UNEP

AFRICA'S LAKES

Atlas of Our Changing Environment

Africa's Lakes

Atlas of Our Changing Environment

UNEP

Belgian Development Cooperation .be

Editorial and Production Team

UNEP
Ashbindu Singh
Salif Diop
Patrick L. M'mayi

Science Applications International Corporation (SAIC)
Mark A. Ernste
Kim Giese
Jane S. Smith
Bruce Pengra
James Rowland

Consultants/Visiting Scientists
Hua Shi, University of Toronto, Canada
H. Gyde Lund, Forest Information Services, USA
Tejaswi Giri, Nepal
Munyaradzi Sithole, Zimbabwe
Peter Mwangi, Kenya
Ralph Johnstone, Editor – Nairobi
Assaf Anyamba, NASA GSFC
Jean Pierre Tchouankoue, Cameroon
Clever Mafuta, Southern African Research and Documentation Centre (SARDC)

We extend our sincere appreciation to the United States Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS), the National Aeronautics Space Agency (NASA), and the University of Maryland (UM) who provided project support for this atlas. Funding for the Atlas was provided by the Directorate-General for Development Cooperation (DGDC)–Belgian Development Cooperation.

ISBN: 92 807 2694 3
Job Number: DEW/0804/NA

United Nations Environment Programme
PO Box 30552, Nairobi, Kenya
Tel: +254 20 7621234
Fax: +254 20 7623943/44
http://www.unep.org
http://www.unep.net

United Nations Environment Programme
Division of Early Warning and Assessment-North America
47914 252nd Street, USGS Center for EROS
Sioux Falls, SD 57198-0001 USA
Tel: 1-605-594-6117
Fax: 1-605-594-6119
info@na.unep.net
www.na.unep.net

United Nations Environment Programme
Regional Office for North America
1707 H Street, NW, Suite 300
Washington, D.C. 20006
Tel: 1 (202) 785 0465
ashbindu.singh@rona.unep.org
http://rona.unep.org/

For bibliographic and reference purposes this publication should be referred to as:
UNEP (2006), "Africa's Lakes: Atlas of Our Changing Environment."
Division of Early Warning and Assessment (DEWA)
United Nations Environment Programme (UNEP)
P.O. Box 30552
Nairobi, Kenya

This book is available from Earthprint.com, http://www.earthprint.com.

Printed by

Distribution by SMI (Distribution Services) Ltd. UK .

This publication is printed on 100 per cent recycled, chlorine free paper.

Cover Photos (left to right): Horst Wagner/UNEP/IFAD, UNEP/NASA, Ernest Janes/UNEP/TopFoto, Gyde Lund/UNEP, William M. Ciesla/UNEP/Forest Health Management International, M. Marzot/UNEP/FAO, Betty K Bruce/UNEP/TopFoto

Table of Contents

Foreword

As we proceed into the 21st century, at least one-third of the world's population lives in countries with moderate to high water stress. The report on Water Policy Challenges, which was considered by the African Ministers' Council on Water (AMCOW) at the Pan African Implementation and Partnership Conference in December 2003, and the first United Nations World Water Development Report have both highlighted the water-related threats and vulnerabilities confronting humankind. These vulnerabilities are on the increase, particularly in Africa, and notably with regard to the continent's river and lake basins.

It is becoming increasingly clear that the availability of water resources will have a critical impact on the success of future efforts to alleviate poverty across Africa. The data provided in this Atlas of African Lakes makes abundantly clear just how threatened our precious water resources are becoming, through over-use, pollution, the destruction of ecosystems, and climate change. Satellite images of Africa confirm that dramatic environmental changes are affecting the continent's 677 natural and human made reservoirs, which contain an estimated 30 000 cubic kilometres of fresh water—the world's largest volume. It is, indeed, a wake-up call for Africans— and the international community—to take urgent action.

The rapid shrinking of Lake Songor in Ghana, partly as a result of intensive salt production, and the extraordinary changes in the Zambezi river system as a result of the building of the Cahora Basa Dam sit beside more familiar images of the 90 per cent shrinkage of Lake Chad. Other impacts, some natural and some human-made and which can only be truly appreciated from space, include the extensive deforestation around Lake Nakuru in Kenya. Satellite measurements detailing the falling water levels of Lake Victoria are also mapped. Africa's largest freshwater lake is now about a metre lower than it was in the early 1990s.

The Water Agenda of the new Partnership for Africa's Development (NEPAD) and the constitution of AMCOW exemplify positive recent developments in addressing these threats. At the 2003 Pan African Implementation and Partnership Conference on Water in Addis Ababa, African ministers pledged their commitment to the coordinated, multi-sectoral development of the continent's water resources in order to provide sustainable freshwater supplies for urban development, agricultural and industrial uses, low and flat lands management, and other activities covered by the new Integrated Water Resource Management (IWRM) policies.

It is estimated that over 300 million people in Africa face water scarcity conditions. By 2025, 18 African countries are expected to experience water stress. On the other hand, Africa has 60 international river basins whose freshwater potential could benefit all of their riparian communities. Transboundary cooperative mechanisms for the management of these shared resources are underdeveloped, however, further reducing their potential to meet growing freshwater requirements. The achievement of the MDGs will remain elusive in Africa without a major paradigm shift in water resources management.

A high-level African ministerial dialogue on The Management of Lake Basins for their Sustainable Use: Global Experience and African Issues, held during the 11th World Lakes Conference in Nairobi in November 2005, called for making the integrated management of lake basins a long-term element of government and public priorities, planning and financing processes, integrated water resources management, habitat and biodiversity conservation, and economic development programmes. The resulting ministerial resolution recommended:

- The strengthening of local capacities for managing lake basins in a sustainable manner;
- The establishment of a Centre of Excellence in Africa for promoting a new generation of water and environmental planners and managers with skills in limnology and aquatic and environmental sciences;
- Consideration by the UN of the need to establish an International Year for Lakes; and
- The mobilisation of funds for supporting IWRM to meet the MDGs.

One of the priority areas for NEPAD is water and sanitation, and in response to the challenges faced in this sector the African Water Vision for 2025 was developed to stimulate more equitable and sustainable use and management of Africa's water resources for poverty alleviation, socio-economic development, regional cooperation, and environmental conservation. It is within this political and institutional setting that AMCOW has emerged as the principal mechanism for policy dialogue and coordination of strategies on water and sanitation among African countries, as well as with the international community.

AMCOW's efforts and increasing credibility have resulted in many successes already. It has established the African Water Facility (AWF), hosted by the African Development Bank, for the mobilisation of resources towards the MDG/WSSD targets for water and sanitation. Major development partners have committed resources to the AWF. AMCOW has cooperated with the UN agencies dealing with water, and has begun a strategic partnership with the EU Water Initiative. It is also charged with oversight of the implementation of NEPAD's water component. Through its Technical Advisory Committee and sub-regional arrangements, AMCOW cultivates a clear relationship with the Regional Economic Communities and River and Lake Basin Organisations for transboundary water management and development programmes.

As the current President of AMCOW, I strongly believe the Council is on the right track and warrants support from all stakeholders to translate the African Water Vision into reality and to put Africa on the road to achieving her commitments to the global community. The protection and management of freshwater resources is being addressed through AMCOW's triennial work programme, 2005-2007, which itself is designed as the platform on which Africa will move forward towards meeting the Millennium Development Goals on water and sanitation, as well as the WSSD targets for development of IWRM strategies. We firmly believe that it is only through the increasing coordination of our efforts—and through joining forces with civil society, the private sector and our international partners—that these challenges will be met.

H.E. Mrs. Maria Mutagamba

President of the African Ministers' Council on Water

Minister of State for Water Resources, Uganda

Preface

As well as being the principal source of livelihood for many individual communities, Africa's lakes contribute significantly to the continent's socio-economic development. However, these lakes are undergoing rapid changes due to human activities and climate change. This has altered ecosystem processes and resulted in several growing threats, including loss of biodiversity, over-fishing, eutrophication, the proliferation of invasive weeds, siltation, toxic contamination, and over-abstraction of water. If they are not carefully managed, Africa's lakes face a growing risk of becoming unsustainable for future generations.

There is a critical need for valid scientific data and environmental information to enlighten decision-makers and various stakeholders on the changes taking place in and around most lakes in Africa. Satellite imagery vividly captures these changes over large areas and long periods of time. Large water bodies can easily be mapped, identifying changes in their surroundings. This is particularly useful for illustrating human-induced changes across country borders, especially for transboundary lakes.

This Atlas was prepared as part of United Nations Environment Programme's (UNEP) contribution to the 11th World Lakes Conference, which was hosted in Africa for the first time in November 2005. Its overall objective is to show various changes within Africa's lakes in an integrated manner, by the use of remote sensing technologies, geographic information systems, and case studies on particular lakes. This publication uses satellite images to document, assess and vividly illustrate the changes in and around African lake basins over recent years.

It is important to note that water systems are sensitive barometers of the health of our planet. While water covers most of the Earth's surface, less than two per cent of water bodies consist of fresh water – and most of that is bound in the polar icecaps. Indeed, fresh water in a liquid state is very scarce. Severely aggravating the problem is that most of the world's available fresh water is concentrated in relatively few large lakes, many of which are shared by two or more countries.

We hope the information contained in this Atlas will prove useful not only for managing and monitoring selected lakes, but will also underscore the intrinsic value of harnessing, visualising, assessing and promoting new technologies to gain a deeper understanding of the changes affecting Africa's lakes, and their impacts on the environment and societies living around them. As a follow up to the 11th World Lakes Conference, UNEP will be updating this Atlas in order to enlarge its scope and content. In Africa, as elsewhere, UNEP continues to work closely with governments and other partners on a number of initiatives aimed at the environmentally sound management of the continent's vital freshwater lakes.

Klaus Töepfer
Executive Director, UNEP

NP Clark/UNEP/MorgueFile.com

Main Findings

Status and trends

- Due to differences in methods for classifying water bodies as lakes, the precise number of lakes in Africa is difficult to determine. However, according to the WORLDLAKE database, there are 677 lakes in Africa.
- Lakes are a source of livelihoods for many African communities. However, Africa's lakes are subject to a variety of human-induced pressures as well as climate change. If they are not managed properly, the continent's lakes risk over-exploitation and loss of sustainability for future generations.

Pressures on Lake Victoria

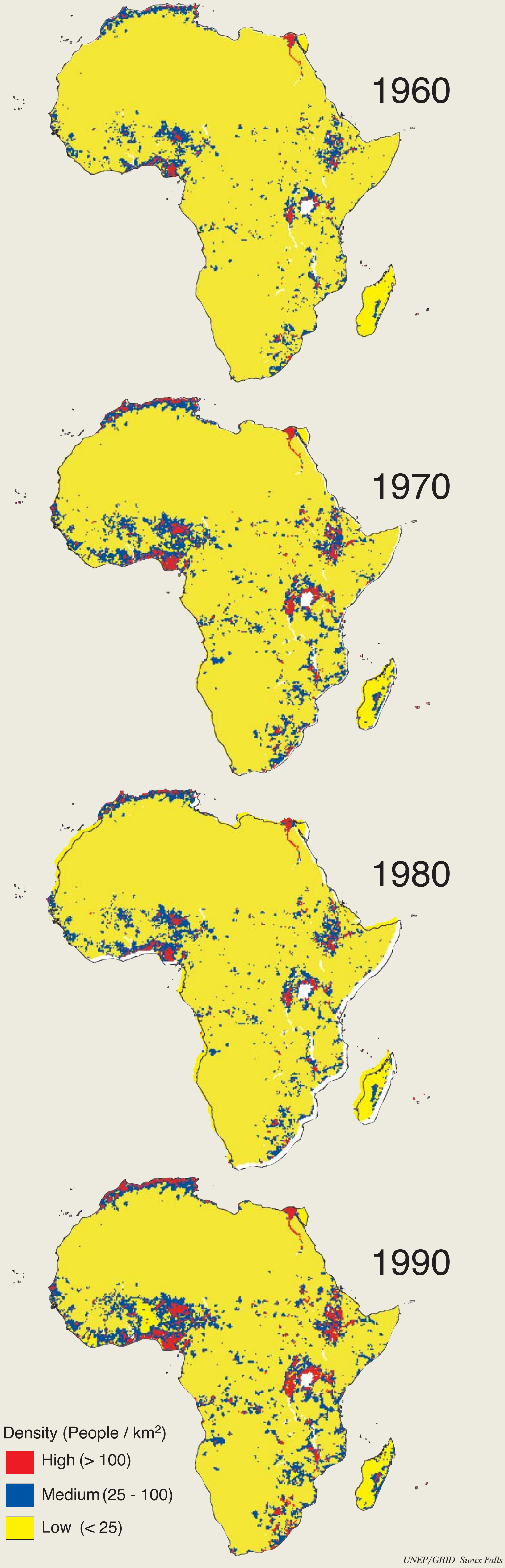
- Population growth around the continent's largest lake, Lake Victoria, is significantly higher than the rest of Africa. In recent decades, the rate of population growth within a 100 km (62 mile) buffer zone around the lake has outpaced the continental average, reflecting growing dependency and pressure on the lake's resources.
- Lake Victoria's level variation, derived from satellite altimeter measurements, shows a negative height variation trend—even after the significant inflows of water from the 1997-98 flooding. This pattern should be of long-term concern to all the countries of East Africa, as well as those along the Nile Basin.
- Lake Victoria was widely invaded by water hyacinth during the 1990s. Initially, the hyacinth was controlled by hand, with the plants being manually removed from the lake. More recent control measures include the careful introduction of natural insect predators and some improvements can be seen, even from space.

Unsustainable use of Lake Chad and Lake Tonga

- Lake Chad's area has shrunk by 95 per cent over the past 35 years, driven by a complex interaction between climatic and human causes. Lake Chad's surface area decreased from 22 902 km^2 (8 843 square miles) in 1963 to a mere 304 km^2 (117 square miles) in 2001. Studies reveal that the drastic decline in the lake level and area since the 1970s can be attributed in nearly equal parts to the continued decrease in precipitation over the basin and to the widespread increase of irrigated agriculture.
- Uncontrolled damming, the withdrawal of water for irrigation, and climate variability are the major cause of the drying up of Lake Tonga in Algeria.

Transboundary lakes and river basins

- There are 15 natural lakes that cross the political boundaries of two or more countries in Africa, namely Lakes Victoria, Chad, Turkana, Tanganyika, Tana, Rudolf, Natron, Malawi, Mweru, Kivu, Kariba, Edward, Chilwa, Albert and Abe. The extent of water in the human made Lake Nasser falls across the boundaries of Egypt and Sudan.
- There are 60 transboundary river basins in Africa, covering over 63 per cent of the continent's land area. Of these, two countries share 30 basins and more than two countries share the remainder. The Congo Basin is shared by 13 countries, followed by the Niger and Nile basins with 11 countries, and the Zambezi and Chad basins, with nine and eight countries respectively.
- The Congo, Nile, Niger, Chad and Zambezi river basins occupy about 42 per cent of Africa's land area and sustain over 44 per cent of the continent's population.



UNEP/GRID–Sioux Falls

- Population density is the highest in the Nile Basin, followed by the Niger Basin. The Chad Basin had the lowest population growth between the 1960s and the 1990s.

"Killer lakes"

- Some lakes in central Africa have become known as "killer lakes," because of the catastrophic natural events that have occurred in their vicinities. Lakes Monoun, Nyos and Kivu are located in active volcanic areas; in 1984 and 1986, CO_2 bursts in Lakes Monoun and Nyos led to the sudden deaths of 37 and 1 746 people respectively.
- A breach of the natural dam in Lake Nyos appears imminent, with a high likelihood of this occurring within the next five years.

Threats to Africa's lakes

- Rapid population growth continues to pose a major threat to Africa's lakes and its most significant freshwater reservoirs.
- The continent's freshwater supplies are being threatened by both natural phenomena and human factors.

The major natural threats facing Africa's lakes include:

- The transboundary nature of most freshwater resources
- Extreme and temporal variability of climate and rainfall
- Growing water scarcity, the shrinking of some water bodies, and desertification

The main human-induced threats include:

- The multiplicity of transboundary river basins, with different countries pursuing their own management and extraction agendas, often in conflict with conservation priorities
- Depletion of water resources through pollution, deforestation, overgrazing and soil erosion
- Failure to invest adequately in resource assessment, protection and development
- The expansion of large-scale irrigation and dams
- Unsustainable financing of investments in water supply and sanitation

Other threats include:

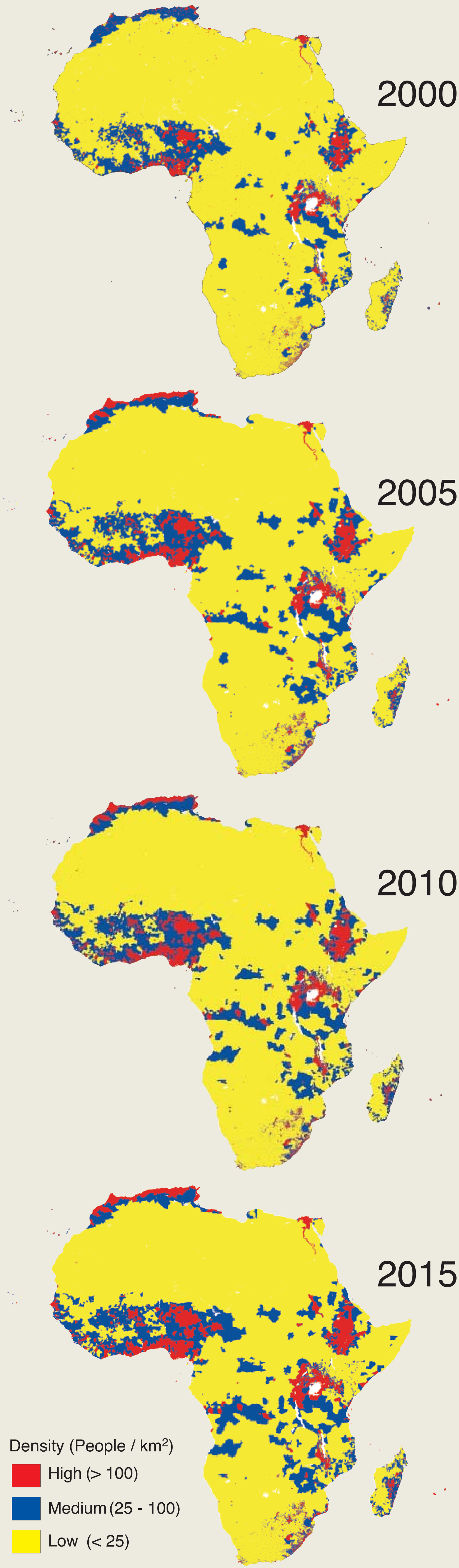
- Drought and flooding
- 'Killer lakes'
- Invasive species
- The potential collapse of dams

Hope for the future?

The Africa Water Vision for 2025 (World Commission on Water for the 21st Century) calls for:

- Strengthening the governance of Africa's freshwater resources
- Improving national and regional water wisdom
- Meeting the most urgent water needs
- Strengthening the financial base for a sustainable water future

By supporting this vision, it is hoped that the conditions in and around Africa's lakes can be steadily improved over time.



Modified from CIESIN

Figure 1-1: A satellite composite image of Africa (Source: NASA)

1 Africa's Lakes
Introduction

Seen from space, the Earth appears as a largely blue planet, suggesting the presence of vast quantities of water. Although this is true, only about two per cent of the Earth's water is fresh, with the majority of this small fraction locked up in icebergs and glaciers, or located far underground beyond our easy reach. Lakes appear like blue diamond mosaics in the terrestrial mass. As a relative perspective, if all the water on Earth could be put into a four-litre bottle, the readily-available quantity for use by people would be about one tablespoon, or less than half of one per cent of the total. Nevertheless, even this small amount is deemed sufficient to meet all the present and foreseeable people's needs – if it were evenly distributed around the world and protected from degradation.

A lake is defined as a large body of water, usually fresh water, which is surrounded by land. Lakes are usually formed when natural depressions or basins in the land surface become filled with water over time. They can range from small ponds to water-bodies stretching hundreds of kilometres and containing vast quantities of water; large lakes are sometimes referred to as 'inland seas'. Some small seas are also often referred to as lakes (Wikipedia 2005). As definitions of what constitutes a lake also vary, the precise number of the world's lakes is difficult to determine.

In contrast to flowing streams and rivers, lakes provide a means for pooling or storing water for varying periods of time. Lakes are one of our most important natural resources, especially in the tropics, where they form highly productive biological systems. They provide water for consumption, fishing, irrigation, power generation, transportation, recreation, and a variety of other domestic, agricultural and industrial uses (Zinabu 1998).

Natural and human made lakes and wetlands provide significant storage of somewhat easily accessible global terrestrial water, which varies seasonally and annually according to climate variation and anthropogenic activities. There are approximately 50 000 natural lakes and 7 500 human made lakes in the world (Ryanzhin 2004). Despite the publication of several world lakes datasets and databases (Herdendorf 1982; Birkett, Mason 1995; ILEC 2002; Wetlands International 2002; Lehner, Döll 2004), most data on limnologically studied natural and human made lakes are dispersed over a wide range of literature.

Africa, with a total area of 30 244 050 km^2 (11 677 293 square miles), is the second largest and second most populous continent after Asia. It covers approximately 20.3 per cent of the total land area on Earth. With over 800 million people, it accounts for about one seventh of the world's population (Wikipedia 2005). It is also the largest of the three great southward projections from the main mass of the Earth's surface. It is estimated that Africa has about 30 000 km^3 (7 197 cubic miles) of water in large lakes (Anon 1978; WCMC n.d.), which is the largest volume of any continent.

Africa is endowed with hundreds of lakes, both natural and artificial (Table 1.1). For example, Lake Bosumtwi is a natural lake that was formed by a crater when a large meteoroid smashed into the continent. Lake Nasser, on the other hand, is a reservoir or artificial lake created behind the Aswan Dam in Egypt. Africa is also home to some of the largest lakes in the world, many of which are bordered by two or more countries. Lake Victoria is the largest of all African lakes and the second largest freshwater body in the world, with a surface area of about 68 800 km^2 (27 000 square miles). Its extensive surface is divided among three countries: the northern half to Uganda, the southern half to Tanzania, and part of the northeastern sector to Kenya.

According to the WORLDLAKE database, there are 677 lakes in Africa, with 88 of them listed as principal lakes (see Appendix). Although lakes are a source of livelihoods in most African societies, they are also a major source of natural disasters, tropical diseases and pandemics. It is important to note that Africa's lakes are also undergoing significant changes due to a combination of human activities and climate change, with potentially serious implications for people's livelihoods and aquatic biodiversity.

Figure 1.1: Distrubution of Africa's major lakes

UNEP/GRID–Sioux Falls

The Mankwe Dam in Pilanesberg National Park, South Africa. *UNEP/MorgueFile.com*

Table 1.1: Africa's lakes by country

Country	# of Lakes	Percentage
Uganda	69	10%
Kenya	64	9.50%
Cameroon	59	8.70%
Tanzania	49	7.20%
Ethiopia	46	6.80%
South Africa	37	5.50%
Rwanda	29	4.30%
Ghana	29	4.30%
Morocco	26	3.80%
Madagascar	25	3.70%
Egypt	16	2.40%
Nigeria	16	2.40%
Mali	15	2.20%
Tunisia	15	2.20%
Zaire	15	2.20%
Malawi	13	1.90%
Botswana	12	1.80%
Gabon	8	1.20%
Others	134	<20%
Total	**677**	**100%**

Source: World Lakes Network (2004)

Africa, and particularly East Africa, has numerous lakes that support very important fisheries—providing a livelihood to millions of people, and contributing significantly to the food supply. In many of these lakes, however, fisheries are reaching a state of maturity and unsustainability. The fisheries of just 11 lakes in the 11 countries of eastern Africa employ close to half a million people, with perhaps three times as many engaged in secondary activities and related services—thus supporting about four per cent of the region's entire population (Petr 2005). This has also resulted in transboundary water conflicts, despite the creation of regional initiatives on integrated water management. Transboundary freshwater resources will clearly become a source of growing conflict in Africa without the development of—and adherence to—sound multilateral agreements for their shared management.

The degree of resource utilisation differs greatly from lake to lake, and according to the two main types of fisheries: demersal/onshore and pelagic/offshore. Currently, demersal/onshore resources are being more heavily exploited or overexploited. Africa's large lakes are receiving considerable biological attention through a number of international activities, with research focusing particularly on Lakes Victoria, Tanganyika and Malawi. However, governmental support for lakes remains low in many African countries, with little money allocated from national budgets for their conservation or development (Petr 2005).

Although Africa's lakes are limited and sensitive resources that call for proper care and management, they remain among the most abused of the continent's natural resources. The direct disposal of wastewater into lakes continues to have a damaging impact on their fragile ecological balances. Human impacts in lake basins and catchments also have devastating consequences for the lakes themselves, including: rapid siltation caused by accelerated soil erosion; irreversible uptake of water and/or salinisation due to irrigation; eutrophication; contamination with toxic chemicals and mine tailings; and acidification. Effective integrated watershed management requires not only strict soil conservation measures, but changes in the way that water moves through the agro-ecosystem.

In Africa, human factors, in combination with the natural conditions of climate and geology, may influence water quality to a large extent. Some African nations do not have industries that flourish in developed countries, and pollutants are not produced in such large quantities. However, pollution resulting from land-use changes, environmental modification and other practices associated with rapid population increase, have caused or accelerated many changes in the continent's lakes (Zinabu 1998).

The main threats to water quality in Africa include eutrophication, pollution, and the proliferation of invasive aquatic plants such as the water hyacinth. Industrial wastes are still discharged without treatment into rivers and lakes in most African countries, posing a major and persistent health problem. Recurring droughts are also a major threat to, and cause of, water shortages (Ottichilo 2003).

Africa's freshwater supply, including its lakes, is threatened by certain natural phenomena and human factors. Among the greatest natural threats are:

- The multiplicity of transboundary water basins
- Extreme and temporal variability of climate and rainfall
- Growing water scarcity
- Shrinking of some water bodies
- Desertification

The major human threats include:

- The pursuit of inappropriate governance and institutional arrangements in managing national and transnational water basins
- The depletion of water resources through pollution, environmental degradation, and deforestation
- Failure to invest adequately in resource assessment, protection and development
- Unsustainable financing of investments in water supply and sanitation

These threats pose challenges in managing the continent's water resources and in meeting competing demands for basic water supplies (World Commission on Water for the 21st Century n.d.).

Water supplies are undoubtedly one of the most important resources for Africa's social, economic and environmental well-being. Currently, about two-thirds of the rural population and one-quarter of the urban population are without safe drinking water, and even higher proportions lack proper sanitation. Climate change will likely make the situation even worse. The greatest impact will continue to be felt by the poor, who have the most limited access to water resources (Watson et al. 1997).

Other threats to Africa's lakes include:

- Poisoning: Mercury poisoning is affecting at least three of Africa's Great Lakes: Turkana, Naivasha and Baringo (Campbell et al. 2003).
- Drought: Lake Chad, once one of the continent's largest freshwater bodies, has dramatically decreased in size due

Lagune de Porto-Novo Ramsar Site, near Cotonou, Benin *Nassima Aghanim/UNEP/Ramsar*

to climate change and extraction. Once close in surface area to North America's Lake Erie, Lake Chad is now a ghost of its former self. According to a study by University of Wisconsin- Madison researchers, working with NASA's Earth Observing System programme, the lake is now one-twentieth of the size it was 35 years ago (NASA 2001).

- Killer lakes: In August of 1986 Lake Nyos in Cameroon "exploded," releasing up to 1 km^3 (0.6 cubic miles) of CO_2 and killing about 1 700 people up to 26 km (16 miles) away. A smaller gas burst from Lake Monoun in August 1984 killed 37 people. Steps are being undertaken to reduce such risks in the future (Kling 2005).
- Flooding: In addition to drought, lakes may flood, posing threats to human populations living close by. An example is Lake Kyoga (Goulden 2005).
- Potential collapse of dams: The United Nations team of experts dispatched on 21 September 2005 to Lake Nyos, in Cameroon's Northwest province, to assess the stability of its natural dam warned of the risk of its potential collapse within the next five years, and called for urgent measures to prevent it.

The Africa Water Vision for 2025 (World Commission on Water for the 21st Century n.d.) calls for:

- Strengthening the governance of Africa's water resources
- Improving national and regional water wisdom
- Meeting the most urgent water needs
- Strengthening the financial base for a sustainable water future

This Atlas vividly illustrates some of the changes that people and nature have wrought on Africa's lakes – both good and bad – in recent decades, and presents an overview analysis of the situation of 24 major lakes (see Table 1.2). In doing so, it also serves as an early warning of the precarious environmental situation of many of Africa's lakes, and seeks to inform policymakers on the need to consciously assess and regularly monitor changes affecting lakes in their countries. An integrated approach will be taken in mapping out the changes in African lakes, including the main causes and effects of human activities. As water sustains life, the effective management of our water resources demands a holistic approach, linking social and economic development with the protection of natural ecosystems. Sustainable management must link land and water uses across entire catchment areas, as well as direct uses of lakes themselves, and should include the mainstreaming and crosscutting of population, health and climate changes in evaluating utilisation and management strategies. The analyses in this publication have been aided by the use of satellite imagery to map out demographic and environmental changes within Africa's lake ecosystems. The publication intends to provide a clear and practical basis for promoting more effective management and monitoring of Africa's lakes, and for informing policy decisions and individual actions to help sustain the livelihoods of the communities that live around them.

Table 1.2 Lakes, reservoirs and lagoons featured in this Atlas*

Name	Country	Surface area [km^2]	Maximum depth [m]
Alaotra, Lake	Madagascar	200	
Al Wahda, Lake	Morocco	123	
Challawa Gorge Reservoirs			
Cahora Basa Reservoirs	Mozambique	2739	157
Chad, Lake	Chad/Cameroon/Niger	1540	10.5
Djoudj, Lake	Senegal	160	
Ichkeul, Lake	Tunisia	120	
Kariba, Lake	Zambia/Zimbabwe	5400	78
Kivu, Lake	Rwanda, Zaire/Congo (DR), Rwanda	2220	480
Lesotho Highlands Reservoirs	Lesotho		
Malawi (Nyasa, Niassa)	Malawi, Mozambique, Tanzania	29500	706
Manantali, Lake	Mali	200	
Nakuru, Lake	Kenya	40	2.8
Monoum, Lake	Cameroon		
Nasser, Lake	Egypt	5248	130
Nyos, Lake	Cameroon		96
Sibaya, Lake	South Africa	78	43
Songor Lagoon	Ghana		
St. Lucia, Lake	South Africa	300	8
Tana, Lake	Ethiopia\Kenya	3600	14
Tanganyika, Lake	Tanzania/Zaire/Zambia/Burundi Burundi, Congo (DR), Tanzania, Zambia	32000	1471
Tonga, Lake	Algeria		
Toshka Project, Reservoirs	Egypt		
Victoria, Lake	Tanzania/Uganda/Kenya	68800	84

Source: WorldLakes 2004

** See appendix for more statistics.*

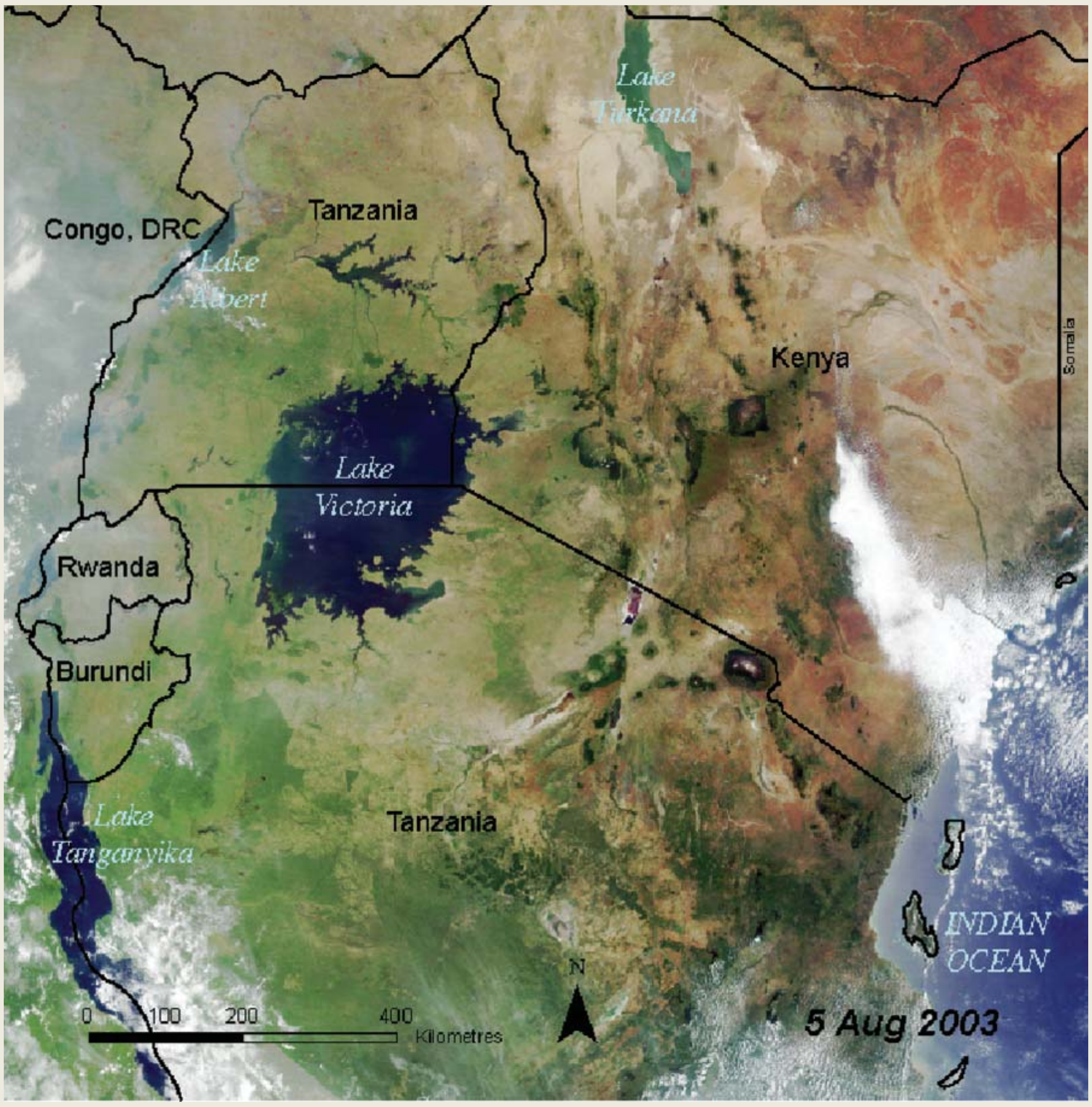


Figure 1.2: Satellite image showing the Great Lakes of Africa. This image vividly shows the major lakes of eastern Africa as they twist down the two arms of the Great Rift Valley in nine countries in East and Central Africa. The Great Lakes of Africa include some of the largest and most ecologically diverse freshwater systems on the planet. Eight of the 15 lakes in this region are ranked as 'Great Lakes' – a testimony to their size and depth. Lake Victoria is ranked as the second-largest freshwater lake in the world, and Lake Tanganyika as one of the deepest.

Source: http://www.nationmaster.com/encyclopedia/Lake-Victoria.

References

Anon (1978). World Water Balance and Water Resources of the Earth. UNESCO Press, Paris, France, 663p. USSR Committee for the International Hydrological Decade.

Birkett, C.M. and Mason, I.M. (1995). A new global lakes database for a remote sensing programme studying climatically sensitive large lakes. J. Gr. Lakes Res., 21 (3).

Campbell, L.M., Osano, O., Hecky, R.E. and Dixon, D.G. (2003). Mercury in fish from three Rift Valley lakes (Turkana, Naivasha, Baringo), Kenya, East Africa. Environmental Pollution 125: 281–286. Available at http://biology.queensu.ca/~campbelm/CampbelletalEP2003.pdf.

Goulden, Marisa (2005). Adaptation to climate variability in East African lakes and wetlands: The role of social capital in promoting resilience. Human Security and Climate Change. International workshop, Asker, Sweden, 21-23 June 2005. 27 p. Available at http://www.cicero.uio.no/humsec/papers/Goulden.pdf.

Herdendorf, C.E. (1982). Large lakes of the world, J. Gr. Lakes Res., 8 (3).

ILEC (2002). Survey of the State of World Lakes: Online-database, Japan, Otsu: International Lake Environment Committee /United Nations Environment Progamme (ILEC/UNEP). Available at http://www.ilec.or.jp/database/database.html.

Kling, George (2005). Using Science to Solve Problems: The Killer Lakes of Cameroon. http://www.globalchange.umich.edu/globalchange1/current/lectures/kling/killer_lakes/killer_lakes.html.

Lehner, B. and Döll, P. (2004). Development and validation of a global database of lakes, reservoirs and wetlands, J. Hydrology, 296 (1-4).

NASA (2001). A Shadow of a Lake: Africa's Disappearing Lake Chad. National Aeronautics and Space Agency: Goddard Space Flight Center. Available at http://www.gsfc.nasa.gov/gsfc/earth/environ/lakechad/chad.htm.

NationMaster.com (2006). Africa's Great Lakes, Lake Victoria. Availiable at http://www.nationmaster.com/encyclopedia/Lake-Victoria.

Ottichilo, Wilber K. (2003). Use of Space Technology in Disaster Risk Assessment and Monitoring. 8 p. Available at www.ewc2.org/upload/downloads/Ottichilo2003AbstractEWC2.doc.

Petr, Tomi (2005). Inland Water Resources and Aquaculture Service. Available at http://www.oceansatlas.com/world_fisheries_and_aquaculture/html/ecosys/inland/nateco/lakes.htm.

Ryanzhin, S.V. (2004). Global statistics for surface area and water storage of natural world lakes. Verh. Internet. Verein. Limnol., vol. 29 (to be published).

UN Fact Sheet (2002). Implementing the Millennium Declaration: The Millennium Development Goals and the United Nations Role. Available at http://www.un.org/millenniumgoals/MDGs-FACTSHEET1.pdf.

UN (2005). UN Millennium Development Goals. Available at http://www.un.org/millenniumgoals/#.

UNEP (n.d.). The Watershed: Water from the Mountains into the Sea. Newsletter and Technical Publications. Lakes and Reservoirs vol. 2. Nairobi, Kenya: United Nations Environment Programme, Division of Technology, Industry, and Economics. Available at http://www.unep.or.jp/ietc/publications/short_series/lakereservoirs-2/6.asp.

Watson, Robert T., Zinyowera, Marufu C., Moss, Richard H. and Dokken, David J. eds. (1997). IPCC Special Report on the Regional Impacts of Climate Change – An Assessment of Vulnerability. 517 p. Available at http://www.grida.no/climate/ipcc/regional/index.htm.

WCMC (n.d.). Freshwater Biodiversity: a preliminary global assessment. WCMC Biodiversity Series No. 8. Cambridge, UK: World Conservation Monitoring Centre. Available at http://www.unep-wcmc.org/index.html?http://www.unep-wcmc.org/information_services/publications/freshwater/1.htm~main.

Wetlands International (2002). Ramsar Database (RDB). Wetlands International, Wageningen, The Netherlands. Available at http://www.wetlands.org/rdb.htm.

Wikipeda (2005). Africa - Wikipedia. Available at http://en.wikipedia.org/wiki/Africa.

World Commission on Water for the 21st Century (n.d.). The Africa Water Vision for 2025: Equitable and Sustainable Use of Water for Socioeconomic Development. 34 p. Available at http://www.worldwatercouncil.org/Vision/Documents/AfricaLatest.pdf.

World Lakes Network (2004). Protecting and reshaping the health of lakes throughout the world. Available at http://www.worldlakes.org/.

Zinabu, Gebre-Mariam (1998). Human Interactions and Water Quality in the Horn of Africa. Available at http://www.aaas.org/international/africa/ewmi/zinabu.htm.

UNEP/NASA

2 People and Lakes
Human Influences on Africa's Lakes

Africa's lakes are among the most heavily exploited of all the continent's freshwater resources. With human populations continuing to grow, this pressure shows no sign of abating. While some countries may have high annual averages of available water per capita, many already face water stress—1 700 m^3 (2 223 cubic yards) or less per person annually—or scarcity conditions—1 000 m^3 (1 308 cubic yards) or less per person—(UNEP 1999). At present, 14 African countries are subject to water stress or scarcity, with those in Northern Africa facing the most pressure with 11 more countries expected to join them within the next 25 years (Hinrichsen 1997).

Freshwater fisheries are the main source of income and protein for millions of African people. The annual freshwater fish catch is estimated at about 1.4 million tonnes, with Egypt alone contributing about 14 per cent (UNEP 1999). However, the damming of the Nile, and the disposal of untreated sewage and industrial effluents, has endangered fish species and reduced the catch in many regions, including the Nile Delta and Lake Chad (Hinrichsen 1997). The introduction of exotic fish species into Africa's lakes has also reduced the number and size of indigenous fish populations – the most notable example being the impact of the Nile Perch (Lates niloticus) on the Tilapia (Oreochromis spp.) and other indigenous species in Lake Victoria.

The health of a lake is intrinsically linked to its watershed, and to changes made to the landscape. Over-extraction of water and diversions from rivers that feed lakes have been compounded by pollution and sedimentation. Many lakes also support extensive fisheries, with accompanying problems of stock depletion and invasive species. Meaningful long-term improvements in lakes can only result from a comprehensive look at their entire watersheds or basins.

Reservoirs serve many different and diverse functions. They improve water supplies for irrigation and for households, provide power, mitigate floods, and reduce dependence upon fossil fuels through the generation of hydroelectric power. The meeting of the combined needs of water and energy from dams and reservoirs must be balanced by the minimising and mitigating of their adverse environmental and social impacts.

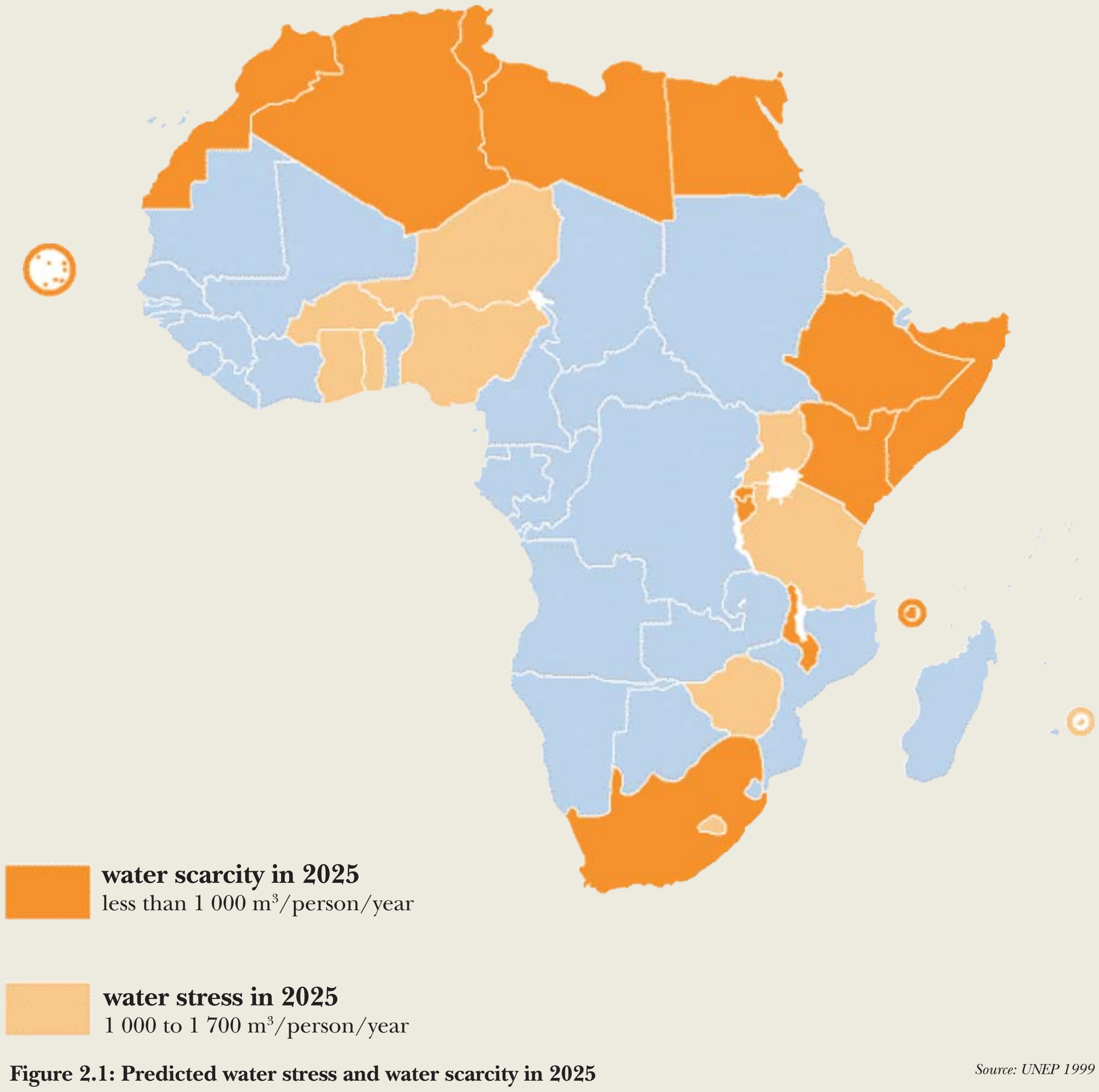


Figure 2.1: Predicted water stress and water scarcity in 2025

Lakes also play a critical role in meeting the United Nations' Millennium Development Goals (MDGs) (IUCN 2004) as shown in Table 2.1.

Wetlands are defined as areas that are regularly saturated by surface water or groundwater, and are characterised by vegetation that is adapted for life in saturated soil conditions. They include swamps, bogs, fens, marshes and estuaries (USEPA 1994), and they generally support a rich biological diversity with many endemic and rare flora and fauna. Wetlands are found in most African countries. The largest include the Okavango Delta, the Sudd in the Upper Nile, Lake Victoria and Chad basins, and the floodplains and deltas of the Congo, Niger and Zambezi rivers. Despite being among the most biologically productive ecosystems on the continent, wetlands are often regarded, locally, either as wasteland, habitats for pests and a threat to public health, or as potential areas for agriculture. As a result, many wetlands are being lost due to increasing pollution or conversion to agricultural use.

During the past two decades, Niger has lost more than 80 per cent of its freshwater wetlands (Niger Ministry of Environment and Hydraulics 1997). Coastal wetlands in Egypt and Tunisia and freshwater wetlands in the Sudan are also under increasing threat. Freshwater ecosystems found in lakes, rivers and wetlands may be the most endangered ecosystems of all. They have already lost a greater proportion of their species and habitats than terrestrial or marine ecosystems, and are in danger of further losses due to damming, pollution, over-fishing, and other threats (WRI, UNEP, UNDP and WB 1998).

Rising demands for increasingly scarce freshwater resources are leading to growing concerns about future access to these resources – particularly where they are shared between countries. Two or more countries share about 50 rivers in Africa. Access to water from any of these rivers

Flamingos—Kenya

Unknown/UNEP/Program for Global Environmental Teachings

could provoke conflict, particularly in the Nile, Niger, Volta and Zambezi basins (Hinrichsen 1997).

As in other dry regions, agriculture is the largest user of fresh water in Africa, accounting for an estimated 88 per cent of total water use (WRI, UNEP, UNDP and WB 1998). However, with only six per cent of cropland under irrigation, there remains considerable potential to increase food production through irrigation, and water demand for irrigation will inevitably continue to grow. Some 40-60 per cent of the region's irrigation water is currently lost through seepage and evaporation. This contributes to serious environmental problems such as soil salinisation and waterlogging, although water 'lost' in this way may end up in aquifers where it can be pumped to irrigate nearby fields.

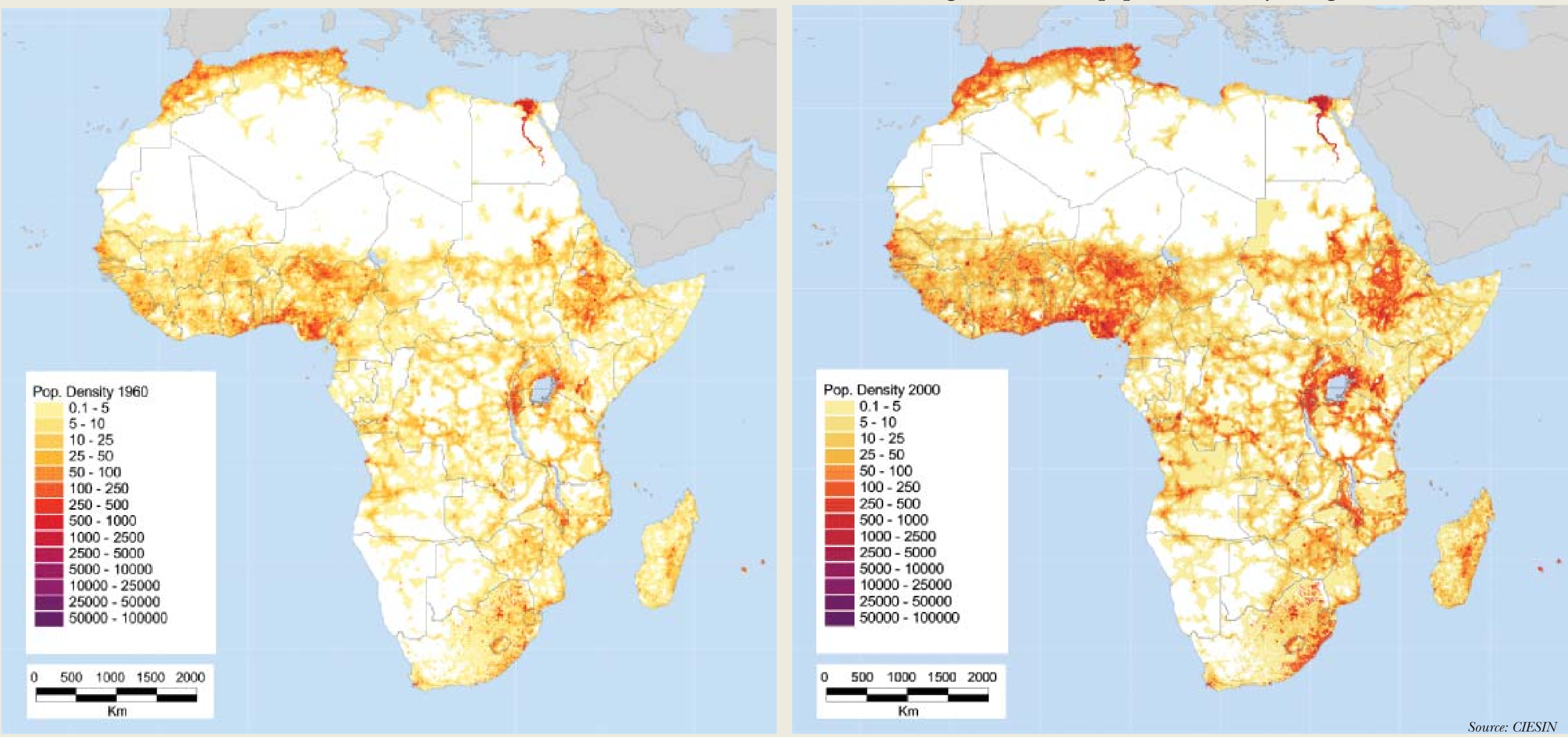
2.1 Population

Africa's population is expected to grow by 2.21 per cent from 2005-2010, and the growth rate is expected to decline by 1.8 per cent from 2020-2025. This compares to expected world population growth of 1.2 per cent from 2005-2010, and 0.8 per cent growth from 2020-2025. Increasing populations and corresponding water shortages will exacerbate the challenges the continent faces in the third millennium, giving rise to an ever-greater need for regional cooperation in addressing water-related issues.

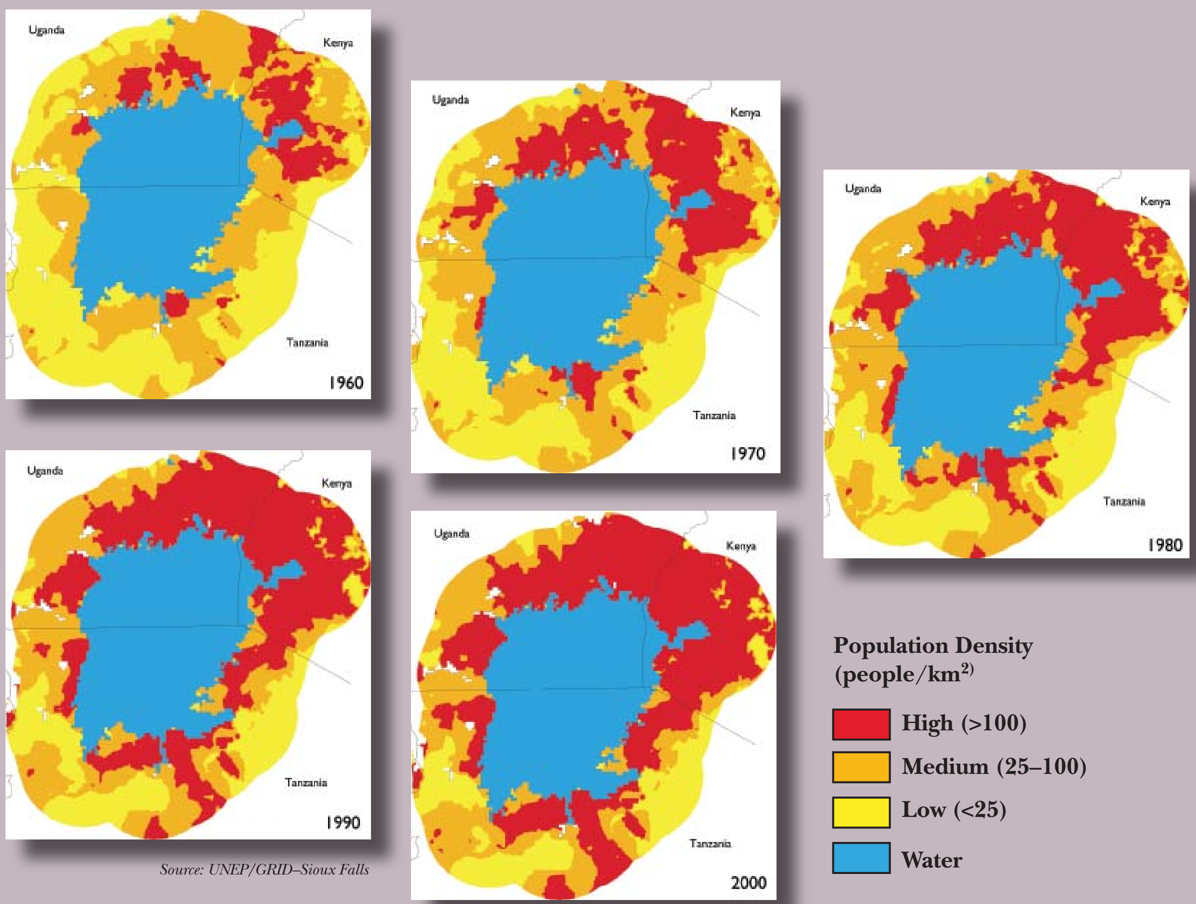
According to Harden (1968), Africa's growing population is the major cause of the degradation and pollution of most of the continent's lakes. Harden's theory appears to have stood the test of time, as high population increases continue to have negative impacts on most of Africa's lakes (Figure 2.2).

a) b)

Figure 2.2: Africa population density changes. a) 1960s b) 2000s



Source: CIESIN



Source: UNEP/GRID–Sioux Falls

Ed Simpson/UNEP/PhotoSpin

Lake Victoria, Kenya

Population growth around Lake Victoria, Kenya, is significantly higher than in the rest of Africa because of the wealth of natural resources and economic benefits the lake region offers. Note the increase in population in a 100-km (62-mile) buffer zone around Lake Victoria between 1960 and 2000. During each decade, population growth within this zone outpaced the continental average.

2.2 Mainstreaming Culture and Tradition in the Management of Africa's Lakes

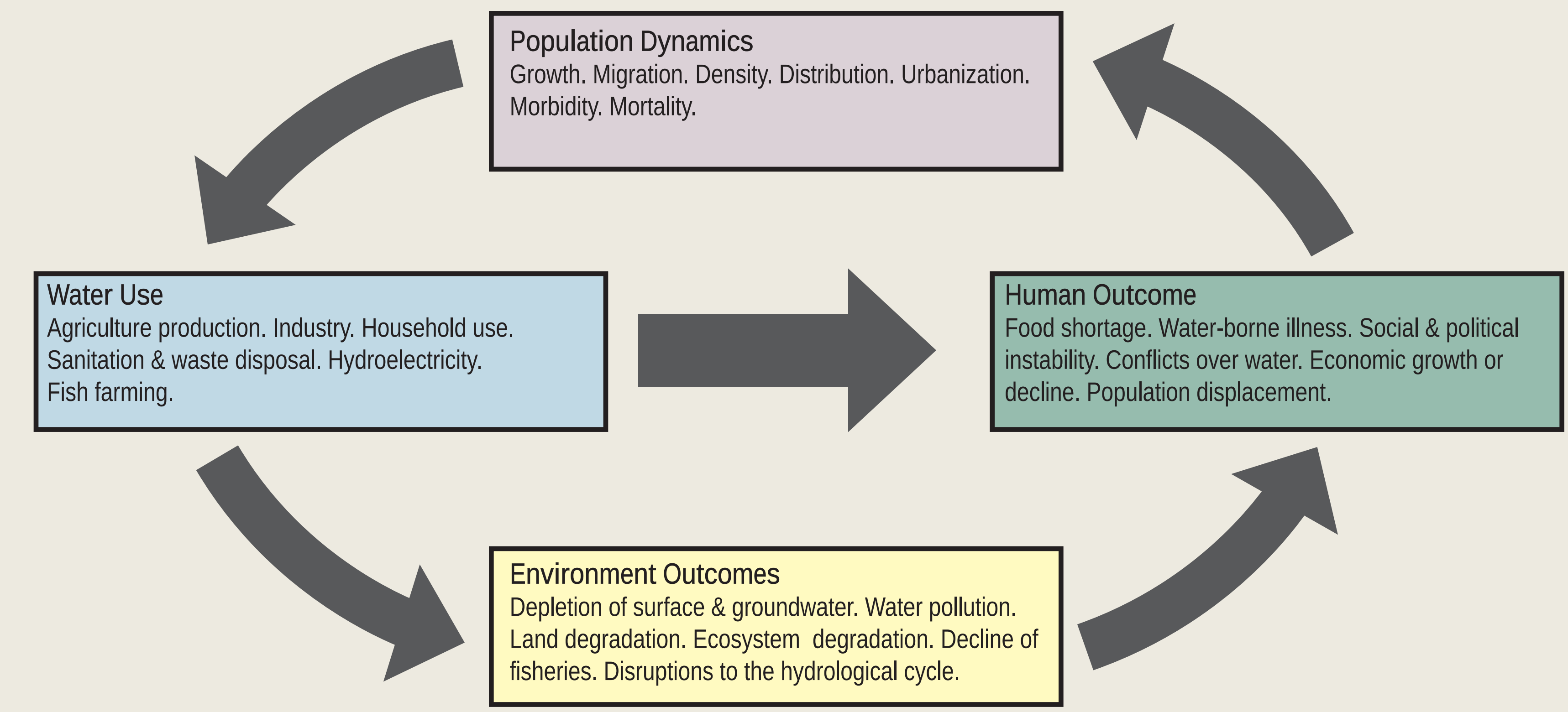
More than 3 000 ethnic groups, cultures and languages reside on the African continent. The tremendous beauty of its natural resources, its modern urban centres, its great mineral wealth, and its ancient cultures all establish that Africa has much to offer the world.

Although African cultures are not heterogeneous, many attach strong religious or spiritual significance to large water bodies such as lakes. Across Africa, people refer to water by evocative names such as Mvura, Maji and Woha, which can all basically be translated as a thing that does something significant, causes something to be— "the fluid of creation."

Lakes are also significant repositories of natural and human history, with ancient local political centres often arising on or near their shores. Specific lifestyles based entirely on lakes and their resources have developed in many locations, for example the ancient indigenous cultures that have sprung up around Ethiopia's Lake Tana basin.

Many Africans believe that water is a living entity, controlling the life forces of every bird, fish and other creature. As such, major freshwater lakes engender significant respect. Older cultures hold that pollution occurs in a river upstream, the water gods will become angry and dry up lakes or cause flooding. The Tonga people of Zambia believe that floods in Lake Kariba are the result of the anger of the water snake, Nyaminyami. They celebrate the lake's natural rhythm through poems, songs, dances, and other events in their daily lives. The pattern of Lake Kariba is the pattern of life in Zambia, and if that

Figure 2.3: Lakes and population dynamics



Modified from SARDC

Figure 2.4: Lake Tana, Ethiopia: Source of the Blue Nile. Lake Tana is an important cultural heritage site for the people of Ethiopia, with its islands housing some 20 monasteries—one of which is said to be the final resting-place of the Ark of the Covenant. Every year, thousands of Ethiopians and other pilgrims visit the lake, seeking divine healing from its holy waters. *Credit: UNEP/GRID–Sioux Falls*

pattern is damaged through the unsustainable use of its water, the whole web of life in the country will begin to unravel.

Many African cultures also have natural totems, some of which are linked to aquatic species such as fish or crocodiles. People who identify themselves with a certain water species are not allowed to eat it or exploit it in any other way (Chenje 2000). Lakes that are regarded as holy or sacred often boast the greatest diversity of aquatic life, as exploitation of their resources is regarded as taboo or as a sin to the gods of water or lakes.

Lake water is also used for medicinal purposes by some traditional healers, who believe that drinking or bathing in it can remove human misfortunes. The 'holy' attributes of lake water, its use in baptisms or for exorcising evil spirits, also indirectly help in the conservation of lakes. However, due to globalisation and the gradual erosion of traditional African cultures, such beliefs are dying out – and with them traditional controls over the exploitation and pollution of these large water bodies.

Gender differences also have an impact on the utilisation of Africa's lakes and their natural resources (Nakijoba 1996; Nanjunya 2001). Degradation of resources tends to affect men and women differently, as evidenced by the impact of the reclamation of the Nakivubo Wetlands around Lake Victoria. Declining wetland resources affect women more adversely as they tend to utilise them more than men for their households' food and medicinal resources (Nakijoba 1996). There is a clear emerging need to mainstream gender and culture in the sustainable management and utilisation of Africa's lake resources.

2.3 Human Health – Water for Health: Taking Charge

"Improving water management is a powerful tool that can be used by individuals, communities and households to protect their own health."
– Dr. Gro Harlem Brundtland, Director-General of the World Health Organisation

Water-related diseases are among the most common causes of illness and death, particularly among poor communities in developing countries. Such diseases kill more than five million people each year—more than ten times the number killed in wars. They can be divided into four categories: water-borne, water-based, water-related, and water-scarce diseases. These diseases are very common among commu-

Angels' Flight over Victoria Falls, Zambezi River. *Kenneth M. Gale/UNEP/Forestry Images*

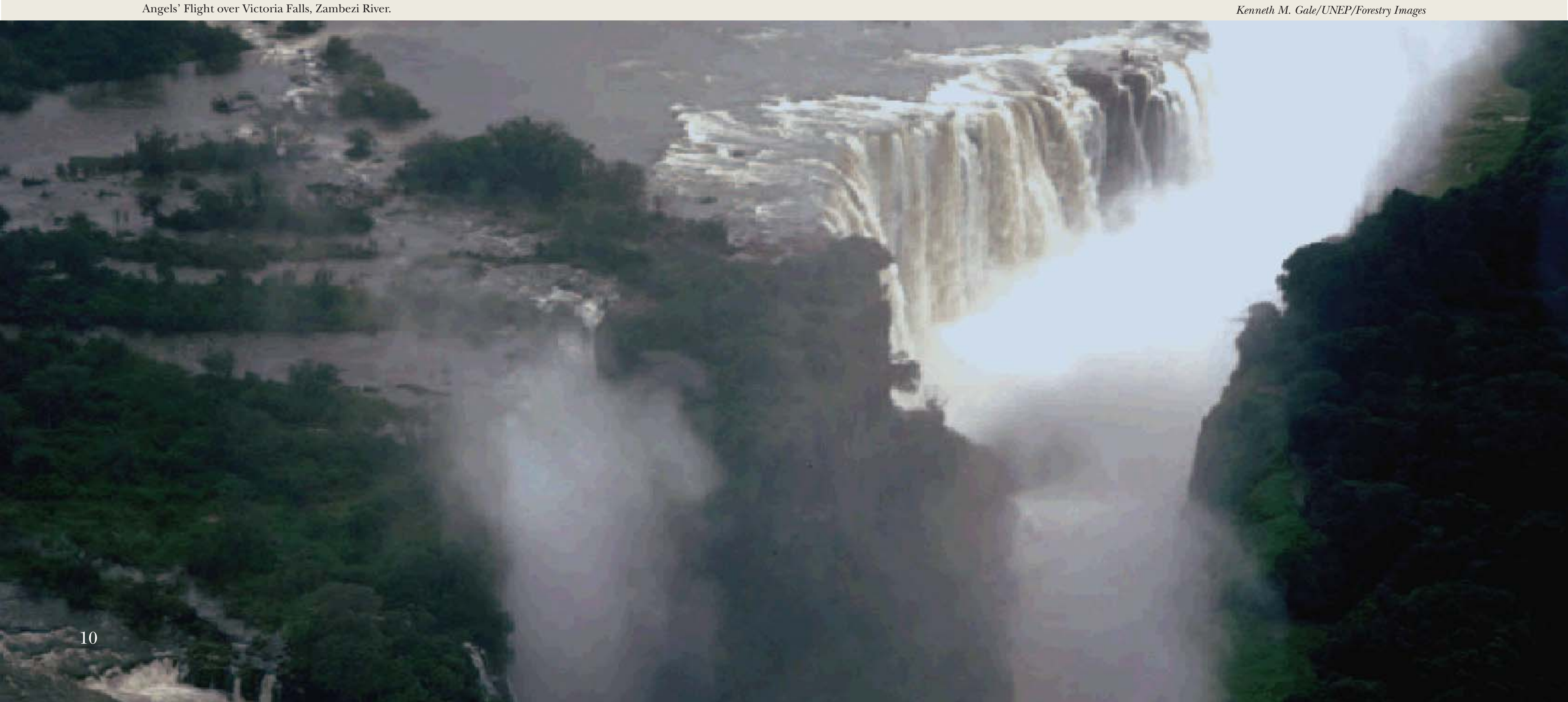


Table 2.1 Human well-being in Africa

Country	Total Population (thousands)	Total Fertility Rate (children per woman)	Mortality Under Age 5 (per 1000 live births)	Life expectancy at birth (years)	Health-Adjusted Life Expectancy (years)	Adults Ages 15-49 Living With HIV or AIDS (%)	Access to Improved Sanitation (% of population) 2000	
	2002	*2000-2005*	*2000*	*2000-2005*	*2000*	*2001*	*Urban*	*Rural*
WORLD	6211082	2.7	83	66	57	1.2	85	40
Algeria	31403	2.8	65	70.2	58.4	0.1	99	81
Angola	13936	7.2	295	45.8	36.9	5.5	70	30
Benin	6629	5.7	154	54	42.5	3.6	46	6
Botswana	1564	3.9	101	36.1	37.3	38.8	88	43
Burkina Faso	12207	6.8	198	48	34.8	6.5	39	27
Burundi	6688	6.8	190	40.6	33.4	8.3	68	90
Cameroon	15535	4.7	154	50	40.4	11.8	92	66
Central African Rep	3844	4.9	180	44.3	34.1	12.9	38	16
Chad	8390	6.6	198	46.2	39.3	3.6	81	13
Congo	3206	6.3	108	51.6	42.6	7.2	14	..
Congo, Dem Rep	54275	6.7	207	52.1	34.4	4.9	54	6
Côte d'Ivoire	16691	4.6	173	47.9	39	9.7	71	35
Egypt	70278	2.9	43	68.3	57.1	<0.1	100	96
Equatorial Guinea	483	5.9	156	52	44.8	3.4	60	46
Eritrea	3993	5.3	114	52.4	41	2.8	66	1
Ethiopia	66040	6.8	174	43.3	35.4	6.4	33	7
Gabon	1293	5.4	90	52.9	46.6	..	55	43
Gambia	1371	4.8	128	47.1	46.9	1.6	41	35
Ghana	20176	4.2	102	57.2	46.7	3	74	70
Guinea	8381	5.8	175	48.5	40.3	..	94	41
Guinea-Bissau	1257	6	215	45.4	36.6	2.8	95	44
Kenya	31904	4.2	120	49.3	40.7	15	96	82
Lesotho	2076	4.4	133	40.2	35.3	31	72	40
Liberia	3298	6.8	235	55.6	37.8	..	..	..
Madagascar	16913	5.7	139	53.6	42.9	0.3	70	30
Malawi	11828	6.3	188	39.3	30.9	15	96	70
Mali	12019	7	233	52.1	34.4	1.7	93	58
Mauritania	2830	6	183	52.5	41.4	..	44	19
Morocco	30988	3	46	68.6	54.9	0.1	86	44
Mozambique	18986	5.9	200	38	31.3	13	68	26
Namibia	1819	4.9	69	44.3	35.6	22.5	96	17
Niger	11641	8	270	46.2	33.1	..	79	5
Nigeria	120047	5.4	184	52.1	41.6	5.8	66	45
Rwanda	8148	5.8	187	40.9	31.9	8.9	12	8
Senegal	9908	5.1	139	54.3	44.8	0.5	94	48
Sierra Leone	4814	6.5	316	40.5	29.5	7	88	53
Somalia	9557	7.2	225	48.9	35.1	1	..	..
South Africa	44202	2.8	70	47.4	43.2	20.1	93	80
Sudan	32559	4.5	108	57	45	2.6	87	48
Tanzania, United Rep	36820	5	165	51.1	38.1	7.8	99	86
Togo	4779	5.4	142	52.2	42.7	6	69	17
Tunisia	9670	2.1	28	70.9	61.4	..	96	62
Uganda	24780	7.1	127	46	35.7	5	93	77
Zambia	10872	5.7	202	42.2	33	21.5	99	64
Zimbabwe	13076	4.5	117	42.8	38.8	33.7	71	57

Source: WRI 2004

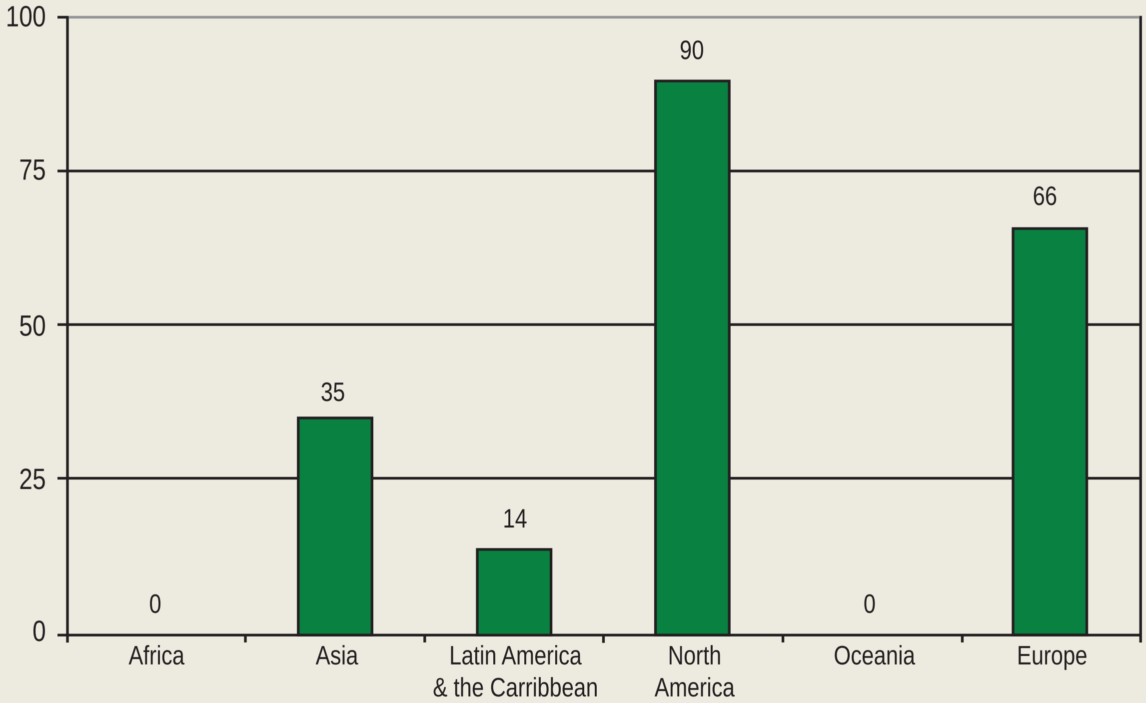


Figure 2.5: Median per cent of wastewater treated by effective treatment plants *Source: WHO 2001*

nities living close to lakes in Africa.

The most common water-borne diseases—cholera, dysentery, typhoid and hepatitis—are among the greatest emerging and re-emerging infectious diseases, contributing up to 70-80 per cent of all health problems in developing countries. Their causative agents may be bacterial or viral in nature and generally have endemic and epidemic periods. The burden of these diseases is felt in almost every African country—particularly those with large water bodies like lakes.

More than half of Africa's people lack access to safe drinking water, leaving them vulnerable to water-borne diseases. Whatever the quality, water is often in short supply. In rural Africa, people use four to nine gallons of water a day per person for domestic purposes, and much of this is untreated water drawn directly from rivers or lakes.

Food production also suffers from major water shortages. Of all the renewable water available in Africa each year, only four per cent is actually used, because most Africans lack the wells, canals, pumps, reservoirs and other irrigation systems needed to make use of potential water supplies from their lakes.

Point and non-point source pollution of surface and ground water also poses a major threat to public health, coming not only from human waste but also from agricultural runoff, waste dumps, mining and industry. For example:

- High concentrations of nitrates from agriculture in drinking water result in oxygen-starvation in the brain. This is especially dangerous for babies;
- Benzene, a component of petrol, is carcinogenic (cancer-causing);
- Most heavy metals are toxic. For example, arsenic is carcinogenic, lead damages the nervous system, cadmium results in kidney problems, and chromium can cause severe skin reactions;
- Most organic components of products like pesticides, tar and solvents are toxic; they can lead to kidney and liver problems, heart problems, damage to the nervous system, cancer, and skin problems.

Ensuring access to safe fresh water is imperative. Water is an economic issue as it is essential for agriculture, food and energy production, as well as for recreation. In the developing world, it is a women's issue as women have the primary responsibility for domestic water collection. Time spent gathering water robs women and girls of time for education or for engaging in meaningful work. It is also, of course, a children's issue as water is essential for healthy development. It is estimated that a child dies every eight seconds from water-borne diseases.

It is clear that the proper management of waste disposal into lakes is critical in order to ensure the health and wellbeing of African communities. The use of dichlorodiphenyltrichloroethane (DDT) to control malaria around many lakes can also threaten people's health due to its environmental persistence and ability to bioaccumulate, especially in higher animals. Significant amounts of DDT have been discovered in fish in Lake Kariba, which are believed to be the major cause of the death of fish-eating birds. Of particular concern is DDT's potential to mimic hormones and thereby disrupt endocrine systems in wildlife and people.

Some lakes in Africa contain large amounts of carbon dioxide (CO_2), which when released can be fatal to people and animals. Lake Nyos is one of Africa's best-known "killer lakes." On 21 August 1986, the lake released a large cloud of CO_2, which flowed down neighbouring valleys, travelling as far as 26 kilometres (16 miles) from the lakeshore. The cloud reportedly moved fast enough to flatten much of the vegetation in its path, including several trees. A total of 1 746 people suffocated, while an additional 845 people had to be hospitalised.

2.4 Recreation and Tourism

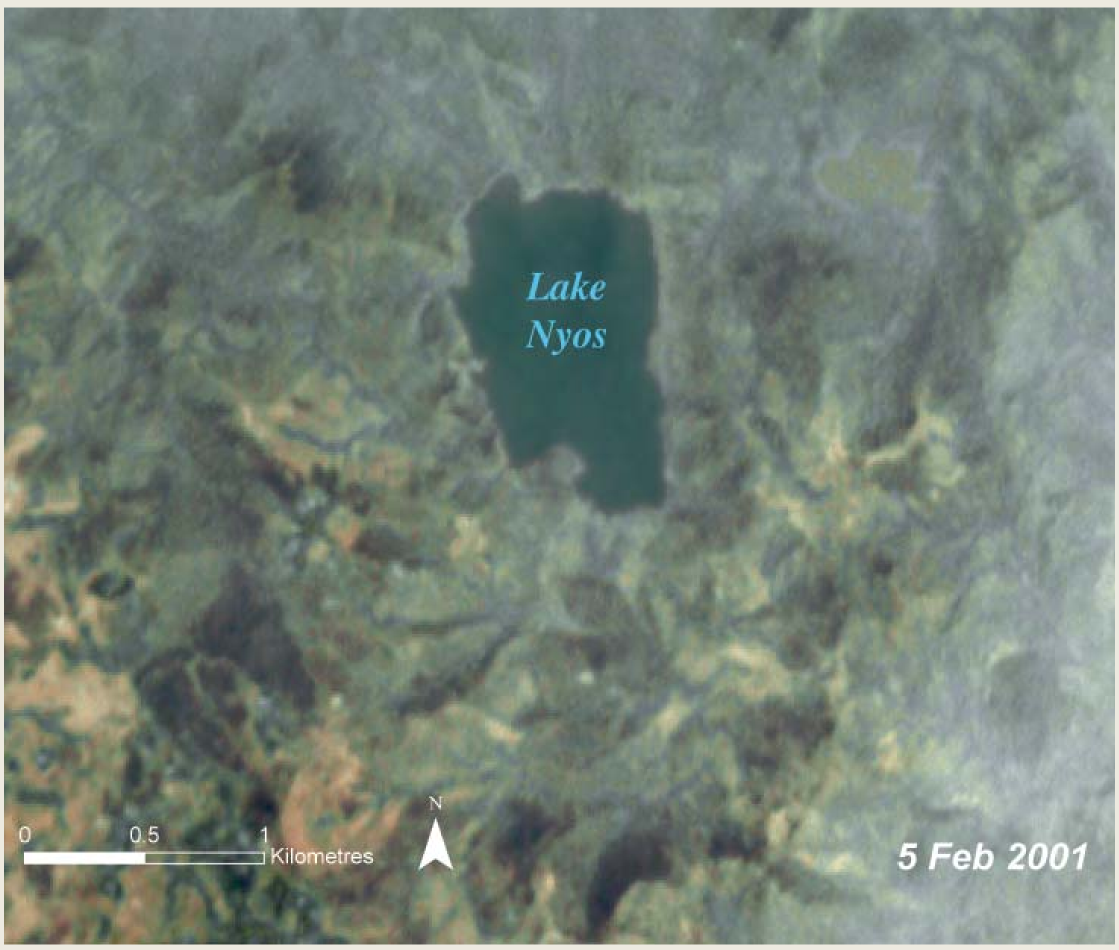


Figure 2.6: Lake Nyos in Cameroon. In August 1986, a cloud of carbon dioxide gas from the lake killed more than 1 700 people and several animals within a 25 km (16 mile) radius (USGS 1986). *Credit: Jack Lockwood*

Nature-based tourism is one of Africa's fastest-growing industries, with a growth rate of nearly seven per cent in international visitor arrivals between 2004 and 2005. As well as national parks and wildlife reserves, lakes provide some of the continent's most important flora and fauna areas and recreation destinations. Some lakes, such as Lake Malawi and the St. Lucia wetlands, are also protected as World Heritage Sites under the World Heritage Convention of 1975 (Chenje 2000). Visitors come to these lakes to enjoy boating and watersports, as well as to witness the remarkable range of freshwater and inland biodiversity that they support.

Ecotourism has also increased environmental conservation as people struggle to maintain Africa's lakes in their natural state as a way to sustain local tourism activities. Many riparian states have gazetted conservation areas and enacted strict laws to protect wildlife and plant life around their lakes. Elephants, which were about to face extinction, have increased around Lake Tanganyika and Lake Kariba as tourists seek them out. The establishment of game parks around lakes is a strategy that allows tourists to see many different kinds of animals in one location (IUCN 2004). African lakes also house about 500 different aquatic species, creating the potential for sustainable fishing activities.

Despite all these opportunities, however, increasing tourism can also have negative impacts. Without proper management and regulation, growing tourist facilities, roads and other infrastructure can wreak havoc on fragile freshwater environments. A rapid increase in visitor numbers can render lakeside developments environmentally unsound—and negatively impact the very creatures that brought people there in the first place. Areas within easy reach of large population centres are particularly under threat.

Even apparently harmless activities such as boating and rafting can pose a threat to fragile lake environments. The growing number of boats on Lake Kariba, for example, is increasing oil and fuel pollution of the lake waters – both from ac-

Figure 2.7: According to scientists, climate change in East Africa is harming Lake Tanganyika's ecosystem, decreasing fish stocks by as much as 30 percent over the past 80 years. Lake Tanganyika is large and deep, filling the chasm of a rift valley bordering the Democratic Republic of Congo, Tanzania, Zambia and Burundi. An ecosystem unto itself, the lake supports many types of fish. Only a few species are eaten by people, yet they supply 25 to 40 per cent of the animal protein for the communities of that region. Recently, the fish supplies have diminished, and catches are shrinking (NASA 2003). *Credit: UNEP/GRID–Sioux Falls*

Lake Tanganyika *Science Museum of Minnesota/UNEP/Wildchimpanzees.org*

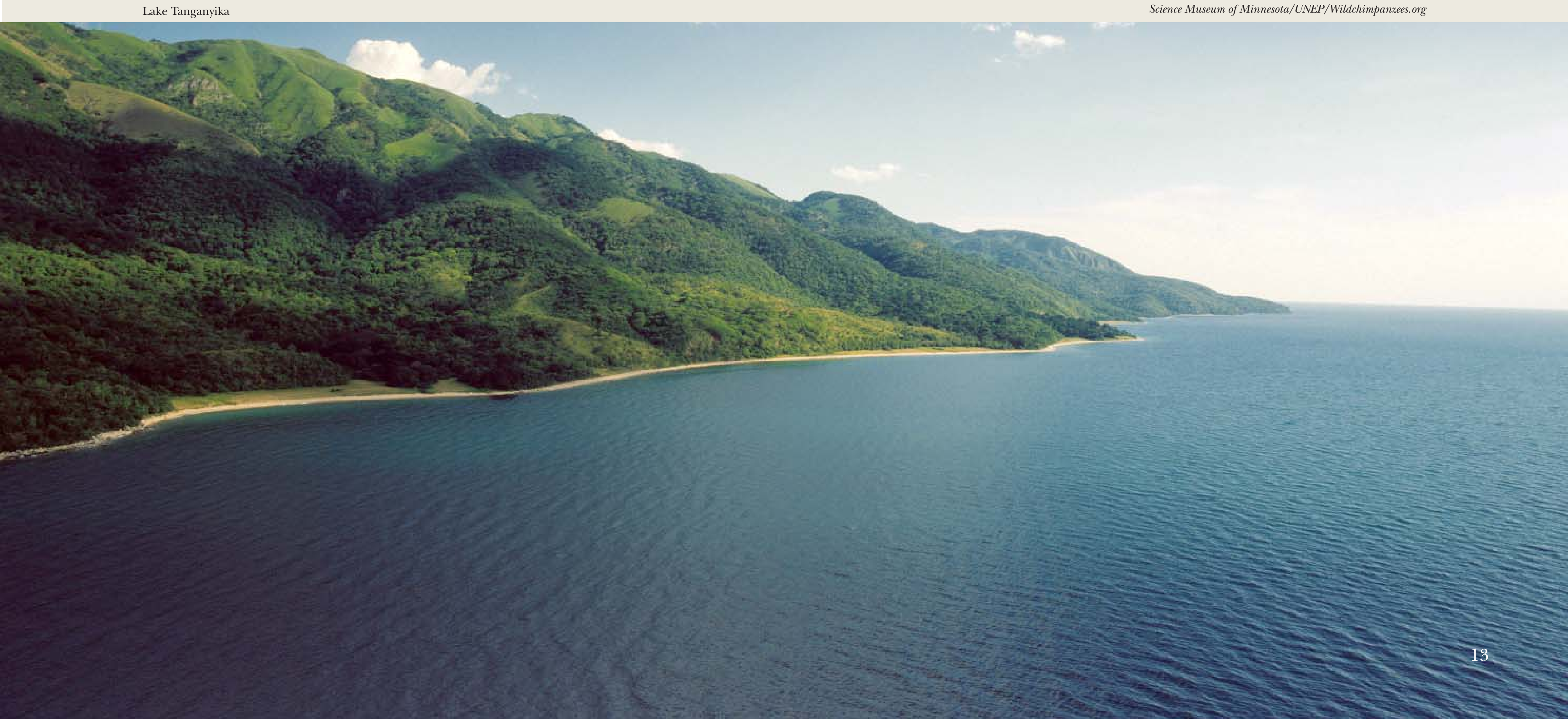


Table 2.2: Examples of the link between MDGs and environment in Africa's Lakes

Eradicate extreme poverty and hunger	Livelihood strategies and food security of people often depend directly on healthy ecosystems and the diversity of goods and ecological services they provide.
Achieve universal primary education	Time spent collecting water and fuelwood by children, especially girls, can reduce time at school.
Promote gender equality empower women	Women are especially exposed to indoor air pollution, have the burden of collecting water and fuelwood, and have unequal access to land and other natural resources.
Reduce child mortality	Water-related diseases such as diarrhea and cholera kill an estimated three million people a year in developing countries, the majority of which are children under the age of five.
Improve maternal health	Indoor air pollution and carrying heavy loads of water and fuelwood adversely affect women's health and can make women less fit for childbirth and at greater risk of complications during pregnancy.
Combat major diseases	A large proportion of total burden of diseases in Africa's Lakes may be associated with environmental risk factors. Preventive environmental health measures are as important and at times more cost-effective than health treatment.
Ensure environmental sustainability	Current trends in environmental degradation in Africa's lake basins must be reversed in order to sustain the health and productivity of the basins' ecosystems.
Develop a global partnership for development	Too many developing countries are spending more on debt service than on social services. The aim is to build coalitions for action and help governments set priorities and use resources, including water resources, more effectively.

Source: IUCN 2004

cidental leakages and the deliberate dumping of waste oil into the lake. Oil reduces the water quality, and can be fatal to many aquatic animal and plant species.

Likewise, noise pollution and the wave action of motorboats can harm riverbanks and, over time, cause irreparable damage to their micro-ecology. There is mounting concern about the impact of sport angling on certain game-fish species, as well as the effects of introducing alien species such as trout and bass, which are favoured by anglers.

At Lake Kariba, concerns are growing over the impact of sewage discharges from local lodges and settlements, siltation from erosion caused by riverbank disturbance, overexploitation of wetland resources such as reeds and fish, and pollution by fuels and pesticides. All of these factors pose a significant threat to the flora and fauna upon which the lake's tourism industry is based.

The souvenir or curio industry has developed as a byproduct of tourism and is a big consumer of indigenous hardwoods. The over-harvesting of large and increasingly rare indigenous trees is occurring—unsustainably, and often illegally—in many parts of Africa where tourism is thriving. The World Wide Fund for Nature recently estimated that nearly 250 m^3 (327 cubic yards) of wood is carved per year (WWF 2005).

2.5 Fishing

Fishing is vital to Africa, supporting annual exports worth about US$3 000 million. Fish is crucial to the health of 200 million Africans, providing a source of inexpensive protein, and income for over 10 million people engaged in fish production, processing and trade. The fishing sector also plays an important role in the alleviation of poverty and general food security in Africa. In Malawi, the FAO states that 70 per cent of dietary animal protein is derived from fish, and the fishing sector constitutes a major source of income and livelihood for more than 300 000 people.

Lakes in Africa support 16-17 per cent of inland fisheries (Sithole 2000). Across much of the continent, lake fisheries provide an important source of food and livelihood for millions of people. Yet these benefits are at risk as the exploitation of natural fish stocks is reaching its limit and aquaculture production has not yet fulfilled its potential (FAO 2004).

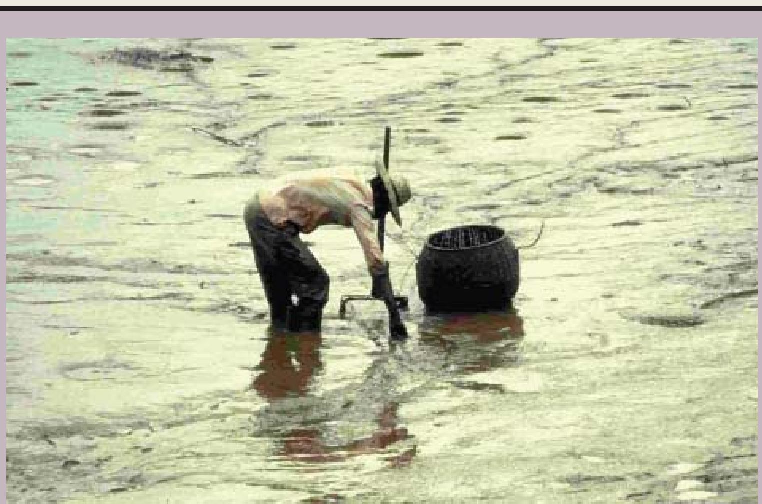
Table 2.2 shows the link between Millennium Development Goals and fisheries in Africa. It is important to note that the sound management of Africa's fisheries is vital if these Millennium Development Goals are to be attained. This includes the integrated management of all major freshwater bodies, including lakes.

African lakes are among the largest and most ecologically diverse on Earth—but are also among its most endangered water systems. Population densities are higher along the shores of Lakes Tanganyika,

Box 2.1: Economic Value of Some Lake Fisheries

- More than 60 per cent of the fish consumed in Tanzania comes from inland fisheries, and about 60 per cent of the protein intake in Malawi comes from freshwater fish.
- The creation of Lake Kariba produced a viable regional fishery in an area in which freshwater fish were previously absent from the diet of Zimbabweans.
- Lake Victoria generates an annual GDP of US$3 000–4 000 million, providing more than 25 000 people with an annual income of US$90-270 per capita.
- The eutrophication of Lake Chivero threatens the health and livelihoods of nearly three million inhabitants in the greater Harare/Norton urban areas, and has caused the virtual collapse of a once-thriving fishing industry.

Source: ILEC 2003



Harvesting fish in a pond after periodical drainage. *R. Cannarsa/UNEP/FAO*

Table 2.3: Summary results of agricultural water use and comparison with water resources

Region	Total renewable water resources (km^3)	Irrigation water requirements (km^3)	Water requirement ratio	Water withdrawal for agriculture (km^3)	Water withdrawal as percentage of renewable water resources
Latin America	13 409	45	24%	187	1%
Near East and North Africa	541	109	40%	274	51%
Sub-Saharan Africa	3 518	31	32%	97	3%
East Asia	8 609	232	34%	693	8%
South Asia	2 469	397	44%	895	36%
90 developing countries	28 545	814	38%	2 146	8%

Source: FAO 2005, AGL 2005

Victoria and Malawi. With four of Africa's Great Lakes on its borders, Uganda ranks as one of the world's largest producers of freshwater fish. But pollution, the introduction of non-native fish, and over-fishing have all taken a heavy toll on these waters.

Africa's fishing sector urgently needs strategic investments to safeguard its future contribution to poverty alleviation and regional economic development. Broadly, Africa needs investments to (i) improve the management of natural fish stocks, (ii) develop aquaculture production, and (iii) enhance fish trade in domestic, regional and global markets. In support of this investment, capacity needs to be strengthened at both the regional and national levels for research, technology transfer and policy development. As a first step, stakeholders in the region need to build a common and strategic understanding of the importance of fisheries and aquaculture for Africa's development and of the challenges being faced by the sector.

The New Partnership for Africa's Development (NEPAD) is taking the lead in developing regional priorities for future investments in fisheries and aquaculture as part of its wider agriculture programme. Following an invitation from President Olusegun Obasanjo of Nigeria, the WorldFish Center and the FAO are supporting NEPAD in developing an integrated approach for the sustainable management of fisheries in Africa's lakes. This is critical, as poor fishing habits are still known to be poisoning large water bodies in most African countries.

2.6 Water Withdrawal and Irrigation

On the African continent as a whole, 85 per cent of water withdrawals are used for agriculture—and the percentage is even higher in sub-Saharan Africa (Table 2.3). Sub-Saharan Africa lags far behind the rest of the world in the proportion of irrigated arable land to its contribution to the total food supply. In North Africa, 11 per cent of the land is irrigated (excluding Egypt's 100

A hydropower station in Lake Kariba

A. R. Turton/UNEP/SAOS

per cent), whereas in sub-Saharan Africa, it is only 3.5 per cent of total cropped land (FAO 1986a, b, c). In North Africa, 3.4 million ha are irrigated by large-scale systems, whereas in sub-Saharan Africa, half of the 5.3 million ha is irrigated by large- and medium-scale systems; the other half is by small-scale systems. In terms of value, irrigation is responsible for an estimated 33 and nine per cent of the crops produced in North Africa and sub-Saharan Africa respectively (Yudelman 1994). In those areas, the water withdrawn for agriculture from the hydrologic system may represent a significant part of the total water resources.

The ways in which freshwater resources are used for agriculture leave much to be desired. In some places, water use exceeds renewable supply rates and cannot be indefinitely continued. Elsewhere, overuse in one area deprives users in other areas, leading to agricultural production decreases and the loss of jobs. Misuse occurs where water is returned to the water system in an unusable state. Used irrigation water is often contaminated with salts, pesticides and herbicides.

Irrigation from lakes can also jeopardise aquatic ecosystems such as wetlands, leading to losses in their productivity and biodiversity. This has important implications for people who depend upon the major inland fisheries that such areas support. Wetlands serve as natural filters that have historically been responsible for cleaning up much of the world's wastewater. Where they have been eliminated in the name of irrigation, the results are usually regretted.

A positive impact is that highly productive irrigation of a small area can often replace the use of a much larger area of marginal land for growing crops. Improving the environmental performance of irrigation projects is important for their long-term sustainability.

2.7 Aquatic Biodiversity and Habitats

Lakes provide critical habitat for an amazing array of plants and animals, including bacteria, fungi, algae, plankton, mussels,

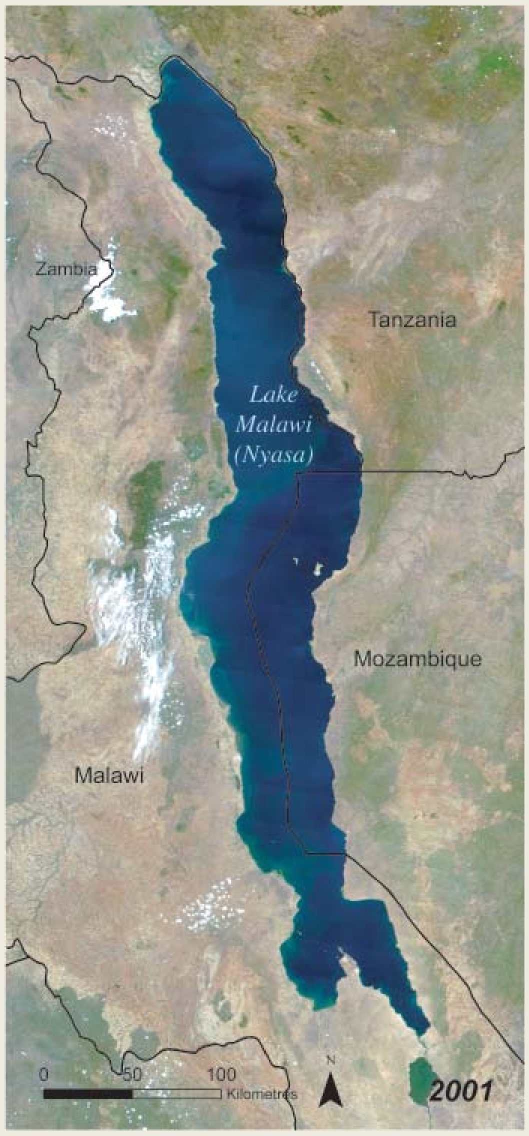
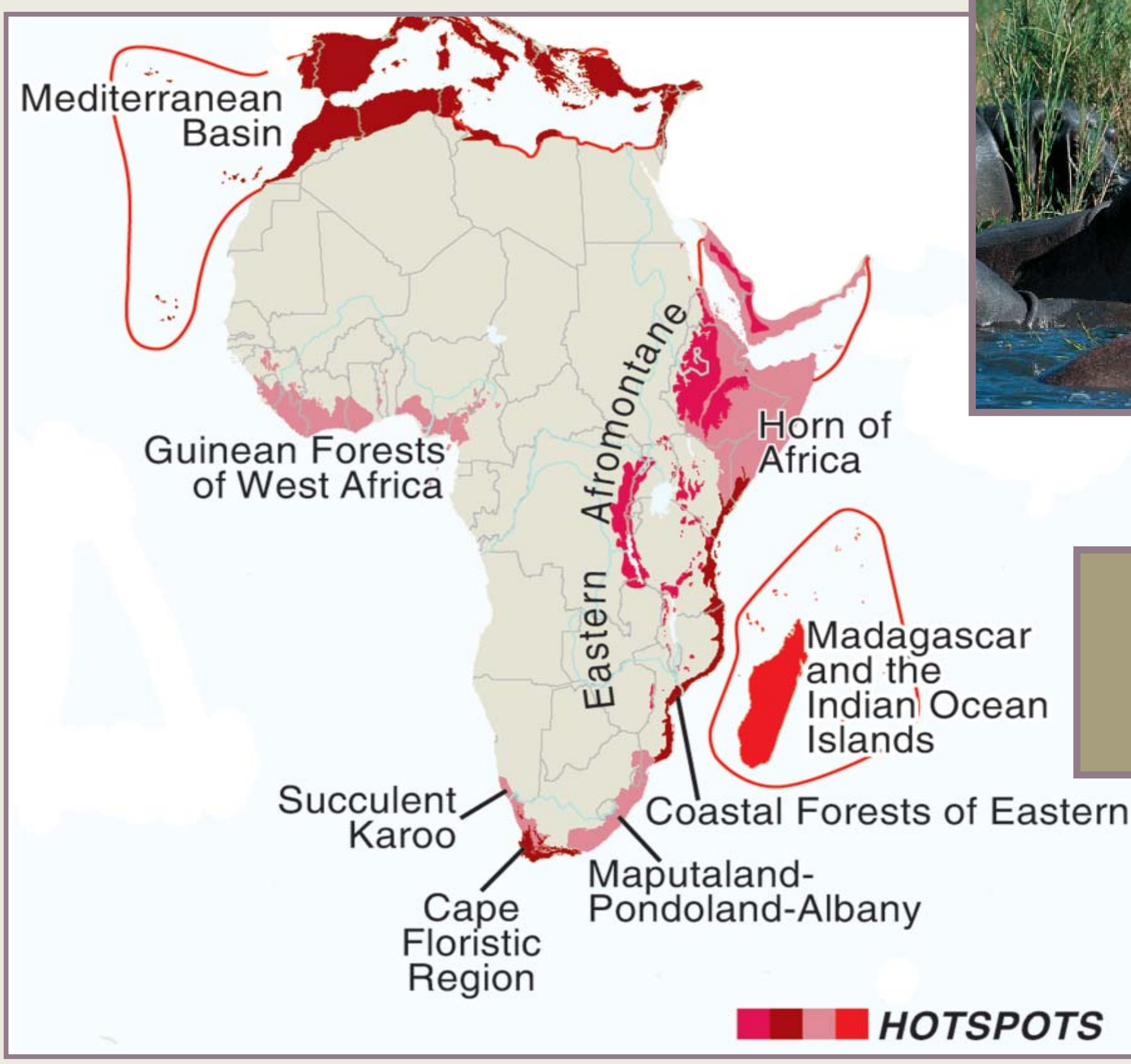


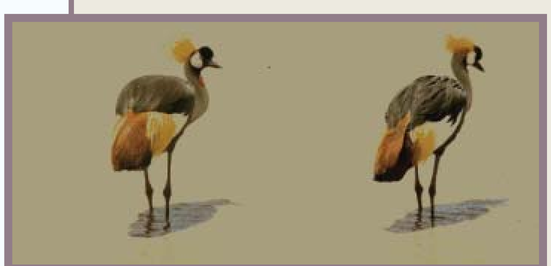
Figure 2.9: A satellite image of Lake Malawi, which occupies one-fifth of its country's total area. The lake drains an area larger than Malawi itself, yet surprisingly, only one river—the Shire—flows from it. The lake has one of the highest diversities of freshwater tropical fish in the world, some of which are only found here. Fishing for salmon, bream, bass and tigerfish are popular here, as are snorkelling and diving. The 587 km (365 mile) long, 84 km (52 mile) wide lake—often called the "calendar lake"—is the third largest in Africa, and the ninth largest in the world. *Credit: UNEP/GRID–Sioux Falls*

Figure 2.8: Biodiversity hotspots of Africa



Source: Conservation International 2005

Biodiversity in lake Malawi
Unknown/UNEP/Tourismmalawi



Golden crowned cranes (Balearica regulorum), Uganda. *William M. Ciesla/UNEP/Forest Health Management International, www.forestryimages.org.*

Box 2.2: Alien Invasion: the Nile Perch of Lake Victoria

Nile Perch (*Lates niloticus*) were introduced into Lake Victoria in the mid-1950s, with the goal of boosting local fisheries production. With a voracious appetite for other fish, the perch decimated the lake's 350 native fish species, reducing the number to less than 50 according to some estimates. In short order, it worked its way to the top of the lake's food chain.

The nile perch can grow to enormous sizes. Typical commercial specimens range from 3-6 kg (7-13 lbs), but the fish can grow to 1.8 m (6 ft) and weigh over 90 kg (200 lbs). Because of the fish's large size, the nature of indigenous fisheries has also changed. While the native lake fish were much smaller and ideal for sun drying, the larger perch require factory processing.

An unusually large Nile perch, netted near a fishing village along the White Nile in southern Sudan. The fish is often dried, salted and exported to neighbouring countries.

Sudanese Gov./UNEP/FAO

snails, crustaceans, insects, fish, amphibians, reptiles, birds and mammals. Despite their importance, however, lakes continue to be fairly invisible on the global conservation screen. Lakes and their watersheds are dramatically underrepresented both in protected areas and in the significance of the aquatic biodiversity they hold. Many African lakes boast some of the world's richest freshwater ecosystems, harbouring a broad diversity of endemic species that exist nowhere else on Earth. They are often surrounded by wetlands that store significant volumes of fresh water, as well as serving as vital habitats for endemic wildlife and transit-points for migratory species.

Lake Victoria is home to more than 300 endemic species, Lake Tanganyika 140, and Lake Malawi nearly 500. Lake Malawi provides over 60 per cent of the animal protein consumed by the country's entire population. Such figures demonstrate the major 'natural capital' generated by Africa's lakes – the broad range of social, economic, ecological and hydrological functions on which people, especially the poor, often directly depend. Understanding the full range of benefits and services provided by these aquatic ecosystems is critical to the conservation of the continent's lakes.

As biodiversity 'hotspots' – regions of the Earth with vitally important but critically endangered biodiversity – Africa's lakes and wetlands share high concentrations of unique plant and animal species and high degrees of threat. Although they are clearly of great regional importance to livelihoods and economies, development activities are not always compatible with the conservation of their biodiversity. One of the main reasons for the inadequate representation of biodiversity in development planning processes is a widespread lack of readily available information on the status and distribution of inland water taxa.

Pollution and sedimentation, as well as the introduction of invasive species, pose the greatest threat to the aquatic biodiversity of Africa's lakes. On a basic level, activities that influence aquatic environments and biological systems, like forest clearing, the burning of fossil fuels, agricultural pollution and soil loss, lead to greater emissions of carbon dioxide and an increase in global warming. The impacts of climate change are projected to accelerate aquatic plant and animal population losses and the extinction of a wide range of species and ecosystems. Some of those lakes richest in aquatic biodiversity are already being affected, most notably Lake Victoria and the Okavango Delta. It is estimated that at least 30 per cent of freshwater fish and over 800 other freshwater species are on the brink of extinction in Africa's lakes (IUCN 2002).

Figure 2.10: A satellite image of Lake St. Lucia. St. Lucia Lake is part of the St. Lucia estuarine system, the largest estuarine system in Africa. Like other estuaries, the level and salinity of the lower reaches of St. Lucia especially varies with the inflow of freshwater from several rivers and with the ebb and flow of marine tides. It also is most of biodiversity rich lake in Southern Africa. In some years, the water's salinity has risen to three times the level of sea water in northern parts of the lake, causing mass die-offs of aquatic plants and animals. *Credit: UNEP/GRID–Sioux Falls*

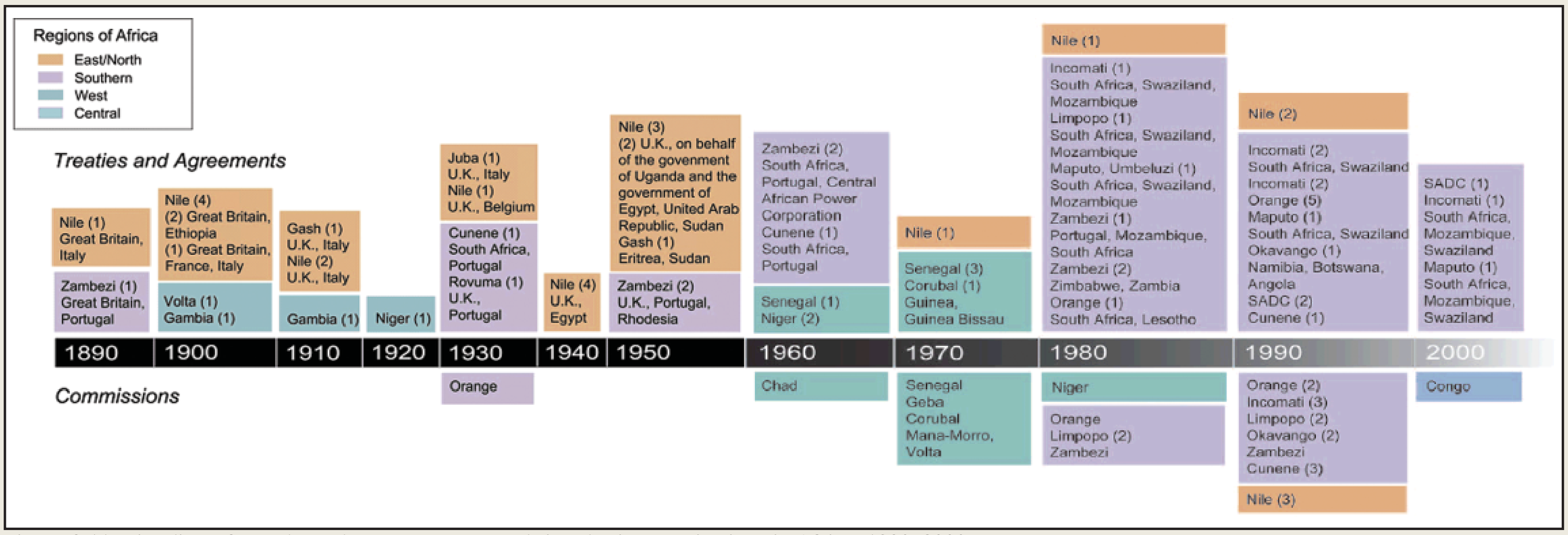


Figure 2.11: Timeline of transboundary agreements and river basin organizations in Africa, 1890–2000

Source: UNEP 2005

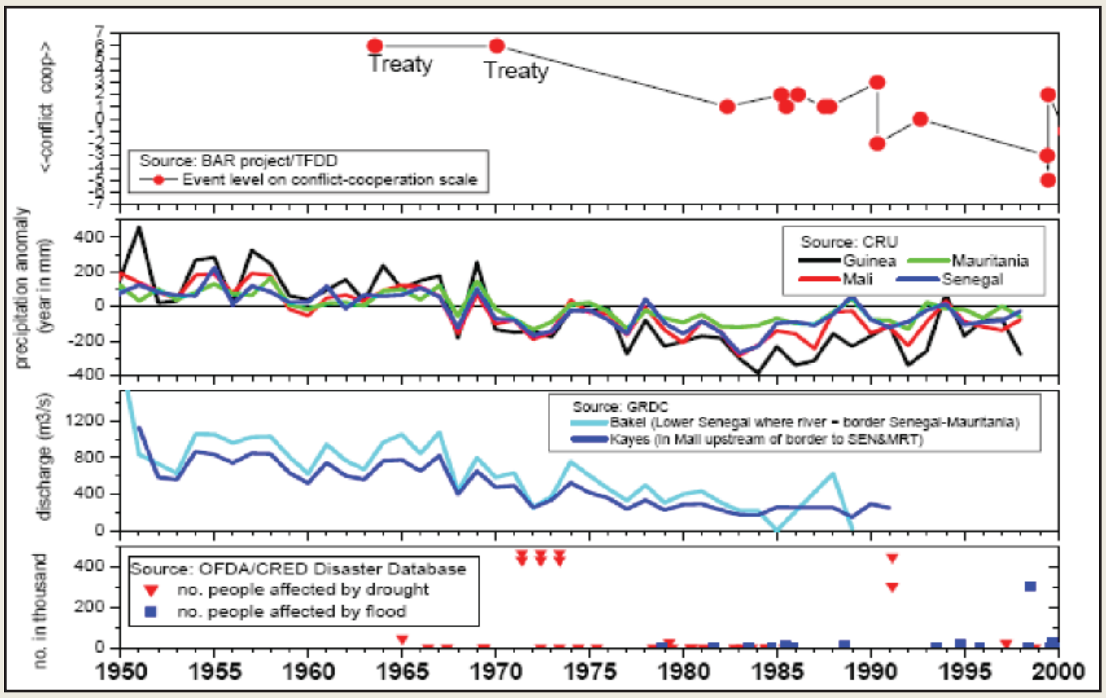


Figure 2.12: Time-series of events of conflict and cooperation, precipitation anomaly, annual mean discharge and the occurrence of natural disasters in the Senegal River Basin. Note: BAR – Basin at Risk; TFDD – Transboundary Freshwater Dispute Database; CRU – the Climate Research Unit; GRDC – Global Runoff Data Center; OFDA – Office of U.S. Foreign Disaster Assistantance; CRED – Center for Research on the Epidemiology of Disasters.

Source: Wolf et al. 2003

2.8 Transboundary Lakes and Water Resources Issues

Africa has some 80-transboundary river and lake basins, and the catchments areas of the 17 largest exceed 100 000 square kilometers (24 710 538 acre) each (UNU n.d.). There are 15 principal lakes and 24 principal watersheds that cross the political boundaries of two or more countries in Africa (Figures 2.14 and 2.15). Almost all the landmass falls within transboundary river and lake basins in 14 African countries (UNU n.d.). These international basins cover 45.3 per cent of the continent's land surface, affect about 40 per cent of its population, and account for approximately 60 per cent of global river flows (Wolf *et al.* 1999).

The main challenge in water resources management is to create an enabling environment that encourages joint management of transboundary water resources. Agenda 21, the plan of action adopted at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, recognized the great significance of transboundary water resources and their use by riparian states, and called for cooperation among those states for integrated approaches to the development, management and use of their transboundary freshwater resources. Water is

Box 2.3: Impacts of Lake Sedimentation in Lake Baringo (Kenya)

Until the mid-1979s, Lake Baringo was very rich in biodiversity. Growing human and livestock populations, drainage basin destruction, indiscriminate cutting of forests and charcoal burning, and poaching have since reduced this richness. For example, although there were seven rivers continuously flowing into the lake in the mid-1970s, only one river now flows into the lake during all seasons. It is estimated that five million cubic metres (6.5 million cubic yards) of sediment are currently being deposited into the lake each year from the drainage basin. The combination of reduced inflows and increased sediment loads has reduced the depth of the lake from about 8.9 metres (29 ft) in the mid-1970s to about 1.9 metres (6 ft) today. It is estimated that if the lake continues to accumulate sediment at the present rate, it will change dramatically in character within the next 20 years, possibly drying up altogether or becoming a swamp. The impacts of sedimentation are best illustrated by its effects on fish biodiversity, with species that contributed to local livelihoods (e.g., Sharks [Labeo spp.]) becoming almost extinct. Depleted fish stocks also have had impacts on other biodiversity, including fish-eating birds, many species of which have been significantly reduced since 1980. (Source: ILEC 2003) identified as a central issue in the Millennium Development Goals, a set of time-bound and measurable goals and targets for combating various environmental and development problems adopted by heads of state gathered at the UN Millennium Summit in September 2000. Water resource management was also high on the agenda at the World Summit on Sustainable Development (WSSD) held in Johannesburg in September 2002 (Rio +10). The importance of management of transboundary water systems has also been explicitly and concretely recognized by the international community, as signified by the establishment of the Convention on the Law of the Non-navigational Uses of International Watercourses adopted by the UN General Assembly in 1997 after nearly three decades of drafting (Ruphael 2004).

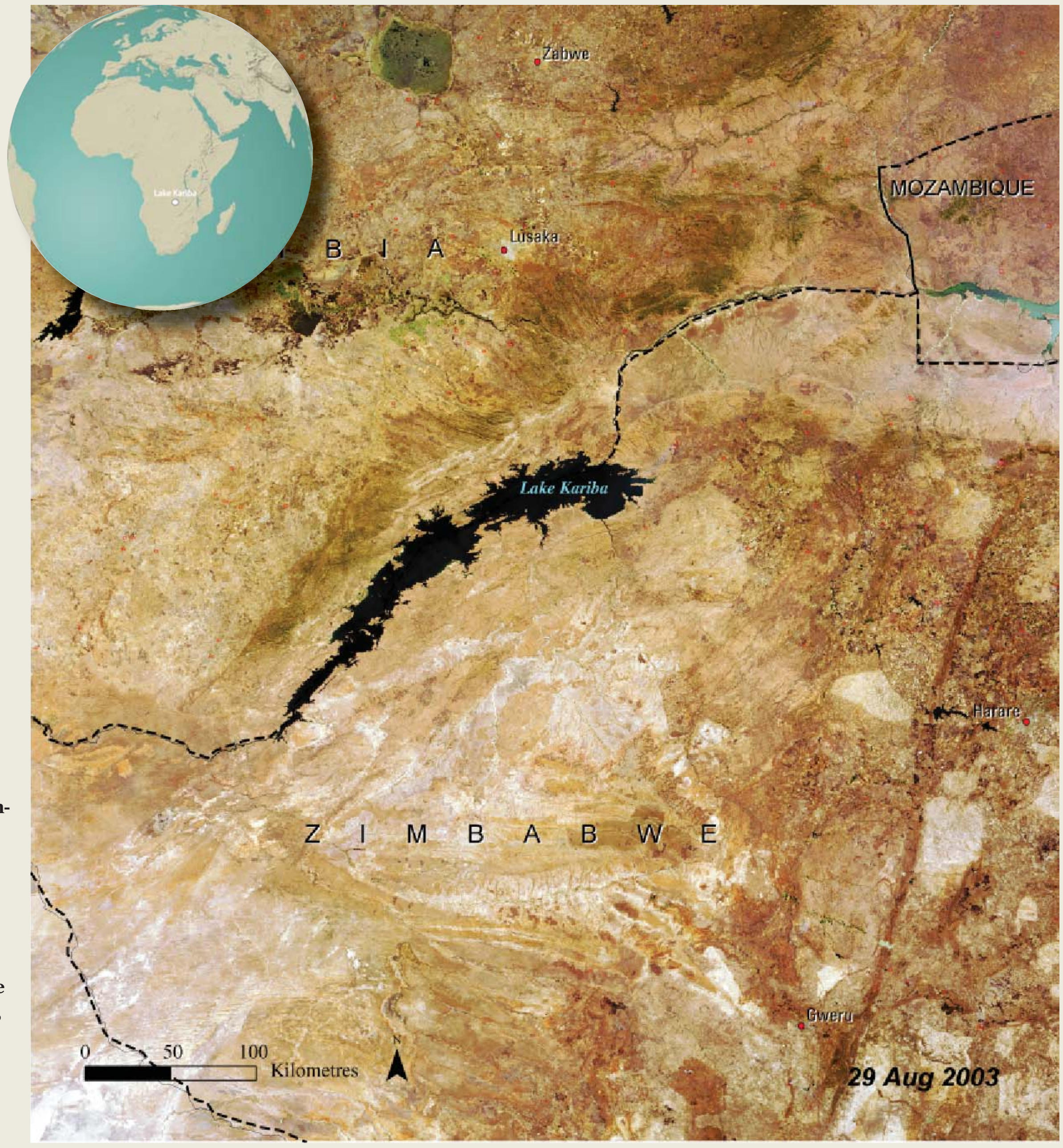


Figure 2.13: A satellite image of Lake Kariba. It is found in the Zimbezi River between the Zambia-Zimbabwe borders. Although at present water supply exceeds demand by far, this situation might change in the future due to the possible development of water use by the upstream-riparian Angola as civil war ends. In addition to ambitious new projects and possible further Inter-Basin Transfers threaten future water conflicts in the basin. Pollution of Lake Kariba by the two countries, Zimbabwe and Zambia, is also a seen as future source of conflict. However, there is need for equity and sustainable utilization of the lakes resource to avoid conflict among the two countries. *Credit: UNEP/GRID–Sioux Falls*

References

Biraben, Jan Noel (1979). Essai sur le nombre des hommes. Population 34, pp.13-24.

Chenje, Munyaradzi (2000). Mainstreaming water resources in Southern Africa. Published by SARDC.

Conservation International (2005). Available at www.conservation.org.

FAO (2005). AQUASTAT - FAO's Information System on Water and Agriculture. Review of global agricultural water use per country. Available at http://www.fao.org/ag/agl/aglw/aquastat/water_use/index5.stm.

FAO (2004). The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organisation (FAO), Rome, Italy.

Harden, Garrett (1968). The Tragedy of the Commons, Science, 162:1243-8.

Hinrichsen, D., Robey, B. and Upadhyay, U.D. (1997). Solutions for a Water-Short World. Population Reports, Series M, No. 14. Baltimore, Johns Hopkins School of Public Health, Population Information Program. http://www.infoforhealth.org/pr/m14/m14creds.shtml#top.

ILEC (2004). World Lake Vision – A call for action. World Lake Vision Project Secretariat, International Lake Environment Committee Foundation (ILEC), Kusatsu, Shiga 525-0001, Japan.

IUCN (2004). Freshwater Biodiversity Assessment. Programme. Centre for Mediterranean Cooperation.

NASA (2003). Lake Ecosystem Critical to East African Food Supply Is Threatened by Climate Change, 13 August 2003. Available at http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2003/2003081315329.html.

Nakijoba, V (1996). Effects of wetland reclamation on women's socio-economic survival:a case of Kampala District. M.A. Dissertation, Makerere University, Kampala.

Nanyunja, R.K (2001). Awareness and attitudes towards wetlands conservation in Rakai District:A case study in the Sango bay area. M. Sc. Dissertation, Makerere University, Kampala.

Niger Ministry of Environment and Hydraulics (1997). Plan National pour l'Environnement et le Developement Durable du Niger. Niamey, Niger. Available at http://africa.unep.net/freshwater/content1.asp.

O'Reilly, Catherine M., Alin, Simone R., Plisnier, Pierre-Denis, Cohen, Andrew S. and McKee, Brent A. (2003). Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa. Nature 424 (14):766-768.

Ruphael Y. (2004). Energy Bulletin: Water Crisis Looms in Africa, 17 September 2004. Available at http://www.energybulletin.net/2177.html.

SARDC (n.d.). South African Research and Documentation Centre: Water and Population Dynamics: Local Approaches to a Global Challenge. Available at http://www.sardc.net/.

Sithole, R. (2000). Fisheries in Africa. Global Water Partnership (GWP), Zimbabwe.

Emilio, G. (2004). GWP in Action 2004.Global Water Partnership (GWP), UK.

UNEP (1999). Global Environment Outlook (GEO 2000). Nairobi, Kenya: United Nations Environment Programme. 398 p. Available at http://www1.unep.org/geo-text/0056.htm.

UNEP (2005). Hydropolitical Vulnerability and Resilience along International Waters. UNEP, Nairobi, Kenya (in press).

USEPA (1994). Great Lakes Report to Congress 1994 – Report to Congress on the Great Lakes Ecosystem. Washington, DC: U.S. Environmental Protection Agency. Available at http://www.epa.gov/glnpo/rptcong/1994/glossary.htm.

UNU (n.d.). Environment and Sustainable Development. Water Crisis: International Rivers and Lake Basins Management. Available at http://www.unu.edu/env/water/transboundary-water.html#introduction.

WCD (2000). Dams and development – a new framework for decision-making. The World Commission on Dams (WCD), Available at http://www.dams.org/.

WHO (2001). Water Treatment Plants. World Health Organization (WHO), Available at http://www.who.int/docstore/water_sanitation_health/watreatplants/ch01.htm#TopOfPage on 28 September 2005.

Wolf, A., Natharius, J., Danielson, J., Ward, B. and Pender, J. (1999). International River Basins of the World, International Journal of Water Resources Development, 15(4) 387-427.

Wolf, Aaron T., Stahl, Kerstin and Macomber, Marcia F. (2003). Conflict and cooperation within international river basins: The importance of institutional capacity. Water Resources Update, Vol. 125. Universities Council on Water Resources.

WRI, UNEP, UNDP and WB (1998). World Resources 1998-99: A Guide to the Global Environment (and the World Resources Database diskette). Oxford University Press, New York, and Oxford, UK. Available at http://africa.unep.net/freshwater/content1.asp.

WRI (2004). EarthTrends – Data CD-ROM: Decisions for the Earth: Balance, Voice and Power. World Resources Institute, Washington DC.

WWF (2005). Chimpanzee facts and issues. World Wildlife Foundation. Available at http://www.wwf.org.uk/researcher/issues/rarespecies/0000000147.asp.

UNEP/USGS

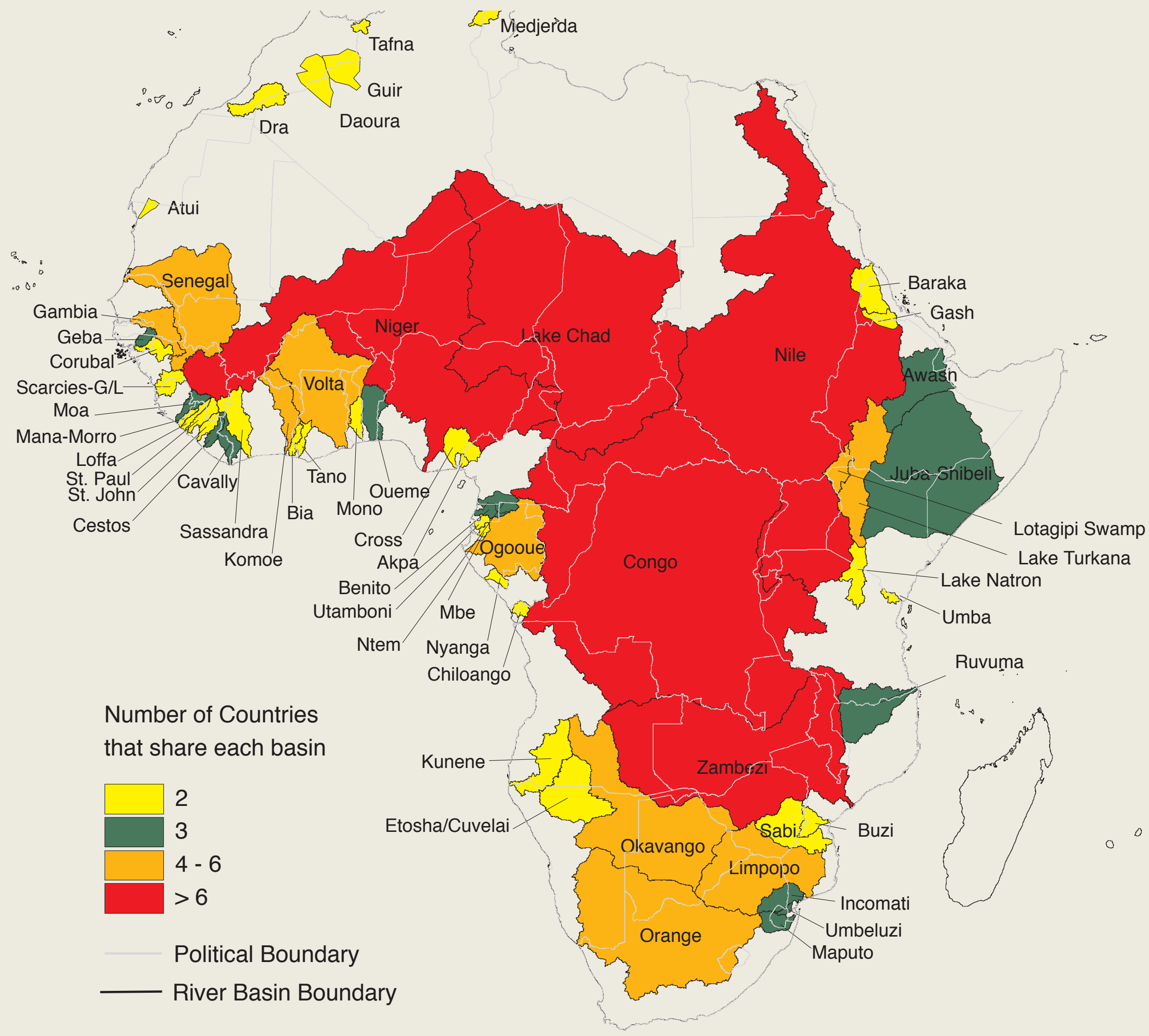
3 Impacts on Africa's Lakes

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.



UNEP/GRID–Sioux Falls

Figure 3.1: Transboundary river basins

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 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

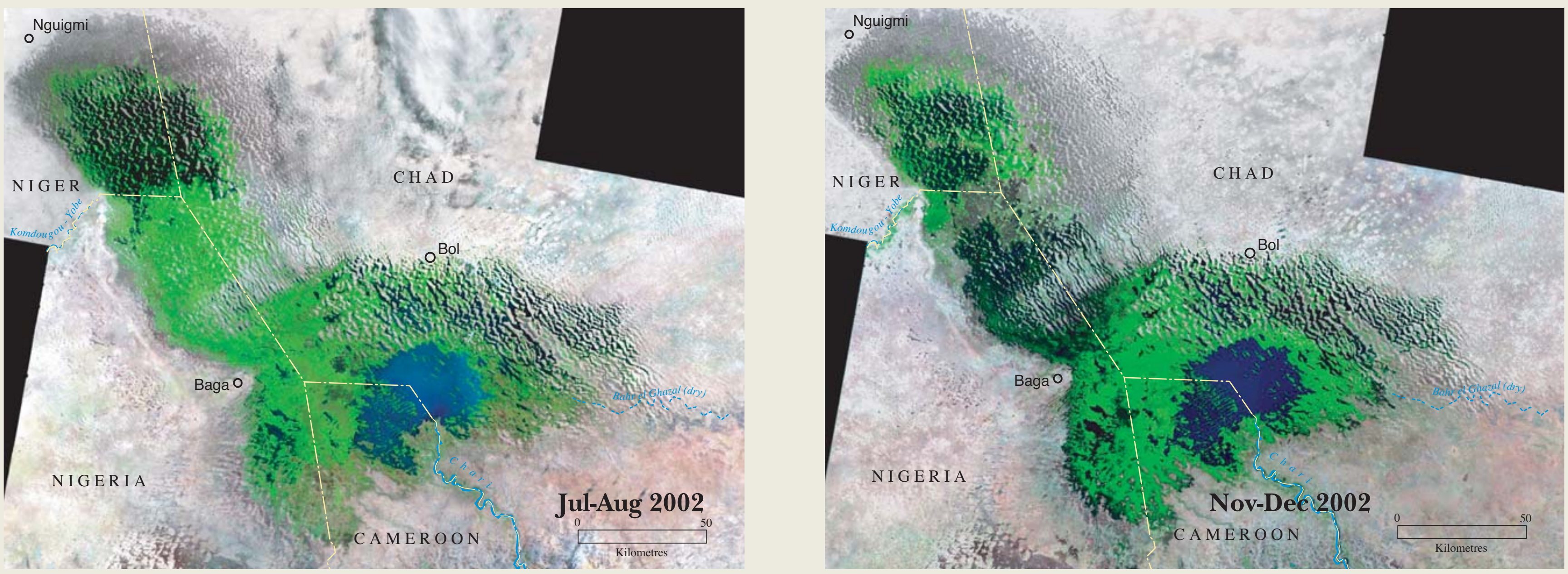
Ledru et Martel/UNEP/UNESCO

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).

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.

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.

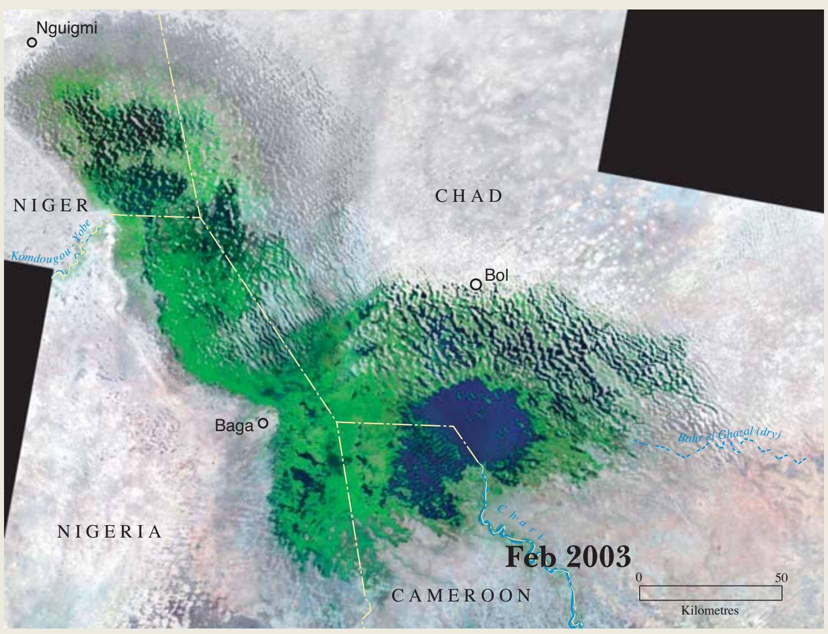
In the late 1960s, the western Sahel appears to have undergone an abrupt hydro-climatic transition from a wetter to a drier rainfall state. Rainfall became intermittent at Lake Chad, culminating in two major droughts in 1972-74 and 1983-84. In the mid-1990s, rainfall again increased with several good 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).

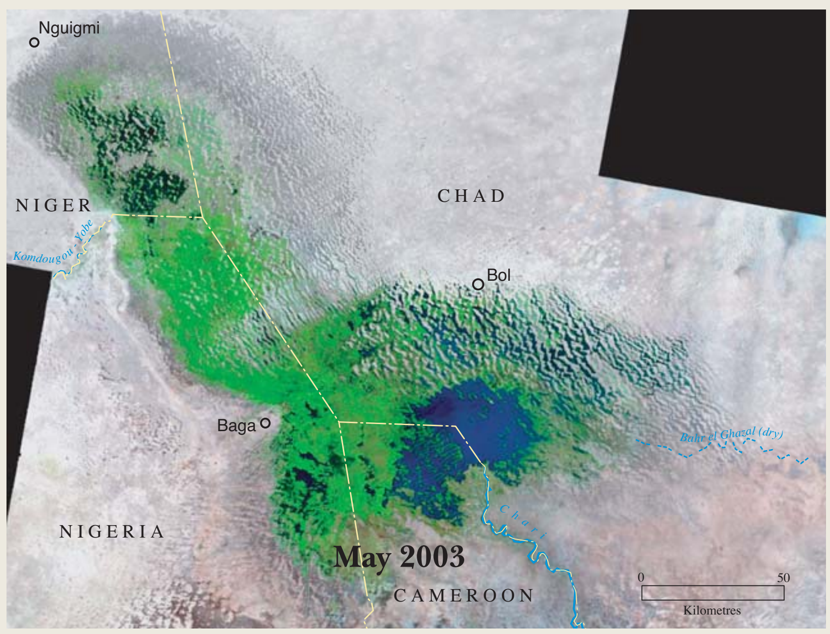
UNEP/Forestry Images

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).

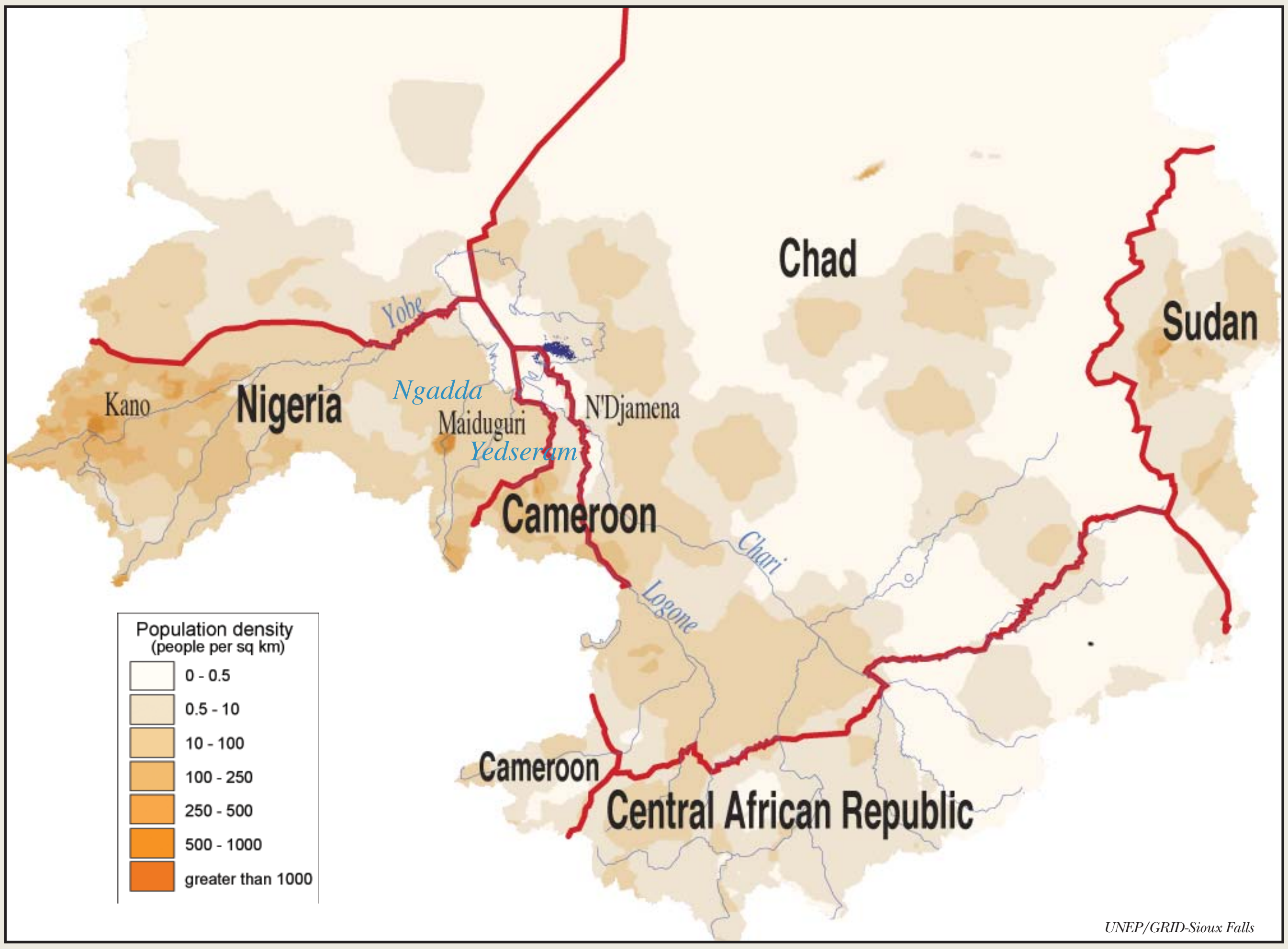
In addition to irrigation, dams have influenced the rivers that feed Lake Chad. In the Kano and Hadejia basins, there are believed to be about 23 earth dams. The Komadougou-Yobe river system provides an example of the dramatic impact of human diversion. The upper basin used to contribute approximately 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

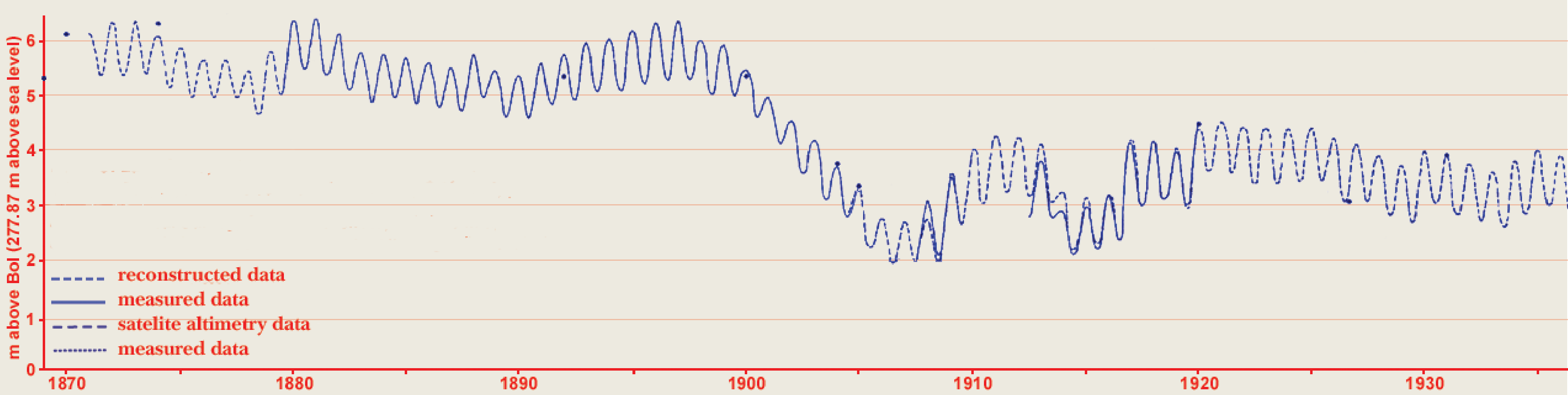


Table 3.1: The nine largest international basins in Africa

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.

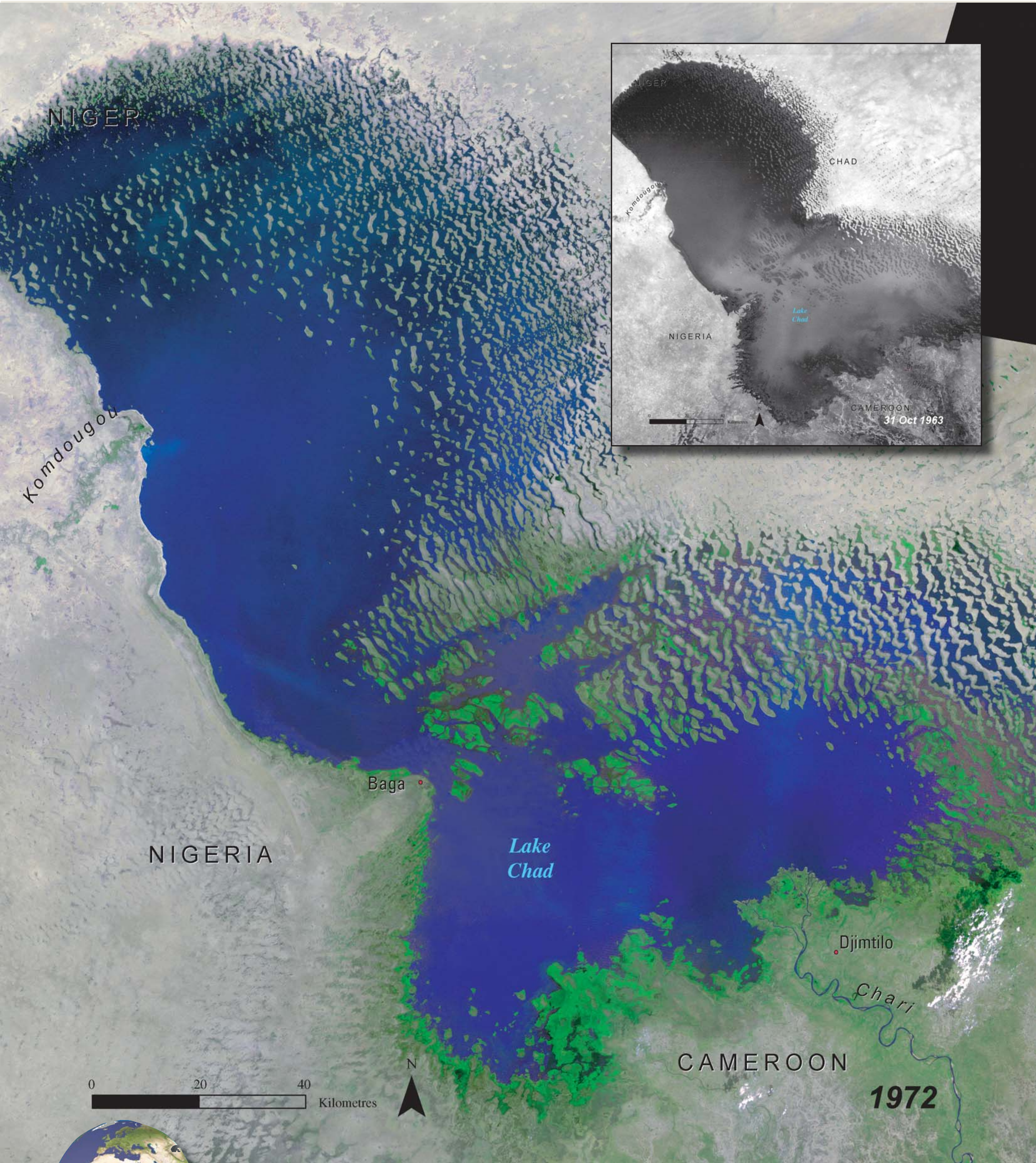
The Future

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, of course, 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).

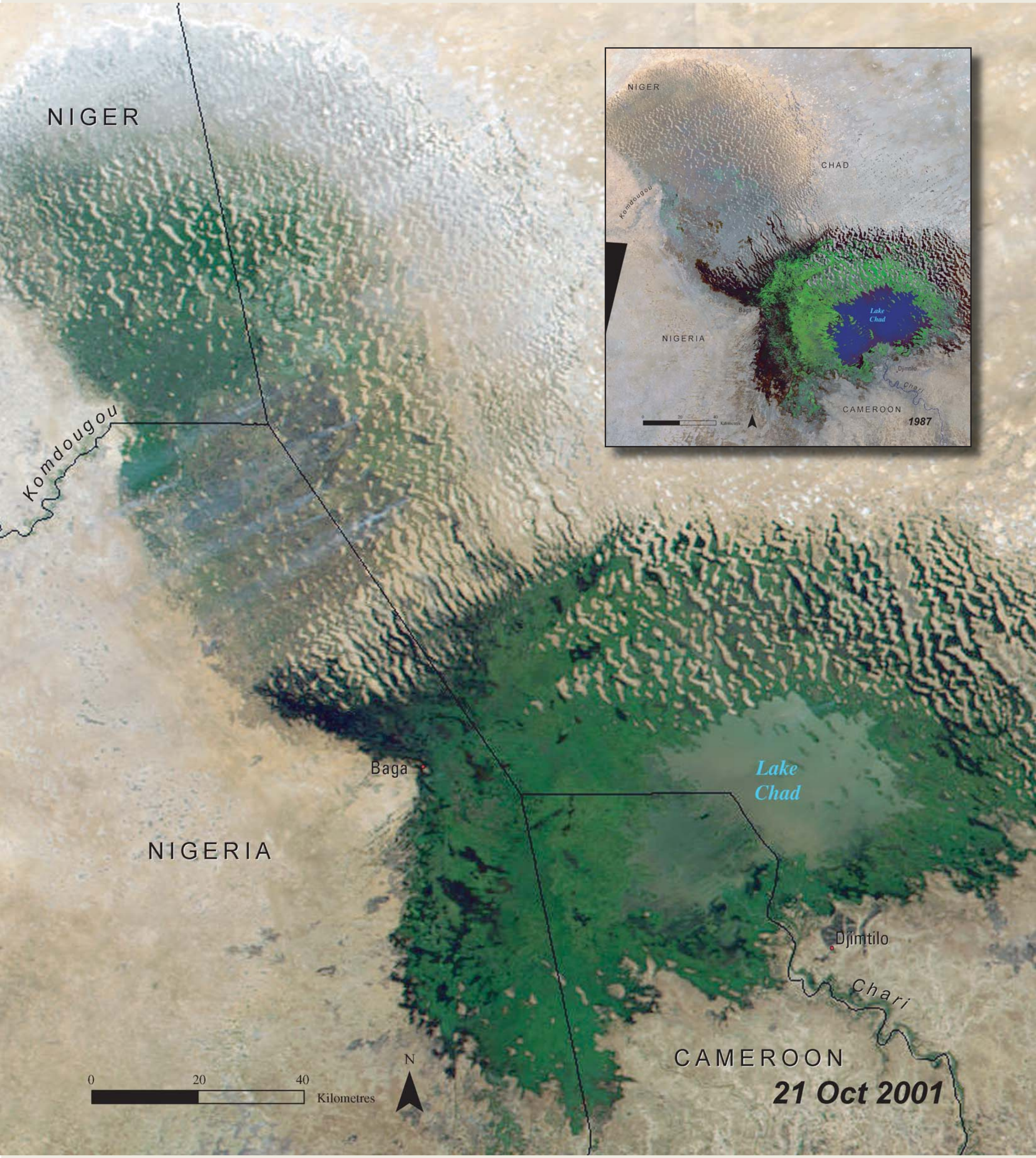
For now, the future of Lake Chad does indeed look bleak. With a high population growth rate, pressures on water resources in the lake basin will invariably continue. While in the past Lake Chad has been able to rebound from low to high water levels, climate change and people's water use may now act in 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).

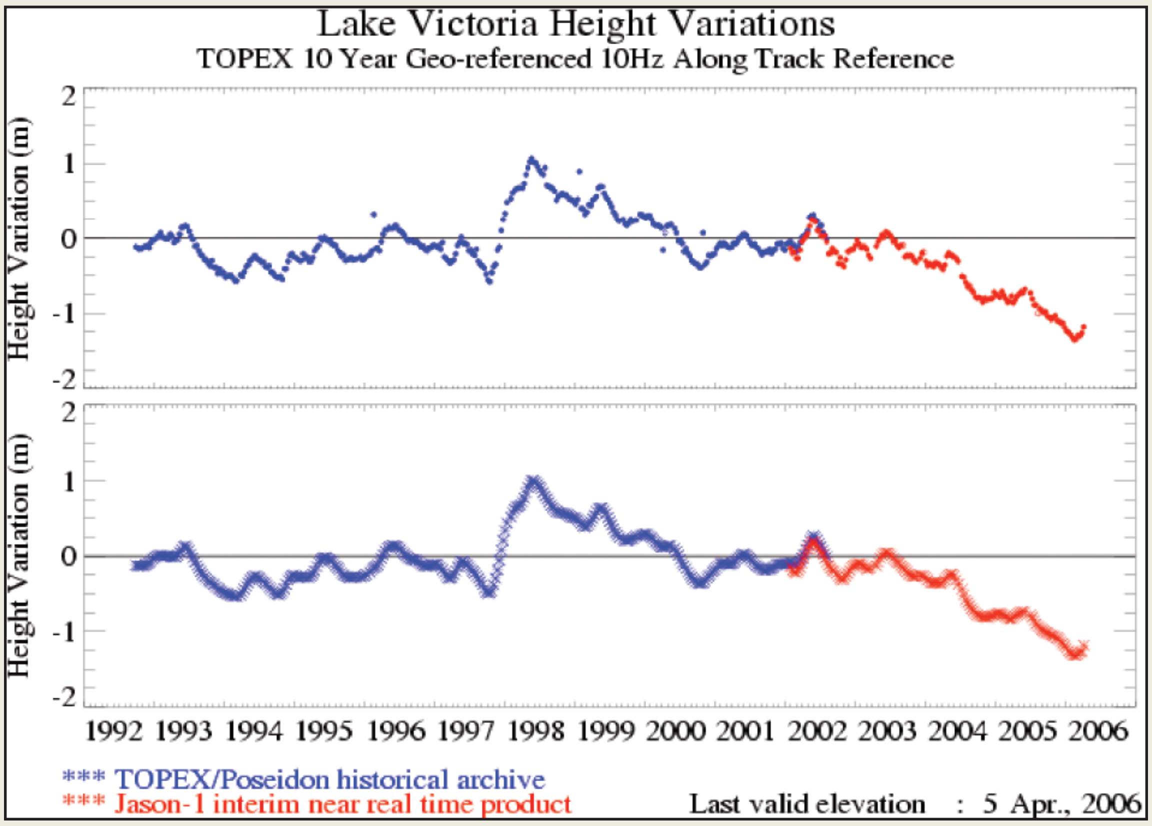


Figure 3.5: The declining levels of Lake Victoria, shown through relative lake height variations computed from TOPEX/POSEIDON (T/P) and Jason-1 altimetry, and compared to a 10-year mean level derived from T/P altimeter observations (Source: USDA 2005)

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).

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

Murchison Bay, the bay near Kampala

Robb Campbell/UNEP/USGS

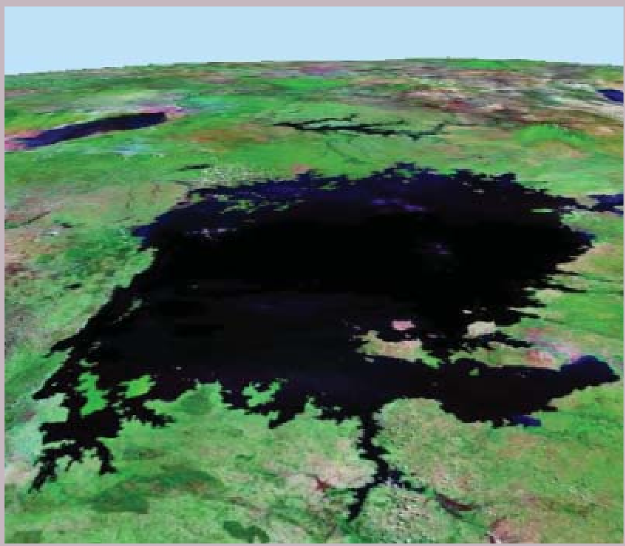


Figure 3.4: A 3D view of Lake Victoria

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 km^2 (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 km^2 (1 358 square miles) of the lakes basin—or 1 624 km^2 (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.

Table 3.2: Country lake statistics.

Country	Lake surface area		Shoreline		Tributary basin	
	km^2	%	km	%	km^2	%
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

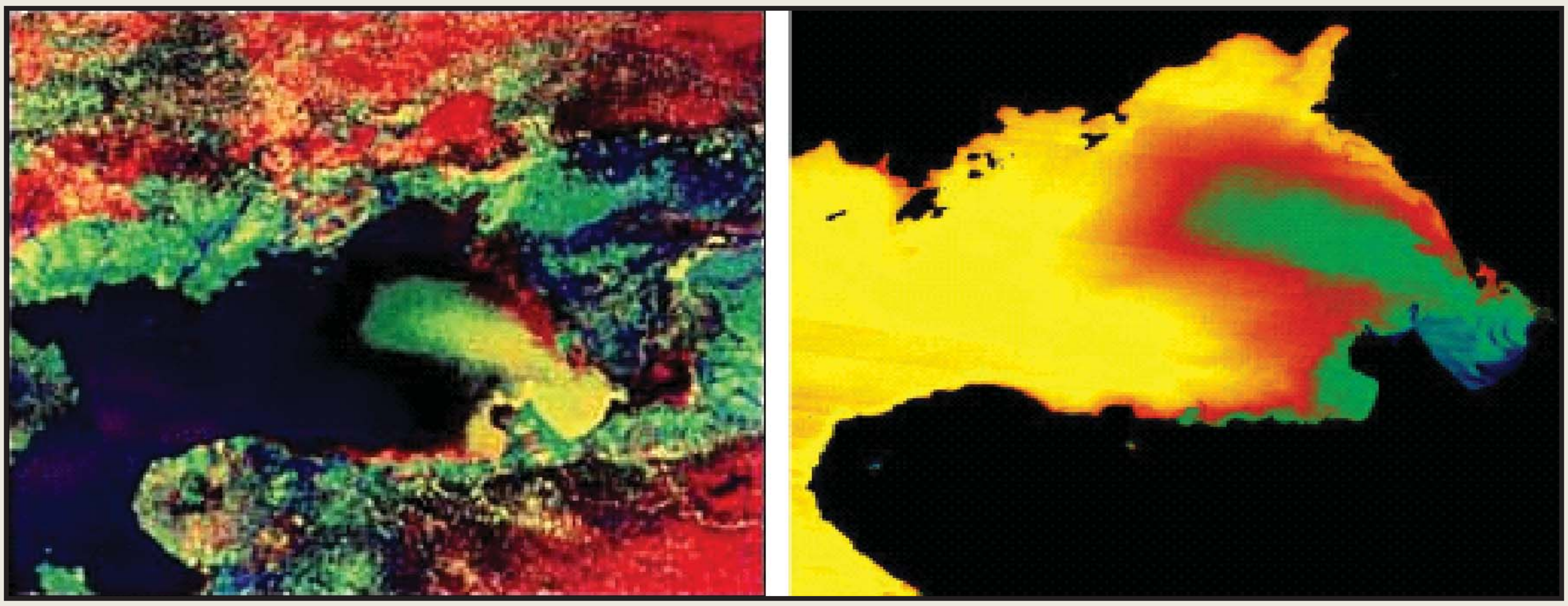
most overpopulated areas. Most of the land has fragile ecosystems that need to be protected, soils with low fertility and poor texture, biotic constraints such as tsetse fly, and areas prone to flooding. Despite these unfavourable conditions, however, major population increases have resulted in the widespread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

Figure 3.6: Satellite images depicting plumes of nutrient-rich sediments flowing into Lake Victoria

Courtesy: Future Harvest/ICRAF



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.

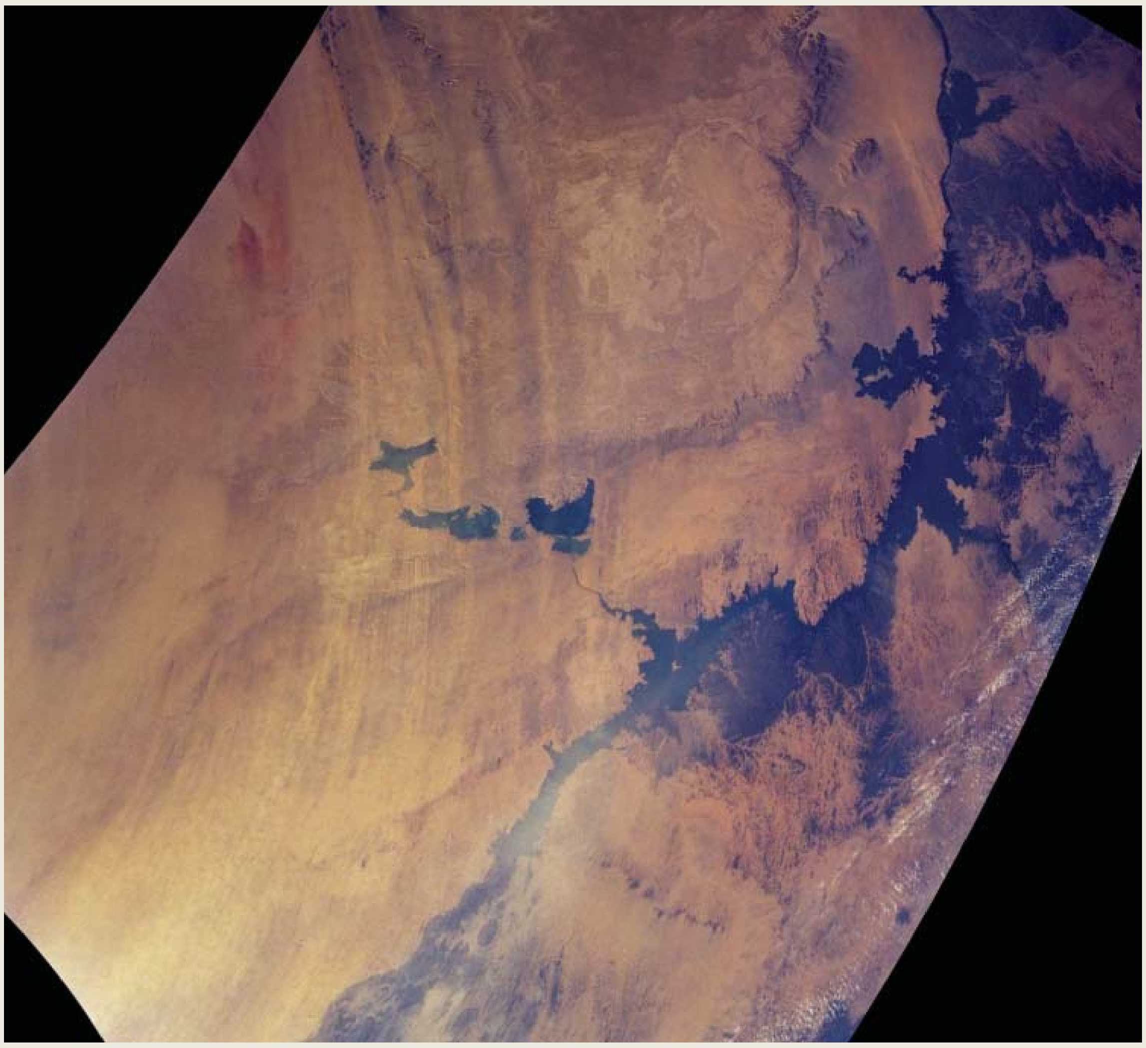
Along with the famed Aswan High Dam, many proposed infrastructure projects for land reclamation and other development have been on the agendas of both Egypt and Sudan since the 1970s and 80s. However, down the years, most of these projects have either stalled or been cancelled. Since it was built in 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.

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

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

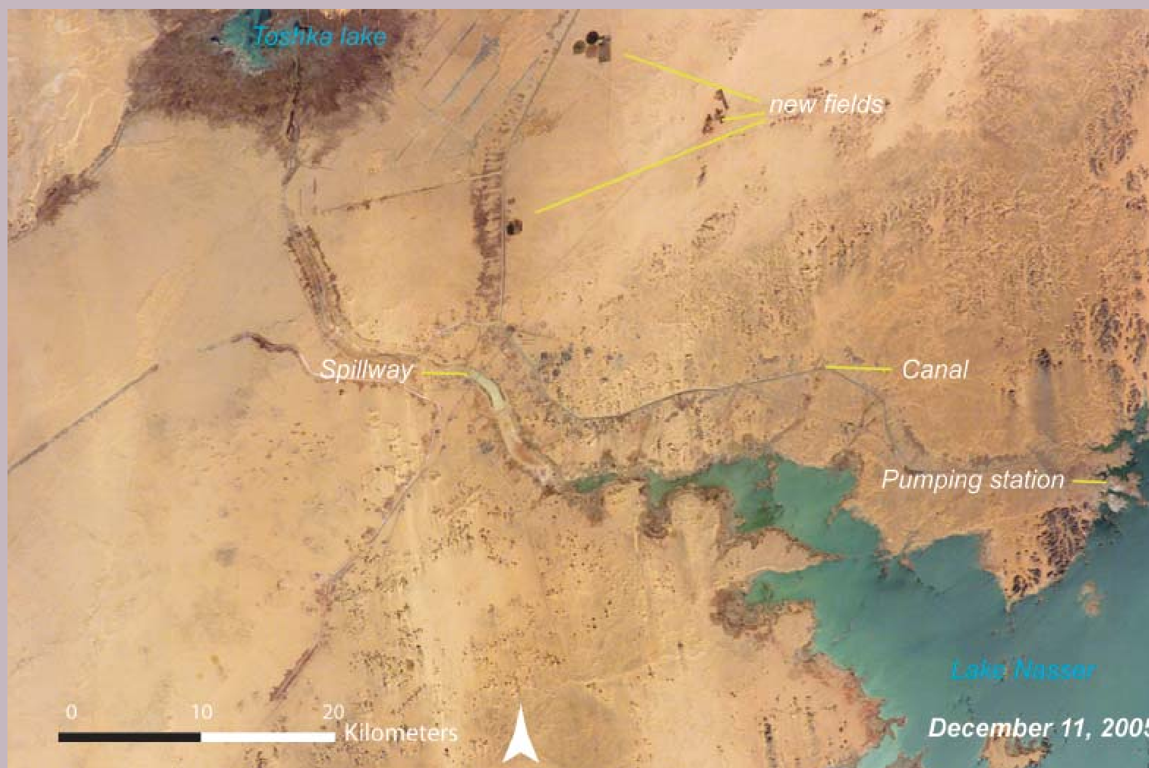


Figure 3.9: This 2005 picture from space shows the completed Mubarak Pumping Station, together with the spillway that originally flooded the Toshka Depression, the southern end of the first of the Toshka Lakes, part of the 50 km (31 mile) Sheikh Zayed Canal, and several new fields in the Egyptian desert 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.

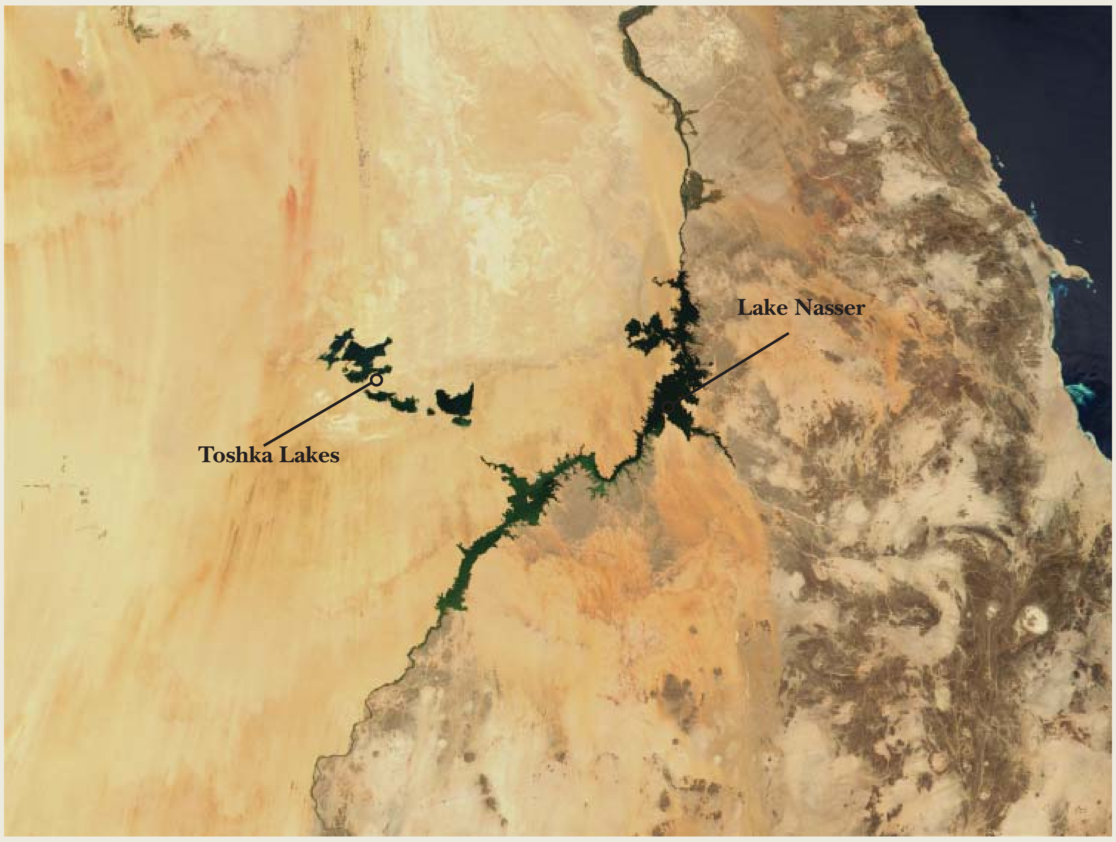
However, with an annual 1 000 million m^3 (1 300 million cubic yards) of rainfall, 7 500 million m^3 (9 810 million cubic yards)of groundwater, and 5 000 million m^3 (6 540 million cubic yards) of recycled agricultural drainage water, Egypt argues that the scheme can be achieved without increasing the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

Sheikh Zayed Canal — *Brian Czarnecki/UNEP*

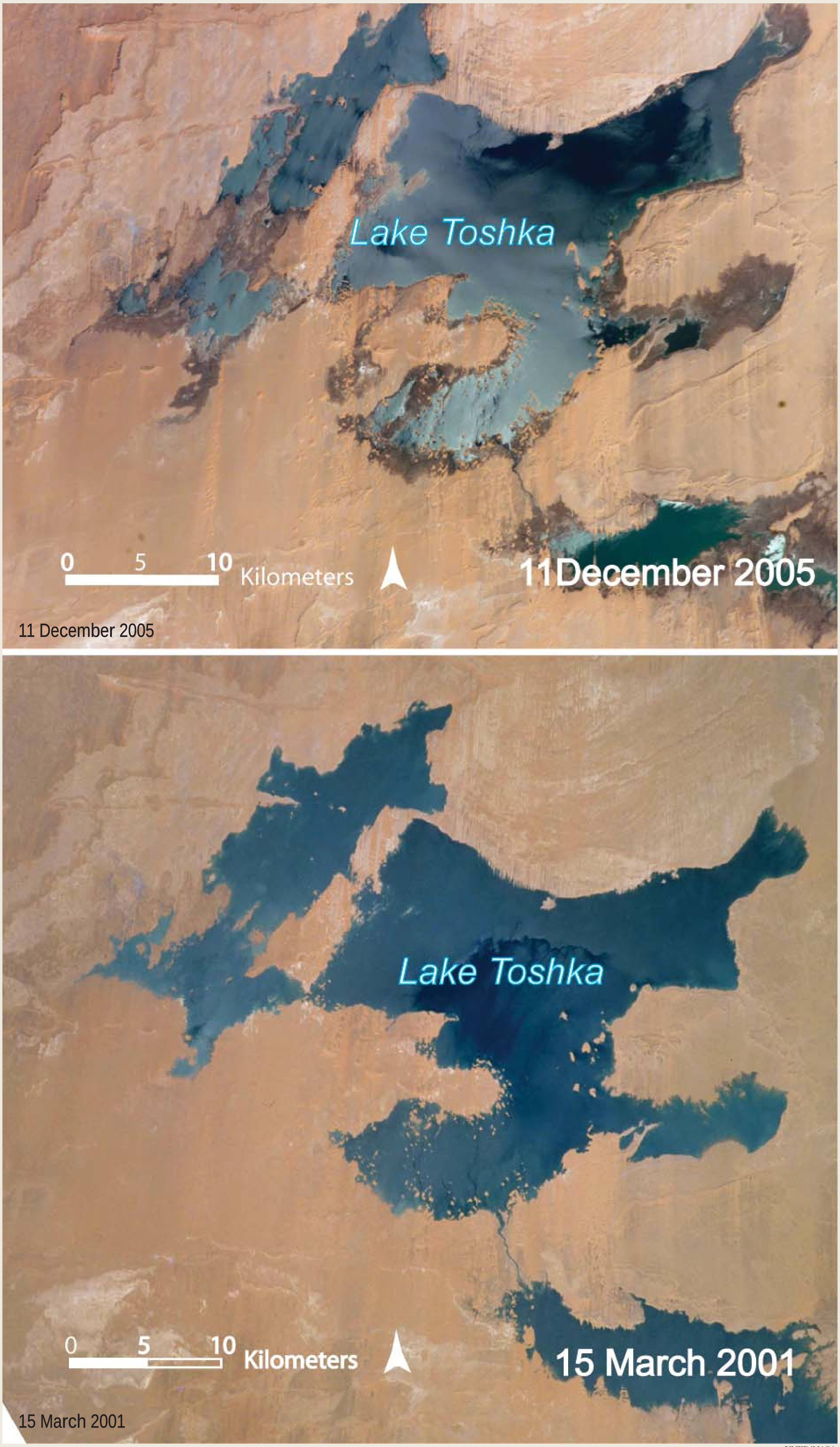
Sheikh Zayed Canal

The second key element of the project is a 30 m (98 ft) wide, eight metre (26 feet) 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.



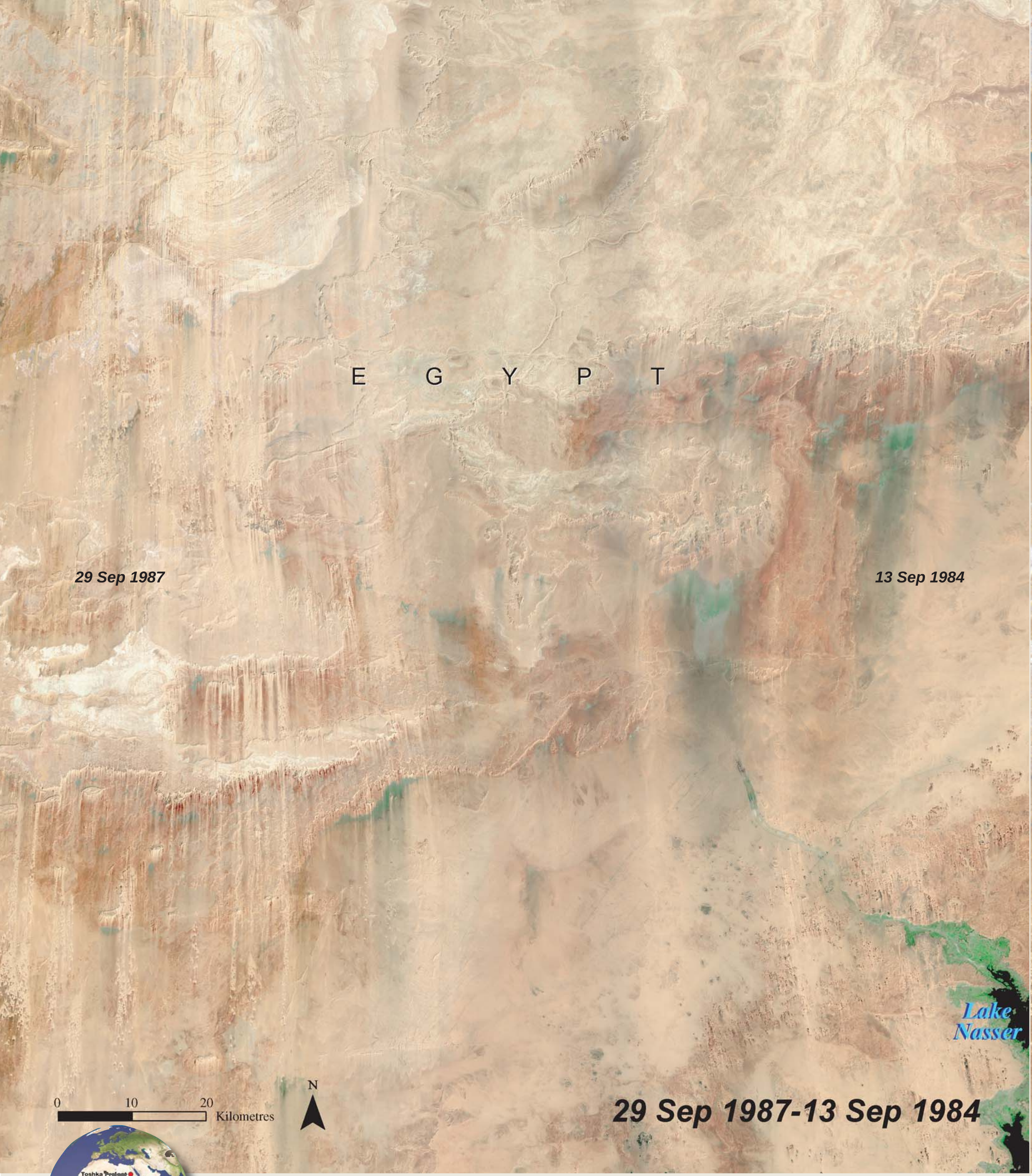
Satellite image showing location of Toshka Lakes. — *UNEP/NASA*



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

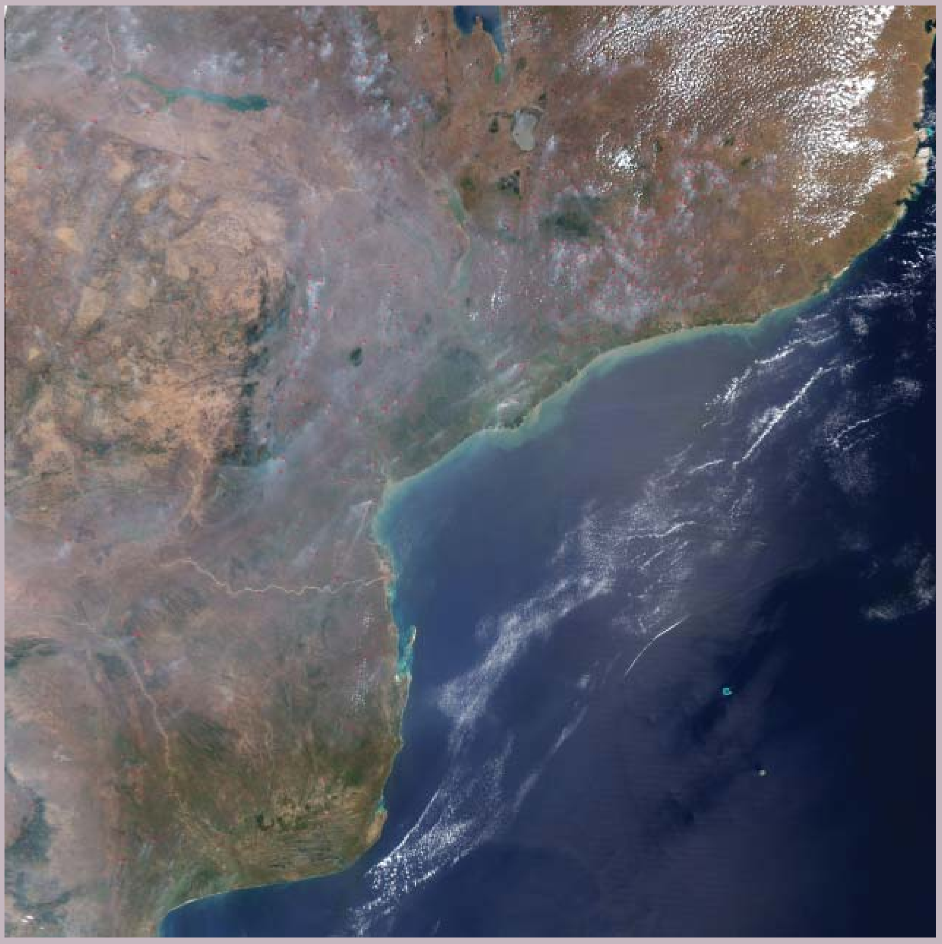
Toshka Project, Eygpt

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.

Fires Near Lake Malawi, Africa

This image of southeastern Africa, acquired on 25 September 2004, shows scores of fires burning in Mozambique south of Lake Malawi, whose southern tip is at the top center of the image. Active fire detections are marked in red. The fires created a layer of smoke that darkened the surface of the land beneath it. At upper left in the image, the turquoise-colored body of water is the Lake Cahora Basa, created by a dam on the Zambeze River just inside Mozambique after the river leaves its course along the border of Zambia and Zimbabwe (NASA 2004).



3.2 Images of Change: Africa's Lakes

Various types of ground-based instruments, together with in situ surveys and analyses, can be used to measure the changes being brought about on the Earth through human activities and global changes. But such changes can also be observed in more detail and with a "big picture" perspective from space, through Earth-orbiting satellites that gather images of the Earth's surface at regular intervals. The Landsat series of Earth-observing satellites has compiled a data record of the planet's land and water surfaces, which spans the past 30 years and continues today.

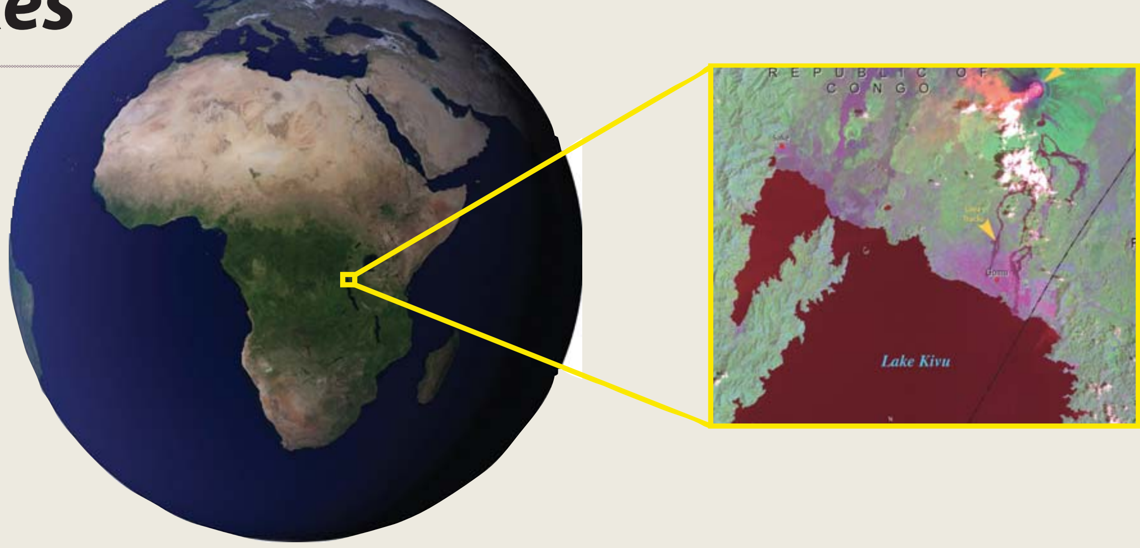
By comparing two images of the same area taken 10, 20 or even 30 years apart, it is often easy to see human and naturally-induced changes in a specific location. There are very few places remaining on the planet that do not show at least some impact from people's activities. Freshwater lakes are often among the most affected areas.

The focus of this chapter is a set of specific case studies, in which satellite images taken at different times are paired to reveal human and natural impacts on African lakes, freshwater ecosystems and wetlands, and forests, croplands, grasslands and urban areas around the lakes.

Changes seen in pairs of satellite images should serve as a call to action. While some are positive changes, many more are negative. They are warning signs, which should prompt us to ask some serious questions about our impact on these vital freshwater systems – and about how we can minimise this impact in future. How can we use Africa's lake and wetland resources in ways that will not reduce the ability of the Earth to support us in perpetuity?

Julie Brazier/UNEP/MorgueFile

Africa's Killer Lakes



There are three lakes in Africa that contain dangerously high proportions of dissolved methane and carbon dioxide gases in their deeper waters, which if released can suffocate millions of living creatures. These are Lakes Nyos and Monoun in Cameroon and Lake Kivu on the border between Rwanda and the Democratic Republic of Congo.

Lakes Monoun, Nyos and Kivu are of the 'maars' type: lakes formed following a phreatomagmatic (water-rich) eruption that produced volcanoes with broad craters, characterised by low-gradient outer slopes and steep inner walls. When the volcano becomes extinct, a lake is frequently formed in the crater, which gradually becomes filled with sediment, producing swamps and peat deposits.

Carbon dioxide bursts in Lakes Monoun and Nyos led to the sudden deaths of 37 and 1 746 people in 1984 and 1986 respectively. At Lake Kivu, the Mount Nyiragongo volcano made international news when it erupted in January 2002, pouring molten lava into the city of Goma in the Congo and also into Lake Kivu. In addition, fears that the water had been contaminated by magma falling into the lake were confirmed by complaints of diarrhea, dysentery and headaches, but people had little choice but to drink it. Outbreaks of cholera were also reported (Christian Aid, Relief-Web, 2002).

Lake Kivu remains a cause for serious concern. A rift in the area is pulling apart and causing a crack to move closer to the bottom of the lake. Large amounts of boiling lava entering the lake could be more than sufficient to trigger a large overturn releasing huge amounts of deadly CO_2 would be released. In addition, the lake contains a large quantity of methane that could also cause explosions above the lake. It is estimated that Kivu contains enough methane to power the United States for a month, and five times as much CO_2—about 200 km^3 (262 cubic yards).

The waters of Lake Kivu manifest a particularly distinctive 'stair-like' stratified structure, with their physic-chemical parameters changing with depth. The exact explanation for this stratified phenomenon is complex. The waters of the lake are made up of homogenous layers—in which mixing by convection easily takes place—separated by layers with a high-density gradient, which act as barriers to the mixing process. The lower levels are anoxic, saturated with siderite and retaining a large amount of carbon dioxide in the water (as a balance of both carbonic acid (HCO_3) and CO_2), producing ferric hydroxide and carbon dioxide. Another factor that could add to the already unstable situation within the lake is that carbon dioxide is more soluble in cold water than in warm. Therefore any disturbance that mixes layers of warmer water with cooler water, already heavily charged with carbon dioxide, could lead to a reaction, producing a discharge of CO_2 gas.

Degassing Lake Nyos

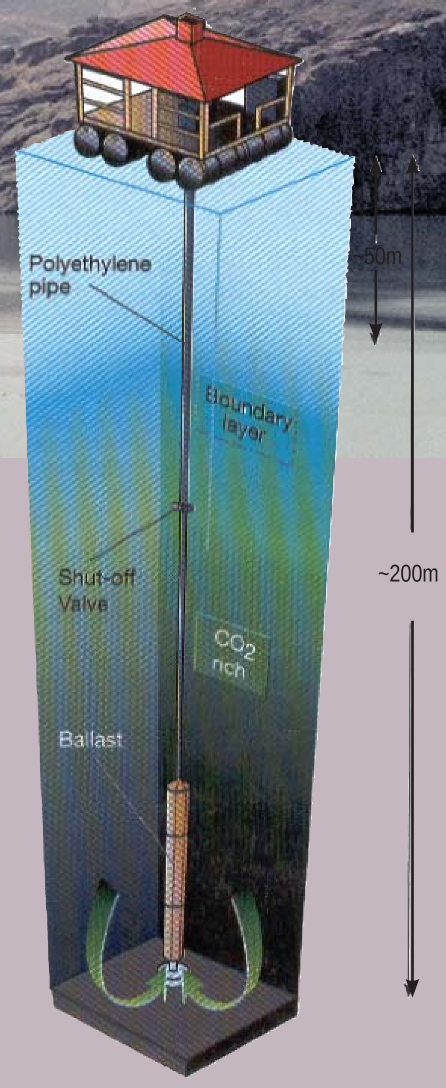
Lake Nyos is situated in the crater formed from the collapse of the pipe feeding a now extinct volcano. The lake is compositionally stratified, with fresh water in the upper 50 m (164 ft) and heavier sodium- and carbon dioxide-rich water below that. The water below 180 m (591 ft) is particularly rich in sodium and carbon dioxide. Most of the sodium and carbon dioxide come from numerous sodium-bicarbonate bearing springs—derived from an underlying magma chamber—feeding into the bottom of the lake.

In August of 1986 some event—perhaps a mudslide, heavy rain or wind blowing across the lake—caused the water column to be disturbed. Some of the deep carbon dioxide-rich water moved towards the surface where it was subjected to lower pressure. The dissolved carbon dioxide quickly converted to carbon dioxide gas and rushed to the surface, starting a chain reaction of degassing the deeper water. A huge cloud of carbon dioxide spilled over the lake's outlet and down into the surrounding valleys.

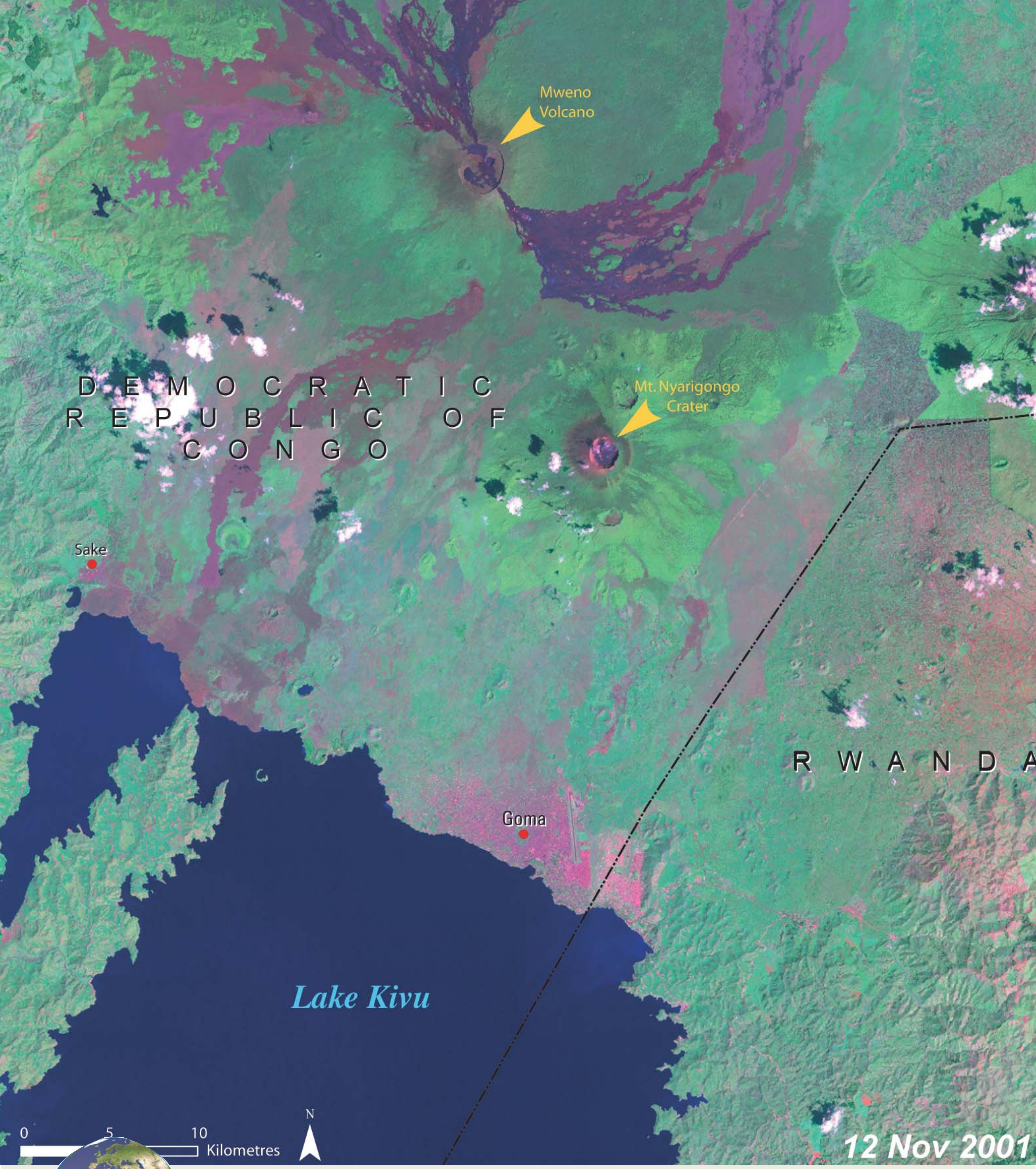
In 1995 an international team of scientists and engineers tested a procedure to degas the lower parts of Lakes Nyos and Monoun in a controlled way, and a team is now in the region to begin the project in earnest. The procedure involves lowering a strong polyethylene pipe to the lake bottom. Some water is pumped out at the top, and as the deep water rises through the pipe the carbon dioxide starts to bubble out. The gas and water then become buoyant and suck more water in at the bottom in a self-sustaining process.

One potential problem is that volcanic rock forming the natural dam which holds water in the lake is weak. If the dam should fail the upper 40 m (131 ft) of water would spill out and this would lead to an immediate limnic eruption and a major flood which could extend all the way into Nigeria (*Earle 2000*).

French scientists degassing Lake Nyos.



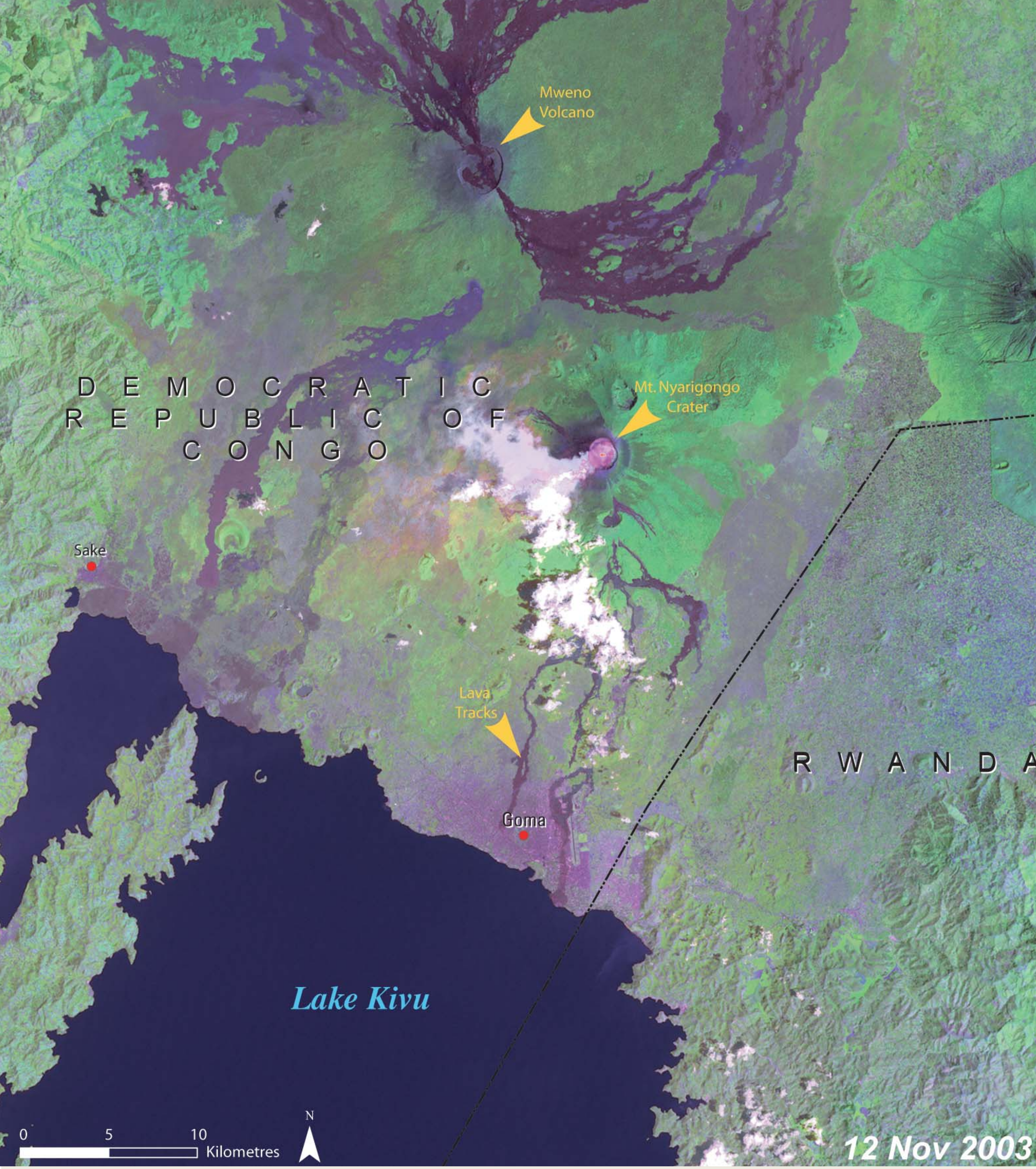
Unknown/UNEP/perso.wanadoo.fr/nyos/



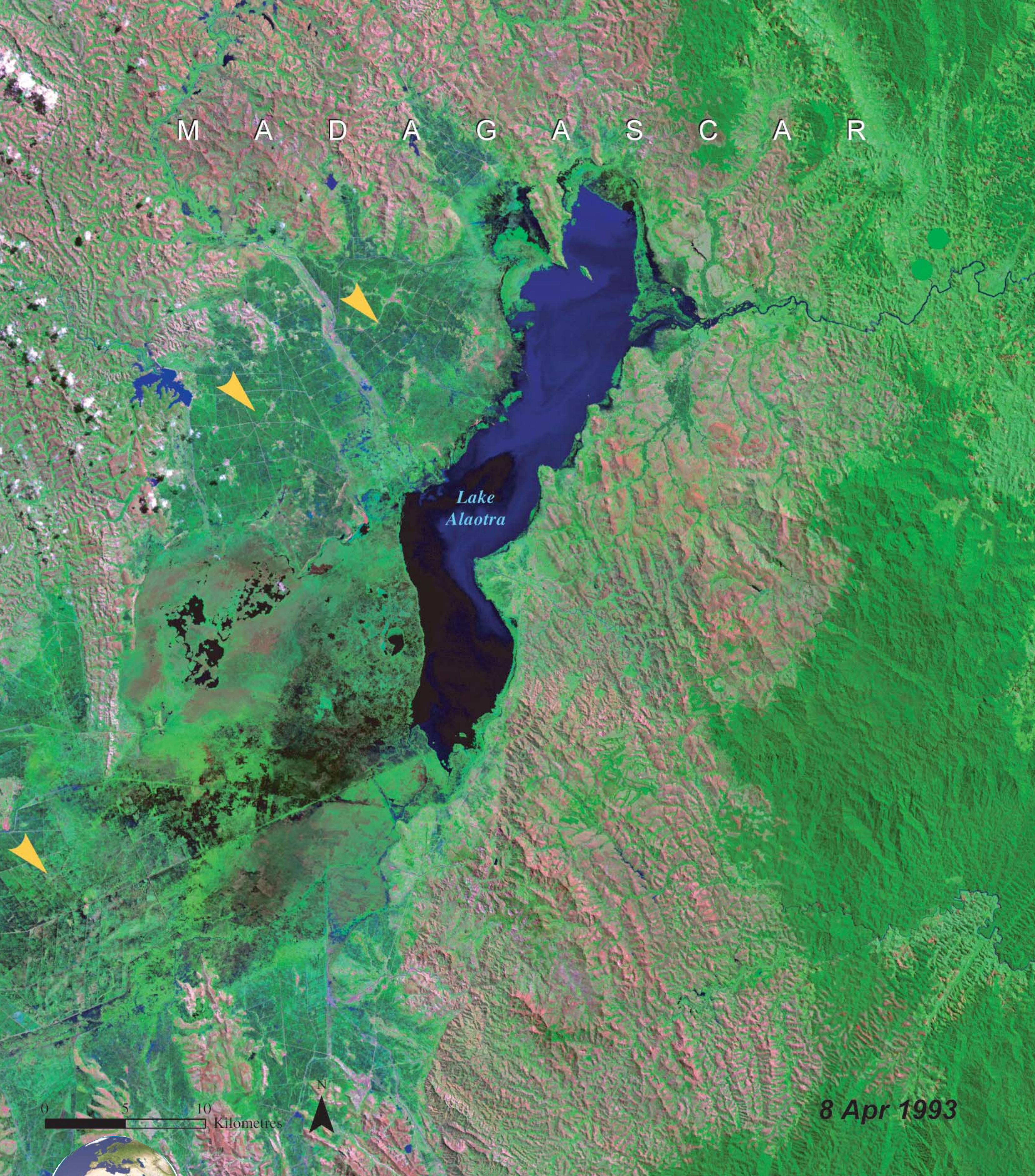
Africa's Killer Lake

Lake Kivu

Lake Kivu on the Congo-Rwanda border is the highest lake in Africa at 1 459 m (4 788 ft). Beneath the lake lie vast reserves of methane gas which has not been exploited. Lake Kivu

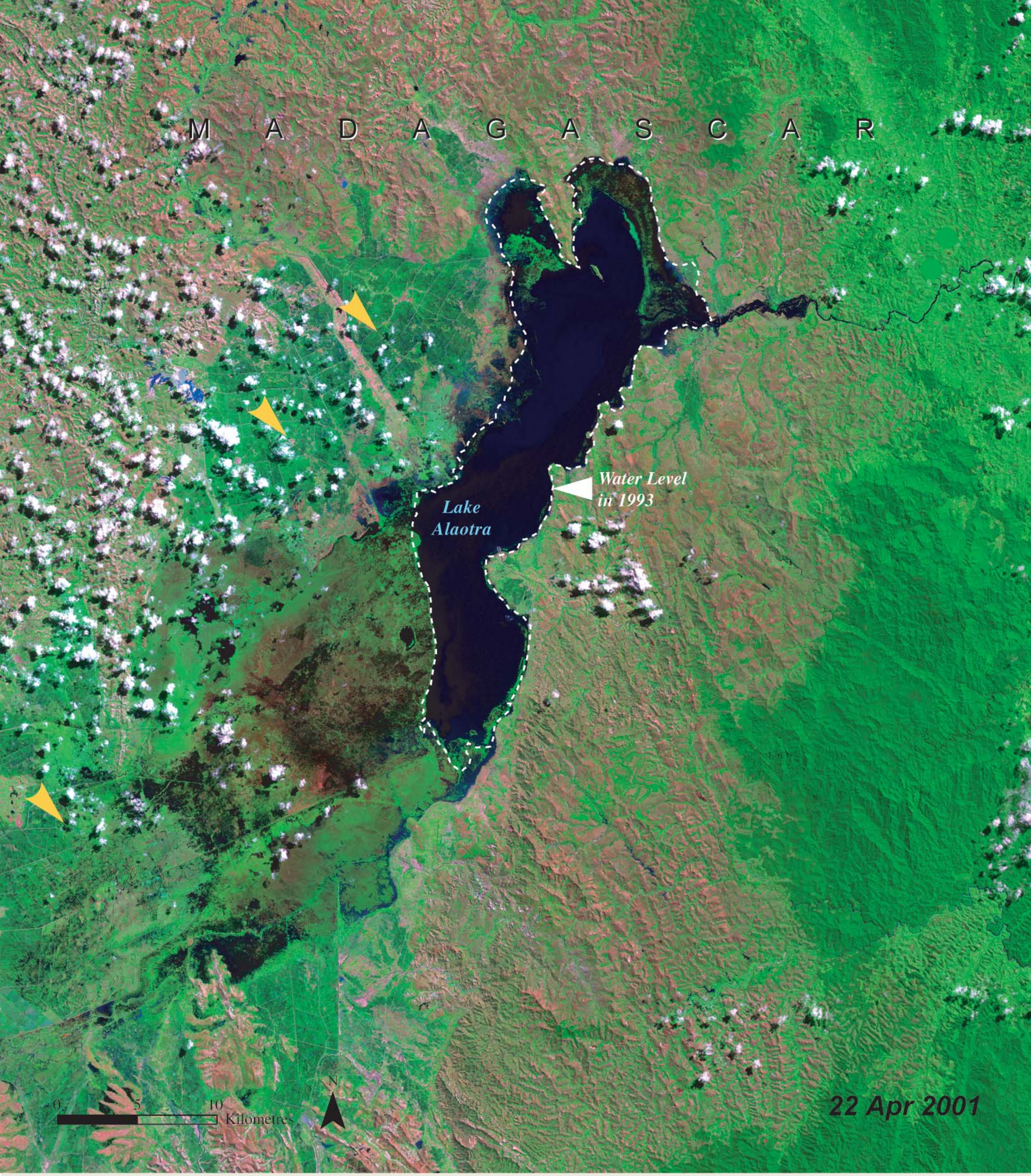


is also an important tourist center. These satellite images of Lake Kivu show dramatic changes before and after the eruption of Mt. Nyiragongo in January 2002. The 2003 image clearly shows the track of the lava flow, which traveled through Goma town and into the northeastern part of the lake, contaminating its waters. Lake Kivu is one of Africa's "killer lakes," containing a volatile combination of methane and carbon dioxide gases with the capacity to kill thousands of people.



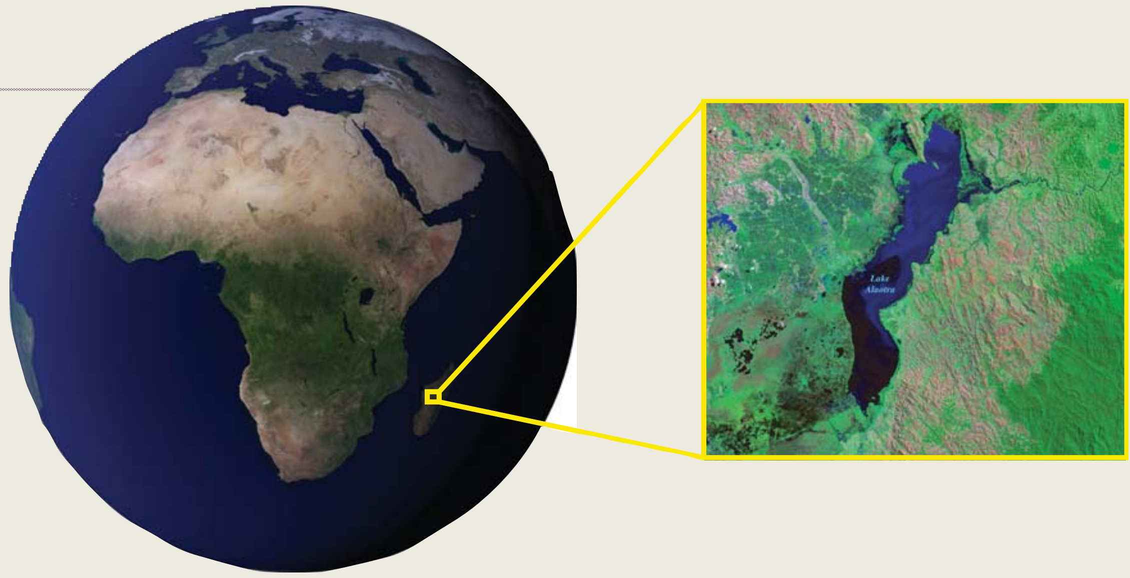
LAKE ALAOTRA
MADAGASCAR

Lake Alaotra is a shallow, reed-fringed lake that lies in a tectonic basin 40 km (25 miles) long and 9.5 km (6 miles) wide. The images from March 2005 show extensive flooding of



the lake, especially along its western and southern shores. Heavy rains, unusual for the time of year, caused severe flooding across Madagascar, destroying an estimated ten per cent of the region's rice crop. This pair of MODIS images shows flooding over a wide area, including Lake Alaotra (outlined in white). In the images, vegetation shows as bright green, water as shades of blue, and clouds as light blue. Intensive rice irrigation occurs at the western part of the lake (yellow arrows).

Lake Alaotra

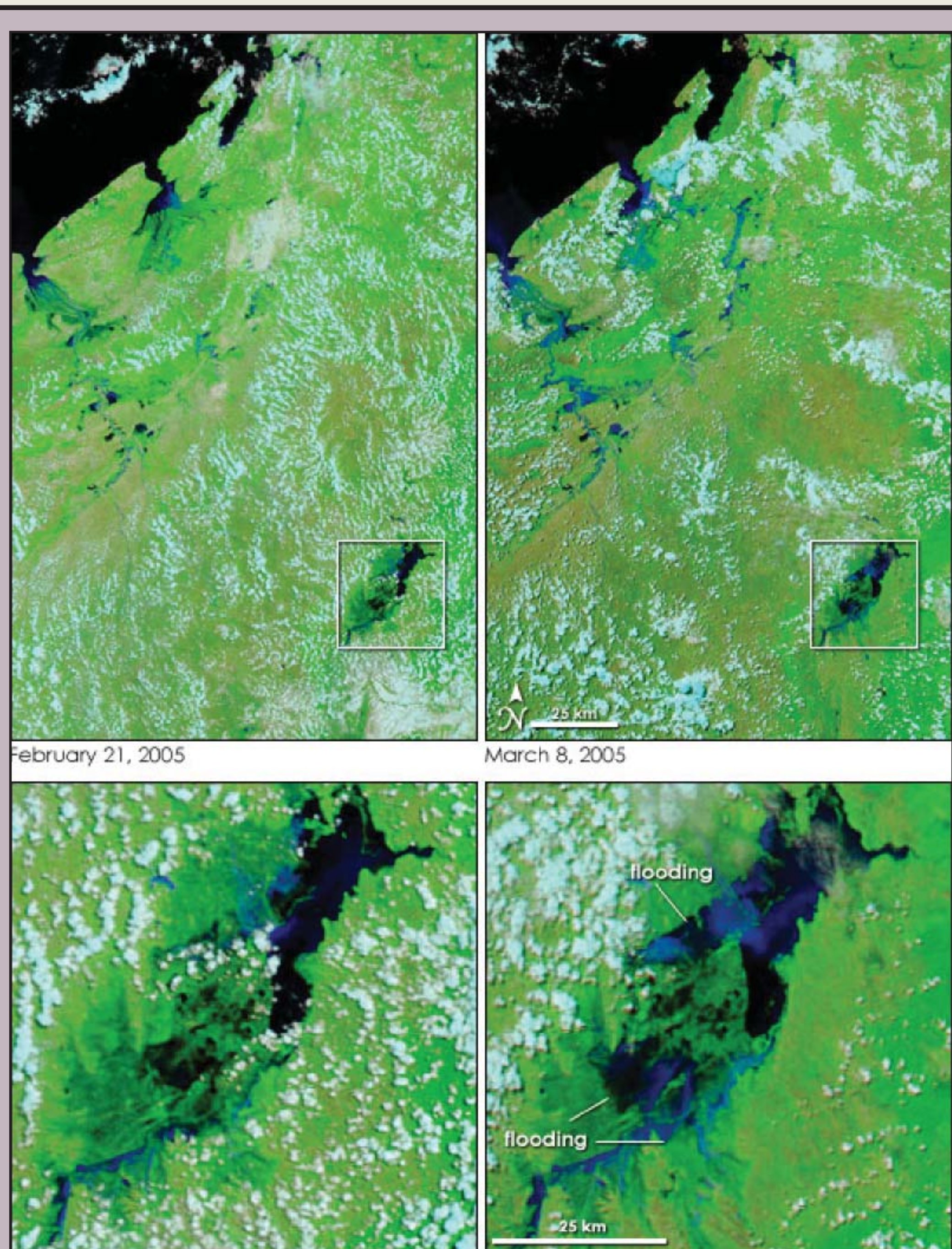


Lake Alaotra (Lac Alaotra) is the largest lake in Madagascar and forms the centre of the island's most important rice-growing region. It is a rich habitat for wildlife, including some rare and endangered species, and is an important fishing ground. Lake Alaotra and its surrounding wetlands cover 7 225 km^2 (2 790 square miles) and include a range of habitats, including open water, reed beds, marshes and rice paddies. The lake was declared a wetland of international importance under the Ramsar Convention in February 2003.

Although the hills surrounding Lake Alaotra were once completely forested, most have been cleared for farmland in the last few decades. Severe erosion on these vulnerable slopes has caused considerable sedimentation of the lake, which is fast disappearing; the lake is now only 60 cm (24 inches) deep during the dry season. Pressure to create more rice fields has also led local people to burn the reed beds around the lake, which provide the sole habitat of the endemic Alaotra Gentle Lemur (*Hapalemur griseus alotrensis*). Limited to just 220 km^2 (85 square miles) of remaining reed beds, the lemur's population has plummeted in recent years—from an estimated 7 500 people in 1994 to just 3 000 in 2001. Serious erosion is being exacerbated by incessant brush and reed fires, which consume the vegetation that could protect the soil from hard rains and flooding. Overfishing is also common. These pressures are jeopardising the ability of the marshes to fulfill their important ecological and economic roles. The lake has been shrinking steadily over the past 20 years, and is today in danger of vanishing completely.

Lake Alaotra is also an important but increasingly threatened habitat for waterbirds, including the endangered Meller's Duck (*Anas melleri*). Two waterbird species endemic to the lake, the Madagascar Pochard (*Aythya innotata*) and the Alaotra Grebe (*Tachybaptus rufolavatus*, also known as Delacour's Little Grebe or Rusty Grebe), are critically endangered and possibly extinct.

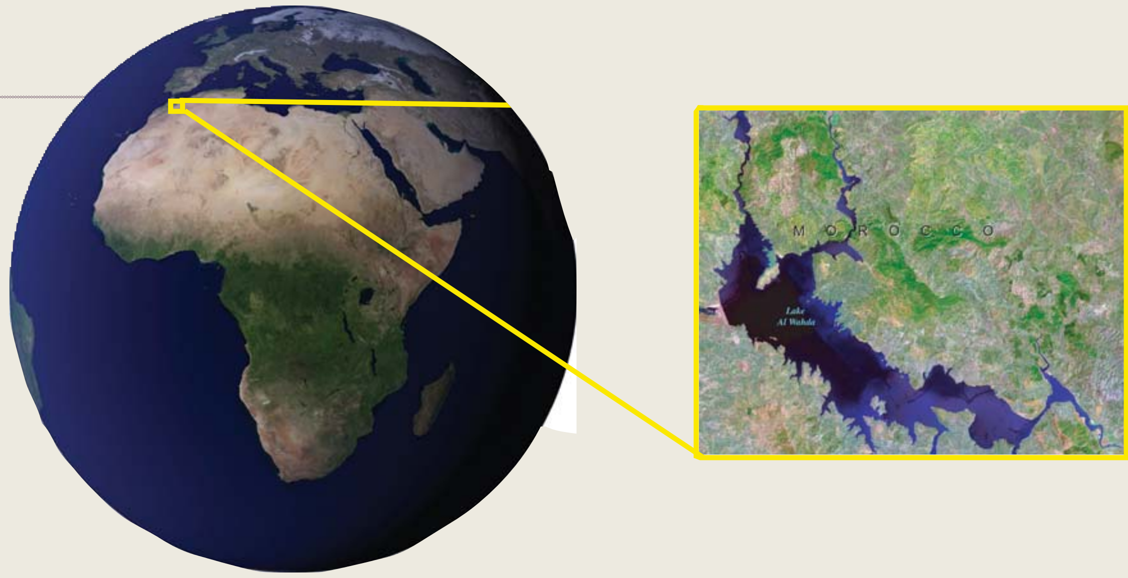
Floods in Central Madagascar



On the island of Madagascar, unusually heavy rains during the first week of March 2005, causing severe flooding across the central latitudes of the island. This pair of images from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra and Aqua satellites shows flooding over a wide area of the country (top two images) as well as a close-up of the flooding around Lake Alaotra (outlined in white) in the east-central part of the island. The image at left was captured on 21 February by Terra MODIS; the image at right was captured on 8 March by Aqua MODIS. Vegetation is bright green, water is shades of blue, and clouds are light blue.

Along the rivers flowing into the sea from the northwest (upper left) coast of the island, a dramatic widening of streams and small areas of standing water are noticeable in the later image (lower right). The lighter blue color likely indicates high amounts of sediment clouding the water. In the bottom two images, close-ups of Lake Alaotra show the extensive flooding of the lake, especially along the western and southern shores. According to news reports, several people were killed or injured, and thousands were left homeless as lakeside villages were flooded. Early estimates suggest that as much as 10 per cent of the region's rice crop may have been lost or degraded. (*Image courtesy the MODIS Rapid Response Team, NASA-GSFC-NASA-GSFC, NASA 2005b*)

Lake Al Wahda



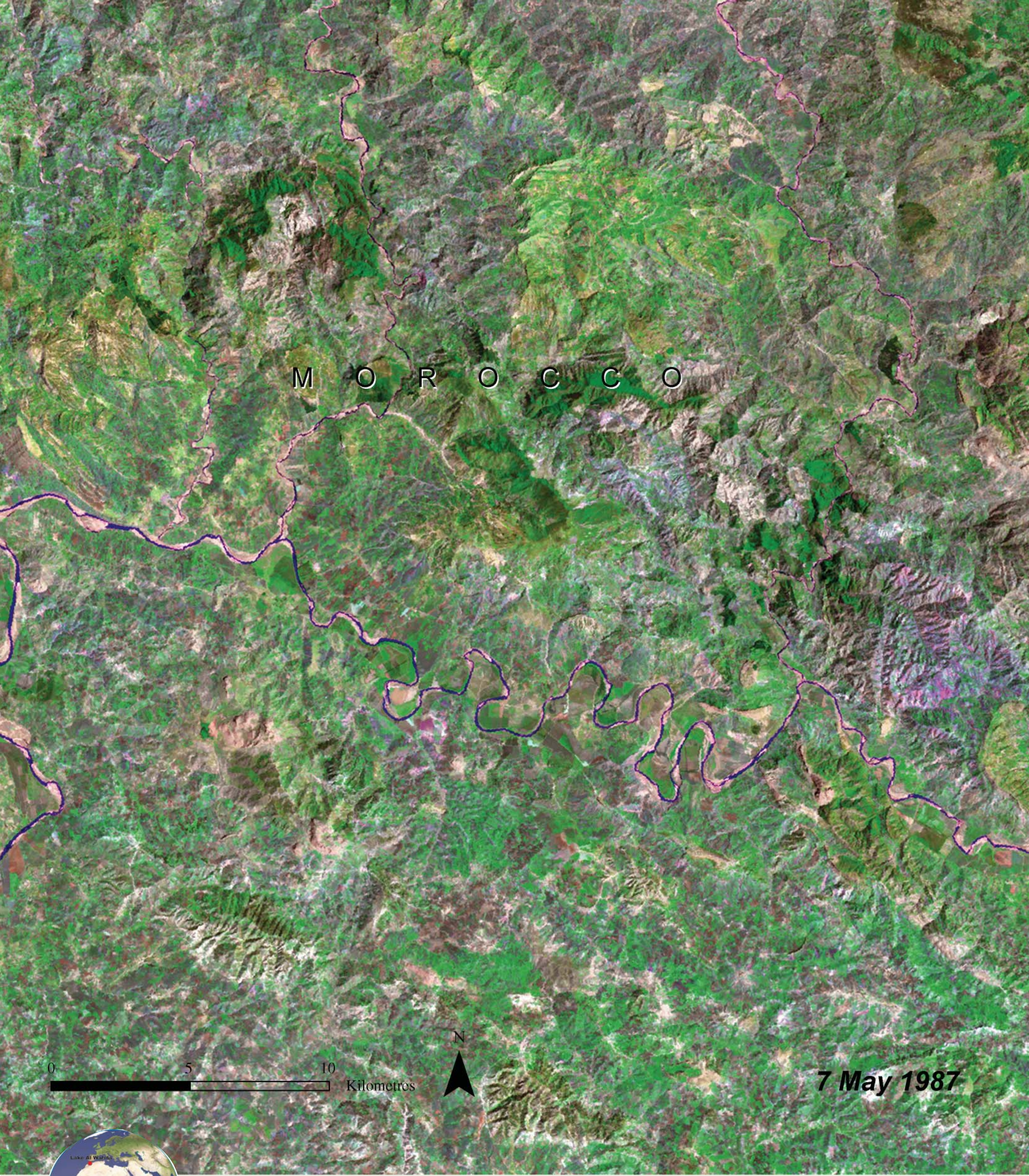
Morocco's Al Wahda reservoir is the largest in the El Abid Basin, with a capacity of 13 109 m^3 (17 146 cubic yards). It is used for irrigation, electric power generation and drinking water supply.

The entrance of the lake is situated to approximately 18 km (11 miles) upstream of the dam wall located in central Morocco. The El Abid Basin can be sub-divided into two sub-basins: the more important sub-basin (2 635 km^2 or 1 017 square miles) whose main tributary is the El Abid and the sub-basin drained by the Assif Melloul (2 030 km^2 or 783 square miles).

The snow-rainfall hydrological regime can be divided into two periods. The wet winter-spring season lasts from December to May when average monthly precipitation can reach 80 mm (3.1 inches), with average monthly temperatures varying between 10°C and 17°C (50°F and 63°F). The dry season lasts from June to October with an average monthly precipitation not exceeding 5 mm (0.2 inches) and average monthly temperatures between 17°C and 28°C (50°F and 82°F).

Long term hydrological records for Lake Al Wahda (1970–1988) demonstrate the annual and seasonal variability in discharge with winter and spring periods typically representing 87 per cent of the flow. The lake is also affected by pollution from the irrigation schemes around it and the increased agricultural run-off has caused an increase in water weeds. The lake also generates about a third of the electrical supply for Morocco. Built in 1954, it is one example of an artificial lake in Africa, which supports large irrigation schemes. However, proper management of water withdrawal must be put in place to support sustainable utilization of water from this lake (Cherifi and Loudiki 2002).

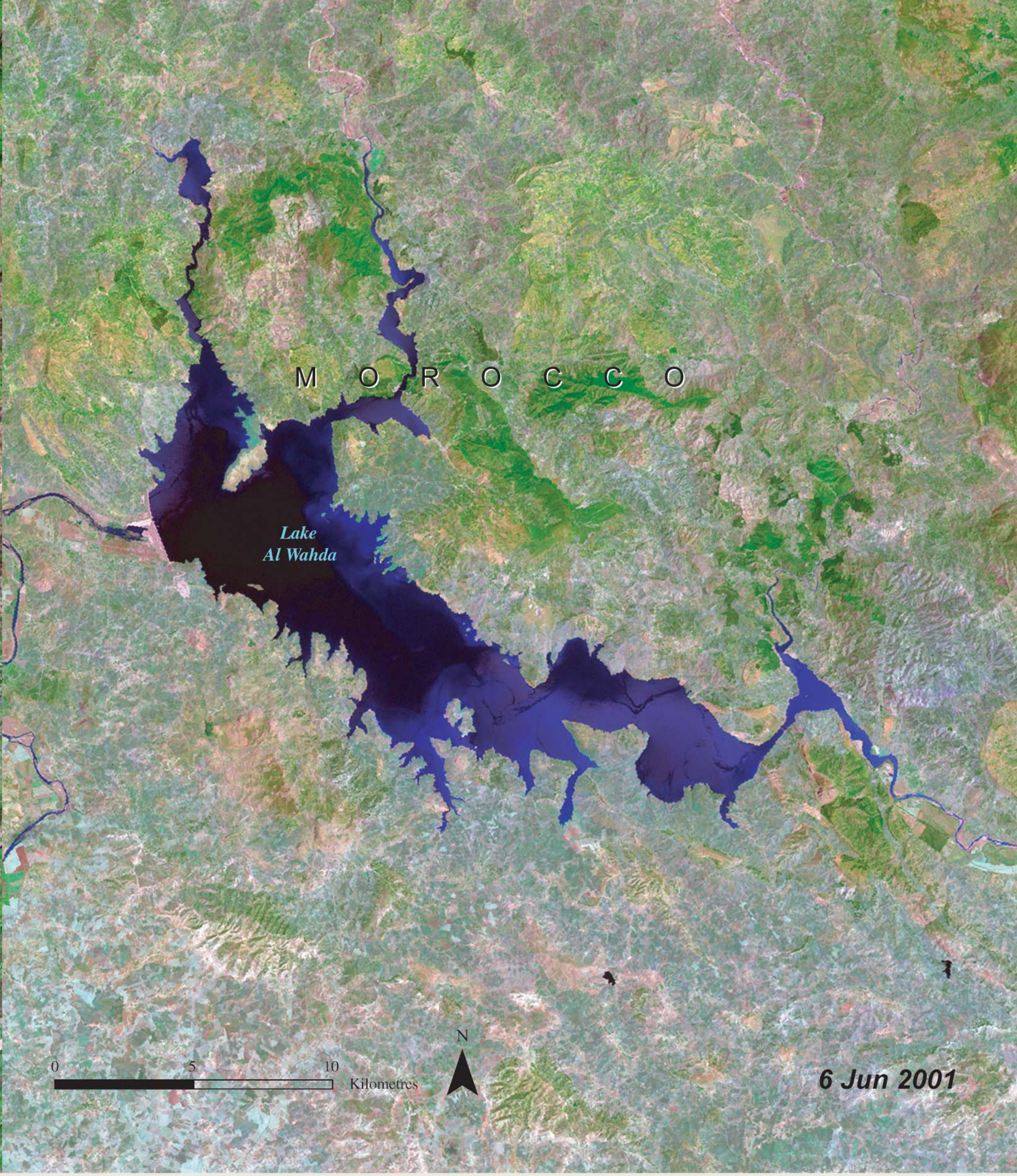
Riverbed in Atlas mountains, Morocco. *Jason Webber/UNEP/MorgueFile*



LAKE AL WAHDA

MOROCCO

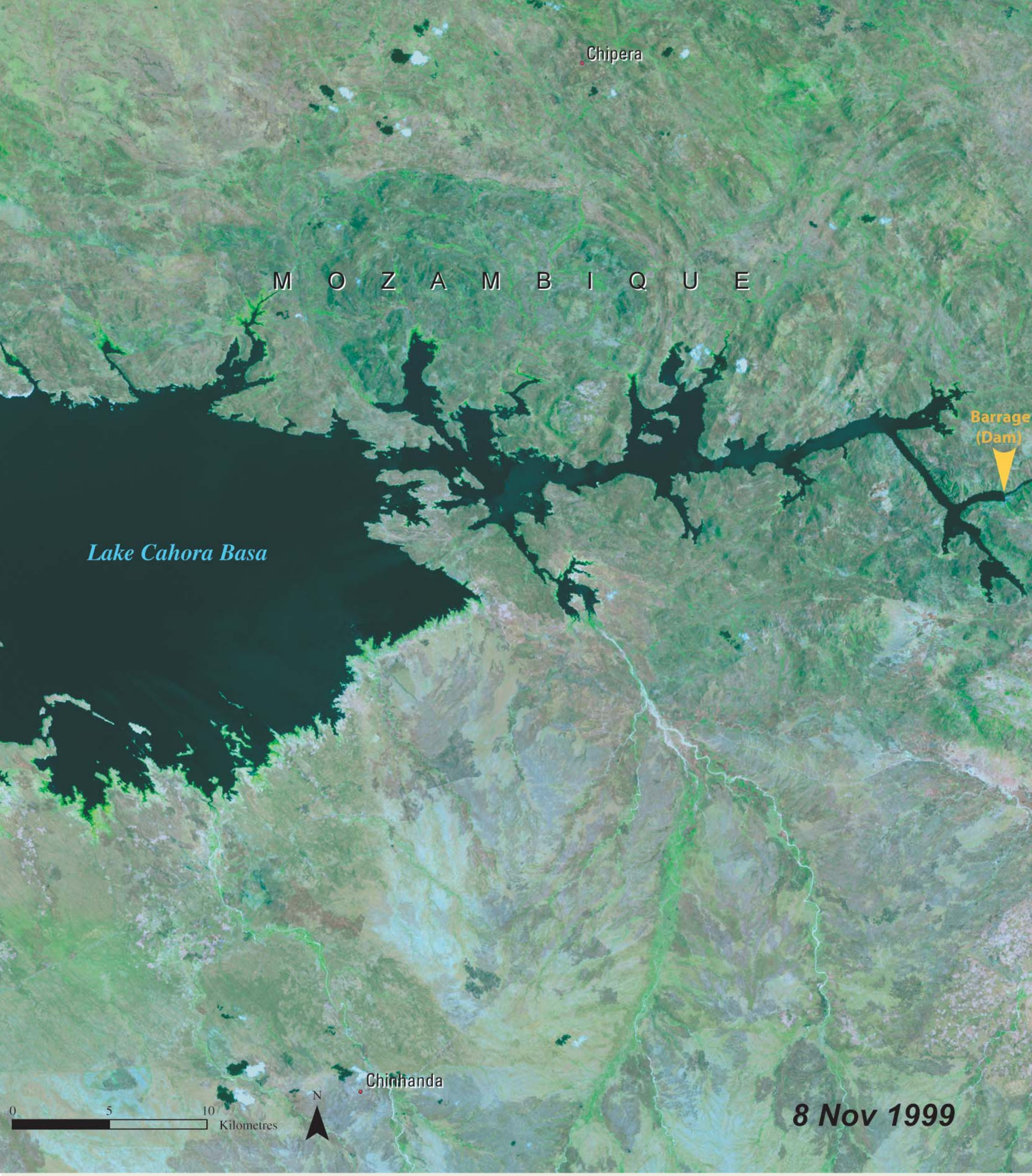
The center of the Kingdom of Morocco is occupied by the high Atlas Mountains which separate fertile coastal plains from inland pre-Saharan semi-arid areas. In Morocco,



the rain rate varies strongly from one region to the other, when going southward or eastward. To reduce the effects of that disparity, Morocco has adopted a policy for transferring water from regions with surplus towards regions with water deficits. The dam policy initiated at the beginning of the 1960s has had beneficial fallouts for social and economic development of the country. There are now 110 large dams in Morocco, with a storage capacity of 158 000 millions of m^3. These two satellite images illustrate the change in land cover before and after the Al Wahda reservoir was constructed.

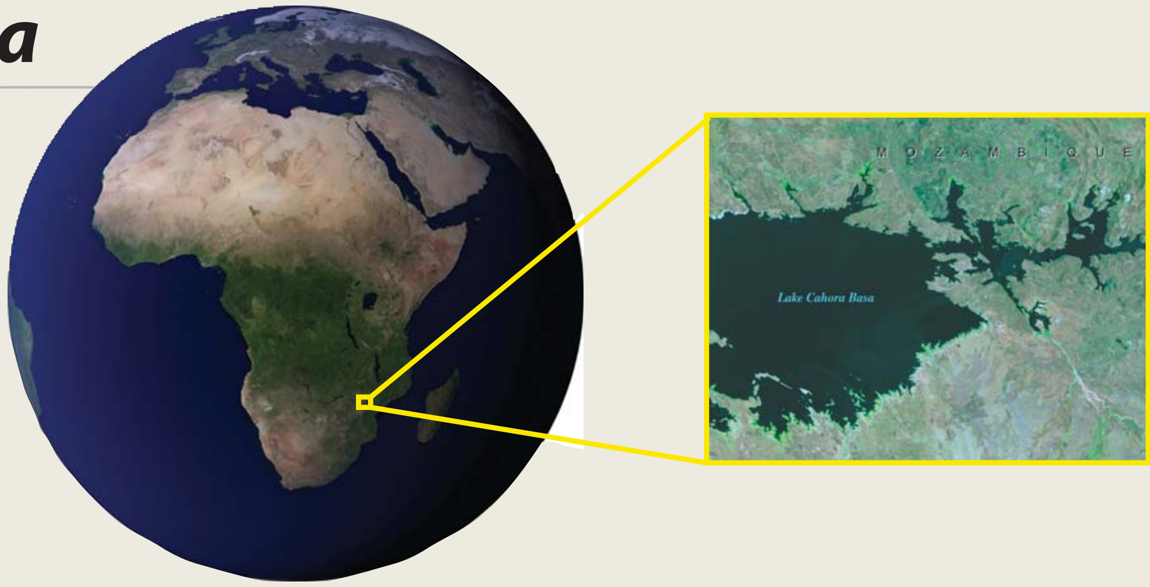
Lake Cahora Basa
Mozambique

Cabora Bassa Reservoir in Tete Province of Mozambique is the site of the country's largest dam on the Zambezi River. These satellite images show spectacular changes in the Zambezi riverine system over the past three



decades. The 1972 image shows the Zambezi River a few years before the Cahora Basa Dam was constructed, while the 1999 image shows part of the enormous dam and the lake. The eastern/right tip of the river is visible in both images, entering into a narrow gorge, which provides an obvious location for a power-producing barrage (dam) of this size. Although the construction of Cahora Basa was seen as a strategic move to meet the region's growing energy needs, it has also reduced the extent of annual flooding on the Zambezi River downstream—in turn reducing the size of the floodplains on which local communities grow their crops.

Lake Cahora Basa



Lake Cahora Basa is a human made reservoir in the middle of the Zambezi River in Mozambique, which is primarily used for the production of hydroelectricity. Created in 1974, this 12 m (39 ft) deep lake has been strategically built on a narrow gorge, enhancing the rapid collection of water and creating the pressure required to drive its giant turbines. The lake's dam has a production capacity of 3 870 megawatts, making it the largest power-producing barrage on the African continent.

After the construction of Cahora Basa Dam, its water level held constant for 19 years, resulting in a near-constant release of 847 m^3 (1 108 cubic yards) over the same period. Observations before and 20 years after the dam's impoundment, however, reveal the following negative impacts, some of which may also have been caused by other dams on the river (e.g. Kariba), as well as the effects of the country's 20-year civil war—but nearly all of which have been directly influenced by the over-regulation of a major river system:

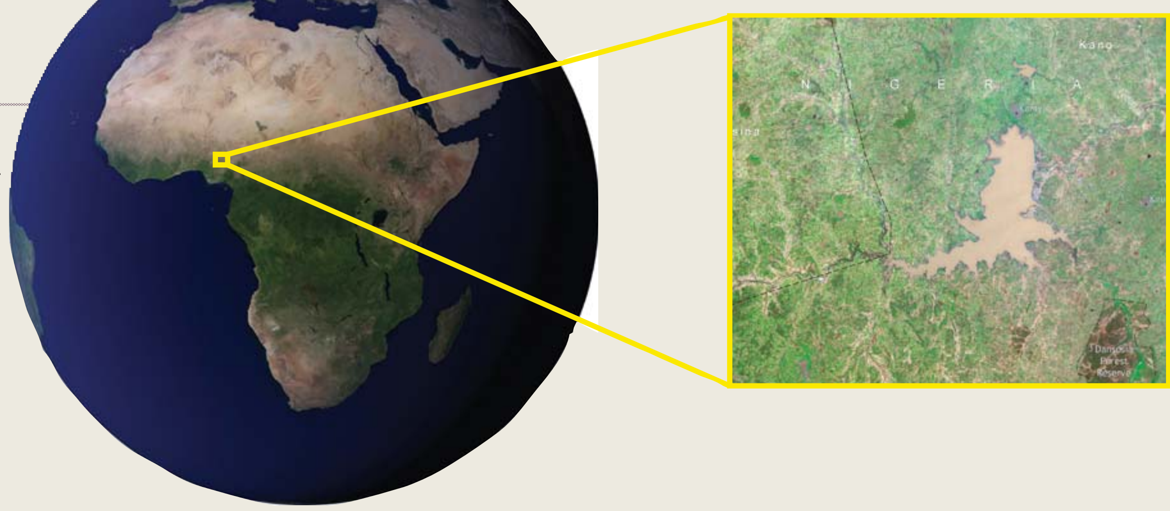
- Many of the mangroves in the delta have dried out and died back
- The community structure of the floodplain vegetation has changed, with a substantial increase in trees
- Meanders and oxbows, once a major feature of the floodplain, have become clogged with reeds and trees
- Productive, flood-dependent grasslands have been depleted of grasses, the favoured food of herbivorous mammals
- Large mammals, including the once-abundant buffalo, have almost disappeared from the delta
- The abundance of waterfowl has declined significantly
- Floodplain 'recession agriculture' has declined significantly
- Vast vegetated islands have appeared in the river channel, many of which have been inhabited by people
- Dense reeds have lined the sides of the river channels
- Erosion of the coastal zone has increased, probably more as a result of the release of sediment-hungry water from Cahora Basa Dam than of changed flow patterns
- Water levels in the lower Shire River, the largest tributary of the Zambezi downstream of the dam, have dropped, prohibiting navigation of this river (Chenje & Jonson 2002).

The majority of power generated by the Cahora Basa Dam is used in Mozambique, with some sold to South Africa and Zimbabwe. Lake Cahora Basa can actually be seen as a 'powerhouse' of Southern Africa, although damage to the generators during the civil war in 1972 has kept the plant from functioning at its originally anticipated levels. The construction of the dam has been opposed by communities down the Zambezi River, where it reduced the annual flooding on which they rely for cultivation. The Zambezi used to overflow its riverbanks, creating rich floodplains ideal for cultivation. However, the Cahora Basa has proved important as the major source of hydroelectrical power in Southern Africa. In 2005, the Southern African Development Community (SADC) member states agreed on a regional power generation initiative, which aims to boost the power supply generated by Cahora Basa, as well as building a second plant 60 km (37 miles) downstream (SADC Today 2005).

Reservoir behind the Cahora Basa Dam

Unknown/UNEP/The Water Page

Challawa Gorge Reservoir



Challawa Gorge Dam on the Challawa River in Nijeria is designed to release water into the Hadejia River for subsequent storage behind the barrage of the Hadejia Valley Project (Thompson 2005). The dam was built for securing supplies of potable water and irrigation for agricultural land around the state capital Kano.

With 1 000 million m^3 (1 308 million cubic yards) capacity, the Challawa Gorge Dam is the second-largest dam supplying water to the city of Kano. The dam is 7.8 km (5 miles) long and 42 m (138 ft) high, and required 5.1 million m^3 (6 671 million cubic yards) of filling material. The reservoir thus created has an area of 100 million m^2 (120 million square yards). The project essentially consisted of a homogeneous dam of decomposed rock. Core drilling performed at the dam's center, however, detected the existence of various seams in the underlaying rock which made it necessary to construct an anti-seepage grout curtain. The dam also includes construction of a 30 m (98 ft) intake tower, intake main and a 600 m (1 967 ft) long spillway. Since work on the dam commenced as far back as 1977 and was interrupted in 1987, considerable erosion damage occurred to the structure. This made it necessary to scratch off the damaged layers prior to excavation and fill-work. After 26 months of construction, the dam was completed (Julius Berger Nigeria Plc n.d.).

After completion, the Hadejia river system—one of the major water sources for the Hadejia-Nguru Wetlands located in the Lake Chad basin—became more than 80 per cent controlled by the Tiga and Challawa Gorge dams. These two dams feed the Kano River Irrigation Project, the Hadejia Valley Irrigation Project and the Kano City Water Supply (KCWS). Earlier agreements to guarantee certain amounts of flow from the Hadejia river system for the downstream communities living in the floodplains, who are dependent on flood recession agriculture, have so far not been implemented (IUCN 2004).

In this arid region, the fast-growing population and its economic activities demand a large share of the water resources. Demand is approximately 2.5 times higher than available water. Decreasing rainfalls, possibly due to climate change have already reduced flows in the basin.

The result is growing tension between water users and regions. This is already leading to conflicts. Illustrations include the dogged opposition of the downstream states of Yobe and Borno to the construction of Kafin Zaki Dam, and the incessant conflicts between farmers and pastoralists over access to water.

Action is being taken to address these issues. The Nigerian National Council on Water Resources established a Hadejia-Jama'are-Komadugu-Yobe Coordination Committee in 1999. Also, the Lake Chad Basin Commission (LCBC) is implementing a GEF-supported programme for the integrated management of Lake Chad and associated river systems (FAO 1997).

Hadejia-Jama'are River Basin, Northern Nigeria

In Northern Nigeria, an extensive floodplain exists where the Hadejia and Jama'are Rivers converge. The floodplain provides essential income and nutrition benefits in the form of agriculture, grazing resources, non-timber forest products, fuelwood and fishing for local populations. It also helps to recharge the regional aquifer which serves as an essential groundwater source. However, in recent decades the floodplain has come under increasing pressure from the construction of the Tiga and Challawa Gorge dams upstream. The maximum extent of flooding has declined from 300 000 ha in the 1960s to around 70 000 to 100 000 ha more recently and there are plans for a new dam at Kafin Zaki.

Economic analysis of the Kano River Project, a major irrigation scheme benefiting from the upstream dams and traditional use of the floodplain, showed that the net economic benefits of the floodplain (agriculture, fishing, fuelwood) were at least US$ 32 per 1000 m^3 of water (at 1989 prices). However, the returns per crops grown in the Kano River Project were at most only US$ 1.73 per 1000 m^3 and when the operational costs are included, the net benefits of the Project are reduced to US$ 0.04 per 1000 m^3.

The Kadawa River Project in the northern state of Kano includes a short-range scheme for safeguards against further drought. Here farmers are being taught new irrigation techniques

B. Imevbore/UNEP/FAO

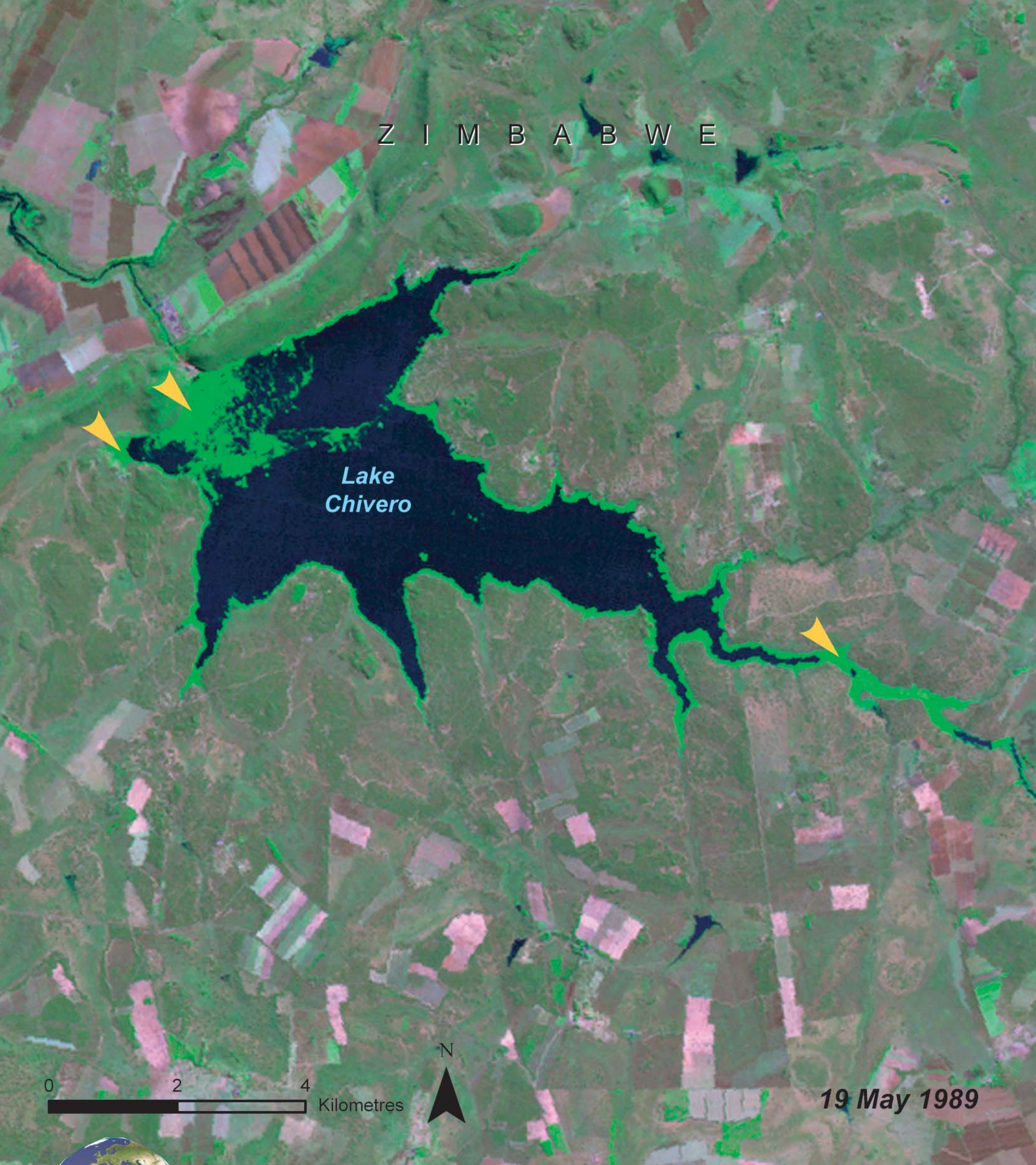
A combined economic and hydrological analysis was conducted to simulate the impacts of these upstream projects on the flood extent that determines the downstream floodplain area. The economic gains of the upstream water projects were then compared to the resulting economic losses to downstream agricultural, fuelwood and fishing benefits. Given the high productivity of the floodplain, the losses in economic benefits due to changes in flood extent for all scenarios are large, ranging from US$2.6-4.2 million to US$23.4-24.0 million. As expected, there is a direct trade-off between increasing irrigation upstream and impacts on the floodplain downstream. Full implementation of all the upstream dams and large-scale irrigation schemes would produce the greatest overall net losses, around US$20.2-20.9 million.

These results suggest that the expansion of the existing irrigation schemes within the river basin is effectively "uneconomic." The introduction of a regulated flooding regime would substantially reduce the scale of this negative balance, to US$15.4-16.5 million. The overall combined value of production from irrigation and the floodplain would, however, still fall well below the levels experienced if the additional upstream schemes were not constructed (UNEP n.d.a).

Challawa Dam
Nigeria

The Challawa Gorge Dam, completed in 1993, is the second largest of the 23 dams along the rivers in Nigeria's Hadejia-Jama'are River Basin. Although the dam has improved the water supply for irrigation,

it has also ruptured the fragile natural balance along this stretch of water. When it rains heavily, the river can break its banks and flood farms and land upstream from the dam. Areas downstream, meanwhile, do not receive enough water to maintain the wetlands bordering the river. Under these conditions, the soil dries out and overgrazing occurs, which in turn leads to wind erosion of the topsoil. These satellite images provide a comparison of the area before and after the dam's construction. The 1999 image shows the degree to which flooding upstream impacts the landscape, and how the lack of water downstream negatively affects riverine wetlands and cropland. The colour of the water in the flooded area is also indicative of high-sediment content.



Lake Chivero
Zimbabwe

Lake Chivero holds about 250 000 million litres (264 000 million quarts) of water and is approximately 26 km^2 (10 square miles) or 2 632 ha. Beginning in the mid 1980s, the

lake became progressively eutrophic, after a recovery period from a previous eutrophication phase in the mid 1960s. While these two images suggest an overall reduction of the presence of invasive water weeds in Lake Chivero between 1989 and 2000, there is evidence that this remains a persistent problem. The weeds show up as green strands along the edges of the lake. Like most of Zimbabwe's freshwater bodies, freeing Lake Chivero from the weed menace will require long-term eradication strategies, continuous monitoring, and a comprehensive integrated water basin management programme.

Lake Chivero

In recent years, Zimbabwe has instituted major control programmes to tackle the negative effects of aquatic weed infestations in its rivers, wetlands and other freshwater bodies. The problems have proved hard to solve. Three free-floating weeds—Water Lettuce (*Pistiastratiotes*), the Water Carpet, Azolla (*Azolla azolla*), and Water Hyacinth (*Eichhornia crassipes*)—are the major culprits, with the latter creating by far the biggest problem. Aquatic weeds disrupt domestic and industrial water supplies, as well as fishing activities, irrigation schemes, hydroelectric power generation, and water-borne recreational activities. Eradication strategies can also cause additional problems, with the use of herbicides such as 2,4-D linked to serious health risks, including cancer, and the use of some non-endemic biological predators disrupting fragile ecological balances.

Further investigations are required to identify the most effective control strategies for combating Zimbabwe's water hyacinth infestations. This robust, fast-growing weed has a large number of fibrous roots, which are highly adapted to absorb nutrients in eutrophic waters. Either free-floating or rooted in shallow waters, it forms dense mats, which can weigh as much as 25 kg/m^2 (55 lbs/m^2)or 2500 t/ha. The hyacinth thrives in nutrient-rich waters, particularly those adjoining agricultural lands, such as Lake Chivero. In such waters, the plant's growth rates can reach a staggering five per cent per day. Water hyacinth propagates itself through vegetative means and through seeds, which can remain viable for up to 15 years (Gurure 2000). This means that, even if the weed is totally removed, possibilities for regeneration still exist through its seeds. Therefore, long-term eradication strategies need to include continuous monitoring programmes.

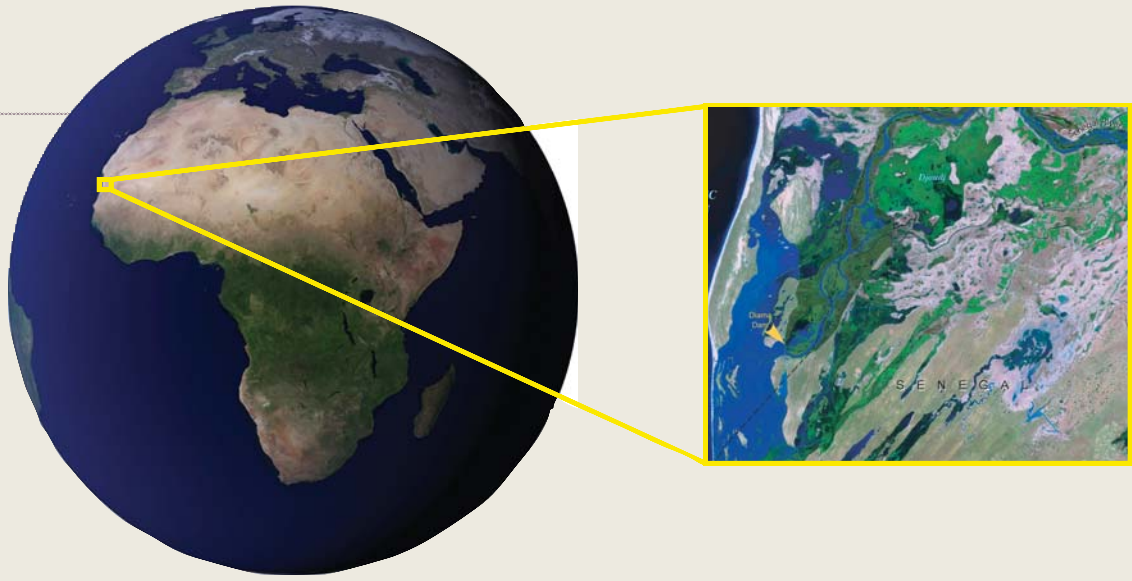
Table 3.3: Historical trends in phosphorus loading to Lake Chivero

Parameter	*1967*	*1978*	*1996*
P- load, tons yr^{-1}	288	39.6	350
Mean P concentration in inflow mg l^{-1}	2.25	0.13	1840
Conductivity mS cm^{-1}	160	120	800

UNEP (n.d.b)

Water hyacinth *Ron Bergeron/UNEP/MorgueFile*

Lake Djoudj



Lake Djoudj is about 60 km (37 miles) from Senegal's regional capital of St. Louis, close to its northwestern border with Mauritania. The lake is part of the Djoudj Sanctuary, a 16 000-hectare wetland in the Senegal River delta. The sanctuary is composed of lakes surrounded by streams, ponds and backwaters. The lakes are large, open expanses of brackish water with no vegetation, whereas the creeks and ponds are relatively enclosed and bordered by fairly thick vegetation. In 1977, the sanctuary was added to the Ramsar Convention's list of Wetlands of International Importance. Since 1981, UNESCO has also listed it as a World Heritage Site.

Nature tourism is the predominant activity within the lake's vicinity. The local people also gather cattails (*Typha australis*) and grass (*Sporobolus robustus*) to make mats. Stray domestic animals pose a threat to the wildlife in the area. Navigable waterways have become overgrown and choked because of the commissioning of the Diama Salt Dam on the Senegal River 20 km (12 miles) downstream (23 km or 14 miles upstream from the river's mouth) in 1986. The dam's primary function is to prevent saltwater intrusion from the Atlantic Ocean; it is closed during the dry season from November to June, and gradually opened during the rainy season, generally around July. The Diama Dam has improved river navigation, and a series of dikes were also built to protect the banks along the river downstream from the dam.

The Djoudj Sanctuary forms a living but fragile reserve for an estimated 1.5 million resident waterbirds, including the Purple Heron, the African Spoonbill, the Great Egret, the Cormorant, and the Great White Pelican (*Pelecanus onocrotalus*), which has a large breeding colony numbering 15 000 birds. The Arabian Bustard (*Ardeotis arabs*), a highly endangered species, is starting to make occasional appearances. Almost 3 million birds from more than 350 species visit the sanctuary each year.

Over the past 30 years, however, agricultural activities have taken a heavy toll on this vital wetland. Before 1965, flood-based agriculture was dominant in the Djoudj basin. Then, as a result of a hydro-agricultural improvement programme instituted by the state-run Delta Improvement and Exploitation Society (SAED), irrigation-based agriculture took over. Since the SAED's withdrawal and the introduction of an agricultural loans system, individual farmers' development groups have overseen the expansion of small-scale irrigation schemes—and increasing freshwater extraction from the Senegal River.

Giant Salvinia

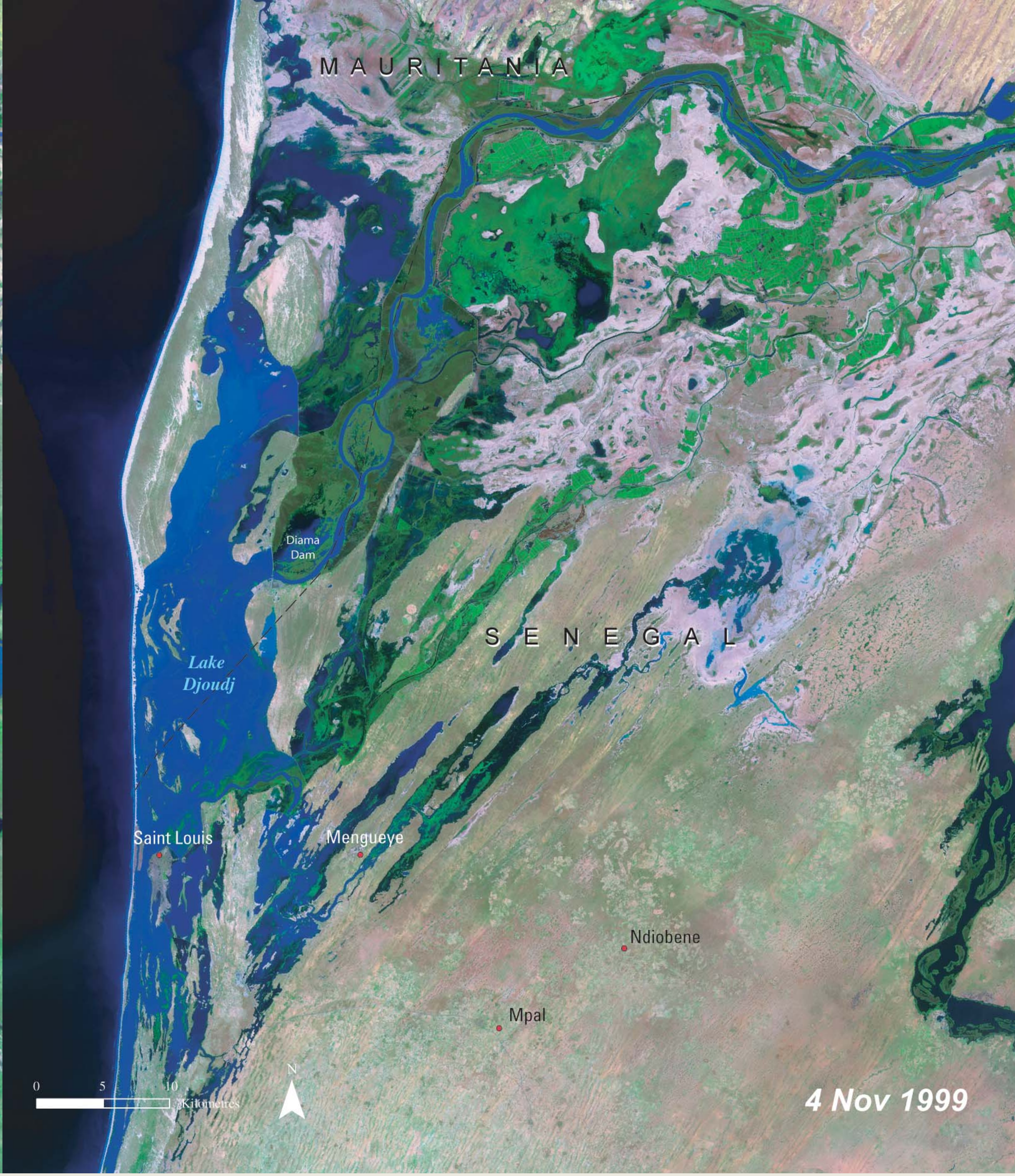
Giant salvinia (*Salvinia molesta*) is considered to be one of the world's worst aquatic pests. It is an aggressive, competitive species that can impact aquatic environments, local economies, and human health. In favorable environments plants can be expected to double within about a week and excessive growth of giant salvinia can result in complete coverage of water surfaces. This degrades natural habitats in several ways by competing with and shading desirable native vegetation. Mats of floating plants prevent atmospheric oxygen from entering the water while decaying salvinia drops to the bottom, consuming dissolved oxygen needed by fish and other aquatic life. Animal habitat is most noticeably altered by the loss of open water. Migrating birds may not recognize or stop at waterbodies covered with giant salvinia. Giant salvinia clogs water intakes, interfering with agricultural irrigation and electrical generation, and the floating mats provide excellent habitat for disease carrying mosquitoes. Salvinia reproduces so rapidly that infestations rapidly become impossible to eradicate. The mats have been reported to be up to 91 cm (3 ft) thick which hinders management by chemical control (WAPMS, 2006).

Salvinia molesta — *© Barry Rice/sarracenia.com*

Giant Salvinia first appeared in the Senegal River delta in September 1999 and has since spread to many bodies of water and water basins, disturbing the existing biological equilibrium and threatening human health as well as the overall ecological and economic characteristics of the delta. This invasive species directly threatens the Parc National des Oiseaux du Djoudj (Djoudj Sanctuary), included in the Montreux Record in 1993 and formerly placed on the list of endangered UNESCO World Heritage sites in 1984, and the Parc National du Diawling in Mauritania (UNESCO, 2006).

Lake Djoudj
Senegal

Situated in the Senegal river delta, the Djoudj Sanctuary is a wetland of 16 000 ha, comprising a large lake, referred to as Lake Djoudj in this publication, surrounded by streams, ponds and backwaters. These two



images show the Djoudj Sanctuary before and after the construction of the Diama Dam. The image from September 1979 shows the impact of drought on the Djoudj Sanctuary, while the image from November 1999 shows rejuvenation of the sanctuary wetlands due to the significant floods of that year. The two images vividly depict the impact of climate variability on the Djoudj Sanctuary—and demonstrate the broader need for close monitoring of the impacts of climate variability and climate change on lake environments.

Lake Ichkeul
Tunisia

Lake Ichkeul is the last remaining lake in a chain that once extended across North Africa. The construction of three dams on rivers supplying Lake Ichkeul and its marshes has cut off almost all inflow of fresh water, caus-

ing a destructive increase in the salinity of the lake and marshes. The 1972 image shows the three feeder rivers supplying the lake before they were dammed. The 2000 image shows the location of the dams (yellow arrows) built to increase irrigation and water supplies to local communities. However, the decreasing water discharge into the lake caused by the damming lead to prolonged drought of the surrounding marshlands. Changes to the prevalent vegetation and other serious ecological changes have inevitably led to a decrease in the number of birds using the lakeshores as a breeding site.

Lake Ichkeul

Lake Ichkeul is the only natural lake left in Tunisia, and the sole survivor of a chain of lakes that once extended across North Africa. The lake and its surrounding marshes are an important stopover for hundreds of thousands of migrating waterbirds, including several species of geese and ducks, storks, coots, flamingoes, and the globally threatened White-headed Duck (*Oxyura leucocephala*). All stop to feed and nest here. But recent human changes to the lake's ecology, including the damming of three of its main feeder rivers, have resulted in a significant decline in the number of birds using Lake Ichkeul as a breeding site.

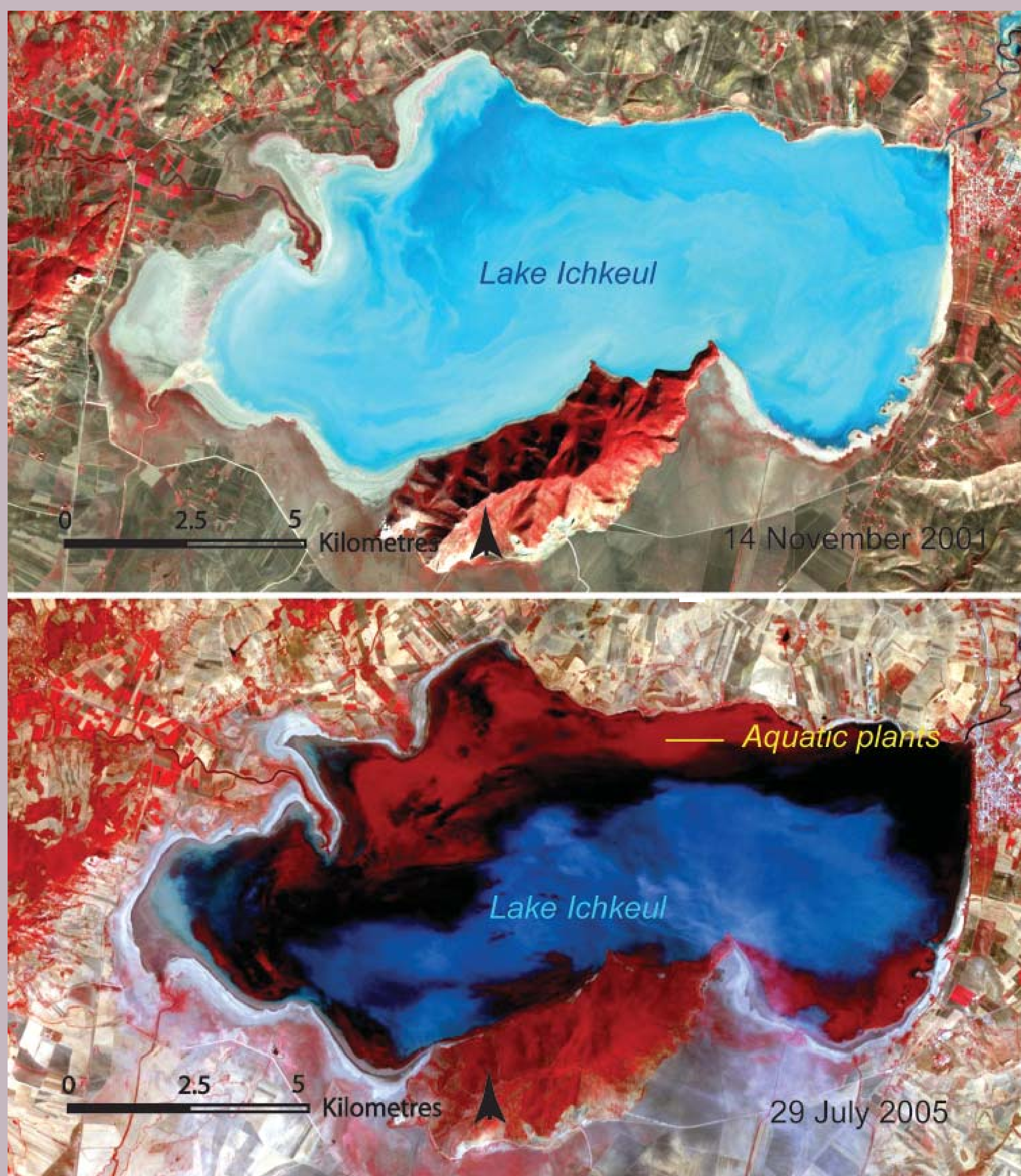
Ichkeul sits in an endorheic basin—in other words, it is a lake with no outlet. During the dry summer months, it becomes progressively shallower and more saline as a result of evaporation and salty inflows from the neighbouring Bizerte Lagoon, to which it is linked by canal. Between October and March each year, the lake receives runoff from winter rains via six inflow channels, or "oueds," which raises its levels and reduces its salinity (which averages about 13.5 per cent). However, over the past two decades, the Tunisian Government has partially implemented plans for damming all of the oueds that feed the lake—leading to a prolonged drought of the surrounding marshlands.

Ichkeul National Park

In northern Tunisia near the shore of the Mediterranean Sea, the lake and wetlands of Ichkeul National Park are an important stopping-over point for hundreds of thousands of migrating birds each year. Among the lake's visitors are ducks, geese, storks, and pink flamingoes. The park is on the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) list of World Heritage sites, and since 1996, the park has also been on the group's List of World Heritage Sites in Danger. Dam construction on the lake's feeder rivers has produced major changes to the ecological balance of the lake and wetlands.

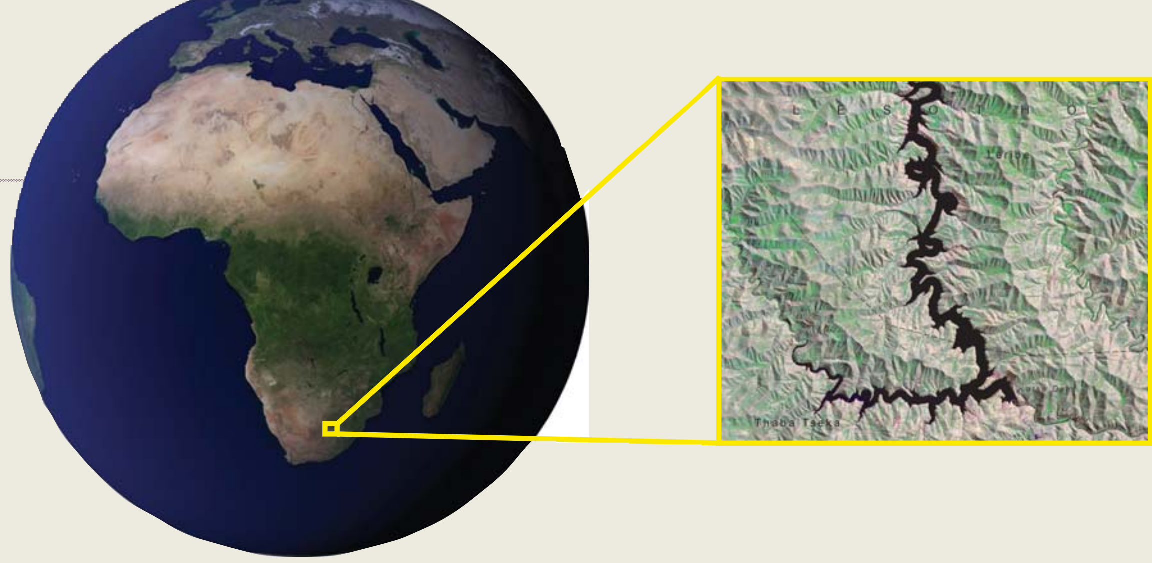
The pair of satellite images shows changes in the lake level and aquatic vegetation between 14 November 2001 (top), and 29 July 2005 (bottom). Vegetation appears red, bare or thinly vegetated ground is tan, and water is blue. Although the lake level is higher in 2005 than in 2001, a large part of the lake appears red due to the presence of aquatic plants. Because dams have sharply reduced the freshwater inflow to the lakes and marshes, reed beds, sedges, and other fresh-water plant species have been replaced with salt-loving plants. These changes have produced a sharp reduction in the migratory bird populations, which depended on the mix of plants that used to exist.

According to the UNESCO Website, the Tunisian government has undertaken some steps to retain freshwater and reduce salinity, but some reports from the World Conservation Union suggest that the salinity has already become excessively high and the possibility for rehabilitation may be rapidly disappearing (NASA 2005c).



The large images each cover an area of 11.4 by 20.0 kilometers, and they are centered near 37.1 degrees North, 9.7 degrees East.

Lesotho Highlands Water



The Lesotho Highlands Water Project (LHWP) is bi-national, multi-purpose undertaking between the Kingdom of Lesotho and the Republic of South Africa. It is one of Africa's largest ever water transfer projects as well as the largest ongoing bi-national construction project on the continent. The project consists of five proposed dams, 200 km (124 miles) of tunnels blasted through the Maluti Mountains, and a 72 megawatt hydropower plant that will supply power to Lesotho. Construction began in 1984 with the first dam, Katse, which was finished in 1998. Mohale, the second dam, began impoundment in Novenmber 2002 and reached over-spill 13 February 2006, indicating that the reservoir was at full capacity. The entire project is expected to cost US$8 000 million by the time of its completion in 2020 (South Africa Info 2004).

The Lesotho Highlands Water Project lies within the summer rainfall area of Southern Africa where more than 85 per cent of the annual rainfall occurs in the seven months from October to April. The Lesotho Highlands—with its high level of rainfall and high basalt surface area of the Maloti mountains—is an outstanding catchment area. Water originating in the mountains is characterised by good chemical quality and low sediment content. Estimates by the LHWP of the natural mean annual run-off at the sites of four dams are in Table 3.4. Although the mountain region of Lesotho constitutes only five per cent of the the total catchment of the Senqu/Orange river, it provides about 50 per cent of the total catchment run-off.

The project also aims to address the needs of South Africa's rapidly growing Gauteng province. Home to 40 per cent of South Africa's population, it generates almost 60 per cent of the country's industrial output and 80 per cent of its mining output. The region's main water source, the Vaal river, is not able to meet current demands. With the completion of the latest building phase many of Gauteng's water problems will be solved for the immediate future. The dam is expected to help rejuvenate the Vaal River.

Critics of the controversial project point to a number of problems that include the dramatic changes of the formerly remote mountain communities of the Lesotho Highlands; the moving of 20 000 people into the project region; the introduction of AIDS by the work force; and significant increases in prostitution and alcoholism. Environmental concerns include the prospective loss of thousands of hectares of arable or grazing land, downstream reductions in wetlands habitat, less water available downstream for people and wildlife, reductions in fisheries, and cessation of natural flooding (Byers 2002).

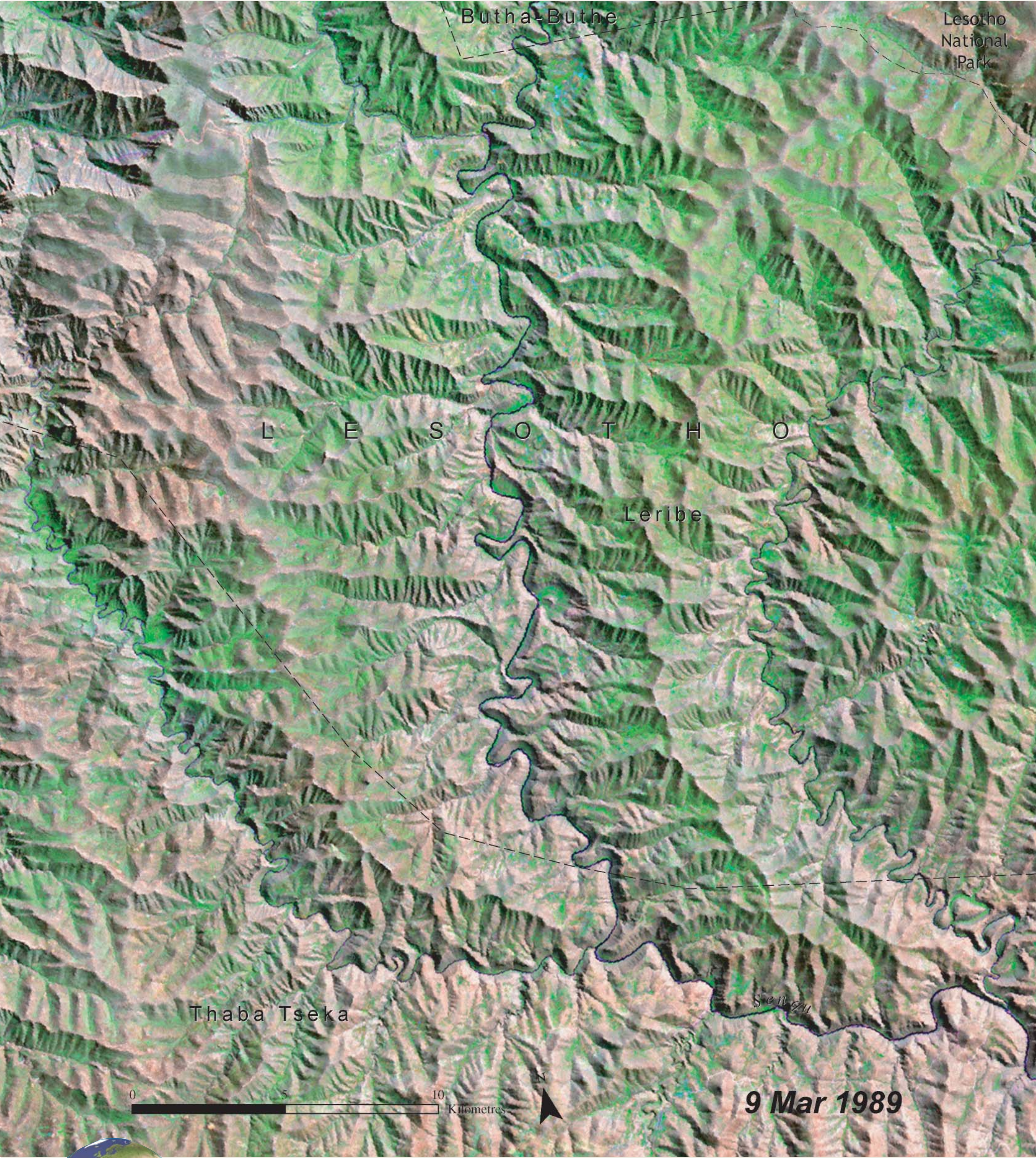
Table 3.4: Annual natural mean run-off at four dam sites

Dam	River	Catchment Area km^2	Mean Annual hm^3	Run-Off m^3/s
Katse	Malibamats'o	1 860	656	20.8
Mohale	Senqunyane	938	367	11.6
Mashai	Senqu	7 977	1 569	49.7
Tsoelike	Senqu	10 375	1 891	59.9

Source: LHWP n.d.

Katse Dam, Lesotho

Unknown/UNEP/The Mountain Club of South Africa



Lesotho Highlands
Lesotho

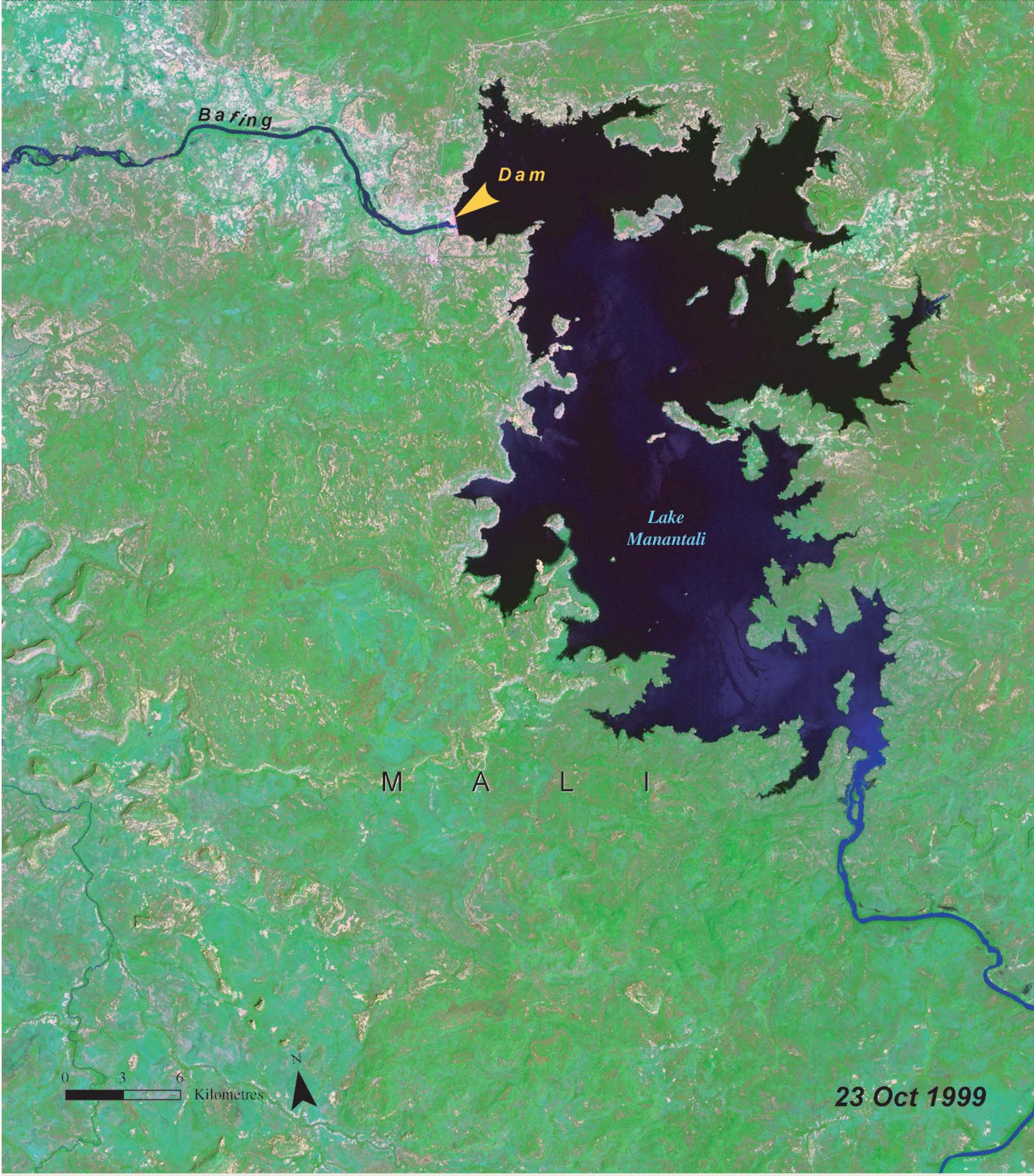
The Lesotho Highlands Water Project is one of the largest infrastructure projects ever undertaken on the African continent. The project is designed to divert water from Lesotho's

Maloti Mountains to South Africa's urban and industrial Gauteng Province, while providing impoverished Lesotho with hydroelectric power and profits from the sale of water. An 82 km (51 mile) water transfer-and-delivery system is already in place, and four major dams are at various stages of completion in key locations. However, many questions remain unanswered about these dams' social and environmental impacts. The first, the Katse Dam on the Orange River, closed its gates in 1995, creating an enormous reservoir—along with serious social and environmental concerns. These two images provide a comparison of the area before and after the Katse Dam's completion, with its full extent and effects clearly visible in the 2001 image.

Lake Manantali

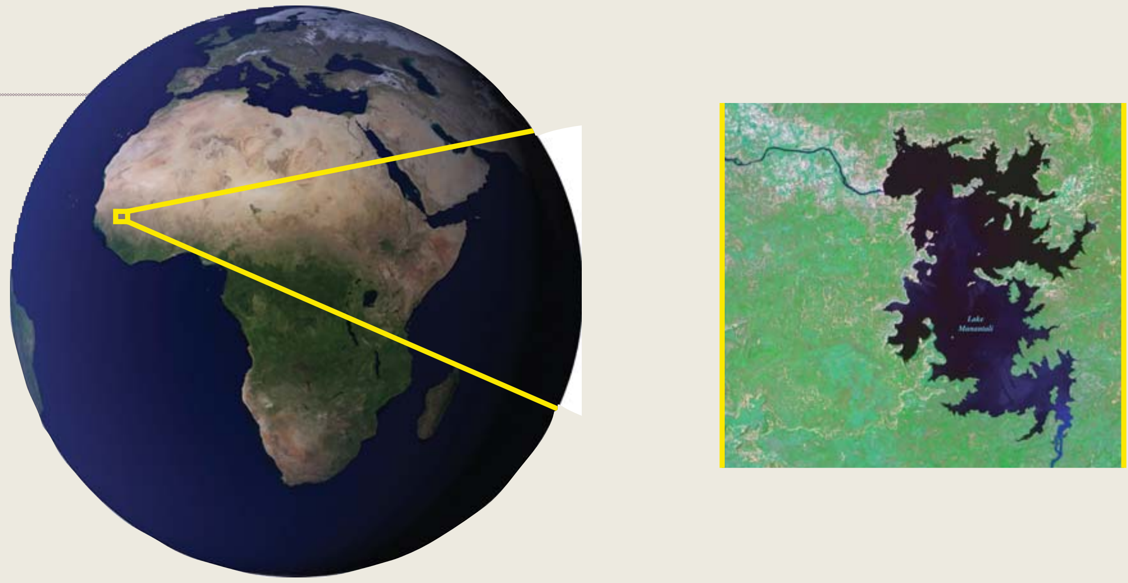
Mali

Lake Manantali on the Bafing River contributes to power generation and irrigation in the surrounding areas. These two images illustrate some of the physical changes that have occurred in the Bafing riverine system



since the construction of the Manantali Dam, which began in 1981. The 1977 image shows the original meandering nature of the Bafing River, which annually deposited rich fluvial soils used by local people for growing sorghum and other crops on its floodplains. The 1999 image shows the extent of irrigated agriculture in the surrounding area, which rapidly expanded after the dam was filled between 1986 and 1988. The increase in water quantity is also clearly visible in 1999 image.

Lake Manantali



Built in the early 1980s on the Bafing River, one of the three main tributaries of the Senegal River, the Manantali Dam was originally intended to power a 200 MW hydroelectric station, with 1 300 km (808 miles) of transmission lines serving the capital cities of Bamako (Mali), Nouakschott (Mauritania), and Dakar (Senegal). Measuring 1 460 m (4 790 ft) long and 65 m (213 ft) high, the dam created a reservoir with a storage capacity of 11.3 million million m^3 (14.8 million million cubic yards) and a surface area of 477 km^2 (184 square miles) (IRN 1997).

Built under the auspices of the Organization pour la Mise en Valeur du Fleuve Senegal (OMVS), the dam was designed to generate hydropower, to irrigate an area of 3 750 km^2 (1 448 square miles), and to expand navigation between the cities of St. Louis and Kayes. At US$25 000-40 000 per hectare, however, the construction of the irrigation networks fed by the reservoir proved to be more expensive than originally planned. Instead of 3 750 km^2 (1 448 square miles), only about 1 000 km^2 (386 square miles) of land has been brought under irrigation so far. With irrigation, the traditional sorghum crop has been replaced by rice. Even for the richer farmers, however, irrigation has proved to be more cumbersome and less productive than envisaged, with the lack of electric power necessitating the purchase of expensive diesel to run their pumps.

The Manantali Dam has not just affected local patterns of agriculture, but has led to violent conflicts at both national and regional levels. When the dam project opened new prospects of commercial agriculture, land legislation in Mauritania was rewritten in order to abrogate the land rights of black peasants who had lived along the riverbank for generations. In 1989, the killing of Senegalese farmers by Mauritanians triggered an outbreak of ethnic violence that saw hundreds of people killed and some 70 000 Mauritanian peasants expelled to Senegal. The two countries' militaries engaged in armed skirmishes, and nearly went to war over the conflict.

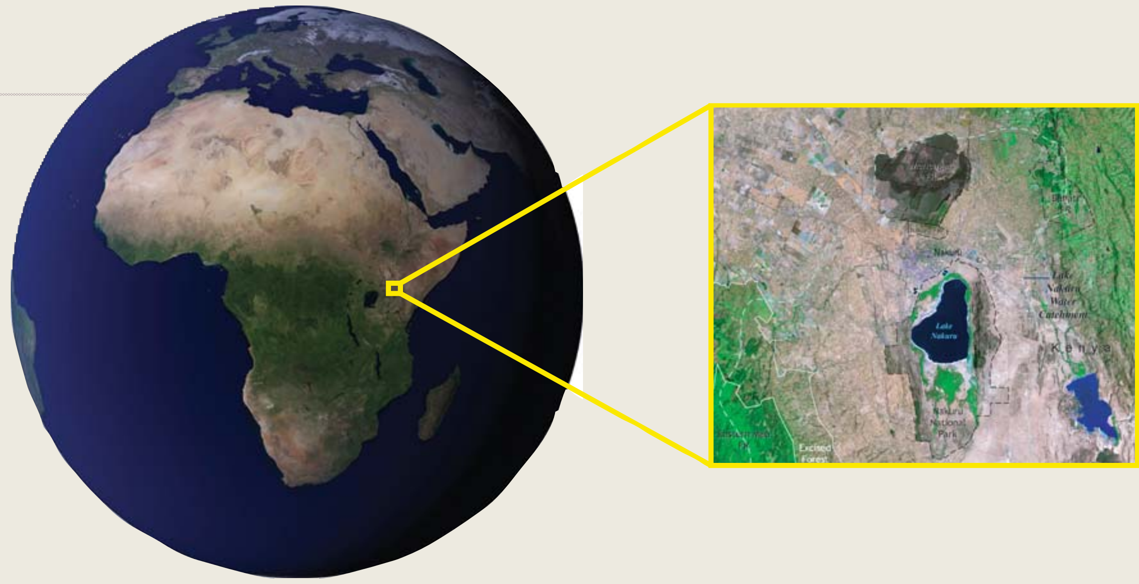
The impact of the Manantali Dam on traditional agriculture has been equally serious. For many centuries, the annual flood of the Senegal River has been the basis for flood-recession agriculture, fishing and cattle-grazing. Sorghum is still the staple food for more than 100 000 families in the floodplains. With the construction of the dam, however, the annual flood has been reduced to an artificial two-week flood. The new hydropower plant will compete with the artificial floods for agriculture, and will reduce the flooded area by another 20 000 ha (World Bank n.d.).

Traditionally, the Senegal River inundated about 150 000 ha on average and up to 350 000 ha in high-flow years. The World Bank reports that after hydropower construction, floods will still allow farming on at least 50 000 ha, except in very dry years. There is reason to doubt this statement. Critics argue that the World Bank's forecast is based on outdated hydrological data and does not reflect the reduced rainfall patterns that have prevailed since the 1970s. On the basis of actual recent flows, the average flood is more likely to extend to 30 000 ha, and every third year there will be insufficient water for any flood at all.

A field of grain sorghum

Larry Rana/UNEP/USDA

Lake Nakuru



Lake Nakuru National Park is the second most visited protected area in Kenya. It hosts the world's largest concentration of flamingos, as well much of the wildlife that makes Kenya a highly valued tourism destination, including lions, leopards, rhinos, and buffalo. In its total area of 18 800 hectares (46 456 acres), there are over 450 bird species and 56 mammal species. Recognized as a wetland of international importance, Lake Nakuru was declared a Ramsar Site in 1990.

One of the most pressing threats to the lake is the degradation of its catchment which is most likely to increase fluctuation in water flow and decrease water quality. On 16 February 2001, the Government of Kenya announced its intention of excising 35 301 hectares (87 231 acres) of forest in Eastern Mau Forest Reserve.

This excision took effect in October 2001 by Legal Notice 142 that appeared in the Kenya Gazette Supplement of 19 October 2001. With this excision, most of the forest cover in the upper catchment of the main rivers that feed Lake Nakuru will disappear.

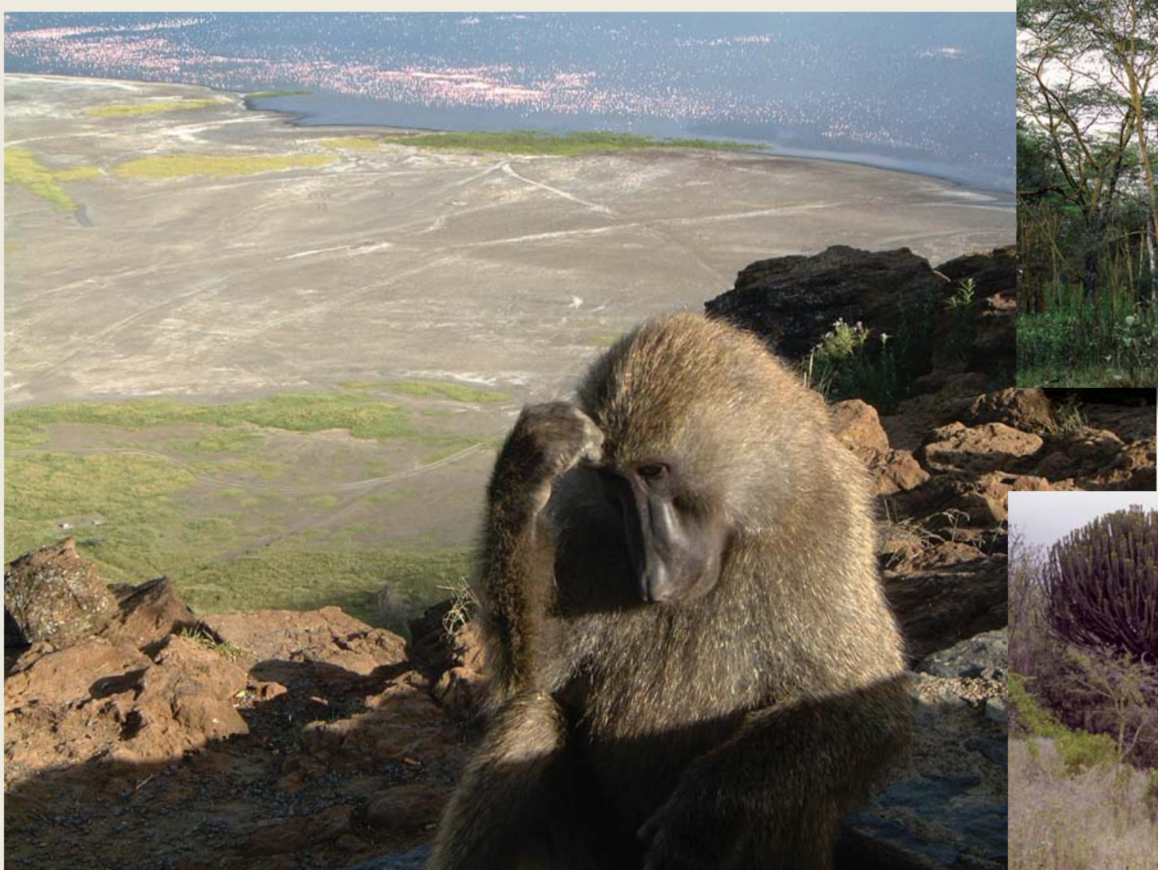
Table 3.5: Vegetation cover changes in the catchment of Lake Nakuru*

Forest Reserves	*1973 (ha)*	*2001 (ha)*	*Changes (%)*
Inside Forest Reserves			
Closed forest	33 230	15 925	-52%
Bush / open forest	5 441	5 665	4%
Outside Forest Reserves			
Closed forest	8 509	7 323	-14%
Bush / open forest	28 287	8 507	-70%
TOTAL	75 467	37 420	-50%
% of total catchment area	46%	23%	

* Changes are based on a preliminary interpretation of Landsat images.

No ground truthing exercise has yet been undertaken.

Source: UNEP 2002.

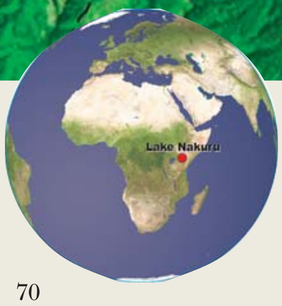


Christian Lambrechts/UNEP

Christian Lambrechts/UNEP

Gray Tappen/UNEP/USGS

Flamingos on Lake Nakuru *Credit: Gray Tappan*

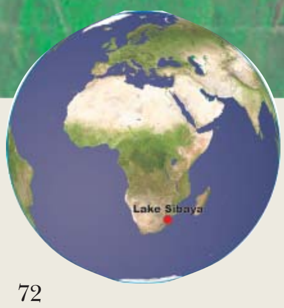


LAKE NAKURU
KENYA

Located in southwest Kenya's Great Rift Valley, Lake Nakuru is the centrepiece of Lake Nakuru National Park, the country's second most visited protected area. The lake hosts the world's largest concentration of flamin-

Vegetation around Lake Nakuru *Credit: Gray Tappan*

gos, as well as many of Kenya's more charismatic mammal species, including leopards and the rare black rhinoceros. Its 188 km^2 (73 square miles) are home to more than 450 bird and 56 mammal species. Despite its declaration as a Ramsar-protected wetland in 1990, the continuing degradation of land cover in Nakuru's populous catchment area is likely to increase flow fluctuations and decrease water quality in the lake. In 2001, the Kenyan Government announced its intention to excise 353 km^2 (136 square miles) of forest in the Eastern Mau Forest Reserve (ringed in white in the 2000 image)—a decision that could result in the disappearance of most of the forest cover in the upper catchment of the main rivers feeding Lake Nakuru.

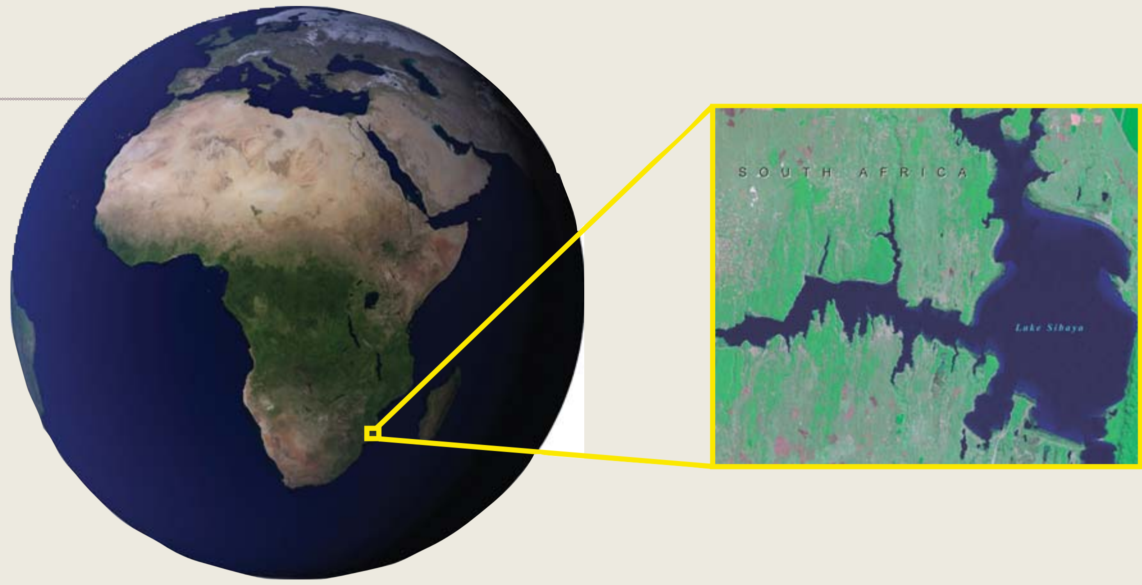


Lake Sibaya
South Africa

Lake Sibaya is narrowly separated from the sea by a range of high forested coastal dunes. The lake is home to large hippopotamus and crocodile populations, although their numbers have dropped over the last fifteen

years due principally to poaching. The lakeshore is also home to the only known population of a rare climbing orchid. The yellow arrows vividly show the increase in cultivation of marginal lands around Lake Sibaya. Agriculture in the lake catchment and along its drainage lines may cause erosion, eutrophication, pollution, and the drying up of wetlands around the lake raising concerns among environmentalists. Although Lake Sibaya has been designated a wetland of international importance, there has been little effort by communities around the lake to practice sustainable management or to protect the rare species found in the region.

Lake Sibaya



Lake Sibaya, situated on the coastal plain that makes up north-eastern KwaZulu-Natal in South Africa, is the country's largest natural freshwater lake, with an area of 60–70 km^2 (23–27 square miles). Surface water in the surrounding coastal plain often disappears completely during dry years, making the lake the only permanent source of water for mammals and birds. This wetland also supports several of the region's rural communities, which in many cases are totally dependent on its water and associated flora and fauna. A Ramsar conservation site, Lake Sibaya is also an important link between Kosi Bay and St. Lucia—providing a vital stepping stone for the extension of tropical elements down the east coast.

The lake system contains the second largest population of hippos and crocodiles in KwaZulu-Natal, together with 18 species of fish, one of which, a freshwater goby, is endemic to the system. Twenty-two species of frogs and eight reptile species are associated with the lake. Of 279 bird species recorded in the area, 60 nest and breed around the lake. Numerous threatened species occur within the lake system, including the only known population of a particular species of climbing orchid, *Vanilla roscheri*.

Although Lake Sibaya has an abundance of coastal resources, it is also susceptible to pollution and siltation due to human influences and the endothecia mosses that grow around the lake. DDT spraying for malaria control in the area is a cause of concern, while more recently interest has been shown in spraying molluscacide in the wetlands to destroy the bilharzia snail known to carry *schistosomiasis* . However, molluscacide is a poison that is also known to kill invertebrates and small fish (World Lakes, 2005). Hippo and crocodile numbers have plummeted by 40 per cent over the past 15 years, principally due to poaching.

Since 1990, extensive cultivation and deforestation in the lake's catchment area has increased erosion and eutrophication in most of the drainage lines feeding the lake system. Many of the poor local communities see logging as a means of improving their standard of living, leading to the injudicious burning of large areas of forest. There is clearly a growing and urgent need to educate these communities on the sustainable use of their natural coastal resources.

Schistosomiasis (Bilharzia)

Schistosomiasis, also known as bilharzia (bill-HAR-zi-a) or snail fever, is a disease caused by a blood fluke—a parasite which has a life-cycle split between humans and freshwater snails. The adult flukes, up to 2 cm (0.8 in) long, live inside the blood vessels surrounding the gut or bladder of the human host.

Infection occurs when skin comes in contact with contaminated fresh water in which certain types of snails that carry *schistosomes* are living. This fresh water becomes contaminated by *Schistosoma* eggs when infected people urinate or defecate in the water. The eggs hatch, and if certain types of snails are present in the water, the parasites grow and develop inside the snails. The parasite leaves the snail and enters the water where it can survive for about 48 hours. Schistosoma parasites then can penetrate the skin of persons who are wading, swimming, bathing, or washing in contaminated water. The parasites can also enter through the lining of mouth or intestinal tract of people who drink untreated water. Within several weeks, worms grow inside the blood vessels of the body and produce eggs (MCW 1999).

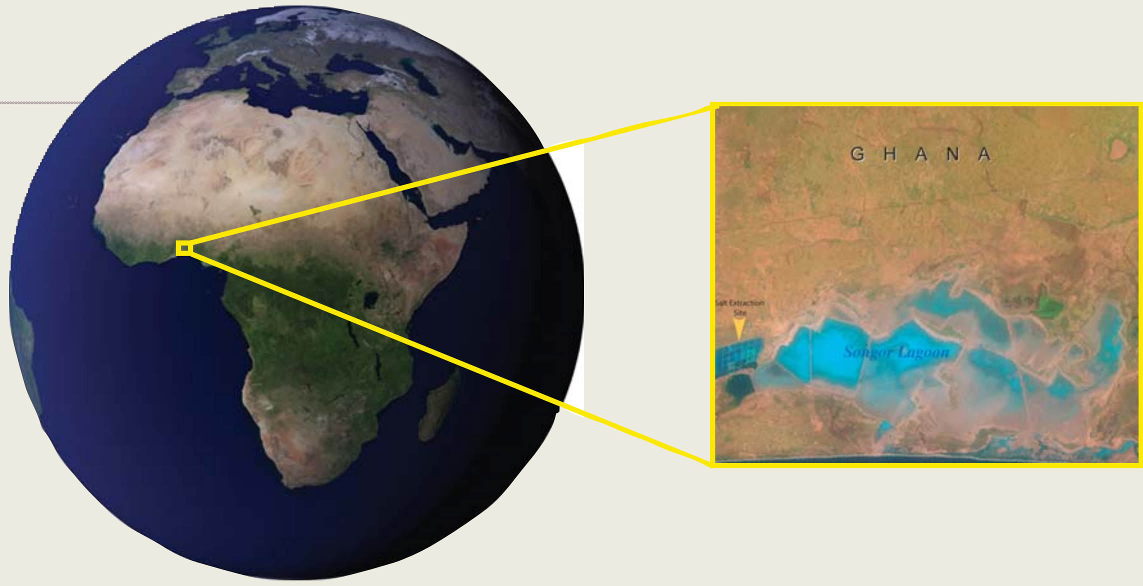
The body's immune system recognises that the eggs of the fluke are foreign invaders and tries to destroy them. The side effects of this powerful immune response include anaemia, inflammation, formation of scar tissue, dysentery, enlargement of the spleen and liver, cancer of the bladder, and cirrhosis of the liver. Some of these eggs travel to the bladder or intestines and are passed into the urine or stool.

Collective fishing in in Mali, a common means of *Schistosomiasis* transmission from snail to human hosts, often with serious health consequences. *Geoff Garnett/UNEP/Imperial College–London*

Some 200 million people are thought to suffer from this disease in the tropics, and 750 000 people a year die. *Schistosomiasis* ranks second behind malaria in terms of parasitic diseases and is endemic in 74 developing countries, mostly in Africa.

Schistosomiasis is readily treated using a single oral megadose of the drug Praziquantel. While Praziquantel is safe and highly effective in curing an infected patient, it does not prevent re-infection and is not an optimum treatment for people living in endemic areas. As with other major parasitic diseases, there is ongoing and extensive research into developing a vaccine that will prevent the parasite from completing its life cycle in humans (Wikipedia n.d.).

Songor Lagoon



The shallow 74 km^2 (29 square miles) Songor Lagoon is situated to the west of Ghana's Volta River estuary, and is one of two large lagoon systems associated with this major river estuary. Comprising a brackish lagoon with extensive mudflats and islands, saltpans, a broad sandy beach, and a number of small streams, the open water of the lagoon covers about 11 500 ha and extends about 20 km (12 miles) along the coast and 8 km (5 miles) inland. It is separated from the sea by a narrow sand dune on which several small villages are situated. The lagoon's importance to birdlife and marine fauna, including several endangered species of turtle, earned its designation as a Ramsar protected wetland (Finlayson et al 2000; Piersma and Ntiamoa-Baidu 1995).

Human activities in and around the lagoon include farming, fishing and intensive salt extraction. Salt production, the main human activity, has led to the extensive modification of the ecosystem and the reduction of endemic fish and benthic fauna. As well as many waterbird species, the lagoon hosts several globally threatened turtles, including the Leatherback (*Dermochelys coriacea*), the Olive Ridley (*Lepidochelys olivacea*), and the Green Turtle (*Chelonia mydas*). Some recreation and tourism occurs here, including bird-watching, turtle-watching, and boating.

Songor lagoon is the site of an artisanal salt industry dating back to over a century and continuously expanding. The lagoon is also convenient for tourism. Expatriates and Ghanaians go there for speed boating, recreational fishing and bird watching during weekends and public holidays. About 200 hectares of the Songor lagoon is also suitable for shrimp pond development (Ghana Tourism n.d.).

The land around the lagoon is low-lying, with the highest point less than 10m (33 ft) above sea-level. Channels, which in the past provided direct connection with the Volta River, are effectively blocked. The lagoon has no direct access to the sea and seawater replenishment is from seepage through the sand-dunes. The main wetland vegetation-type is saline marsh, with degraded mangroves (mainly *Avicennia sp.*) and waterlogged grassland along the margins of the lagoon, and riverine woodland, scattered thickets of shrubs, climbers and small trees on higher ground. Terrestrial vegetation away from the lagoon is largely degraded coastal savanna. Human activities in and around the lagoon comprise mainly farming, fishing and intensive salt extraction (BirdLife International 2006).

A leatherback turtle comes in closer for a better look

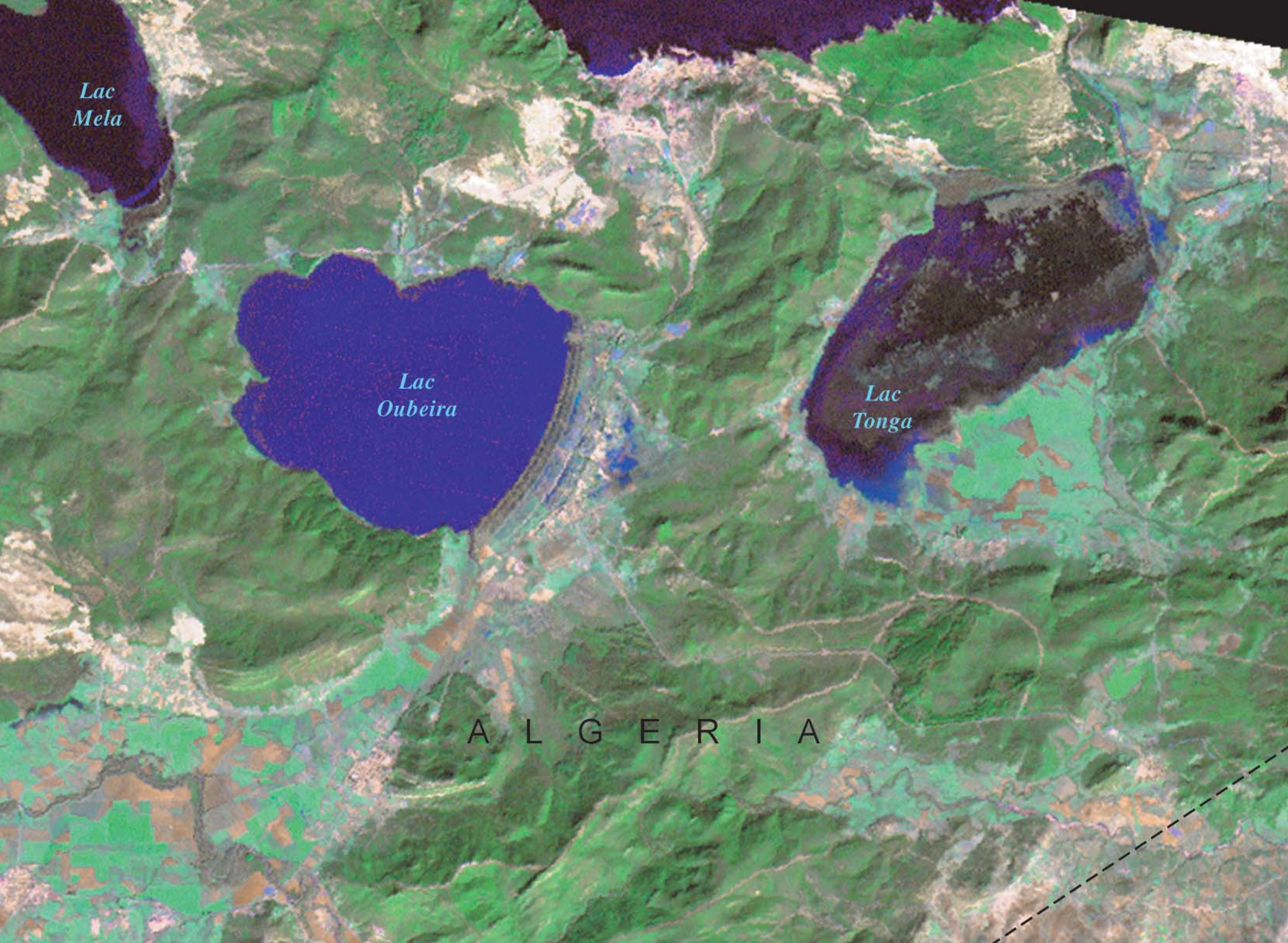
Unknown/UNEP/Gulf of the Farallones NMS

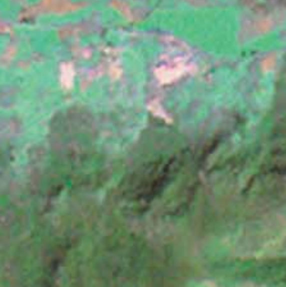
Songor Lagoon

Ghana

Songor Lagoon is one of the major lagoon systems, associated with the Volta river estuary, with a surface area of about 115 km^2 (44 square miles). These two images show a conspicuous reduction in the surface area

of Songor Lagoon—and the environmental health of the wider region. The deep blue open-water area is dramatically reduced in the 2000 image, with large areas of bare ground exposed. Although some of these changes may reflect seasonal or annual rainfall variability, closer analysis indicates a more permanent and significant decline in the lagoon's surface area. The two main reasons for this appear to be salt extraction at the western end of the lagoon and diversion of feeder streams for irrigation.





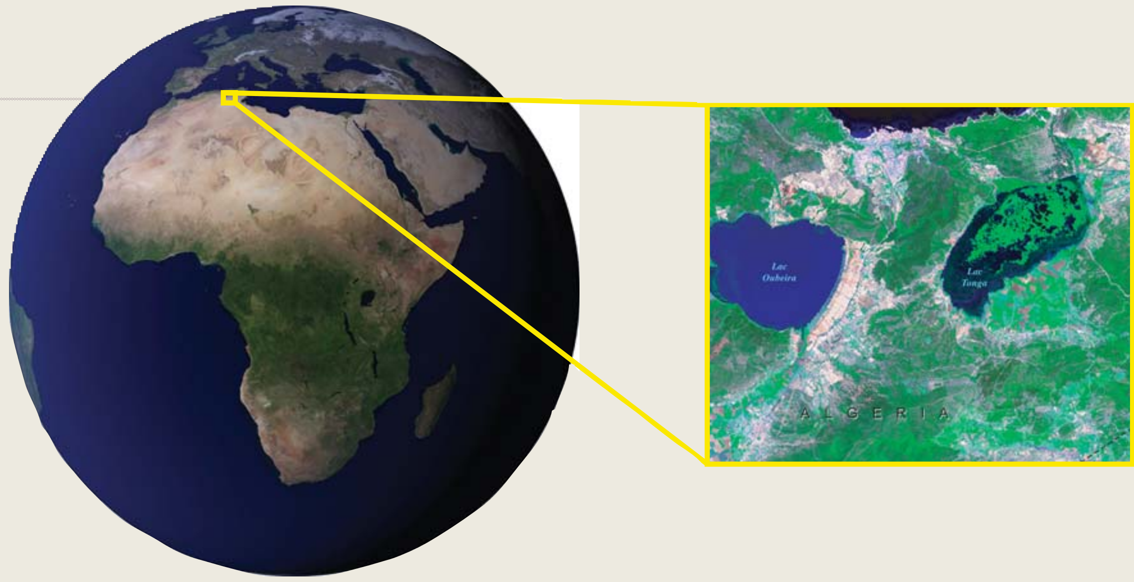
Lake Tonga

Algeria

These two images show the dramatic human-induced changes in and around Lake Tonga over the past 15 years. The damming of the feeder rivers of Lakes Tonga and Oubeira (shown in the bottom part of the 2000 im-

age) has resulted in increasing irrigation around the dams and a drastic reduction in the volume of water entering the lake. The 2000 image was acquired during the rainy season, showing an increase in the water volume after the 1999 drought, which had left the lake virtually dry. The widespread ecological changes caused by the construction of dams around Lake Tonga should serve as an eye-opener to the community. Environmental Impact Assessments of the area could assist African policymakers with information to make informed choices about future projects.

Lake Tonga



Lake Tonga is one of the lakes in Africa that has been most dramatically affected by human influences and climate change. Situated east of the town of El Kala in the most northeastern part of Algeria, the lake dried up completely in 1999 due to the uncontrolled withdrawal of its water and the damming of its upper stream, following a serious drought in the area.

Lake Tonga's catchment area includes the natural wetlands of the Mediterranean region, and the lake itself harbours a significant variety of waterbirds, invertebrates, reptiles, amphibians and flora. It supports several endangered species, including the White-headed Duck (*Oxyura leucocephala*), the Ferruginous Duck (*Aythya nyroca*), and the otter (*Lutra lutra*). The lake is an important wintering and breeding area for numerous waterbirds, although their presence is threatened by its dramatically reduced water levels.

The state-owned lake faces numerous human-induced threats, including poaching, eel fishing, invasive weeds, siltation of its outlet river, wastewater disposal from surrounding settlements, and water extraction for irrigation and domestic supplies. Its microclimate allows some tropical species of vegetation to persist, although many may have disappeared as a result of drainage works over the centuries. Early drainage led to the replacement of much of the open water by dense emergent vegetation. In 1937, attempts to drain the marsh ceased. In the 1980s the outflow sluice was closed in winter to store water for irrigation and to improve lakeside grazing. The elevated water levels, however, also killed off up to 90 per cent of the alder forest (*Alnus spp.*) and some of the clubrush beds (*Scirpus lacustris*) in the northern half of the lake. The proposed planting of exotic poplars and cypresses on the shores of the marsh could also lower the water-table. There is also reported to be high hunting pressure around the lake, especially on weekends.

A Monitoring Procedure Mission to Lake Tonga in 1990 made several recommendations, including establishing the lake itself as a zone of strict protection within the Parc National d'El Kala, with strict bans on hunting and eel fishing. It was reported that many birds and otters were being killed in eel fishing nets. The mission further recommended that surface and groundwater extraction from the lake should be strictly controlled, and that a regional plan should be drawn up for the conservation of the area's land and water resources. The site was added to the Montreux Record in 1993 because of concern about decreases in water supply to the lake and the spread of emergent aquatic vegetation in open water areas (BirdLife International 2005).

IBAs in Algeria

Algeria is the second largest country in Africa hosting over 400 species of birds. Algeria's wetlands, in particular those along the coast and on the plateau south of Constantine, are of huge importance for migratory and resident waterbirds including three globally threatened species Marbled Teal (*Marmaronetta angustirostris*), Ferruginous Duck (*Aythya nyroca*) and White-headed Duck (*Oxyura leucocephala*). The coastal lagoons around El Kala are considered to be the most important site for breeding waterbirds in eastern Algeria and one of the most important in the Mediterranean. A total of 31 Important Bird Areas (IBAs) have been identified in Algeria which cover 130 000 km^2 or some 5.5 per cent of the land surface (although the exact boundaries of some sites remain undefined). Lake Tonga is one of the IBAs in this complex. The site comprises a marshy basin and a shallow, seasonal freshwater to brackish lake bounded in the north by an extensive sand dune system (Africa Bird Club 2006).

White-headed duck *Unknown/UNEP/Wikipedia*

Marbled teal *O. Peyre and G. Durand/UNEP/Africa Bird Club*

Black-shouldered Kite *O. Peyre and G. Durand/UNEP/Africa Bird Club*

Spotted Flycatcher *O. Peyre and G. Durand/UNEP/Africa Bird Club*

References

African Bird Club (2006). Birding Africa: Algeria. Available at http://www.africanbirdclub.org/countries/Algeria/introduction.html.

African Unification Front (n.d.). Nile Basin. Available at http://www.africanfront.com/water_sheds/water_sheds2/water_sheds5.php.

Arabic News.com (1999). 'Toshka Project will continue.' Egypt, Economics, 12/11/1999. Available at http://www.arabicnews.com/ansub/Daily/Day/991211/1999121145.html.

Bagine, R.K.N. (1998). Biodiversity in Ramogi Hill, Kenya, and its evolutionary significance. Afr. J. Ecol. 1998, Volume 36, pages 251-263.

Baker, Marcia Merry. (1997). The Executive Intelligence Review. Mubarak: Toshka Project Opens Way Towards New Civilization In Egypt. Available at http://members.tripod.com/~american_almanac/toshka.htm.

Bank, W. (1996). Kenya, Tanzania and Uganda: Lake Victoria Environmental Management Project. GEF Documentation Report No.15541-ARF.

Birch-Thomsen, T., Frederiksen, P. & Sano, H. O. (2001). A Livelihood Perspective on Natural Resource Management and Environmental Change - A case analysis from a semi-arid village in Tanzania. Economic Geography 77(2):41-66.

BirdLife International (2005). BirdLife's online World Bird Database: the site for bird conservation. Version 2.0. Cambridge, UK: BirdLife International. Available at http://www.birdlife.org/datazone/sites/?action=SitHTMDetails.asp&sid=6157&m=0.

BirdLife International (2006). BirdLife IBA Factsheet, Songor Ramsar Site. Available at http://www.birdlife.org/datazone/sites/?action=SitHTMDetails.asp&sid=6346&m=0.

Byers, A.C. (2002). The Mountain Institute. The Lesotho Highlands Water Project: Supporters, Critics, and Mountain Voices. Available at http://www.mtnforum.org/resources/library/byera02c.htm.

Carbonnel J.P., Hubert P. (1985). Sur la sécheresse au Sahel d'Afrique de l'Ouest. Une rupture climatique dans les séries pluviométriques du Burkina Faso (ex Haute-Volta), CRAS, 301, Série II, 13, 941-944.

Chenje, M. and Jonson, P. (2002). Defining and Mainstreaming Water Resources in Southern Africa. SARDC Zimbabwe. Available at http://www.sardc.net/WaterBook/chap3/principle2.htm.

Cherifi, O. and Loudiki, M. (2002). 12th ISCO Conference Beijing 2002: Impact of El Abid River Basin Loads on Water Quality of the Bin El Ouidane Lake-Reservoir, Morocco. Available at http://www.tucson.ars.ag.gov/isco/isco12/VolumeII/ImpactofElAbidRiverBasin.pdf.

Christian Aid (n.d.). Christian Aid, Relief-Web. Available at http://www.christianaid.org.uk/aboutca/liblinks.htm.

Coe, M.T. and Foley, J.A. (2001). Human and natural impacts on the water research of the Lake Chad basin. Journal of Geophysical Research, v. 106 n. D4 p. 3349-3356.

Dumont, H.J. (1992). The regulation of plant and animal species and communities in African shallow lakes and wetlands. Revue d'Hydrobiologie Tropicale, v. 25, pp. 303-346.

Earle, S (2000). Earth Science News: Degassing Lake Nyos. Available at: http://www.mala.bc.ca/~earles/nyos-feb01.htm

Ecoport (n.d.). Image ID 18686, Photo/illustration by: IRAT. Available at www.ecoport.org/TN/000018/18686.jpg.

El-Din, Gamal Essam. (2000). Toshka in the crossfire. Al-Ahram Weekly Online. Issue No. 466, 27 January – 2 February 2000. Available at http://weekly.ahram.org.eg/2000/466/eg7.htm.

El Ghissassi, A. (2005). The Dams Newsletter, No. 4, Page 8, May 2005. Available at http://www.icold-cigb.org/PDF/newsletter4.pdf.

El Sineity, Hend. (2003). Industry Canada: Egypt's Toshka Project. Available at http://strategis.ic.gc.ca/epic/internet/inimr-ri.nsf/en/gr114228e.html.

Evans, Martin and Mohieldeen, Yasir (2002). Environmental Change and Livelihood Strategies: the Case of Lake Chad. Geographical Association, Sheffield, UK, v. 87, n. 1, pp. 3-13.

Famine Early Warning System (FEWS) (1997). Lake Chad Untapped Potential, FEWS special Report 97-4, Available at http://www.fews.org/fb970527/fb97sr4.html

Famine Early Warning System (FEWS) (2003). Rainfall estimates. Available at http://www.fews.org/.

FAO (1997). Irrigation potential in Africa: A basin approach. FAO Land and Water Bulletin 4. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/W4347E/w4347e11.htm.

FAO (2005). Irrigation in Africa in figures – AQUASTAT Survey 2005. Available at ftp://ftp.fao.org/agl/aglw/docs/wr29_eng.pdf.

FAOSTAT (2004). FAOSTAT Statistical Database. Food and Agriculture Organisation [Geo-2-196]. Available at http://www.fao.org/.

Finlayson, B., Schnick, R., Cailteux, R., Demong, L., Horton. W., McClay, W., Thompson, C. and Tichacek, G. (2000). Rotenone use in fisheries management: administrative and technical guidelines. American Fisheries Society, Bethesda, Maryland. 212 p.

Ghana Tourism (n.d.). The Greater Accra Region: Wildlife and Nature Reserves, Coastal Ramsar Site. Available at (http://www.ghanatourism.gov.gh/regions/highlight_detail.asp?id=11&rdid=367.

Gichuki, N.N. (2003). Review of wetland research activities in Lake Victoria basin, Kenya: Analysis and Synthesis Report. SIDA/Inter-University Council for East Africa, Kampala, Uganda.

Global Environment Facility (GEF) (2002). Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem, Project Brief. Available at http://www.gefonline.org/projectDetails.cfm?projID=767.

Global International Waters Assessment (GIWA) (2004). Lake Chad Joint Publication,United Nations Environment Programme. Soon to be available at http://www.unep.org/dewa/water/.

Gurure, Richard (2000). Water Hyacinth: Searching for Lasting Solutions to Control the Weed Menace in Zimbabwe Available at http://www.ilec.or.jp/newsfiles/031029_dev_rep/h10/.

Hoekstra D.A. and Corbett J.D. (1995). Sustainable agricultural growth for the highlands of East and Central Africa: Prospects to 2020. International Food Policy Research Institute, Washington, D.C

IPCC (2001). Climate Change 2001: Impacts, Vulnerability and Adaptation. IPCC Working Group II, Geneva. Available at http://www.grida.no/climate/ipcc_tar/.

IRN (1997). International Rivers Network: Manantali Dam Changes Will Make a Bad Situation Worse. Available at http://www.irn.org/programs/safrica/manantali.html.

IUCN (2004). Water and Nature Initiative: Komadugu Yobe (Nigeria). Available at http://www.iucn.org/themes/wani/1d.html.

Julius Berger Nigeria Plc (n.d.). Challawa Gorge Dam, Kano State. Available at http://julius-berger.com/divisions/pdfs/18a_dams_and_water_supply.pdf.

LakeNET (n.d.). World lakes Network Available at http://www.WORLDLAKEs.org/index.asp.

Lesotho Highland Water Project (n.d.). Overview of the Lesotho Highlands Water Project: The Lesotho Highlands Water Project, The Beginning and Lesotho's Water Resources. Available at http://www.lhwp.org.ls/overview/default.htm.

LHWP (n.d.). Lesotho Highlands Water Project (LHWP). Available at http://www.lhwp.org.ls/overview/default.htm

LVEMP (2002). Lake Victoria Environmental Management Project, Phase 1, Draft, Kenya Stocktaking Report, World Bank.

MCW (1999). Medical College of Wisconsin: Schistosomiasis (Bilharzia), Centers for Disease Control and Prevention. Available at: http://healthlink.mcw.edu/article/935097450.html.

Meine, Curt D. and Archibald, George W. (Eds) (1996). The Cranes: Status survey and conservation action plan. IUCN, Gland, Switzerland, and Cambridge, U.K. 294pp. Northern Prairie Wildlife Research Center. Available at http://www.npwrc.usgs.gov/resource/distr/birds/cranes/cranes.htm (Version 02MAR98).

Mockrin, Miranda and Thieme, Michelle (2001). Lake Chad flooded savanna (AT0904). World Wildlife Fund (WWF). Available at www.worldwildlife.org/wildworld/profiles/terrestrial/at/at0904_full.html.

Nami B. (2002). Environmental Degradation of the Lake Chad Basin: Implications for Food Security.

NASA (2003). The Human Footprint, 25 February 2003. Available at http://earthobservatory.nasa.gov/Study/footprint/.

NASA (2004). Fires Near Lake Malawi, Africa. Available at http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=12453.

NASA. (2005a). Lake Nasser and the New Valley. Available at http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17141.

NASA (2005b). Floods in Central Madagascar, 10 March 2005. Available at http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=12763.

NASA (2005c). Ichkeul Lake, Tunisia. Available at http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17159.

Ochola, W.O., Muhia, R.N. and Mwarasomba, L.I. (2000). Culture, Traditions and Society: The Challenges to Natural Resource Management and Development. A Report of a Socio-Cultural Study of the Lake Victoria Region, Kenya. National Soil and Water Conservation Programme, Ministry of Agricultural Research and Development, Nairobi.

Olivry, J.C., Chouret, A., Vuillaume, G., Lemoalle, J. and Bricquet, J.P. (1996). Hydrologie du Lac Tchad, ORSTOM, 266 pp., Monograph Hydrologie, v. 12, Paris, France.

Oyebande, Lekan. (2001). Streamflow regime change and ecological response in the Lake Chad basin in Nigeria, Hydro-ecology: Linking Hydrology and Aquatic Ecology, Proceedings of Workshop HW2, Birmingham, UK, July 1999. IAHS Publication n. 26. pp. 101-111.

Piersma, T. and Ntiamoa-Baidu, Y. (1995). Waterbird ecology and the management of coastal wetlands in Ghana: NIOZ-Report 1995-6, Texel.

Relief Web (2002). DR Congo: Humanitarian Situation Update, 21 January 2002. Available at http://www.reliefweb.int/rw/rwb.nsf/AllDocsByUNID/e0a90cc6096bff1f85256b4800717449

Ruphael Y. (2004). Energy Bulletin: Water Crisis Looms in Africa, 17 September 2004. Available at http://www.energybulletin.net/2177.html.

SADC Today (2005). The Southern African Development Community (SADC), Zimbabwe. Available at http://www.zamsoc.org/html/news.html.

Sanderson, E.W., Jaiteh, M., Levy, M.A., Redford, K.H., Wannebo, A.V. and Woolmer, G. (2002). The human footprint and the last of the wild. Bioscience. 52(10):891-904.

Sarch, Marie-Thérèse and Birkett, Charon (2000). Fishing and Farming at Lake Chad: Responses to Lake-level Fluctuations. The Geographical Journal, v. 166, n. 2, pp. 156-172.

Secretariat of the Convention on Wetlands (2005). The List of Wetlands of International Importance. 36 p. Available at http://www.ramsar.org/sitelist.pdf.

Sikes, S. (2003). Lake Chad versus the Sahara Desert. Newbury: Mirage Newbury.

South Africa Info (2004). Africa's biggest water project, 17 March 2004. Available at http://www.southafrica.info/doing_business/economy/infrastructure/sa-lesothowaterproject.htm.

The Ramsar Convention on Wetlands (n.d.). Lake Uvs and its surrounding wetlands. Iran. Available at http://www.wetlands.org/RSDB/Default.htm.

Think Liquid.Net (n.d.). Lake Bin El Ouidane. Available at http://www.thinkliquid.net/news/index.php?imagepopup=1/MarJ1-018.jpg&width=468&height=311&imagetext=Lake+Bin+El+Ouidane.

Thompson, J. (2005). University College London, Department of Geography: The Hadejia-Jama'are River Basin. Available at http://www.geog.ucl.ac.uk/~jthompso/hadejia-jam.htm.

U.S. Geological Survey (1998). Earthshots: Satellite Images of Environmental Change: Lake Chad, West Africa. Available at http://www.earthshots.usgs.gov.

UN FactSheet (2002). Implementing the Millennium Declaration: The Millennium Development Goal and the United Nations Role. Available at http://www.un.org/millenniumgoals/MDGs-FACTSHEET1.pdf.

UNEP (n.d.a). Dams and Development Project. Available at http://www.unep.org/dams/documents/ell.asp?story_id=28.

UNEP (n.d.b). Planning and Management of Lakes and Reservoirs: An Integrated Approach to Eutrophication, Abridged Version-A Student's Guide. Available at http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-12/7-3.asp.

UNEP (1999). Early Warning of Selected Emerging Environmental Issues in Africa: Change and Correlation from a Geographic Perspective. UNEP/DEWA Environment Information and Assessment Technical Report, TR. 99-2, p. 42.

UNEP (2002). Christen Lambrecht. Degradation of the catchment of Lake Nakuru. Poster prepared by DEWA/GRID-Nairobi, January 2002.

UNEP (2005). One Planet, Many People: An Atlas of Our Changing Environment. United Nations Environment Programme (UNEP), Nairobi, Kenya. 332 p. Available at http://www.na.unep.net/OnePlanetManyPeople/index.php.

UNESCO (2006). Djoudj National Bird Sanctuary. Available at http://whc.unesco.org/en/list/25.

UNU (n.d.). Environment and Sustainable Development. Water Crisis: International Rivers and Lake Basins Management. Available at http://www.unu.edu/env/water/transboundary-water.html#introduction.

URT (2001). United Republic of Tanzania, Statistics 2001.

USDA (2005). Crop Explorer. Washington, DC: U.S. Department of Agriculture: Lake Victoria Height Variations. Available at http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/gr_regional_chart.cfm?regionid=eafrica&region=&reservoir_name=Victoria.

Verhoeye, J. (2001). Imaging radar for mapping and monitoring of wetland ecosystems in the Lake Chad basin. Available at allserv.rug.ac.be/-educheyn/projecten/lake_chad2001/StudyArea/StudyArea.html.

Verschuren, D., Johnson, T.C., Kling, H.J., Edgington, D.N., Leavitt, P.K., Brown, E.T., Talbot, M.R. and Hecky, R.E. (2002). History and Timing of Human Impact of Lake Victoria, East Africa. Proc. Roy. Soc. London B, 269, 289-294.

WAPMS (2006). The Western Aquatic Plant Management Society: Giant Salvinia. Available at http://www.wapms.org/plants/salvinia.html.

Water Technology. (1996). Available at http://www.water-technology.net/projects/mubarak/.

Wetland International (n.d.). World wetland. Available at http://www.wetlands.org/.

Wikipedia (n.d). Morocco. Available at http://en.wikipedia.org/wiki/Morocco. Schistosomiasis. Available at http://en.wikipedia.org/wiki/Bilharzia.

World Bank (1995a). Cameroon: Diversity, Growth and Poverty Reduction. Report No. 13167-CM. Available at http://poverty.worldbank.org/library/.

World Bank (1995b). Nigeria: Poverty in the Midst of Plenty, The Challenge of Growth with Inclusion. Report No. 14733-UNI. Available at http://poverty.worldbank.org/library/.

WORLDLAKE (2005). World Lakes. Available at http://www.worldlakes.org/.

WRI (1994). World resources 1994-95, guide to the global environment. Washington, DC.

Zimbabwe Parks and Wildlife Management Autority: Lake Chivero Recreational Park. Available at http://www.zimparks.com/html/chivero.html.


Unknown/UNEP/Program for Global Environmental Teachings

Africa's Lakes

Epilogue

4

As shown in this Atlas, Africa's lakes contribute significantly to socio-economic development of the African region. Systematically, three main categories of values are distinguished: direct, indirect and symbolic values. The most obvious (direct) use of lakes is as a source for drinking water, irrigation, transportation, fishing and the water supply for households and industry. Additionally, water bodies are breeding grounds for migratory waterfowl and home to myriad species of flora and fauna. Indirect values imply water-retention mechanisms during flooding, impacts on local climate and sinks for wastewater discharges. Symbolic values include religious and spiritual purposes, and the references to water in the expressions of art.

However, these lakes are subject to high levels of rapid population growth, urbanization, industrialization, mining development, expansion of irrigated agriculture, and impacts of climate change. These pressures alter ecosystem processes and result in several threats on the lakes including: loss of biodiversity, over-fishing, eutrophication, proliferation of invasive weeds, siltation, toxic contamination and over-abstraction of water. It is important to note water systems are sensitive barometers of the health of our planet. While water covers most of the earth's surface, only about two per cent of the water body consists of freshwater—and most of that is bound in polar icecaps. Freshwater in a liquid state is, indeed, very scarce. Greatly aggravating the problem is the fact that a great part of the world's available freshwater is concentrated in a relatively few large lakes, many of which are shared by two or more countries. At the same time lakes are a source of livelihoods for most African communities yet there is a lot of mismanagement and over utilization of these water bodies in Africa. African lakes are also subject to climatic change despite human-induced pressures. Lakes in Africa are avenues of economic development. They are also sources of diseases if they are not sustainably managed.

In the years since UNCED, the importance of lakes as invaluable natural resources has increasingly been acknowledged. For instance, water is identified as a central issue in the Millennium Development Goals, a set of time-bound and measurable goals and targets for combating various environmental and development problems adopted by heads of state gathered at the UN Millennium Summit in September 2000. Water resource management has also come high on the agenda at the World Summit on Sustainable Development (WSSD) held in Johannesburg in September 2002 (Rio +10). One of its major output documents agreed to by the participating governments, the Plan of Implementation, calls for a number of immediate actions for the promotion of integrated water management. The importance of management of Tran boundary water systems has also been explicitly and concretely recognized by the international community, as signified by the establishment of the Convention on the Law of the Non-navigational. Although there is a lot said about lakes as avenues for development little has been done to assess the impact of human influence on these lakes. There is need to monitor and evaluate the changes and pressure exerted in humanity as a way to map out sustainable management of this water bodies. The use of satellite imagery is one of the modern ways that we can use to show and map out the changes experienced in most African lakes. The imagery can show changes over different time periods and have a wide coverage. The use of geographic information systems (GIS) and remote sensing technology are powerful tools for monitoring, management, modeling and evaluation of environmental impacts. These tools, as illustrated in this Atlas, will help policymakers develop informed decisions on management of African lakes and their related ecosystems.

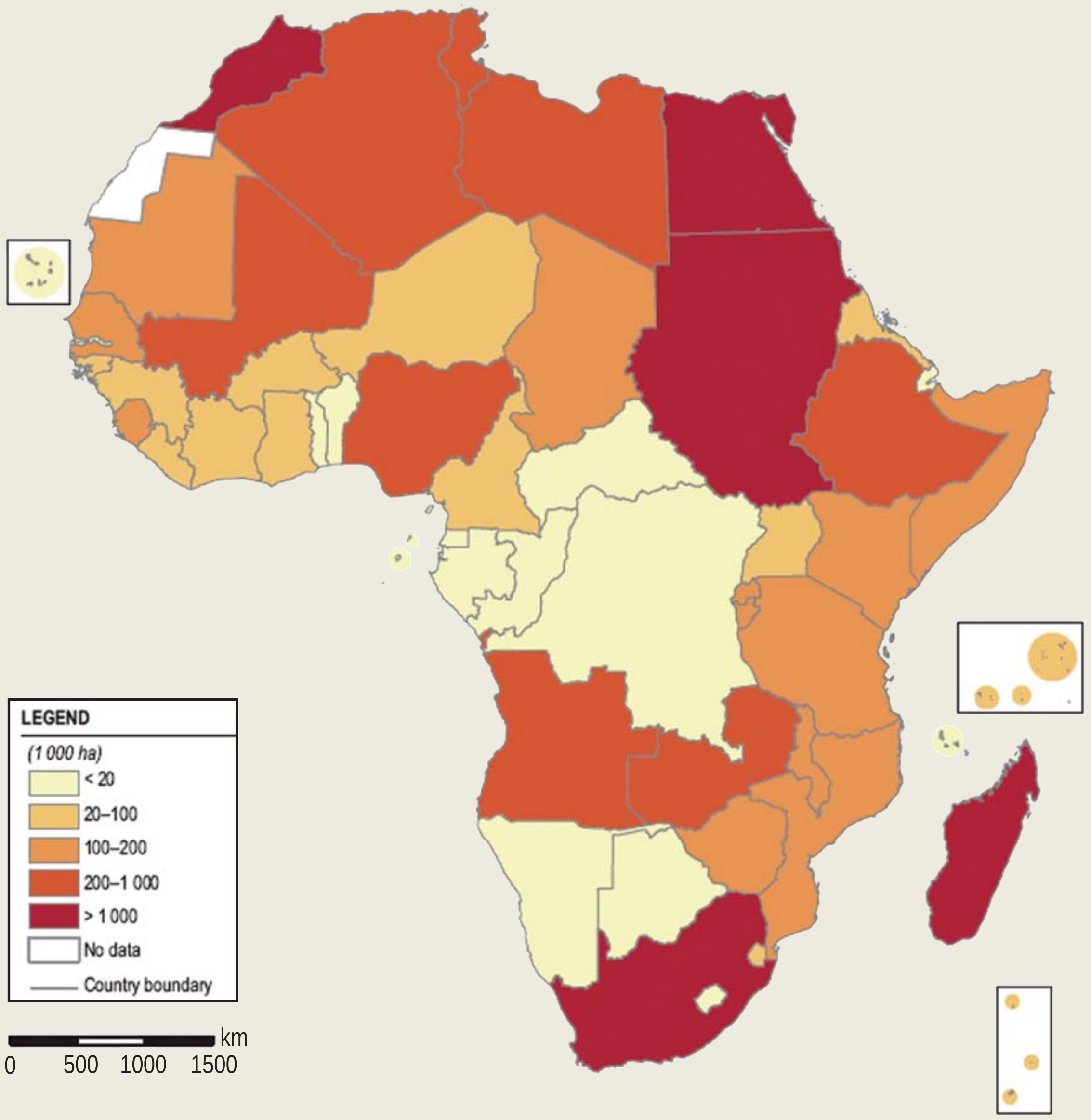


Figure 4.1: Water managed areas

FAO 2005

Appendix: Some principle lakes, reservoirs, and lagoons of Africa. (Those highlighted are illustrated case studies in this Atlas).

Name	Country	Longitude	Latitude	Altitude [m]	Surface area [km²]	Maximum depth [m]	Length of shore-line[km]	Volume [km³]	Mean depth[m]
A el- Gsebaia, Lake	Libya	24.70E	29.61N						
Abaya, Lake (formerly Lake Margherita)	Ethiopia	37.4E	6.1N	1,285	1,160	7	13	8.2	225
Abe, Lake	Djibouti, Ethiopia	41.45E	11.10N	310	780				
Abhe, Lake	Ethiopia	41.4E	11.1N	243	320	8.6	37	3	
Abijata, Lake	Ethiopia	38.4E	7.3N	1,573	205	7.6	13	0.75	205
Aby Lagoon	Cote d'Ivoire	3.08W	5.15N	1	780				
Afambo Hayk, Lake	Ethiopia	41.71E	11.41N						
Afrera ye'ch'ew, Lake	Ethiopia	40.94E	13.29N		100				
Aheme, Lake	Benin	1.95E	6.47N						
Al Massira, Lake	Morocco	7.56W	32.46N		141			2.76	
Al Wahda, Lake	Morocco	5.34W	34.77N		123			3.8	
Alaotra, Lake	Madagascar	48.5E	17.5S		200		4		
Albert, Lake	DR Congo, Uganda	30.5E	1.4N	615	5,300	25	58	280	
Allemanskraal, Lake	South Africa	27.23E	28.34S						
Am 'Abd et Gabbar, Lake	Egypt	25.33E	29.26N						
AManzamnyama, Lake	South Africa	32.84E	27.06S						
Amaramba, Lake	Mozambique	35.93E	14.49S						
Ambadi, Lake	Sudan	29.32E	8.66N						
Ambendrana, Lake	Madagascar	48.84W	13.57S						
Aougoundou, Lake	Mali	3.33W	15.71N		100				
Asejire, Lake	Nigeria	4.1E	73N	137	15		19		
Atuo, Lake	Ethiopia	34.26E	7.61N						
Awassa, Lake (Awasa, Awusa)	Ethiopia	38.2E	7.0N	1,708	129	11	22	1.3	52
Ayame, Lake	Cote d'Ivoire	3.20W	5.75N		150				
Bahi, Lake	Tanzania	35E	6S						
Bamendjin, Lake	Cameroon	10.55E	5.83N		400				
Banda Nwanta, Lake	Ghana	2.25W	8.33N		180				
Bangweulu, Lake (Bangweolo)	Zambia	29.45E	11.05S	1,140	15,100	4	10	148	490
Banyoles, Lake	Zambia	2.4E	42.1N	175	1.12	14.8	46.4	0.0161	9.13
Bardawil, Lake	Egypt	33.08E	31.08N		5,390				
Baringo, Lake	Kenya	36.63E	0.61N		108	2.5	3.5	0.73	
Barombi-Mbo, Lake	Cameroon	9.39E	4.66N						
Beda, Lake	Ethiopia	40.41E	9.90N						
Bemamba, Madagascar	Madagascar	44.39W	18.89S						
Bisina, Lake	Uganda	33.98E	1.65N		150				
Bloemhofdam, Lake	South Africa	25.67E	27.67S		300			0.56	
Bogoria, Lake	Kenya	36.1E	0.25N	960	34	5.4	10	0.18	
Botsumtwi, Lake	Ghana	1.42W	6.50N		49	45	81		
Burigi, Lake	Tanzania	31.29E	2.06S		100				
Burullus, Lake	Egypt	30.83E	31.50N		350				
Buyo, Lake	Cote d'Ivoire	6.98W	6.64N		989			8.3	
Cahora Basa Reservoir	Mozambique	31.4E	15.4S	314	43,63	20.9	157	55.8	246
Calueque, Lake	Angola	14.63E	17.22S		250				
Chad, Lake	Chad, Cameroon, Niger, Nigeria	14.17E	13.2N	280	1,540	4.1	10.5	72	650
Challawa Gorge Reservoir	Nigeria	6.9E	10.0N		101			0.10	
Chamo, Lake	Ethiopia	37.57 E	5.83 N	1,235	551		13		118
Chilwa, Lake (Shilwa)	Malawi, Mozambique	35.72E	15.33S	622	1,750	1	2.7	1.8	200
Chishi, Lake	Zambia	29.78E	8.90S		1,000				

Name	Country	Longitude	Latitude	Altitude [m]	Surface area [km^2]	Maximum depth [m]	Length of shore-line[km]	Volume [km^3]	Mean depth[m]
Chiuta, Lake	Malawi, Mozambique	35.87E	14.8S		100				
Chott el-Hodna, Lake	Algeria	4.67E	35.30N	400	3,620				
D'Afennourir, Lac	Morocco	5.17W	33.33N						
Darlington (Mentz), Lake	South Africa	25.15E	33.17S		40				
De Hoop Vlei, Lake	South Africa	20.38E	34.49S						
Debo, Lake	Mali	4.10W	15.32N		100				
Densu Reservoir (Weija)	Ghana	0.35W	5.55N	14.1	2,564		15.6		
Djoudj, Lake	Senegal	16.2W	16.33N	0	160				
Do, Lake	Mali	2.92W	15.88N		150				
Dziani Boundouni, Lake	Comoros	43.75E	12.35S		0.3				
Ebrie, Lake	Cote d'Ivoire	4.26W	5.30N		589				
Edward, Lake	DR Congo, Uganda	0.42 E	29.58 N	912	2,325	17	112	39.53	
Elmenteita, Lake	Kenya	36.26 E	0.44 S	1,776	20	0.9	1.2		
Er Rosieres, Lake	Sudan	34.42E	11.67N		450				
Eyasi, Lake	Tanzania	35.07 E	3.60 S		1,200				
Faguibine, Lake	Mali	4.00W	16.75N	280	590		10	4	
Fetzara, Lake	Algeria	7.53E	36.78N						
Finch'a', Lake	Ethiopia	37.18E	9.50N		200				
Fitri, Lake	Chad	17.43E	12.90N		100				
Garou, Lake	Mali	2.79W	16.04N		150				
Gemeri, Lake	Ethiopia	41.69E	11.54N						
George, Lake	Uganda	30.21E	0.00	914	250	2.4	4.5	0.8	
Gessi, Lake	Ethiopia	34.20E	7.65N						
Gove, Lake	Angola	15.83E	13.42S		300				
Grand Lahou, Lake	Cote d'Ivoire	5.26W	5.17N		199				
Great Bitter Lake	Egypt	32.39E	30.37N		200				
Guiers, Lake	Senegal	15.83W	16.25N	0	228	1.3	2.5	0.415	150
Hartbeespoort Dam Reservoir	South Africa	27.86 E	25.78 S		20	9.6			
Hayq, Lake	Ethiopia			2,030	35		23		
Hendrik Verwoerd, Lake	South Africa	25.67E	30.67S		400				
Ichkeul, Lake	Tunisia	9.67 E	37.17 N		126	1	2		
Idriss, Lake	Morocco	4.65W	34.14N		40			1.19	
Ihema, Lake	Rwanda	30.78E	1.88 S	1,291	90	4.8	7.8	512.6	78
Ihotry, Lake	Madagascar	43.67E	21.92S		100				
Iro, Lake	Chad	19.42E	10.10N		100				
Ist'Ifanos (Chew Bahir), Lake	Ethiopia	36.95E	4.72N		300				
Jebba, Lake	Nigeria	4.75E	9.25N		360			1.0	
Jebel Aulia, Lake	Sudan	32.22E	14.73N		398				
Jipe, Lake	Kenya,Tanzania								
Kabamba, Lake	DR Congo	27.03E	7.92S		150				
Kabele, Lake	DR Congo	25.95E	8.93S		100				
Kabwe, Lake	DR Congo	26.03E	9.17S		100				
Kachira, Lake	Uganda	31.13E	0.57S		46				
Kafue Reservoir	Zambia	28.37E	15.81S		1,500			20.3	
Kainji Reservoir	Nigeria	4.55E	10.40N		1000				
Kampolombo, Lake	Zambia	29.4E	11.33S		150				
Kanyaboli, Lake	Kenya				11	3			
Kariba, Lake	Zambia, Zimbabwe	27.5E	16.79S	485	54	31	78	160	2164
Kifukula, Lake	DR Congo	28.53E	9.76S		100				
Kikuletwa, Lake	Tanzania	37.42E	3.67S		200				
Kinkony, Lake	Madagascar	45.83E	16.15S		100				
Kioga, Lake (Kyoga)	Uganda	33.1E	1.4N	914	1,720		5.7	6.21	

Name	Country	Longitude	Latitude	Altitude [m]	Surface area [km²]	Maximum depth [m]	Length of shore-line[km]	Volume [km³]	Mean depth[m]
Kisale, Lake	DR Congo	26.45E	8.25S		200				
Kitangiri, Lake	Tanzania	34.33E	4.08S		100				
Kivu, Lake	Rwanda, DR Congo	29.26W	2S	1,460	2,220	240	480	333	
Koka, Lake	Ethiopia	39.1E	8.3N	1,590	250	9.14	13	0.01	
Komango, Lake	Mali	3.69W	16.5N		200				
Kompienga, Lake	Burkina Faso	0.63E	11.16N		220			2.00	
Korarou, Lake	Mali	3.28W	15.30N		100				
Kossou, Lake	Cote d'Ivoire	5.58W	7.17N		1,500				
Kouilou, Lake	DR Congo	12.44E	3.55S		874			35	
Kyle, Lake	Zimbabwe	31E	20.23S		100				
La Vallee d'Iherir Lakes	Algeria	8.25E	25.24N						
Lagdo, Lake	Cameroon	13.97E	8.88N		586			7.70	
Lagos, Lake	Nigeria	3.66E	6.52N		378				
Langana, Lake	Ethiopia	38.62E	7.62N		170				
Lesotho Highlands Reservoirs	Lesotho	28.52E	29.33S						
Liambezi, Lake	Namibia	24.33E	17.90S						
Magadi, Lake	Kenya	36.27E	1.87S		200		1	0,05	
Mai-Ndombe, Lake (Lake Leopld II)	DR Congo	18.20E	2S	340	8,210	5	12	41	
Malawi, Lake (formerly Lake Nyasa or Niassa)	Malawi, Mozambique, Tanzania	34.5E	0.1S	500	29,500	292	706	7,775	245,000
Malombe, Lake	Malawi	35.25E	14.67S		300				
Manambolomaty Lake Complex	Madagascar	44.24E	19.1N		7,491				
Manantali, Lake	Mali	10.50W	13N		200				
Manyara, Lake	Tanzania	35.83E	3.58S		500				
Manzala, Lake	Egypt	32E	31.15N	<1	1,360				
Mape, Lake	Cameroon	11.31E	6.18N		520			3.20	
Marais de Toumbos	Mauritania	16.33W	16.83N		200				
Mare aux hippopotames	Burkina Faso	4.7W	11.37N						
Mare d'Oursi	Burkina Faso	0.30W	14.30N						
Mariout, Lake	Egypt	29.90E	31.12N		66			0.98	
Massinger Barragen, Lake	Mozambique	32.08E	23.87S		150				
Mcilwaine, Lake	Zimbabwe	30.5E	17.5S	1,364	26	9.4	27.4	0.25	74
Mita Hills, Lake	Zambia	29.09E	14.1S		47			0.67	
Mohammed V, Lake	Morocco	2.93W	34.63N		32			0.73	
Monoum, Lake	Cameroon	10.58E	5.58N						
Mweru Wantipa, Lake	Zambia								
Mweru, Lake	Zambia, DR Congo,	28.45E	9S	922	4,350		37	33	340,000
Mylius, Lake	Ethiopia	36.84E	7.07N						
Naivasha, Lake	Kenya	36.2E	0.5S	1,890	160	6.5	11.5	4.6	68
Nakivale, Lake	Uganda								
Nakuru, Lake	Kenya	36.1E	0.2S	1,759	40	2.3	2.8	0.092	27
Nasser, Lake	Egypt, Sudan	32.1E	22.6N	183	5,248	25.2	130	132.5	7,844
Natron, Lake	Kenya, Tanzania	36.1E	2.15S		600			0.35	
Ngami, Lake	Botswana	22.77E	20.5S		120				
Ngobe, Lake	Gabon	9.50E	1.98S		209				
Niangay, Lake	Mali	3.22W	15.83N		300				
Nokoue, Lake	Benin	2.45E	6.42N		150				
Nubia, Lake	Sudan	30.4E	21.1N	183	968			24.4	1,406
Nyos, Lake	Cameroon	10.18E	6.27N						
Nzilo, Lake	DR Congo	25.70E	10.88S		280				

Name	Country	Longitude	Latitude	Altitude [m]	Surface area [km²]	Maximum depth [m]	Length of shore-line[km]	Volume [km³]	Mean depth[m]
Oguta, Lake	Nigeria						8		
O'Higgins, Lago-San Martin	Nigeria	72.1W	48.5S	250	1,058				525
Oiseaux, Lac des	Algeria	8.7E	36.47N						
Okavango Delta	Botswana	22.02E	18.59S						
Onangue, Lake	Gabon	10.05E	1.01S		254				
Oponono, Lake	Namibia	15.30E	19.15S						
Oro, Lake	Mali	3.88W	16.25N		100				
Parc national des Virunga	DR Congo	29.30E	1.15S						
Petit Loango	Gabon	9.45E	2.15S		120				
Piso, Lake	Liberia	11.15W	6.45N		760				
Poelela, Lake	Mozambique	35.08E	24.53S		100				
Pongolapoort, Lake	South Africa	31.96E	27.41S		58			2.45	
Pool Malebo, Lake	DR Congo	15.42E	4.25S		300				
Quiminha, Lake	Angola	13.71E	8.99S		36			1.56	
Quran, Lake	Egypt	30.61E	29.45N		200				
R.K.Roux, Lake	South Africa	24.88E	30.17S		150				
Retenue de la Lufira	DR Congo	27.03E	10.92S		200				
Revue, Lake	Mozambique	33.08E	19.13S		200				
Rkiz, Lake	Mauritania	15.33W	16.83N		150				
Rudolf, Lake	Ethiopia, Kenya	36E	3.30N	427	6,400	7	73	187	340
Rukwa, Lake	Tanzania	32.25E	8S	793	3,000		1		
Rweru, Lake	Burundi	30.32E	2.38S		100				
Selingue, Lake	Mali	8.25S	11.50N		200				
Shala, Lake	Ethiopia	38.4E	7.3N	1,558	329	87	266	36.7	
Shamo, Lake	Ethiopia	37.40E	5.50N	1235	550		13		
Shiroro, Lake	Nigeria	6.91E	9.97N		312			7.0	
Sibaya, Lake	South Africa	32.2E	27.2S	23	78	12.6	43	0.981	126.9
Songor Lagoon	Ghana	0.30E	5.45N						
St. Lucia, Lake	South Africa	32.30E	28S		300		8		
Sterkfontein, Lake	South Africa	29.03E	28.47S		83			2.62	
Tana, Lake	Kenya	37.46E	0.87S		159			1.56	
Tana, Lake (2)	Kenya	37.50E	0.88N		250				
Tana, Lake (Tsana)	Ethiopia	37.2E	11.4N	1,788	3,600	9	14	28	385
Tanda, Lake	Mali	4.72E	15.75N		100				
Tanganyika, Lake	Tanzania, Zambia, Burundi, DR Congo	30.1E	6.0S	773	32,000	572	1,471	17,800	1,900
Tonga, Lake	Algeria	8.31E	36.53N			2			
Toshka Project, Reservoirs	Egypt	30.52E	23.13N						
Tsimanampetsotsa, Lake	Madagascar	43.48E	24..13S	114	456				
Tumba, Lake	DR Congo	18.00E	0.83N	340	500		5		
Turkana, Lake (Lake Rudolf)	Ethiopia, Kenya	36.1E	3.3N	360	6.750	30.2	109	203.6	
Turkwel, Lake	Kenya	35.14E	1.71N		37			1.6	
Tuska Lakes	Egypt	23.08E	30.87N		200				
Upemba, Lake	DR Congo	26.40E	8.67S	580	450		4	0.9	
Vaaldam, Lake	South Africa	28.33E	27S		400				
Velorenvlei, Lake	South Africa					2.5	5		
Victoria, Lake	Tanzania, Uganda, Kenya	33.1E	1.4S	1,134	68,800	40	84	2,750	3,440
Volta, Lake	Ghana	1E	7.4N	85	8,502	18.8	75	148	4,800
Zeekoevlei, Lake	South Africa	18.4E	34.0S	5	3	1.9	5.2	0.005	12.6
Zimbambo, Lake	DR Congo	26.87E	8.17S		150				
Ziway, Lake	Ethiopia	38.4E	7.5N	1,636	485	2.5	9	1.1	102

Source: LakeNet http://www.worldlakes.org/searchlakes.asp

Acronyms and Abbreviations

AIDS	Acquired Immunisation Deficiency Syndrome
AVISO	Archiving Validation and Interpretation of Satellite
BAR	Basin at Risk
˚C	degree Centigrade
CIESIN	Center for International Earth Science Information Network
cm	Centimetres
CNPPA	Commission on National Parks and Protected Areas
CO	Carbon monoxide
CO_2	Carbon Dioxide
CRED	Center for Research on the Epidemiology of Disasters
CRU	the Climate Research Unit
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSR	Climatological Solar Radiation
DEWA	Division of Early Warning and Assessment
DR	Democratic Republic
DDT	Dichlorodiphenyltrichloroethane
E	East
EROS	Earth Resources Observation and Science (National Center)
ETM	Enhanced Thematic Mapper (ETM+).
FAO	Food and Agriculture Organization of the United Nations
FEWS	Famine Early Warning Systems
ft	Foot/Feet
GDP	Gross Domestic Products
GEF	Global Environment Facility
GEO	Global Environment Outlook
GEO3	Global Environmental Outlook Report 3 (UNEP Publication)
GHG	Greenhouse Gas
GIS	Geographic Information System
GLC	Global Land Cover
GLCF	Global Land Cover Facility
GPS	Global positioning system
GPW	Gridded Population of the World
GRDC	Global Runoff Data Center
GRID	Global Resource Information Database
GWP	Global Water Partnership
HIV	Human Immunodeficency Virus
H_2O	Water - Hydrogen dioxide
ha	Hectares
HCO_3	Carbonic Acid
ICRAF	International Centre for Research in Agroforestry
ICE	Inventory of Conflict and Environment
ILEC	International Lake Environmental Committee
IRN	Intelligent Remote
IPC	International Programs Center, United States Census Bureau, Population Division
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources
kg	kilogrammes
km	kilometres
km^2	square kilometres
km^3	cube kilometres
LVEMP	Lake Victoria Environmental Management Project Phase
LHWP	Lesotho Highlands Water Project
m	metres
MDG	Millennium Development Goal
mm	Milllimetres

MODIS	Moderate Resolution Imaging Spectroradiometer
MOPITTMRS	Metropolitan Region of Santiago
MSS	Multispectral scanner
Mt.	Mount
n.d.	Not dated
N	North
N_2	Nitrogen
N_2O	Nitrogen dioxide
NASA	National Aeronautics and Space Administration
NEPAD	New Partnership for Africa's Development
OFDA	Office of U.S. Foreign Disaster Assistant
OMVS	Organization pour la Mise en Valeur du Fleuve Senegal
OWF	Our World Foundation
S	South
SADC	Southern Africa Development Community
SAED	Delta Improvement and Exploitation Society
SAIC	Science Applications International Corporation
SARDC	Southern African Research and Documentation Centre
SOFIA	Stratospheeric Observatory For Infrared
T/P	TOPEX/POSEIDON
TBR	Transboundary Biosphere Reserve
TFDD	Transboundary Freshwater Dispute Database
TM	Thematic Mapper
UMD	Universal Mutation Database
UN	United Nations
UN-DHA	United Nations, Department of Humanitarian Affairs
UNDP	United Nations Development Programme
UNDRO	United Nations Disaster Relief Organization
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNF	United Nations Foundation
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
UNICEF	United Nations International Children Emergency Fund
USAID	United States Agency for International Development
USGS	United States Geological Survey
W	West
WB	World Bank
WCMC	World Conservation Monitoring Center
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resource Institute
WSSD	World Summit on Sustainable Development
WWF	World Wildlife Foundation

ACKNOWLEDGEMENTS

UNEP would to thank the following for their contributions to Africa's Lakes: Atlas of Our Changing Environment

Elaine Anderson, Dartmouth College – USA

Evelyne Apire, UNEP – Nairobi

G. Robert Brakenridge, Dartmouth College – USA

Brian Czarnecki, Eastern Illinois University – USA

Jeffrey Danielson, Science Application International Corporation – USA

Caryn Davis, Oregon State University – USA

Mark Denil, Conservation International – USA

Chandra Giri, Science Application International Corporation – USA

Veronica Grasso – Italy

Beth Ingraham, UNEP – Nairobi

Christen Lambrecht, UNEP – Nairobi

Kent Lethcoe, Science Application International Corporation – USA

Satella Musiiwa, IUCN International Union for Nature Conservation – Zimbabwe

Webster Muti, Zimbabwe National Water Authority – Zimbabwe

Caleb Ouma, UNEP – Nairobi

René Siwe – Cameroon

Asamensaw Seyoum – Ethiopia

Ronald Smith, Science Application International Corporation – USA

Gray Tappan, Science Application International Corporation – USA

James P. Verdin, United States Geological Survey – USA

Kevin Vervuurt, UNEP – Nairobi

Patrick Waeber, Madagascar Wildlife Conservation – Madagascar

Aaron Wolf, Oregon State University – USA

Junqi Wu, INBAR – China

Gregory Yetman, Centre for International Earth Science Information Network – USA

INDEX

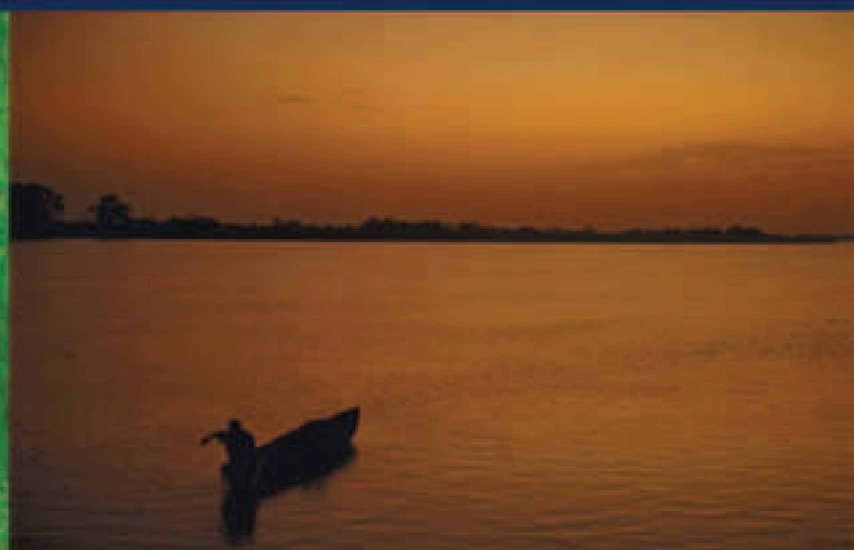
www.unep.org
United Nations Environment Programme
P.O. Box 30552, Nairobi 00100, Kenya
Tel: (+254) 20 7621234
Fax: (+254) 20 7623927
E-mail: cpiinfo@unep.org
Web: www.unep.org

UNEP

Increasing concern as to how human activities impact Africa's lakes has led to documentation and quantification of the lakes and the environmental changes taking place. Through a combination of ground photographs, current and historical satellite images, and narrative based on extensive scientific evidence, this publication illustrates how humans have altered their surroundings and continue to make observable and measurable changes to Africa's lakes and their environment.

This atlas underscores the importance of developing, harnessing and sharing technologies that help provide deeper understanding of the dynamics of the changes. The words and pictures within these pages also serve as a vivid reminder that Africa's lakes are a source of livelihoods for many African communities, contribute significantly to socio-economic development of the continent, and sound policy decisions and positive actions by societies and individuals are needed to sustain the lakes and the well-being of its inhabitants. The information provided will not only be useful in the context of the selected locations, but will also underscore the intrinsic value of the harnessing, visualizing and communicating technologies to gain a deeper understanding of the dynamics and impacts for Africa's lakes and their environmental changes.

UNEP



92 807 2694 3
DEW/0804/NA