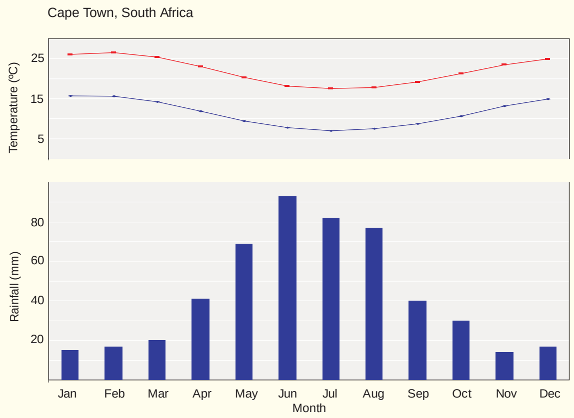



## Climate Zones

The equator lies very near to the halfway mark of the African continent; it is 37 degrees from Africa's northernmost point and 35 degrees from its southernmost tip. Consequently, Africa's climate is predominantly tropical, with the majority of the continent having mean temperatures above 21 degrees Celsius for nine months of the year (Goudie 1996). Moving away from the equator, climate zones vary in nearly mirror-image patterns to the north and south. These patterns are not interrupted by the climatic influence of long mountain ranges comparable to those that divide the Americas and Eurasia (Goudie 1996).

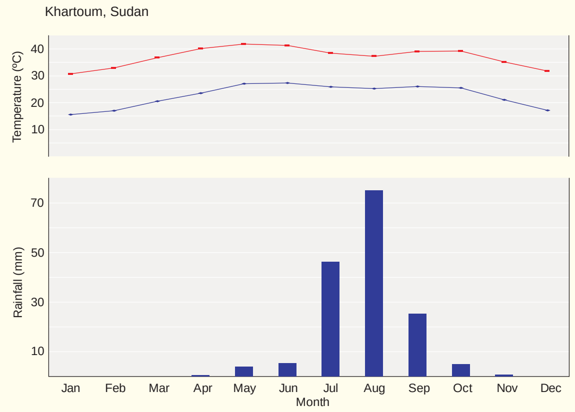
The primary determinant of precipitation in Africa is the air movement surrounding the Inter-Tropical Convergence Zone (ITCZ) and associated equatorial trough (Griffiths 1966). In simple terms, winds are pushed out from two sub-tropical high-pressure belts toward the equator, where they meet and force air and moisture upward. This upward movement cools the air, forcing the moisture out as precipitation. The now dry air cycles back toward the subtropics where it descends, producing arid climates at latitudes approximately 20 degrees north and south of the equator.

The mean temperature in the hottest and coldest months of the year varies little for most of equatorial Africa. For instance, mean temperature during summer and winter months at Barumbu, Democratic Republic of the Congo, varies only 1.4 degrees Celsius (Griffiths 2005). However, away from the equator and the coast, seasonal variation can be dramatic. In the heart of the Sahara Desert there can be up to a 24 degree Celsius difference between the mean temperatures of the coldest and hottest months (Griffiths 2005). Daily temperature variability is primarily influenced by proximity to a coast; generally, the further inland, the more extreme the variation (Griffiths 2005). Deep in the Sahara, the daytime and nighttime temperatures vary by an average of 20 degrees Celsius (Griffiths 2005).



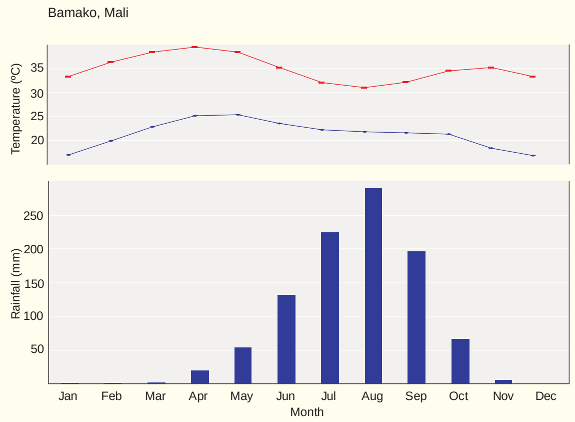

## Mediterranean Zone

At the northern and southern extremes of Africa, there are zones of Mediterranean climate with hot dry summers and wet mild winters (Chi-Bonnardel 1973). A few locations receive as much as 700 mm of precipitation, but most receive less than 500 mm. In the summer, temperatures typically average around 25 degrees Celsius; however more inland locations often see freezing temperatures in the winter, especially at higher elevations (Chi-Bonnardel 1973).

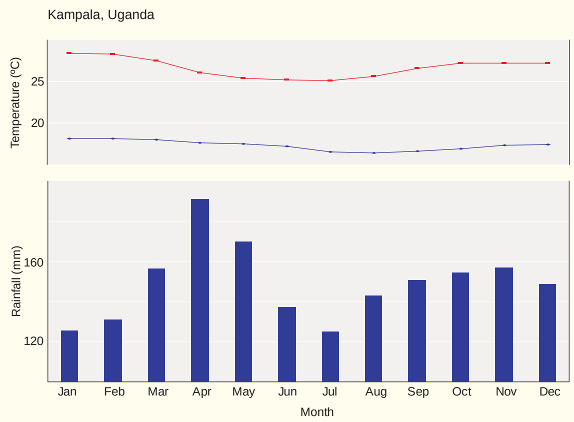

## Sahelian Zone

Only about 250 to 500 mm of rain falls in the Sahelian climate zone (Stock 2004; FAO 2001). With considerable seasonal and inter-annual variation in rainfall, the potential for rain-fed agriculture is very low (IWMI 2001). Average annual temperatures in areas adjacent to the Sahara and in the Horn of Africa range from 26 to 29 degrees Celsius, with somewhat cooler temperatures in elevated areas (CRES 2002). Before the spring rains, daily maximum temperatures often reach 40 degrees Celsius (Chi-Bonnardel, 1973). Average annual temperatures in the Sahelian climate zones adjacent to the Namib Desert are several degrees cooler (CRES 2002).

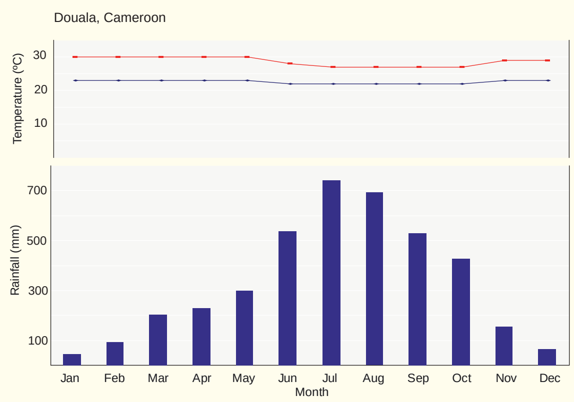

## Tropical Zone With Dry Seasons

To the north and south of the humid tropical climate zone are zones of tropical climate, characterised by long dry seasons, where precipitation and temperature are more seasonal (Goudie 1996). Here, dry seasons last more than six months and tend to increase in length with distance from the equator (Chi-Bonnardel 1973). Annual average precipitation is generally 600 to 1 200 mm (FAO 2001) with pronounced inter-annual variation (Goudie, 1996). Both annual and daily temperatures vary more here than in the climate zones closer to the equator (Stock 2004).

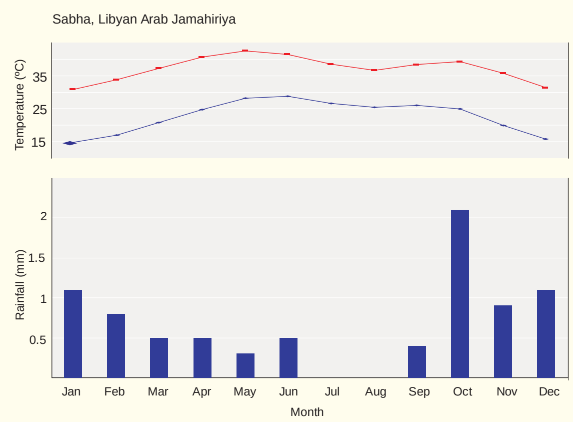

## Humid Tropical Zone

The humid tropical zone exhibits peaks in precipitation and a short dry season. Some areas in this zone experience two rainfall maxima; the first occurs as weather systems associated with ITCZ migrate toward higher latitudes, while a second occurs as those weather systems move back toward the equator and toward the lower latitudes (Stock 2004). The average annual rainfall generally ranges between 1 100 mm and 1 800 mm in this zone (FAO 2001). Temperatures are relatively high, but with somewhat more seasonal variation than temperatures in the equatorial zone (Goudie 1996).

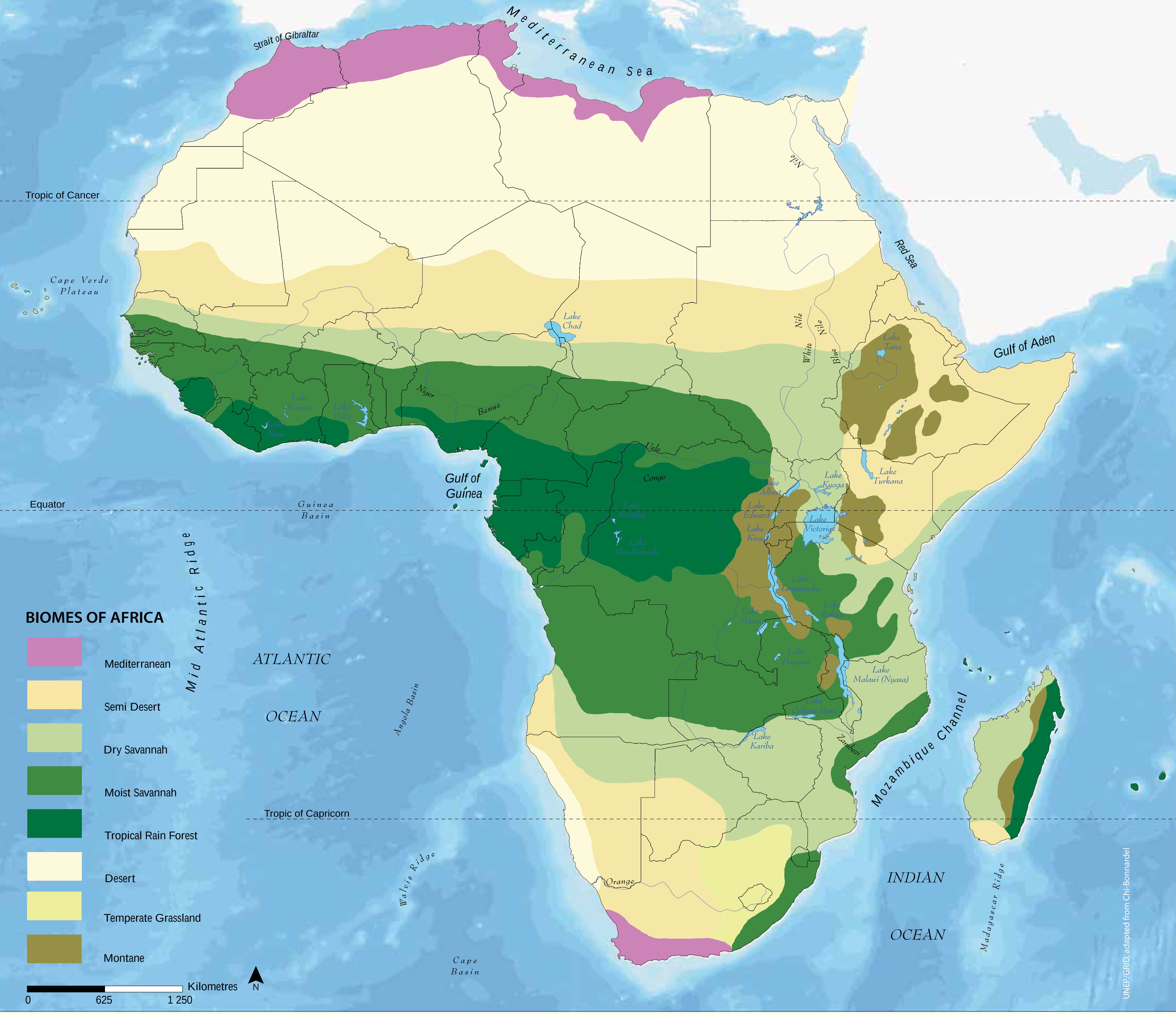

## Equatorial Zone

Africa's equatorial climate zone is found along the equator from Gabon to Uganda, as well as in coastal Liberia and Sierra Leone and in eastern Madagascar. In this zone, rain falls throughout the year; if there is a dry period, it is very brief (Goudie 1996). Average annual rainfall generally exceeds 1 700 mm and reaches 3 000 mm at points along the Liberian and Sierra Leone coasts and in eastern Madagascar (FAO 2001). Mean annual temperatures are high, around 25 degrees Celsius, with very small variation throughout the year (Stock 2004).


## Desert Zone

Africa's desert climates receive little precipitation and in the case of the Sahara, daytime temperatures can be extremely high. At Faya-Largeau, Chad, the daily maximum temperature for June averages 42 degrees Celsius (WMO n.d.). With little cloud cover, humidity or coastal influence in the Sahara, the average daily temperature range is as much as 15 to 20 degrees Celsius. Average annual precipitation is scant, exceeding 100 mm only in a few areas and tending to be below 25 mm for much of the Sahara and the western edge of the Namib Desert in southern Africa.




## The Plants and Animals

Most of the flora and fauna currently found in Africa are descended from plant and animal species that were present on the continent when it separated from other land masses during the breakup of Gondwanaland, roughly 150 million years ago. As Africa slowly moved to its current location straddling the equator, its climate changed as well, and those original populations of plants and animals evolved into forms that adapted to the new climate conditions, eventually diversifying into the variety of species seen today. Around 20 million years ago, Africa arrived and has since remained at roughly its current latitude (Meadows 1996). However, climate change continues to impact Africa, as does the selective pressure for species to adapt to changing environments (Meadows 1996).

Taken as a whole, Africa's pattern of vegetation zones largely mirrors its climate zones. Areas with the greatest rainfall have the greatest volume of biomass or primary productivity (Stock 2004). In general, this high productivity is closely linked to high biodiversity (Waide and others 1999). Accordingly, Africa's equatorial climate zone is its most species-rich area (Meadows 1996). Timing of precipitation also influences the amount and nature of vegetation (Stock 2004). For example, savannahs with few trees and dry deciduous forests occur where there are long dry seasons, while dense rain forests occur where rainfall is consistent year round.

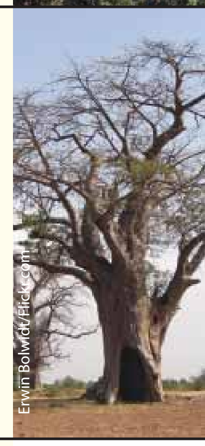
Biomes—large areas with ecologically similar communities of plants and animals—generally are defined by and result from climate, which in turn is largely shaped by temperature and precipitation. Biomes provide a useful tool for characterising flora and fauna at the broadest scale. Significant variation within these generalized vegetation zones results from local changes in elevation, soils, microclimate, wildlife, and human populations. A brief description of Africa's largest biomes provides a highly generalised but nevertheless useful picture of its habitat at a continental scale.

### Mediterranean

The Mediterranean biome—found in northern Africa across the mountainous landscape stretching from Morocco to Tunisia and in southern Africa along the southwest coast of South Africa—has hot dry summers. Enough rain falls during the cool winter months to maintain continuous vegetation cover over most of the landscape (Allen 1996). Plants characteristic of the Mediterranean biome are drought tolerant, or xerophytic (Stock 2004) and able to survive occasional freezing winter temperatures in elevated and inland areas. The Cape Province of South Africa is famous for its tremendous biodiversity (MacDonald 2003). This region, known as the Fynbos, is considered a distinct floral kingdom and has the highest rate of generic endemism in the world (Allen 1996). The Mediterranean region of North Africa is almost as biologically rich, with many species endemic to that region (Allen 1996).


### Semi-Desert

The Kalahari (Kgalagadi) and the Karoo in southern Africa and the Sahel in northern Africa fall into the category of semi-desert, a region of transition between savannah and desert. Limited, variable rainfall and extremes in temperature have produced a variety of adaptive responses in the plants and animals found here (Meadows 1996). Short grasses and scattered spiny plants predominate (Chi-Bonnardel 1973). Many plants adopt a strategy of avoidance such as surviving the long dry season as a seed and actively growing only during the short wet season (Meadows 1996). Trees generally have small waxy leaves and thick bark to reduce moisture loss. Many trees drop their leaves during the dry season, going dormant to conserve moisture (Stock 2004). The most important and characteristic trees here are the iconic acacias (Chi-Bonnardel 1973). Floral diversity is surprisingly high, particularly in the Karoo-Namib region where there may be as many as 7 000 plant species (Meadows 1996). Humans and animals must also adapt to these climate conditions and to the flora that result from them. Trapped by the lack of moisture and pasture to the north and by the tsetse fly and disease to the wetter south (Reader 1997), for centuries local pastoralists on the Sahel have moved their cattle seasonally to find adequate pasture. (Reader 1997).

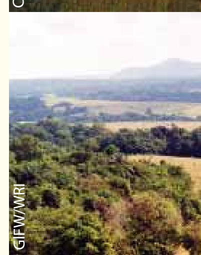



### Dry and Moist Savannah

Covering two-thirds of the land area, Africa's savannah is the characteristic ecosystem of the continent (ME Adams 1996). It is found in a broad band flanking tropical rain forests in areas with a significant dry season. African savannahs are home to a greater diversity of large mammals than are found in similar ecosystems on other continents (MacDonald 2003).

The primary characteristics of savannah are seasonal precipitation, a more or less continuous cover of grasses tolerant of seasonal precipitation and intense sunlight, and tree cover that does not form a closed canopy (ME Adams 1996). Precipitation is the fundamental determinant of the savannah vegetation structure. However soils, wildlife, human population, and fire are factors as well (ME Adams 1996). Wet seasons produce abundant fire fuels and dry seasons create conditions that lead to frequent fires. The fires kill many shrub and tree seedlings before they are large enough to survive the flames, thus the savannah favours grasses which can quickly regenerate (ME Adams 1996).

Dry parkland savannah—also called Sudan savannah—is characterised by relatively long dry seasons supporting scattered trees, and relatively short grasses (Stock 2004). Moist woodland—or Guinean savannah—tends to be closer to the equator than dry savannah and is characterised by more precipitation. In moist savannah, trees are more closely spaced and gallery forests can be found along streams and rivers (Stock 2004).

### Tropical Rain Forest

Tropical rain forest vegetation generally forms in layers. A few of the very tall trees, some as tall as 50 m (Meadows 1996), rise above a dense, closed canopy formed by the crowns of slightly shorter trees; the canopy is so dense that only a little sunlight reaches the forest floor (MacDonald 2003). The layer of vegetation nearest the ground can be fairly open (Stock 2004; MacDonald 2003). A significant portion of rain forest vegetation is made up of vines and lianas, which climb up the trunks of trees to reach the sunlight (Mongabay n.d.).

The biodiversity in the tropical rain forest is the greatest of all terrestrial biomes. However, of the world's tropical rain forests, those in Africa have the fewest number of species (Meadows 1996). Many of the fauna in the tropical rain forest live primarily in the canopy, where most resources are concentrated (Chi-Bonnardel 1973). Madagascar's rain forests, isolated from those of the African continent, have a remarkable number of unique species. As many as 90 per cent of Madagascar's animal species and 80 per cent of its plant species are endemic to the island (Stock, 2004; KEW n.d.).

### Desert

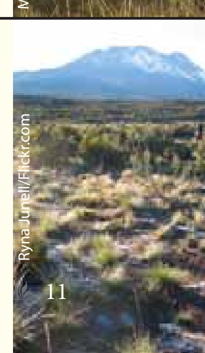
Desert vegetation is adapted to sparse and unpredictable precipitation, extremes of temperature, and very poor soils (Stock 2004). The seeds of many desert plants can lie dormant for years until rain brings about a brief explosion of life (Chi-Bonnardel 1973). Although some plants are adapted to the extreme heat and lack of moisture, Africa's deserts have much lower biomass than its other biomes (Jürgens 1997). The various African deserts have distinct communities of living things. For example, many plants in the Namib Desert differ genetically from plants in the Sahara Desert. This is probably the result of plants adapting to different environmental conditions over time as well as varied bio-geographical histories (Meadows 1996). In the Namib Desert, some plants are able to utilise moisture from fog that forms when warm air moving inland from the Atlantic Ocean passes over the cold waters of the Benguela current (Meadows 1996). In the Sahara, plants tend to cluster in dry river beds (wadis) where water will collect after rare rains.

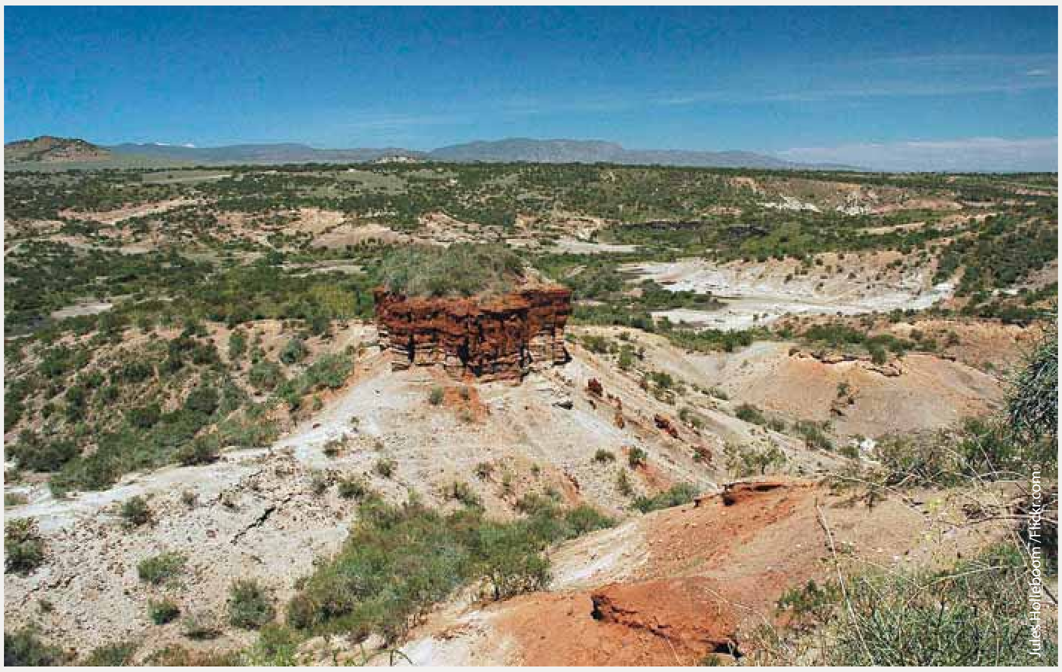

### Temperate Grassland

A large expanse of temperate grassland is found in southern Africa where the Drakensberg Mountains and the Great Escarpment create an interior area of high elevation and moderate rainfall (Palmer and Ainslie 2005). These conditions, coupled with fertile soils, produce vegetation that is dominated by grasses with scattered trees (Stock 2004). Biomass decreases with precipitation along an east-to-west gradient (Palmer and Ainslie 2005). Although substantial expanses of native temperate grassland remain in this part of Africa, conversion of large tracts to dryland agriculture and livestock production has altered the plant species composition in these areas (Palmer and Ainslie 2005).


### Montane

Relatively isolated areas of high-elevation montane forest, shrubland, and grassland are found in the Ethiopian Highlands, the Albertine Rift, and the Arc Mountains of East Africa. Beginning around 1 000 m and extending to above 3 500 m (CI n.d.b), the montane biome is characterized by a series of zones of vegetation that coincide with a gradient of increasing elevation and decreasing temperature (Meadows 1996), with montane forest and bamboo at lower elevations and heather and alpine tundra at higher elevations (Stock 2004). Few species can withstand the daily temperature swings and harsh conditions found on mountain summits (Meadows 1996). However, both the conditions and the isolation of these areas have led to the evolution of unique plant communities that are found nowhere else.






Olduvai Gorge in the United Republic of Tanzania has been the site of several important archaeological finds of early hominids. Among them was *Homo hablis* (right) discovered in the early 1960s by Mary and Louis Leakey and thought to be at least 1.6 million years old.

## People

Africa is widely believed to be the birthplace of humankind (Stock 2004). Fossil evidence of ancestral hominids that lived 1.5 to 2.5 million years ago is abundant from Ethiopia to South Africa (Reader 1997). Around 1.6 million years ago, *Homo erectus*, predecessor to modern humans, emerged in Africa (Reader 1997). *Homo erectus* is found in the fossil record until around 200 000 years ago (Reader 1997). Fossil evidence indicates that modern humans, the species *Homo sapiens sapiens*, appeared approximately 130 000 years ago (Reader 1997).

Fossil, linguistic, and genetic evidence indicate that approximately 100 000 years ago a small number of these *Homo sapiens sapiens* left Africa and proceeded to populate all the other continents (Reader 1997). The fact that most of the world's population outside of Africa is derived from this very small gene pool is supported by genetic research, which shows much greater genetic variation within Africa than among all the rest of the world's population (Reader 1997).

This original group of emigrants—perhaps as few as 50 people (Stock 2004)—who left the continent 100 000 years ago evolved into many races and has now grown into a population of roughly 5 500 million people outside of Africa (UN 2007). Africa's population, however, did not grow as rapidly. Africa had an estimated one million inhabitants 100 000 years ago. By 2007, Africa's population had grown to an estimated 965 million (UN 2007).

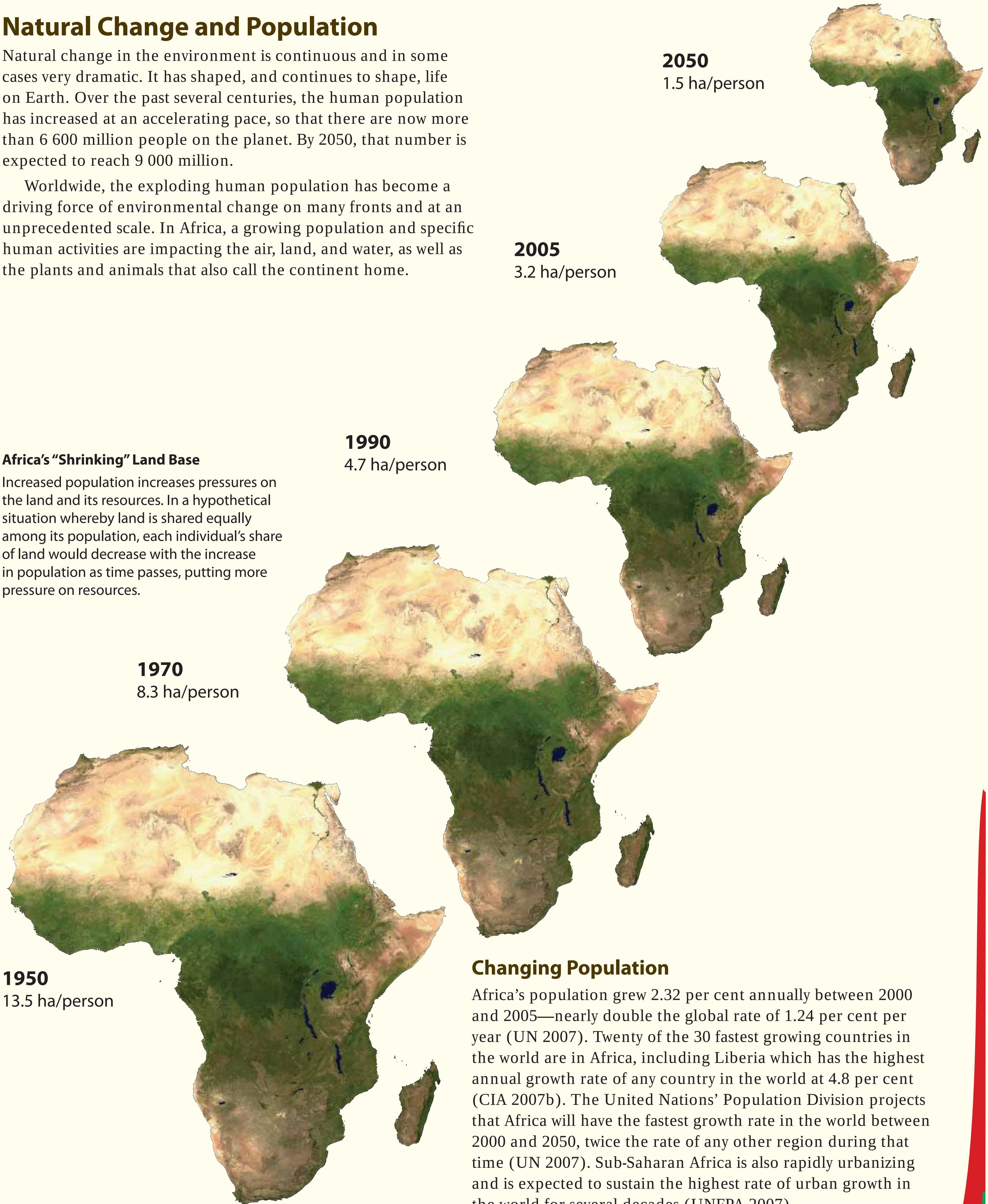
Currently, Africa is the second most populous continent after Asia (UN 2007). In 2007, Africa's average population density was 32.6 people per square kilometre (UN 2007). While parts of the continent such as the Sahara have few permanent settlements, other areas—including countries such as Nigeria, Burundi, Rwanda and regions such as the Nile Delta—are very densely populated.

Crowd in Malawi

## Natural Change and Population

Natural change in the environment is continuous and in some cases very dramatic. It has shaped, and continues to shape, life on Earth. Over the past several centuries, the human population has increased at an accelerating pace, so that there are now more than 6 600 million people on the planet. By 2050, that number is expected to reach 9 000 million.

Worldwide, the exploding human population has become a driving force of environmental change on many fronts and at an unprecedented scale. In Africa, a growing population and specific human activities are impacting the air, land, and water, as well as the plants and animals that also call the continent home.




Source: NASA Data Source: CIESIN

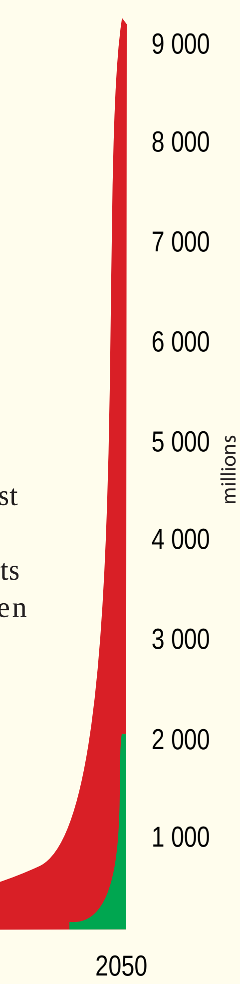
**Africa's "Shrinking" Land Base**

Increased population increases pressures on the land and its resources. In a hypothetical situation whereby land is shared equally among its population, each individual's share of land would decrease with the increase in population as time passes, putting more pressure on resources.

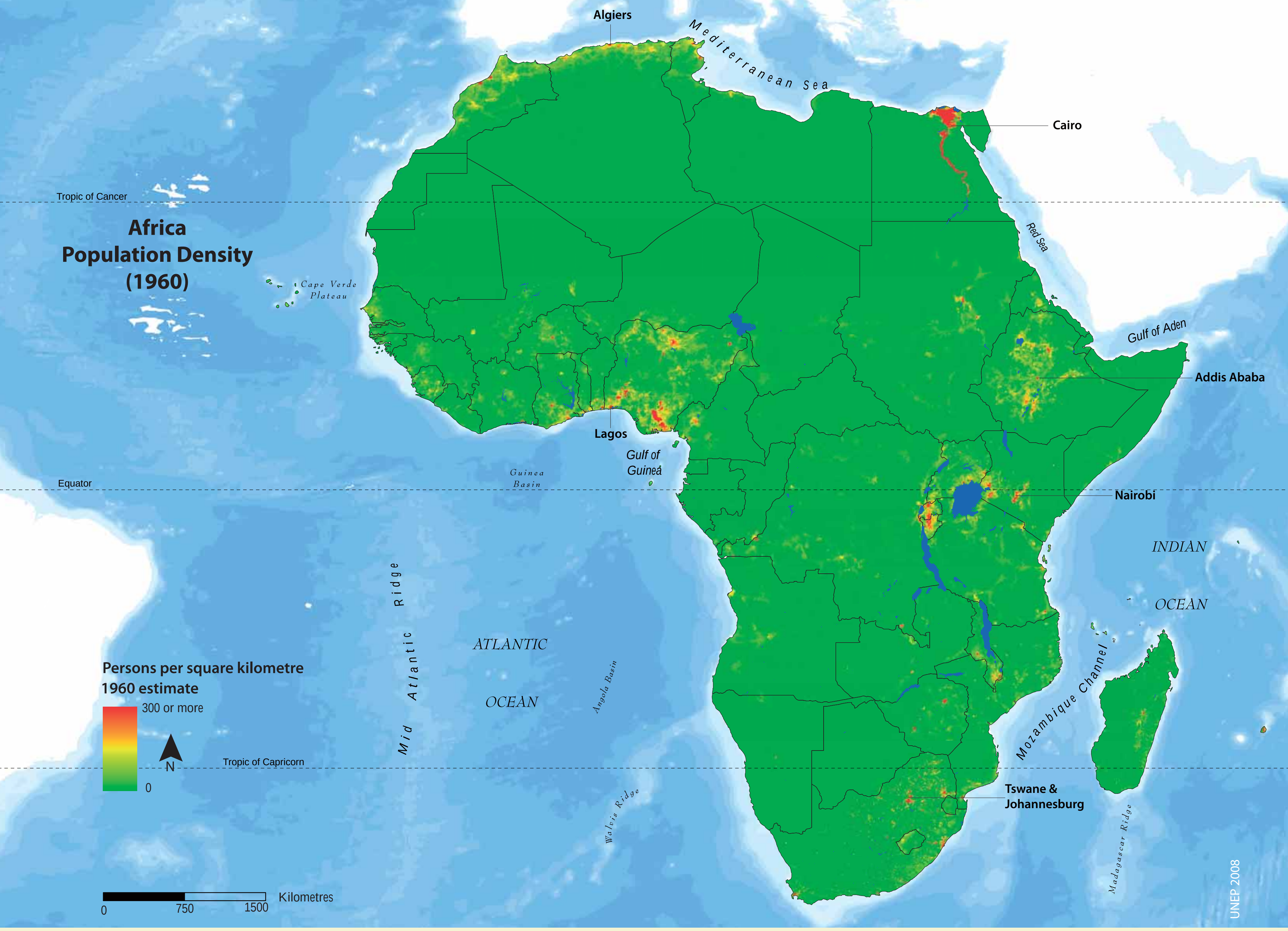
## Changing Population

Africa's population grew 2.32 per cent annually between 2000 and 2005—nearly double the global rate of 1.24 per cent per year (UN 2007). Twenty of the 30 fastest growing countries in the world are in Africa, including Liberia which has the highest annual growth rate of any country in the world at 4.8 per cent (CIA 2007b). The United Nations' Population Division projects that Africa will have the fastest growth rate in the world between 2000 and 2050, twice the rate of any other region during that time (UN 2007). Sub-Saharan Africa is also rapidly urbanizing and is expected to sustain the highest rate of urban growth in the world for several decades (UNFPA 2007).

With more people to feed, Africa must devote more land to agriculture. However, increasing agricultural lands means



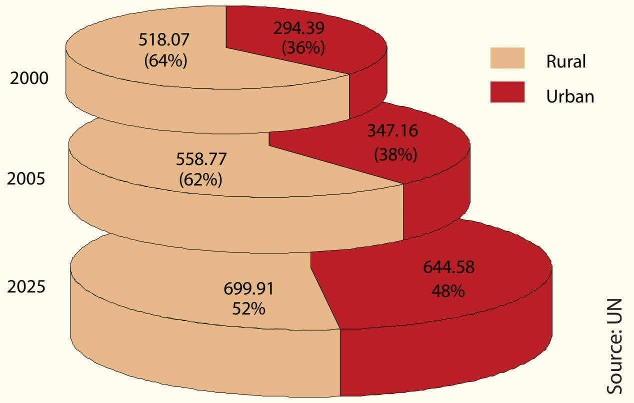

Source: US Census Bureau, UN 2007, CIESIN




decreasing forests and other types of land cover, and reducing or eliminating natural habitats and their resources. In some cases, increased human impact has caused serious environmental damage in Africa. For example, the loss of West Africa's rain forests and their associated goods and services has contributed to social unrest and exacerbated poverty across the region (Gibbs 2006).

## Urban Population

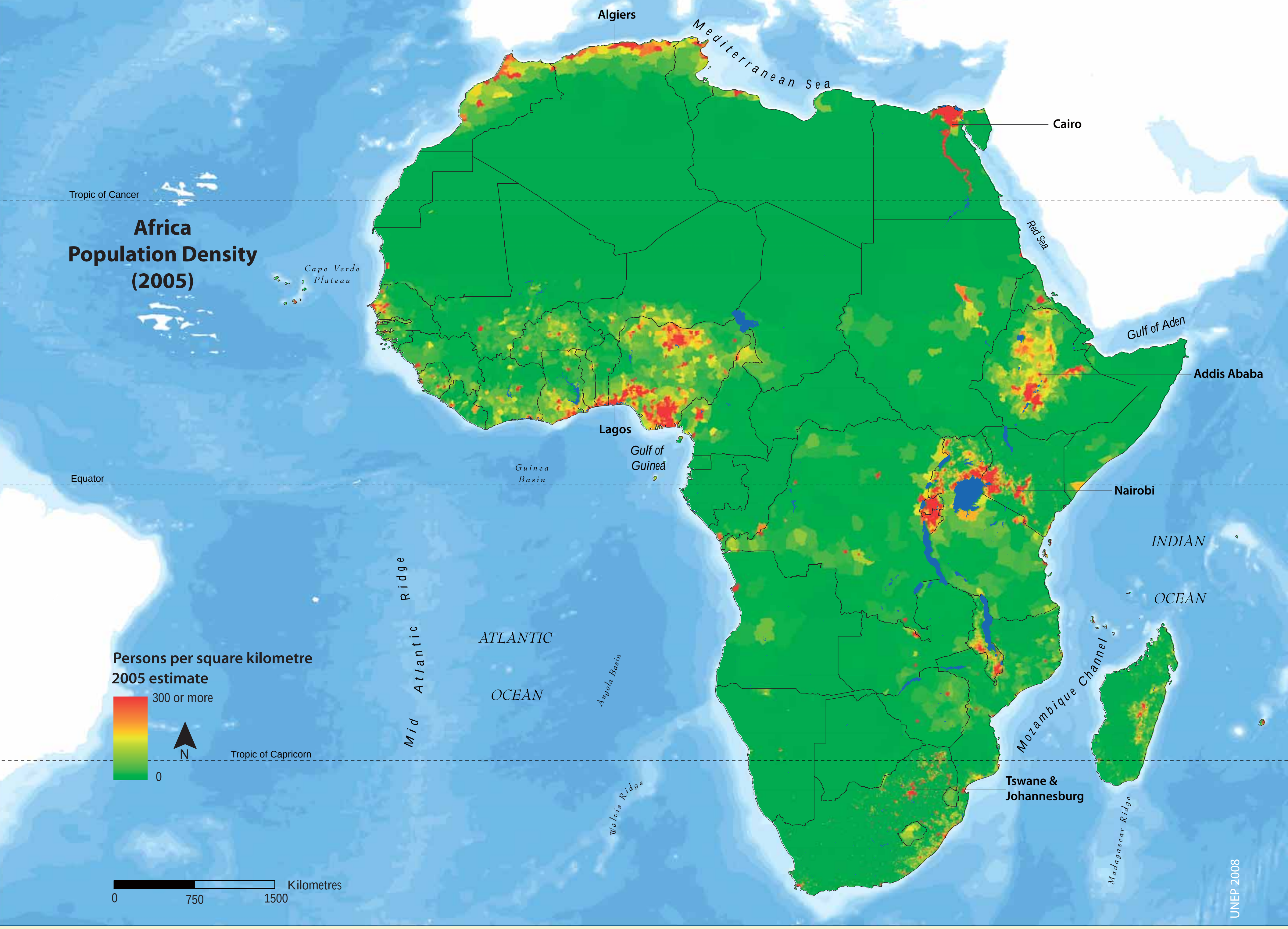
More than 60 per cent of Africa's population was still living in rural areas in 2005. But Africa has the fastest urban growth rate in the world. This trend is mainly due to people migrating from rural communities to cities—especially young adults looking for work—as well as high urban birth rates (IUSSP 2007). Cities and towns, growing at twice the rate of the rural population, are expected to add 400 million people to

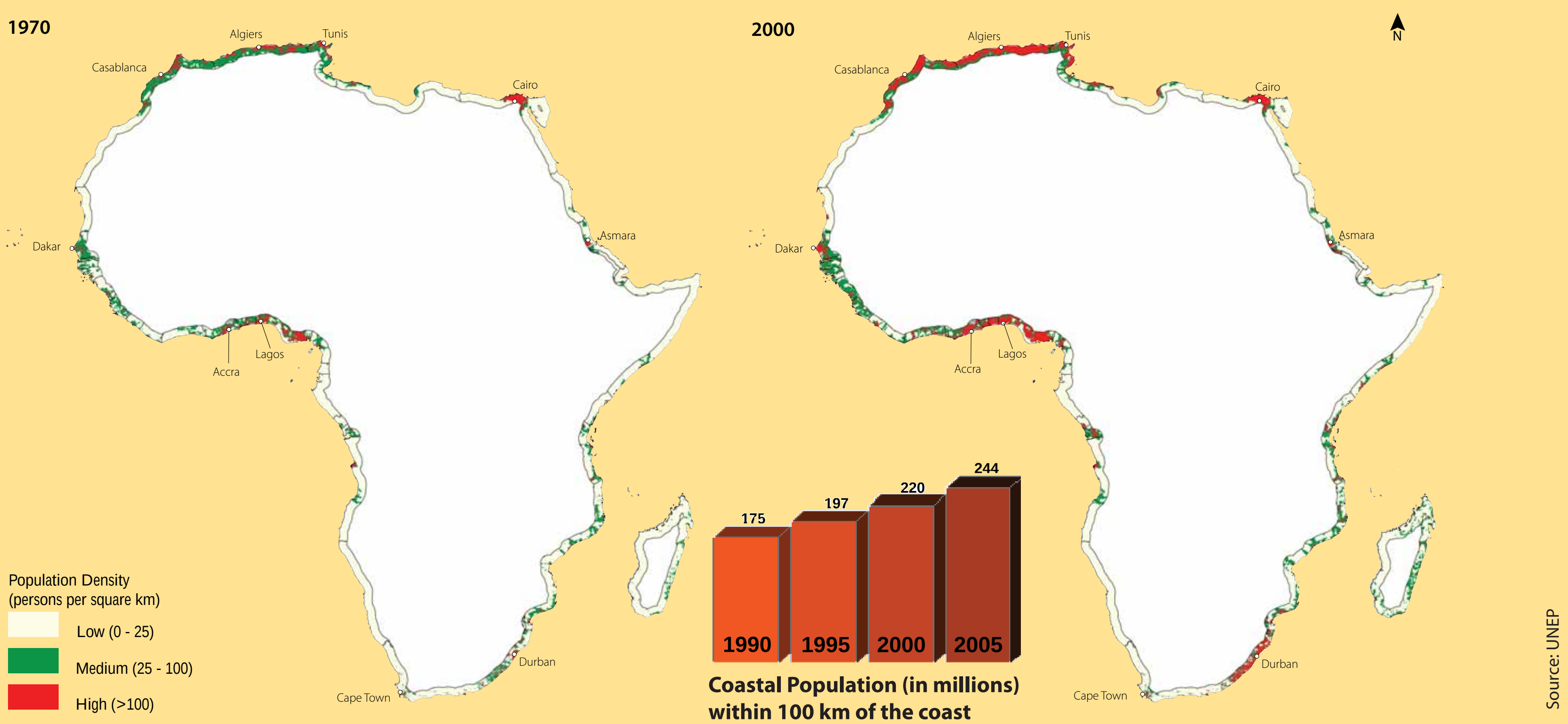



Africa's urban population over the next 25 years (Auclair 2005). By 2025, more than half of Africa's population will live in urban areas (Tibaijuka 2004; UN-HABITAT 2006).

## Coastal Population

About 2.7 per cent of Africa's population lives within 100 km of the coast. Since the 1980s, coastal urban areas have been growing by four per cent a year or more (ODINAFRICA Project 2007). Poorly planned and managed coastal cities, the lack of adequate sanitation treatment, as well as pollution from land-based activities such as agriculture and industry, threaten human health and the quality of habitat for fish and other marine life (UNEP 1998; O'Toole and others 2001). Human-induced activities such as construction, dredging and mining for sand, and harvesting corals have led to severe problems of coastal erosion. The Niger River Delta is losing 400 hectares of land a year to erosion (Hinrichsen 2007). The Intergovernmental Panel on Climate Change (IPCC) projects that toward the end of the 21st century, climate change will have caused sea-level rises that will affect Africa's highly populated low-lying coastal areas. Adaptation costs could amount to at least 5-10 per cent of GDP (Adger and others 2007).


Africa
Population Density
(2005)
Persons per square kilometre
2005 estimate
300 or more
0
N
Kilometres
0
750
1500
Algiers
Mediterranean Sea
Cairo
Red Sea
Gulf of Aden
Addis Ababa
Lagos
Gulf of Guinea
Guinea Basin
Nairobi
INDIAN OCEAN
ATLANTIC OCEAN
Mid Atlantic Ridge
Angola Basin
Walvis Ridge
Mozambique Channel
Madagascar Ridge
Tswane & Johannesburg
Cape Verde Plateau
Tropic of Cancer
Equator
Tropic of Capricorn
UNEP 2008


1970
2000
Algiers
Tunis
Casablanca
Cairo
Dakar
Asmara
Accra
Lagos
Durban
Cape Town
N
Population Density
(persons per square km)
Low (0 - 25)
Medium (25 - 100)
High (>100)
175
197
220
244
1990
1995
2000
2005
Coastal Population (in millions)
within 100 km of the coast
Source: UNEP

## Air and Atmosphere

Given Africa's relatively low level of industrial development, air pollution is not as severe or as widespread as in some other parts of the world. However, in Africa's most populous cities, long-term exposure to congested traffic and poor air quality is a health hazard. In rural areas, biomass burning releases unhealthy particulates into the air, contributing to air pollution and health problems such as respiratory illnesses and allergies.

Like the rest of the world, Africa is seeing changes in its atmosphere. Global warming, an increase in the world's average surface temperature, is affecting every continent, including Africa. The main cause of global warming is human activities—particularly the burning of coal, oil, and natural gas, deforestation, and certain agricultural practices—that add heat-trapping gases to the atmosphere, primarily carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), and methane ($CH_4$). Global warming is already changing the climate in some parts of the world. In the coming decades, climate change is expected to negatively impact many natural systems worldwide.

Africa is particularly vulnerable to climate change. Computer models project major changes in precipitation patterns on the continent, which could lead to food shortages and increased desertification. Yet on the whole, African nations lack the resources and technology to address such changes (Adger and others 2007; UNECA 2001).


Early morning smog in Cairo, Eygpt

Gary Denham/Flickr.com

## Land Cover and Land Use

Land cover refers to the physical attributes of the Earth's surface that can be seen readily, such as water, trees, grass, crops, and bare soil. Land use refers to the social and economic purposes for which land (or water) is managed, such as grazing, timber extraction, conservation, irrigation, and farming.

Traditional African societies are agrarian or pastoral, depending directly on the environment to meet peoples' daily needs from what they can grow, raise, catch, or gather. Three-fifths of African farmers subsist by directly utilising land resources (Dlamini 2005). Two-thirds of the population of sub-Saharan Africa lives in rural areas, and therefore depends on the natural resource base more than people in any other part of the world (EIA 2003). Africa's land resources are rapidly changing, and in some cases shrinking, due to changes in land cover, land use, and land productivity.

### More People, More Trees: A Success Story in Niger

In the thirty years since the great drought of the 1970s, Niger's population has more than doubled. Most of the people are rural, securing their livelihoods in Africa's biggest dryland—the Sahel. Rainfall levels are still well below the 1950-1970 average, and the threat of environmental degradation and desertification continues to dominate thinking in the development community. Yet, despite the statistics of more people living with major constraints of aridity, variable rainfall, and soils with low natural fertility, Niger's rural communities have somehow coped and continue to live and evolve in a harsh environment. Indeed, people in the development community who knew Niger in the 1970s now speak of environmental improvement and increasing agricultural productivity resulting from investments in ecosystem management.

Preliminary findings by a team of United States Geological Survey (USGS) scientists, who have been monitoring environmental change in Niger, suggest a human and environmental success story at a scale not seen before in the Sahel. The team started by selecting a dozen village-based sites in two ecological regions—the rocky plateau and valley country known as the "Ader-Doutch-Maggia" east of Tahoua, and the vast sandy agricultural plains that stretch across south-central Niger. To get a sense of how the vegetation and land use had changed, they compared historical aerial photographs from 1975 to images they acquired from the air in 2005. The comparisons were dramatic—giving the team the first real evidence of a major environmental transformation. At every study site in south-central Niger, sandy fields with few trees were now punctuated with many trees. Today, agricultural parklands replace the wind-swept fields of the 1970s. On-farm tree densities have increased ten to twenty-fold. Village sizes have also dramatically increased in the area, generally by a factor of three, a direct indicator of rural population growth. The changes were equally surprising on the rocky slopes and plateaus east of Tahoua. Almost totally denuded in 1975, a patchwork of terraces and rock bunds now extends throughout the regions that were constructed to stem soil erosion, trap precious rainfall, and create micro-catchments for planting and nurturing trees. As a result, trees now occur on most plateaus, and farmers have taken advantage of the new environment to plant fields of millet and sorghum between the ribbons of trees. Windbreaks of mature trees crisscross the wide Maggia Valley and its tributaries. Many of the valleys now have dikes and low dams to create ephemeral lakes. As their waters recede in the dry season, farmers plant vegetables. A vibrant dry season market gardening economy has developed. Large tracts of valley lands are now green with produce—including onions, lettuce, tomatoes, sweet potatoes, and peppers.


Locals gathered around an aerial map, Niger

Gray Tappan/SAIC/USGS

**Table 1.1 - Recent changes in Africa's population and land cover/land use area (1 000 hectares) for selected years**

| Topic | 1980 | 1990 | 2000 |
|---|---|---|---|
| Population (1 000) Medium Variant | 364 132 | 637 421 | 820 959 |
| Land area | 2 962 648 | 2 962 648 | 2 962 648 |
| Agricultural area | 1 102 575 | 1 124 531 | 1 136 660 |
| Arable land | 158 354 | 167 137 | 181 409 |
| Permanent crops | 19 776 | 22 935 | 25 328 |
| Permanent pasture | 898 595 | 907 134 | 900 198 |
| Forest | N/A* | 699 358 | 655 611 |
| Woodland | N/A* | 444 433 | 471 190 |

*Source: UN ESA 2004; FAO 1997*

*** Not Available**
**Note: Land areas do not add up to the total because of overlap in definitions.**

## Land Conversion

Land conversion is the process of changing land use or land cover. Land conversions may be natural or human-induced. Human-induced conversion may be deliberate or unintentional. Table 1.1 shows changes in land cover and land use brought about in Africa due to increasing human population.

Deforestation is a form of land conversion that is most evident in Africa. Forests and woodlands provide multiple goods and services that contribute to social and economic development. At the local level, forests provide construction materials, food, energy, medicine, catchment protection, soil protection, shelter and shade, habitat for wildlife, and grazing, as well as sites of cultural significance such as sacred groves. Forests and woodlands also help ensure water quality, regulate river flows (and thus hydropower potential), and prevent soil erosion; they represent sources of energy, timber products, and non-timber products such as fruits, resins, and gums as well as genetic resources that can be used in developing pharmaceuticals. At the global level, Africa's forests and woodlands are valued for their role in climate regulation and as repositories for biodiversity (UNEP 2006c).


Vegetables planted between wind rows
Gray Tappan/SAIC/USGS

Early findings from the team's groundwork are equally compelling. Many interviews with village informants at all sites confirm that there has been notable environmental improvement since the 1970s. Farmers point to the increase in woody cover, to the diversity of high-value trees, and to the rehabilitation of the productive capacity of tens of thousands of hectares of degraded land. The projects of the 1970s and 1980s demonstrated what could be done, giving villagers options. Since then, there has been a huge spread effect, particularly in farmer-managed natural regeneration—a significant change in the way farmers maintain their fields, allowing high value trees to grow in their fields. This change also represents an increased sense of land tenure security. Trees are no longer considered the property of the State, and farmers have more control over this resource. Another significant improvement has been a rise in the local water table in many villages. In Batodi, for example, the ground water rose from a depth of 20 m in 1992 to three metres in 2005. Women have organized themselves to start dry season vegetable gardens that they manually irrigate from a shallow well. The local economy has strengthened as the systems of production have diversified. There are new local markets for vegetables, firewood, and forest products. Farmers are even buying and selling degraded plateau land, since they see the potential for its rehabilitation.

One of the most significant findings in environmental improvement is the sheer scale of farmer-managed natural regeneration of field trees in the vast sandy agricultural plains of south-central Niger. This region comprises some 6.9 million hectares. The research team believes that farmers are actively protecting tree regeneration in over at least half this area, leading to the formation of a dense agricultural parkland with up to 200 trees per hectare. Farmers have observed that crop production is better in fields with trees, not to mention trees' benefits as sources of fruit, leaves, traditional medicines, and firewood. In 2004, many crops failed following poor rainfall, leading to a real food crisis in 2005. In Dan Saga, one of the study villages, farmers pointed out that not a single child died of hunger because families were able to rely on their trees as a resource by selling wood for cash. The trees made a huge difference in their coping strategy.

The team soon hopes to provide definitive conclusions on the conditions that have led to the positive biophysical and economic trends that they are seeing in these two regions of Niger. They believe that farmers have reacted proactively to the large-scale land degradation that occurred during the droughts of the 1970s and 1980s, and have begun protecting their resources on a massive scale, encouraging natural regeneration, rebuilding their soils, and harvesting scarce rainfall. Beyond the physical efforts, there has been a notable change in Niger's environment policy, in particular a reform in the rural development code that mandates a decentralized approach—thus empowering local people to manage their own resources.

*Source: Tappan 2007*

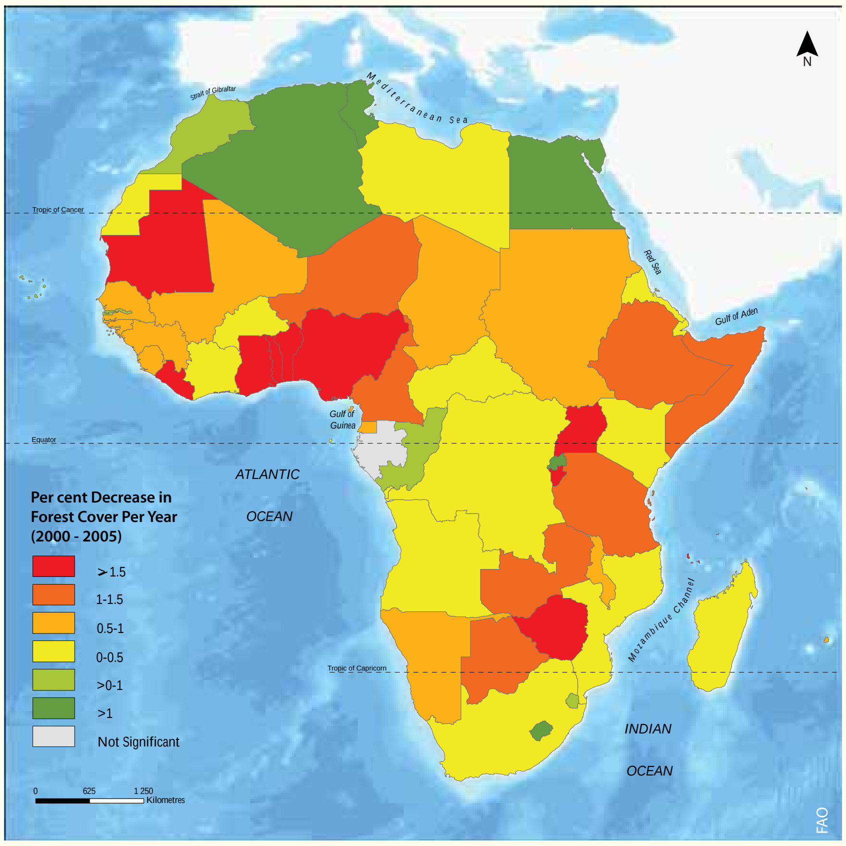
## Deforestation

Deforestation is the conversion of forested area to non-forested land for use as arable land, pasture, urban development, logged area, or wasteland. Generally, the removal or destruction of significant areas of forest cover results in a degraded ecosystem with reduced biodiversity.

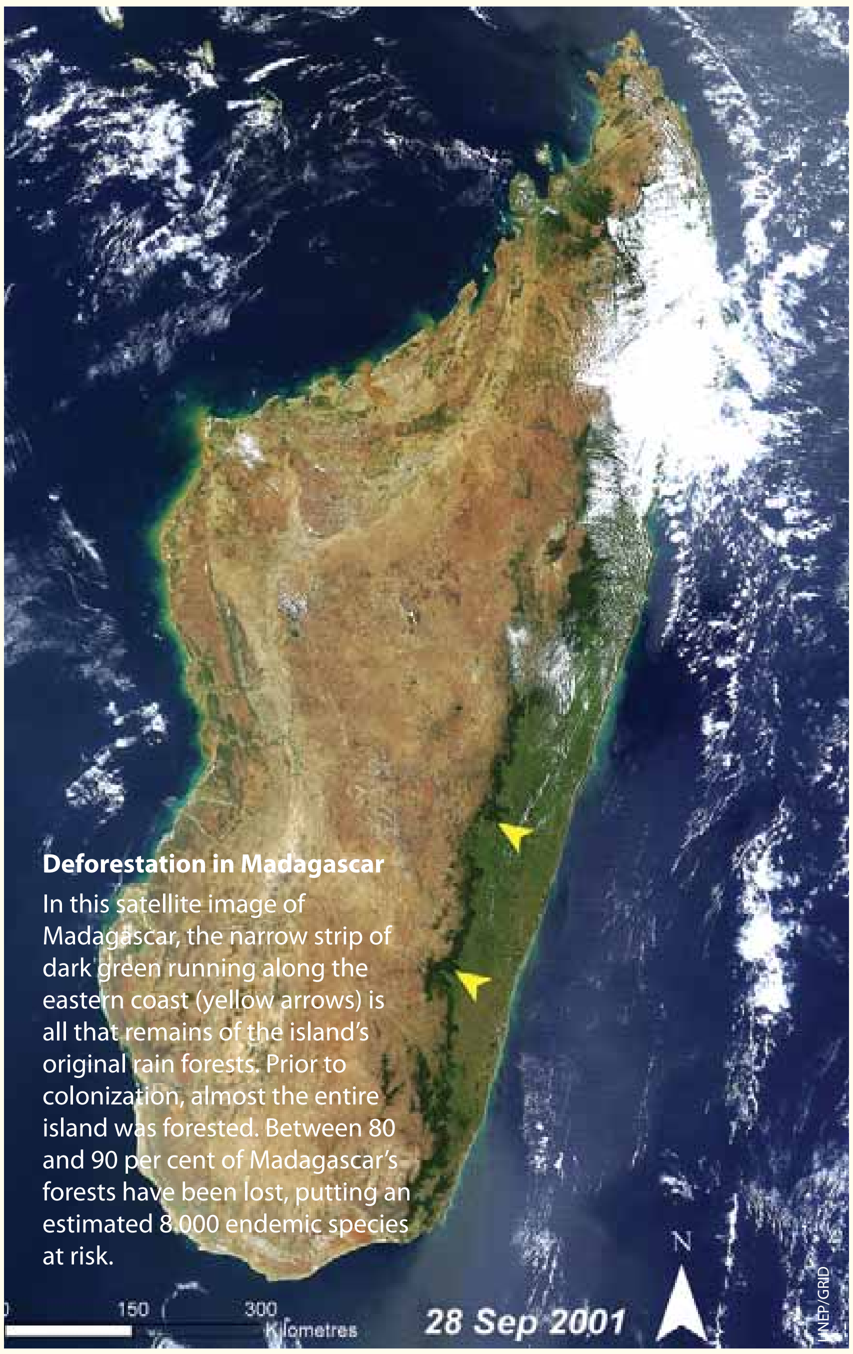
Forests cover over one-fifth of Africa's 30 million km$^2$ of land area (Kelatwang and Garzuglia 2006). The rate of deforestation is higher in Africa than on any other continent, although the rate of deforestation has slowed since the 1990s (Kelatwang and Garzuglia 2006). Of the ten countries in the world with the largest annual net loss of forested area, six are in Africa (FAO 2005). Africa loses an average of 40 000 km$^2$, or 0.6 per cent, of its forests annually, with the greatest losses occurring in heavily forested countries (FAO 2005). Logging, land conversion to agriculture and settlements, wildfires, cutting for firewood and charcoal, and civil unrest are the primary causes of deforestation in Africa; many of these pressures are driven by population growth.

Converting forests to agricultural land is necessary for food production but such deforestation negatively impacts local ecosystems as habitats are lost. Deforestation also impacts the global carbon cycle; carbon released when trees are cut, burned, or as they decompose enters the atmosphere as $CO_2$ and contributes to global warming (Willcocks 2002). Deforestation is a major reason for land degradation in Africa, especially when followed by over-cultivation and overgrazing (Slack 2002). This is especially true in areas not suited to agriculture where soil is easily eroded.

**Deforestation Rates**




Globally, deforestation continues at a rate of about 13 million hectares per year. At the same time, planting and natural expansion of forests have significantly reduced the net loss of forest area (FAO 2007).




**Deforestation in Madagascar**

In this satellite image of Madagascar, the narrow strip of dark green running along the eastern coast (yellow arrows) is all that remains of the island's original rain forests. Prior to colonization, almost the entire island was forested. Between 80 and 90 per cent of Madagascar's forests have been lost, putting an estimated 8 000 endemic species at risk.


A sifaka (*Propithecus verreauxi*) in Madagascar

Picking tea leaves, Kenya

Christian Lamberchts/UNEP

## Changes in Land Productivity

Changes in land productivity may be positive (such as irrigating or fertilizing the soil) or negative (such as pollution or erosion). As with land conversion, land productivity changes may be natural or human-induced, and if human-induced, may be accidental or deliberate. Environmental concern in Africa surrounds negative changes in land productivity due to land degradation and desertification.

## Land Degradation

Land degradation is the process of reducing the capacity of land to produce food or materials. An estimated 65 per cent of Africa's agricultural land is degraded due to erosion and / or chemical and physical damage. Thirty-one per cent of the continent's pasture lands and 19 per cent of its forests and woodlands also are classified as degraded (FAO 2005).

As of 2000, over 19 per cent of African grasslands had been converted to agricultural land, and 0.4 per cent to urban areas. Other grassland areas were lost to land degradation, often due to overgrazing by livestock (White and others 2000). Grasslands support some of the continent's highest concentrations of cattle.

More than one-quarter of Africa's arid and semi-arid lands are degraded (White and others 2000) due to soil erosion, loss of soil nutrients, pollution, or salinization. Poor farmers often have little choice but to cultivate crops or graze cattle on marginal lands, which can lead to a cycle of increasing soil erosion and land degradation. Land degradation in arid and semi-arid regions can eventually lead to desertification.

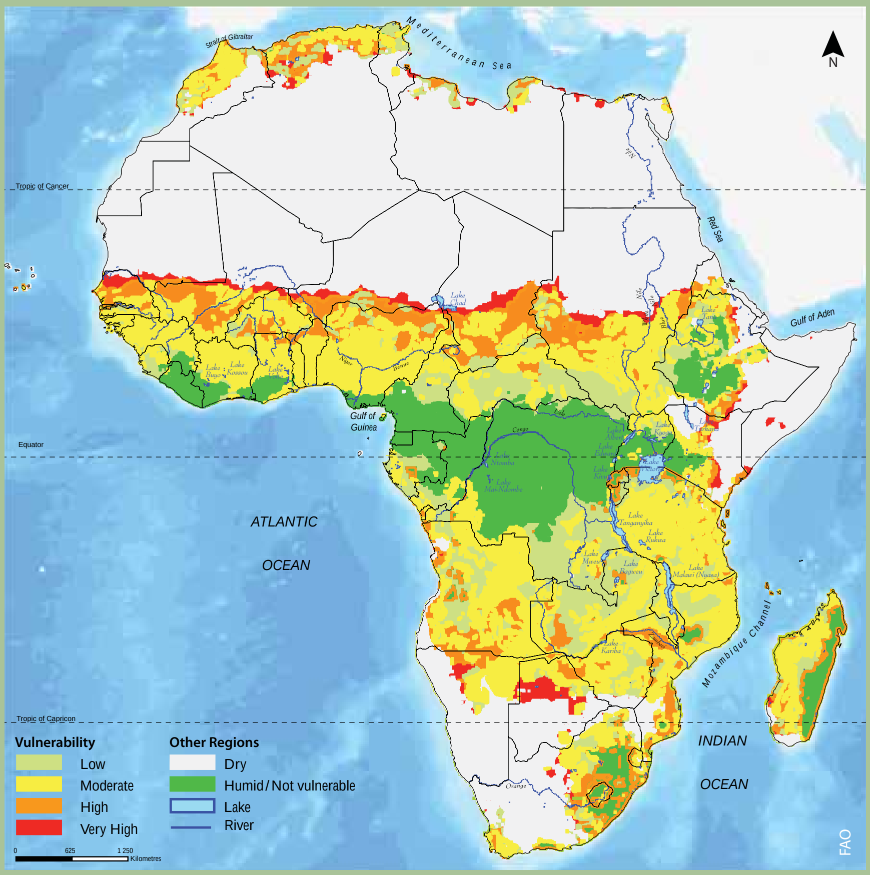
## Desertification

Desertification is one of the most severe forms of land degradation. Dry lands that form desert margins, such as those found in Sudan, the Sahel, and southern Africa are most prone to desertification. Such vulnerable lands—which occupy about five per cent of Africa's land mass—are home to 22 million people (Reich and others 2001).

Erosion and desertification are fundamentally linked. It is estimated that some areas in Africa are losing over 50 metric tonnes of soil per hectare per year. This is roughly equivalent to a loss of 20 000 million metric tonnes of nitrogen, 2 000 million metric tonnes of phosphorus, and 41 000 million metric tonnes of potassium per year. Areas of serious erosion can be found in Sierra Leone, Liberia, Guinea, Ghana, Nigeria, Democratic Republic of the Congo, Central African Republic, Ethiopia, Senegal, Mauritania, Niger, Sudan, and Somalia (FAO 1995).

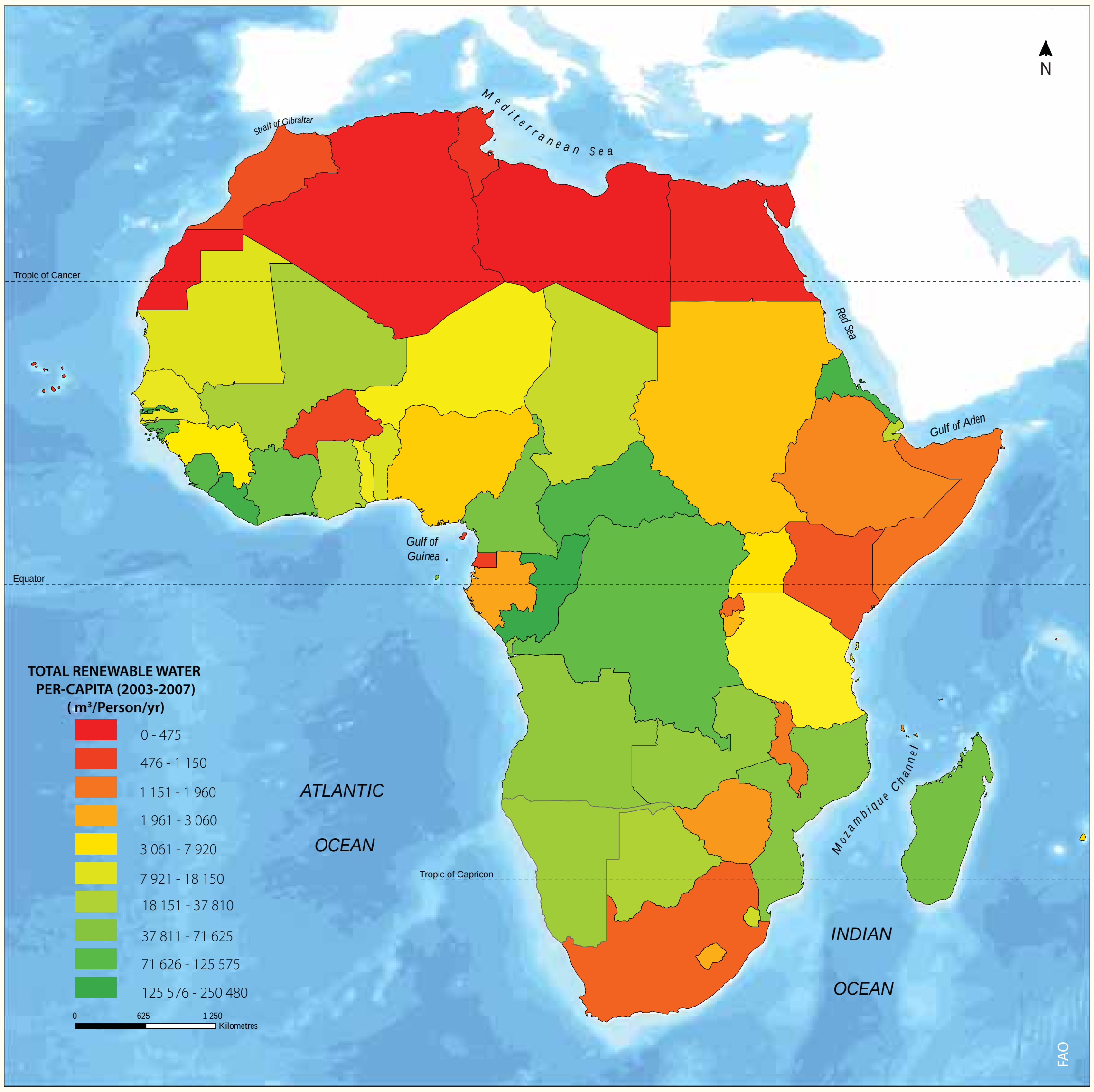
Land degradation and desertification processes result from both human activities and climatic variability. People use controlled fire to manage grasslands and savannahs for livestock production and wildlife, control pests, clear dying vegetation, and convert wild lands to cropland (Trollope and Trollope 2004). Fires are necessary to maintain the health and extent of grassland and savannah ecosystems, but if the interval between fires is too short, the land can be degraded beyond its ability to sustain farming and grazing. Land degradation and desertification can occur quickly when fire is used too much or too often in fragile arid and semi-arid areas.

**Vulnerability to Desertification**



## Water

Per Capita Renewable Water




Changes in water quality and quantity —in freshwater environments (lakes and rivers) and in coastal and marine environments—rank among the most challenging environmental and social issues that Africa currently faces.

An increasing population and a decreasing water supply leads to water scarcity and stress. Water scarcity is defined as less than 1 000 $m^3$ of potable water available per person per year, while water stress means less than 1 700 $m^3$ of potable water is available per person per year (UNEP 2002).

## Freshwater

The availability of fresh water is essential to development in Africa. Nevertheless, the per capita water consumption in Africa, 31 $m^3$ per year, is still comparatively lower than other regions—eg. North America—221 $m^3$ per year (UNESCAP 2007). Agriculture, by far, accounts for most of the water consumption and withdrawal in Africa, followed by reservoirs, municipal use, and industrial use.

In terms of agriculture, water consumption can be defined as the amount of surface and groundwater absorbed by crops and transpired, or used directly in the building of plant tissue, together with water that evaporates from the area where crops are located. Water consumption also includes all activities where the use of water results in a loss of the original water supplied, such as industrial or community consumption (UNESCO 2007). Withdrawal is the extraction of water from surface or subsurface reservoirs (UNESCO 2007).

Engineered water transfers and dams, as well as the exploitation of nonrenewable groundwater supplies, account for the overuse of freshwater supplies throughout the world. In Africa, irrigation of agricultural lands occurs in the arid and semi-arid regions in northern and southern regions of the continent and along the Sahel. In these areas, much of the surface and groundwater resources are highly exploited.

While water consumption and withdrawal in Africa has been increasing over time, the continent's water resources have been decreasing, mainly as a result of persistent droughts and changing land use patterns. The volume of water estimated to have been

### Freshwater Fish

An estimated one-fifth of all animal protein in the human diet is derived from fish. In the coastal countries of Equatorial Guinea, the Gambia, Guinea, Senegal, and Sierra Leone, at least half of the total animal protein intake comes from fish (FAO 2006). Even in many of Africa's land-locked countries, fish is the primary protein source (Finlayson and D'Cruz 2005). Urban and rural poor in Malawi get a remarkable 70 to 75 per cent of their protein from wild and aquaculture fish (Revenga and Cassar n.d.). As with other inland fisheries that depend on natural production, Africa's inland fish resources are being exploited at or above sustainable yield levels (Revenga and Cassar n.d.).

Africa is second only to Asia in the global capture of inland fish. Nile perch, tilapia, and cyprinids represent the majority of the catch in Africa's top inland fishing nations, which include Uganda, United Republic of Tanzania, Egypt, Kenya, and Democratic Republic of the Congo. Aquaculture is gaining importance in Africa. Egypt is the largest producer of fish by aquaculture, and is second only to China in the production of tilapia, a native African species (FAO 2006). Despite its potential, local populations often do not benefit from the introduction of aquaculture (or new fish species), since they usually cannot afford the technologies needed to harvest the resource (Revenga and Cassar n.d.).


Tub of tilapia

K. Santos/Flickr.com

The abundance of fish in a number of Africa's major river systems has declined (as it has in Asia, Australia, Europe, the Middle East, North America, and South America) due to targeted fishing for large freshwater species (FAO 2006). Many species, including the Nile perch, are destined for export, thereby reducing the availability of fish for local consumption (Revenga and Cassar n.d.). In addition to unsustainable harvests, inland fisheries are affected by environmental degradation and exotic species introductions (Balirwa 2007).


Getting water from a well, Nigeria

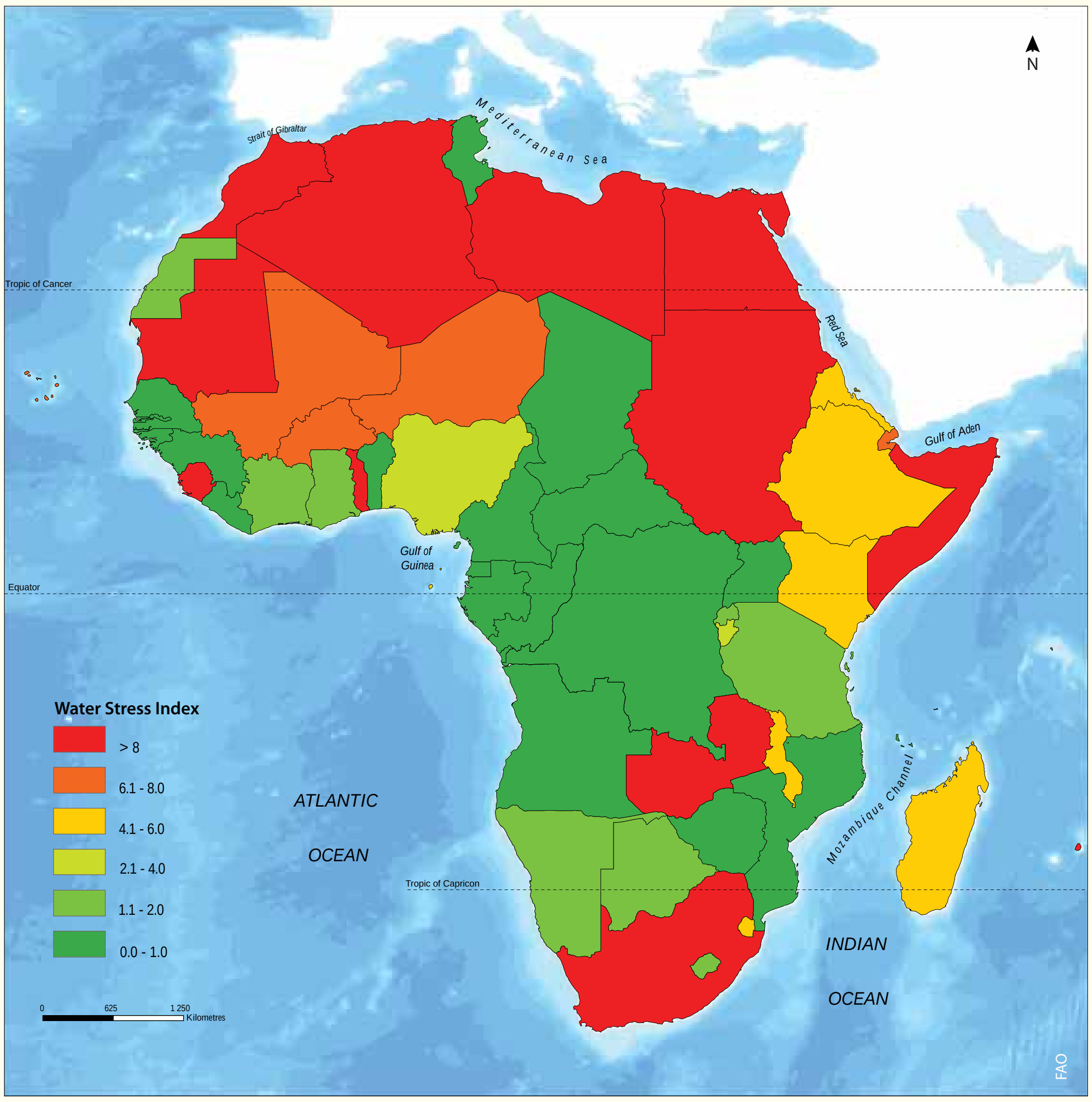
Chrystina Gastelum/Flickr.com

lost from the African land mass during a three-year period ending in approximately 2006 was about 334 km$^3$, which is as much water as Africans consumed over the same period (Amos 2006).

Lack of water often constrains farming and human activities, while water pollution diminishes its availability and is a source of waterborne disease. An increase in the need for fresh water by growing populations, coupled with a history of periodic drought and evidence of recent increased rainfall variability due to climate change, has created conditions of water scarcity and water stress in many regions throughout Africa.

Continued climate change will aggravate this situation. By 2050, it is expected that areas experiencing water shortages in sub-Saharan Africa will have increased by 29 per cent. By 2100, water flow in the Nile River region is expected to decrease by 75 per cent, with damaging consequences for irrigation practices. Declining water levels in many rivers and lakes is expected to affect water quality, exacerbate waterborne diseases, and reduce available hydropower (UNEP 2006c). Lack of clean water and sanitation leads to a wide range of potential diseases including malaria, yellow fever, filariasis, river blindness, sleeping sickness, guinea worm, bilharzia, trachoma, and scabies. Most importantly, dirty water is often the cause of childhood diarrhoea, a leading killer of African children (AMREF 2008).

**Water Stress**




Water pollution exacerbates water scarcity and impacts fisheries. Dams and water transfer can affect water quality. The damming of the Nile River at Aswan, for example, has reduced the level of nutrients so much that the sardine catch in the Nile Delta has fallen from 22 618 million metric tonnes in 1968 to under 13 500 million metric tonnes in 2002, and it is still declining (Bird and Medina 2002).

It is estimated that over 300 million people in Africa face water scarcity conditions. By 2025, 18 African countries are expected to experience water stress (UNEP 1999).

## Wetlands

Africa's many types of wetlands, from West Africa's saline coastal lagoons to East Africa's fresh and brackish-water lakes, provide natural resources for many rural economies. Rising poverty, increasing population, periodic droughts, and exploitation by private landowners have degraded these ecosystems to the detriment of wetland organisms and local populations (Schuijt 2002).

There are few data concerning wetland losses in Africa. A 2005 review of wetland inventories in ten countries in southern Africa found significant losses in two areas in KwaZulu Natal: Tugela Basin, where over 90 per cent of wetland resources have been lost in parts of the basin, and the Mfolozi catchment (10 000 km$^2$), where 58 per cent of the original wetland area (502 km$^2$) had been lost (Taylor and others 1995). Another study in 1992 reported an overall loss of 15 per cent of wetland area in Tunisia and 84 per cent wetland loss in the region's Medjerdah catchment (Moser and other 1996). Losses may be due to land conversion, water extraction, and climate change.

## Coastal and Marine Environments

Africa's coastal and marine resources have great ecological, social, and economic importance, both locally and for the global community (UNEP 2002). Local communities are heavily dependent on coastal resources such as mangrove trees for construction, for medicinal and food products, and for subsistence or small-scale trade. Commercial fishing, tourism, and the oil and gas industry all make substantial contributions to the national economies of coastal African countries as well (UNEP 2002). Many of these activities, however, are over-exploiting, degrading, and polluting Africa's marine and coastal resources and habitats.

Countries whose main source of revenue comes from oil extraction, such as Nigeria and Angola, have been unable to protect their coastal and marine environments from damaging oil spills from refineries, wells, ports, and transportation routes (EIA 2003). Coastal development and modification is also undermining the ability of natural landforms and other features to protect and stabilize shorelines. Coastal communities have suffered economic and social losses related to the depletion of fish stocks, the deterioration of recreational and tourism attractions, and rising costs for water treatment and coastal protection (UNEP 1999).

### Benguela Current Large Marine Ecosystem

The Benguela Current Large Marine Ecosystem (LME) is located along the southwest coast of Africa, alongside Angola, Namibia, and South Africa. It is the world's most powerful wind-driven coastal upwelling. It is also a highly productive ecosystem—its mean annual primary productivity of 1.25 kg of carbon per square metre is about six times higher than that of the North Sea ecosystem. It thus harbours a globally significant reservoir of biodiversity and biomass of marine organisms. There are also rich deposits of precious minerals and oil and gas reserves in near-shore and off-shore sediments. The Benguela Current LME is subject to high variability. Local fisheries are periodically affected by episodic warming in the eastern Atlantic that causes sea temperatures to rise offshore of Namibia and southern Angola. These events displace fish stocks and cause massive marine-life mortalities. The region is also subject to harmful algal blooms (HABs), since much of the water is naturally hypoxic (lacking in oxygen), a condition exacerbated by local oxygen depletion processes. For many decades, a large variety of fish species have been exploited in this region, especially pilchards and mackerels, ground fish, rock lobster, high seas tuna, shrimps, and deep-sea species. The artisanal fishery provides food and income to many coastal communities. The commercial fisheries off the coast of Namibia have been over-exploited, but generally other marine activity has been minor. However, a number of new or increasing developments in oil, gas, and diamond extraction, as well as aquaculture, industrial fishing, and tourism are poised to expand posing new or more serious threats to the Benguela Current LME. In addition, the ecosystem is very vulnerable to the potential impacts of climate change, further increasing the challenge to manage its resources sustainably.


In 1995, the governments of Angola, Namibia, and South Africa initiated the BCLME Programme to manage the Benguela Current LME in a sustainable way, recognizing that a coordinated ecosystem approach is needed to deal with issues such as migrating or straddling fish stocks, invasive alien species, pollutants, and HABs that cross national boundaries, and that there are economic benefits to be gained from such an effort.

*Sources: BCLME n.d.; Shannon and O'Toole 2003; UNEP/RSP 2006*


The Skeleton Coast Park spans over 16 400 km$^2$, running 500 km north from the Ugab River in Namibia to the Kunene River along Angola's coast.

Rwenzori Mountains National Park, Uganda

Christian Lambrechts/UNEP

## Biodiversity

Biological diversity, or biodiversity, is the term used to describe the full array of life in a region, including species richness, ecosystem complexity, and genetic variation. Biodiversity may be the greatest natural resource, as it is a source of food, medicines, clothes, energy, building materials, clean air, clean water, psychological well-being, and countless other benefits (Norse and others 1986). The effective use of biodiversity at all levels—genetic material, species, communities, and ecosystems—is a precondition for sustainable development. However, human activities are the root cause of declining biodiversity worldwide; losses of plants, animals, and other species are taking place at a rate far higher than the natural background rate of extinction (UNEP 2008).

It may be too late to stem the loss of biodiversity in certain parts of the world; however, in most of Africa the opportunity still exists for proactive intervention (Biodiversity Support Program 1993). Africa's competitive advantage is enhanced not only by the fact that its environment is among the world's richest biologically but also by the fact that it has not yet sacrificed its endowment of these resources (Biodiversity Support Program 1993). Africa's living organisms account for almost one-third of global biodiversity, with the greatest concentrations occurring in the African equatorial ecosystems and those that border them.

Of the world's 4 700 mammal species, one-quarter occur in Africa. Huge populations of mammals are found in the eastern and southern savannahs, including at least 79 species of antelope (UNEP and McGinley 2007). Africa also has more than 2 000 species of birds—one-fifth of the world's total—and at least 2 000 species of fish, more than any other continent.

In addition, Africa has about 950 million amphibian species. New species of amphibians and reptiles are still being discovered. For example, during the 1990s, discoveries of new amphibian and reptile species in Madagascar alone increased the number of known species of these organisms by 25 per cent and 18 per cent, respectively (Anon 2007).

The African mainland has between 40 000 and 60 000 plant species. Southern Africa alone has at least 580 families and about 100 000 known species of insects, spiders, and other arachnids (Anon 2007).

Eight of the world's 34 biodiversity hotspots are in Africa (CI 2007c). To qualify as a hotspot, a region must contain at least 1 500 species of vascular plants (> 0.5 per cent of the world's total) as endemics, and it must have lost at least 70 per cent of its original habitat (CI 2007b).

Scientists have designated the African biodiversity hotspots on the basis of both existing biodiversity and the threats to that biodiversity with the intention of focusing protection efforts on these valuable areas. Over the last 30 years, the efforts to protect and sustain biodiversity have strengthened. More recently, there has been a shift toward focusing on the sustainable use of biodiversity resources and the sharing of their benefits.

Nevertheless, biological diversity in Africa continues to decline (UNEP 2002). Over 120 plant species are extinct, with another 1 771 threatened (Bird and Medina 2002). Threats to species are both direct (such as bushmeat hunting) and indirect (such as habitat loss). Some species, such as the Bonobo or pygmy chimpanzee (*Pan paniscus*), exist in very limited areas. Loss of habitat in these relatively small areas can lead to the rapid extinction of species (Brooks and others 2002). Much effort has gone into designating protected areas in Africa with the hope of saving these areas of crucial habitat.

**Table 1.2 - African Hotspots and Their Vital Signs**

| Hotspot | Vital signs | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Hotspot Original Extent (km²) | Hotspot Vegetation Remaining (km²) | Endemic Plant Species | Endemic Threatened Birds | Endemic Threatened Mammals | Endemic Threatened Amphibians | Extinct Species† | Human Population Density (people/km²) | Area Protected (km²) | Area Protected (km²) in Categories I-IV* |
| Cape Floristic Region | 78 555 | 15 711 | 6 210 | 0 | 1 | 7 | 1 | 51 | 10 859 | 10 154 |
| Coastal Forests of Eastern Africa | 291 250 | 29 125 | 1 750 | 2 | 6 | 4 | 0 | 52 | 50 889 | 11 343 |
| Eastern Afromontane | 1 017 806 | 106 870 | 2 356 | 35 | 48 | 30 | 1 | 95 | 154 132 | 59 191 |
| Guinean Forests of West Africa | 620 314 | 93 047 | 1 800 | 31 | 35 | 49 | 0 | 137 | 108 104 | 18 880 |
| Horn of Africa | 1 659 363 | 82 968 | 2 750 | 9 | 8 | 1 | 1 | 23 | 145 322 | 51 229 |
| Madagascar and the Indian Ocean Islands | 600 461 | 60 046 | 11 600 | 57 | 51 | 61 | 45 | 32 | 18 482 | 14 664 |
| Maputaland-Pondoland-Albany | 274 136 | 67 163 | 1 900 | 0 | 2 | 6 | 0 | 70 | 23 051 | 20 322 |
| Succulent Karoo | 102 691 | 29 780 | 2 439 | 0 | 1 | 1 | 1 | 4 | 2 567 | 1 890 |

† Recorded extinctions since 1500 *Categories I-IV afford higher levels of protection

Source: Conservation International: Biodiversity Hotspots, 2007

# 8 Biological Hotspots of Africa




## Guinean Forests of West Africa

The Guinean Forests of West Africa are home to more than a quarter of Africa's mammals, including more than 20 species of primates. These and other species are threatened by logging, mining, hunting, and ever-increasing numbers of people.

## Cape Floristic Region

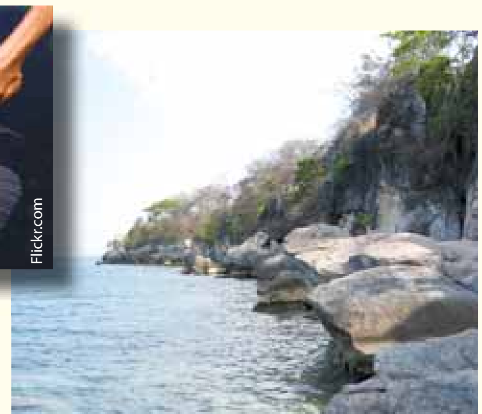
This is one of the world's five Mediterranean climate zone hotspots and contains its largest non-tropical concentration of higher vascular plant species. It is the only hotspot encompassing an entire floral kingdom.





## Succulent Karoo

The Succulent Karoo of South Africa and Namibia boasts the world's richest succulent flora and exceptional plant endemism—69 per cent of its plants are found nowhere else—as well as a number of unique reptile species. It is one of only two of the world's completely arid hotspots. Grazing, agriculture, and mining threaten this fragile region.



## Eastern Afromontane

This hotspot is formed by scattered mountains with very similar plant communities. The Albertine Rift has more endemic mammals, birds, and amphibians than any other African region. The Eastern Afromontane also contains some of the world's most extraordinary lakes, which harbour about 617 endemic fish species. Agricultural expansion of crops such as bananas, beans, and tea, as well as the growing demand for bushmeat, are threatening the region's biodiversity.

## Maputaland-Pondoland-Albany

Maputaland-Pondoland-Albany, which stretches along the east coast of southern Africa, is an important centre of plant endemism, with nearly 600 tree species alone. This region has the world's highest tree diversity of any temperate forest. One of the region's most well-known endemic plants is the Bird of Paradise flower (*Strelitzia reginae*). This hotspot is also world-renowned for its conservation efforts to save the southern subspecies of white rhinoceros from extinction. Commercial and local small-scale farming and the expansion of grazing lands are encroaching on the extensive grassland habitats here, threatening many of its large mammals.






## Coastal Forests of Eastern Africa

This tiny and fragmented hotspot has exceptional levels of biodiversity. It is the original source of the world's lucrative trade in cultivated African violets and is home to a wide variety of threatened primates, including some that are endemic. The expansion of both commercial and subsistence agriculture is severely threatening this habitat.


## Madagascar and the Indian Ocean Islands

Madagascar and the Indian Ocean Islands have exceptional biodiversity: eight plant families, four bird families, and five primate families that are found nowhere else on Earth. Madagascar has more than 50 lemur species, although 15 others have become extinct since the arrival of humans. A number of critically endangered bird species inhabit the Seychelles, Comoros, and Mascarene islands in the Indian Ocean.

## Horn of Africa

The Horn of Africa is one of the two entirely arid global hotspots and is renowned for its biological resources. It has Africa's highest number of endemic reptiles and a number of endemic and threatened antelope. With only five per cent of its original habitat remaining, this hotspot is also one of the world's most degraded. It has been devastated by overgrazing and charcoal harvesting.






# A Few African Species Extinct in the Wild


## Barbary Lion

***Panthera leo leo***

### North Africa

The Barbary (also called Atlas or Nubian) lion was found throughout northern Africa from Morocco to Egypt. Studies have concluded that the Barbary lion was most closely related to Asian lions. The last known individual in the wild was killed in the Atlas Mountains in 1922.


## Pinstripe Dambo

***Paretroplus menarambo***

### Madagascar

The pinstripe dambo was endemic to a small region of Madagascar but is presumed extinct in the wild. Despite targeted surveys, no specimens have been collected in recent years. However, breeding populations of this species are maintained in captivity. The main causes for the loss of this species were deforestation, introduced alien species, and overfishing.


## West African Black Rhino (Extinct)

***Diceros bicornis longipes***

### Central West Africa

Among two of Africa's most threatened rhinoceros subspecies is the West African Black Rhino. According to the African Rhino Specialist Group of the International Union for the Conservation of Nature and Natural Resources (IUCN) Species Survival Commission, the West African Black Rhino is now feared extinct. An intensive survey of the West African black rhino in early 2006 has failed to locate any sign of their continued presence in their last refuges in northern Cameroon. Poaching for rhino horn is the main cause of their demise.


## Scimitar Oryx

***Oryx dammah***

### Algeria, Burkina Faso, Chad, Egypt, Israel, Libyan Arab Jamahiriya, Mali, Mauritania, Morocco, Niger, Nigeria, Senegal, Sudan, Tunisia, Western Sahara

The scimitar oryx, or scimitar-horned oryx is a species of oryx which once inhabited the whole of North Africa and was one of the most common large mammals of the region. There are conflicting reports as to whether it is extinct in the wild, or whether small populations still survive in central Niger and Chad. Currently listed as extinct on the IUCN Red List, the scimitar oryx is now part of a major captive breeding and reintroduction programme.


## Dodo (Extinct)

***Raphus cucullatus***

### Mauritius

The Dodo was a flightless bird that lived on the island of Mauritius. Related to pigeons and doves, it stood about one metre tall, lived on fruit, and nested on the ground. The dodo has been extinct since the mid-to-late 17th century. It is commonly used as the archetype of an extinct species because its extinction occurred during recorded human history and was directly attributable to human activity. The birds were killed by sailors and settlers for food, and their eggs and young were devoured by cats, dogs, and other non-native animals that were introduced to Mauritius.


## Blue Antelope or Bluebuck (Extinct)

***Hippotragus leucophaeus***

### South Africa

The bluebuck, or blue antelope, was the first large African mammal to become extinct in historical times. Bluebuck numbers began dropping about 2 000 years ago and the species was already rare by the 1700s. Various factors have been suggested as the cause of their extinction, including the change of grassland into bush and forest when the climate became warmer, and the human introduction into their habitat of livestock, particularly sheep, at about that time. Competition with sheep, diseases, or hunting may all have contributed to a decline in bluebuck. The last bluebuck was reportedly killed in 1799.


## Giant Tortoise

***Cylindraspis***

### Mauritius, Seychelles

Giant tortoises were considered extremely valuable by early mariners for food as they could survive for months in captivity without food and water. Their flesh and oil was considered a cure for scurvy. Sadly, thousands were wastefully harvested, with many specimens being left to rot after their valuable liver and oil had been removed. Most sub-species became extinct in the early years of the 18th century.

## Egyptian Barbary Sheep

***Ammotragus lervia ornata***

### Eygpt

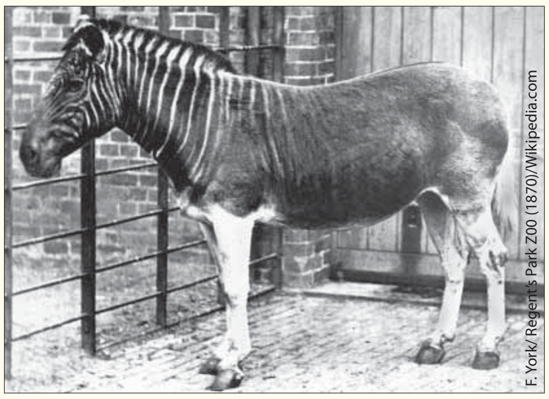
The native range of the Egyptian Barbary sheep was the arid hills east of Cairo, Egypt, and the rugged terrain bordering both sides of the Nile River in southern Egypt. It is thought that the Egyptian Barbary sheep probably became extinct in the wild in the 1970s or 1980s. The species does survive, however, in captive breeding programmes.


## Seychelles Parakeet (Extinct)

***Psittacula wardi***

### Seychelles

The Seychelles parakeet was endemic to Mahé and Silhouette, two islands in the Seychelles group. This small, primarily green parrot was already rare when it was first described by Europeans in the 1860s. The Seychelles parakeet was finally driven to extinction in 1906, largely due to the clearing of its forest habitat for coconut plantations and eradication efforts to keep it from eating crops.




## Quagga (Extinct)

***Equus quagga***

### South Africa

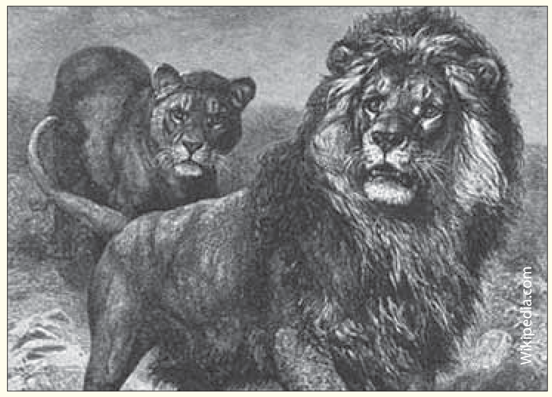
The quagga, a grazing mammal closely related to zebras, was native to desert areas of southern Africa. It was especially abundant in South Africa's Cape Province. Quaggas were distinguishable from zebras by the fact that they had brown-and-tan stripes on the front part of the body only. The stripes faded toward the hindquarters, which were solid brown. Prized for its meat and hides, the quagga was hunted to extinction in the 1870s. The last specimen in captivity died in 1883.


## Mauritius Blue Pigeon (Extinct)

***Alectroenas nitidissima***

### Mauritius

This beautiful red, white, and blue pigeon was also named Pigeon Hollandais because of its resemblance to the colours of the Dutch flag. It was hunted extensively and had already become rare by the 1730s. Monkeys and rats preyed on the pigeon's eggs and chicks, and deforestation fragmented its habitat. The last specimen was collected in 1826, and hunting and habitat loss eventually brought about the species' extinction in the 1830s. There are three surviving skins of this species, one in Edinburgh, England, one in Paris, France and one in the Mauritius Institute, the latter belonging to the last surviving individual.




## Cape Lion (Extinct)

***Panthera leo melanochaitus***

### Cape of South Africa

The Cape lion was once found throughout southern Africa from the Cape of Good Hope to the Province of KwaZulu Natal. Cape lions were the largest and darkest of all sub-Saharan lions. The last known Cape lion in the wild was killed in 1858. Until recently, researchers disputed whether the extinct Cape lion was a true species, or merely a subspecies, of African lion. Genetic research, published in 2006, did not support the "distinctness" of the Cape lion. It now seems probable that the Cape lion was only the southernmost population of the extant southern African lion.


## Haplochromis Ishmaeli

***syn. Labrochromis ishmaeli***

### Lake Victoria in Kenya, United Republic of Tanzania, Uganda

*Haplochromis ishmaeli*—a specialized snail eater—is not only extinct in the wild but also rare in the aquarium fish industry. This small muscular fish eats mollusks. But unlike other snail-eating fish, which extract the mollusk from its shell, *Haplochromis ishmaeli* ingests the entire animal, shell and all.

*Sources: Creighton, B 2000, IUCN n.d., National Geographic News 2006, The Bay Science Foundation, Inc. 2007, Pedersen, M. 1999, Mass, P. 2007, Preservation Station Inc. 2005, Steeves, G. and A. 2007*

NASA 2001a

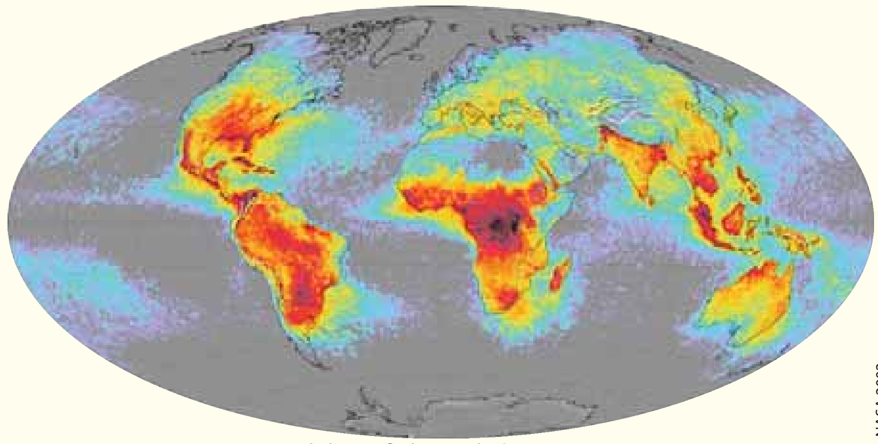
The foundation of science is observation. Throughout the history of science, instruments have been developed to allow observation of objects and processes that had previously been inaccessible. The microscope, the telescope, X-ray imaging, and the particle accelerator have brought unknown realms of the physical world into view. In the science of Earth observation, satellite remote sensing is the tool that has allowed us to study and monitor our planet in entirely new ways.

## Africa at Night

This 2001 satellite image mosaic (NASA 2001a) shows the African continent at night. Concentrations of electric lights stand out as white dots and streaks against a much darker background. Light distribution correlates with population density. Africa's large cities and other densely populated areas, located primarily along the coast and major river systems, are brightly lit. But much of the Sahara and the dense rain forests of the continent's interior remain dark. In 2004, Africa, with about 12 per cent of the world's population, consumed a mere one-tenth of the electricity used in North America, which had 5.1 per cent of global population (IEA 2005).

## Africa—Lightning Centre of the World

Lightning, a discharge of energy during severe storms, may affect public safety, electrical and transportation systems, and may even trigger wildfires. Detecting lightning helps scientists to understand Earth's climate system and monitor changes in severe storms and precipitation patterns over time. The map (right) shows the average yearly number of lightning flashes per square kilometre based on data collected between 1995 and 2002. The places with the highest number of lightning flashes per square kilometre per year appear as dark red patches. Although lightning is common across much of Africa, it is very common near the heart of the continent. It is probably no coincidence that this is also the region where most of Africa's wildfires occur (NASA 2002a). Africa has more lightning flashes per square kilometre than anywhere else on Earth.

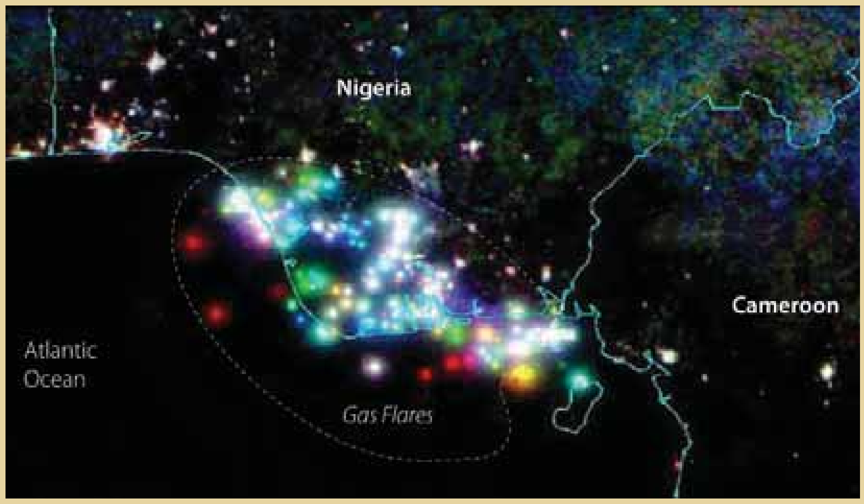



NASA 2002a

### Gas Flaring in the Niger Delta

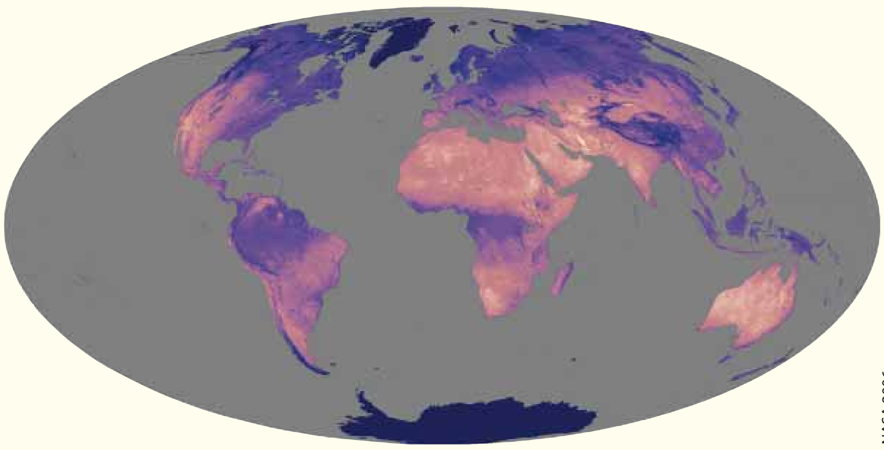
Nigeria has significant petroleum and natural gas reserves in its Niger River delta region. During the production of petroleum, most of the associated natural gas ends up being burned off, or flared. The flaring of gas has been practiced in the Niger Delta region for over four decades. Alongside carbon dioxide emissions, about 4 580 million kilowatts of heat are discharged into the atmosphere above the Niger Delta from flaring 548.6 million cubic metres of gas every day. This practice not only has economic implications in terms of wasted resources that could be used in energy generation, but is also a source of environmental degradation.

Nigeria, however, has been gradually reducing the amount of gas flared, with the aim of stopping the practice altogether. This change is confirmed by analysis of a series of satellite images produced by the World Bank in collaboration with the U.S. National Oceanic and Atmospheric Administration (NOAA) over a period of 14 years. The composite satellite image (above) shows a reduction in gas flaring in Nigeria over 14 years. The year 2006 is in red, 2000 is in green and 1992 is in blue.



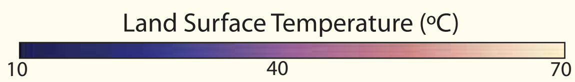

*Source: Uyigue and Agho 2007; World Bank 2007*

## Global Land Surface Temperature



NASA 2006a

This image shows the highest land surface temperatures recorded worldwide between 2003 and 2005. Africa is one of the world's hottest regions. The hottest places, shown in light pink, are largely barren or sparsely vegetated deserts. These areas are prevalent in northern Africa, southern Asia, Australia, and parts of western North and South America. Densely vegetated areas are much cooler and appear purple in the image (NASA 2006a).



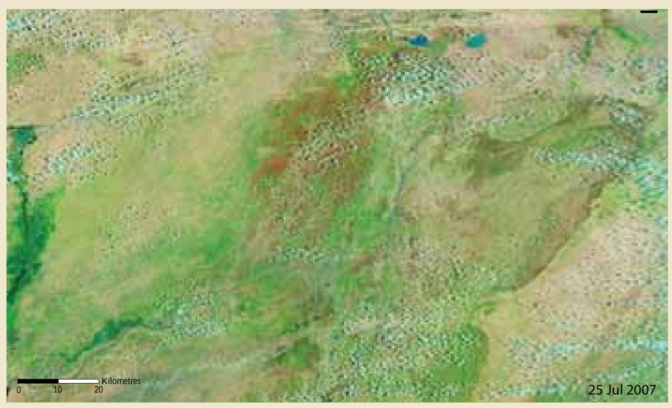

### Flooding in Mali

Like many other countries in Africa's Sahel region, Mali was flooded in September 2007. Heavy rains pushed the converging Niger and Bani Rivers over their banks and filled the surrounding wetlands with water.

The 25 July 2007 satellite image taken before the heaviest rains settled in, shows smudges of light blue along the left edge, which are water-soaked ground typical of flooding, indicating that the floods had already started. The Niger and Bani Rivers, however, were still too small to be seen clearly.

By 15 September 2007, the rivers had widened, expanding into pools throughout the surrounding wetlands. In the September 2007 image, water is black or dark blue, in contrast to the pale tan earth and the bright green plant-covered areas (clouds are light blue and white). The Niger River remained flooded along its entire length, through Mali and Niger, and into Nigeria. A further testament to the rainfall is the greening of the landscape. Wetlands bordering the rivers went from tan-red, a colour typical of recently burned areas where few or no plants are growing, to vivid green. The floods extended far beyond the region. As many as 17 countries and more than a million people were affected by flooding across Africa.

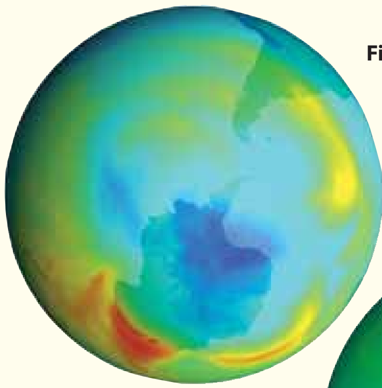
*Source: NASA 2007a*



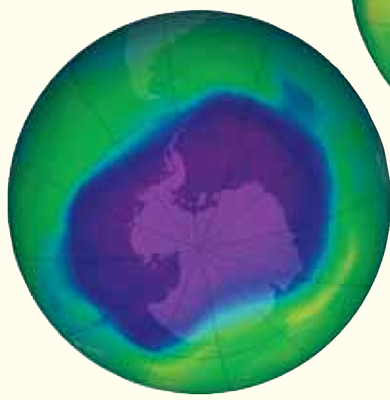

## Africa and Ultra Violet (UV) Exposure

The ozone layer in the upper atmosphere provides a shield that blocks harmful ultraviolet rays from reaching the Earth's surface. Human-made ozone-depleting substances such as chlorofluorocarbons and related chemical compounds have led to a thinning of the ozone layer. As a result of ozone loss worldwide, more dangerous UV radiation reaches the Earth's surface, increasing the potential risk of skin cancer in people and adversely impacting marine organisms, plants, and animals.

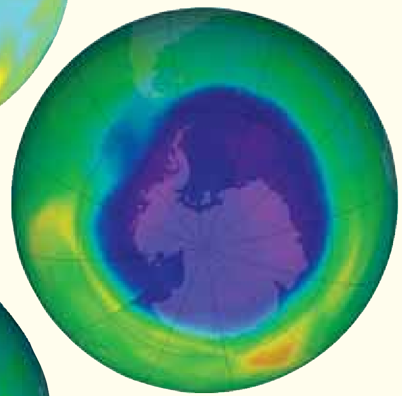
In addition to general loss of atmospheric ozone worldwide, massive ozone loss occurs each austral spring over Antarctica, resulting in what is known as the Antarctic "ozone hole." In the Northern Hemisphere, a similar although less extensive ozone hole forms over the North Pole each spring. Although the protective ozone layer thins each year significantly more at the poles than at the equator, Africa and other equatorial regions tend to receive more UV radiation than do higher latitudes. One reason for this is because UV radiation is somewhat blocked by cloud cover, and at certain times of the year, many regions in Africa are relatively cloud-free. Another factor is that equatorial regions receive more sunlight than higher latitudes where the sun's rays strike at oblique angles, spreading UV radiation over a wider surface area (NASA 2008b; Allen 2001).



19 December 1979
**First Antarctic Zone Hole Recorded** (NASA 2002b)

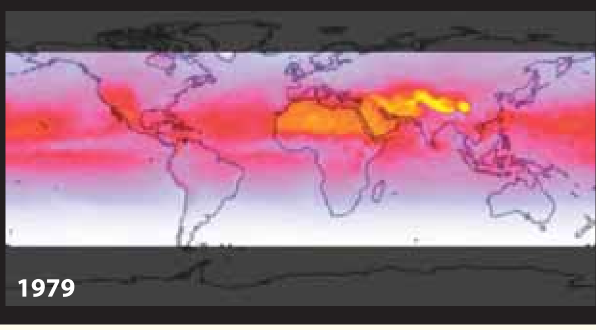


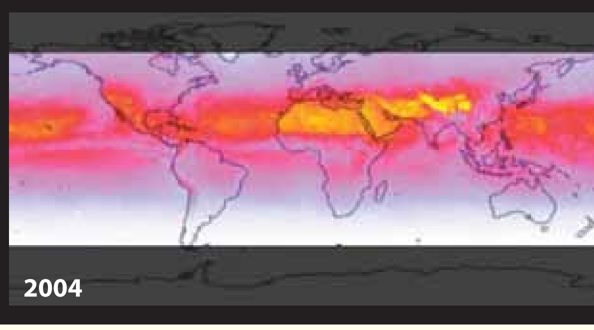
24 September 2006
**Largest Hole Recorded**
(NASA 2006b)

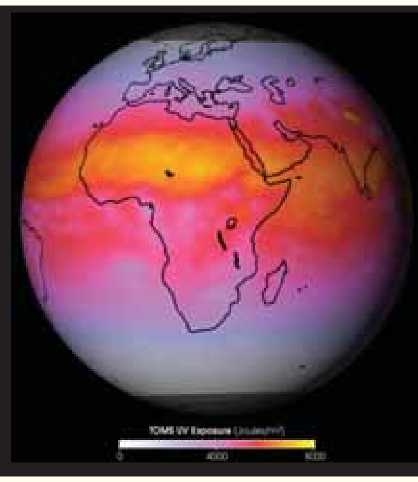


13 September 2007
**Most Recent Recording**
(NASA 2007b)

This image shows UV radiation levels based on data collected during the month of July in 1979 (below left) and 2004 (below right). Very high UV levels, represented by orange and yellow colouration, appear over the Sahara, Saudi Arabia, the southwestern United States, and the Himalayan Mountain regions in northern India and southern China.



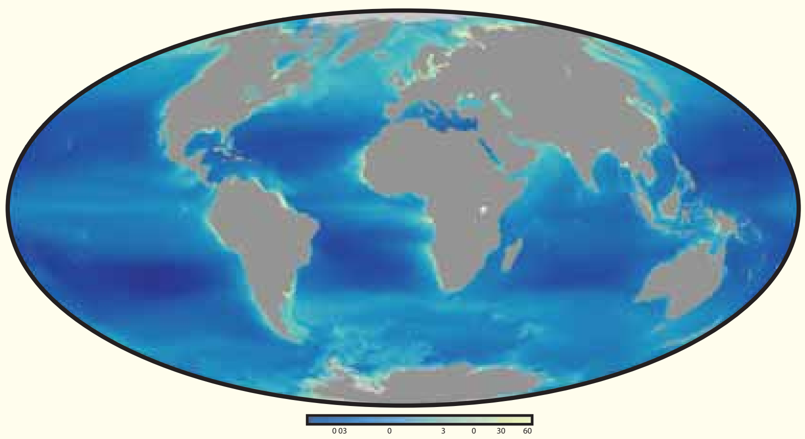



## Global Phytoplankton Distribution

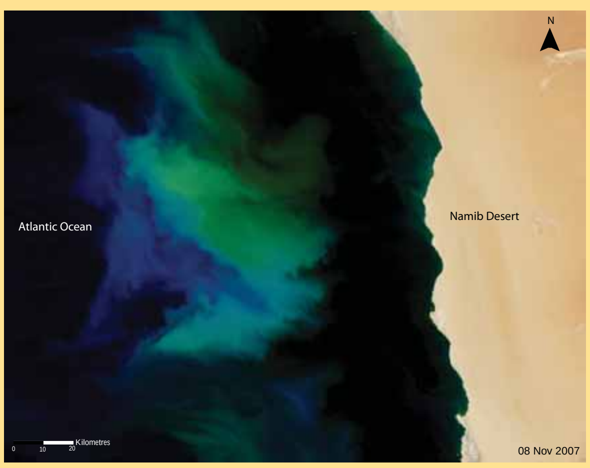
This image represents a decade of satellite observations showing average chlorophyll concentrations in the Earth's oceans from mid-September 1997 through the end of August 2007. Satellite sensors record the amount of light characteristically absorbed by chlorophyll in algae and other marine organisms that carry out photosynthesis. Photosynthesis is the biochemical process in which water and carbon dioxide are converted into sugar (glucose) and oxygen using energy from sunlight.

In general, high chlorophyll concentrations correspond with high numbers of these marine photosynthesizers, which form the base of nearly all ocean food webs. Where these organisms thrive, the ocean appears light blue to yellow in the image; less productive regions are dark blue. Thus, this image gives an overall view of global ocean productivity, although it should be noted that productivity in polar regions is seasonal. Marine algae and other photosynthesizing ocean organisms absorb more carbon dioxide than any other group of living things on Earth, including dense tropical forests. Since $CO_2$ is an important greenhouse gas, these organisms play an important role in mitigating global warming (NASA 2007c).



Chlorophyll Concentration

NASA 2007c




### Phytoplankton Bloom off Namibia

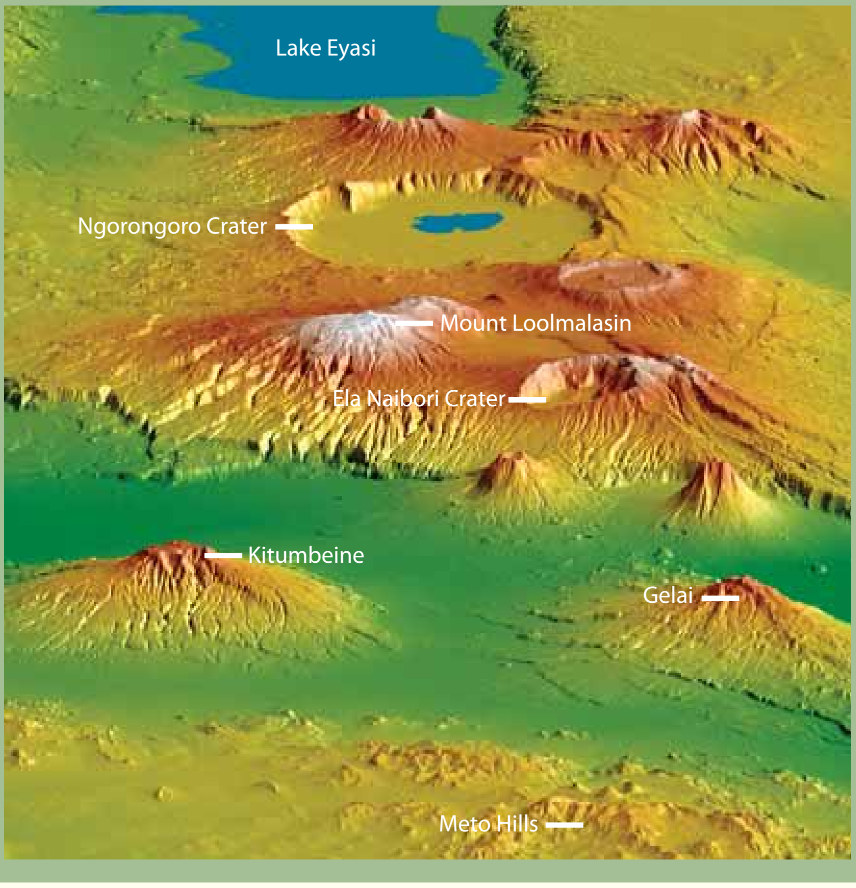
Phytoplankton are tiny photosynthesizing algae and other organisms that make up the vast drifting mass of marine life known as plankton. Phytoplankton "blooms" are common off the coast of Namibia. The eventual death and decomposition of the vast numbers of organisms in these blooms robs the water of dissolved oxygen. This creates an oxygen-depleted "dead zone" where fish cannot survive.

This satellite image, captured in 08 November 2007, shows a phytoplankton bloom (light blue and green areas) stretching along hundreds of kilometres off the Namibian coast. Such blooms are common in the coastal waters off southwest Africa. Cold, nutrient-rich currents flowing north along the ocean floor from Antarctica rise to mix with warmer surface waters. Phytoplankton thrive where such upwellings occur. (NASA 2007d).

### Crater Highlands, United Republic of Tanzania

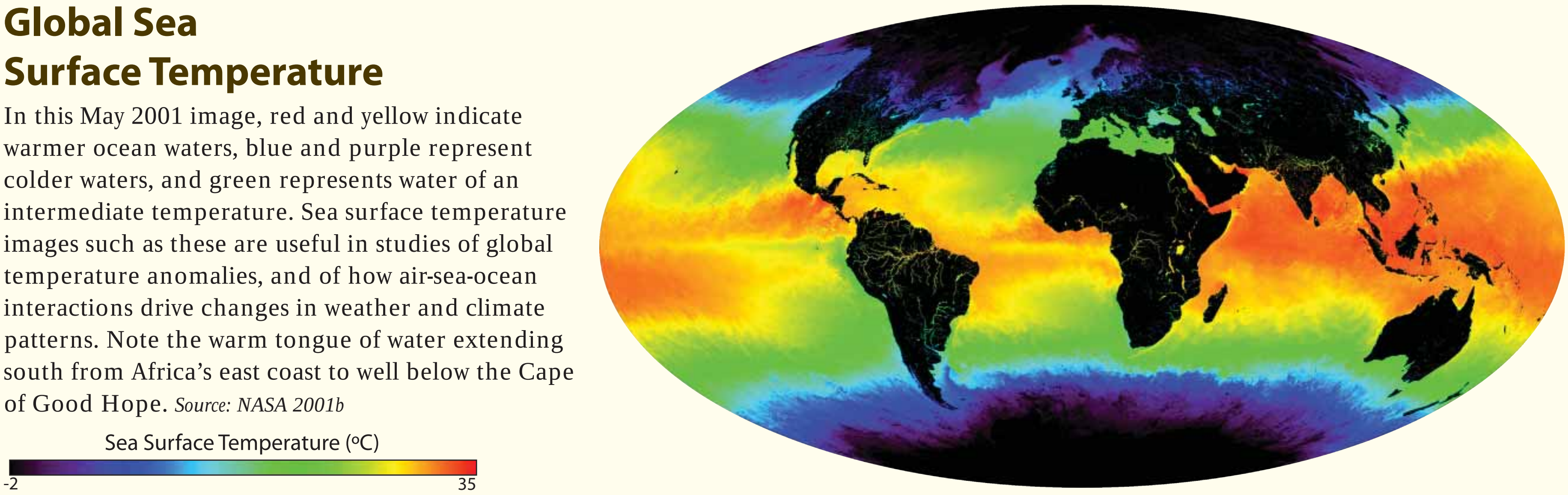
Plate tectonics, volcanism, landslides, erosion and deposition—and their interactions—are all very evident in this computer-generated view of the Crater Highlands, along the East African Rift (based on satellite and other data). The lower elevations are shown as green while higher elevations appear as brown; snow-capped peaks are white. These Crater Highlands rise far above the adjacent savannahs, capture moisture from passing air masses, and are home to dense rain forests.

The East African Rift is a zone of spreading, or rifting, between the African tectonic plate (on the west) and Somali tectonic plate (on the east). Two branches of the Rift intersect in the United Republic of Tanzania, resulting in distinctive and prominent landforms. One rift runs from southwest to northeast (top to bottom in this southwest facing view). The other rift, running southeast to northwest, corresponds to the band of low elevation crossing the bottom of the image (green). Volcanoes are often associated with spreading rift zones where magma, rising to fill gaps between moving plates, reaches the surface, erupts, and builds cones. Craters form when part of a volcano explodes. Calderas, such as Ngorongoro Crater, are a type of crater that forms when a volcano collapses into itself. *Source: NASA 2000*




## Global Sea Surface Temperature

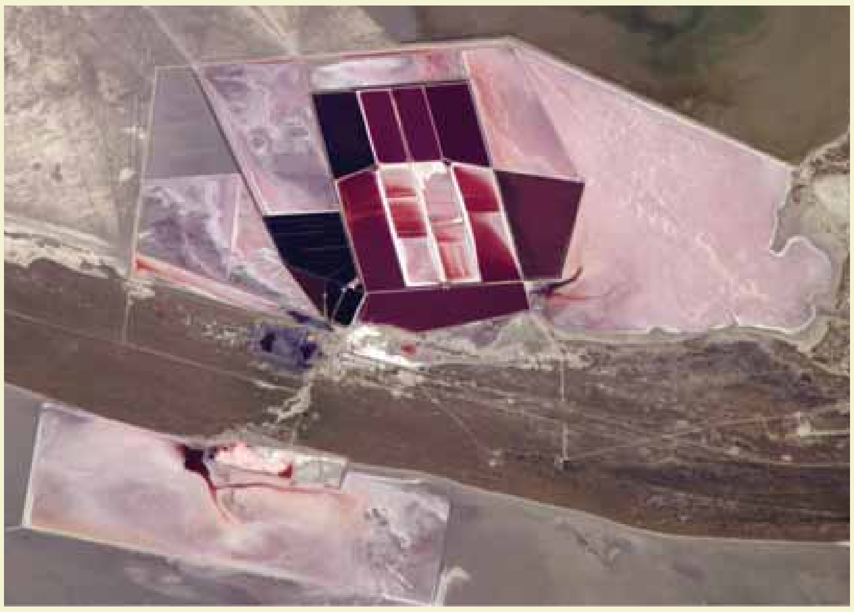
In this May 2001 image, red and yellow indicate warmer ocean waters, blue and purple represent colder waters, and green represents water of an intermediate temperature. Sea surface temperature images such as these are useful in studies of global temperature anomalies, and of how air-sea-ocean interactions drive changes in weather and climate patterns. Note the warm tongue of water extending south from Africa's east coast to well below the Cape of Good Hope. *Source: NASA 2001b*




### Botswana Salt Pans

The Makgadikgadi Pans complex is situated in the northeastern part of Botswana, southeast of the Okavango Delta. Covering over 12 000 km$^2$, it is one of the largest saltpan complexes in the world. The Makgadikgadi Pans are in a geographic depression (the Kalahari (Kgalagadi Basin) that once held an enormous lake that spanned most of what is now northern Botswana. The formation of various faults at the southern end of the East African Rift Valley diverted the flow of rivers away from the ancient lake, causing it to slowly dry up. This drying process concentrated salts in the lake bed, eventually leaving flat, salt-saturated clay-pan expanses: the Makgadikgadi Pans complex. The harsh conditions in and around the Makgadikgadi Pans are unsuitable for most animals. The only fauna to permanently inhabit the pans are highly specialized invertebrates. These invertebrates, mainly crustaceans, are adapted to withstand the long dry periods and to reproduce very quickly after a rain. After heavy rains the pans are transformed into a vibrant paradise, attracting thousands of waterbirds that come to feed and breed. The most spectacular visitors are greater and lesser flamingos (*Phoenicopterus ruber* and *Phoeniconaias minor*, respectively) that flock to the pans by the thousands. The greater flamingos feed on the newly hatched crustaceans while their smaller relatives feast on the blue-green algae (cyanobacteria) that also thrive in the salt pans.

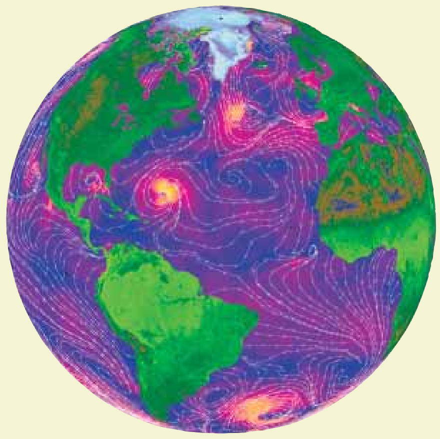
*Source WWF 2001: NASA 2007e*



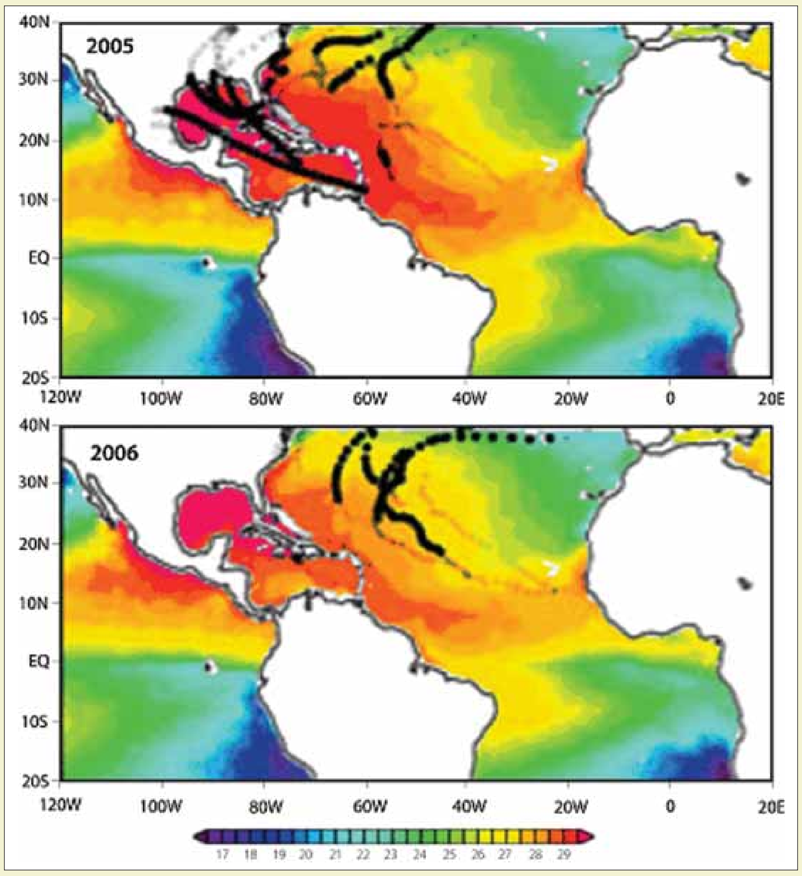
Flamingos at Makgadikgadi Pans, Botswana

## Saharan Dust Has Chilling Effect on the North Atlantic

Dust and other aerosols can both absorb and reflect sunlight, and thus affect surface temperature in different parts of the Earth. For years, however, research on the impact of aerosols was largely confined to global climate modeling. (Miller and  Tegen, 1998; Schollaert and Merrill 1998 ). A recent study by the National Aeronautics Space Administration (NASA), however, makes made use of aerosol data and satellite earth observation techniques to suggest that the 2006 hurricane season was relatively calm as a result of an abundance of dust blowing off the West African coast and over the Atlantic Ocean (NASA 2007f).



This figure shows the pattern of ocean winds from West Africa across the Atlantic Ocean




In June and July 2006, there were several significant dust storms over the Sahara Desert in Africa. As this dust traveled westward into the Atlantic, satellite data showed that the particles blocked sunlight from reaching the ocean surface, causing ocean waters to cool.

Sea surface temperatures in 2006 across the prime hurricane-breeding regions of the Atlantic and Caribbean were found to be as much as one degree Celsius cooler than in 2005. Following the most significant dust outbreak, which occurred in June and July, ocean waters cooled abruptly in just two weeks, suggesting that the dust had an almost immediate effect. These cooler waters may have impeded some  the development of hurricanes, since the storms rely on warm waters to form.

Cooler ocean waters in 2006 did result in fewer summertime tropical storms and hurricanes in the Atlantic than in 2005. Average sea surface temperature in degrees Celsius for the July-September period are shown for 2005 (top) and 2006 (bottom). During 2005, there were nine distinct tropical storms (open circles) and hurricanes (black circles) in the western Atlantic Ocean, Caribbean Sea, and the Gulf of Mexico. During the same period in 2006, only two tropical storms formed and none developed into hurricanes.

The dust worked to cool the ocean, but it also warmed the atmosphere by absorbing more of the sun's energy. This temperature difference resulted in a shift in the large-scale atmospheric circulation. As air rose over West Africa and the tropical Atlantic, it sank and became less moist over the western Atlantic and Caribbean. This pattern helped to increase surface winds that enhanced ocean evaporation and churned deeper, colder waters, causing the area of cool seas to expand.

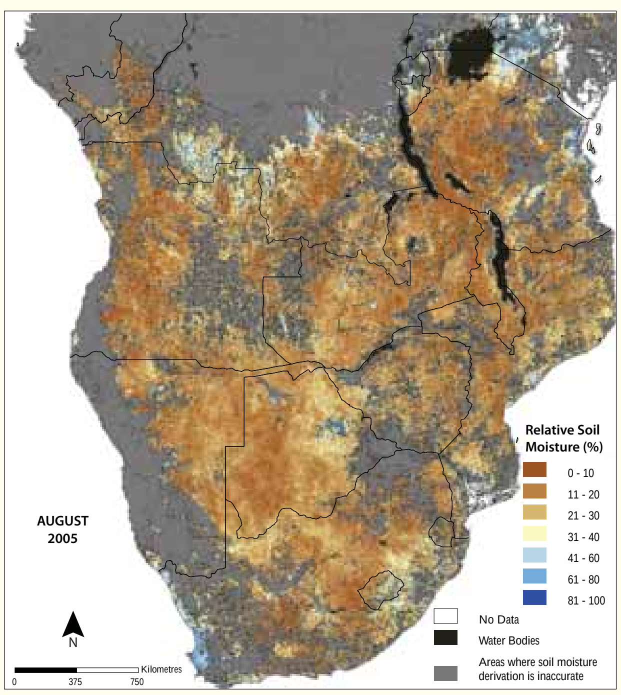
*Credit: NASA 2007g*

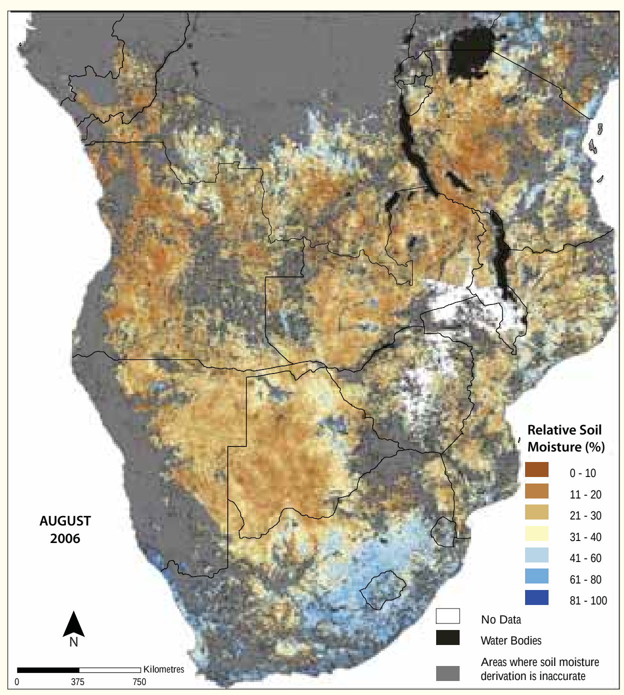
## Soil Moisture Monitoring in Southern Africa

Active radar instruments onboard satellites have been successfully used for scientific studies in hydrology, oceanography, geomorphology, and geology. Radar instruments generate and transmit electromagnetic energy, making them independent of solar energy and allowing them to acquire data both during the day and at night. These sensors can also monitor changes in soil water content, as well as soil moisture patterns (Wagner and others 2007).

Radar was used in monitoring soil moisture in countries of the Southern African Development Community (SADC) (SHARE 2008). Data from the Advanced Synthetic Aperture Radar (ASAR), an active remote sensing instrument onboard the European Space Agency Environmental Satellite (ENVISAT) platform, were used to derive the soil moisture levels. The maps show marked differences in soil moisture between August 2005 and August 2006, as a result of above average rainfall in 2006.

The use of satellite technology in soil moisture monitoring eliminates the disadvantages associated with conventional monitoring methods. Conventional in-situ methods are labour intensive, costly, non-uniform, and local in scale. ENVISAT presents an opportunity for monitoring soil moisture patterns over large regions with, at the same time, high temporal resolution. Such information can then be used to help predict and monitor floods and droughts (Scipal and others 2005).




## Smart Sensing of Volcanoes

The Democratic Republic of the Congo in central Africa is home to two active volcanoes: Nyiragongo and Nyamuragira. At 3 470 m high, Nyiragongo Volcano is a stratovolcano, a steep-sloped structure composed of alternating layers of solidified ash, hardened lava, and rocks ejected by previous eruptions. Prior to its 2002 eruption, this volcano wrought havoc in 1977 when it emptied a lava lake at its summit and caused a very fluid, fast-moving lava flow. Nyamuragira Volcano is a shield volcano, composed of old lava flows. Lava flows from this volcano cover some 1 500 km$^2$, and the volcano rises very gradually, reaching an altitude of 3 058 m. Despite its subtler shape, this volcano drained its own lava lake in 1938, sending lava flows all the way to Lake Kivu.

Besides their proximity to Lake Kivu, these volcanoes have both produced catastrophic eruptions since the early 20th century. Their tendency to release catastrophic lava flows prompted volcanologists to look for innovative ways to monitor the behaviour of both volcanoes, and even develop “smart” sensing systems that can act independently to collect observations as quickly as possible.

This satellite image above, taken on 31 January 2007, shows Nyamuragira and Nyiragongo, about five years after Nyiragongo sent a devastating lava flow through the town of Goma. Lava flows from neighboring Nyamuragira, however, are more prominent in this picture with their sombre shades of brown and purplish-black contrasting with the lush green of surrounding vegetation. Nyiragongo shows evidence of continued activity. The dark pink dot at its summit is a hotspot where the satellite sensor has detected unusually warm surface temperatures. The bright white plumes in the image are clouds, likely resulting from water vapour released by the volcano. The blue area near the clouds is part of the volcanic plume. Along the shores of Lake Kivu, areas of purple-brown indicate bare ground and human-made structures.

*NASA 2007h*


## References:

**Reader's Overview**


UNFCCC (2007). United Nations Framework Convention on Climate Change. Carbon Dioxide emissions- Total (UNFCCC-CDIAC) (Accessed on 1 April 200) http://geodata.grid.unep.ch/download/all%20%20co2_mdg_total.xls

UNHABITAT (n.d.). Dakar. Identifying Geographic and Thematic Environmental Issues Through Consultation. (Accessed 2 April 2008) http://ww2.unhabitat.org/programmes/uef/cities/summary/dakar.htm

USGS. (2007). United States Geological Survey Mineral Information. Platinum-Group Metals Statistics and Information. (Accessed on 2 April 2008) http://minerals.usgs.gov/minerals/pubs/commodity/platinum/mcs-2008-plati.pdf

USGS. (2008). United States Geological Survey Mineral Information. Gold Statistics and Information (Accessed on 2 April 2008) http://minerals.usgs.gov/minerals/pubs/commodity/gold/mcs-2008-gold.pdf


*All material in this section is derived from the book, where references are clearly marked.*

**Chapter One**


Adams, W.M. (1996a). Lakes. In: Adams W, Goudie A, Orme A (eds). The physical geography of Africa. Oxford University Press, Oxford pp.122-133

Adams, M.E. (1996b). Savanna Environments. In: Adams W, Goudie A, Orme A (eds). The physical geography of Africa. Oxford University Press, Oxford p.197-210.

Adger, N. and others (2007). Summary for Policymakers. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. IPCC WGII Fourth Assessment Report. http://www.ipcc.ch/SPM6avr07.pdf [Accessed 10 July 1007]

Allen, H.D. (1996). Mediterranean Environments. In Adams W, Goudie A, Orme A (eds). The physical geography of Africa. Oxford University Press, Oxford pp. 307-325

Allen, J. (2001). Ultraviolet Radiation: How it Affects Life on Earth. Earth Observatory Library, http://earthobservatory.nasa.gov/Library/UVB/uvb_radiation3.html [Accessed 10 July 1007]

Amos, J. (2006). Satellites weigh Africa's water. BBC News, 13 December 2006. http://news.bbc.co.uk/2/hi/science/nature/6174689.stm [Accessed 17 January 2008]

AMREF. (2008). Safe Water and Basic Sanitation. African Medical and Research Foundation. http://www.amref.org/index.asp?PageID=50&PiaID=6 [Accessed 17 January 2007]

Anon. (2007). Species richness and endemism. Biology-online.org. http://www.biology-online.org/articles/biodiversity_africa/species_richness_endemism.htm [Accessed 17 January 2008]

Auclair C. (2005). Charting a Framework for Sustainable Urban Centres in Africa. UN Chronicle Online Edition. http://www.un.org/Pubs/chronicle/2005/issue2/0205p26.html [Accessed 18 June 2007]

Balirwa, J. S. (2007). Ecological, environmental and socioeconomic aspects of the Lake Victoria's introduced Nile perch fishery in relation to the native fisheries and the species culture potential: lessons to learn African Journal of Ecology, 45, 2, 120-129, http://www.ingentaconnect.com/search/article?title=fishery+Africa&title_type=tka&year_from=1998&year_to=2007&database=1&pageSize=20&index=1 [Accessed 04 June 2007]

BCLME Programme Co-ordinating Unit (n.d.). The Benguela Current Large Marine Ecosystem. BCLME Programme Co-ordinating Unit, Windhoek, Namibia http://www.bclme.org/resources/docs/BenguelaBrochureEng.pdf [Accessed 04 June 2007]

Biodiversity Support Program. (1993). African Biodiversity: Foundation for the Future. A Framework for Integrating Biodiversity Conservation and Sustainable Development, pp. 19 Available at http://www.worldwildlife.org/bsp/publications/africa/issues_3/afbiodiv.pdf [Accessed 24 June 2007]

Bird, G., Medina, S. (2002). African Environment Outlook (eds.), Past, present and future perspectives. UNEP. http://www.grida.no/aeo/ [Accessed 14 June 2007]

Brooks, T.M., Mittermeier R.A., Mittermeier, C.G., da Fonseca G.A.B., Rylands A.B., Konstant W.R., Flick P., Pilgrim J., Oldfield S., Magin G. and Hilton-Taylor C. (2002): Habitat Loss and Extinction in the Hotspots of Biodiversity. Conservation Biology 16(4):909-923

Chi-Bonnardel, Regine Van (1973). Atlas of Africa. Institut geographique national (France). Paris: Editions Jeune Afrique, pp.335

CI (2007a). Biodiversity Hotspots – Eastern Afromontane. Conservation International. http://www.biodiversityhotspots.org/xp/Hotspots/afromontane/Pages/default.aspx#indepth [Accessed 14 January 2008]

CI (no date-b). Biodiversity Hotspots – Eastern Afromontane. Conservation International. http://www.biodiversityhotspots.org/xp/Hotspots/afromontane/Pages/default.aspx#indepth [Accessed 14 January 2008]

CI (2007b): Conservation International: Biodiversity Hotspots, 2007. Available at: http://web.biodiversityhotspots.org/xp/Hotspots/hotspots_by_region/ and Hotspots Defined. Conservation International 2007. http://www.biodiversityhotspots.org/xp/hotspots/hotspotsscience/Pages/hotspots_defined.aspx [Accessed 14 January 2008]

CIA (2007a). Field Listing – Elevation Extremes. World Factbook. Available at: https://www.cia.gov/library/publications/the-world-factbook/fields/2020.html [Accessed 10 September 2007]

CIA (2007b). Field Listing – Population growth rate – The World Factbook. Central Intelligence Agency. Available at: https://www.cia.gov/library/publications/the-world-factbook/fields/2002.html [Accessed 11 September 2007]

Creighton,B (2000). An Endangered Africa: List of Those Endangered/Threatened in Africa (as of 30 June 1999). Available at http://www.geocities.com/RainForest/Andes/6859/list.html [Accessed 06 December 2007]

CRES (2002). Mean Monthly Air Temperature of Africa – data layer, Center for Environmental Studies. http://www.fao.org/geonetwork/srv/en/main.home [Accessed September 11, 2007]

Dlamini, C. (2005). The Wisdom of Africa: If There Were No Africa. In Aichi Expo 2005, March, Aichi, Japan, http://www.cedzadlamini.com/pdf/aichi1.pdf [Accessed 21 July 2007]

EIA (2003). Sub-Saharan Africa: Environmental Issues. Energy Information Administration, Washington, DC http://www.eia.doe.gov/emeu/cabs/subafricaenv.html [Accessed 27 April 2007]

EIA (2005). Country Analysis Briefs. United States Energy Information Administration, Available at http://www.eia.doe.gov/emeu/cabs/Region_af.html [Accessed 04 June 2007]

EPA (2006). Wetlands Definitions.U.S. Environmental Protection Agency. http://www.epa.gov/owow/wetlands/what/definitions.html [Accessed 15 September 2007]

Eswaran, H, Almaraz, R. van den Berg, E. and Reich, P. (1996). An Assessment of the soil Resources of Africa in Relation to Productivity. Washington, DC: US Dept. of Agriculture. http://soils.usda.gov/use/worldsoils/papers/africa1.html [Accessed 10 September 2007]

FAO (1995). Land and environmental degradation and desertification in Africa. X5318/E . Available at: http://www.fao.org/docrep/X5318E/x5318e00.htm#Contents [Accessed 11 September 2007]

FAO (2001). Global average annual precipitation. GIS Layer. Available at: http://www.fao.org/geonetwork/srv/en/metadata.show?id=66&currTab=simple [Accessed 10 September 2007]

FAO (2002). Mean Monthly Air Temperature of Africa – data layer, Center for Environmental Studies. Available at: http://www.fao.org/geonetwork/srv/en/main.home [Accessed 11 September 2007]

FAO (2005). State of the World's Forests 2005. Food and Agriculture Organization of the United Nations, Rome ftp://ftp.fao.org/docrep/fao/007/y5574e/y5574e00.pdf [Accessed 28 April 2007]

FAO (2006). The State of World Fisheries and Aquaculture 2006. Food and Agriculture Organization of the United Nations, Rome http://www.fao.org/docrep/009/A0699e/A0699e00.htm [Accessed 01 June 2007]

FAO (2007). Dominant Soils – Dataset. http://www.fao.org/geonetwork/srv/en/metadata.show?id=30587&currTab=simple [Accessed 16 January 2008]

Finkl, C.W. (2004). Coastal Classification: Systematic Approaches to consider in the Development of a Comprehensive Scheme. Journal of Coastal Research 20(1): pp.166-213

Finlayson, C. M. & D'Cruz, R. (2005). Chapter 20: Inland Water Systems. In Hassan, R., Scholes, R. & Ash, N. (eds.). Ecosystems and Human Well-Being:Current State and Trends Assessment, Volume 1. Island Press, Washington/Covelo/London, http://www.maweb.org/documents/document.289.aspx.pdf [Accessed 01 June 2007]

Frenken, K. (2005). Irrigation in Africa in figures – AQUASTAT Survey – 2005. FAO Water Reports 29. Food and Agriculture Organization of the United Nations, Rome, 2005

Gibbs, H. (2006). Africa's deforestation rate may be underestimated. Mongabay.com. http://news.mongabay.com/2006/0622-africa.html [Accessed 13 July 2007]

Goudie, A.S. (1996). Climate: Past and Present. In Adams W, Goudie A, Orme A (eds). The physical geography of Africa. Oxford University Press, Oxford pp.34-59

Griffiths, J.F. (1966). Applied Climatology. Oxford University Press, London

Griffiths, J.F. (2005). Climate of Africa. In John E. Oliver (ed). Encyclopedia of World Climatology, Springer 2006, Berlin

Herrmann, S.M. and Hutchinson, C.F. (2005). The changing contexts of the desertification debate. Journal of Arid Environments 63:538-555

Hinrichsen, D. (2007). Ocean planet in decline. Peopleandplanet.net, 25 January, http://www.peopleandplanet.net/doc.php?id=429andsection=6 [Accessed 01 June 2007]

IUCN (2008). The IUCN Red List of Threatened Species. http://www.iucnredlist.org/search/details.php/44492/all and West African Black Rhino Extinct http://www.iucn.org/en/news/archive/2006/07/7_pr_rhino.htm

IUSSP (2007). Urbanization and Poverty in Africa: Evidence on Linkages Between Urbanization, Poverty and Human Well-Being in Sub-Saharan Africa: Panel on Population Growth and Human Welfare in Africa. International Union for the Scientific Study of Population (IUSSP). Scientific Panel on Population Growth and Human Welfare in Africa, http://www.iussp.org/Activities/popgrowth/call07.php [Accessed 26 July 2007]

IWMI (2001). Estimating Potential Rain-fed Agriculture. P. Droogers, D. Seckler and Ian Makin. International Water Management Institute Working Paper 20. Colombo, Sri Lanka

Jürgens, N. (1997). Floristic biodiversity and history of African arid regions. Biodiversity and Conservation 6(3):pp. 495-514

Kelatwang, S. and Garzuglia, M. (2006). Changes in forest Area in Africa 1990-2005. International forestry Review 8(1):pp. 21-30

KEW (no date). Madagascar, Madagascar Science Team web-page, Royal botanic Gardens, Kew. http://www.kew.org/scihort/madagascar/ [Accessed 11 September 2007]

Kious, W.J. and Tilling, R.I.(1996), Inside the Earth, This Dynamic Earth, USGS. http://pubs.usgs.gov/gip/dynamic/dynamic.html [Accessed 08 September 2007]

Lamprey, H.F. (1988). Report on desert encroachment reconnaissance in Northern Sudan: 21 October to 10 November 1975. Desertification Control Bulletin 17, pp 1–7

Laporte, N.T., Stabach, J.A., Grosch, R., Lin, T.S., Goetz, S.J. (2007).Expansion of Industrial Logging in Central Africa, 2007. Science, Vol. 316. no. 5830, pp. 1451

LIMBE Botanical and Zoological Gardens (2002). Mount Cameroon. Available at http://www.mcbc-climbe.org/mc_intro.shtml [Accessed 08 November 2007]

MacDonald, G.M. (2003). Biogeography: Space, Time & Life. John Wiley & Sons, Inc., New York

Mass, P. (2007). Recently Extinct Animals. Available at http://extinctanimals.petermaas.nl/ and http://home.conceptsfa.nl/~pmaas/rea/bluebuck.htm [Accessed 07 August 2007]

Meadows, M.E. (1996). Biogeography. In Adams W, Goudie A, Orme A (eds). The physical geography of Africa. Oxford University Press, Oxford pp. 161-172

Miller, R. L. and Tegen, I. (1998). Climate response to soil dust aerosols. Journal of Climate. 11: pp. 3247 – 3267

Mongabay (2007). Vines and Lianas. Available at: http://rainforests.mongabay.com/0406.htm [Accessed 11 September 2007]

Mortimore, M. (2005). Dryland Development, Success stories from West Africa. Environment 47(1):8-21

Moser, M., Crawford, P., and Frazier, S. (1996). A Global Overview of Wetland Loss and Degradation. Paper presented to Technical Session B of the 6th Meeting of the Conference of the Contracting Parties in Brisbane, Australia, March 1996; thereafter it was published in vol. 10 of the Conference Proceedings http://www.ramsar.org/about/about_wetland_loss.htm [Accessed on 07 July 2007]

NASA (2000): Crater Highlands, Tanzania. Available at http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17196 [Accessed on 18 January 2007]

NASA (2001a): Earth's Nightlights. Available at http://www.nasa.gov/vision/earth/lookingatearth/NIGHTLIGHTS.html [Accessed on 18 January 2007]

NASA (2001b): MODIS Global Sea Surface Temperature. Available at http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=5196 [Accessed on 18 January 2007]

NASA (2002a): Patterns of Lightning Activity. Available at: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17314 [Accessed on 18 January 2007]

NASA (2002b): Unusually Small Antarctic Ozone Hole This Year Attributed To Exceptionally Strong Stratospheric Weather Systems. Available at: http://www.gsfc.nasa.gov/topstory/20020926ozonehole.html [Accessed on 18 January 2007]

NASA (2004). NASA Data Offers a Safari into Vast African Topography, 17 June 2004. Available at http://earthobservatory.nasa.gov/Newsroom/NasaNews/2004/2004061717144.html [Accessed on 07 July 2007]

NASA (2005). Topography of Western Algeria. Available at http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17734 [Accessed on 07 July 2007]

NASA (2006a): The Hottest Spot on Earth. Available at: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17470 [Accessed on 18 January 2007]

NASA (2006b): Ozone Hole Reaches Record Size. Available at: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17436 [Accessed on 18 January 2007]

NASA (2006c). Seawinds – Oceans, Land and Polar Regions, 20 November 2006. Available at: http://visibleearth.nasa.gov/view_rec.php?id=320 [Accessed on 18 January 2007]

NASA (2007a). Floods in West Africa. Available at: http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=14534 [Accessed on 18 January 2007]

NASA (2007b): 2007 Ozone Hole. Available at: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17809 [Accessed on 18 January 2007]

NASA (2007c): A Decade of Ocean Color. Available at: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17801 [Accessed on 18 January 2007]

NASA (2007d). Phytoplankton Bloom off Namibia. Available at: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17840 [Accessed on 18 January 2007]

NASA (2007e): Salt Ponds, Botswana Available at: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17643 [Accessed on 18 January 2007]

NASA (2007f). Saharan Dust Has Chilling Effect On North Atlantic. Available at: http://earthobservatory.nasa.gov/Newsroom/NasaNews/2007/2007121425986.html [Accessed on 27 December 2007]

NASA (2007g). Hurricanes: Did Dust Bust the 2006 Hurricane Season Forecasts? 28 March 2007.

http://www.nasa.gov/mission_pages/hurricanes/archives/2007/hurricane_dust.html [Accessed on 27 December 2007]

NASA (2007h). Nyiragongo Volcano before the Eruption. Available at: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17855 [Accessed on 18 January 2007]

NASA (2008a): Ozone Hole Watch. Available at: http://ozonewatch.gsfc.nasa.gov/index.html [Accessed on 18 January 2007]

NASA (2008b). Ultraviolet Radiation Exposure. Available at : http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=4491 Ultraviolet Radiation: How It Affects Life On Earth – How Much Ultrviolet (UV-B). Radiation Are We Getting? Available at: http://earthobservatory.nasa.gov/Library/UVB/uvb_radiation4.html and http://earthobservatory.nasa.gov/Observatory/Datasets/uv.toms.html [Accessed on 18 January 2007]

National Geographic (2003): Mount Kilimanjaro's Glacier Is Crumbling, National Geographic Adventure, 23 September 2003. http://news.nationalgeographic.com/news/2003/09/0923_030923_kilimanjaroglaciers.html [Accessed 28 November 2007]

National Geographic News (2006): West African Black Rhino Extinct, 12 July 2006. Available at http://news.nationalgeographic.com/news/2006/07/060712-black-rhino.html [Accessed 28 November 2007]

Norse, E. A., Rosenbaum, K. L., Wilcove, D.S., Wilcox, B.A.., Romme, W. H., Johnston, D. W., Stout, M.L. (1986). Why Conserve Biological Diversity? From "Conserving Biological Diversity in Our National Forests." The Wilderness Society. http://www.magicalliance.org/Forests/why_conserve_biological_diversit.htm [Accessed 02November 2007]

Nyamweru, C.K. (1996). The African Rift System. In Adams W, Goudie A, Orme A (eds). The physical geography of Africa. Oxford University Press, Oxford pp. 18-33

Nyblade, A.A. and Robinson. S.W. (1994). The African Superswell. Geophysical Research Letters, pp. 21:765-8

ODINAFRICA Project (2007). African Marine Atlas. Intergovernmental Oceanographic Commission's (IOC). International Oceanographic Data and Information Exchange (IODE). Programme, http://www.africanmarineatlas.net/index.htm [Accessed 01 June 2007]

O'Toole, M.J., Shannon, L.V., de Barros Neto, V., and Malan, D.E. (2001). Integrated Management of the Benguela Current Region. In: Science and Integrated Coastal Management, ed. B. von Bodungen and R.K. Turner, pp. 231-253. Dahlem University Press.

Orme, A.R. (1996). Coastal Environments. In: Adams W, Goudie A, Orme A (eds). The physical geography of Africa. Oxford University Press, Oxford pp. 238-266

Palmer, A.R. and M. Ainslie, A.M. (2005). Grasslands of South Africa. In: Grasslands of the world, J.M. Suttie, S.G. Reynolds and C. Batello (eds). Plant Production and Protection Series No. 34 FAO 2005

Peakware-World Mountain Encyclopedia (2007). Available at http://www.peakware.com/peaks.html?pk=37 [Accessed 08 November 2007]

Preservation Station Inc. (2005). Barbary Lion.com Back from the brink of extinction. Available at http://www.barbarylion.com/ [Accessed 08 December 2007]

Reader, J. (1997). Africa: a biography of the continent. Alfred A. Knopf, Inc. New York

Reich, P. F., Numbem, S. T., Almaraz, R. A. & Eswaran, H. (2001). Land Resource Stresses and Desertification in Africa. In: Bridges, E. M., Hannam, I. D., Oldeman, L. R., Pening De Vries, F. W. T., Scerr, S. J. & Sompatpanit, S. (eds.). Responses to Land Degradation. Proceedings of the 2nd InternationalConference on Land Degradation and Desertification, Oxford Press, New Dehli, India, Khon Kaen, Thailand http://soils.usda.gov/use/worldsoils/papers/desertification-africa.html [Accessed 07 July 2007]

Revenga, C. and Cassar, A. (n.d.). Freshwater Trends and Projections: Focus on Africa. WWF International, http://www.wwf.org.uk/filelibrary/pdf/africa_freshwater.pdf [Accessed 5 June 2007]

Schollaert, S.E. and Merrill, J.T. (1998). Cooler sea surface west of the Sahara desert Correlated to dust events. Geophysical research letters: 25 - 18, pp 3529-3532

Schuijt, K. (2002). Land and Water Use of Wetlands in Africa: Economic Values of African Wetlands. International Institute for Applied Systems Analysis, Laxenburg, Austria http://www.iiasa.ac.at/Admin/PUB/Documents/IR-02-063.pdf [Accessed 06 June 2007]

Scipal, K., Scheffler, C., Wagner, W.G. (2005). Soil moisture-runoff relation at the catchment scale as observed with coarse resolution microwave remote sensing, Hydrology and Earth System Sciences, Volume 9, Issue 3, 2005, pp. 173-183.

Shannon, L. V. and O'Toole, M. J. (2003). Sustainability of the Benguela: ex Africa semper aliquid novi. In Hempel, G. & Sherman, K. (eds.). Large Marine Ecosystems of the World: Trends in Exploitation, Protection and Research. Elsevier B.V., pp. 227-253, http://www.bclme.org/pubs/docs/OTooleShannon.pdf [Accessed 04 June 2007]

SHARE (2008).SHARE - Soil moisture for Hydrometeorologic Applications in the SADC region, ESA Tiger Project, http://www.ipf.tuwien.ac.at/radar/share/ or http://www.ipf.tuwien.ac.at/radar/share/ [Accessed 18 January 2007]Slack, G. (2002). American Museum of Natural History Digital Library Online Collection: Africa's Environment in Crisis. American Museum of Natural History. http://diglib1.amnh.org/articles/Africa/Africa_environment.html [Accessed 27 April 2007]

Smith, O.B. and Koala, S. (1999). Desertification: Myths and Realities. Presented at the Canadian Science Writers' Annual General Meeting May 1999. http://idrinfo.idrc.ca/archive/corpdocs/113273/MythsRealities2.htm [Accessed 10 September 2007]

Steeves, G and Steeves, A. (2007). AfricanCichlids.net. Available at http://www.africancichlids.net/articles/labrochromis_ishmaeli/ [Accessed 08 December 2007]

Stock, R. (2004). Africa South of the Sahara: A Geographical Interpretation. Guilford Press, New York.

Summerfield, M.A. (1996). Tectonics, geology and long-term landscape development. In: The Physical Geography of Africa (ed. Goudie, A.C., and Orme, A.R.), Oxford University Press, Oxford p.1-17

Tappan, G.G (2007). In Niger, Trees and Crops Turn Back the Desert, The New York Times Company, Reprinted with permission from More People, More Trees: Natural Resource Management Success in Niger, USGS, March 2007on Sunday, February 11, 2007 (#14854).

Taylor, D. (1996). Mountains. In: The Physical Geography of Africa (ed. Goudie, A.C., and Orme, A.R.), Oxford University Press, Oxford p. 287-306

Taylor A. R. D. , Howard G. W. and Begg G. W. 1995. Developing wetland inventories in Southern Africa: A review. Plant ecology. 118 pp 57-79

The BayScience Foundation, Inc. (2007). Haplochromis lividus Available at: http://zipcodezoo.com/Animals/H/Haplochromis_lividus.asp [Accessed 18 January 2008]

Tibaijuka, A. K. (2004). Africa on the Move: An Urban Crisis in the Making: A submission to the Commission for Africa. United Nations Human Settlements Programme, Nairobi, Kenya http://www.unhabitat.org/downloads/docs/4626_83992_GC%2021%20Africa%20on%20the%20Move.pdf [Accessed 27 June 2007]

Trollope, W. S. W. & Trollope, L. A. (2004). Prescribed burning in African grasslands and savannas for wildlife management. Arid Lands Newsletter, 55, May/June, http://www.ag.arizona.edu/OALS/ALN/aln55/trollope.html [Accessed 25 June 2007]

UN (2001a). State of the Environment in Africa. United Nations Economic Commission for Africa, Addis Ababah http://www.uneca.org/eca_resources/Publications/FSSD/EnvironmentReportv3.pdf [Accessed 20 June 2007]

UN (2001b). World Population Prospects: The 2000 Revision, Highlights. United Nations, ESA/P/WP.165, February 2001 http://www.un.org/News/Press/docs/2001/dev2292.doc.htm [Accessed 20 June 2007]

UN (2004): Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision, http://esa.un.org/unpp, 06 December 2006; 11:01:10 AM. http://esa.un.org/unpp/p2k0data.asp [Accessed 10 January 2008]

UN (2005). United Nations Population Division – Population, Resources, Environment and Development: The 2005 Revision. Available at: http://unstats.un.org/pop/dVariables/DRetrieval.aspx [Accessed 11 September 2007]

UN (2006a). African Water Development Report, 2006. United Nations Economic Commission for Africa, Addis Ababa http://www.uneca.org/awich/AWDR_2006.htm [Accessed 07 June 2007]

UN (2006b): UN World Statistics Pocket Book, Department of Economic and Social Affairs, Statistics Division Series V No. 30, New York, 2006

UN (2007). World Population Prospects: The 2006 Revision Population Database. United Nations Population Division. http://esa.un.org/unpp/ [Accessed 10 January 2008]

UNEP and McGinley, M. (2007). Biodiversity in Africa. In Cleveland, C. J. (ed.). Encyclopedia of Earth. Environmental Information Coalition, National Council for Science and the Environment, Washington, D.C. Available at: http://www.eoearth.org/article/Biodiversity_in_Africa [Accessed 15 June 2007]

UNEP (1998). Overview of Land-based Sources and Activities Affecting the Marine, Coastal and Associated Freshwater Environment in the Eastern African Region. UNEP/Institute of Marine Sciences, University of Dar es Salaam/FAO/SIDA, http://www.unep.org/regionalseas/Publications/rsrs167.pdf [Accessed 01 June 2007]

UNEP (1999). Global Environment Outlook-2000. United Nations Environnent Programme, Nairobi. http://www.grida.no/geo2000/english/index.htm [Accessed 4 June 2007]

UNEP (2002). Africa Environment Outlook - Past, present and future perspectives. Nairobi, Kenya: United Nations Environment Programme, pp.400. Available at: http://www.grida.no/aeo/ [Accessed 01 June 2007]

UNEP (2006a). Africa's Lakes: Atlas of Our Changing Environment. United Nations Environment Programme, Nairobi, Kenya. Available at http://www.unep.org/dewa/assessments/EcoSystems/water/Africas_Lakes(5-Apr-06).pdf [Accessed 05 June 2007]

UNEP (2006b). Global Environment Outlook, Geo Data Portal 2006. http://geodata.grid.unep.ch/ [Accessed on 10 January 2008]

UNEP (2006c). African Regional Implementation Review for the 14th Session of the Commission on Sustainable Development (CSD-14). Report on Climate Change, May 2006. http://www.un.org/esa/sustdev/csd/csd14/ecaRIM_bp1.pdf [Accessed 17 January 2008]

UNEP (2008). Biodiversity, On the Move to 2010. Available at: http://www.unep.org/Themes/Biodiversity/About/index.asp [Accessed 07 January 2008]

UNEP/RSP (2006). Accounting for Economic Activities in Large Marine Ecosystems and Regional Seas. UNEP/RSP and NOAA LME Partnership, http://www.unep.org/regionalseas/Publications/Economic_Activities_in_LMEs_and_RS.pdf [Accessed 01 June 2007]

UNEP-WCMC (2008). Protected Areas and World Heritage. Available at http://www.unep-wcmc.org/sites/wh/ [Accessed 17 January 2008]

UNECA (2001). State of the Environment in Africa. United Nations Economic Commission for Africa, Addis Ababa http://www.uneca.org/eca_resources/Publications/FSSD/EnvironmentReportv3.pdf [Accessed 20 June 2007]

UN ESA (2004). Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision. http://esa.un.org/unpp/p2k0data.asp [Accessed 06 December 2006]

UNESCAP (2007). United Nations Economic and Social Commission for Asia and the Pacific. Statistical Yearbook for Asia and the Pacific 2007. http://www.unescap.org/stat/data/syb2007/26-Water-use-syb2007.asp [accessed March 20 2008]

UNESCO (2008). World Heritage List. Available at http://whc.unesco.org/en/list [Accessed 17 January 2008]

UNESCO (2007). International Glossary of Hydrology. Available at http://webworld.unesco.org/water/ihp/db/glossary/glu/aglu.htm [Accessed 17 January 2008]

UN-HABITAT (2006). State of the World's Cities 2006/7. United Nations Human Settlements Programme [Accessed 01 June 2007]

UN FAO (1997). Food and Agriculture Organization of the United Nations FAOSTAT, http://www.fao.org/docrep/004/y1997e/y1997e1r.htm#bm63. [Accessed 06 December 2006]

UNFPA (2007). State of World Population 2007: Unleashing the Potential of Urban Growth. United Nations Population Fund. Available at: http://allafrica.com/sustainable/resources/view/00011168.pdf [Accessed 03 July 2007]

Uyigue, E and Agho M., (2007). Coping with Climate Change and Environmental Degradation in the Niger Delta of Southern Nigeria, Community Research and Development Centre (CREDC), Nigeria

Wagner, W., G. Blöschl, P. Pampaloni, J.-C. Calvet, B. Bizzarri, J.-P. Wigneron, Y. Kerr (2007), Operational readiness of microwave remote sensing of soil moisture for hydrologic applications, Nordic Hydrology, Volume 38, No 1, pp. 1–20. DOI 10.2166/nh.2007.029.

Waide, R.B., Willig, M.R., Steiner, C.F., Mittelbach, G., Gough, L., Dodson, S.I., Juday, G.P. and Parmenter, R. (1999). The Relationship Between Productivity and species Richness. Annual Review of Ecological Systems 30: pp. 257-300

Walling, D.E. (1996). Hydrology and rivers. In Adams W, Goudie A, Orme A (eds). The physical geography of Africa. Oxford University Press, Oxford pp. 101-121

Watson, R. T., Zinyowera, M. C. & Moss, R. H. (eds.). (1997). IPCC Special Report on The Regional Impacts of Climate Change: An Assessment of Vulnerability. A Special Report of IPCC Working Group II, Cambridge University Press, Cambridge, UK.

White, R.P., S. Murray, M. Rohweder. (2000). Pilot Analysis of Global Ecosystems: Grassland Ecosystems. Washington, D.C.: World Resources Institute, pp. 100 Available at: http://www.wri.org/biodiv/pubs_description.cfm?pid=3057 [Accessed 18 July 2007]

Wikipedia (2007): Africa animals extinct in the wild - http://en.wikipedia.org/wiki/List_of_extinct_animals_of_Africa#Extinctions_in_the_wild; List of extinct animals of Africa http://en.wikipedia.org/wiki/List_of_extinct_animals_of_Africa; Seychelles Parakeet http://en.wikipedia.org/wiki/Seychelles_Parakeet; and Dodo http://en.wikipedia.org/wiki/Dodo

Willcocks, A.D. (2002). Carbon Dioxide. In: Goudie, A.S. (ed). Encyclopedia of Global Change – Environmental Change and Human Society. Oxford University Press, New York.

WMO (n.d.). Project Brief: West Indian Ocean Marine Application Project (WIOMAP). World Meteorological Organization (WMO), Available at: http://www.wmo.int/pages/prog/tco/pdf/WIOMAP.pdf [Accessed 06 July 2007]

World Bank (2007). Bank-Led Satellite Imagery Sheds More Light on Gas Flaring Pollution. Available in August 2007. Available at: http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:21454461~pagePK:64257043~piPK:437376~theSitePK:4607,00.html [Accessed 06 December 2007]

World Commission on Dams (2001). Dam Statistics: Africa and the Middle East Regions. Available at: http://www.dams.org/kbase/consultations/afrme/dam_stats_eng.htm [Accessed 10 September 2007]

WRI (1998/1999 and 1996/1997). A Guide to the Global Environment. World Resources Institute Listed at http://www.water.org/waterpartners.aspx?pgID=916#Ref_7 [Accessed 10 January 2007]

WWF (2001): Zambezian halophytics - AT0908 Available at: http://www.worldwildlife.org/wildworld/profiles/terrestrial/at/at0908_full.html [Accessed 18 January 2007]