UNEP/USGS

3 Impacts on Africa's Lakes

Case Studies of Africa's Changing Lakes

For much of our history, human impacts on the Earth's surface have been relatively minor. However, during the past two centuries, these impacts have grown exponentially. Changes brought about by human activities can now be objectively measured; many of them can even be seen from space. A study by the National Aeronautics and Space Administration (NASA 2003), known as 'The Human Footprint', provides a quantitative analysis of people's influence across the globe – and illustrates the growing impact of people and their activities on the Earth (UNEP 2005).

While evidence of change is not always clearly visible on lakes, wetlands and coastal environments, human impacts on Africa's lakes can be "seen" by detecting and measuring rising water temperatures, sediment accumulation, and various chemical contaminants in their waters. Another obvious human impact is the rapid decline in fish species and numbers in many lakes. A recent 10-year study on the ecological effects of industrialised fishing in Africa's lakes found that large predatory fish species have declined by at least 20 per cent from pre-industrial levels (World Resources Institute 1994). Furthermore, the average size of surviving individuals among these species is only one-fifth to one-half of their previous size.

The composition of the Earth's atmosphere is also undergoing rapid change, with subsequent impacts on Africa's lakes. Today, increases in atmospheric concentrations of greenhouse gases are expected to cause more rapid changes in the Earth's climate than have been experienced for millennia. At least some of the global increase is due to human activity, and certainly local impacts such as urban 'heat islands' have profound effects on regional climatic conditions, which will in turn impact on Africa's lakes, wetlands and coastal environments. Lakes in Africa are major sites for water extraction and waste disposal, often with a negative impact on human health. Some contain vast amounts of CO_2, which when released can kill thousands of people. There is a need for continuing assessment and monitoring of these lakes, most of which are located in the Great Rift region, making them also susceptible to earthquakes and volcanic eruptions, which can cause flooding.

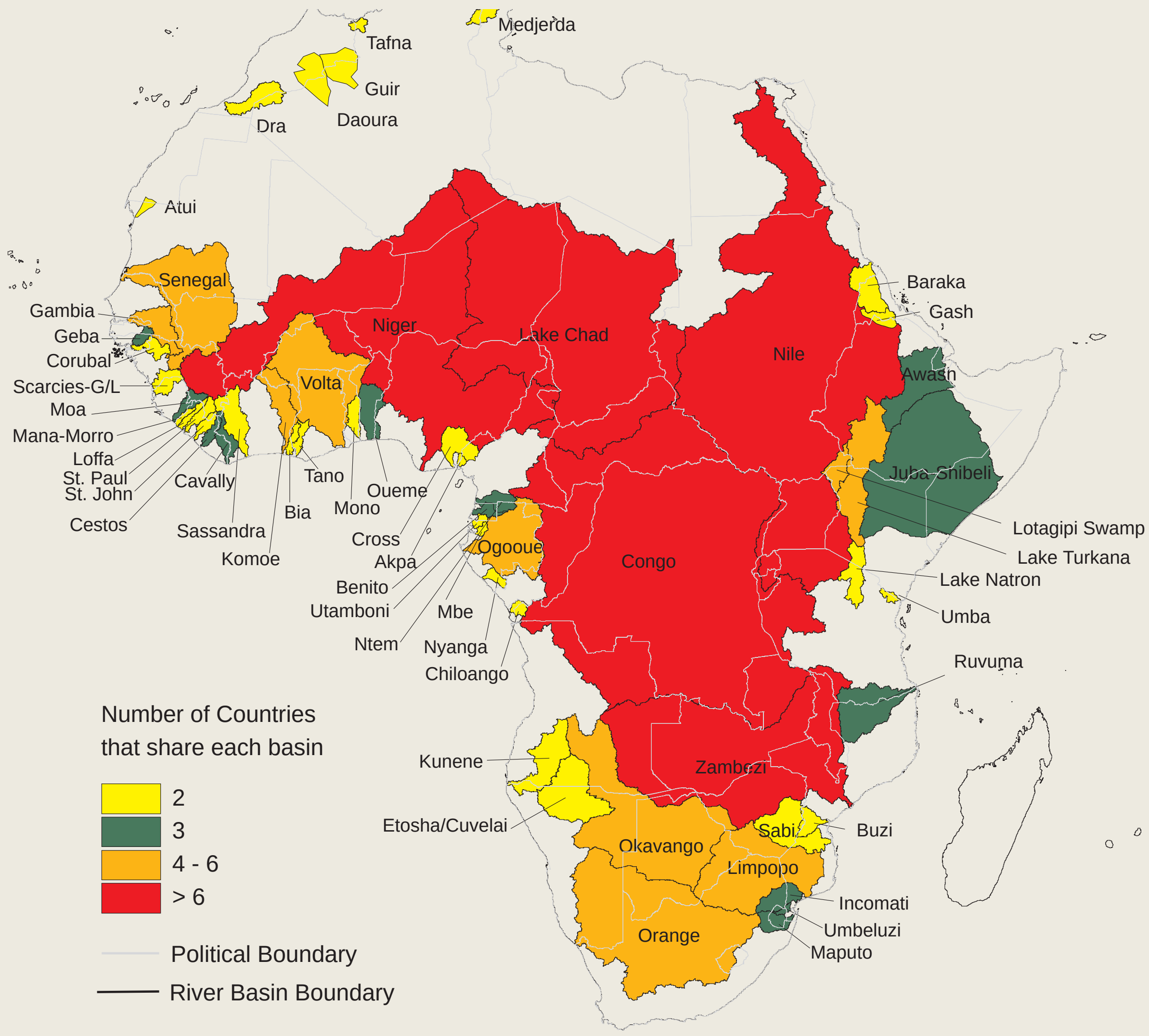


Figure 3.1: Transboundary river basins

UNEP/GRID–Sioux Falls

Constant evaluation and reporting on the state of Africa's lakes are critical if they and their connected wetlands are to be sustainably managed. Pressures from logging, gold-panning, hydropower and other developments are leading to the conversion of large areas of wetlands, with devastating implications for their ecological integrity. Such developments also have long-term implications for the integrity of watersheds, rivers and related coastal resources, as well as their ability to support complex biodiversity.

Several globally significant environmental trends that occurred between 1980 and 2000 may also be contributing to the pollution and degradation of Africa's lakes, including global warming, three intense El Niño events, changes in cloudiness and monsoon dynamics, and a 9.3 per cent increase in atmospheric CO_2. Although these factors are thought to exert their influence globally, their relative roles are still unclear and their impacts are likely to be significant for African communities whose livelihoods depend upon resources from lakes, wetlands and coastal environments.

An observed decline in freshwater fisheries is one of the more important recent challenges to African governments that depend upon the export of aquatic resources (although none of the existing surveys can accurately simulate this effect). It is known that continued reductions in fresh water, if accompanied by reduced rainfall, will have profound implications for poor communities that depend upon lake and wetlands resources for a living.

3.1 Case Studies

Lake Chad

Persistent droughts and the ravages of a rapidly growing human population have decimated what was once the sixth-largest lake in the world, Lake Chad—straddling the borders of Nigeria, Chad and Cameroon. Over the past four decades, the lake's surface has reportedly shrunk from 22 000 km^2 (8 494 square miles)to a meager 300 km^2 (115 square miles). Today, it is hard to reconcile the fact that this largely dry lakebed was once the second largest wetland in Africa, supporting a rich diversity of endemic animals and plant life.

Seen from space, the shallow Lake Chad is a circular wetland with open water in two distinct basins, divided by ancient sand dunes, which act as a swamp belt. Seated at the southern edge of the Sahara desert, where temperatures often exceed 40˚C (104˚F), the lake's very existence is a fascinating enigma.

Lake Chad's maximum-recorded depth, prior to the start of its decline in the 1970s, was 12 metres (39 feet). Today, the lake is far shallower, although fluctuations in volume result in substantial changes to its surface area. The lakebed itself is not flat, but lies on an ancient bed of fossilized sand dunes, many of which surface as islands when the lake level falls (Sikes 2003). Submerged dunes form hidden anchorages for floating vegetation, which covers vast areas of the lake.

About 90 per cent of Lake Chad's water comes from the Chari-Logone River, which enters the lake from the southeast, with its sources in the humid uplands of the Central African Republic. The Komadougou-Yobe River, which enters the lake in the northwest, historically has contributed about 10 per cent of its water. As well as a vital source of fresh water for local communities, Lake Chad's unique mix of terrestrial and aquatic habitats hosts biodiversity of global significance—although most of its large mammal species have been hunted virtually to extinction (Nami 2002). Crocodiles and hippos were particularly important agents for maintaining a healthy wetlands ecosystem (Mockrin & Thieme 2001). Today, however, the replacement of these mammals with cattle has severely degraded the wetlands ecosystem.

Within Lake Chad itself, the major plant communities comprise floating 'sudd' weeds, permanent reed swamps, and seasonal herbaceous swamps (GEF 2002). Grasslands dominate in areas that flood, interspersed with acacia woodlands, with dryland woodlands in sandy soils further from the lake (Mockrin & Thieme 2001).

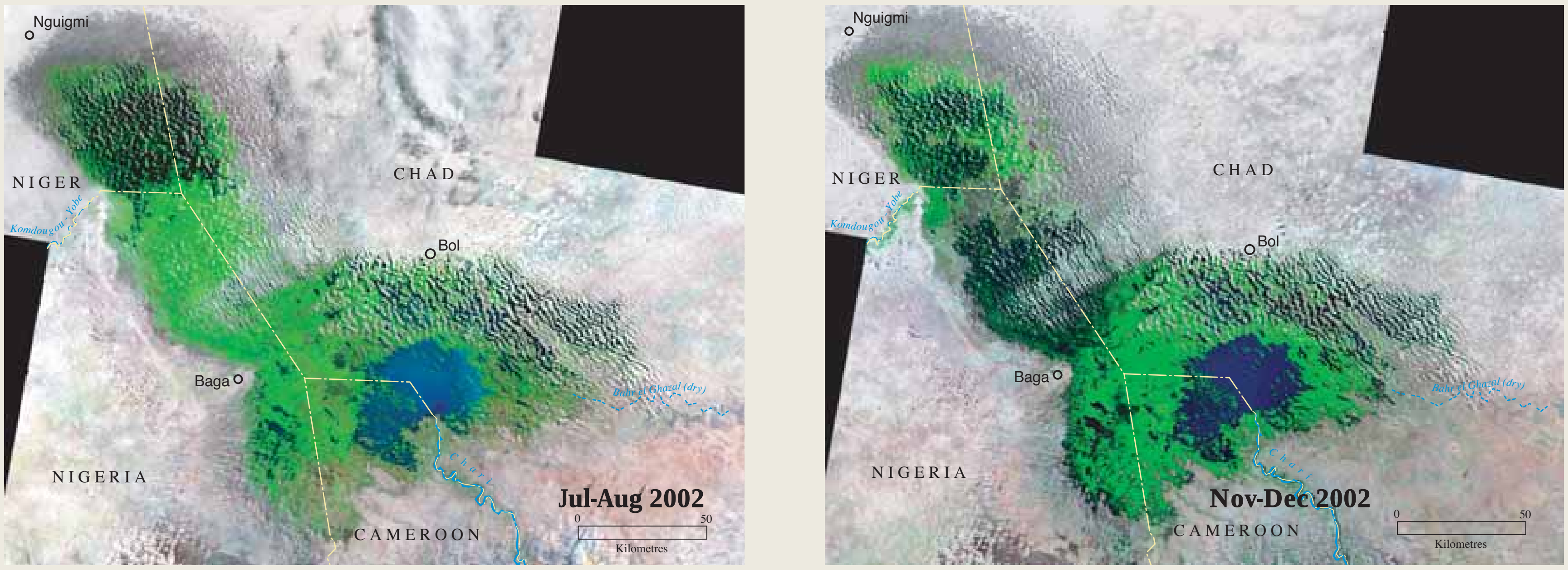
Lake Chad's level has varied greatly over time. Some 50 000 years ago, Paleo-Chad formed a freshwater inland sea covering nearly 2 million km^2 (772 thousand square miles). Lake levels regressed until, between 5 000 and 2 500 years ago, the lake assumed its current level with periodic oscillations. By 1908, lake levels were so low that the lake resembled a vast swamp with small northern and southern pools (Sikes 2003). During the 1950s, levels again increased, joining the southern and northern pools, so that by 1963 the lake covered 22 902 km^2 (8 842 square miles). Water levels then decreased, and by 1972 the lake covered 16 884 km^2 (6 519 square miles). The most dramatic reductions occurred between 1972 and 1987, by which time the lake had shrunk to just 1 746 km^2 (674 square miles). From the mid-1980s, the north basin rarely held any water at all—although, since the mid-1990s, levels have once again started to rise in response to increased rainfall (FEWS 2003).

Ledru et Martel/UNEP/UNESCO

The dramatic fluctuations of Lake Chad are usually attributed to a complex

Figure 3.2: Landsat images of Lake Chad: Jul-Aug 2002, Nov-Dec 2002, Feb 2003 and May 2003

Source: USGS/EROS



The within-year lake level variation for Lake Chad is as great as the between-year variation. The May-October rains, with up to 50 per cent falling in August, reach Lake Chad by October/November. The Chari-Logone river systems first fill the south basin. If the rainfall is sufficient, as it was in 2002, water from the south basin will breach the barrier between the basins along the west shore, as can be seen in the Nov-Dec 2002 image. In extremely dry years, however, the barrier is interaction of climatic and human forces. Recent modelling studies have attempted to quantify the interplay of two climatic factors: variability and water use. In a nutshell, climate variability sets the parameters within which humans must operate. As the human impact upon the local landscape becomes more severe, humans are in danger of changing these parameters.

Unknown/UNEP/Forestry Images

Climate

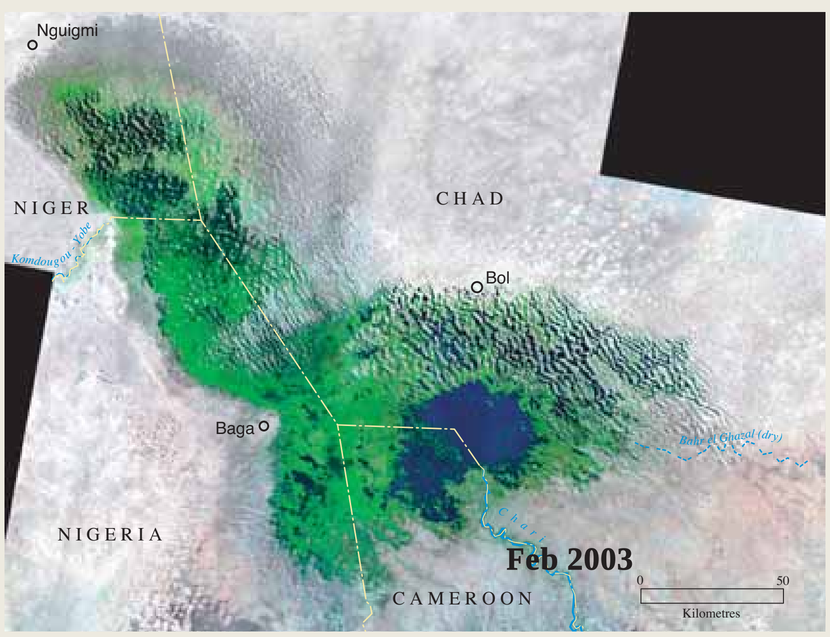
The climate around Lake Chad is hot and dry, with highly variable annual rainfall ranging from 565 mm (22 in) in 1954 to just 94 mm (4 in) in 1984 (Olivry et al. 1996). However, the lake level relies little on local precipitation, with the Chari-Logone's sources receiving an average rainfall of some 1 600 mm (63 in). Precipitation in the basin varies geographically, with much more in the south than the north. Rainfall also varies seasonally with about 90 per cent of it falling from June to September (USGS 2001). During the dry season, low humidity and high winds increase evaporation rates from the lake. Although evaporation is generally very high, salinity is not a significant issue as heavier saline water leaves the lake through fissures in its floor. Water loss through the lakebed accounts for about eight per cent of the water outflow from the lake.

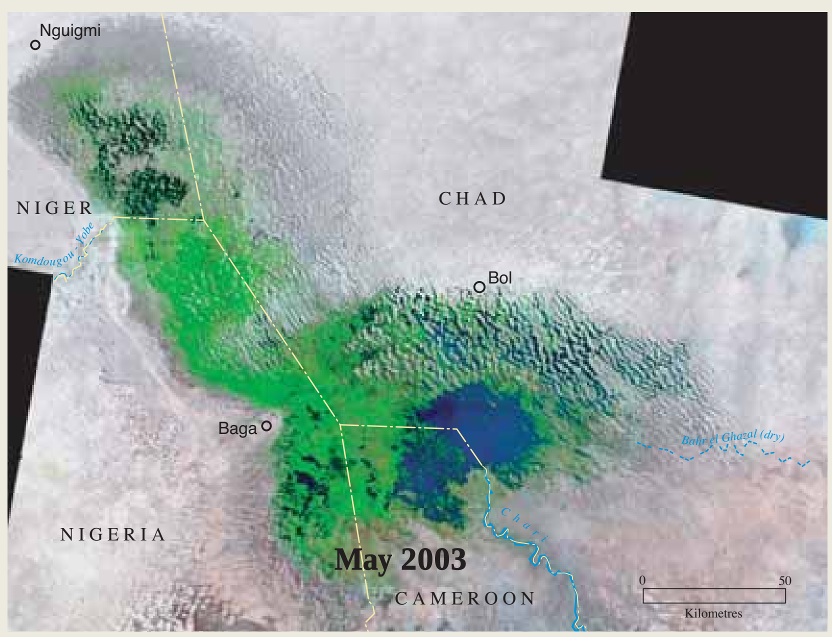
In the late 1960s, the western Sahel appears to have undergone an abrupt hydro-climatic transition from a wetter to a drier rainfall state. Rainfall became intermittent at Lake Chad, culminating in two major droughts in 1972-74 and 1983-84. In the mid-1990s, rainfall again increased with several good years ensuing. Areas of the lake that once experienced a mean rainfall of 320 mm (13 in) currently receive less than 210 mm (8 in)(GEF 2002). The size of the region affected by this change and its duration are without precedent in hydro-climatic chronicles. Some authors have speculated that the change is symptomatic of a "climate rupture" (Carbonnel & Hubert 1985, in Nami 2002).

Water use

Since the 1960s, human demands for water near Lake Chad have grown rapidly. Between 1960 and 1990, the number of people living in the lake's catchment area has doubled from 13 million to 26 million (UNEP 1999). With agriculture providing the main livelihood in 60 per cent of the lake basin, demand for water for irrigation is estimated to have quadrupled between 1983 and 1994 (GEF 2002). At present, some 135 000 hectares of land are irrigated in the lake basin. The most extensive irrigation projects, totaling over 100 000 ha, have been developed in Nigeria, where the Southern Chad Irrigation Project alone had the goal of irrigating 67 000 ha of land with an average cropping intensity of 130 per cent, and resettling about 55 000 families onto the irrigated land (Sikes 2003). Unfortunately, since the droughts of the early 1970s, the water level of Lake Chad has not been high enough to reach the intake canals of the irrigation system (Sarch & Birkett 2000).

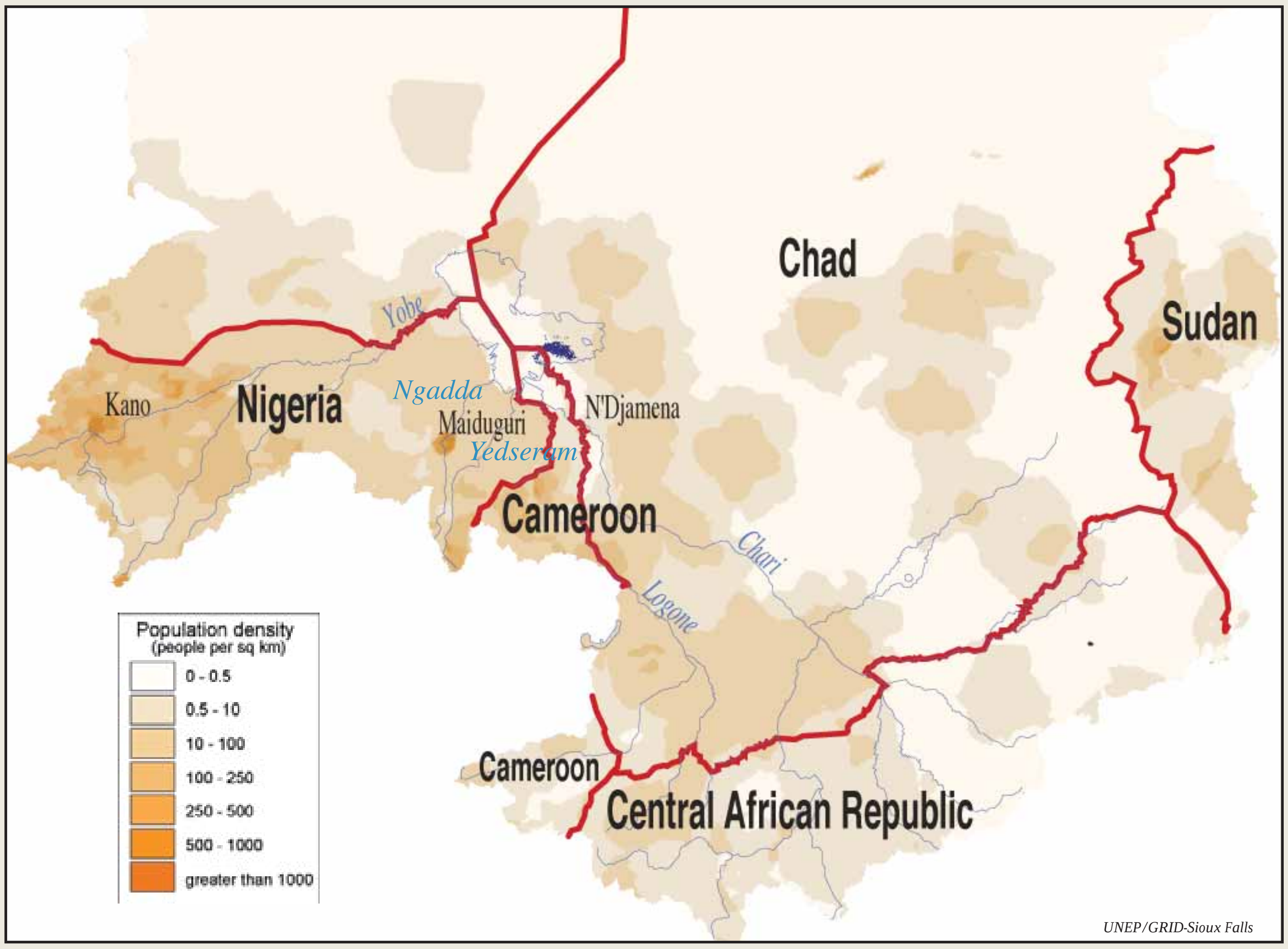
In addition to irrigation, dams have influenced the rivers that feed Lake Chad. In the Kano and Hadejia basins, there are believed to be about 23 earth dams. The Komadougou-Yobe river system provides an example of the dramatic impact of human diversion. The upper basin used to contribute approximately 7 km^3/yr (4 cubic miles/yr) to Lake Chad. Today, the bulk of this water is impounded in reservoirs within Kano province in northern Nigeria, and the system provides just 0.45 km^3/yr (0.23 cubic mile/yr).





never breached. This water will join the limited discharge from the Komadugu-Yobe to fill the north basin, which is about 3 metres lower than the south basin (Dumont 1992). By February, the lake level starts to recede to once again approach an annual low by May.

Figure 3.3: Within the Lake Chad Basin, the drainage basins of the Komadougou-Yobe and Yedseram-Ngadda, which contain the cities Kano and Maiduguri respectively, have the greatest population densities, placing a particularly high demand on their water sources. The boundary of the early 1960s Lake Chad is shown with the open water in 1987 filled in.



Nor is there any likelihood of increasing discharge down the Komadougou-Yobe, as demands for water for irrigation in the densely populated upper basin near Kano will never decrease.

Although the contribution from the Komadougou-Yobe drainage system was only 10 per cent of the total contribution to Lake Chad, once the lake divided into a north and a south basin its loss to the north basin became critical, as good pasture for livestock became harder to find (Sikes 2003). The loss of water behind dams has been further compounded by an increase in irrigation from wells and boreholes since the 1960s, resulting in reduced groundwater regeneration.

Research by Oyebande (2001) suggests that dam construction in the upper Komadugu-Yobe system is largely to blame for the change in the flow regime. He suggests that the river course was heavily influenced by the spring flooding prior to the dams' construction, and that the leveling out of the flow would result in less water reaching downstream provinces and Lake Chad, even if the flow volume was increased. By contrast, decreasing input from the Chari-Logone river system, where human consumptive use has been estimated at less than five per cent of the basin yield, is attributed mainly to lower rainfall (Olivry et al. 1996).

Using an integrated biosphere model, run with and then without extraction for irrigation, Coe and Foley (2001) concluded that water-level fluctuations in Lake Chad over the past 35 years have been caused by both climate variability and water use. From 1956 to 1975, decreases in the lake's level and surface area resulted primarily from long-term climate change, with only five per cent of the lake level decrease attributed to water management practices. Since the 1970s, however, with marked population increases, human activities have begun to play a more significant role in accelerating lake-level declines. The onset of dry climatic conditions in the early 1970s induced people to dramatically increase their irrigation activities, almost doubling water loss from Lake Chad (Coe & Foley 2001). The balance between the lake and its wetlands has always been precarious, as inputs balance losses to groundwater and evaporation. However, increased irrigation, which would be modest for many river systems, is particularly critical to the fate of the carefully balanced climatic-ecological system of Lake Chad.

Traditionally, fishing and farming near the lake have followed its rise and fall, both seasonally and through the years. During dry seasons and years, farmers move to the rich soils of the newly exposed lake bottom, and then fish during floods (Sarch & Birkett 2000). However, as lake levels recede, the danger increases that the lake will not reach villages during the annual floods. The cost of exporting surplus crops has also increased as cheap water transportation across the open

Figure 3.4: Level of Lake Chad, redrawn from Olivry et al., 1996, USGS 2001, and USDA 2004

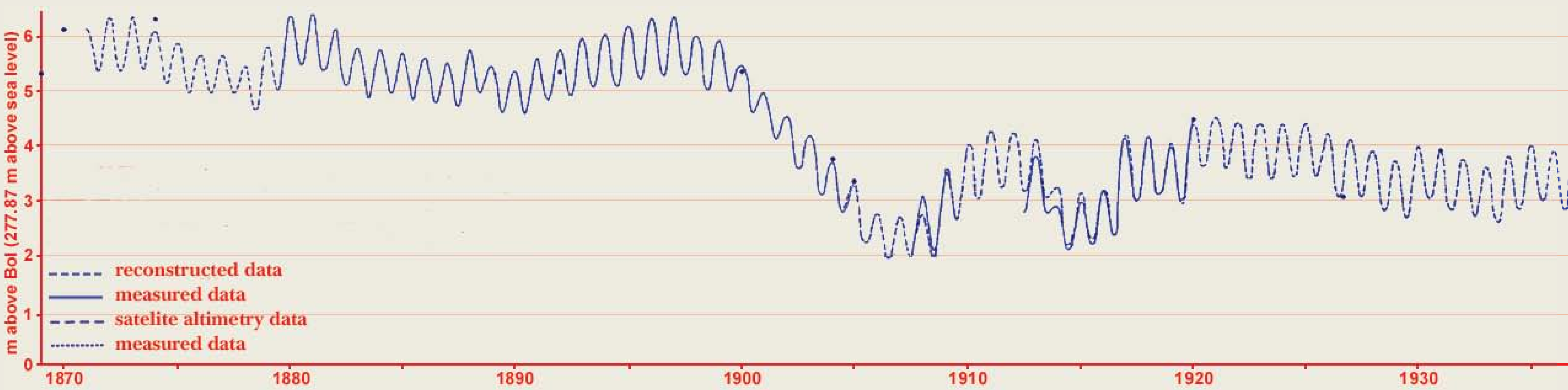


Table 3.1: The nine largest international basins in Africa

Basin	Area		Countries included
	km²	% of Africa	
Congo/Zaire	3 789 053	12.5	Angola, Burundi, Cameroon, Central African Republic, Congo, Democratic Republic of the Congo, Rwanda, United Republic of Tanzania, Zambia
Nile	3 112 369	10.3	Burundi, Democratic Republic of the Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Uganda, United Republic of Tanzia
Lake Chad	**2 381 635**	**7.8**	**Algeria, Cameroon, Central African Republic, Chad, Niger, Nigeria, Sudan**
Niger	2 273 946	7.5	Algeria, Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria
Zambezi	1 340 291	4.5	Angola, Botswana, Malawi, Mozambique, Namibia, United Republic of Tanzania, Zambia, Zimbabwe
Orange-Senqu	896 368	3.0	Botswana, Lesotho, Namibia, South Africa
Senegal	483 181	1.6	Guinea, Mali, Mauritania, Senegal
Limpopo	412 938	1.3	Botswana, Mozambique, South Africa, Zimbabwe
Volta	394 196	1.3	Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Togo
Total	**15 083 977**	**42.3**	

Source: Modified from FAO 2005

lake is increasingly being replaced by transport via road or maintained canals. The introduction of irrigation and the movement of people to the lake, who only know the lake in its present state, shift the perspective from water use to water management. In fact, a danger exists that, if the water were to rise again to 1960 levels, the long-time inhabitants of the basin may no longer be able to retreat from its rising waters, as the land behind them is increasingly exploited for irrigated agriculture.

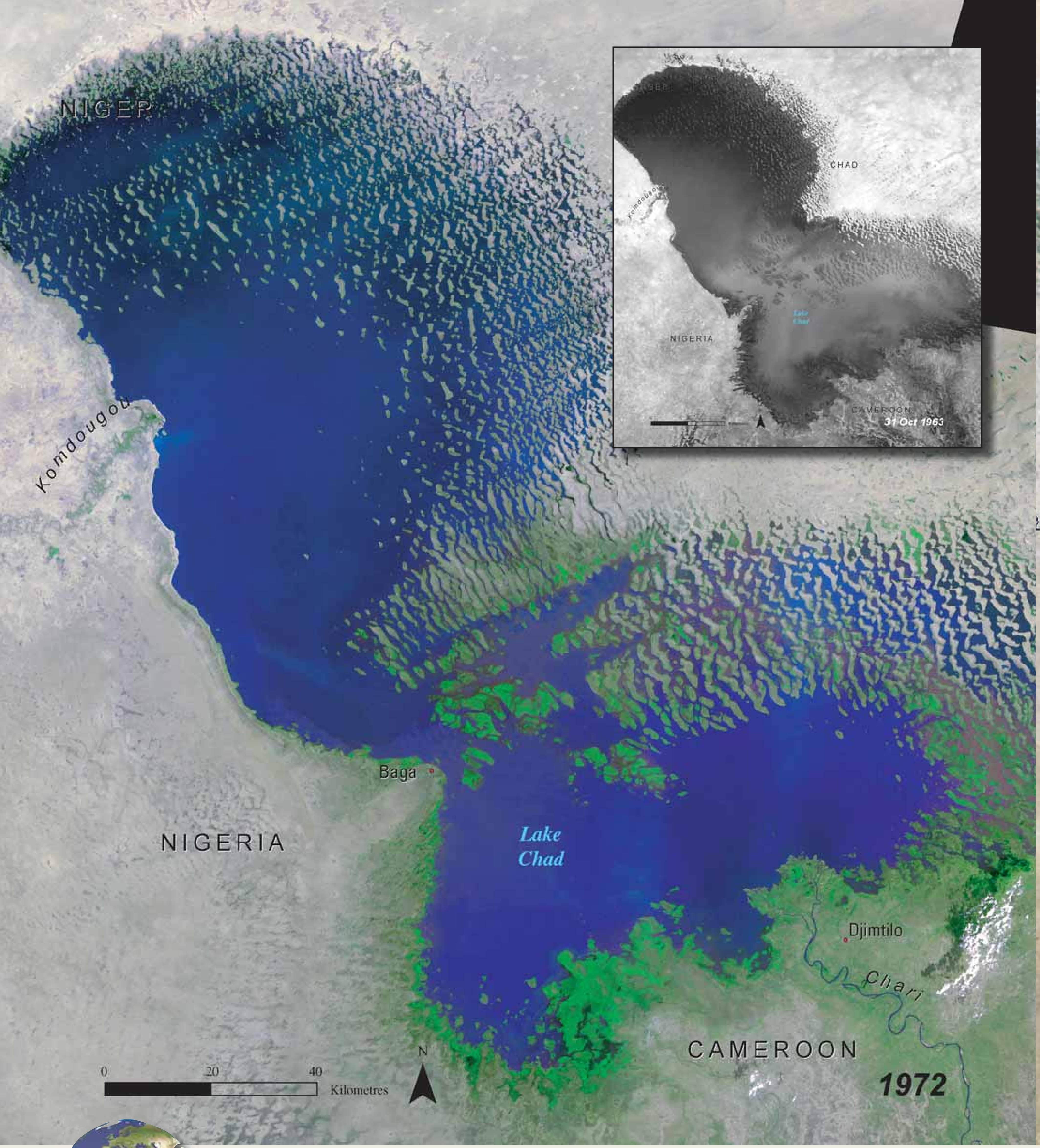
The Future

As Lake Chad continues to shrink, its future as Africa's second largest wetland is increasingly uncertain. Plants that require water, or are adapted to changing water levels, are becoming more disadvantaged than those adapted to water stress. With little fresh water entering the north basin from the Komadougou-Yobe, the basin will become more saline if it is isolated for long periods (Dumont 1992). As annual grasses replace productive perennial grasslands, biodiversity is also declining (Verhoeye 2001). Declines in vegetation associated with the lake ecosystem may result in increased erosion, and ultimately in desertification. The IPCC has predicted reduced rainfall and run-off, and increased desertification, in the Sahelian belt near Lake Chad (IPCC 2001).

The biodiversity of fish and birds in the Lake Chad region is also under threat. The drying up of water basins and ponds both directly and indirectly increases fish mortality. The *Alestes naremoze*, a species that once contributed up to 80 per cent of the local catch, is becoming rare due to the disappearance of its natural spawning beds. Migratory birds like the European white stork, which depend upon Lake Chad as a key resting place on their migrations across the Sahara, may no longer be able to complete this vital part of their annual lifecycle.

Diminishing water resources and continued ecosystem decline also have severe health and economic implications for the people living around Lake Chad. The northern states of Nigeria and Cameroon are among the poorest in these two countries (World Bank 1995b). Sarch and Birkett (2000) report a rapidly shrinking average annual fish catch in the Lake Chad Basin, from 243 000 tonnes in 1970-77 to 56 000 tonnes in 1986-89. As fish decline, economic losses may also lead to cultural losses – particularly among the Yedina, a unique fishing people that occupies the lake's islands and swamps (Sikes 2003). Around the lake, domestic plant and animal production may become untenable due to increasing soil erosion and desertification. In the lower Yobe, dunes and layers of sand are already invading date palm plantations (Nami 2002). And finally, health problems also appear to be increasing, with less potable water leading to cases of diarrhea, cholera and typhoid fever throughout the basin (GIWA 2004).

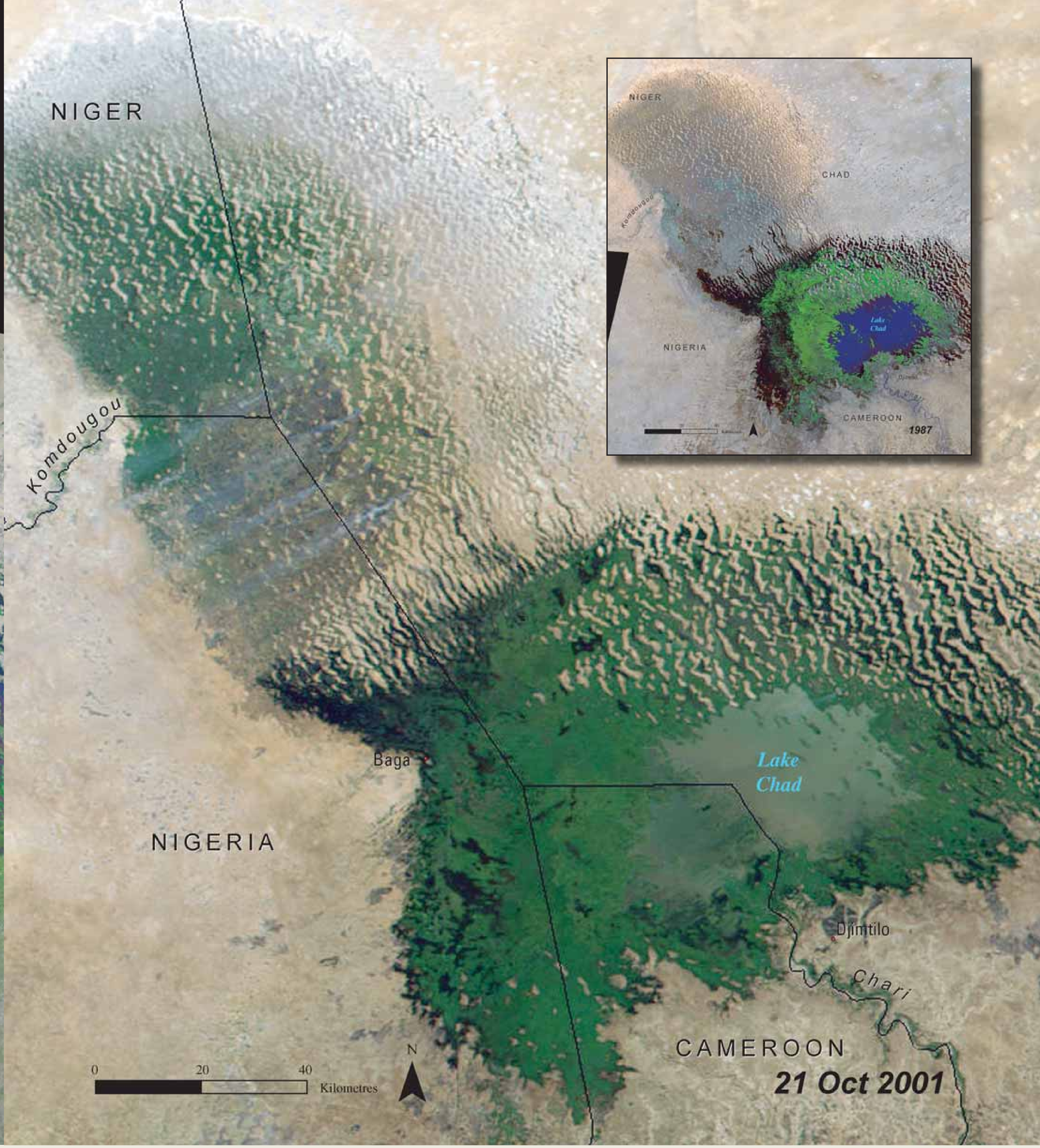
For now, the future of Lake Chad does indeed look bleak. With a high population growth rate, pressures on water resources in the lake basin will invariably continue. While in the past Lake Chad has been able to rebound from low to high water levels, climate change and people's water use may now act in concert to block the natural forces of recovery. While renewed rainfall has recently returned to the region, it is clear that the lake's future continues to hang in the balance – and will require very careful planning and multilateral management commitments in order to prevent one of Africa's greatest life-forces from becoming yet another extinct species.



Lake Chad

Nigeria/Cameroon

Persistent droughts have shrunk it to about a tenth of its former size. The lake has a large drainage basin—1.5 million km^2 (0.6 million square miles)—but almost no water flows in from the dry north. Ninety per cent of lake's water flows in from the



Chari River. The lakebed is flat and shallow; even before the drought, the lake was no more than 5-8 m (16-26 ft) deep. Considered a deep wetland, Lake Chad was once the second largest wetland in Africa, highly productive, and supporting a diversity of wildlife.

The lake is very responsive to changes in rainfall. When rains fail, the lake drops rapidly because annual inflow is 20-85 per cent of the lake's volume. Human diversion from the lake and from the Chari River may be significant at times of low flow, but rainfall is still the determining factor in lake level.

Lake Victoria

The largest freshwater lake in Africa and the second largest in the world, Lake Victoria occupies a total catchment of about 250 000 km², of which 68 870 km² is the actual lake surface (URT 2001). Located in the upper reaches of the Nile River Basin, the lake waters are shared by the three East African countries of Kenya, Uganda and Tanzania. The lake draws 20 per cent of its water from the Kagera, Mara, Simiyu, Grumeti, Yala, Nyando, Migori and Sondu-Miru rivers, while the remaining 80 per cent comes from rainfall. Mountains surround the catchment area on all sides except for the north.

Lake Victoria supports one of the densest and poorest rural populations in the world, with densities of up to 1 200 persons per square kilometre in parts of Kenya (Hoekstra and Corbett 1995). An average annual population growth rate of three per cent is exerting increasing pressures on the lake's natural resources. In all of the riparian countries, the people living around the lake have become increasingly vulnerable to environmental change over the past two decades, due to natural processes and inappropriate human actions (Birch-Thomsen *et al.* 2001).

Water erosion is extensive in many parts of the Lake Victoria Basin, with approximately 45 per cent of the land prone to such erosion. Increased siltation of the lake and increased risk of flooding in estuaries are the direct effects of soil erosion and other degradation forces in the basin. The near annual flash floods on the Lake Victoria plains have been linked to such forces emanating from point and non-point processes (Gichuki 2003).

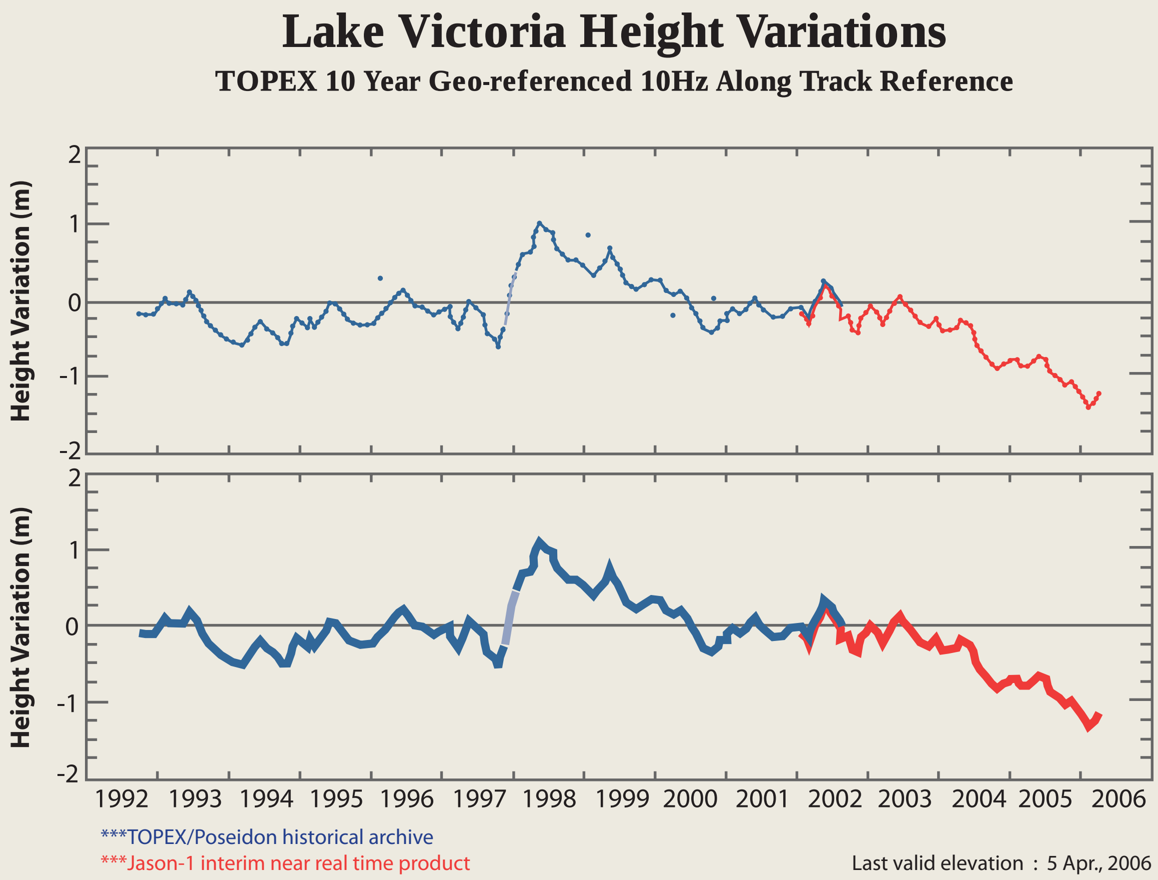


Figure 3.5: The declining levels of Lake Victoria, shown through relative lake height variations computed from TOPEX/POSEIDON (T/P) and Jason-1 altimetry, and compared to a 10-year mean level derived from T/P altimeter observations (Modified from USDA 2005).

The eutrophication of Lake Victoria is clearly linked to land-use changes and rapid population growth in the lake catchments, with impacts clearly affecting the lake from about 1930. Only a small proportion of land around the lake has favourable agro-ecological conditions for agricultural development, and these tend to be the

Figure 3.6: Many of the activities around Lake Victoria were affected by the uncontrolled growth of water hyacinth along its shores.

Images clockwise: Tom Albright/UNEP/USGS, UNEP/Flickr.com, UNEP/Flickr.com

Storm over Lake Victoria. *Courtesy: UNEP/Flickr.com*

Table 3.2: Country lake statistics.

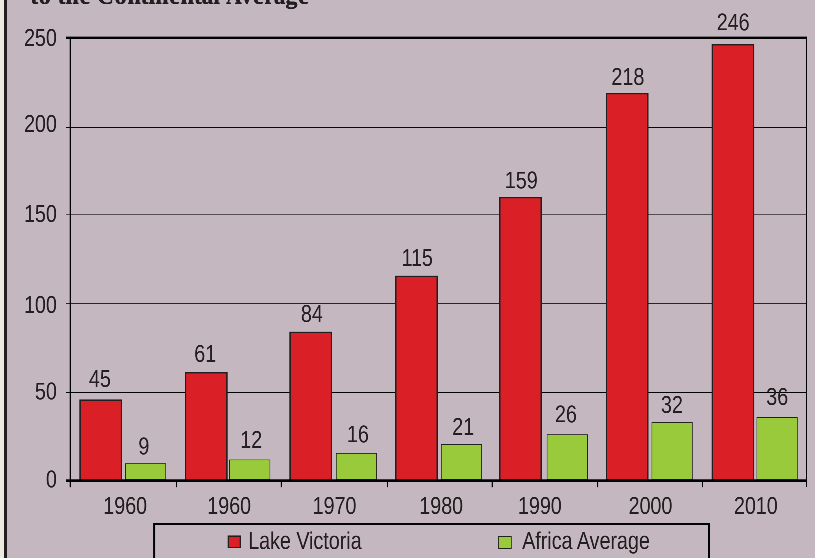
Country	Lake surface area		Shoreline		Tributary basin	
	km²	%	km	%	km²	%
Kenya	4 113	6	550	17	38 913	21.5
Tanzania	33 756	49	1 150	33	79 570	44
Uganda	31 001	45	1 750	50	28 857	15.9
Rwanda	0	0	0	0	20 550	11.4
Burundi	0	0	0	0	13 060	7.2
Total	68 870	100	3 450	100	180 950	100

most overpopulated areas. Most of the land has fragile ecosystems that need to be protected, soils with low fertility and poor texture, biotic constraints such as tsetse fly, and areas prone to flooding. Despite these unfavourable conditions, however, major population increases have resulted in the widespread cultivation of these fragile pockets of land—accelerating the degradation of the entire lake ecosystem.

The infestation of Lake Victoria by water hyacinth in the 1990s disrupted transportation and fishing, clogged municipal water pipes, and created a habitat for disease-causing insects. This led to the initiation of the Lake Victoria Environmental Management Project in 1994, which prioritised the removal of hyacinth infestations, particularly from the severely affected bays of Uganda.

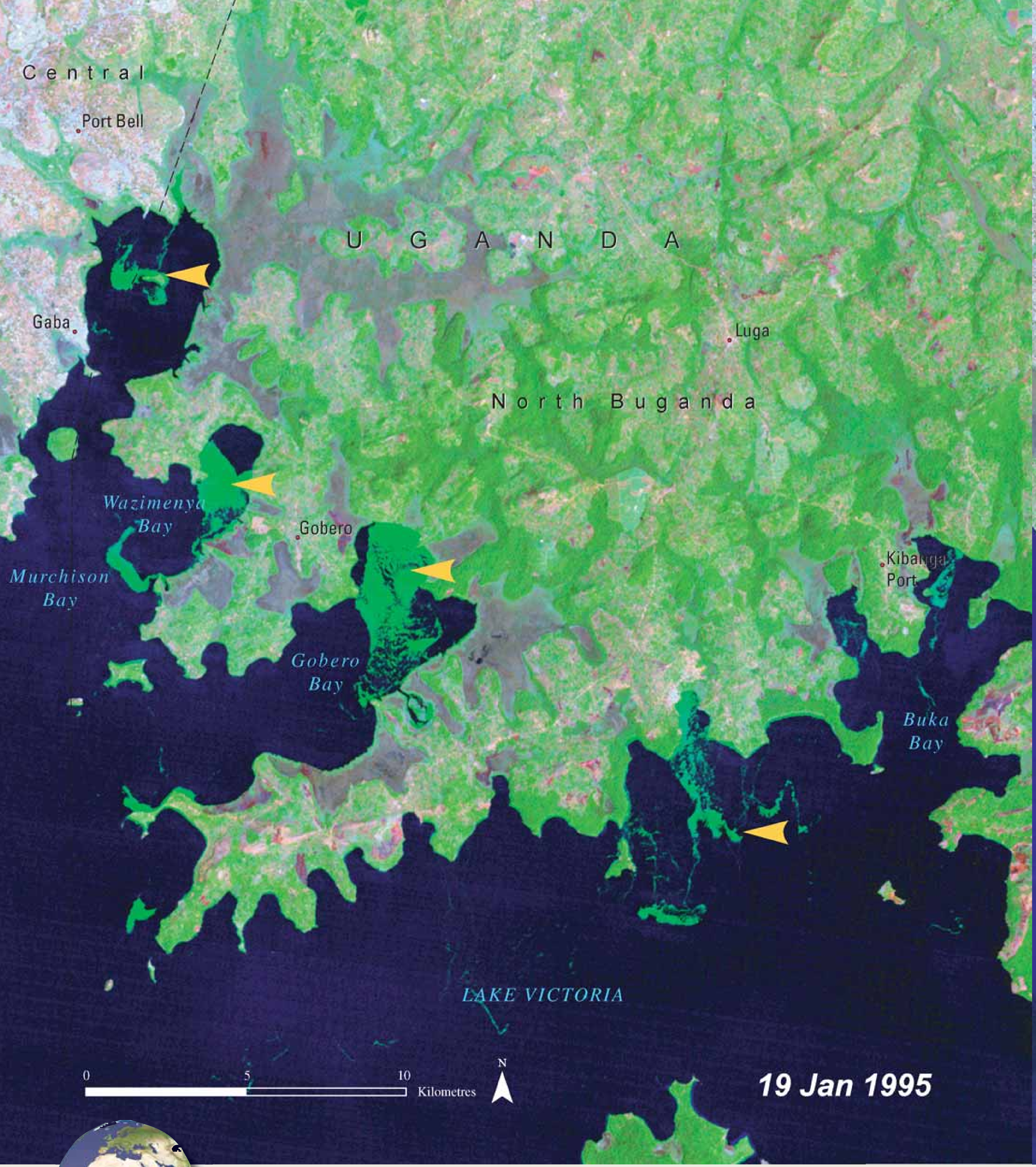
The urgent need to rapidly transform land use in the Lake Victoria Basin is underscored by the fact that the region's anticipated population growth will not only reduce the availability of land per capita, but will accelerate the rate of its degradation. Dwindling land resources in the basin present its inhabitants and their development partners with monumental paradoxes, from the mounting freshwater demands of some 30 million people, to growing industrialisation and urbanisation, increasing agricultural pollution, the loss of freshwater biodiversity, and the overexploitation of fishery resources.

Population Density Growth Around Lake Victoria Compared to the Continental Average



Box 3.1: Impacts of population increase around lake Victoria

- Average regional per capita land holding is about 0.75 ha.
- Average regional per capita income is under 250 US$.
- Population increases at an annual rate of 3 per cent.
- An estimated 150 000 km² (58 000 square miles) of land has been affected by soil degradation since 1980 including as much as 60 per cent of agricultural land.
- About 75 per cent of wetland area has been significantly affected by human activities and about 13 per cent is severely degraded.
- Approximately 46 per cent of the 3 516 km² (1 358 square miles) of the lakes basin—or 1 624 km² (627 square miles)—has experienced severe soil physical erosion.
- The efforts needed to meet land use needs for the additional 5 million people in the next 20 years will be immense.
- A two-fold reduction of degraded land is necessary in the next 20 years for the growing needs of the inhabitant.



LAKE VICTORIA

UGANDA

The 1995 image shows several hyacinth-choked bays: Murchison Bay near Gaba; large parts of Gobero and Wazimenya Bays; an area outside Buka Bay; and near Kibanga

Port (yellow arrows). Initially, water hyacinth was controlled by hand, with the plants being manually removed from the lake. But re-growth quickly occurred. A more recent control measure has been the careful introduction of natural insect predators. As the 2001 image shows, this approach seems to have been successful, as the floating weeds have all but disappeared from the above-mentioned bays.

Toshka Project

The Toshka Project, also known as the 'Southern Valley' or 'New Southern Valley Project', plans to reclaim more than a million acres (>404 685.64 ha) of empty desert and create a series of settlements for 3-6 million Egyptians where nothing existed but wind and sand. Dubbed "Egypt's hope for the 21st century", this ambitious engineering project aims to create a second Nile Valley— redirecting 10 per cent of the country's allotment of water from the Nile via a massive irrigation scheme. Unlike Lakes Chad and Victoria, this is a farsighted example of an African country working to improve its long-term water situation.

Inaugurated by President Mubarak in January 1997, the project is located in a portion of Egypt's Western Desert known as the Toshka Depression. Its basic premise is simple: using the natural Nile overflow phenomenon, to pump water out of Lake Nasser and, through gravity, to convey it hundreds of miles into the desert via a canal following what some geologists believe was the former western branch of the Nile (El Sineity 2003). By the time the project is completed in 2020, it will have cost the Egyptian Government in the region of US$7 000 million.

Over the past 20 years, the population of Egypt has risen from 20 million to nearly 70 million and it is predicted that this trend will continue, reaching an anticipated 120 million in the next 20 years. Over 60 per cent of Egyptians already live in cities that are growing faster than the infrastructure to support them, with ever-increasing urbanisation placing growing demands on water supplies in a country that is 95 per cent desert.

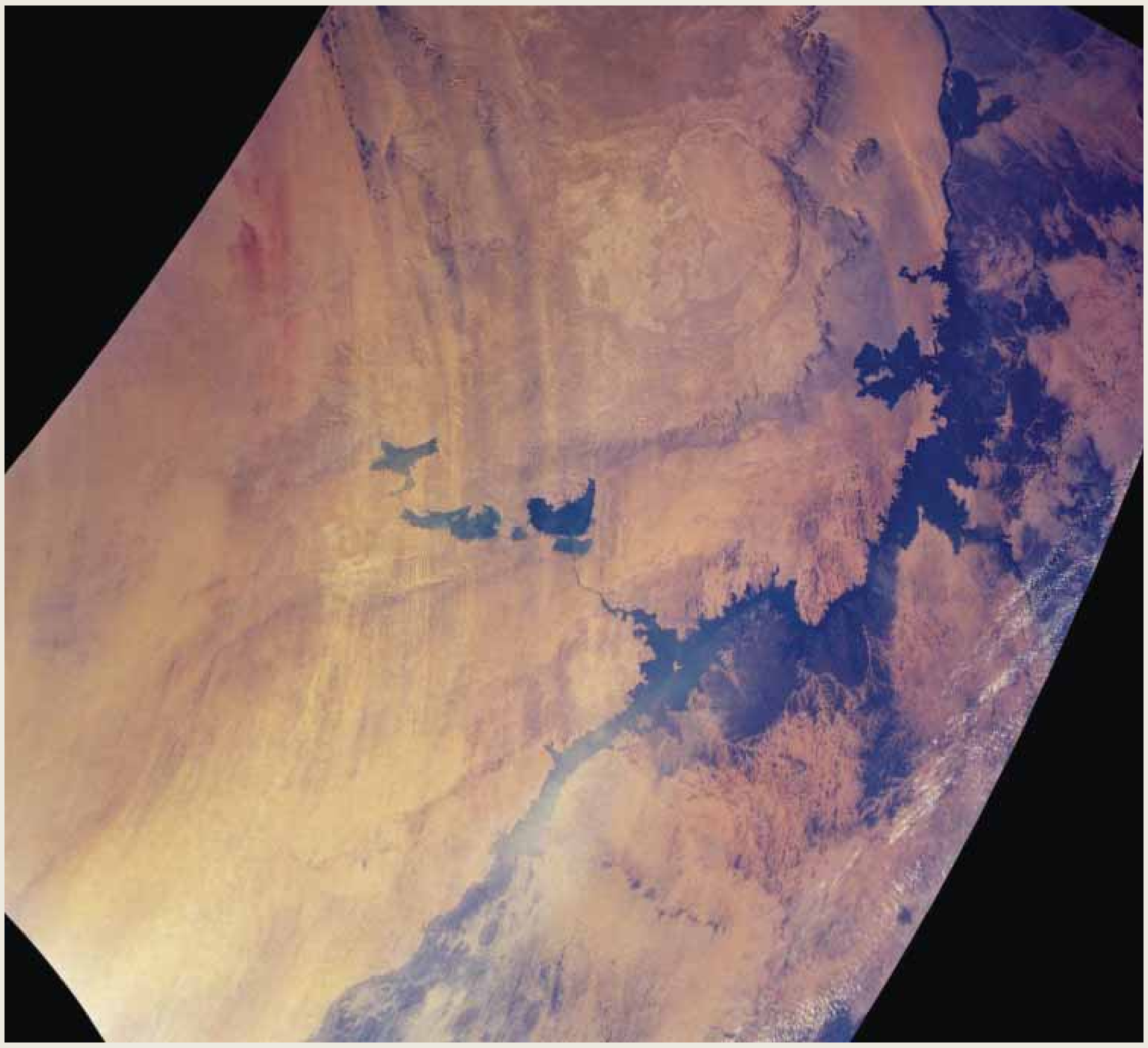
Along with the famed Aswan High Dam, many proposed infrastructure projects for land reclamation and other development have been on the agendas of both Egypt and Sudan since the 1970s and 80s. However, down the years, most of these projects have either stalled or been cancelled. Since it was built in the 1960s, the Aswan Dam has created major changes in the Nile's flow, ending the annual flooding that had carried the fertile soils on which Egypt's ancient agricultural traditions were based. Decreases in flows below the dam also changed the nature of the eastern Mediterranean, which has become saltier, affecting its fish and fisheries.

As homegrown agriculture dwindled, Egypt became increasingly dependent upon food imports. By 1990, the country depended on imports for at least 40 per cent of its basic cereal grains. However, given the climate, rich soils, and large volumes of water potentially available in the Egypt-Sudan Nile corridor, this region still has the potential to feed hundreds of millions of people across Africa and the Middle East.

Figure 3.7: Map showing the location of Lake Nasser in Egypt and Sudan *Source: Mark Dingemanse*

With the new Toshka Project, the Egyptian Government plans on taking some 5 000 million m^3 (6 000 million cubic yards) of water out of Lake Nasser each year. Under the terms of the 1959 Nile-sharing agreement with Sudan, which gives Egypt an annual entitlement of

Figure 3.8: The Toshka Lakes from space, 1999 *Earth Observatory/UNEP/NASA*



Mubarak Pumping Station

Described as a venture that has "expanded the boundaries of civil engineering", the US$430 million Mubarak Station is capable of pumping 1.2 million m^3 (1.5 million cubic yards) of water out of Lake Nasser each hour. Inaugurated in March 2005 after a five-year construction, its innovative design places the pumphouse like an island in the lake—completely surrounded by water, with 24 vertical pumps arranged in parallel lines along both sides. An open 50 m (164 ft) deep intake channel—the deepest ever constructed—allows the pumphouse to be smaller, yielding reduced capital and running costs.

The geographical location of the site also necessitated some innovative thinking. Using traditional concrete piles to support the structure in the event of an earthquake would have been very costly, so a system of steel mini-piles were installed around the base of the pumping station, connected to a foundation raft. This allows the piles to avoid compression loading, but leaves them free to tense against any seismic movement, as well as offering a degree of resistance to shearing or overturning forces. Since coming into service, the station has pumped over 14 million m^3/day (18 million cubic yards/day) of water out of Lake Nasser, enabling over 202 000 hectares of land to be irrigated.

Model of Mubarak Pumping Station

Brian Czarnecki/UNEP

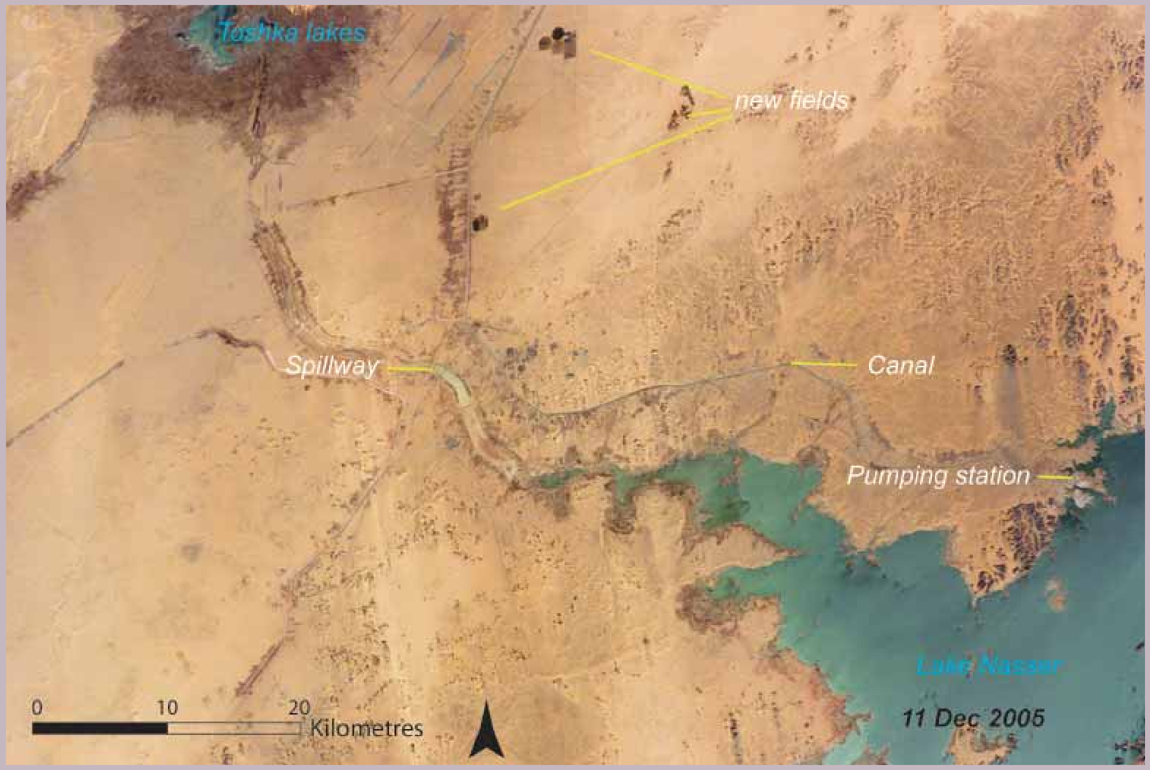


Figure 3.9: This 2005 picture from space shows the completed Mubarak Pumping Station, together with the spillway that originally flooded the Toshka Depression, the southern end of the first of the Toshka Lakes, part of the 50 km (31 mile) Sheikh Zayed Canal, and several new fields in the Egyptian desert northwest of Lake Nasser. The Toshka Lakes and the developments surrounding them represent one of the most visible and rapid human made changes on the surface of the Earth (NASA 2005a).

UNEP/NASA

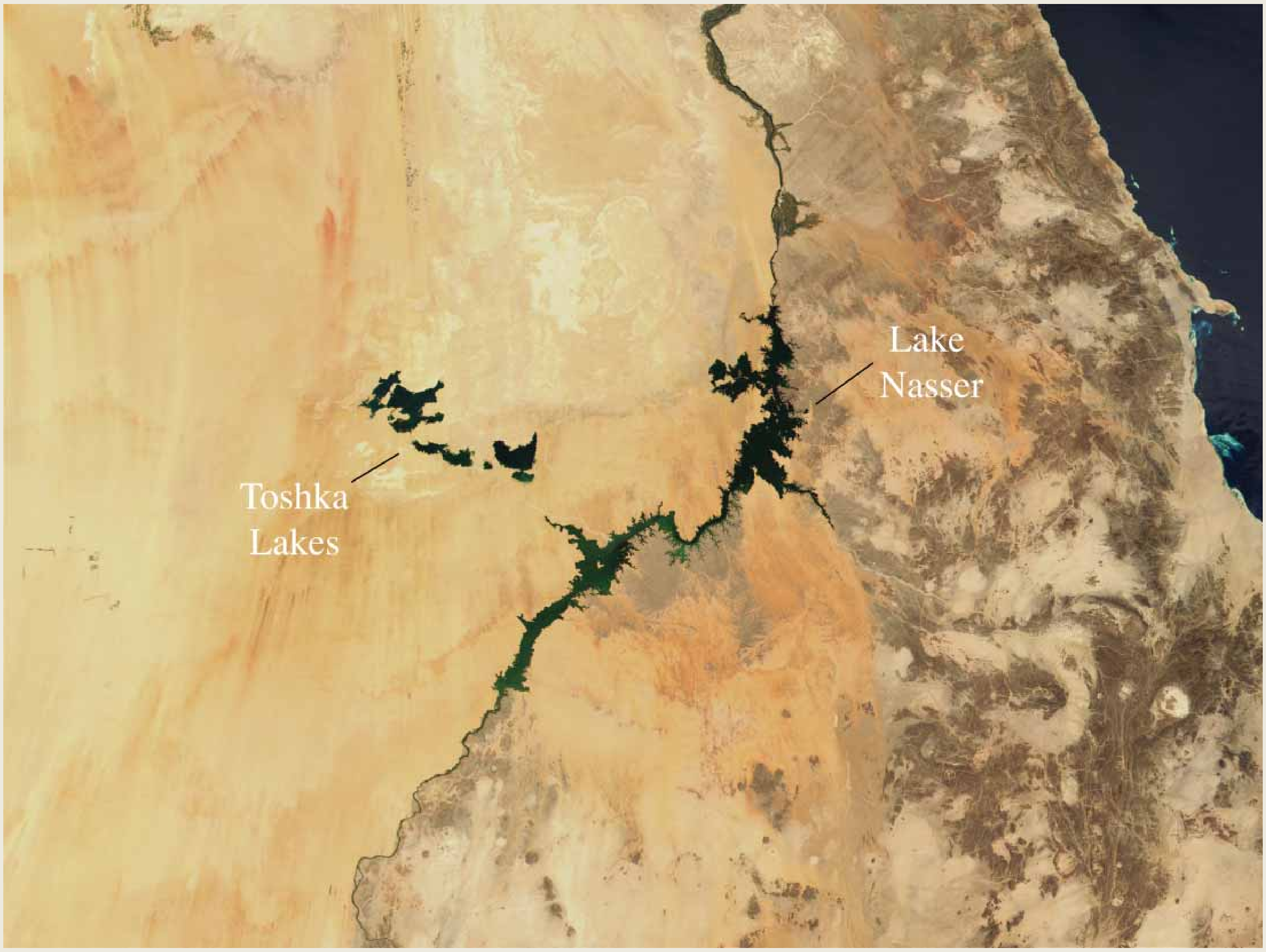
55 000 million m^3 (72 000 million cubic yards), Egypt would then offset the Lake Nasser withdrawals by limiting use elsewhere, which the government has said can be done by a number of means, including recycling treated wastewater and improving agricultural methods in the Nile Delta.

Current Status

The Toshka Project is part of a long-term plan by the Egyptian Government to increase the country's inhabitable land from five to 25 per cent of its total area. Although funding constraints have held up some parts of the project, by the end of June 2005, 90 per cent of its infrastructure was described as completed, with the remaining work progressing on schedule.

As might be expected with any undertaking of this magnitude, the project has provoked its share of controversy, both domestically and internationally. Skepticism has been expressed over the wisdom of developing water-hungry agricultural production in the hottest part of the country, as well as over the likely long-term economic and social benefits to local communities. In addition, the 10 countries that share the Nile basin remain involved in a variety of long-running disputes over the division of its water resources—scarcely surprising in the world's most water-scarce region—and many of Egypt's neighbours continue to regard the Toshka Project with understandable concern.

However, with an annual 1 000 million m^3 (1 300 million cubic yards) of rainfall, 7 500 million m^3 (9 810 million cubic yards)of groundwater, and 5 000 million m^3 (6 540 million cubic yards) of recycled agricultural drainage water, Egypt argues that the scheme can be achieved without increasing the country's 55 500 million m^3 (72 591 million cubic yards) quota awarded by the 1959 Nile Treaty.



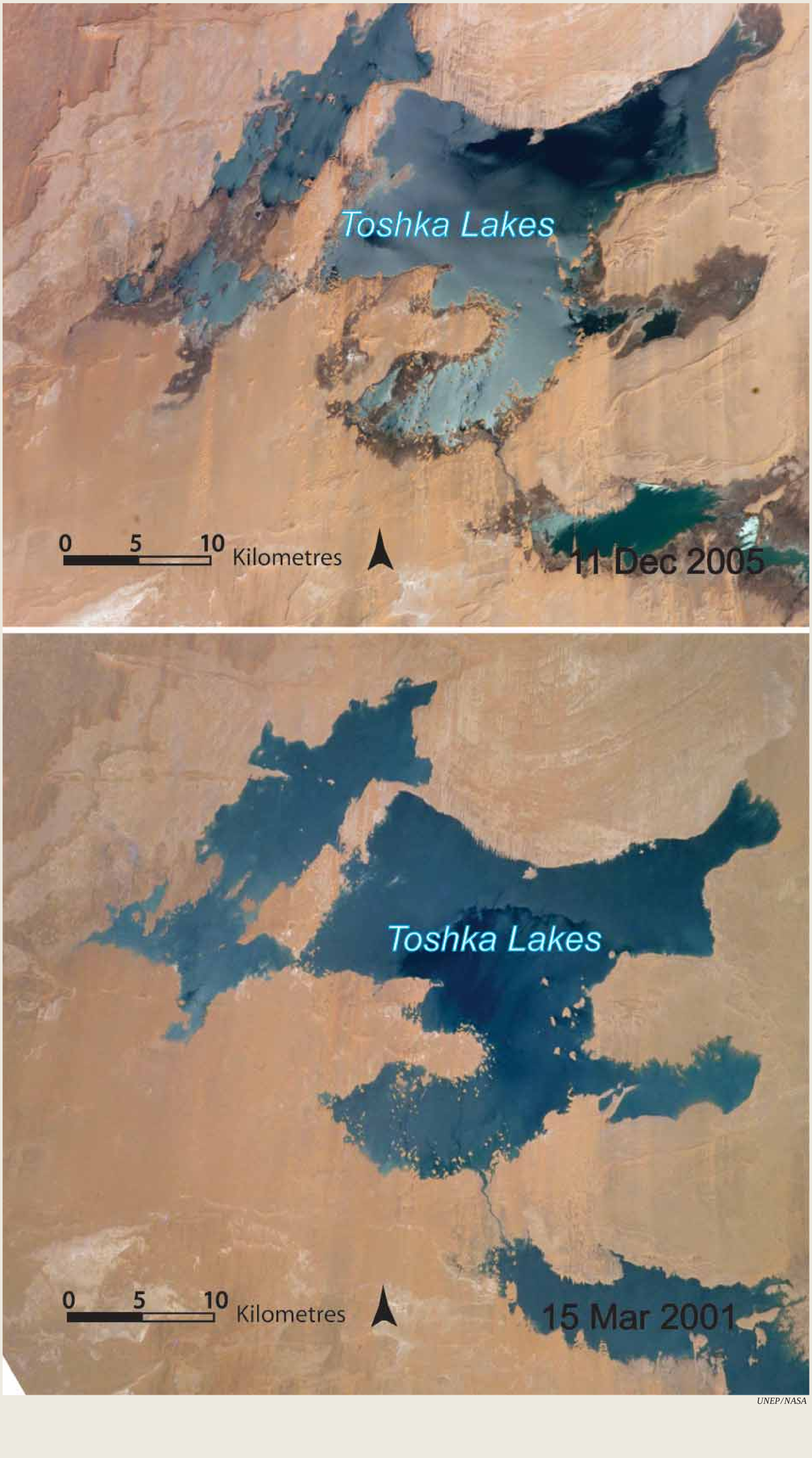
Satellite image showing location of Toshka Lakes. *UNEP/NASA*

Sheikh Zayed Canal

The second key element of the project is a 30 m (98 ft) wide, 8 m(26 ft) deep canal named in recognition of the President of the United Arab Emirates, who donated US$100 million to the project. The decision to use a canal rather than a pipeline appears to have been driven by the volume of water involved, though it obviously also has ramifications regarding loss through evaporation during the hot summer months. Seepage losses were minimised by lining the canal with layers of cement and polymer sheeting.

The final system comprises of the main canal running 50 km (31 miles) westward from the Mubarak Pumping Station, with four additional 22 km (14 mile) branches reaching out in a north-south direction, to provide the four designated areas of cultivation with their irrigation supplies. The final cost of the canal system will be about US$1 200 million.

Sheikh Zayed Canal *Brian Czarnecki/UNEP*



UNEP/NASA

Figure 3.10: Decreasing water levels in Egypt's Toshka Lakes, 2001-05.

The regional drought that has gripped eastern Africa since the late 1990s has seriously impacted the source regions of the Nile River, reducing water flows downstream into Egypt and Lake Nasser. This pair of images documents recent drops in water levels in the Toshka Lakes region. Following floods in the late 1990s, when Lake Nasser's level was at an all-time high, the flooded regions to the west of the lake have decreased significantly, exposing the former dune fields (which appear as islands in the lake and along the shoreline in the top image), and leaving a dark 'bath-tub ring' of wetlands along the lakeshore. As both the drought and development continue, this region of Egypt is sure to continue to change (NASA 2005a).

Toshka Project

Toshka Project, Eygpt

Egypt's Toshka Project has transformed part of the country's scorching hot southern desert into a region of lush, neatly tended vegetable farms supplied with water and fertiliser through drip irrigation systems.

These images from 1984-87 and 2000 document the changes and success that Egypt has had in this ambitious desert reclamation project. The project created four new lakes in the desert by drawing water through a concrete-lined canal from Lake Nasser, which was formed by damming the Nile River at Aswan. The water flows through the canal into the Toshka Depression, where it forms the lakes visible in the 2000 image. The faint blue-green areas around some of the lakes are agricultural lands, newly created by irrigation. While providing local communities with new arable land, the Toshka Project's environmental impacts are still under study.