

# Ecosystem and Biodiversity in the Nile Basin “Case Study: Lake Nasser”

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**Abstract** The Nile Basin consists of a number of ecological zones between two extreme opposites: the rainforest in the Democratic Republic of Congo (DRC) and the Sahara desert, which receives almost no rain. Some regions receive most or exclusively all of their water from the Nile, while others receive most of the water from rain, or from a combination of water sources. Still, it is the water in the Nile which links the otherwise different ecological zones together. It is the rains in the DRC, Burundi, Rwanda, Tanzania, Kenya, Uganda, and Ethiopia which provide the Nile with water so the river can flow and give life to barren and desert areas in Sudan and Egypt. Some places become drier and experience more droughts, whereas others are more regularly flooded or experience more fluctuations in precipitation patterns. These are overall climatic premises, but there are also human factors. The richness of species depends partly on climate variables such as temperature and rainfall patterns but also on population pressure and human activities and their interaction with the environment.

This chapter describes aspects of environmental issues of ecosystem and biodiversity, endangered species, and threats to biodiversity in the Nile Basin countries to provide a partial illustration of the diversity of ecosystem and the habitat types that exist to support a variety of living organisms. In addition, the chapter describes the case study of Lake Nasser. The study showed that there are several problems that can reduce the species biodiversity in the Nile Basin countries. Some of these problems are, but not limited to, inefficient water use, water pollution, population pressure and land degradation, deforestation and soil loss, over hunting and fishing, and sedimentation. In addition, the study concluded that the main sources of biodiversity degradation in Lake Nasser are development of land, expansion of agricultural land, and disappearance of habitat from excessive grazing or

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application of agrochemicals, and also habitats are being polluted and hunting, fishing, and tourism activities are disturbing the natural habitat especially within the shoreline zone.

**Keywords** Nile Basin countries, Species biodiversity

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## 1 Introduction

Biodiversity refers to the variety of life on earth. Neither the number of species on earth nor the ecological role of many described species is well known, but it is certain that a variety of life is essential to the functioning of earth's ecosystems. The most widely accepted definition of biodiversity is found in Article 2 of the Convention on Biological Diversity: "Biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems [1]."

Many of these valuable ecosystems have survived for centuries because of low-intensity land use. However, new practices are a major threat to the conservation of these ecosystems. Human activity (such as urbanization, industrialization, and changing patterns of land and water use due to population growth, conflict, resettlement, and the influence of financial policies and planning processes) influences the variety and composition of life forms within an ecosystem and threatens the habitats, diversity of species, and the nutrient cycle. Threats to biodiversity

include habitat loss or alteration, overexploitation, and the introduction of species that alter existing community structures. Habitat loss and degradation are perhaps the most significant threats to biodiversity. The introduction of new (alien) species into geographical areas can occur naturally and has increased dramatically due to human influence. This can threaten biodiversity if the new species competes with indigenous species for resources and alters the food web, habitat, or other aspects of the original community.

Over 99% of all species that have ever existed are now extinct. While extinction is a natural process, scientists have estimated that the current rate of extinction is approximately 100–1,000 times the background (or natural) rate. Extinctions of this magnitude have occurred only five times in earth’s history, the most recent being the end of the dinosaur age. Clearly, human influence on biodiversity is significant. The most commonly used system for classifying a species’ risk of extinction is the International Union for Conservation of Nature and Natural Resources (IUCN; now known as the World Conservation Union) Red List of Threatened Species. The goals of this program are to [2]:

1. Identify and document those species most in need of conservation attention to reduce global extinction rates.
2. Provide a global index of the state of degeneration of biodiversity.

This system rates each species at risk of extinction as critically endangered (CR), endangered (EN), or vulnerable (VU). Specific criteria for each of these categories are available, but general definitions are as follows:

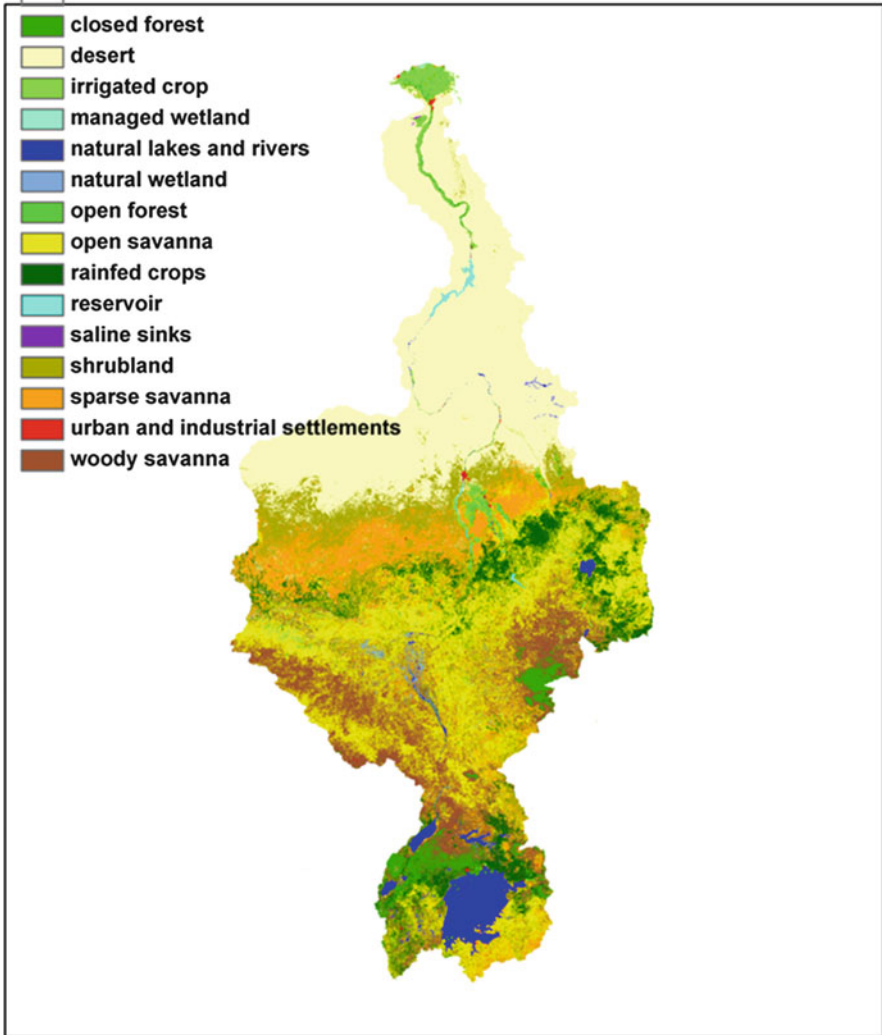
1. Extinct: There is no reasonable doubt that the last individual has died.
2. Critically endangered: The species faces an extremely high risk of extinction in the wild.
3. Endangered: The species faces a very high risk of extinction in the wild.
4. Vulnerable: The species faces a high risk of extinction in the wild.

World leaders at the 1992 Earth Summit in Rio de Janeiro adopted a strategy for sustainable development. One of the key agreements adopted at the Earth Summit was the Convention on Biological Diversity, which sets out commitments for maintaining earth’s ecological foundations during the pursuit of economic development. The objectives of the Convention on Biological Diversity include:

1. The conservation of biological diversity
2. The sustainable use of the components of biological diversity
3. The fair and equitable sharing of the benefits arising from the use of genetic resources

Concerning the Nile Basin, this basin has many diverse ecosystems, including mountainous highlands, freshwater lakes and wetlands, grasslands, tropical rainforest, desert, and the Nile River Delta (Fig. 1).

Tropical rainforests are located along the Nile–Congo divide, in parts of the Lake Plateau, and in southwestern Ethiopia. Heat and copious rainfall produce thick forests with a great variety of tropical trees and plants, including ebony, banana,



**Fig. 1** The Nile Basin land use and water use map. Global Cover Land Cover 2008: the map is produced by European Space Agency. It has 22 land cover global classes, which are defined according to the UN Land Cover Classification System (LCCS) [3]

rubber, bamboo, and coffee shrub. Mixed woodland and grassland (savanna), characterized by a sparse growth of thinly foliated trees of medium height and a ground covering of grass and perennial herbs, occur in large parts of the Lake Plateau, in parts of the Ethiopian Plateau, in the area that fringes the Blue Nile near Ar-Rusayris, and in the southern Al-Ghazal River region.

On the Sudanese plains, a mixture of thin bush, thorny trees, and open grassland prevails. This area is swampy during the rainy season, particularly in the Sudd

region of the south central Sudan. The vegetation there includes papyrus, tall bamboo-like grasses, reed mace ambatch (or turor), water lettuce, a species of convolvulus, and the South American water hyacinth.

North of latitude 10° there occurs a belt of thorny savanna or orchard shrub country characterized by small scattered tree stands, thornbush, and, after rain, grass and herbs. North of this, however, rainfall decreases and the vegetation thins out, so that the countryside is dotted with small thorny shrubs, mostly acacias. From Khartoum, northward there is true desert, with scanty and irregular rainfall and no permanent vegetation at all except for a few stunted shrubs. Grasses and small herbs may be scattered along drainage lines after rainfall, but these die away in a few weeks. In Egypt, the vegetation near the Nile is almost entirely the result of irrigation and cultivation.

In the arid desert zones of the Nile Basin, the biodiversity is low. However, it is high in the lakes, rivers, and other wetlands. The lakes and rivers support 545 species of fish. Notable among those found in the lower Nile system are the Nile perch, the Tilapia, the barbel, several species of catfish, the elephant-snout fish, and the tiger fish, or water leopard. Most of these species and the sardine-like *Haplochromis*, the lungfish, and mudfish are observed as far upstream as Lake Victoria. The common eel penetrates as far south as Khartoum, and the spiny eel is found in Lake Victoria. The Nile crocodile, found in most parts of the river, has not yet penetrated the lakes of the upper Nile Basin.

Other reptiles found in the Nile Basin include the soft-shelled turtle, 3 species of monitor lizard, and some 30 species of snakes, of which more than half are venomous. The hippopotamus can also be observed in the Nile system, especially in the Sudd region.

In addition, the wetlands of the Sudd provide essential habitat to numerous species of birds migrating between Europe and Central Africa, while other wetlands in the basin, including Lake Burullus in Egypt and Yala Swamp in Kenya, provide habitat for globally threatened species.

In the Nile Basin country, land degradation occurs naturally, but it is mainly induced by misuse and/or overuse. Land degradation in the basin is associated with management issues including erosion, salinization, and waterlogging. Other causes of land degradation include soil degradation (surface sealing, soil acidity, structure decline, and fertility decline) and vegetation degradation such as loss of plant biodiversity. Irrigation, particularly in Sudan and Egypt, has been associated with high levels of land degradation associated with waterlogging. In the equatorial lake region, reclaimed swampy land has experienced yield decline after several years of cultivation. Wetlands, mainly swamps and marshes in Rwanda, Burundi, Kenya, Uganda, Ethiopia, and Sudan, continue to experience encroachment by farmers. Encroachment into marginal lakeshore, wetlands, and riverine ecosystems results in modification of the ecosystem, including community structure and/or species composition. Soil erosion in the basin is highly variable in time and space. The main hot spots are in cultivated steep sloping lands in the highlands of Ethiopia, Kenya, Uganda, Rwanda, and Burundi and the overgrazed grassland in Sudan, Ethiopia, and Uganda. Desertification induced by extremes in climate and unsustainable land

use practices is becoming a serious problem in southern Sudan, Ethiopia, and Eritrea. The causes of deforestation vary widely, but include high land use and population pressure, cultivation on steep slopes and on river banks, annual crop cultivation, deforestation, bush fires and burning of crop residue, high-intensity storms and high soil erodibility, poor vegetation cover, overgrazing, and highly degraded soils [4].

Although species extinction is part of the natural cycle, the human activities on the Nile Basin countries have accelerated the rate at which species are disappearing. The list of endangered species in the Nile Basin is growing due to a range of causes from overhunting to a loss of habitat. The best source of data on this is the Red List, compiled by the IUCN species program (last modified on Wednesday 11 June 2014). Table 1 summarizes the endangered species by country in the Nile Basin.

This chapter describes a sample of the species biodiversity within the Nile Basin countries and Lake Nasser (case study) and considers some of the threats as well as initiatives to conserve biodiversity.

## **2 Biodiversity in the Nile Basin Countries**

### **2.1 *Burundi***

#### **2.1.1 Important Environmental Issues**

Due to its geographical position in the heart of Africa, temperate climate, and attractive landscapes, Burundi is referred to as the “Switzerland of Africa.” The climate varies from temperate in the mountainous area of the peak Congo–Nile to tropical, which is found in the central plateau and its surrounding hills and the depressions in the eastern and northeastern part of Burundi.

At the root of Burundi’s environmental threats is one of the highest population densities in Africa: approximately 405.5 people per km<sup>2</sup> as of February 2016 [5]. Land pressure has led individuals to cultivate on hillsides, where soils are shallow, low in fertility, and easily affected by erosion. Cultivation is also spreading to low-lying wetlands, where constructed drainage systems accompanied by siltation from surrounding hillsides are destroying many of these ecologically valuable areas. Additionally, much deforestation of the original forest covers occurs due to intensification of agriculture as well as timber and fuel wood harvesting. Little of Burundi’s native fauna or flora remain today; species such as elephants and gorillas have become locally extinct. The remaining habitats and natural flora are largely in the national parks of Kibira and Ruvubu, and possibly in some pockets of forest reserves scattered throughout the country, which have not benefited from continuous or effective management over the last decade.

Roughly 91% of the total land area is utilized for crops or livestock. Intensive cultivation has led to severe soil erosion on Burundi’s naturally steep terrain.

**Table 1** Endangered species by country in the Nile Basin

Country	Mammal	Bird	Reptile	Amphibian	Fish	Mollusk	Other inverts	Plants	Total
Burundi	16	30	0	7	23	5	5	1	87
Congo, D. R.	45	62	3	16	32	17	12	67	254
Egypt	14	30	9	0	38	0	132	2	225
Eritrea	7	24	1	0	24	0	148	3	207
Ethiopia	44	42	1	11	3	3	11	21	136
Kenya	44	55	2	8	81	19	151	103	463
Rwanda	25	32	0	9	9	0	2	2	79
Sudan	23	33	2	0	22	0	130	16	226
Tanzania	52	71	3	52	161	22	161	240	762
Uganda	37	45	0	7	62	11	16	39	217

Source: compiled and computed from 2009 IUCN Red List of Threatened Species (last modified on Wednesday 11 June 2014)

Seventy-six percent of land is considered severely degraded. In addition, Burundi losses about 5.2% of its forest cover annually between 2000 and 2005 [6, 7].

Forests and other wooded land suffer from deforestation. Forest area decreased from 1.011 million hectares in 1990 to 0.847 million hectares in 2005 [8]. Such deforestation has influenced Burundi's species biodiversity and ecosystems. It has contributed to the extirpation of both gorillas and elephants. In addition, soil erosion from deforestation has caused siltation of rivers, lakes, and wetlands, threatening both aquatic ecosystems and freshwater supplies.

Moreover, Burundi suffers from bacteriological pollution from animal waste, organic pollution due to waste effluent from coffee processing plants, and industrial pollution due to chemical fertilizers such as nitrates, phosphates, and pesticides. Some of the causes of pollution are high demographic density, lack of latrines and waste dumping, and mining activities resulting in discharge of heavy metals and arsenic, especially in River Akanyaru's tributary, Nowgere [9].

### 2.1.2 Critical Sites

Kibira National Park to the northwest (comprising a small region of montane rainforest adjacent to Nyungwe Forest National Park in Rwanda) is home to ten primate species, among them chimpanzees. In addition, a large variety of birds can be observed in Kibira National Park.

Ruvubu National Park to the northeast along the Ruvubu River Valley teems with buffalo, antelope, red colobus monkeys, over 400 species of birds, hippos, and crocodiles.

Freshwater resources in Burundi include three large lakes (Tanganyika, Cohoha, and Rweru); several significant rivers and streams, which feed into the Nile and Congo River Basins; and numerous marshes and wetlands. Lake Tanganyika is particularly important for its large number of endemic fish species, especially cichlids.

Rusizi National Park (near Katumba) is located some 25 km from Bujumbura, along the Congo border. It is a wetland environment that provides a habitat for hippos, crocodiles, sitatungas (aquatic antelopes), and a wide variety of birds.

The main forests are Congo–Nile Ridge (Kibira); Kigwena Natural Forest, located on the shores of Lake Tanganyika; Bururi Rumonge–Vyanda Natural Forest; and the forest of Nyakazu and Mwishanga.

The Rusizi Managed Nature Reserve is an interesting area of floodplain habitats, although most of the large mammals have died out. It remains important for other species.

Kirundo, 200 km from Bujumbura in the northeast of Burundi, is a region of extensive depressions dotted with many lakes abounding in bird life, including Cohoha, Rweru and Rwhinda, Kacimirinda, and Kanzigiri.



### 2.1.3 Endangered Species

The geographical structure of Burundi and the microclimates within the country provide for a diversity of vegetation. The fauna is also quite rich and comprises antelopes, hares, buffalo, and other animals. There are crocodiles and hippopotami in Lake Tanganyika. Land pressure is a considerable risk causing extinctions of certain species because the remaining habitats are not large enough to support viable populations. Eighty-seven species have been listed as endangered [2] as shown in Table 1.

### 2.1.4 Threats to Biodiversity

1. Owing to the high human population density in Burundi, most of the natural habitats are disturbed, and those that survive are often small and fragmented.
2. Land clearing for cultivation is the greatest cause of deforestation in Burundi.
3. Poorly protected and managed of the wetlands.
4. Some protected areas are in danger because they contain human settlements.
5. There is a continuing threat to the fish fauna (especially in Lake Tanganyika) from pollution, overfishing, and the potential introduction of alien fish species.
6. The ongoing civil conflict negatively influences biodiversity.

## 2.2 *The Democratic Republic of Congo (DRC)*

### 2.2.1 Important Environmental Issues

About 45% of the DRC contains primary rainforest, which provides a refuge for several large mammal species driven to extinction in other African countries. Overall, the country has more than 11,000 species of plants, 450 mammals, 1,150 birds, 300 reptiles, and 200 amphibians. Home to the greatest extent of tropical rainforest is Africa; deforestation caused by agricultural activity and the national dependence on fuel wood and mining are the main evident.

The forests and savannahs of DRC support abundant and rare wildlife [10]. The DRC is home to more types of great apes than any other country on earth, including the critically endangered lowland eastern gorilla and the bonobo. Poaching is an issue throughout Central Africa, although the situation is perhaps most severe in the DRC, where armed conflict, widespread poverty, and illegal mining all contribute to the problem.

The DRC is nearly 60% forested and alone accounts for one-fifth of Africa’s total forest area. Much of this forest is relatively undisturbed, making it an ecosystem of global importance. However, many areas are threatened by fuel wood collection, agriculture, and logging. Because of these activities, forest and other wooded land in the DRC decreased from 223,807 million hectares in 1990 to

216,886 million hectares in 2005. DRC has lost nearly 7 million hectares of forest since 1990 [11].

The DRC possesses substantial mineral resources, including diamonds, gold, copper, and coltan. Mining of these various deposits increases human activity in forest interiors, causing substantial degradation to surrounding ecosystems and increasing exploitation of forest resources such as wildlife and timber. Coltan mining in Kahuzi–Biega National Park, for example, has been implicated in the precipitous decline of the lowland gorilla population (less than 1,000 gorilla) [12].

### 2.2.2 Critical Sites

The most extensive terrestrial ecoregion in western DRC is the western Congolian forest-savanna mosaic with small areas of Atlantic Equatorial coastal forests and Central African mangroves near the coast. Aquatic ecoregions are the lower Congo, the lower Congo Rapids, Malebo Pool, and the Gulf of Guinea South Marine Ecoregion.

The area around Kinshasa and extending westward to the coast has varied topography and vegetation and a high human footprint associated with high population density, intensive agriculture, industries including oil and hydropower, port facilities, and relatively good roads and communications. Protected areas near the coast are the Mangrove National Park and the Luki Biosphere Reserve. Included in the former are most of the mangrove swamps on the DRC side of the Congo River and Estuary, and the sandy beaches along the coast, important for marine turtle nesting, have partial protection. Luki Reserve, although small, protects about 8,000 ha of Mayombe Forest, important for plant conservation [13].

Along with the eastern mountains and the Katanga mining area, western Congo has the largest human footprint; biodiversity loss and forest degradation are more severe here than in less disturbed areas. Problems include both species extinction and loss of diversity within landscapes, including diversity useful to communities [13].

The Congo River and Estuary below Matadi in the Bas Congo have high richness of birds including pelicans, the black-crowned crane, herons, and egrets and are key staging, feeding, and breeding areas for migratory water bird species. In addition, the area harbors populations of manatees and dwarf buffalo.

The Aruwimi-Ituri-Uele wetland (Oriental Province) on the Ituri River is a key site for migratory birds and a feeding or resting ground for many species.

The moist forest is the vast rainforest that covers the uplands and swamps along both sides of the Congo River, including the forests in the big bend. This area is very high in biodiversity and endemism, but it contains also poorly explored and might even yield new species of larger mammal, like the new *Cercopithecus* monkey, resembling the endangered owl-faced monkey, recently discovered in the Tshupa–Lomami–Lualaba area. The forest is very important for great apes, bonobos, chimpanzees, and gorillas, listed by the World Conservation Union

(IUCN) as critically endangered or endangered. Okapis are endemic to the eastern part of the moist forest, and populations of forest elephants continue to decline [13].

Dry deciduous forest (miombo), widespread in eastern and southern Africa, is the climax vegetation over much of the southeast DRC and constitutes about 10% of the countries’ total forest cover. The vegetation is a large-scale mosaic of forests interspersed with edaphic grasslands, especially on sand or dry ridges, and riparian/wetland vegetation in depressions. Miombo is rich in species, especially plants and birds, and low in endemism, though rare birds occur around the wetlands and rare plants occur on copper-rich soils and elsewhere. Formerly, dry forests were moderately rich in large mammals, with higher densities around wetlands, but populations have been greatly reduced by poaching [13].

The ecoregions southern Congolian forest-savanna and the Kasai aquatic ecoregion cover a large area of about 570,000 km<sup>2</sup> mostly in southern DRC. The southern Congolian forest-savanna mosaic is a blend of forest, woodland, shrubland, and grassland habitats. In DRC, this ecoregion is a plateau that slopes downward from the Angola border and the Katanga upland toward the Congo River and is drained by the large Kasai River and other Congo tributaries. While the forests have only a few known endemic species, they have a rich fauna, including a number of different antelope species and high numbers of African elephants [13].

### 2.2.3 Endangered Species

In DRC, there are three different classes of ecoregions: terrestrial, freshwater aquatic, and marine, with the first two overlapping because of the extensive freshwater swamps.

In DRC, the forests cover an area of 2 million km<sup>2</sup> which represents roughly half of the high rainforests. The remainder is open forests and woody savannah. Designated parks and conservation areas occupy around 18 million hectares, or 8% of the national territory. DRC contains an estimated 10,000 species of plants, 409 species of mammals, 1,117 species of birds, and 400 species of fish – making it the 5th most biodiverse country on earth [14]. Forest types include the moist evergreen/semi-deciduous forest across the center of the country and extensive dry forest (miombo) in the south. In addition, there are forest/savanna mosaics. The mammal’s category contains most of the highest-profile endangered species. Some species continue to decline because of illegal trade in wildlife products, especially ivory and rhino horn.

In DRC, there are a number of threatened and endangered species across all orders. There are 72 species which are completely protected by law in DRC, though in practice, this protection is very weak, and 234 partially protected species, whose exploitation requires a permit. In DRC, there are 254 endangered species [2] as shown in Table 1.

#### **2.2.4 Threats to Biodiversity**

1. Fish introductions can have a major deleterious effect on native fish populations. In addition, the species biodiversity and the fishery productions are also at risk from pollution and overfishing.
2. Agricultural expansion especially in eastern DRC threatens the biodiversity and the richness of fauna and flora.
3. The commercial bush meat trade is the primary cause of wildlife extinction.
4. Industrial mining activities – without adequate safeguards, including the use of biodiversity offsets – will continue to threaten the DRC’s forests and biodiversity.
5. Cutting for fuel wood is a major driver of forest degradation around DRC’s urban areas.
6. Illegal artisanal logging and cross-border trade are linked to industrial logging concessions.
7. Illegal trade in endangered species continues to have an impact on the DRC’s elephant, hippo, and gray parrot populations as well as on important plant species including *Prunus africana* and *Afromosia* spp.

### **2.3 Egypt**

#### **2.3.1 Important Environmental Issues**

Egypt is facing increasing water needs, demanded by rapidly growing population, increased urbanization, and higher standards of living. An agricultural policy has further emphasized expanding production in order to feed the growing population. The population is currently increasing by more than one million people a year. With a population of approximately 90 million in 2016, it is expected to increase to 100 million by 2025. The most critical constraint facing Egypt is the growing shortage of water resources accompanied by the deterioration of water quality.

Main sources of biodiversity degradation are development of land, expansion of agricultural land, and disappearance of habitat from excessive grazing or application of agrochemicals, as well as polluted habitats especially the wetland of the Delta area. In addition, hunting, fishing, and tourism activities are disturbing the natural habitat areas.

Habitat loss includes those belonging to mammals like the African lion, raptors, and bird species like geese and ducks, which have lost habitat due to expansion of agricultural land or stockbreeding. In addition, development in coastal areas threatens animals like desert rats. Human-induced pollution has also had negative effect on species biodiversity, i.e., soil pollution and water degradation effects on raptors like lesser kestrel and bird species like white-tailed sea eagles and lesser flamingo. In addition, overhunting and overfishing cause biodiversity degradation. Mammals such as the African lion and fennec fox, and bird species such as duck

and snipe, are for game hunting, whereas various birds and sea turtles and fish including gilthead and sandfish are in decrease for hunting for living. Human-caused turmoil from tourism is threatening bird species living in coastal region.

According to the Strategic Foresight Group [9], the Nile waters that pass through Egypt undergo a process of cleansing as they pass through the reservoir of Lake Nasser. However, water quality is still a concern because of agricultural drainage, industrial development, domestic, and wastewater pollution.

Presently, the annual industrial water usage is 5.9 BCM, of which 550 MCM is discharged untreated into the Nile River. There are approximately 125 major industrial plants within the Nile Valley, which contribute to heavy metal loads.

Because of excessive use of fertilizers, estimated at almost 6.5 million tons each year, there are runoff and seepage into surface and groundwater.

In addition, upward seepage of seawater is leading to high salinity levels in the Delta. In the Delta region, the Rosetta Branch receives a higher concentration of organic compounds, nutrients, oil, and grease than the Damietta Branch.

Consisting mostly of hyperarid lands that are highly vulnerable to desertification, Egypt cultivates a very small percentage of its land. Virtually 100% of this irrigated cropland is contributing to annual cereal yields that are the highest in Africa [15]. However, pressures on agricultural land, including urban encroachment, waterlogging and soil salinity, pollution, and erosion from intensive farming have contributed to degradation and exacerbated the land scarcity problem. The estimated production loss from land degradation is about 8% in some areas north and northeast of the Nile Delta [16].

### 2.3.2 Critical Sites

Of the sources of pollution to the Nile River, discharge of raw sewage, especially in the rural areas, is the most critical. Most waterways receive raw sewage directly from units or sewage-/sludge-emptying trucks.

There are about 24,000 industrial enterprises in Egypt, of which about 700 are major industrial facilities. In general, the majority of heavy industry is concentrated in the Greater Cairo and Alexandria areas. Approximately 387 million m<sup>3</sup> are discharging from industrial effluents to the Nile, its canals, and drains.

Throughout Egypt, the course of irrigation and drainage canals is a total of approximately 55,000 km. Degradation of water quality in the Nile River and associated irrigation and drainage canals is a major issue in Egypt.

Delta drains receive discharge from predominantly untreated or poorly treated wastewater (domestic and industrial), as well as drainage of agricultural areas. Furthermore, the drainage water in the Delta region is becoming more saline; on average, its salinity increased from 2,400 g/m<sup>3</sup> in 1985 to 2,750 g/m<sup>3</sup> in 1995.

Four coastal lagoons fringe the north coast of the Nile Delta area in Egypt: Lake Manzala, Lake Mariout, Lake Edku, and Lake Burullus. One further lake also borders the Mediterranean Sea in the north of Egypt, Lake Bardawil in the Sinai Peninsula. The environmental quality of Lake Bardawil, which is a Ramsar site, is

pristine. The other four lakes on the north coast of Egypt, however, suffer from a great deal of environmental pressures.

### 2.3.3 Endangered Species

Egypt consists of a large desert plateau, interrupted only by the Nile River Valley and Delta, which constitute less than 5% of the nation's territory. Approximately 97% of the population occupies these latter lands; reaching Egypt population density is 87.1 people per km<sup>2</sup> as of February 2016 [17].

The main characteristic for Egypt is the desert and draught; however, Egypt's biodiversity is of global significance for 143 species, because it is located at the juncture of three continents: Europe, Africa, and Asia. It is the home of at least 800 species of nonflowering plants, 2,302 flowering species and subspecies, 116 mammal species, 447 bird species, 109 reptile species, 9 amphibians, and more than 1,000 fish species. Invertebrates are very diverse, for instance, insects vary between 5 and 10 thousand species, more than 200 coral species, 800 mollusks, and more than one thousand crustaceans.

Natural forest distribution is limited in the mountain area of the Gebel Elba, at latitude 22°–22°30'N, and tropical rainforest, mainly composed of acacias and mangrove forest, at the coastal area of the Red Sea. Protectorates of Elba, Ras Mohamed, Nabq, and Abu Galum existed in these areas.

Regarding losses of habitats, there are 225 endangered species in Egypt such as African lion, raptors, and bird species like saker falcon, gray sea eagle, etc. (*Falco cherrug*, *Haliaeetus albicilla*, etc.); sociable lapwing, long-billed curlew, etc. (*Vanellus gregarius*, *Numenius tenuirostris*, etc.); and lesser white-fronted goose, white-headed duck, etc. (*Anser erythropus*, *Oxyura leucocephala*). Also, animals like desert rats are threatened by development in coastal areas. Many species are adversely affected by human-induced pollution, i.e., raptors like lesser kestrel are for soil pollution and bird species like white-tailed sea eagles and lesser flamingo are affected by water degradation. In addition ferruginous duck (*Aythya nyroca*), gray sea eagle (*Haliaeetus albicilla*), and Audouin's gull and white-eyed gull (*Larus audouinii*, *Larus leucophthalmus*) are affected by human disturbances. Table 1 shows the Egyptian endangered species [2].

### 2.3.4 Threats to Biodiversity

1. Loss or degradation of the habitat is the main concern for decreasing the mammal, bird, fish, and reptile biodiversities.
2. Development in coastal areas threatens some animals like desert rats.
3. Human-induced pollution negatively affects many species, i.e., raptors like lesser kestrel are for soil pollution and water degradation affects bird species like white-tailed sea eagles and lesser flamingo.

4. Mammals such as the African lion and fennec fox, and bird species such as duck and snipe, are for game hunting, whereas various birds and sea turtles and fish including gilthead and sandfish are in decrease for hunting.
5. Human-caused turmoil from tourism is threatening bird species living in coastal regions.
6. Most cultivated agricultural areas are spreading across Nile Valley and Nile Deltas. Almost all of these areas are indigenous habitats and their species have long been replaced by valuable agricultural land.
7. Due to loss and/or contamination of habitat, mammals like shrew, snipes and plovers, geese, and raptors are in decline.
8. Egypt’s coral reefs are attracting millions of international tourists to the region. However, pollution from solid waste and chemical residues from agricultural, industrial, and urban development threaten coastal ecosystems.

## **2.4 Eritrea**

### **2.4.1 Important Environmental Issues**

Historically Eritrea accommodated a wide range of animal species including elephant, hippopotamus, buffalo, giraffe, greater kudu, wild ass, Nubian ibex, waterbuck, lion, leopard, cheetah, and colobus monkey as well as numerous other smaller species. At present, population of these species persists in parts of Eritrea, but they are few in number and threatened [18] because of water stress, population pressure, land degradation, and deforestation.

With only one perennial river and no natural fresh surface water bodies, Eritrea is facing scarcity of water. The country depends on groundwater resources that are regionally limited in both quantity and quality. Agriculture accounts for 95% of all water withdrawals [18]. The percentage of groundwater use in full/partial control schemes was 96.6% or 3,961 ha in year 1993. Area actually irrigated was about 62.5% of the equipped area in year 1993 [20].

Eritrea is at extremely high risk of desertification due to its arid climate and heavy reliance upon agriculture despite limited availability of arable land. Only 6.3% of land is suitable for cultivation and most of this potential has already been exploited [16]. However, continued population growth has forced expansion onto marginal lands and steep slopes. Livestock grazing, which is concentrated predominantly in the semiarid western lowlands, has also exposed soils to water and wind erosion.

Forests account for only 15% of land in Eritrea. The area of forest and other wooded land decreased from 9.2 million hectares in 1990 to 8.8 million hectares in 2005 [21]. Agricultural expansion, deliberately set forest fires, and demand for fuel wood are the main causes of deforestation (about 1 million hectares). Deforested terrain is particularly vulnerable to soil erosion due to torrential and erratic rainfall. Furthermore, deforestation removes valuable habitat for threatened species,

including elephant, wild ass, greater kudu, and civet, all of which are in danger of national extirpation.

In the Red Sea, there is a relatively pristine coastal and marine environment because of its low population density. The Red Sea coast and the 350 islands of the Dahlak Archipelago support fertile fishing grounds, with over 1,000 species of fish, 220 species of corals, and 851 km<sup>2</sup> of mangrove forest.

#### 2.4.2 Critical Sites

Eritrea consists of diverse climates and landscapes, from the hot and dry Red Sea coastal plain to temperate central highlands. Dividing the country between semiarid lowlands to the east and west, the highlands range between 1,500 and 2,000 m in altitude and are among the oldest areas cultivated by humans in the world. Sixty-five percent of the population lives in the highlands, although the highlands account for only 19% of the total land surface [19].

Eritrea exhibits a well-distributed, wide variety of natural ecosystems. Extensive grassland systems include *Aristida* grasslands in the west and *Sorghum purpureo-sericeum* grasslands in the southwest which are punctuated by riverine forest and border on large tracts of *Acacia* woodland. The vegetation of the mountainous north is primarily steep, with patches of semidesert and riverine woodland. The south central region hosts several forest systems, including *Acacia* woodland, *Juniperus* forest, and north of Asmara, the last remnant of mixed evergreen tropical forest.

Eritrea's lengthy coastline is a mixture of semidesert and halophytic vegetation with small patches of mangrove forest. Offshore, Eritrea harbors healthy coral reefs as well as over 350 islands, many of which are home to a variety of wildlife species. There have been reported sightings of *Oryx* and gazelle, but these need to be verified. The island system offers sanctuary to endangered species such as the dugong (*Dugong dugon*) and the green sea turtle (*Chelonia mydas*). These ecosystems are under pressure, and current protective measures are insufficient to ensure the long-term survival not only of these habitats but also the species that occur therein.

There are three areas of particular interest for forest biodiversity: mixed forest, riverine forest, and the marine environment.

The dense and disturbed highland forest ecosystem is located in the eastern escarpments of Eritrea encompassing 1,001 km<sup>2</sup> [22]. There are two types of forestlands, namely, disturbed *Juniperus* (coniferous) forest and dense and disturbed mixed forest. Both types of land use and land cover units are found in Semenawi and Debubawi Bahri or in the Green Belt, although small highly disturbed patches of juniper groves are found at Abahane, Kohaito, and Soira in the south and Rora Habab in the north [22, 23]. Abehane, Soira, and Rora Habab juniper forests are extremely disturbed and look unstable.

The riverine forests are found mainly in the western lowlands, alongside the Gash, Barka, and Anseba intermittent rivers, encompassing a total area of 1,865 km<sup>2</sup> [22].



The marine environment makes a major contribution to Eritrea’s natural heritage and biological diversity. There are many different marine and coastal habitats and ecosystems in Eritrea, such as (1) sabkha, (2) sandy shores, (3) rocky shores and cliffs, (4) intertidal mud flats, (5) mangroves, (6) sea grass beds and macro-algal hard bottoms, (7) coral reefs, (8) open sea, and (9) sea bottom and continental slope.

### 2.4.3 Endangered Species

In Eritrea, about 49% of the country is rangeland, and approximately 75% of the total population depends on livestock production [24]. The major resources in the rangelands include indigenous grasses and browse plants, water points, and shade provided by vegetation. Environmentally friendly management techniques are missing in the rangelands. However, in most cases, pastoralists do allow large trees to persist in limited numbers as they provide shade for livestock [24]. Only one century ago, forest covered 30% of Eritrea. By 1952, that amount had dwindled to 11%. In 1960, the estimated forest cover was about 5% of the country. Currently, the estimated cover is about 1%, or even less [24, 25]. This is mainly due to agricultural clearance, war, and severe drought in the country. In Eritrea, a variety of natural resources have been declining because of human-made and natural calamities such as drought, deforestation, and prolonged war. Historically, the country accommodated a wide range of wildlife species such as African elephant, hippopotamus, buffalo, giraffe, greater kudu, African wild ass, Nubian ibex, waterbuck, lion, leopard, cheetah, colobus monkey, and numerous other smaller species [24]. At present, a few of these species such as African wild ass, Nubian ibex, greater kudu, waterbuck, leopard, and numerous other avifauna species exist in Eritrea, but these populations are small and are considered to be under threat. In Eritrea, there are 207 endangered species [2] as shown in Table 1.

### 2.4.4 Threats to Biodiversity

1. Excessive collection
2. Forest fire
3. Overgrazing
4. Recurrent droughts
5. Alien avifauna parakeet
6. In coastal zone, sedimentation has been the main threat because of land reclamation on few coastal sites of Massawa. Anchoring is also happening by some fishermen and tourist boats at sea grass beds of the frequently visited islands.
7. In Eritrean Red Sea, many corals are relatively pristine, away from human and economic impact. However, in Massawa, coastal rapid development (such as fisheries infrastructure, fishing operations, aquarium fish collection, tourism, oil pollution from loading and unloading, siltation from land reclamation and road construction) caused negative effects on the habitat structure.

## 2.5 *Ethiopia*

### 2.5.1 Important Environmental Issues

Ethiopia has some of the world's rarest animals and plants, but these are now in danger of disappearing forever due to overuse and loss of natural habitat. Uncontrolled population growth has put ever-increasing pressures on the country's natural resource base.

Desertification, soil erosion, and water pollution are widespread in Ethiopia, particularly in the highlands where the terrain is very steep and where the majority of agricultural production occurs.

Although surface water resources are relatively abundant, they are largely undeveloped and unevenly distributed. Approximately 70% of runoff occurs during June and August, and recurring droughts and erratic rainfall are frequently responsible for widespread food insecurity and significant loss of livestock and crops [26].

In Ethiopia, the main industries are textiles, soft drinks, food, metals, and tannery. However, most of these industries do not have any waste treatment facilities. The notable point pollutants are chromium, hydrogen sulfide, dyes, and caustic soda. The nonpoint pollutants include domestic solid waste and effluents. Additionally, fecal pollution from cattle, pesticide, and fertilizer runoff also contribute significantly [9].

Deforestation and the associated land degradation threaten species biodiversity for both flora and fauna. A loss in biodiversity ultimately implies economic losses to Ethiopia. In addition, the removal of vegetative cover reduces the amount of carbon that can be sequestered from the atmosphere. As the growth stock of Ethiopia's forestry resource base is depleted, its value as a "carbon sink" is reduced. According to Environmental Protection Authority in Ethiopia, 2003 [27], the major causes for the depletion of forest resources are the following:

1. Increases in population and consequent increases in the demand for agricultural land, fuel wood, as well as construction and industrial use
2. Settlements around forest areas
3. Forest fires
4. The expansion of large commercial farms in forest areas
5. The absence of a forest protection and conservation policy
6. The absence of a strong forest administration system capable of arresting the rapidly increasing rate of deforestation as well as controlling and preventing the disruption of the various ecosystems
7. Lack of effort to ensure the participation of communities in forest protection and conservation and the sharing of benefits
8. Failure to clearly demarcate and enforce the boundaries of natural forest reserves

In Ethiopia, up to 400 tons of fertile soil/hectare is annually lost from land with insufficient vegetation cover as well as from land where there is no effective soil conservation. The estimated amount of soil lost annually from wind and erosion is

1.5–1.9 billion tons. About 45% of this soil loss occurs on crop farmlands and 21% occurs on overgrazed rangelands [27].

Furthermore, the wetlands in Ethiopia face threats from demographic pressure with a 2.1% increase in growth rate, overgrazing, soil erosion, and deforestation and urbanization and industrialization [9].

### 2.5.2 Critical Sites

Ethiopia has many critical sites for biodiversity and several managed protected areas such as Simien Mountains National Park and Awash National Park.

The Awash National Park was established and gazetted in 1966 and 1969, respectively. The park covers at least 756 km<sup>2</sup> of acacia woodland and grassland. Wildlife in this park includes the East African oryx, Soemmerring’s gazelle, dik-dik, and the lesser and greater kudus, as well as more than 450 species of native birds.

Abijatta–Shalla National Park is located in the Oromia region, 200 km south of Addis Ababa and east of the Ziway–Shashamane highway. The park contains 887 km<sup>2</sup>, including the Rift Valley lakes of Abijatta and Shalla. These two lakes are separated from each other by three kilometers of hilly land. There are more than 450 species of birds in the park that is recognized as an important bird area by Birdlife International [28].

Bale Mountains National Park is in the Oromia region of southeast Ethiopia. The park covers about 2,200 km<sup>2</sup> of the Bale Mountains to the west and southwest of Goba in the Bale Zone. UNESCO’s Man and the Biosphere Programme lists the park as a Biosphere Reserve. It is as a World Heritage Site, which is recognized by UNESCO (UNESCO World Heritage) and is currently on the tentative list pending final status [29]. The park is the most important component of the Ethiopian highland biodiversity hotspot as recognized by Conservation International.

Yabello Sanctuary was set up to afford protection to the endemic Swayne’s hartebeest.

The Simien Mountains National Park represents an area of spectacular scenic beauty, as well as being of critical importance for a number of rare species.

There are important wildlife resources in the Yabello region of Sidamo Province, including five endemic bird species and a population of the endemic Swayne’s hartebeest.

There are important areas for large mammals such as Omo and Mago National Parks and Tama and Chew Bahar Conservation Areas.

All of the lakes in the Rift Valley need some form of conservation measures. Lakes Abijatta and Shalla are included in the Abijatta–Shalla National Park (still ungazetted and inadequately managed). Part of the Lakes Abaya and Chamo and the intervening areas are protected in Nechisar National Park (also still ungazetted). Sufficient protection is lacking for Lakes Zwai, Langano, and Awasa and for wetland habitats in general in the Rift Valley. The Senkelle Swayne’s Hartebeest Sanctuary is located near Lake Awasa.

Very important wildlife populations exist in the Awash River Valley, including populations of the Somali wild ass. Protected areas, all lacking sufficient resources to ensure adequate protection, include Awash National Park, Awash West Conservation Area, Gewane Conservation Area, Yangudi Rassa National Park, and Mille Sardo Wild Ass Reserve (of these, only Awash National Park has been legally gazetted).

Further to the north, in Tigray and southern Eritrea, there is a similar array of species, likewise poorly protected. Likely little action can be taken to remedy this during the current security situation, but this should remain a long-term goal.

The far northern conservation areas of Yob, Nafka, Gash Setit, and Chire are very important for antelopes, though the security situation prevents conservation action.

The Gambella National Park in the west remains ungazetted and adjacent agricultural development threatens it.

### **2.5.3 Endangered Species**

With broad latitudinal and altitudinal ranges, Ethiopia encompasses an extraordinary number of ecological zones, which in turn host rare and endangered species and high rates of endemism.

Species biodiversity in Ethiopia includes 280 mammals, 861 birds, 201 reptiles, and more than 6,000 plants with high rates of endemism [2]. However, the International Union for the Conservation of Nature's (IUCN's) 2014 "Red List" of these species has recorded 136 of endangered species [2] as shown in Table 1.

### **2.5.4 Threats to Biodiversity**

1. Draining for agriculture use.
2. Specifically, the wetlands are often a last destination for pastoralists during the dry season in most parts of the country. However, increases in the livestock population, shortages of fodder, and the simultaneous expansion of agricultural activities have contributed to exacerbating the grazing pressure on wetlands.
3. Deforestation, siltation, soil erosion, and land degradation within a wetland catchment area – the starting cause for an accumulation of silt within the wetland ecosystem.

## 2.6 Kenya

### 2.6.1 Important Environmental Issues

Deforestation, soil erosion, and water pollution from urban and industrial wastes are three environmental concerns for Kenya. About 83% of Kenya’s land area is vulnerable to drought and desertification. Nevertheless, Kenya’s protected areas have increased to over 30 national parks and reserves.

Water pollution in Kenya is caused by point and nonpoint sources such as agricultural practices (salts, fertilizers, and pesticide residues), urbanization, industry, leachates from solid waste tips, and sediments. Additionally, municipal sewerage plants discharge untreated wastewater into watercourses, causing significant health hazards and localized eutrophication. Tanneries, pulp and paper mills, coffee-processing factories, breweries, and sugarcane-processing facilities do not have effective wastewater treatment plants, and their effluents contribute organic loads, heavy metals, and other toxic substances. Although only 8% of Lake Victoria falls into Kenyan territory, tributaries such as Sio, Nzoia, Yala, Nyando, and Mara are already severely polluted [9].

The Nyanza province bordering Lake Victoria is undergoing rapid catchment deterioration due to frequent droughts, deforestation, and old agricultural practices [9]. In the arid and semiarid regions where livestock are grazing, recurring drought exacerbates desertification and threatens the livelihoods of over 3.5 million pastoralists [30].

Widespread deforestation is also contributing to desertification. The estimated deforestation rate is about 5,000 ha/year by 2010 [31].

Concerning the degradation of freshwater ecosystems, Lake Nakuru is suffering from a high load of siltation that comes from surrounding agricultural activities and industrial and domestic effluent from nearby Nakuru Town [32].

Lake Victoria, which accounts for most of Kenya’s freshwater fish production, is also threatened. Increased nutrient input from agricultural runoff and the spread of the invasive water hyacinth plant have significantly reduced water quality.

### 2.6.2 Critical Sites

Kenya’s diverse climate ranges from tropical along the Indian Ocean coast to arid in the extreme north. The Great East African Rift Valley bisects highland areas in the center of the country, the location of Africa’s second highest peak Mount Kenya. Kenya’s dry lands account for 88% of her land surface area. The dry lands are home to a population of approximately 10 million people. About 50 and 70% of livestock and wildlife, respectively, are located in the dry lands [33].

Lake Victoria is the world’s second largest freshwater lake, covering an area of 67,850 km<sup>2</sup>. Three nations share the waters of the lake (Kenya, Tanzania, and Uganda). Kenya’s share is the smallest (3,785 km<sup>2</sup>), but is a busy network of

waterways between the trading towns and villages, which lie along the shores of the lake.

Ruma National Park was established in 1966. It is a fine place to see roan antelope and Jackson's hartebeest. Oribis, one of the smallest of the antelope family, are also found here and among the predators are lion and cheetah.

The Masai Mara National Reserve is Kenya's finest wildlife sanctuary. The wildlife is abundant and the gentle rolling grasslands ensure that animals are never out of sight. Birds, too, are prolific. Including migrants well over 450 species have been recorded, among them 57 species of birds of prey. The climate is gentle, rarely too hot and well-spread rainfall year round. Between July and October, when the great wildebeest migration is in the Mara, the sensation is unparalleled. The reserve is about 1,510 km<sup>2</sup> having been reduced from 1,672 km<sup>2</sup> in 1984. However, the wildlife is far from being confined within the reserve boundaries and an even larger area, generally referred to as the "dispersal area" extending to north and east of the reserve. Here the great herds of shuffling elephants browse among the rich tree-studded grasslands with an occasional sighting of a solitary and ill-tempered rhino.

Thomson's and Grant's gazelle, topi, and eland and many more species of plains' game offer a rich choice of food for the dominant predators, lion, leopard, and cheetah, which hunt in this pristine wilderness. In the Mara River, hippo can be seen. Seemingly, drowsy crocodile sunbathe on the riverbanks, with its mouth agape, waiting with subtle cunning for prey at which to strike with lightning swiftness. Each year, far south in the great vastness of the Serengeti, the wildebeest raise their dignified but quaint heads, sniff the air, and, as if by one accord, start the long trek to the Kenya border and the Masai Mara. After exhausting the grazing in Tanzania's northern Serengeti, a large number of wildebeest and zebra enter the Masai Mara around the end of June drawn by the sweet grass raised by the long rains of April and May. It is estimated that more than half a million wildebeest enter the Mara and are joined by another 100,000 from the Loita Hills east of the Mara. Driving in the midst of these great herds is an unimaginable experience. The herds draw ravaging packs of predators, especially hyenas and lions, and thousands of the lame, laggard, and sick never complete the cycle. More die by drowning or by the teeth of the cunning crocodile while trying to cross the swirling muddy waters of the Mara and Talek rivers. Once the Mara's grass has been devoured and when fresh rain Tanzania has brought forth a new flush there, the herds turn south, heading hundreds of kilometers back to Serengeti and the Ngorongoro plains. There the young grow sufficiently strong to undertake the long march north 6 months later.

Mt Elgon National Reserve, whose peaks reach 4,320 m, lies astride the Kenya-Uganda border. Like most of the other great mountains of East Africa, it represents the remains of an immense volcano. There is no permanent snow on the mountain, but its bleak and craggy peaks are surrounded with the typical afro-alpine vegetation of the high mountains of the equator. Giant groundsel and lobelia grow over the 3,650 m level and for much of the year, everlasting flowers (*Helichrysum* sp.) cover the moorlands. At lower levels giant heath, bamboo, and montane forest prevail and in these areas, there are elephant and plenty of buffalo. Part of the eastern aspect is set aside as the Mt Elgon National Park stretching from the peaks to the boundary of

the forest and the heavily cultivated country of the Luhya people. Within the park are a wondrous multitude of wildlife and wild flowers and some exciting oddities, among them the celebrated Kitum and Makingeny caves where elephants probe deep in the dark interiors to sample mineral salts from the cave walls.

Saiwa Swamp National Park (190 ha) is not far from Mount Elgon and only 24 km from Kitale town. Created primarily for the protection of the rare sitatunga antelope, the park is a perfect example of how a small area can survive as a complete ecological entity. The semiaquatic sitatunga relying on a swamp habitat has evolved to survive in such conditions and despite the size of the park seems certain to continue to thrive there. The sitatungas at Saiwa are sufficiently numerous to ensure seeing them. In addition, there are de Brazza, colobus, and vervet monkeys and an exciting variety of birds – some 250 species have been noted in this small area.

Homa Mountain, gaunt and grand, dominates the peninsular. It shelters the small town of Homa Bay. Near Homa Bay are two islands, Rusinga and Mfangano. Rusinga is locally claimed as the burial place of Tom Mboya, a great son of Kenya who was assassinated in Nairobi in 1969.

Kenya is probably the best endowed country in Africa for marine protected areas. These are the Kisite–Mpunguti and Malindi–Watamu protected area complexes and Kiunga Marine National and Biosphere Reserve. Additional protected areas are proposed for Diani and Ras Tenewi. These areas include coral reefs, sea grass beds, dugong and turtle populations, and seabird colonies of international significance, but current levels of protection are limited.

### **2.6.3 Endangered Species**

According to the World Conservation Monitoring Center in the UK, Kenya is among the world’s top 50 countries in terms of species richness; neighboring Tanzania and Uganda also fall into that range. Kenya’s tropical moist mountain forests, East African woodland/savanna areas, and Rift Lakes wetland areas rank it among the highest geographic priorities for USAID’s biodiversity conservation goals, according to the Agency’s Biodiversity Strategy of 1996. Kenya has about 35,000 known species of plants, animals, and microorganisms. This number includes 24,995 described animals’ species. For some taxa, notably birds (1,079 species) and mammals (325 species), the total reported approximate the true species biodiversity. In other taxa, the majority of the species have yet to be formally described. The total number of plant species documented is 6,817 (excluding 229 species of algae), of which the majority are flowering plants.

The most endangered ecosystems in Kenya are forests, terrestrial wildlife habitats, and freshwater and coastal wetlands. Coral reefs will be increasingly threatened if uncontrolled development, existing pollution, and sedimentation from upstream agricultural areas are not slowed. The threat to many of Kenya’s animal and plant species is considered to be high, relative to other countries with similar rankings of species richness and endemism [34]. The following illustrates

this point with recent statistics from the IUCN Red Lists, which shows that 463 are endangered [2] as shown in Table 1.

## 2.6.4 Threats to Biodiversity

1. The habitats and species of the arid northern part of the country, as well as those of the forests and wetlands, are not protected.
2. Agricultural expansion and the need for fuel, wood, and charcoal represent the main cause of deforestation (most notably Arabuko-Sokoke and Kakamega).
3. Wildlife tourism and illegal hunting of large animals threaten the species biodiversity.
4. In many places, the management of protected areas is maintained at a sufficient level.
5. Water management projects are threatening several wetland areas.
6. Fish introductions, pollution, and overfishing are probably having a major deleterious effect on native fish populations, especially in Lake Victoria.
7. Marine areas, particularly coral reefs, are under severe threat from siltation, dynamiting, pollution, over-collection of shells and corals, and tourist pressure.

## 2.7 Rwanda

### 2.7.1 Important Environmental Issues

Rwanda is a small, mountainous country located only a few degrees south of the equator, but its high elevation provides for a tropical temperate climate with two rainy and two dry seasons. Rwanda is dominated by the hills and valleys of the central plateau, which are bordered to the east by marshy lowlands, to the north by a chain of volcanoes, and to the west by a mountain system, which forms the boundary between the watersheds of the Nile and Congo River Basins. Surface water is relatively abundant in Rwanda, covering over 8% of the country [35].

Population pressure on land, deforestation, soil erosion and sedimentation, and water pollution are environmental concerns for Rwanda.

Rwanda is the most densely populated country in mainland Africa. Rwanda's current population density is 485.6 per km<sup>2</sup> as of February 2016 [36]. Approximately 80% of the population is rural and engaged in agriculture, placing significant pressure on land resources and biodiversity. Modification and destruction of natural ecosystems for agriculture, and particularly the drainage and reclamation of wetlands, has resulted in the loss of many plant and animal species. An estimated 115 different plant species are threatened with extinction [37].

Rwanda's rich volcanic soils are historically fertile, but population pressure has resulted in overcultivation and expansion onto marginal lands and steep slopes. As



of 2003, arable land accounted for over half of the country’s surface area and approximately 98% of all potentially cultivatable land in the country [35].

Forests were once extensive throughout Rwanda, but they are now concentrated primarily in the western mountains. The swampy gallery forests that historically characterized the eastern lowlands now exist only in small locations. Despite recording a net increase in overall forest cover since 1990, natural forests remain threatened by human encroachment and high dependence on fuel wood and charcoal [37].

Nyungwe National Park is the largest tropical mountain forest in Africa, covering over 1,000 km<sup>2</sup> of rainforest, bamboo, grassland, swamps, and bogs. It harbors 13 different primate species, 62 Albertine Rift endemic species, and one of the largest surviving populations of chimpanzees [38]. Buffalo and elephants are extirpated due to human encroachment and illegal poaching, and fires started by honey collectors have damaged large tracks of forest.

Concerning the water pollution, the main sources of water pollution are domestic, commercial, industrial, agricultural activities, water hyacinth, and mismanagement of wetlands. Due to increased population, unsustainable agricultural practices, and inadequate sanitation facilities, there is an extensive use of fertilizers and pesticides. In addition, wastewater from rural towns and villages that contain fecal pollution is left untreated, giving rise to waterborne diseases [9].

### 2.7.2 Critical Sites

Rwanda is a small country with a high human population density, and yet it contains a remarkable variety of different habitats and species. The largest area of natural habitat in the country is the Akagera National Park and the contiguous Mutara Hunting Reserve. This area includes several types of savanna woodland, large swamps, and lakes and is the most important area for large mammals in the country.

The country has several areas of lakes and swamps (including high-altitude swamps in the mountains and papyrus swamps at lower altitudes). Important sites are Lake Kivu, Lake Luhondo, Lake Bulera, and the Akagera, Akanyaru, Nyabarongo, Rugezi, and Mulindo Swamps. These wetlands are under severe threat and are in need of appropriate protection, including new protected areas and sustainable use or better rural development programs. A few swamps are protected in the Volcanoes National Park and the Nyungwe Forest Reserve, but the Kamiranzovu Swamp (in Nyungwe) is threatened by mining [39].

The Kivu Belt Region is one of the most attractive regions in Rwanda. The driving force behind the dynamic increase in tourism in this area is, so far, largely the gorilla tourism. The national parks (mainly Nyungwe National Park) are another main attraction in the area.

The Volcanoes National Park is home to 245 species of plants, including 17 dominant ones of which 13 are internationally protected orchidaceous, 115 species of mammals, 185 species of birds, 27 species of reptiles and amphibians, and 33 species of invertebrates [39].

The Nyungwe Forest Reserve includes some of the most extensive areas of mountain forest in Africa. In this forest, there are more than 1,200 plant species among which are found at least 50 species of fodder and 133 species of orchids. More than 250 wood species have been identified, with more than 275 species of birds, 24 of which are endemic. Thirteen types of primates have been identified, representing 1/5 of Africa's primate species among which is the most threatened, namely, the monkey with an oval face (*Cercopithecus hamlyni*) and the golden monkey (*Cercopithecus mitis kandti*). Nyungwe has one of the remaining biggest populations of chimpanzees of the east (*Pan troglodytes schweinfurthii*). The Angola colobus (*Colobus angolensis*) is generally found in stable groups of between 300 and 400 individuals [39].

In the Akagera National Park, the plant formations are quite diversified. They shelter more than 900 species of plants, including 60 internationally protected orchids. The Acacia Senegal is generally dominant. In the more arid zones of the Akagera National Park, the vegetation tends toward a combination of Acacia–Commiphora, whereas in the wetter areas, Acacia Senegal tends to be replaced by *Acacia polyacantha* and *Acacia sieberiana*. Grassy savannas consist mainly of *Themeda*, *Hyparrhenia*, *Sporobolus*, and *Bothriochloa*. The fauna constitutes the park's major attraction. It comprises 47 species of big mammals, more than 500 species of birds, 9 species of amphibians, and 23 species of reptiles.

The lakes of the Akagera National Park are quite rich in biodiversity: the phytoplankton consists mainly of Chlorophyceae, Cyanophyceae, and Diatomophyceae. The floras are mainly dominated by *Cyperus*, *Phragmites*, *Phoenix*, *Potamogeton*, *Aeschynomene*, *Thelypteris*, etc. Water hyacinth (*Eicchornia crassipes*) is present and has started covering big areas of the lakes, representing a threat to their biological diversity.

The desert alpine zone (above 3,500 m) is composed solely of lichens and mosses. In addition to the gorillas, the Volcanoes National Park afro-montagne forests contain elephants, buffalo, several primates, and other mammals; *Rana angolensis*, *Chamaeleo rudis*, and *Leptosiphos graueri* are endangered. Overall, the flora and fauna inventory of the park includes

- 245 plant species, and of these, 13 species of orchids are internationally protected
- 115 mammal species
- 187 bird species
- 27 species of reptiles and amphibians
- 33 arthropod species [40].

### 2.7.3 Endangered Species

Despite its territorial small size, Rwanda is covered by diversified ecosystems: natural ecosystems consisting of mountain rainforests, gallery forests, savannas, wetlands, and aquatic lands and ecosystems that have been altered by man's

activities consisting of deforestation and cultivated areas. All these ecosystems accommodate a flora and fauna wealth. Rwanda’s 26,338 km<sup>2</sup> is covered predominantly by mixed cropland/natural vegetation (47%), followed by savannah (32%), forests (12%), and water and wetlands (8%) [40].

Rwanda shelters 2,150 species of plants, 151 different types of mammal species, and 670 different birds [37]. Deforestation and conversion of natural habitats to agricultural systems in the last three decades has caused a loss of variability across its entire ecosystems. The flora comprises hundreds of higher and lower plant species. Some of them have been domesticated for years and are today the basis of human diet; others are meant for commercial and medical uses. In Rwanda, there are 79 endangered species [2] as shown in Table 1.

### **2.7.4 Threats to Biodiversity**

1. Population pressure on biodiversity resources and protected areas.
2. Wetlands outside the main reserves are poorly protected and managed. The important biological resources in these ecosystems could easily be lost through clearance and overuse.
3. Kamiranzovu Swamp is threatened by mining.
4. Agricultural inefficiencies and soil erosion.
5. Some protected areas are suffering from poaching of large mammals, in particular Akagera National Park and the Nyungwe Forest Reserve.
6. Montane forest clearance has been serious in some areas, and the most importance sites have not been given adequate conservation status.
7. There is a potential threat to populations of endemic fish from the introduction of alien fish species, as well as from overfishing and pollution.

## **2.8 South Sudan**

### **2.8.1 Important Environmental Issues**

Sudan descended into civil war in 1983. In 2005, after 22 years of war between the National Congress Party (NCP) in the north and the Sudanese People’s Liberation Army (SPLA) in the south, the parties signed the Comprehensive Peace Agreement (CPA), putting an end to Africa’s longest-running conflict. In 2011, the Republic of South Sudan officially became an independent nation. The armed conflict has severely affected the lives of communities in and around protected areas in South Sudan and, as such, has resulted in a major assault on the country’s wildlife and their habitats. Hunting played an important role in human survival during the war and, as a result, uncontrolled and unsustainable hunting decimated wildlife populations [41].

Population pressure on land, hunting, deforestation, and water pollution are environmental concerns for South Sudan.

### 2.8.2 Critical Sites

The wildebeest migration in South Sudan is one of the biggest animal migrations in the world and has been described as more spectacular than other migrations on the African continent. This amazing discovery in the Boma region of Eastern Equatoria and Jonglei states has been attracting all sorts of visitors. Furthermore, all of South Sudan's animals that fled to neighboring countries during the war are now returning in amazing numbers.

The White Nile is the greatest natural resource in south. The town of Nimule is home to a magnificent waterfall. This waterfall presents an amazing storm of water raging downhill causing a radiant smoke of evaporation.

The Sudd Swamp contains green carpet of water lilies and other water plants, which presents a beautiful and extraordinary view. The Sudd is also believed by the "people of the Nile" to contain some animals that are extinct in the rest of the world. That belief may have truth because the Sudd has been free from any scientific exploration. The Sudd has spectacular scenery, especially with an aerial view of this wonder land.

South Sudan is home to the second largest wildlife migration on the globe, making game and wildlife a huge tourist attraction. South Sudan hosts 5 national parks and 14 game reserves, bringing spectacular and important wildlife populations to Africa such as buffalos, elephants, giraffes, and lions.

Bandingalo was established in 1992. It is located in a wooded area near the White Nile River, in South Sudan's Equatoria region, within the states of Central Equatoria and Eastern Equatoria. It is over 10,000 km<sup>2</sup> in size.

Earth's second largest annual animal migration, involving multiple species of antelope including reedbuck, tiang, and white-eared kob, takes place in the park, which is also home to iconic African mega-fauna like the giraffe. It also contains large marshlands stretching up into Jonglei state. The park supports large bird populations. Though a major wildlife preserve, the park lies within a total oil concession, potentially exposing it to surveying and drilling.

In Bandingalo National Park, it is uncertain which subspecies of giraffe exists in South Sudan. There is debate it could be the Rothchild's, Nubian, or Kordofan subspecies. South Sudan is the intersection of these three subspecies. All three subspecies are low in total population numbers: Kordofan 2,500, Rothchild's 670, and Nubian 250.

On the border with Uganda is Nimule National Park. The Nile River cuts along the eastern border of the park for 48 km. The road from Uganda to Juba cuts along the eastern border of the park next to the Nile. The park has 41,000 ha to protect the white rhino, which is now extinct. The park is the most accessible of South Sudan's parks. Herds of elephant have made the park their home, realizing they are safe in the park.

Elephant, Uganda kob, Lelwel hartebeest, crocodile, duiker, hippo, waterbuck, bushbuck, oribi, leopard, olive baboon, vervet monkey, warthog, and incredible bird life exist in the park.

Boma National Park is Africa’s largest wildlife reserve. As water sources dry up after the seasonal rains and then again when the seasonal rains return, enormous herds of animals migrate in Boma National Park. It is estimated that the migration is far greater than the famous migration of the Serengeti, where nearly two million animals search for grazing.

In South Sudan, as in the Serengeti, the migration takes place all year; it is a slow movement dependent on the grass and the rains. In March/April/May/June, the animals are moving from north to south and west to east, from the Sudd floodplains and Bandingilo National Park, back into Boma National Park and Ethiopia, because the rains will have started. In November/December/January, the animals move from south to north, east to west as the dry season is well under way, and the animals are searching for grass. In November/December/January, the white-eared kob will be calving as they migrate north into the Sudd floodplain and west into Bandingilo National Park. The major migrating species involved are white-eared kob antelope, tiang antelope, and Mongalla gazelle. Prior to the war with the north, there were huge herds of zebra, and these animals were considerably reduced in number. A 2008 survey estimated that there were 6,850 elephants in the park and surrounding area adjacent to the park. The elephants and zebra also migrate with the water and grass seasons.

The Zeraf Game Reserve protects most of the central part of the Sudd wetland at a size of 970,000 ha or 9,700 km<sup>2</sup> and was set aside in the year 1939. The game reserve is important in protecting populations of Nile lechwe antelope, sitatunga antelope, and hippopotamus, not to mention the enormous numbers of migrating birds.

A large portion of this reserve is on Zeraf Island, which floods every wet season. The Bahr el Zeraf River bound the island on the west by the White Nile and on the east.

Mount Kinyeti is the highest peak in South Sudan. Located in the Imatong Mountains in Ikotos county of Eastern Equatoria state, near the Ugandan border, Kinyeti has an elevation of 3,187 m above sea level. The groups of high mountains that contain Kinyeti, extending to the border with Uganda, are sometimes called the Lomariti or Lolobai mountains. The lower parts of the mountain were covered with lush forest. The most important montane forests in Sudan are in the Imatong Mountains in the extreme south. The natural forests are under threat from continued expansion of tea and forestry plantations. Other areas of mountain forest exist in the south in the Didinga and Dongotona Mountains (although these have been degraded by burning) and in the proposed Boma National Park in the southeast.

### 2.8.3 Endangered Species

South Sudan embraces diverse biological resources, which represent an important national asset and heritage. The Forest National Corporation (FNC) estimates that, after separation of South Sudan, forests cover about 11.60% of the total area, while agricultural land 13.70%, rangelands 26.40%, and water bodies 0.17%. Data of South Sudan's biodiversity is limited. However, some recent efforts aim to fill the gaps. There are 1,013 species of birds in South Sudan, which represent more than any country in the world [42].

The following list includes all mammals, which represent critically endangered (CR), endangered (EN), or vulnerable (VU) in the 2004 IUCN Red List of Threatened Animals [42].

#### 1. Critically endangered

- Addax (*Addax nasomaculatus*)
- African wild ass (*Equus africanus*)
- Burton's gerbil (*Gerbillus burtoni*) (endemic to Sudan)
- Four-spotted gerbil (*Gerbillus quadrimaculatus*) (endemic to Sudan)
- Lowe's gerbil (*Gerbillus lowei*) (endemic to Sudan)
- Principal gerbil (*Gerbillus*)

#### 2. Endangered

- Chimpanzee (*Pan troglodytes*)
- Dama gazelle (*Gazella dama*)
- Giant African Water Shrew (*Potamogale velox*)
- Grevy's zebra (*Equus grevyi*)
- Nubian ibex (*Capra nubiana*)
- Slender-horned gazelle (*Gazella leptoceros*)
- Wild dog (*Lycaon pictus*)

#### 3. Vulnerable

- African elephant (*Loxodonta africana*)
- Barbary sheep (*Ammotragus lervia*)
- Cheetah (*Acinonyx jubatus*)
- Desert pipistrelle (Bat) (*Pipistrellus ariel*)
- Dorcas gazelle (*Gazella dorcas*)
- Dugong (*Dugong dugon*)
- Large-eared free-tailed bat (*Otomops martiensseni*)
- Lesser horseshoe bat (*Rhinolophus hipposideros*)
- Lion (*Panthera leo*)
- Red-fronted gazelle (*Gazella rufifrons*)
- Soemmerring's gazelle (*Gazella soemmerringii*)
- Spotted-necked otter (*Lutra maculicollis*)
- Tomb bat (*Taphozous hamiltoni*)

## 2.8.4 Threats to Biodiversity

1. The management of the protected areas in the country’s south has become very difficult to maintain under conditions of civil war, and severe poaching of large mammals with some extinctions likely if the situation does not improve. Inevitably, encroachment has also occurred in some areas, particularly Juba and Kidepo.
2. Overgrazing by livestock has become a major problem in many areas, leading to severe environmental degradation.
3. Disease is potentially an increasing threat. Rinderpest is endemic in country and all susceptible ungulates are at risk.

## 2.9 Sudan

### 2.9.1 Important Environmental Issues

Sudan extends over three major climatic zones: the Saharan north, the Sahelian center, and the equatorial south. The population is concentrated largely along the Nile River and its tributaries, where soil fertility and agricultural productivity are high. Rainfall is widely variable throughout the country, ranging from only 25 mm per year in the dry arid north to over 1,600 mm per year in the tropical rainforests of the south [43]. There has been a southward shift ranging from 50 to 200 km of the boundary between semidesert and desert. This boundary is expected to continue to move southward due to declining precipitation.

Sudan faces a number of critical environmental challenges, including land degradation, deforestation, and the impacts of climate change.

In 1974, Sudan passed an act on the application of pesticides; this act was updated in 1994. Unfortunately, the law is not followed by small and poor farmers, who often cause incidents of pollution due to unsafe application of pesticides. Several parts of the country have serious water quality problems; for instance, the Gezira region, Lake Nubia, and eastern and western parts of Sudan. Additionally, urbanization in cities like Khartoum and Wad Medani enhance pollution via sewage [9].

In the agricultural areas surrounding the Nile River, the population density is 21.8 per km<sup>2</sup> as of February 2016 [44]. Sudan is a land of relatively fertile soils and it has the second largest irrigated area in Africa, which accounts for 11% of cultivated area and over half of all production [43]. However, poor cultivation practices as well as overgrazing have led to pollution and land degradation. Resulting soil erosion has already consumed nearly one-fifth of the storage capacity in the country’s four primary dams and damaged irrigation canals. Reduced irrigation capacity has decreased production by up to 40% in some areas [43].

Growing demand for fuel wood and agricultural encroachment contribute to a deforestation rate of nearly 1% per year [43].

Inland fisheries account for 90% of the total fish catch in Sudan. Some major reservoirs associated with the Nile and its tributaries, such as the Gebel Aulia and Roseires, are being fished at a level close to 90% of their estimated capacity.

Marine fisheries along Sudan's Red Sea coast, however, are thought to be underexploited, with only half of their estimated potential fish stocks currently being utilized.

### 2.9.2 Critical Sites

The country has small areas of lowland rainforest in the southwest, and three game reserves protect this habitat: Bangangai, Bire Kpatuos, and Mbarizunga. However, the latter two are tiny, and Bangangai Game Reserve is not currently large enough to contain viable populations of important species.

There are no protected areas in the desert and Sahelian zones of Sudan, which make up half the country, nor are the best sites for such reserves known, in which the species of these arid habitats can be allowed to recover their populations. Such reserves should be established at low altitudes on both the western and eastern sides of the Nile. In addition, protection is needed to conserve the unusual flora and fauna of the Red Sea Hills and of the massifs of Jebel Marra and Jebel Gurgei.

Sudan's marine living resources are partially identified but need further surveying. There are extensive reefs along most of its coastline and these are largely in excellent condition, the Sudanese having little traditional dependence on the sea. The area containing important fringing coral reefs north and south of Port Sudan is under threat from pollution from the expanding port, but there is a proposal for their protection in terms of the Port Sudan Marine National Park.

There is also a proposal for a marine national park on the Sanganeb Atoll (the only atoll in the Red Sea), which has considerable tourism potential. Numerous islands in the Red Sea are probably of importance, but little is known at present. The Suakin Archipelago is known to be important for coral reefs, seabird nesting colonies, and marine turtle nesting beaches, and the Mukawar, Taila, and Mayetib Islands are important for reefs and seabirds [45].

The Red Sea coastal lagoons and sheltered bays "marsas" form natural harbors and fish landing places. The Red Sea has attractive and mostly pristine habitats (particularly coral reefs, mangrove stands, sea grass beds, and associated marine fisheries and biodiversity including sharks, dugongs, turtles, and a variety of sea birds). Sanganeb and Dungenab–Mukawar Island are protected areas with good representation of the Red Sea marine ecosystems [45].

### 2.9.3 Endangered Species

Wildlife ecosystem in Sudan is composed of biosphere reserves, national parks, game reserves, and sanctuaries. The arid and semiarid habitats of Sudan have always had limited wildlife populations. The various areas in which wildlife are



present are derived from a combination of ecological, socioeconomic, historical, and political factors. It should be noted, however, that the boundaries between certain regions are ill defined, and the very limited home range migration of some of the species is within those boundaries. Sudan is endowed with 12 orders of flowering plants out of the 13 found in Africa. In Sudan, there are 3,132 species of flowering plants and 265 species of mammals. Sudan has also 938 of bird species, 105 Nile fish species, and 91 reptile species [45]. In Sudan, there are 226 endangered species [2] as shown in Table 1.

#### **2.9.4 Threats to Biodiversity**

1. Overgrazing by livestock has become a major problem in many areas, leading to severe environmental degradation.
2. The northern desert and semidesert areas and marine ecosystems are not included within the protected area system and consequently have been few attempts to safeguard the biological resources of these areas.
3. Disease is potentially an increasing threat. Rinderpest is endemic in the south of the country and all susceptible ungulates are at risk.

### **2.10 Tanzania**

#### **2.10.1 Important Environmental Issues**

Tanzania has a total area of 942,800 km<sup>2</sup> of which 881,300 km<sup>2</sup> is land and 61,500 km<sup>2</sup> is inland water. A distinctive feature of Tanzania is the Rift Valley whose form is marked in many places by long, narrow, and deep depressions often filled with lakes. Lake Tanganyika lies in the western rift which continues northward through Lake Kivu. Many rivers flow into the Indian Ocean or the great lakes. However, some of them cease flowing during the dry season, and only the Rufiji, entering the Indian Ocean opposite Mafia Island and the Kagera, flowing into Lake Victoria, is navigable by anything larger than a canoe [46].

Tanzania faces a number of critical environmental challenges, including deforestation and land degradation, water pollution, and population pressure.

In Tanzania, the water quality is influenced by natural factors and human activities. The former comprise high fluoride concentrations and salinity in natural waters. The latter include discharge of municipal and industrial wastewater, runoff from agricultural lands, and erosion encompassing high concentrations of nutrients, pathogens, and BOD and COD levels. Additionally, gold mines in the Lake Victoria Basin contribute to heavy metal pollution.

About 80% of the industries, including agrochemical and chemical industries, breweries, and steel manufacturing industries, are located in the coastal zone of Dar es Salaam. Most of the industries directly or indirectly pollute the Indian Ocean.

Besides damaging aquatic ecosystems, this pollution also leads to higher incidence of waterborne diseases [9].

Forests and woodlands that provide for wildlife habitat, unique natural ecosystems and biological diversity, and water catchments cover about 38% of Tanzania's total land area. However, these forests face deforestation at a rate of between 130,000 and 500,000 ha/year, which results from heavy pressure from agricultural expansion, livestock grazing, wildfires, overexploitation, and unsustainable utilization of wood resources and other human activities, mainly in the general lands [47].

### 2.10.2 Critical Sites

Tanzania is home to some of Africa's most famous national parks and the majestic Mount Kilimanjaro rising above the Serengeti. Off Pemba and Mafia islands is a whole other kind of natural wonder, one most appreciated by the scuba divers and snorkelers who come here from around the world to experience the coral gardens, colorful fish, and clear waters.

One of the most frequented attractions in Tanzania Mount Kilimanjaro National Park is home to Africa's highest mountain peak. Unlike other parks in northern Tanzania, this one is not visited for the wildlife but for the chance to greatly admire this majestic snow-capped mountain and, for many, to climb to the summit. The mountain rises from farmland on the lower level to rainforest and alpine meadow and then barren lunar landscape at the peaks. The slopes of the rainforest are home to buffaloes, leopards, monkeys, elephants, and eland. The alpine zone is where bird watchers will find an abundance of birds of prey.

Serengeti National Park is a vast treeless plain with thousands, even millions of animals searching for fresh grasslands. The best months for wildlife viewing are between December and June. The wet season is from March to May, with the coldest period from June to October. The annual migration of millions of zebra and wildebeest takes place in May or early June. Large herds of antelope as well as lion, leopard, cheetah, hyena, bat-eared fox, hunting dog, and jackal are also found in Serengeti National Park. Nearly 500 species of birds have been recorded on the Serengeti.

The Zanzibar archipelago consists of the islands of Zanzibar and Pemba. The island of Zanzibar is also called Unguja. This island has some of the best beaches in the world.

Located between the Serengeti and Lake Manyara, the Ngorongoro Conservation Area is home to the famous volcanic Ngorongoro Crater and one of Tanzania's most popular wildlife viewing areas. This huge volcanic crater has a permanent supply of water, which draws all kinds of animals who stay in this area rather than migrating. This important archeological site has revealed ancient skull and bone fragments that have delivered critical information about early humankind.

The Ngorongoro Crater is the largest intact ancient caldera in the world, nearly three million years old. The Ngorongoro volcano was one of the world's tallest mountains before it exploded and collapsed. Thousands of wild game can be seen

on the crater floor, including lions, elephants, rhinos, Thomson’s gazelles, and buffaloes, but wildebeests and zebras account for over half of the animals that call the Ngorongoro Crater home. Bird watching is superb, especially around Lake Magadi, which attracts flocks of flamingoes to the shallows. Hippos are content to submerge themselves during the day and then graze in the nearby grass in the evening.

The Olduvai Gorge is an archeological site situated on a series of fault lines, where centuries of erosion have revealed fossils and remnants of early humankind.

Lake Manyara National Park is comprised of forest, woodland, grasslands, and swamps. Two-thirds of the park is covered by water and Lake Manyara is host to thousands of flamingoes, at certain times of year, as well as other diverse bird lives. The highlight of Lake Manyara Park is the large population of elephants, tree-climbing lions, and hippos that can be observed at a much closer range than in other parks. This park is also home to the largest concentration of baboons in the world.

Mafia Island draws divers and snorkelers from around the world to the undersea world protected by the Mafia Island Marine Park. The best months for diving are October to March on Mafia Island, while March and April are months of heavy rain. Mafia Island Marine Park has excellent coral gardens, an abundant variety of fish, and a relaxed diving atmosphere. Countless birds and over 400 species of fish can be seen in the area. Mafia Island is also a traditional breeding site for the green turtles, which are unfortunately close to extinction. Mafia is also a desirable location for deep-sea fishing, especially tuna, marlin, sailfish, and other big-game fish.

Tarangire National Park was established in 1970. During the dry season, Tarangire National Park has one of the highest concentrations of migratory wildlife. Wildebeest, zebra, buffalo, impala, gazelle, hartebeest, and eland crowd the lagoons. One of the most noticeable highlights of Tarangire National Park is the baobab trees that dot the grassy landscape. The park is excellent for bird watching, with more than 300 species recorded in Tarangire. These species include buzzards, vultures, herons, storks, kites, falcons, and eagles.

Pemba Island is the northernmost island in the Zanzibar archipelago. Around Pemba are many desert islands and some of the best scuba diving in the Indian Ocean, with visibility that is unparalleled. Lush coral gardens, colorful sponges, and sea fans are all found in the underwater haven. Pemba is a major world clove producer and is also well known for the juju traditions of medicine and magic. People come from throughout East Africa to learn from the voodoo and traditional healers or seek a cure.

Selous is the largest game reserve in Africa. Established in 1922, it covers 5% of Tanzania’s total area. The southern area is a forbidden zone that is undeveloped and heavily forested and contains a series of steep cliffs. This area of the Selous Game Reserve has large open grassland, woodlands, rivers, hills, and plains.

The Rufiji River bisects the Selous Game Reserve and has the largest catchment area of any river in East Africa. The river is an important feature of the reserve providing the opportunity to watch the diverse water-based wildlife. A broad range of game can be found including elephants, hippos, and rhinos as well as buffalo,

antelope, giraffe, warthog, wildebeest, lion, leopard, and cheetah. The diversity of bird life in Selous includes over 350 recorded species.

Arusha National Park, although smaller than most in Tanzania, has a range of habitats that consist of the forest of Mount Meru, Ngurdoto Crater in the southeast section of the park, and Momela Lakes, a series of seven crater lakes. Black and white Colobus monkeys are easily spotted in the forested area, while the marshy floor of the crater is dotted with herds of buffalo, zebra, and warthog. Momela Lake is home to a large selection of resident and migrant water birds.

Mount Meru is one of the most beautiful volcanoes in Africa and the second highest mountain in Tanzania. The summit is reached by a narrow ridge, which provides stunning views of the volcanic cone lying several thousand feet below in the crater. The ascent is steep, but the route passes through parkland, forest, a giant heather zone, and moorland.

Ruaha National Park is the least accessible park in Tanzania and as a result the landscape remains relatively untouched. Birdwatchers can enjoy over 400 species of bird that are not found in northern Tanzania, and the river, spectacular gorges, and majestic trees are especially appealing to photographers. As Tanzania's second largest park, Ruaha has large herds of buffalo, elephant, and gazelle. The densities of elephants are some of the largest in Tanzania.

Katavi National Park is located in a remote location offering unspoiled wilderness. A predominant feature in Katavi is the enormous floodplain, split by the Katuma River and several seasonal lakes. The lakes support enormous groups of hippos, crocodiles, and over 400 species of birds. One of the spectacles in Katavi is the hippos at the end of the dry season when as many as 200 try to squeeze into a pool of water. The male rivalry heats up causing territorial fights. The dry season brings Katavi National Park to life, and herds of impala, reedbuck, lions, zebras, and giraffes can be seen at the remaining pools and streams. An estimated 4,000 elephants and several herds of buffaloes in the thousands also converge on the park when the flood waters retreat.

Gombe Stream National Park is primarily for those who want to get a little off the beaten track and see chimpanzees. Many species of primates and mammals live in the park. Over 200 bird species have been recorded in the tropical forest, including barbets, starlings, sunbirds, crowned eagle, kingfishers, and the palm-nut vulture. Hiking and swimming are other popular activities; a trail leads into the forest to a waterfall in the valley.

Lake Victoria is the largest freshwater lake in Africa and is bordered by Kenya, Tanzania, and Uganda. This lake is the source of the White Nile and provides an income for millions of residents along its shores. The Tanzanian section of Lake Victoria is one of the least visited regions in the country; however, the towns of Bukoba, Musoma, and Mwanza have a number of attractions. Near Mwanza and Musoma are many islands; some have become wildlife sanctuaries. Bird watching and fishing trips are popular excursions, and boat trips or hikes can be arranged around Lake Victoria.

Most of the forests in Tanzania are in the mountains. Those of greatest importance in terms of species diversity and endemism are in the so-called "Eastern Arc"

mountains from the Pares, south to the Southern Highlands. The highest priority areas are the Usambaras, Ulugurus, and Uzungwas. In the Usambaras, where there are numerous isolated forest patches and a very high human population density, current efforts to reconcile human and conservation needs should be intensified. This will include extending the current program in the east Usambaras to the west. In the Ulugurus, protected areas should be created, and further encroachment, especially on the lower eastern slopes, should be prevented. In the Uzungwas, there is a national park recommended for the eastern side and another protected area further south, from Dabaga to Chita, should be considered. It is important that protection in the Uzungwas includes the lowland forests in the eastern foothills and areas of montane grassland. Protection is also insufficient for forests on the Pare, Kama, Nguru, Ukaguru, and Rubeho Mountains and for forests in the Uzungwas away from the proposed national parks. In the Southern Highlands, forest conservation measures are needed for Mount Rungwe and the Poroto, Kipengere, Njombe, and Livingstone Mountains, including areas of montane grassland. Interesting outliers of the main “Eastern Arc” system are to be found in the Mahenge and Matengo Highlands. Conservation needs in these areas should be assessed. In western Tanzania, the most important patches of montane forest are to be found in the Mahale Mountain National Park. Other interesting forest patches are in need of conservation on the Ufipa Plateau, in particular the Mbisi Forest and a few other sites. The remaining montane forests in Tanzania are on volcanic soil, and although they are of less importance for rare and endemic species, they perform essential roles as water catchments.

The montane grasslands of southern Tanzania represent a poorly protected and rapidly declining habitat. This habitat occurs in the Southern Highlands, Udzungwa Mountains, and Ufipa Plateau and lacks the protection necessary to ensure its survival. Of particular importance is the Kitulo Plateau in the Southern Highlands, with its remarkable flora.

### **2.10.3 Endangered Species**

The flora of Tanzania is extremely diverse, with over 10,008 higher plants. For breeding birds, their number is about 229 species. There are more than 360 species of mammals, more than 335 species of reptiles, more than 116 amphibian species, and almost 331 species of fish [48]. The marine environment has more than 7,805 invertebrate species [49].

Tanzania’s unique biogeography has also endowed it with high levels of endemism – species found only in the country, often within a small range. Eastern Arc Mountain forests are one area of high endemism, with about 100 vertebrates (10 mammals, 20 birds, 38 amphibians, 29 reptiles) found there and nowhere else. About 1,500 plant species, including some 68 tree species, are endemic to the Eastern Arc Mountains. The Uluguru Mountains alone have about 135 plant species that are confined to that single mountain block, while more than 100 endemic species are known to exist in west and east Usambara Mountains

and Udzungwa Ranges. Among Tanzania's 20 species of primates, 4 are endemic, including the Zanzibar red colobus (*Procolobus kirkii*). Of the 290 species of reptiles, 75 are endemic; and two of 34 species of antelopes are endemic. The Rift Valley Lakes contain an amazing diversity of cichlid fish, many of which are endemic. Lake Nyassa has over 600 fish species, Lake Tanganyika has more than 200 endemic fish, and Lake Victoria has around 200 species. Lake Tanganyika has over 470 fish species, including about 300 cichlids and over 170 non-cichlids. Lake Tanganyika is exceptional not only for its high level of species richness (animals, plants, and protists estimated at over 1,400 species) but also for high levels of endemism exhibited among several taxa. High numbers of endemic species [50, 51] represent all fish, copepods, ostracods, shrimp, crabs, and mollusks. In Tanzania, there are about 762 endemics species [2] as shown in Table 1.

#### **2.10.4 Threats to Biodiversity**

1. The management of Tanzania's protected areas has not been sufficient to prevent large-scale poaching of mammals and encroachment in certain areas. Similarly, the management of wildlife in multi-use zones outside protected areas has not generally been successful.
2. The country's system of reserves is under serious threat, notably montane and lowland forests, montane grassland, the Itigi thicket, much of the area around Lake Rukwa and Fungu Kisimkase (Latham Island), and the whole coastal and marine zone (including mangroves and coral reefs), where reserves have been designated but not implemented.
3. The coral reefs are subjected to destruction by dynamiting and industrial fishing methods, and forest clearance is very severe in certain areas, especially the Usambaras, and in parts of the coastal zone.
4. Trading of live animal is one of the largest in Africa, especially in birds and tortoises, and yet no attempts have been made to determine the effects of such trade on wild populations.
5. Fish introductions can have a major deleterious effect on native fish populations, as has happened in Lake Victoria. Such fish populations are also threatened by overfishing and pollution.

### **2.11 Uganda**

#### **2.11.1 Important Environmental Issues**

Uganda is a land-locked country that borders Lake Victoria, the second largest freshwater lake in the world. Most of the country is fertile and well watered, with many natural lakes and rivers. Generally, the climate is tropical with one to two

thousand millimeter of rain falling annually in two rainy seasons, although roughly 7% of the country is classified as arid or semiarid.

Ugandans have inherited a very rich flora and fauna, but the country is rapidly losing its biodiversity. The annual percentage of loss is about 1% [52]. The main causes for such loss include land degradation, deforestation, water pollution, wetland degradation, and population pressure.

Seventy-one percent of Uganda’s land area is potentially arable. However, rapid rural population growth and lack of access to improved inputs, overgrazing, and conversion of forests for agriculture have caused land degradation. The resulting rapid deforestation in Uganda (600 km<sup>2</sup>/year) is also threatened by harvesting of wood for fuel as a primary source of energy [53]. Resulting soil erosion now accounts for environmental degradation in Uganda [54]. Those worst affected (85–90%) include the highland areas in the southwest, Kabale and Kisoro [55].

Threats to biodiversity and habitat degradation are directly attributed to natural factors including relief and climate as well as deforestation and unsustainable farming practices such as the cultivation of fragile lands [56].

Freshwater accounts for over 15% of Uganda’s surface area [57]. However, increased demand and use of pesticides, fungicides, herbicides, and fertilizers is affecting the water quality in Uganda. Agricultural practices account for 50% of nitrogen and 56% of phosphorus levels in Lake Victoria Basin. Additionally, the exploitation of petroleum threatens the overall ecosystems of Lake Albert and Edward Basins. The northern end of Lake George and its associated wetlands receive localized metal pollution from a former copper tailings and mine left after metal extraction. There is a high concentration of zinc, copper, cobalt, and nickel in the lake [9].

In 1964, the wetlands are made up 32,000 km<sup>2</sup> of Uganda, which reduced to 26,308 km<sup>2</sup> or 11% of total land area in 2005 [9].

### **2.11.2 Critical Sites**

Uganda has four national parks. In the southwest is the Queen Elizabeth (formerly Rwenzori) National Park (also a biosphere reserve), which consists of grassland, savanna woodlands, swamps, lakeshore, and part of the Maramagambo Forest. Many large mammal populations were lost from this area through poaching.

The Queen Elizabeth Park is part of a much larger complex of contiguous protected areas, the others being the Kigezi, Kyambura, and Kibale Forest Corridor Game Reserves, the Kazinga Channel Sanctuary, and the Kasyoha–Kitomi, Maramagambo–Kalinzu, and Kibale Forest Reserves, as well as the large Virunga National Park in DRC.

The Lake Mburo National Park is also in the southwest and has some important, though depleted, wildlife populations. It is principally an area of wooded savanna, swamps, and lakes.



The Murchison (formerly Kabalega) Falls National Park consists of grassland, wooded savanna, and some small forest patches (e.g., Rabongo Forest) and is bisected by the Nile.

The Bugungu and Karuma Game Reserves are contiguous to it. The management of the area is now in need of improvement, following the years of political instability.

In the more arid northeast is the Kidepo Valley National Park, an area of bushed savanna. Wildlife populations have survived better here than elsewhere in Uganda, but there is a continuing problem with poaching which needs collaboration with the authorities in the adjacent Kidepo Game Reserve in Sudan. There is also a large army present there, which puts additional pressure on the park's resources.

Apart from these national parks and contiguous reserves, Uganda has a number of other reserves in the savanna zone, almost all of which have become seriously compromised. One of the most important is the Toro Game Reserve south of Lake Albert (Mobutu), where wildlife populations have been much reduced through poaching. The Katonga Game Reserve in the southwest is suffering from serious overgrazing by livestock. Poaching has been the problem in four small wooded savanna reserves in the West Nile area: Ajai's Game Reserve and Mount Kei, Otce, and Dufile Sanctuaries. The white rhinoceros is now extinct. In the semiarid northeastern province of Karamoja, there are three large and potentially important contiguous game reserves: Matheniko, Bokora Corridor, and Pian Upe. All have been subject to poaching and severe overgrazing by livestock, and wildlife populations are now sparse.

Uganda has biological resources in its forest ecosystems that are of international importance. The Bwindi (or Impenetrable) Forest Reserve is very important for its very wide altitudinal range of forest and a number of very rare species: there has been severe encroachment of this area, which was stopped in 1988, and the area is now proposed as a nature reserve. Of great richness is the Semliki (or Bwamba) Forest Reserve, which is contiguous with the huge Ituri Forest in DRC. The Rwenzori Forest Reserve including the Rwenzori Mountains is contiguous with the Virunga National Park in DRC. A substantial part of the Rwenzori Mountains is declared as a national park. In the extreme southwest of the country is the Gorilla Game Reserve, which is contiguous with the Volcanoes National Park in Rwanda. Agricultural encroachment of this area is a serious problem. Part of this area (the Mgahinga Forest Reserve) is scheduled to be declared a national park, with the surrounding game reserve being reestablished as a buffer zone and extending to lower altitude than at present. The Kibale Forest Reserve is an important area of intermediate, elevation forest that needs an increased level of protection. Several other forest reserves in western Uganda are generally managed for timber production as well as for conservation, and these require careful management to integrate human and conservation needs, with strict protection where necessary. The reserves in question are Budongo, Bugoma, Itwara, Kalinzu, Kasyoha–Kitomi, and Maramagambo–Kalinzu. Similar measures are doubtlessly required for the remaining forests around Lake Victoria (Sango Bay, Lake Shore, and Mabira) and also on Mount Elgon, where conifer plantations have been extended at the



expense of natural forests in recent years and where a national park to complement the one in Kenya is desirable.

Uganda possesses some major wetland resources, as follows: 8,832 km<sup>2</sup> of swamps, 365 km<sup>2</sup> of swamp forests, and 20,392 km<sup>2</sup> of other wetlands. Important areas include the Lake Opeta floodplain, the surrounds of Lake Kyoga (especially the southern and western sides), and that of Lake Victoria (mainly on the north-western edge of the lake). A large area of swamps adjacent to Lake George is so far the only Ramsar site in East Africa. However, there are swamps, in particular papyrus swamps, in many other places, especially along the Nile Valley, and around the lakes in the Albertine Rift Valley. The unusual upland swamp forests of Kabale District are rapidly disappearing due to agricultural conversion. The conservation of all these areas needs addressing, probably in the context of well-designed integrated rural development projects.

Uganda’s lakes are of great interest and importance, especially Lakes Victoria, Kyoga, Bistna, Kwania, Albert, George, and Edward. None of these lakes is included in any reserve and inclusion of open water in protected areas is proposed.

### 2.11.3 Endangered Species

Uganda’s position in a zone between the ecological communities’ characteristic of the drier East African savannahs and the more moist West African rainforests, combined with wide altitude ranges, has led the country to be one of the most biologically diverse in Africa relative to its size. Uganda has a myriad of natural features including mountains, lakes, rivers, and the Great Rift Valley. It has 7 out of the 18 phytocoria (vegetation classifications) in Africa. The major natural ecosystems are forests, woodlands and savannahs, wetlands, open water, and mountain ecosystems.

In Uganda, the main terrestrial ecoregions are Victoria Basin forest savannah, East Sudanian savannah, and Northern Acacia Commiphora bush lands and thickets. Small patches of East African montane forests, East African montane moorlands, Albertine Rift montane forests, and Rwenzori–Virunga montane moorlands are also present in Uganda [58]. A very diverse set of vegetation types exists, ranging from the montane flora at 5,000 m.a.s.l. in the Rwenzori Mountains to the lowland forest (at 600 m.a.s.l).

There are 5,000 species of flowering plants and 406 gymnosperms and ferns recorded. Of these, 54 woody plants are considered to be under threat. These species are distributed in diverse ecosystem types, both natural and modified, such as forests, woodlands, wetlands and aquatic systems, agroecological zones, and urban environment. In Uganda, the total number of species is not known although a provisional list of 18,783 exists [59], which includes 380 mammals and over 600 fish species. Bird diversity is particularly rich; with 1,007 species, Uganda contains more than half of Africa’s bird species and about 10% of all the bird species in the world (EBAs) [60]. In Uganda, there are about 217 endemics species [2] as shown in Table 1.

### 2.11.4 Threats to Biodiversity

1. Uganda's protected areas have suffered from very extensive poaching and from encroachment.
2. Loss of tree cover to meet rapidly – increasing demands for timber, fuel wood, and charcoal.
3. Increasing pollution which, most noticeably, has affected the whole ecology of Lake Victoria and most other waters.
4. Uganda's wetlands also suffer from lack of protection.
5. Fish introductions can have a major deleterious effect on native fish populations, as has happened in Lake Victoria (most notoriously the Nile Perch into Lake Victoria).

## 3 Case Study Lake Nasser

### 3.1 Important Environmental Issues in Lake Nasser

Water is a key natural resource for future development and prosperity as well as stability. On the other hand, water is a scarce resource; hence water saving is also gaining strategic significance and importance. Existing water shortages due to inadequate development, competing demands, and water quality degradation have been exacerbated. The number of people in countries where water is scarce will continue to increase sevenfold only in the next 25 years. This situation is critical, especially in Egypt, and needs immediate actions. The challenges and opportunities in the water conservation sector in Egypt are big in both magnitude and direction. In 1960, the Government of Egypt took the decision of building Aswan High Dam (AHD) in order to trigger national development, maximize water saving, and protect the country from the flood hazard which Egypt had encountered many times in the past and caused thousands of fatalities and enormous economic loss. The AHD, which was inaugurated in 1970, is about 7 km distance upstream of the Old Aswan Dam. Lake Nasser/Nubia is one of the larger African man-made lakes. The dam formed a 450 km long reservoir, which extends southward 150 km beyond the Egyptian–Sudanese boundary about to the second cataract. The 300 km section in Egypt is known as Lake Nasser, and that part in the Sudan is called Lake Nubia.

Lake Nasser ( $22^{\circ} 31' - 23^{\circ} 45' \text{ N}$  and  $31^{\circ} 30' - 33^{\circ} 15' \text{ E}$ ) reached its operating level of 175 m asl in 1975, with a total amount of  $121 \times 10^9 \text{ m}^3$  of stored water. Of this,  $31.6 \times 10^9 \text{ m}^3$  is dead storage (water below the level of the sluices). The deepest zone is situated between 85 and 150 m asl. The central part is a river–lake: the current at the southern end of the Nubian region reaches  $100\text{--}150 \text{ cm s}^{-1}$ . This speed gradually drops to  $10\text{--}20 \text{ cm s}^{-1}$ , and in Lake Nasser, it is  $0\text{--}3 \text{ cm s}^{-1}$ . The mean depth of the central part gradually increases from 10 m at the southern end to 70 m in the north. Lake Nasser has a number of side extensions known as khors. Their mean length increases from south to north owing to the northwardly declining

ancient riverbed. All khors have a “U” shape in cross section, with a flat sandy central belt. There are 100 important khors in Lakes Nasser and Nubia combined. Their total length when the lake is full is nearly 3,000 km and their total surface area is 4,900 km<sup>2</sup> (79% of total lake surface). In volume, they contain 86.4 km<sup>3</sup> water (55% of total lake volume). Some khors represent auxiliary, semi-isolated lakes. Khor Allaqi, Kalabsha, and Toshka are the largest. They have a sandy bottom, while others like Korosko and El-Sadake are steep, relatively narrow and have a rocky bottom.

Lake Nasser and Egypt are under threat by sedimentation and serious sand encroachment from the western and eastern deserts. Wind power is the most important factor in sand dune mobility because of the non-cohesiveness of the sand. Other factors that influence the mobility and stability of sand dunes are related to human activity such as the destruction of vegetation by grazing, trampling, and wood gathering [61].

The water quality status of the Lake Nasser is dependent mainly on potential impacts that could come from the Nile inflow upstream. The lake water is well oxygenated during winter and spring. Transparency is affected by the turbidity caused by silt and clay (allochthonous inorganic materials) of riverine origin. It is particularly strong in the flood season. The pH values are always on the alkaline side. The variation in EC and TDS follows, to a certain extent, the movement of water masses of the floodwater. The lowest conductivity within the surface water of the lake occurs during the flood period due to the low water conductivity of the flooded from Blue Nile, which contributes about 84% of the Nile flood. The sulfate is considered very low in the lake. Based on the total phosphorus, the lake is classified as eutrophic lake. The maximum record of average nitrate concentrations along the lake does not exceed 2.3 mg N/l. In spring and summer, the concentrations of silica within the lacustrine zone are almost the same; however in winter-time, they decrease. The values of BOD along Lake Nasser are low due to the high capacity of water in the main channel of the lake to assimilate the organic material in the presence of high levels of oxygen. The fecal coliform “FC” values range from 110 to 140 cfu/100 ml at the main channel, while during low water levels, their counts range from 400 to 800 cfu/100 ml at the main channel [62]. The concentration of all heavy metals is below the maximum permissible value set by the Environmental Protection Agency and Egyptian Chemical Standards [63].

Concerning the phytoplankton community structure in Lake Nasser, thirty-nine species belonging to three main groups in addition to some rare groups were recorded. Chlorophyceae was the most diversified group (19 species), followed by Cyanophyceae (10 species), Bacillariophyceae (7 species), and two rare groups which include Dinophyceae (2 species) and Euglenophyceae (1 species) [64]. The different groups were abundant in the reservoir zones with different ratios. Many studies showed that certain environmental factors, such as DO, water temperature, water velocity, turbidity, nitrate, total phosphorus, magnesium, total dissolved solids, and trophic state index, do affect the phytoplankton growth and the biodiversity in Lake Nasser [64, 65].

Concerning the zooplankton community structure in Lake Nasser, the zooplankton is rich and its assemblage consists of Copepoda, Cladocera, and Rotifera, besides Protozoa and meroplankton. The zooplankton population and its species biodiversity are mainly represented by typical limnoplankton forms including 79 species dominated by Copepoda (10 species), Cladocera (10 species), and Rotifera (48 species) [66]. The density of zooplankton is high toward the upstream. This is coincided with rich nitrate and orthophosphate. At the downstream, the fish predation increases due to high transparency, leading to decrease in the zooplankton density, while juvenile crustacean zooplankton and rotifers may actually increase under fish predation [67]. The density of zooplankton in Lake Nasser can be changed with the oscillation of the lake water level. The standing stock of zooplankton is higher at low water level in comparison with the highest level [68]. Furthermore, high fish production leads to high predation on zooplankton and thus decreases zooplankton density [69].

In Lake Nasser, the species composition of benthic organisms exhibited marked variations from one zone to another. This is attributed to the variations in the prevailing physicochemical conditions. The benthic fauna include 50 species dominated by insect (28 species), followed by mollusks (19 species), annelids (5 species), crustaceans (4 species), and one species of cnidarian and another species from bryozoan. The density of the benthic organisms decreases with decreasing the water's transparency and increasing the sedimentation especially in the lower part of the lake. Furthermore, the nature of the bottom sediments has a selective influence on quality and quantity of benthos, and it is considered the most significant factor determining their distribution. A positive correlation is found between most bottom fauna species abundance and the silt and clay fractions. In addition, there are positive correlation stands for the abundance of the bottom fauna and the total organic content. In addition, the temperature, electrical conductivity, dissolved oxygen, and pH are important factors in controlling the flourishing and existence of different species in Lake Nasser. The physicochemical features as well as the characteristics of the bottom sediments in Lake Nasser are in favor for producing high standing crop of benthos, which in turn provides the main food items for the various fish inhabitants of the lake [70].

Concerning the aquatic weed community structure in Lake Nasser, monitoring studies showed that there are no floating weeds in Lake Nasser. However, a total standing crop of the submerged aquatic weeds along the littoral zone of Lake Nasser is made up of nine species (*Potamogeton crispus*, *P. lucens*, *P. perfoliatus*, *P. trichoides*, *Myriophyllum spicatum*, *Najas marina* subsp. *armata*, *N. minor*, *Vallisneria spiralis*, and *Zannichellia palustris*) [71]. The submerged aquatic weeds are located at depths ranging between 1 and 6 m. However, at depths of 5 and 6 m, the existence of such weeds is very limited [72]. The distribution of the submerged aquatic weeds tends to be the highest near the northern and middle parts of the lake, gradually decreases toward the southern part, and almost disappears near the Sudanese border [71–73]. The standing crop for the submerged aquatic weeds at different depths (1–6 m) does not vary greatly with time. The correlation between the standing crop of the submerged aquatic weeds and some

physicochemical parameters within the surface water is poor. The key environmental factors, which affect weeds, are water-level fluctuation, light penetration, bed slope, and hydrostatic pressure. Finally, the sediment texture with its organic content is less useful predictors of the community structure for the submerged aquatic weeds, and many authors consider the water-level fluctuation the most important factor that controls the distribution of shoreline and aquatic vegetation [72, 73].

Concerning the fish community structure in Lake Nasser, 36 species of fish are known from the lake, but it is likely that 57 are present, based on fishes known from the river in upper Egypt and in lower Sudan. The fish biodiversity of the lower Nile River is considerably less rich than that of the upper river. Numerically, the most abundant open-water species are the tiger fish (*Hydrocynus forskahlii*), three species of *Alestes* (*A. baremoze*, *A. dentex*, and *A. nurse*), the pelagic siluroid (*Eutropius niloticus*) and a small cyprinid (*Chelaethiops bibie*). From a weight standpoint of the lake, tiger fish appear to be much more abundant than *Alestes*. The reverse is true toward the upper end. *Alestes baremoze* and *A. dentex* comprised about 12 and 74% of the total catch by weight of all open-water fish from the lower and the upper ends, respectively [74]. During the winter circulation period, tiger fish *A. baremoze* and *A. dentex* are fairly well scattered vertically, down to 20–30 m. During the summer stagnation period, they probably are restricted almost entirely to the upper 10–15 m, in or above the metalimnion. Dense aggregations of any open-water species have not often been observed. The main plankton feeders in open water are three species of *Alestes*, *E. niloticus*, three species of *Labeo*, and two small cyprinids, *C. bibie* and *Barilius niloticus*. The tiger fish is the main predator, but in the spring and early summer, its spawning period the Nile perch also is important. The inshore fish fauna is more complex than the open-water community, but only a few species dominate it also. Numerically, the principal species are *Tilapia nilotica*, two small cyprinids (*C. bibie* and *B. niloticus*), tiger fish, and Nile perch. The smallest species of siluroids are not concentrated anywhere, but discrete pockets of some of those that attain large size, particularly *Clarias lazera*, are seen during the summer stagnation period. Juvenile *T. nilotica* school densely along the shore in shallow water as do adults at the surface over deeper water, except in mid-winter [75, 76].

Concerning the amphibians and reptiles, 2,486 herpetological specimens were collected during 1962 and 1965, representing 51 species and 13 families. Among the herpetological specimens is a series of 1,232 *Chalcides ocellatus* and a recently described species of spitting cobra (*Naja nubiae*). Because most of the collection sites are now under Lake Nasser, most specimens represent extirpated populations [77]. Some specimens are of taxa now considered endangered species in Egypt especially crocodiles, Nile turtle, Nile monitor, and cobras. The activities of human settlements, fishermen, agricultures, and traffic tourism as well as water pollution are having a severe influence on the composition and species biodiversity of both amphibians and reptiles. It is predicted that the amphibian fauna may flourish with flourishing of the agricultural practices along the shoreline of the lake.

Lake Nasser also provides critical habitats for many species of mammals. Mammals of the area, particularly those that are known to be threatened, require further, more detailed studies. These may include the ecology and biology of these species covering basic aspects such as population size and dynamics, home range, habitat requirements, competition with feral domestic mammals, and impact of human activities. Wild carnivores have suffered a great deal of decline in recent years because of secondary poisoning with pesticides widely used to control Nile rat and other rodent pests. Gazelle species are showing decline in population size due to habitat fragmentation, hunting, and grazing overlap with domestic Bovidae family.

Since the construction and filling of the Lake Nasser, the lake began to be suitable habitat for water birds, especially that the area is an important route for migratory birds coming from Europe in autumn, either to stay or as a station to go further south in Africa. There are impressive varieties of birds at Lake Nasser. The lake has become increasingly important as a wintering area for migratory Palearctic water birds [78]. Those kinds of birds could be ecologically a disaster because of mismanagement of shoreline agriculture and tourism activities.

## 3.2 *Endangered Species in Lake Nasser*

### 3.2.1 Fish

*Protopterus aethiopicus*, *Polypterus bichir*, *Mormyrops anguilloides*, *Petrocephalus bane*, *Pollimyrus isidori*, *Gnathonemus cyprinoides*, *M. caschive*, *Hyperopisus bebe*, *Gymnarchus niloticus*, *Labo horie*, *L. coubei*, *L. victorianu*, *Garra dembeensis*, *Barbus neglectus*, *Barbus werneri*, *Barbus anema*, *Leptocypris niloticus*, *Raiamas loati*, *Chelaethiops bibie*, *Hydrocynus vittatus*, *Hydrocynus brevis*, *Alestes dentex*, *Alestes baremoze*, *Distichodus niloticus*, *Citharinus citharus*, *Citharinus latus*, *Bagrus degeni*, *Chrysichthys rueppelli*, *Clarotes laticeps*, *Auchenoglanis biscutatus*, *Auchenoglanis occidentalis*, *Schilbe (Eutropius) niloticus*, *S. uranoscopus*, *Clarias anguillaris*, *Heterobranchus bidorsalis*, *Heterobranchus longifilis*, *Malapterurus electricus*, *Synodontis serratus*, *Synodontis clarias*, *Mochocus niloticus*, *Chiloglanis niloticus* and *Tetraodon lineatus*.

The extinct fishes: *Mormyrus hasselquist*, *M. niloticus*, *Heterotis niloticus*, *Brycinus macrolepidotus*, *Micralestes acutidens*, *Ichthyoborus besse*, *Distichodus rostratus*, *Distichodus engycephalus*, *Nannocharax niloticus*, *Brachysynodontis batensoda*, *Hemisyndontis membranaceus* and *Aplocheilichthys schoelleri* [2].

### 3.2.2 Amphibians and Reptiles

*Bufo kassasii*, *Bufo regularis*, *Bufo viridis*, *Hemidactylus turcicus*, *Ptyodactylus hasselquistii*, *Ptyodactylus siphonorhina*, *Stenodactylus sthenodactylus*, *Tarentola annularis*, *Tropiocolotes steudneri*, *Pseudotrapelus sinaitus*, *Acanthodactylus boskianus*, *Acanthodactylus scutellatus*, *Mesalina guttulata*, *Mesalina rubropunctata*, *Varanus griseus*, *Varanus niloticus*, *Chalcides* cf. *humilis*, *Psammophis aegyptius*, *Psammophis sibilans*, *Naja nubiae*, *Naja haje*, *Cerastes cerastes*, *Crocodylus niloticus* and *Trionyx triunguis* [2].

### 3.2.3 Mammals

*Vulpes vulpes*, *Hyaena hyaena*, *Gazella leptoceros*, *Gazella dorcas*, Nubian ibex and *Felis margarita* [2].

### 3.2.4 Birds

*Marmaronetta angustirostris*, *Gypaetus barbatus*, *Gyps fulvus*, *Terathopius ecaudatus*, *Aquila chrysaetos*, *Chlamydotis undulata*, *Numenius tenuirostris*, *Rynchops flavirostris*, *Oenanthe moesta*, *Vanellus gregarius*, *Neophron percnopterus*, *Buteo rufinus*, *Aquila clanga*, *Aquila heliaca*, *Falco naumanni*, *Falco biarmicus*, *Falco pelegrinoides*, *Alectoris chukar*, *Crex crex* and *Turdoides squamiceps* [2].

## 3.3 Threats to Biodiversity in Lake Nasser

The lake provides good habitat for establishing the community structures for many species that play an important role in providing habitat complexity, food to aquatic animals, nutrient recycling, and nesting for both fish and birds.

Since the early filling of Lake Nasser, extensive and comprehensive studies have been carried out on the various aspects of the lake species biodiversity and social and economic functions, by research workers, experts, and international bodies. These studies concluded that the main sources of biodiversity degradation in Lake Nasser are development of land, expansion of agricultural land, and disappearance of habitat from excessive grazing or application of agrochemicals, as well as habitats being polluted, and hunting, fishing, and tourism activities disturbing the natural habitat especially within the shoreline zone. The summary of all such activities and their effects on biodiversity degradation are shown in Table 2.

**Table 2** Causes of biodiversity degradation in Lake Nasser

Indicators	Factors	Threatened organisms
Water-level fluctuation	Loss or degradation of habitat	Dramatic decline in birds, aquatic weeds, shrubs, mussels, snails, reptiles, fish, and mammals
Thermal stratification	Biodiversity loss Water quality will change	The community structure for certain aquatic organisms will be changed, such as bacteria, fungi, planktons, and fish
Sedimentation	Loss or degradation of the habitat	It affects the benthic organisms, fish, and submerged aquatic weeds
Sand dune	Loss or degradation of the habitat	It affects reptiles, turtles, fish, aquatic weeds, and different benthic organisms, as well as mammals and birds
Over grazing (livestock)	Loss or degradation of the habitat	It affects aquatic weeds, different benthic organisms, mammals, and birds
Pollution of habitat (land pollution)	Dramatic decline of the density and species biodiversity	It affect birds, mammals, and reptiles
Pollution of habitat (water pollution)	Dramatic decline of the density and species biodiversity	It affects all the community structures of aquatic organisms as well as birds and reptiles
Hunting for recreational demands	Dramatic decline of the density and species biodiversity	It affects mammals, birds, and reptiles
Hunting and overfishing for food	Dramatic decline of the density and species biodiversity	It affects mammals, birds, fish, and turtles
Human-caused disturbance: navigations, tourism, or recreation	Loss or degradation of the habitat	It affects fish, mammals, birds, and reptiles
Climate changes	–Change amounts of rain that falls on the Nile Basin with the presence of periods of drought –Increase temp. –Increase wind unit	The climate changes will affect the community structures and the richness of most of the aquatic organisms, mammals, birds, and reptiles because of loss or degradation of the habitat and increase of both air and water temperature

It is clear from Table 2 that both the developmental activities and human behaviors may destroy the ecosystem and species biodiversity in Lake Nasser if the laws and regulations regarding environmental preservation are not activated.



## 4 Conclusions

Nile Basin countries face several problems. Some of these problems are but not limited to inefficient water use, water pollution, population pressure and land degradation, deforestation and soil loss, overhunting and overfishing, and sedimentation problems.

In addition, the study concluded that the main sources of biodiversity degradation in Lake Nasser are development of land, expansion of agricultural land, and disappearance of habitat from excessive grazing or application of agrochemicals, as well as habitats being polluted, and hunting, fishing, and tourism activities disturbing the natural habitat especially within the shoreline zone.

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