AFRICA

WATER ATLAS

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Bruce Pengra/UNEP

Foreword

The Millennium Declaration was our boldest political commitment as heads of state and governments to provide focused leadership and champion good governance to eliminate illiteracy, poverty, disease and environmental degradation by 2015. The Declaration was a pro-poor statement that was subsequently encapsulated into eight Millennium Development Goals (MDGs), setting specific targets negotiated at high-level meetings.

It has been ten years since the Millennium Declaration and as this Atlas makes evident, significant progress has been made in the water sector in Africa, but a lot more remains to be done. It also shows that although there has been important cross-border and sub-regional dialogue and cooperation, a dearth of scientific data and information impedes efforts to manage water issues better. Therefore, this Africa Water Atlas has been wisely and skilfully packaged to trigger continuous debate and dialogue to define an agenda for discussions and strategy planning among ordinary citizens and between water experts within countries and across national borders.

My own country, Liberia, is not dissimilar to many African countries that continue to face challenges in meeting the MDG targets on water and sanitation. At the 64th Session of the UN General Assembly, the Secretary General Ban Ki-Moon noted that "It is clear that improvements in the lives of the poor have been unacceptably slow, and some hard-won gains are being eroded by the climate, food and economic crises." Whereas, on average, the world will meet the MDG water targets by 2015, Africa will not, and the effects of climate change exacerbate the situation of water scarcity.

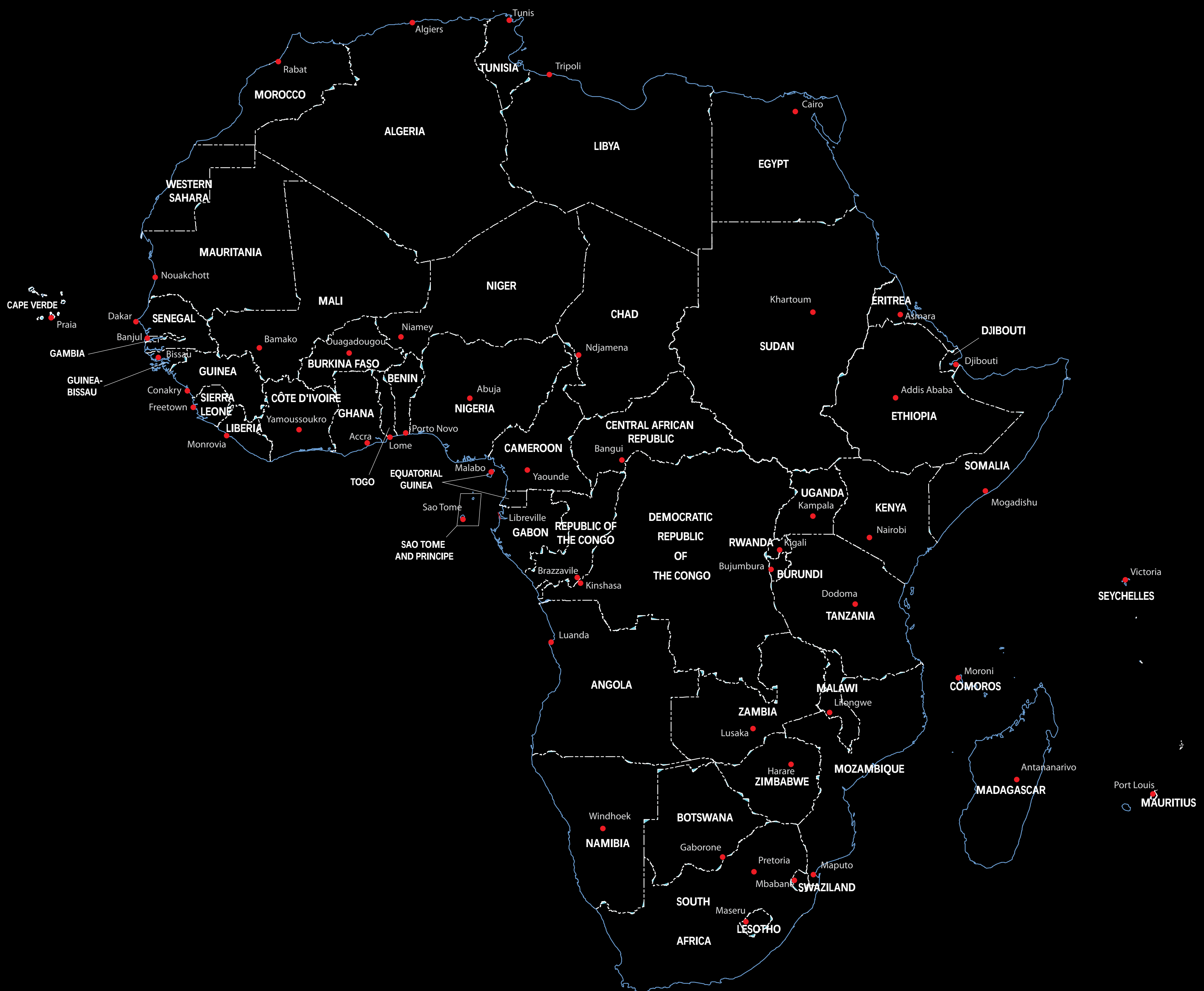
Only 26 countries in Africa are expected to halve the proportion of their citizens without access to improved water by the targeted deadline. It is reliably estimated that in view of increasing population growth and the spiralling cycle of poverty, new models must be developed if the MDG targets on water are to be met by 2015. These estimates show that continental coverage needs to increase from 64 per cent in 2006 to 78 per cent by that date.

The sanitation situation is yet another challenge that needs our special focus as political leaders: only nine countries in Africa will meet the MDG sanitation target. It is heartbreaking and unacceptable that only half of Africa's population use improved sanitation facilities and that one in four has no such recourse. Because of such unsanitary conditions, globally more children under the age of five die of diarrhoea than of AIDS, measles and malaria combined. Investing in safe toilet facilities, clean drinking water supplies and raising awareness of hygiene practices could protect vulnerable populations from these deaths.

The commitment of some African nations to allocating 0.5 per cent of their GDP to sanitation under the e-Thekwini Declaration is an encouraging step forward. In Liberia, just 17 per cent of the population has access to proper sanitation, but increased budgetary allocation by governments to the water and sanitation sector last year alone has reduced child mortality. To meet the MDG sanitation target of halving the proportion of people without sustainable access to basic sanitation, coverage in Africa needs to increase from 38 per cent in 2006 to 67 per cent in 2015.

This Africa Water Atlas vividly illustrates the importance of Africa's water resources in supplying millions of people with life-giving water and in supporting activities that are crucial to our ecosystems and economies. I encourage every leader and policy maker in Africa to open these pages, and not only marvel at the images, but take stock of important messages it has to offer that will help Africa move faster towards the MDG water targets and secure a better future for our children and generations to come.

H.E. President Ellen Johnson Sirleaf
Republic of Liberia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Preface

Since Africa's water resources are so vital to basic livelihoods and economic growth on the continent, an improved understanding of its availability, distribution and limitations is crucial for its better management. Sustainable small-scale and large-scale agriculture, commercial and artisanal fisheries, livestock keeping and range management, industrial growth, hydropower development and biodiversity all depend on water and the better management of this resource.

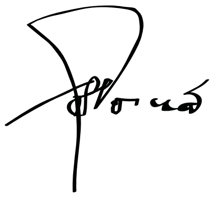
One of the most striking lessons this Africa Water Atlas brings to light is that water resources are plentiful in many African countries. However, one of the untold development ironies and tragedies facing the continent is that too many people don't have access to safe drinking water, and many more lack adequate sanitation facilities. The Atlas reveals the challenges of moving towards the water-provision targets, but also highlights solutions to better manage water and sanitation services that could help achieve them.

Reasons for this disparity in distribution are geographical—topographic elevations and proximity to the Equator cause seasonal variations, for example. These features create climatic variability that is sometimes exacerbated by cycles of floods and drought events. Notwithstanding, there are significant political and economic factors that influence availability and access to water resources. The situation of water scarcity is not made any better by the influx of people to burgeoning cities and slums as they escape from rural environments that are increasingly becoming economically unsustainable. Water stress due to such variability in access has damaged water resources, prevented their development or sparked conflicts between neighbours over shared water.

This Africa Water Atlas provides a reference for our political leaders to work together to develop and implement policies and laws that will protect Africa's water resources, especially by applying Integrated Water Resources Management (IWRM) to better manage water basins and sub-basins. IWRM is a useful strategy in dealing with waters that flow over political boundaries and in managing watersheds and drainage basins shared by two or more countries.

A special feature section of the Atlas gives optimism for addressing water concerns: it shows that although the presence of "hotspots" where rain-fed agriculture is constrained and food security is tenuous is a formidable challenge, Africa has many "hopespots" where long-practiced water-harvesting strategies that have been used as "coping mechanisms" can be expanded and new practices adopted, especially in light of the changing climate. Africa needs to be resilient to develop and spread these promising tools.

It is my pleasure and privilege to be the President of AMCOW when this vital document is released. It is also my hope that its contents will provoke ongoing and fruitful discussions in our classrooms, villages, conference halls and national Parliaments on how best we can manage our African water resources and achieve our sanitation targets for the benefit of all.



Hon. Buyelwa Patience Sonjica
Chairperson of AMCOW and Minister for Water and Environmental Affairs, Republic of South Africa

Statement from Mr. Achim Steiner
UN Under-Secretary General and Executive Director UNEP

The seventh Millennium Development Goal (MDG No. 7) is to Ensure Environmental Sustainability. Its success is measured by targets for achieving sustainable development, reversing the loss of environmental resources, accessing safe drinking water and sanitation and significantly improving the lives of at least 100 million slum dwellers by 2015.

The debate that anchored MDG No. 7 climaxed during the RIO+10 World Summit on Sustainable Development (WSSD) in 2002 in South Africa. It was during this meeting, focused on "Equitable and sustainable use and the protection of the world's freshwater resources as a key challenge", that President Nelson Mandela underscored "the centrality of water in the social, political and economic affairs of a country, the continent, and indeed the world". It was also at this event that Secretary General Kofi Annan's keynote address anchored water in its relevance to energy, health, agriculture and biodiversity.

Africa is often characterized as a dry and arid continent where rainfall fundamentally limits water supplies. This pioneering Atlas and its continental and countrywide assessments challenge this widely-held view. Indeed, as is the case with energy, the problem is rather a question of access. Water resources can be more equitably shared if supplies are better managed for quality and quantity and more and smarter investments are made in sanitation, potable water and protecting ecosystem services that are the very foundation of water resources.

This Africa Water Atlas, the product of the Africa Ministers Council on Water (AMCOW), points to a suite of opportunities that offer a way from a situation of water scarcity to the implementation of strategies that can contribute to sustainable development and improve the likelihood of meeting the MDGs. Rainwater harvesting, for example, is one rapid way to improve water storage in rural as well as urban areas.

In Ethiopia, for example, just over a fifth of the population has access to domestic water supplies and an estimated 46 per cent of the population suffers from food insecurity. On the other hand, its rainwater harvesting potential could provide for the needs of over 520 million people. Evidence elsewhere shows that investing in forests can also generate significant returns, including maintaining and enhancing water supplies.

A recent assessment by the Government of Kenya, with assistance from UNEP, illustrates the value of protecting the forests that help to store water: it estimates that the ecosystem services provided by the Mau forest complex may be worth around US$1.5 billion a year. The Mau Forest Ecosystem, like many other water towers in Africa, provide services that include stabilizing soils, storing carbon and regulating water flows to some 12 major rivers that feed many lakes in the Great Rift Valley of Africa. These rivers and lakes supply drinking water, are harnessed for hydropower and engineered for irrigation and other key services that contribute to the economy and human well-being.

Rethinking agriculture and irrigation is also among Africa's water-related challenges. A recent survey of small-scale farmers in Africa who have switched to organic or near-organic practices found that yields rose by around 100 per cent—in part because of organic matter that improves soil moisture and lengthens the growing season.

The Africa Water Atlas crystallizes the realities and these myriad opportunities in a way that all readers can appreciate. Previous UNEP-supported atlases on Africa, including the Kenya Atlas of Our Changing Environment, have sparked real and tangible action including efforts to rehabilitate the Mau Forest Ecosystem and restore Lake Faguibine in Mali. I am confident that this Africa Water Atlas has the power to trigger debate and guide initiatives that will promote regional peace and the sustainable development of water resources.

Mr. Achim Steiner
Executive Director of UNEP

Statement from H.E. Jean Ping
Chairperson of the African Union Commission

At the WaterDome during the 2002 World Summit on Sustainable Development (WSSD), the text of the MDG No. 7 was reviewed and modified to strengthen metrics to monitor progress towards achieving water targets, incorporating sanitation as an integral part. The clarion call was to reduce by half the proportion of people without access to safe drinking water and adequate sanitation by 2015. In answer to this call, financial commitments were made through political pronouncements, the mood was carnival, and leaders seized these moments to reassure the world they were committed to making a difference.

The WaterDome at the WSSD provided an opportunity for stakeholders and investors to enter into a dialogue on the water agenda. Several initiatives were announced, including the European Union Water Initiative that established a working relationship with the African Ministers Council on Water (AMCOW). Other partners have since joined the partnership, including the African Development Bank, the German Development Cooperation (GTZ) and the Global Water Partnership (GWP), among others. The United Nations agencies led by UNEP have played a pivotal role through the UN Water/ Africa Forum.

To give the water agenda the necessary momentum, the Secretary General constituted the United Nations Secretary General Advisory Board on Water and Sanitation (UNSGAB). UNSGAB has been working closely with the African Water Facility hosted by the African Development Bank. Many other fora have been created as vehicles to support the achievement of water and sanitation targets in Africa.

The debate on water rights and access in Africa is centuries old. The history of the Nile River as the lifeline of riparian communities, beginning with the ancient Egyptian civilization and its modernized agriculture epitomizes the debate. The Nile underscores the importance of water resources for national security and community livelihoods. It is for this reason that treaties have been signed to secure the river's regular flow from its sources. Similar debates are commonplace in most of dryland Africa.

Countries like Libya have invested heavily in harnessing groundwater from the Nubian Sandstone Aquifer, thereby creating the largest man-made river in the world. On a smaller scale, water continues to be a major source of conflict amongst nomadic and pastoral communities in Africa. In urban areas, water is not only scarce for the poor, but costs up to five times more compared to affluent neighbourhoods. The Atlas also covers these issues, illustrating them with case studies and with the ample use of maps and other informative graphics.

Water issues in many parts of Africa can be emotive and politically divisive. Aware of the potential danger of regional conflict over shared waters, the African heads of state and governments provided leadership and mandated their water ministers to seek dialogue through a pan-African platform to make the water agenda a unifying factor for regional cooperation and integration. One of this Atlas's important features is a Chapter on transboundary water basins that points to the issue of shared water as a catalyst for cooperation among riparian countries. It also notes that the emergence of transboundary basin organizations in many of Africa's large basins may provide a powerful opportunity to build an enabling environment as a foundation for cooperation on numerous fronts.

When the President of the Federal Republic of Nigeria, H.E. Olusegun Obasanjo, launched the African Ministers Council of Water (AMCOW) on 22 April 2002 in Abuja, he was well aware of the gravity of the water issue. To ensure stability, President Obasanjo offered that Nigeria take on the role of host to the AMCOW Secretariat. AMCOW has since evolved, and is now recognised in the African Union as a Specialised Technical Committee under the Commissioner for Rural Economy and Agriculture.

As heads of state and governments continue to engage with high-level panels such as the G7 Summit and participate in debates that focus on Africa, it is imperative that the role of the private sector is emphasised in improving water and sanitation technologies through investment in research and development on the continent. The private sector can also invest in infrastructure development such as electricity, irrigation, industry and tourism. This Atlas supports such initiatives.

Because many people in Africa still lack access to potable water and adequate sanitation, one chapter in the Africa Water Atlas has been devoted to profiles of the water situation in each of Africa's 53 countries. This chapter gives a snapshot of the progress each one is making in achieving the water-related MDG targets, and reveals that although Africa has increased access to drinking water sources and sanitation facilities, general developments are not keeping up with population growth and economic activity.

This Africa Water Atlas balances the many challenges Africa faces in dealing with its water problems by stressing the opportunities to improve access to adequate and clean water. The Atlas identifies opportunities that exist to support exciting innovations, such as revolutionizing toilets so that all communities are served, promoting a Green Revolution that is "greener" and more sustainable than its post-World War II predecessor, investing in small-scale hydro and fostering the greening of the Sahel.

I wish to encourage all policy makers in Africa, including diplomats represented at the African Union, to embrace this Africa Water Atlas as a crucial reference document for informed decision-making. I also wish to thank UNEP, USGS, the European Union Commission, and all other partners who have played a part in the development of this seminal document that will accelerate the pace of cooperation and development on the water front in Africa.

H.E. Jean Ping
Chairperson of the African Union Commission

Executive Summary

This Atlas is a visual account of Africa's endowment and use of water resources, revealed through 224 maps and 104 satellite images as well as some 500 graphics and hundreds of compelling photos. However the Atlas is more than a collection of static maps and images accompanied by informative facts and figures: its visual elements vividly illustrate a succinct narrative describing and analyzing Africa's water issues and exemplifying them through the judicious use of case studies. It gathers information about water in Africa and its role in the economy and development, health, food security, transboundary cooperation, capacity building and environmental change into one comprehensive and accessible volume. UNEP undertook the production of this Atlas at the request of the African Ministers' Council on Water (AMCOW) and in cooperation with the African Union, European Union, United States State Department, United States Geological Survey and other collaborators.

The Atlas tells the paradoxical story of a continent with adequate renewable water resources, but unequal access because water is either abundant or scarce depending on the season or the place. Water is the most crucial element in ensuring livelihoods since more than 40 per cent of Africa's population lives in arid, semi-arid and dry sub-humid areas and about 60 per cent live in rural areas and depend on farming for their livelihoods. This particular story is complemented by the encouraging revelation that although rain-fed agriculture is widely constrained, there are also many dry areas where long-practiced and new water-harvesting strategies can be expanded.

The Atlas also tells stories for each of 53 countries, highlighting the salient water issues each faces and tallying the progress they have made towards the Millennium Development Goals' water-related targets. They underscore the still highly inadequate access to potable water and proper sanitation in most countries. These stories are also complemented by useful information about novel strategies and tools that could help to overcome obstacles (from physical, to technical and political) to achieving these targets.

These examples demonstrate that this Atlas is an important tool for decisions makers because it provides clues to address Africa's most challenging water issues.

Special Feature: Hotspots to hopespots and water towers

The Atlas's four chapters are preceded by a Special Feature that focuses on the often two-sided nature of water issues in Africa: surplus and scarcity, under-developed and over-exploited and challenges and opportunities. It makes a unique contribution to the knowledge of water issues on the continent by balancing the recognition of "hotspots" where rain-fed agriculture is highly constrained and food security is tenuous with the identification of "hope spots". These are places where substantial settlements in arid and semi-arid areas coincide with adequate rainfall for water harvesting. Here, traditional and new ways to collect and store water, such as the widespread construction of small farm ponds, could be expanded to support fragile livelihoods, especially in light of the probable impacts of climate change. The Atlas displays the wide distribution of these hope spots on maps generated using datasets of rainfall, soil texture, potential evapotranspiration, topography, landcover and population. Since ninety-five per cent of sub-Saharan Africa's farmland relies on rain-fed agriculture, and agriculture is the single most important driver of economic growth, improving food security through these techniques could very broadly improve human well being in many of Africa's drylands.

The Feature also draws attention to Africa's "water towers". These are forested uplands in several African watersheds, including transboundary basins. They store water and contribute disproportionately to the total stream flow of Africa's major rivers that supply water for hydropower, wildlife and tourism, small- and large-scale agriculture, municipalities, transportation and ecosystem services. Implementing Integrated Water Resources Management (IWRM) could help protect these water towers and sustainably develop their concentrated water resources, especially when two or more countries share them and when upstream activities affect downstream water needs.

Chapter 1: Water resources

The first chapter provides the geographical foundations of water quantity, quality and distribution across Africa's diverse regions. From North Africa to the island countries, it uses various measures to illustrate Africa's hydrological characteristics by charting and mapping water resources at the continental scale. Topics include Africa's overall water resources (lakes and impoundments, rivers, estuaries, wetlands, groundwater and aquifers, etc.), water distribution across the continent and access to that water, the physical setting within which water is found and the climatic conditions that deliver essential rainfall.

After Australia, Africa is the world's second-driest continent. With 15 per cent of the global population, it has only 9 per cent of global renewable water resources. Water is also unevenly distributed, with Central Africa holding 50.66 per cent of the continent's total internal water and Northern Africa only 2.99 per cent. In addition, Africa's climate is highly variable over the seasons. Africa's water availability is also constrained by its groundwater resources, which represent only 15 per cent of total renewable water resources, but supply about 75 per cent of its population with most of its drinking water. Thus, in all regions except central Africa, water availability per person is under both the African and global averages. Africa's annual per capita water availability is lower than that of all of the world's other regions except Asia, the most populous continent.

This chapter is careful to note, however, that differences in water availability and access in African countries does not simply depend on natural conditions—they are influenced by the number of people using that water and compounded by increased water demand because of growing populations, especially in peri-urban areas and slums (between 2005 and 2010, Africa's urban population grew at a rate of 3.4 per cent, or 1.1 per cent more than the rural population), and due to higher standards of living in some population segments; weak city planning and water and sanitation management; a lack of resources; and competition for available freshwater between sectors such as industries, municipalities, agriculture and tourism and often between upstream and downstream users. The chapter also explores the relationship between water and poverty. For example, widespread poverty constrains many communities' ability to address water issues even when significant opportunities such as irrigation, rain-water harvesting, groundwater exploitation or sanitation infrastructure exist. Finally, it looks at the relationship between water and gender, noting that the burden of water collection in Africa falls disproportionately on women and girls, who in some cases spend as much as 40 per cent of their caloric intake carrying water.

Chapter 2: Transboundary water resources

Africa's many borders and its geography pose a challenge to equitably sharing and developing its water resources. Chapter two focuses on water at the scale of major watersheds and groundwater basins that cross national boundaries. Africa's 63 international river basins cover about 64 per cent of the continent's land area and contain

93 per cent of its total surface water resources. They are also home to some 77 per cent of the population.

Chapter two provides in-depth profiles of 13 major transboundary surface-water and 5 shared groundwater basins, illustrated with satellite images, maps and pictures. The groundwater basins represent various regions on the continent, with special emphasis on the Nubian Sandstone Aquifer System, Africa's largest aquifer. Satellite images in time series show striking cases of environmental change within the basins over the past several decades, including landscapes in which lake areas have declined dramatically, dams have created huge artificial lakes, deltas are sinking, saltwater is invading coastal aquifers, transboundary wetlands are shrinking and irrigated agriculture has created spherical green oases in deserts. The case studies examine issues such as water budgets and water quality, irrigation, transport, fisheries and agriculture, invasive species, population growth and development projects including dams and diversions, among others. They analyse past and present conditions, the drivers of change, environmental and social impacts of water development schemes and aspects of transboundary water management. One of the chapter's conclusions is that the need to share water among riparian nations is often a catalyst for effective cooperative water management, rather than the source of conflict.

Chapter 3: Water challenges and opportunities

Chapter three examines nine challenges and opportunities facing Africa as it strives to improve the quantity, quality and use of its water resources. Each of the nine issues is presented by discussing the challenge, the situation, the constraints and the opportunities.

1. The first challenge is to attain the MDG water-provision target of reducing by half the proportion of the population without sustainable access to drinking water by 2015. Africa as a whole will not reach this target and only 26 of the 53 countries are on track to attain it. Opportunities to address this challenge include the targeting of informal and rural settlements and adopting and expanding simple but proven technologies such as a water-disinfection system that already provides drinking water to about four million people.

2. Improving access to clean water will help achieve the second challenge, which is to reduce by half the proportion of the population without sustainable access to basic sanitation by 2015. Of Africa's 53 countries, only nine are expected to attain this target. Opportunities include the potential to encourage and support simple entrepreneurial solutions and to embark on a new drive to revolutionize toilets so they are as desirable as mobile phones.

3. Africa has 63 shared water basins, so it is a challenge to address potential conflicts over transboundary water resources. On the other hand, there are already at least 94 international water agreements in Africa to cooperatively manage shared waters. There is thus an opportunity to learn from their successes and to build on water as a binding factor.

4. Water scarcity challenges Africa's ability to ensure food security for its population. Agriculture uses the most water in Africa and the estimated rate of agricultural output increase needed to achieve food security is 3.3 per cent per year. The potential for meeting this estimate exists, however, since two-thirds of African countries have developed less than 20 per cent of their agricultural production and less than 5 per cent of cultivated area is under irrigation in all but four countries. There is also the opportunity to promote a greener more sustainable version of the Green Revolution, including investments in simple and inexpensive irrigation technologies and breeding drought-tolerant crop varieties.

5. Hydroelectricity supplies 32 per cent of Africa's energy, but its electricity use is the lowest in the world. Africa's hydropower potential is under-developed, however, and hydropower development potential is greater than the entire continent's electricity needs. There are opportunities to develop this untapped resource, but it should be done in ways that avoid the environmental and human costs associated with large dams.

6. Africa faces the challenge of providing enough water for its people in a time of growing demand and increased scarcity. But Africa is endowed with large and often under-utilized aquifer resources that contain excellent quality water and could provide water security in times of drought. There is also the opportunity to improve water-use productivity rather than develop new sources.

7. Land degradation and water pollution reduce water quality and availability. These challenges could be addressed by efforts to maintain vital ecosystem functions, fostering the greening of the Sahel by encouraging adaptation to drought and encouraging adaptive water management strategies.

8. Africa is one of the most vulnerable continents to climate change and climate variability. Given the inherent inter-annual rainfall variability, people in arid and semi-arid lands have a long history of traditional adaptation mechanisms that could be reinforced and adjusted to new circumstances. In addition, there is the opportunity to provide more and better early warning mechanisms.

9. Africa faces a situation of economic water scarcity, and current institutional, financial and human capacities for managing water are lacking. The opportunities for addressing this challenge include reforming water institutions, improving public-private partnerships and expanding the knowledge base through human capacity building.

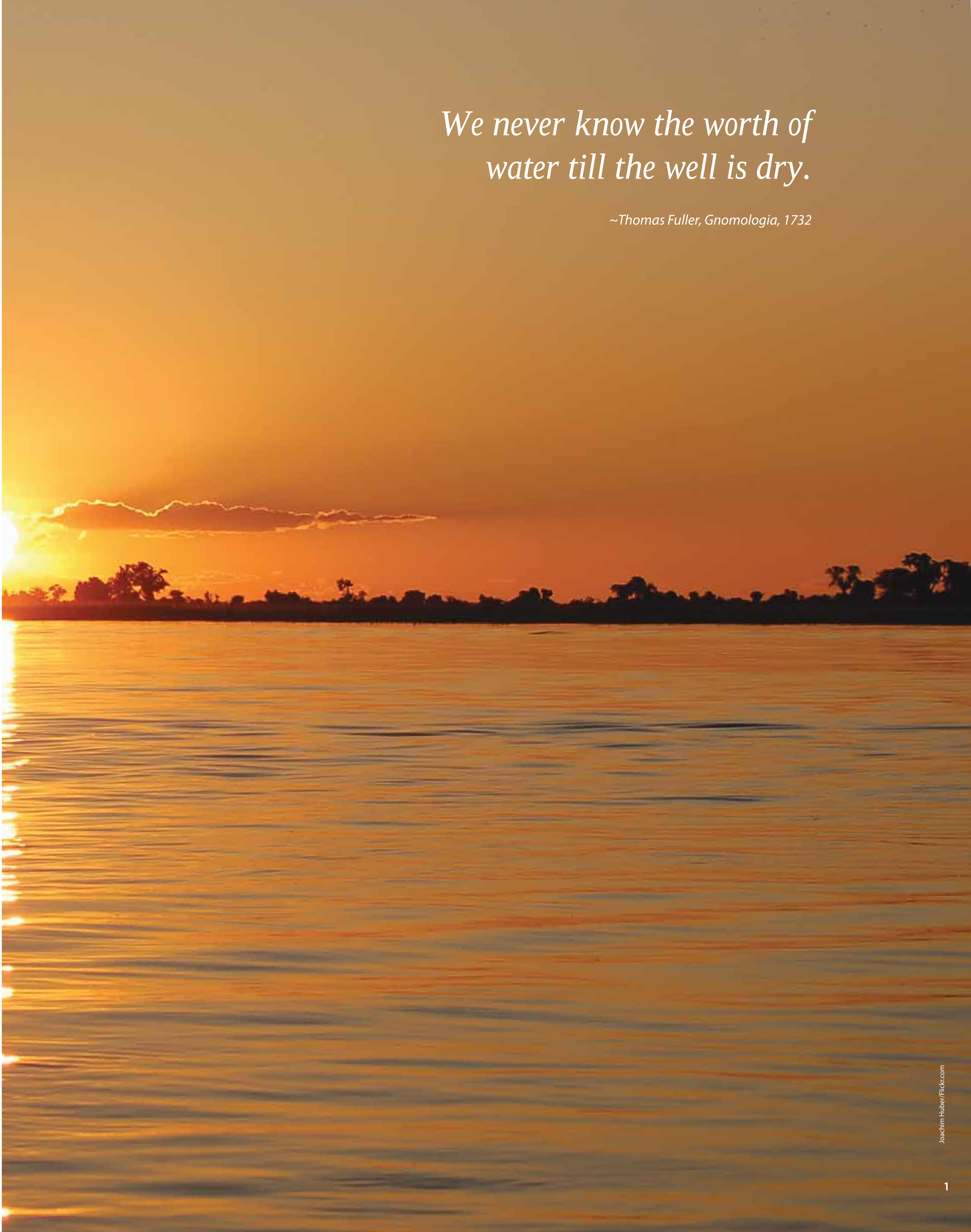
Chapter 4: Water profile of each country

The final chapter is a country-by-country look at water availability and withdrawals, irrigation and water use by sector. Two of the most important water issues in each country are identified and discussed. The country profiles also summarize progress toward the MDG water targets. The MDG summaries frequently highlight the difference between water and sanitation provision in urban versus rural areas. In general, they reveal that the greatest challenges in attaining the targets are not environmentally deterministic; rather, they have to do with political unrest and conflicts that have damaged water and sanitation resources or prevented their development; the influx of people to burgeoning cities and slums; and a lack of resources to support water-management capacity, or simply weak management.

The Atlas is a significant and timely contribution that can inform the implementation of commitments made in the Africa Water Vision 2025. Among other goals, the Vision indicates the minimum need to double the area under irrigation and develop 25 per cent of Africa's hydropower potential. Decision makers can also look to the Atlas for background information and tools to assist in fulfilling commitments made in other recent events and declarations. These include the 2008 Ministerial Conference on Sanitation at eThekwini, where ministers pledged to adopt national sanitation and hygiene policies within 12 months and to ensure these are on track to meet national sanitation goals and the MDGs by 2015; the organization of the First African Water Week and Ministerial Declaration in Tunis; the African Union (AU) Summit's dedication to water and sanitation in June 2008 at Sharm El Sheikh; and the Ministerial Meeting on Water for Agriculture and Energy at Sirte.

We never know the worth of water till the well is dry.

~Thomas Fuller, Gnomologia, 1732



Joachim Huber/Flickr.com

SPECIAL FEATURE
WATER "HOTSPOTS" TO "HOPESPOTS", AND WATER TOWERS OF AFRICA

The title of this special section highlights the often two-sided nature of water issues in Africa: positive and negative, scarcity and surplus, over-exploited and under-developed, challenges and opportunities. It looks at the challenges and opportunities inherent in two quintessential African water issues—uneven spatial distribution of resources and temporal rainfall variability. The two vignettes present both the troublesome and hopeful sides of these two issues.

Hotspots to Hopespots

Over 64 per cent of Africa's population is rural (World Bank 2008), with much of that number living on small subsistence farms. Ninety-five per cent of sub-Saharan Africa's farmland relies on rain-fed agriculture (Wani and others 2009), making most people heavily dependent upon each year's rainfall pattern. For smallholder farms, timely and adequate rains are vital for livelihoods and food security. In some areas, such as West Africa where 80 per cent of employment is in the agriculture sector (Barry and others 2008), timely rainfall is central to the entire economy. However, Africa experiences remarkable variability in rainfall at inter-annual, decadal and longer time scales (Nicholson 1998, Nicholson 2000, Peel and others 2001). This is of particular concern in arid and semi-arid zones where rain-fed agriculture is marginal.

Hotspots

Researchers have consequently identified Africa as one of three global "hotspots" for water-constrained, rain-fed agriculture. They find that people living in these "hotspot" environments are disproportionately undernourished and they link it to climate-driven food insecurity. Most of the 100 million people in Africa living in these areas of water-constrained, rain-fed agriculture are found in a band running through Senegal, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, Ethiopia, Somalia, Kenya, Tanzania, Zambia, Malawi, Mozambique, Zimbabwe and South Africa (Rockström and Karlberg 2009). The red hatching on Figure i shows the areas within Africa's arid and semi-arid regions (Trabucco and others 2009) with populations of 20 persons per km^2 or more (ORNL 2008). These are generally the areas in which food security is most tenuous in Africa.

E. Muench / Flickr.com

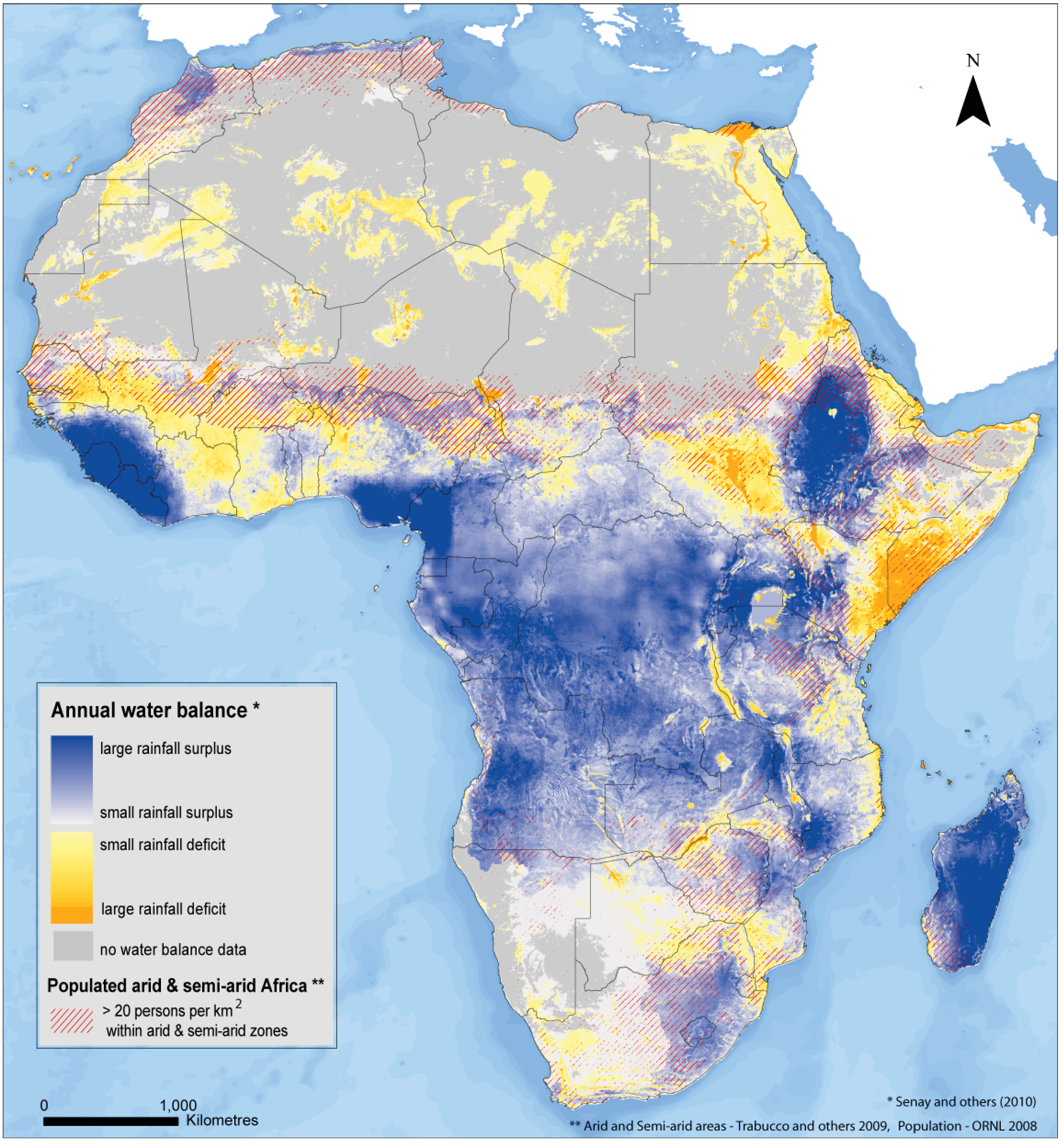


Figure i: Annual water balance is an estimate of the available runoff after evapotranspiration—water that is potentially available for water harvesting. The red hatching overlaying the water balance map shows where population density of greater than 20 persons per km² coincides with areas defined as arid or semi-arid

Water Balance

Hydrologists model Africa's surface water systems using data sets describing precipitation, temperature, evapotranspiration, topography, soils and human-made diversions and impoundments. Recent research has used satellite data to more accurately quantify land-surface processes across the African continent, and in turn, to better estimate vegetation water use. Combined with climate data, this produces a map of "evapotranspiration"—an estimate of the sum of surface evaporation and plant transpiration. This data layer has been used to more accurately generate a water balance map (rainfall minus the water lost to evapotranspiration) as shown in Figure i. This water-balance data is used to model surface water and groundwater behaviour, including stream flow and the potential for dams and other forms of water harvesting.

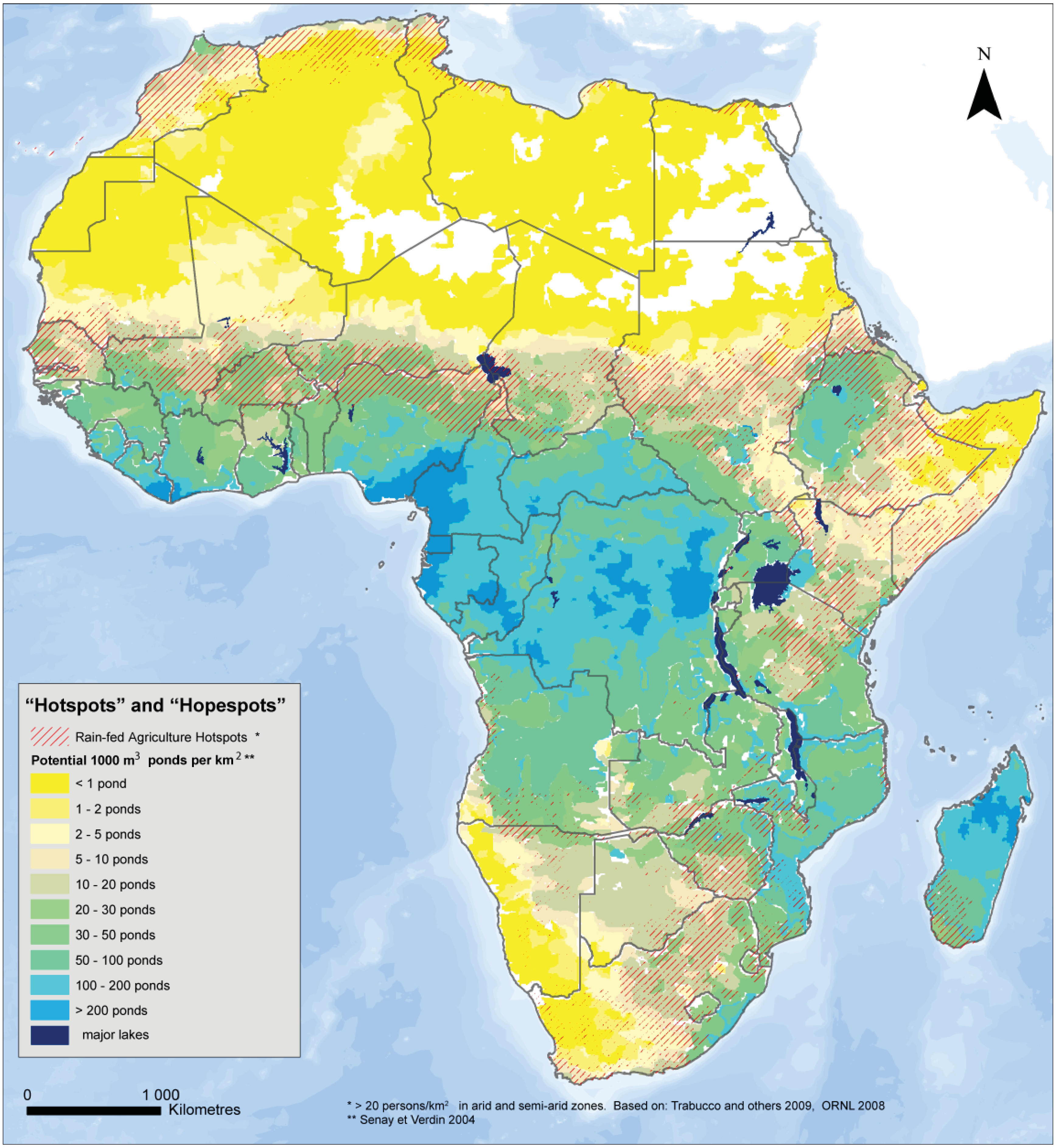
Hopespots

One coping strategy in these drought-prone environments is rainwater harvesting. This can take many forms—from large-scale dams that provide regional benefits to the simple collection of rainwater in a barrel to sustain a household garden through dry periods. For smallholder farms, indigenous techniques for collecting and storing water or enhancing soil moisture are already used in many locations (Barry and others 2008). Expanding these practices and adopting new techniques could make a very significant difference in agricultural production and household food security. Constructing small ponds to collect runoff is an effective practice that has been used in eastern and southern Africa to reduce the risk of crop failure and increase production. This water is then available for multiple uses, such as watering vegetable gardens and smallholder farm fields during water-stressed periods (Rockström 2000).

Researching where this approach is best suited could provide a tool for identifying some "hopespots" where this simple technique can be applied by many smallholder farms (Senay and Verdin 2004).

Lamu District, Kenya—water harvesting pond

Figure ii: Areas of population density greater than 20 persons per km² that coincide with arid and semi-arid zones are potential hotspots of vulnerability for water-constrained rain-fed agriculture (red hatch marks). Many of these areas have adequate runoff for filling small farm ponds, which can reduce vulnerability and improve food security (Senay and Verdin 2004)



This concrete slab in northeastern Kenya collects rainfall and diverts it into an underground storage tank for later use

Water harvesting pond under construction in Lamu District, Kenya

Using datasets for rainfall, soil texture, potential evapotranspiration, topography, landcover and population, researchers have produced a set of maps identifying these potential areas (Senay and Verdin 2004). Figure ii is a broad picture of areas with high potential for this type of technique. Places where these "hopespots" coincide with populated areas in arid and semi-arid Africa (red crosshatches) might be starting points for introducing small farm ponds and other rainwater harvesting techniques that could make a big difference in the lives of rural people.

Because urban areas have less watershed area per person from which to collect water, there is less potential for rainwater harvesting (Senay and Verdin 2004). Nevertheless, water collection from urban watersheds as small as household rooftops can provide valuable water for maintaining urban and peri-urban farming and for domestic use (Kahinda and others 2007, Kabo-Bah and others 2008).

Hope in Action

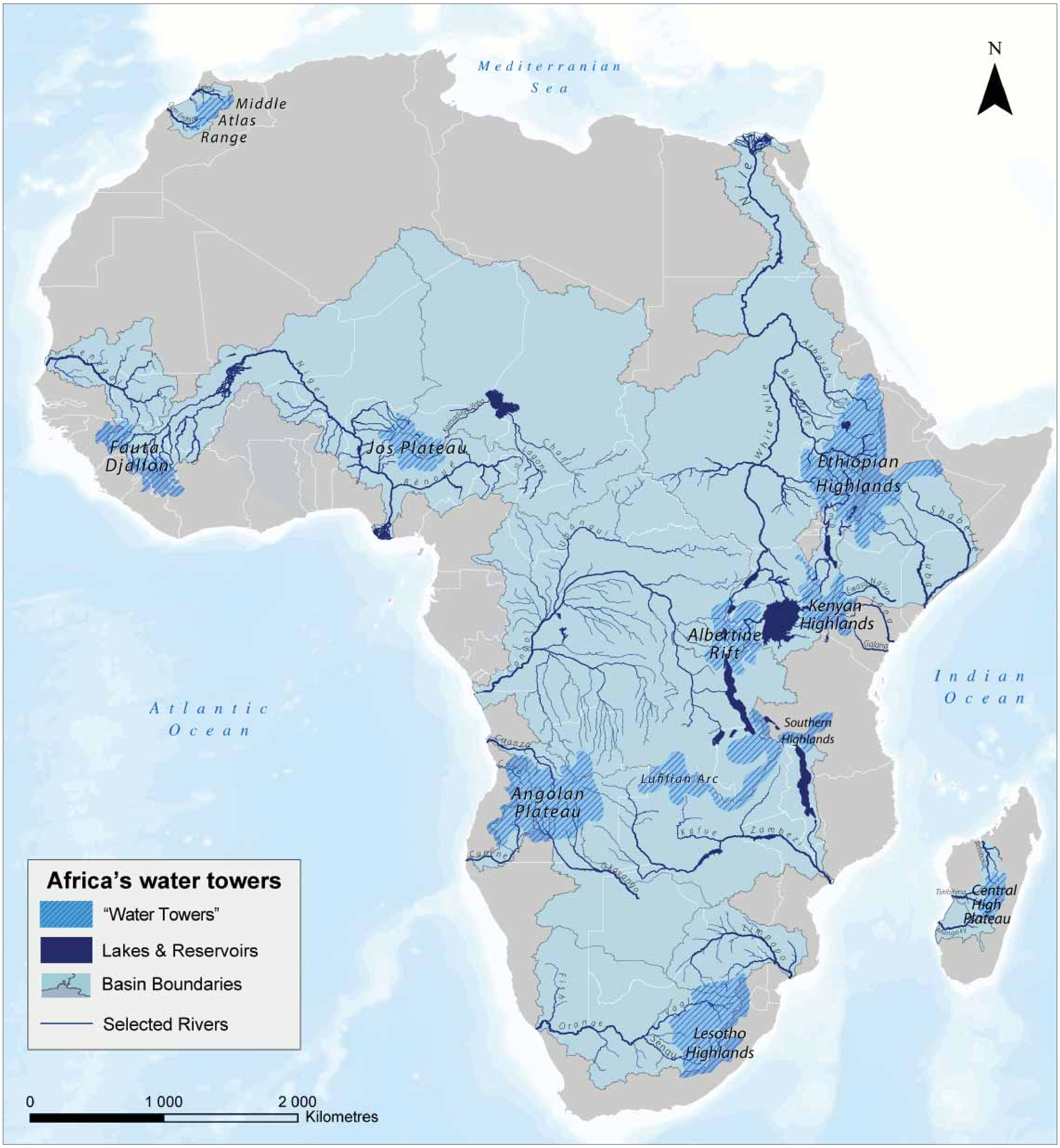
Many areas in the Greater Horn of Africa are "hotspots of water-constrained rain-fed agriculture" (Rockström and others 2009). However, the successful use of rainwater harvesting in many locations across the region is already mitigating the risk for farmers and helping to reduce food insecurity in their communities (USAID 2009, Barron 2004, Pachpute and others 2009). There are numerous examples of successful rainwater harvesting projects in the region, particularly in Kenya, including the use of small farm ponds like those already mentioned. Above are some images from these bright spots of hope.

Water Towers of Africa

Mountainous and other elevated areas in several African watersheds contribute disproportionately to the total stream flow of Africa's major rivers. These areas generally receive more rainfall than their lower surroundings. They also usually lose less water to evapotranspiration because temperatures are lower. Downstream areas often benefit from the abundant runoff. Rivers such as the Nile, the Niger, the Senegal and the Orange flow from relatively rain-abundant areas to areas that would otherwise be too arid to support much life. These important, high-elevation watersheds have been referred to as "the water towers of Africa" for the role they play in supplying millions with life-giving water. The Millennium Ecosystem Assessment (MA) states that mountains act as water towers by storing water in glaciers, permafrost, snow-packs, soil or groundwater (MA 2005).

These "water towers" are sources for many of Africa's transboundary rivers. This can mean upstream communities influence the management of life-giving resources in downstream areas. In many cases, these "water towers" are within multi-national watersheds. While this is sometimes a source of tension, it has seldom led to all-out armed conflict. In fact, it has often proven to be an opportunity for cooperation (Wolf 2007).

Figure iii shows several of Africa's "water towers." They were identified by relative elevation (generally 200–800 m above the surrounding area); precipitation above 750 mm; and runoff above 250 mm. They were also selected for the contribution they make to water resources for populations beyond their delineated boundaries



Several of Africa's transboundary basins are already under the oversight of basin management organizations, such as the Niger Basin Commission in West Africa. Organizations such as these are tasked with presenting their constituent national governments with the science-based understanding of resources shared within these major surface water basins. In this way, the "water towers" concept can complement Integrated Water Resources Management (IWRM) processes by identifying important source areas within major watershed basins. These areas of concentrated resources can then be protected and sustainably developed to equitably address food security, economic development and environmental issues for all stakeholders.

Kenya's Five Water Towers

The five "water towers" of Kenya—Mount Kenya, the Aberdare Range, the Mau Forest Complex, Mount Elgon and the Cherangani Hills—are montane forests and the country's five largest forest blocks. They form the upper catchments of all the main rivers in Kenya (except the Tsavo River originating in Mt. Kilimanjaro). The "water towers" are sources of water for irrigation, agriculture, industrial processes and for all installed hydropower plants, which produce about 60 per cent of Kenya's electricity output. These montane forests are also surrounded by Kenya's most densely populated areas, because they provide enough water for intensive agriculture and urban settlements (DRSRS and KFWG 2006). The integrity of these forests affects their capacity to mitigate floods and drought, prevent soil erosion, maintain water quality, increase groundwater infiltration and influence the micro-climate in and surrounding the forest (GoK 2010).

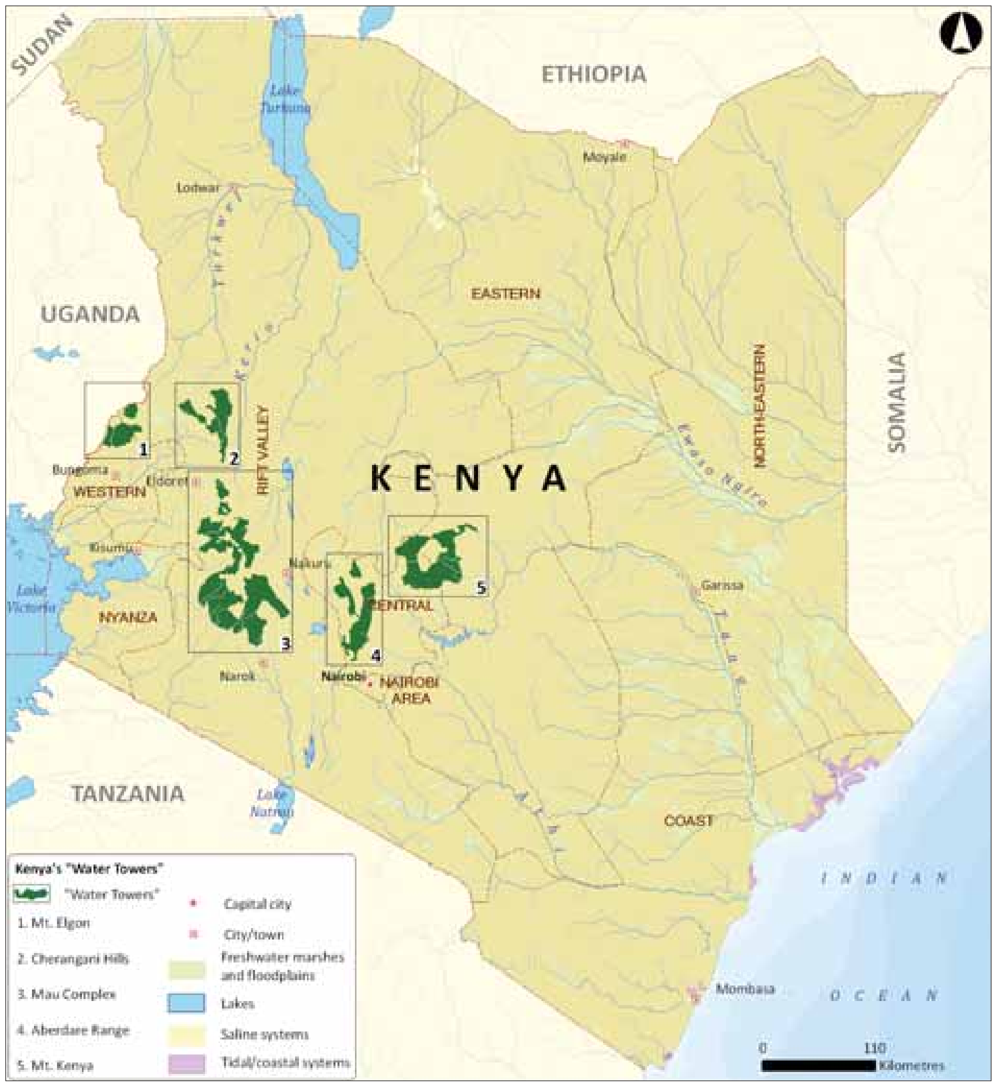


Figure iv: The five "water towers" of Kenya

Agricultural expansion into the Mau Forest Complex

Mau Forest Complex

The Mau Forest Complex, covering over 400 000 ha, is the largest of the five water towers. It is Kenya's largest closed-canopy forest ecosystem and the single most important water catchment in the Rift Valley and western Kenya. The Complex forms part of the upper catchments of all but one of the main rivers on the west side of the Rift Valley. These rivers act as arteries carrying the Mau's waters throughout western Kenya—from Lake Turkana in the north to Lake Natron in the south, as well as to Kenya's most populous rural areas in the Lake Victoria basin. These rivers support agriculture, hydropower, urban water supply, tourism, rural livelihoods and wildlife habitat throughout much of Kenya. As a part of the catchment for Lake Victoria and the White Nile, the Mau Forest is also of international importance, especially with respect to water quality.

In spite of its national importance, many areas of the Mau Forest Complex have been deforested or degraded; much of this damage has taken place in the past few decades. Degazettement of forest reserves and continuous widespread encroachment have led to the destruction of over 100 000 ha of

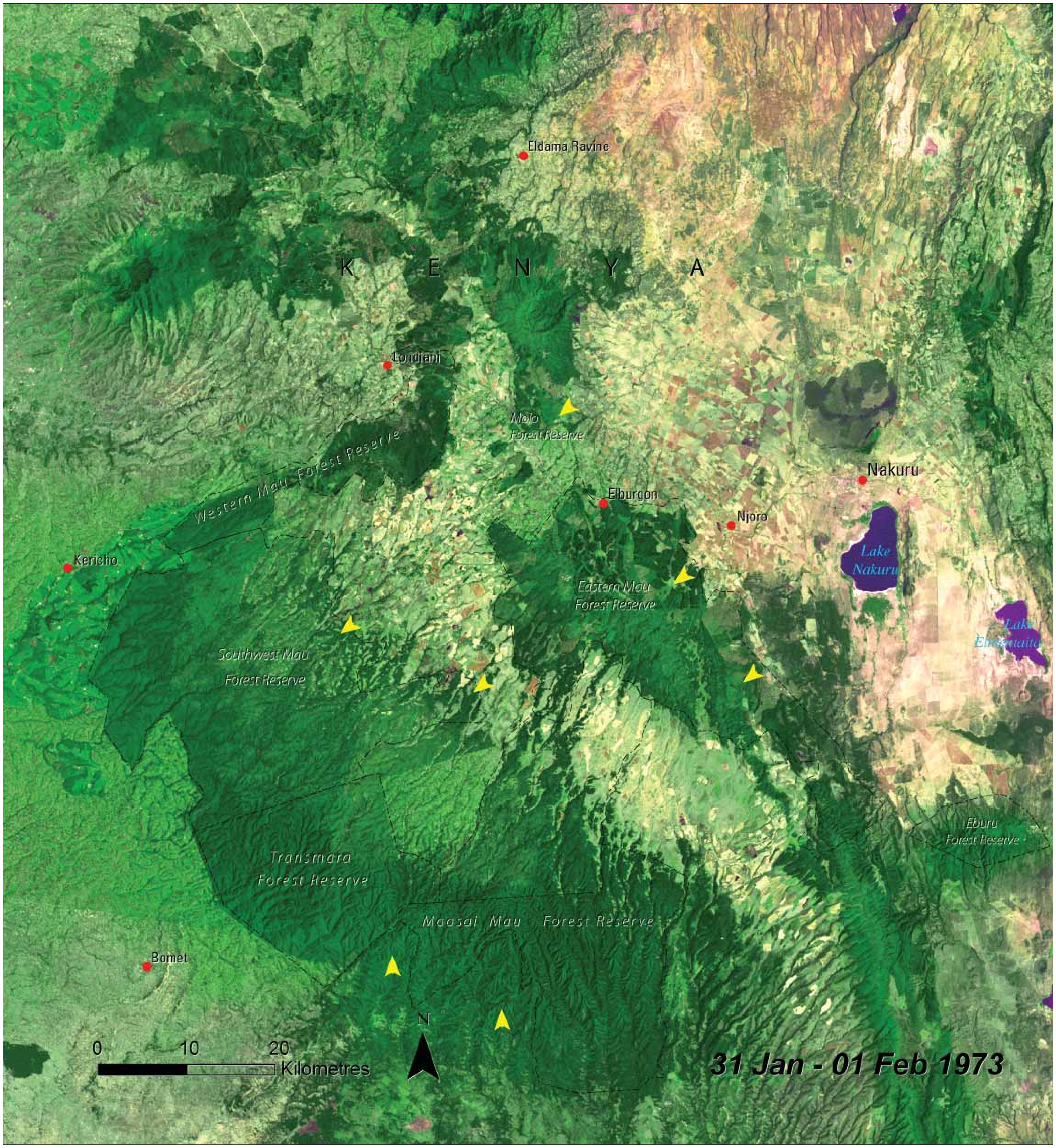


Figure v-a*: Many areas of Kenya's Mau Forest Complex had already been converted to agriculture in the 1970s. Farm fields show as light and dark patches with straight edges between the dark-green forest areas*

forest since 2000, representing roughly one-quarter of the Mau Complex's area (yellow arrows). The satellite images from 1973 and 2009 capture 36 years of forest loss in the Mau Complex.

Since the 1970s, Maasai Mau Forest has lost over 8 214 ha of forest within its official boundaries and another 32 000 ha outside the protected area. The eastern slopes of the Maasai Mau Forest are a crucial catchment for the Ewaso Ngiro River, as are the western slopes for the Mara River. The Mara River is a lifeline for Kenya's most famous tourist destination—the Maasai Mara National Reserve. In 2001 alone, over half of Eastern Mau Forest Reserve was excised. The Eastern Mau Forest is the headwaters for the Njoro River, which drains its eastern slopes into Lake Nakuru, another of Kenya's prime tourist attractions.

Also in 2001, one-quarter of the Southwest Mau Forest Reserve was excised. This forest reserve is the primary source of the Sondu River, site of the Sondu-Miriu hydropower plant. It is estimated that the Mau Forest catchments have the potential to generate over 500 MW of power or about 40 per cent

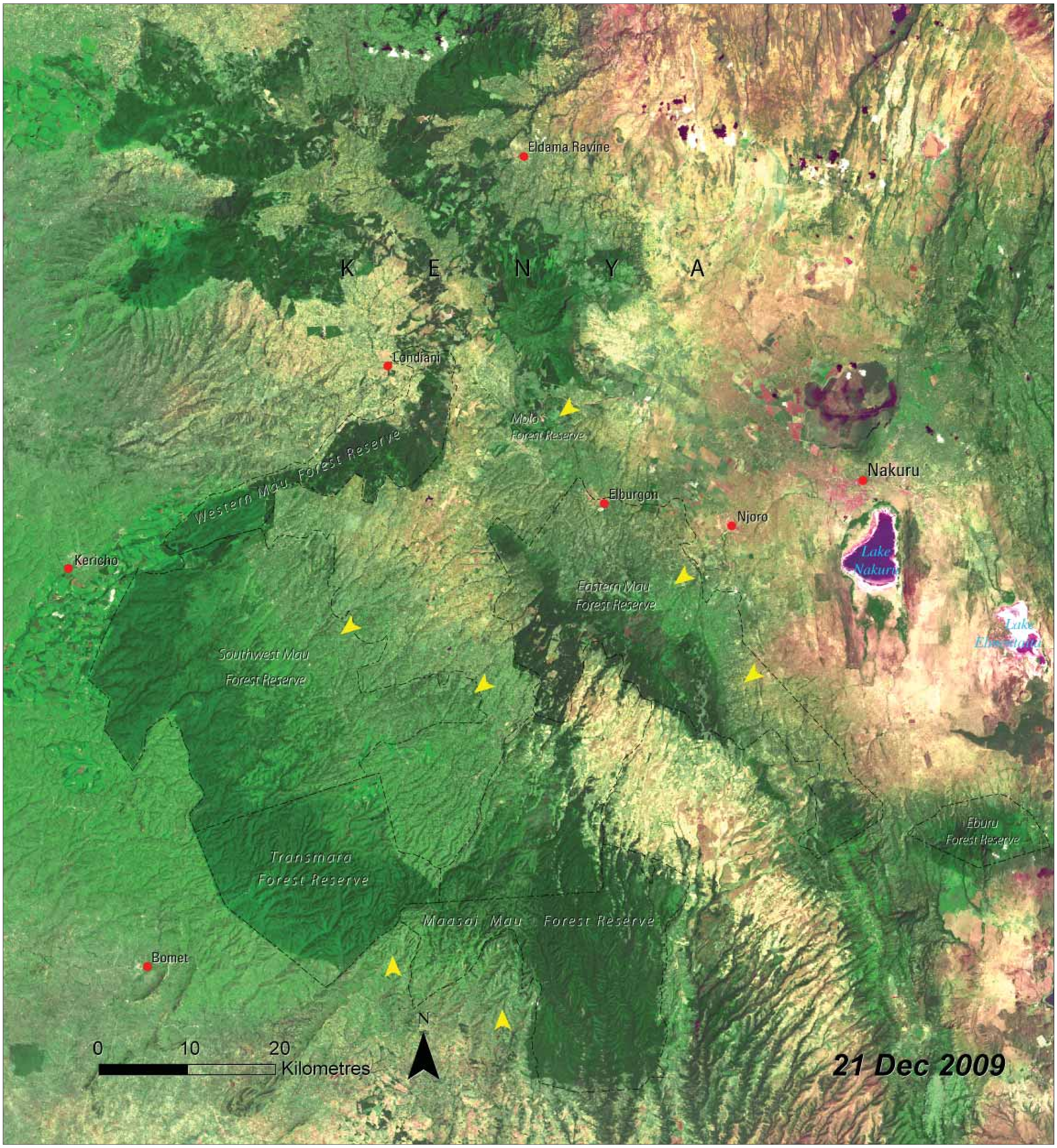


Figure v-b*: By 2009, several additional large forest areas had been converted to agriculture—see areas indicated by the yellow arrows*

of Kenya's current total generating capacity (GoK 2010). On the western edge of the Southwest Mau, the Kericho Highlands tea growing area depends on the montane forest's moderating influence on the micro-climate. Sale of tea from western Kenya was valued at roughly US$170 million in 2007 (GoK 2010).

Recognizing the threat that deforestation poses to these industries and a range of crucial ecosystem goods and services, the Kenyan government convened a forum in 2009 to find ways to address the health of the Mau Forest Complex. A plan to rehabilitate the forest was proposed, with a budget of US$81 million. By early 2010, a commitment of roughly US$10 million had been received from international donor governments (UNEP 2010). The Kenyan government's goal is to rehabilitate the Mau Forest and secure its watershed functions for Kenya and its neighbours (GoK 2010). A new understanding of the Mau Forest as a "water tower" with importance well beyond its immediate area helped mobilize resources and precipitated actions that may make rehabilitation possible.

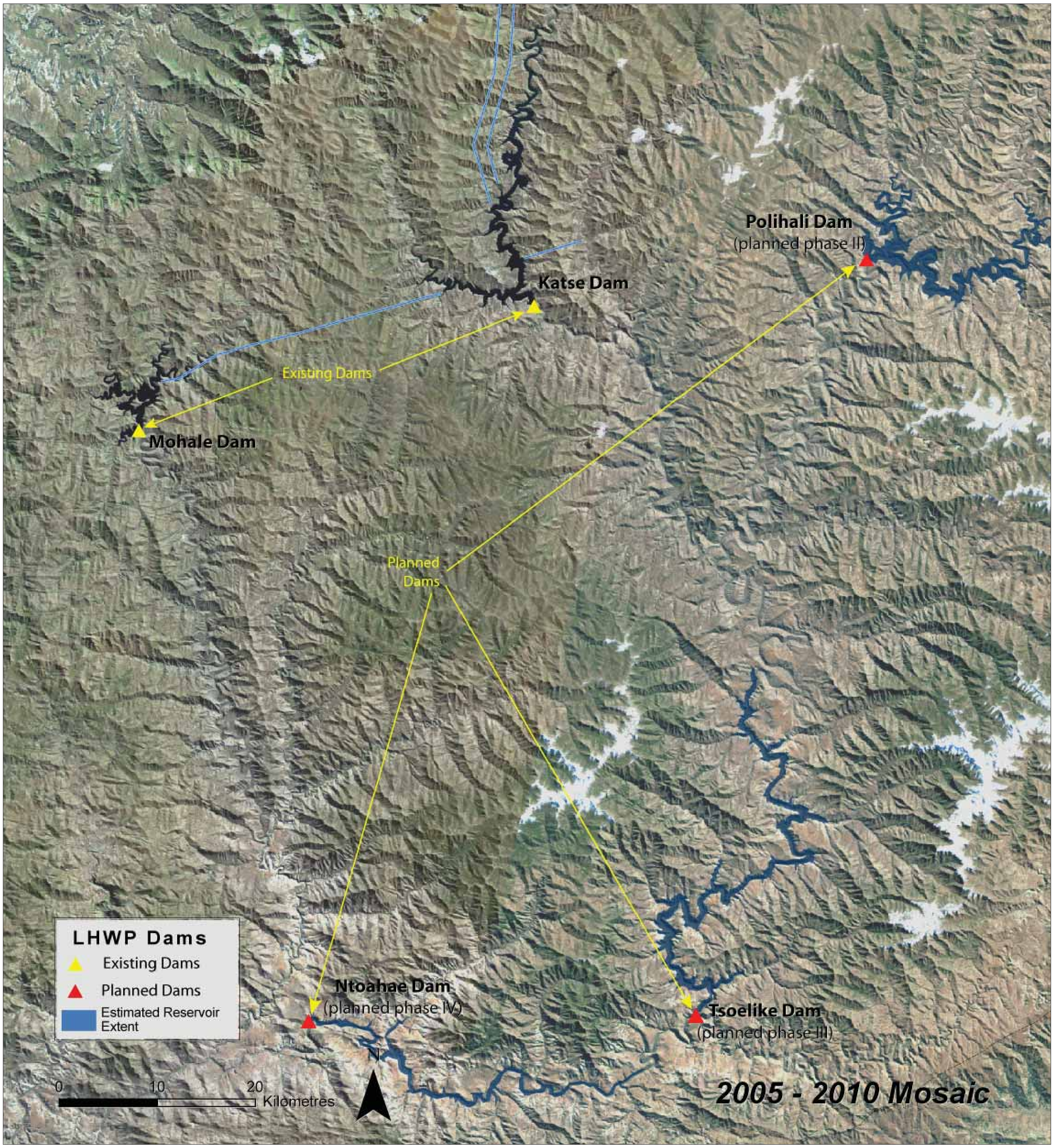


Figure vi: The Lesotho Highlands Water Project will construct several dams and transfer tunnels to generate power and move water to Gauteng Province, South Africa. Katse and Mohale Dams have been completed (yellow triangles). The location and projected reservoir footprints for three additional dams—Ntoahae, Tsoelike and Polihali—are also shown (red triangles)

Lesotho Highlands–A Water Tower in Southern Africa

The cool, wet and misty climate of the Lesotho Highlands makes them a more productive water catchment than the surrounding lower elevations (FAO 2006). Gauteng Province, 250 km to the north, is South Africa's largest urban and industrial centre. In the 1950s, the proximity of these water-rich highlands to thirsty Gauteng Province inspired the idea of using the Lesotho Highlands as a "water tower" (LHDA n.d.).

In 1986, a treaty signed by South Africa and Lesotho initiated the Lesotho Highlands Water Project. Its design included a total of five dams but committed the parties to only the first two dams and related infrastructure (IUCN n.d.) at a cost of over $US1.4 billion (Matete 2006). Its purpose is to deliver water to Gauteng Province in the industrial heartland of South Africa and hydropower and cash to Lesotho (Matete 2006). In 1997, the 185 m Katse Dam was completed on the Malibamatso River; the Mohale Dam, 40 km to the west on the Senqunyane River, was completed in 2003 (LHDA n.d.). Phase II of the

Figure vii: Katse Dam site

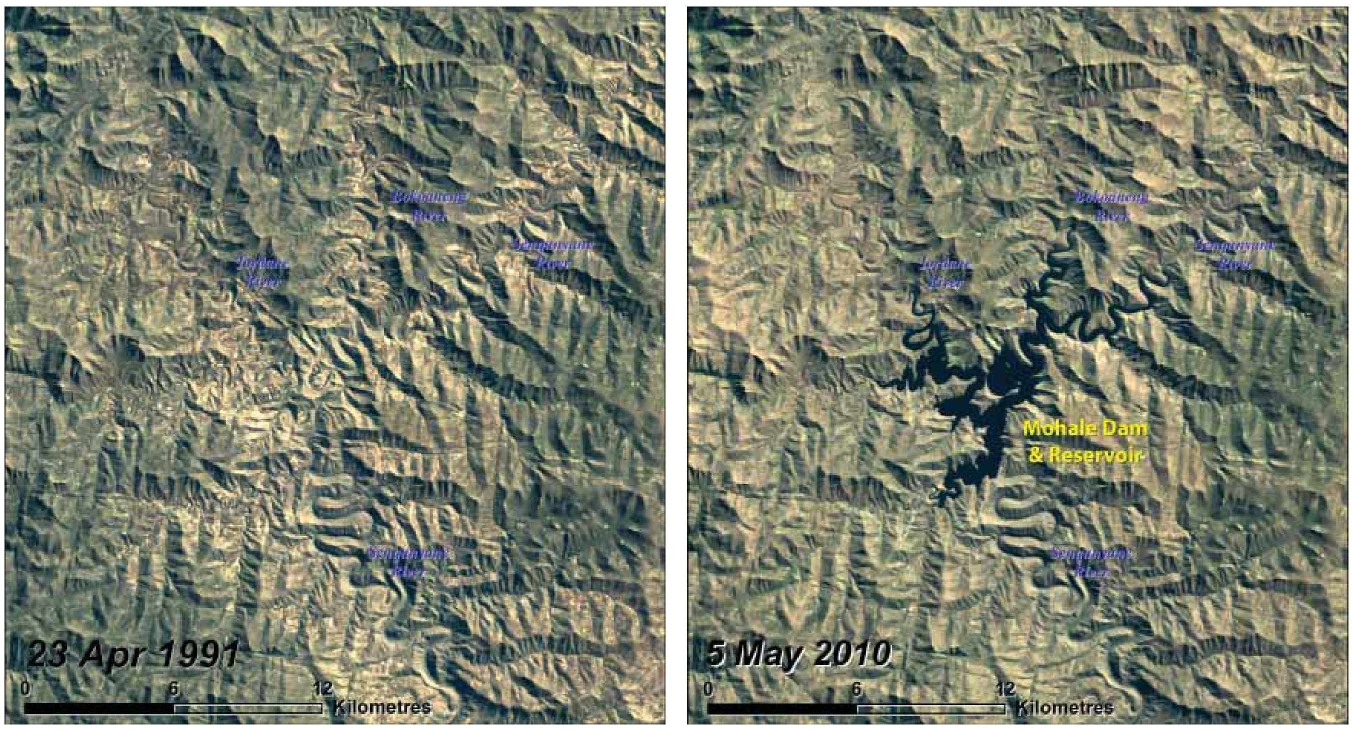


Figure viii: Mohale Dam site

The Katse dam reservoir

project has been revised in light of a recent feasibility study, replacing Mashai Dam and associated infrastructure by the Polihali Dam located just below the confluence of the Senqu and Khubelu Rivers, roughly 35 km east of Katse Dam (Tanner and others 2009). The existing dams, Katse and Mohale, and associated reservoirs can be seen in the upper-left third of the satellite image (Figure vi). The extent of reservoirs for Polihali Dam, Tsoelike Dam (phase III) and Ntoahae Dam (phase IV) have been estimated from digital elevation models and are overlain on the image.

The project has been controversial since it began, with concerns about the social and environmental costs. Katse Dam affected more than 20 000 people and Mohale affected 7 400, with impacts including loss of homes, farmland and communal grazing land (Devitt and Hitchcock 2010). Among the environmental concerns raised were impacts on downstream riparian and coastal habitats (Willemse 2007, IUCN n.d.). Failure to undertake an environmental flow assessment study of the project until 1997 (after the first phase of construction was complete) prevented design changes that could have mitigated downstream environmental impacts (IUCN n. d.).

The 1991 images (Figures vii and viii) show parts of the project area before Katse and Mohale Dams were constructed. The adjacent images from 2010 after both dams had been filled, show the area inundated. The Katse Dam and Muela Hydropower Facility (not shown), took approximately 1 900 ha of croplands out of use and the Mohale Dam removed a further 1 000 ha. The three dams combined decreased pastureland by 5 000 ha. In addition to the impact on the immediate area, approximately 150 000 more people are affected by reduced stream flow below the dams (Hoover 2001).

1

WATER RESOURCES

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In Africa, the world's second-driest continent, the availability and access to water is more crucial to existence than it is almost anywhere else on Earth. Poverty is widespread and although it is rapidly urbanizing, the majority of its population is still rural-based and dependent on agriculture. In sub-Saharan Africa, 69 per cent of the population has no proper sanitation facilities, while 40 per cent has no reliable access to safe water (WHO/UNICEF 2008). Thus, a large number of countries on the continent still face huge challenges in attempting to achieve the United Nations (UN) water-related Millennium Development Goals. Water plays a central role in development, covering a broad cross-section of socio-economic aspects that include meeting people's basic needs, such as drinking and sanitation, demands from various economic sectors, food security, poverty, health, gender issues, governance issues, energy and transport. Water is indeed everyone's business, an essential resource to all aspects of society. In short, water is life.

Water Availability

Very little of the Earth's abundant water is actually accessible and suitable for human needs. This is especially true in Africa. At the continental level, Africa's 3 931 km^3 of renewable water resources represent around 9 per cent of the world's total freshwater resources; by comparison, South America and Asia have the highest proportion each with 28.3 per cent, followed by North America with 15.7 per cent, and Europe with 15 per cent (FAO 2009) (Table 1.1).

Africa is the world's second-driest continent, after Australia, but also the world's most populous continent after Asia. Table 1.1 shows that for the year 2008, the continental annual average water availability per person was 4 008 m^3, well below the global average of 6 498 m^3/capita/yr (FAO 2009).

Water Distribution

There are wide differences in natural water distribution within Africa's sub-regions. Central and Western Africa are endowed with the highest proportions at 51 and 23 per cent respectively, while the share is as low as 3 per cent for Northern Africa (Table 1.2).

A combination of human and natural factors is responsible for differences in water abundance within African countries. When actual total renewable water resources are considered, Nigeria appears to have an abundance of water resources, along with the Democratic Republic of Congo and Madagascar (Figure 1.1). However, average water availability depends not only on internal renewable water resources, but also on the number of people using that water.

Key Facts

Africa has only about 9 per cent of global freshwater resources but 15 per cent of the global population

Africa is the world's second-driest continent, after Australia

Africa's annual per capita water availability of 4 008 m^3 in 2009 is well below other world regions except Asia, the world's most populous continent

Table 1.1: Comparative table of internal renewable freshwater resources by world region (Source: FAO 2009)

Continent/Region	Volume per Year (km^3 or 10^9 m^3)	Percentage of World Freshwater Resources	Per Capita (m^3/year) (2008)
WORLD	**43 802**	**100.0**	**6 498**
Africa	3 931	9.0	4 008
Asia	12 393	28.3	3 037
South America	12 380	28.3	32 165
Central America & Caribbean	781	1.8	9 645
North America	6 877	15.7	15 166
Oceania	892	2.0	32 366
Europe	6 548	14.9	8 941

Key Facts

Renewable water resources are unevenly distributed among Africa's sub-regions

A combination of natural and human factors are responsible for wide differences in water availability between African countries

Table 1.2: Total and proportional renewable water resources in Africa's sub-regions (Source: FAO 2009)

Sub Regions	Total Water Resources (km³/year) (2008)	Percentage of Internal Water Resources of Africa
Central Africa	2 858.08	50.66
Eastern Africa	262.04	4.64
Western Indian Ocean Islands	345.95	6.13
Northern Africa	168.66	2.99
Southern Africa	691.35	12.25
Western Africa	1 315.28	23.32
Total Africa	**5 641.36**	100

There are wide variations in average water availability per person among countries in the continent (Figure 1.2). For example, the annual per capita water availability for Nigeria, Africa's most populous nation, is lower than that of relatively dry states such as Botswana and Namibia in Southern Africa. Annual per capita water availability is high for countries such as Guinea, Sierra Leone and Liberia in West Africa; the Democratic Republic of Congo, Central African Republic and Gabon in Central Africa; and in the Indian Ocean island of Madagascar. In the southern part of the continent, water availability per capita is relatively low for South Africa, as it is in North African states such as Algeria and Libya, as well as Kenya in East Africa.

The unequal water distribution has significant implications for society, often causing widespread acute human suffering and economic damage on a continent where agriculture—largely rain-fed, is the single most important driver of economic growth (Conway and others 2009). In addition to high variability, rainfall across the continent is unpredictable, and characterized by high evaporation losses and low runoff (Batisani and Yarnal 2010, Slimani and others 2010). Groundwater reservoirs underlain by low-storage geological formations also depend on effective rainfall from unreliable rainfall patterns for recharging. The uneven distribution of water resources with respect to time and population distribution challenges water supply (UNEP 2002), forcing water managers to decide between damming the water for distribution to people, or resettling people closer to water resources, among other measures.

Ryan James Johnson

Access to Water

Africa's geography and climate, including periodic drought and highly variable rainfall, are not the only—or necessarily the most significant—reasons for the situations of water scarcity that exist on the continent. Growing populations and the associated increased water demand, the costs of providing water and dwindling water supplies compound the problem. Water availability is also restricted by a trend towards urbanization and higher standards of living, poor or no city planning, a lack of resources and competition for available freshwater between sectors such as industry, municipal water and agriculture and even between nations that share watercourses. These have resulted in water stress or water scarcity conditions in the region where the quantity and quality of water may not be enough to adequately provide safe drinking water, food and hygiene, may limit economic development, and can severely constrain environmental resources (Falkenmark and others 1989).

These factors mean that people suffer from a lack of safe drinking water and access to proper sanitation facilities. The Millennium Development Goals (MDGs), described in depth in Chapter 4 (which

Key Facts

Millions of people in Africa suffer water shortages throughout the year

Water scarcity is not simply due to geography: population growth, rapid urbanization, poor planning and poverty are significant factors

Most urban population growth has taken place in peri-urban slum neighbourhoods, overwhelming municipal water services

Sixty-four per cent of people in Africa use improved drinking water sources

Only 38 per cent of Africa's population has access to improved sanitation facilities

Increases in access to improved drinking water sources and sanitation facilities are not keeping pace with population growth

Table 1.3: Definition of improved drinking water sources and sanitation facilities (Source: WHO/UNICEF 2008)

DRINKING WATER SOURCES		SANITATION FACILITIES	
Improved	Unimproved	Improved	Unimproved[b]
Piped water into dwelling,plot or yard	Unprotected dug well	Flush or pour-flush to: - piped sewer system - septic tank - pit latrine	Flush or pour-flush to elsewhere[c]
Public tap/standpipe	Unprotected spring	Ventilated improved pit latrine (VIP)	Pit latrine without slab or open pit
Tubewell/borehole	Small cart with tank/drum	Pit latrine with slab	Bucket
Protected dug well	Tanker truck	Composting toilet	Hanging toilet or hanging latrine
Protected spring	Surface water (river, dam, lake, pond, stream, channel, irrigation channel)		No facilities or bush or field (open defecation)
Rainwater	Bottled water[a]		

a. Bottled water is considered to be improved only when the household uses water from an improved source for cooking and personal hygiene; where this information is not available, bottled water is classified on a case-by-case basis.

b. Shared or public facilities are not considered improved.

c. Excreta are flushed into the street, yard or plot, open sewer, a ditch, a drainage way or other location.

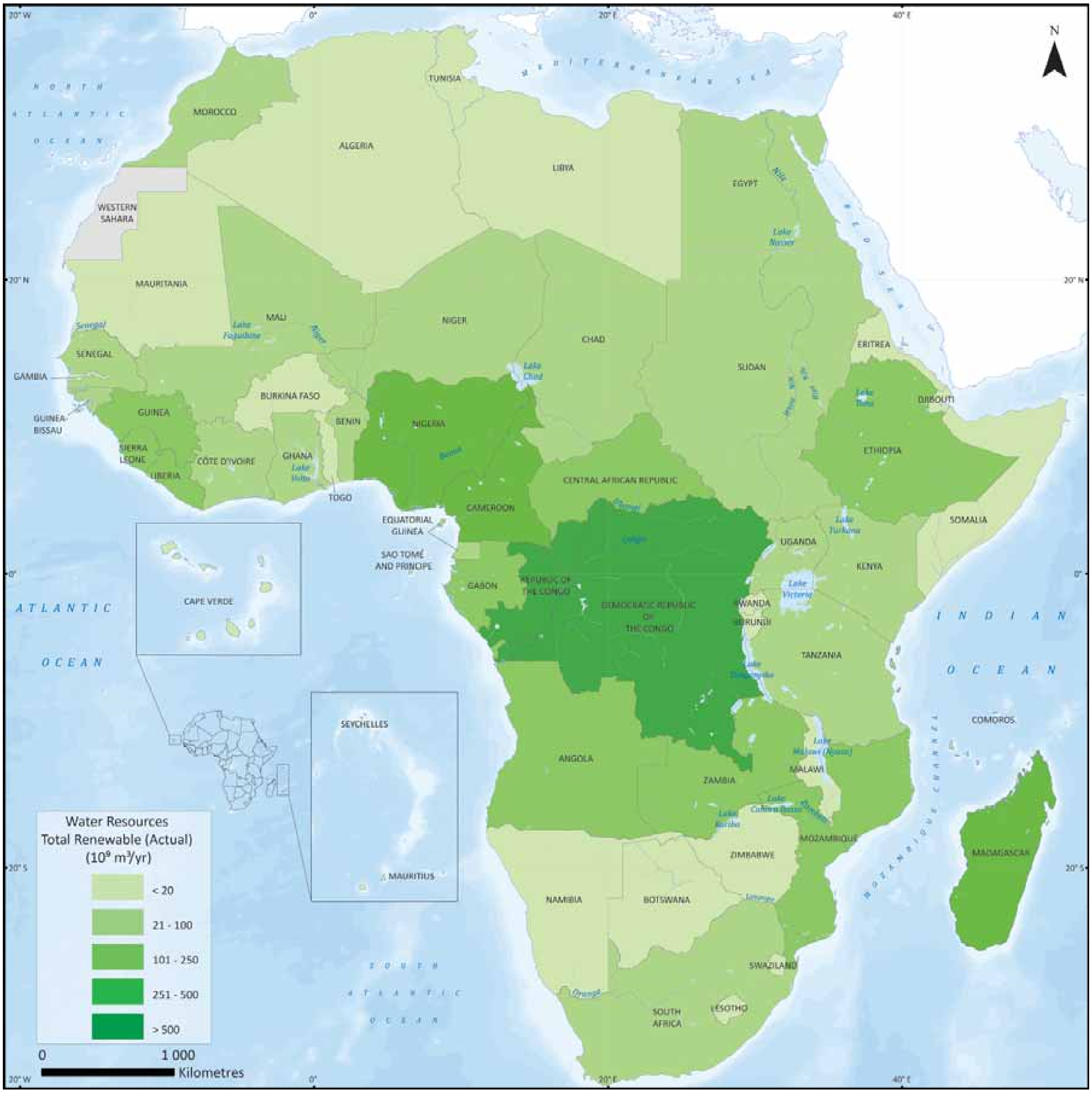


Figure 1.1: Total renewable water resources (Source: FAO 2009)

also provides information by country), set out goals and targets to relieve the most severe poverty in the world and include targets related to the provision of safe drinking water and sanitation facilities.

The water-related target is to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. Data gathered to inform the progress nations are making to meet the MDGs show that in 2006, 341 million people in Africa lacked access to improved drinking water sources (WHO/UNICEF 2008) (See Table 1.3 for the definitions of "improved" drinking water and sanitation). Because of population growth, that number is increasing even though the proportion of people without such access in Africa as a whole decreased from 44 per cent in 1990 to 36 per cent in 2006 (WHO/UNICEF 2008). In other words, increases in coverage are not keeping pace with population growth. Generally, the drinking water situation is worse in rural areas than in urban ones: the average urban drinking water coverage in Africa is 85 per cent while only 51 per cent of people in rural areas have access to improved drinking water (WHO/UNICEF 2008).

Rapid population growth and urbanization, however, have put enormous pressure on municipal water sources. Most of the urban population growth has taken place in peri-urban slum neighbourhoods,

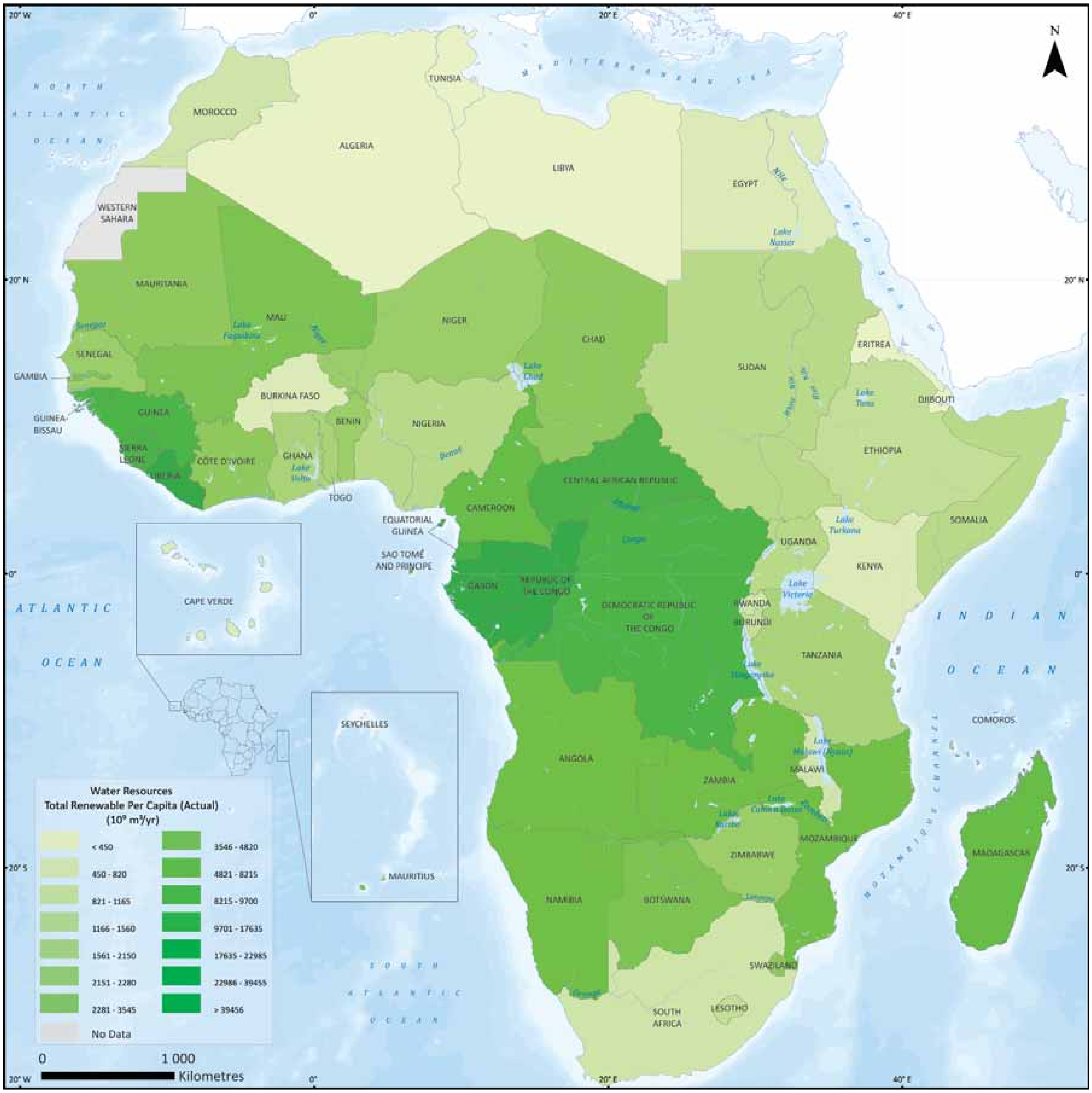


Figure 1.2: Renewable water resources per capita (Source: FAO 2009)

overwhelming the capacity of water supply networks and resulting in an overall decline in piped water coverage in urban areas (Banerjee and others 2008) (Table 1.4).

As for improved sanitation, in 2006 an average of only 38 per cent of Africa's population had access, which represents an increase from 33 per cent in 1990. The African population without access to sanitation increased by 153 million over that time, which shows that the increase in coverage fails to keep pace with population growth. Rural areas are less well served than cities, with urban sanitation coverage in Africa at 53 per cent but only 29 per cent in rural areas (WHO/UNICEF 2010).

Table 1.4: Percentage of urban population accessing various water sources (Source: Banerjee and others 2008)

Years	Piped water	Standposts	Wells/ Boreholes	Surface Water	Vendors
1990 - 1995	50	29	20	6	3
1996 - 2000	43	25	21	5	2
2001 - 2005	39	24	24	7	4

Key Facts

Africa's largest lakes are Lake Victoria, the world's second-largest freshwater lake, and Lake Tanganyika the second-deepest lake in the world

Some of the world's largest dams such as Volta, Kariba and Cahora Bassa are found in Africa

South Africa and Zimbabwe have the most dammed rivers and among the world's countries with large dams ranked 11 and 20 respectively

The Lake Chad basin is the largest endoreic basin (an area with terminal lakes and an interior drainage basin) in the world

Groundwater represents only 15 per cent of Africa's total renewable water resources, but about 75 per cent of its population relies on groundwater as the major drinking water source

Africa's important aquifers such as the Nubian Sandstone, the world's largest fossil water aquifer system, and the Lake Chad sedimentary basin, are losing more water than the rate of recharge

Surface and Groundwater Resources

Rivers

Africa's water is held in large rivers, widespread aquifers, large dams, lakes and wetlands as well as in atmospheric water vapour and soil moisture. The rivers provide transportation arteries, habitat for fish and other freshwater organisms and water for drinking and irrigation.

The Nile River is the world's longest and the Congo and Niger are within the top 25. Africa's rivers have dramatic seasonal variability and inter-annual variation that reflects precipitation patterns in those basins (Walling 1996). For example, the Congo River has a basin area of 3 669 100 km^2, but runoff or discharge at its mouth is 341 mm, which is more than twelve times that of the Nile River, whose comparable basin size covers 3 110 000 km^2 (Table 1.5). This is mainly due to the highly intense rainfall in the Congo's catchment area (Hirji and others 2002, SADC and others 2008). Non-perennial rivers are found mainly in the arid and semi-arid areas such as the Sahara and parts of southern Africa.

Lakes

Africa is also home to some of the world's largest natural lakes (Table 1.6) and human-constructed lakes, or dams. In terms of volume, Africa's natural lakes and dams have a combined capacity that is twenty times that of Latin America's (Wallings 1996). Although it is relatively shallow, Lake Victoria is the

Table 1.5: Characteristics of Africa's four major river systems (Sources: UNEP 2000, Hirji and others 2002)

River	Basin Area (10^3 km^2)	Length (km)	Mean Annual Runoff (10^9m^3)	Unit Runoff (mm)	Interesting Morphological Features
Congo	3 699.1	4 700	1 260	341	Cataracts at Stanley Pool
Nile	3 110	6 850	84	27	Cataracts at Aswan; Drains out of large depression - the Sudd
Niger	2 274	4 100	177	78	Has an inland delta; Entangled in dune fields
Zambezi	1 388.2	2 650	94	68	Falls at Victoria Falls and Caborra Bassa; Linked to the northern Botswana drainage by spillways; Entangled in dune fields

Natural Lakes	Area (km^2)	Maximum depth (m)	Volume (km^3)
Victoria	68 800	84	2 750
Tanganyika	32 000	1 471	17 800
Malawi/Nyasa/ Niassa	30 900	706	7 725
Chad*	18 000	11	72
Turkana	8 660	73	
Albert	5 300	58	

*With low levels 7 000–10 000, with high levels 18 000–25 000 km^2.

Table 1.6: Africa's largest lakes (Source: Shiklomanov and Rodda 2003)

second-largest freshwater lake in the world, with an area of approximately 68 600 km^2 (Swenson and Wahr 2009). Lake Chad is the shallowest major lake and also the fourth-largest in Africa in terms of surface area; it is also the largest wetland in the Sahel region. The Lake Chad basin, with a surface area of 2 500 000 km^2, is the largest endoreic basin (an area with terminal lakes and an interior drainage basin) in the world (LeCoz and others 2009). In the 1960s, Lake Chad was about 25 000 km^2 in surface area, but it experienced a rapid shrinkage in the early 1970s and has since been fluctuating between 2 000 and 15 000 km^2, depending on the season (Lemoalle 2004). The significant shrinkage experienced since the 1960s is due to a combination of severe droughts and irrigation water abstraction (UNEP and WRC 2008).

Lakes Tanganyika and Malawi/Nyasa/Niassa (Table 1.6) are the world's second- and third-deepest lakes respectively, after Lake Baikal in Russia (SADC and others 2008), with the former holding one per cent of the total volume of freshwater on the earth's surface (Bowen 1982).

Africa's natural lakes have very diverse origins. Those along the East African Rift Valley (Lakes Malawi, Albert, Tanganyika and Turkana) are deep tectonic lakes; some lakes were formed by volcanic action, such as Lake Kivu in Rwanda/Democratic Republic of the Congo. There are also shallow floodplain lakes such as those in the Okavango Swamps. The East African Rift Valley has many soda lakes and there are deflation basins or pans such as those found in the Kalahari and Panlands of South Africa. In addition, Africa also has some high altitude lakes of glacial origin (Walling 1996).

Africa's lakes support important fisheries that sustain millions of livelihoods and contribute to food security. At the continental level, Africa is second only to Asia in the global capture of inland fish; its major inland fishing nations include Uganda, United Republic of Tanzania, Egypt, Kenya and Democratic Republic of the Congo (UNEP 2008).

Africa has 63 shared basins covering about 64 per cent of the continental area (UNEP 2005). Chapter 2 looks at the distinctive features of such transboundary water resources.

Rachel Strohm/Flickr.com

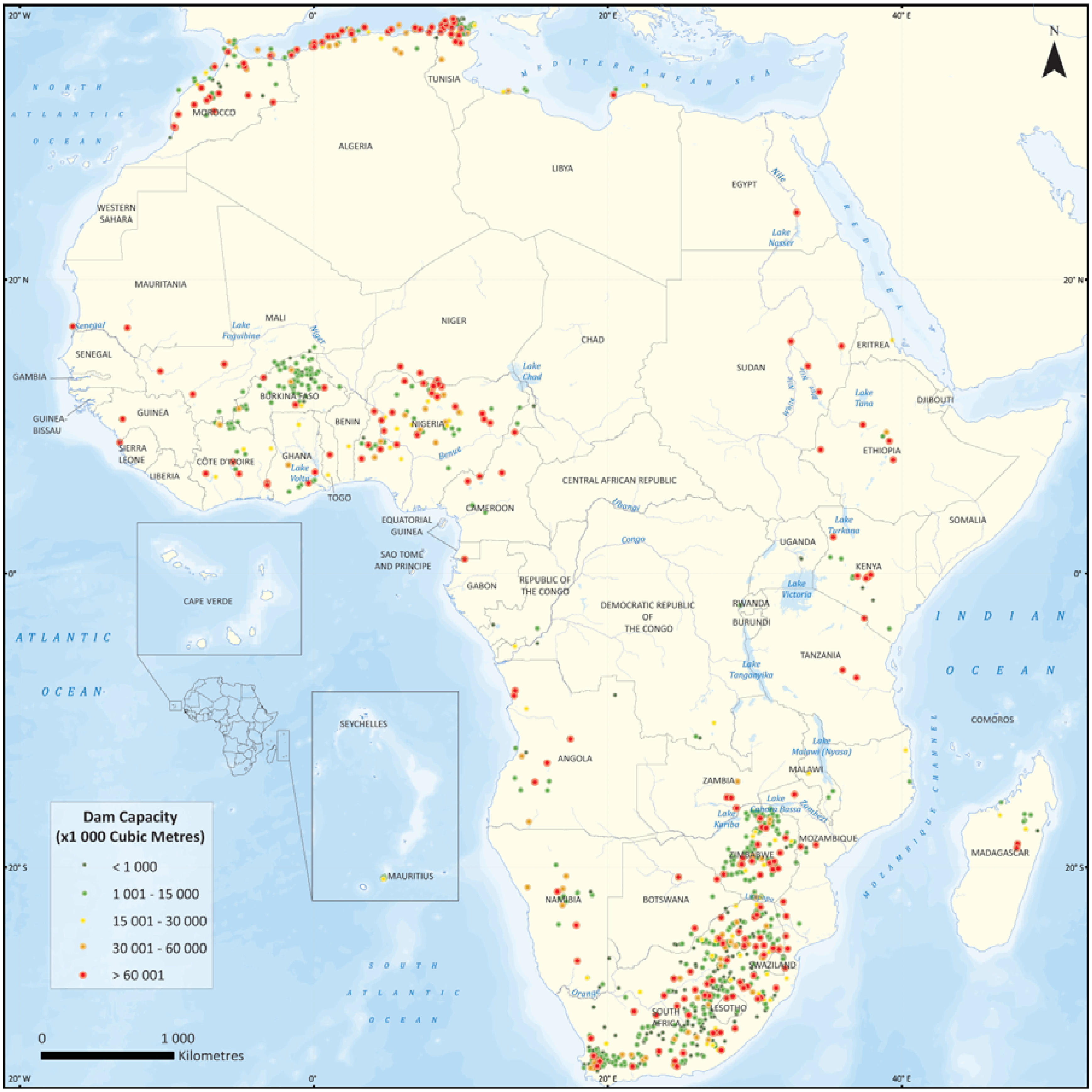
Dams

There is about one dam to every 683 000 persons in Africa, while the equivalent figure for the rest of the world is 168 000 (Strobl, E. and Strobl, R. 2009). More than 1 270 dams have been built on rivers in Africa to store water and supply hydropower and irrigation water (UNEP 2008). Although its large dams are relatively small compared to the continent's natural lakes, a number of African countries have some of the world's largest dams (Figure 1.3, Table 1.7).

Table 1.7: Africa's largest reservoirs (Source: WCD 1999)

Dams/Reservoirs	Area (km²)	Maximum depth (m)	Volume (km³)
Akasombo dam (Lake Volta)	8 480	70	150
Kariba dam (Lake Kariba)	5 250	100	180
Aswan High Dam (Lake Nasser)	5 120	95	162
Cahora Bassa (Lake Cahora Bassa)	2 700	100	52

Figure 1.3: Distribution of dams across Africa



Wetlands

According to the Ramsar Convention on Wetlands (1996), wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

Such areas, which provide many "ecological goods and services", including food sources, wildlife habitat and water storage and filtration, cover about one per cent of the continent's total surface area and are found in virtually all countries.

A wide range of wetland types is found in Africa. Major types include both artificial and anthropogenic lakes, freshwater marshes, river floodplains, swamps and peat lands, in addition to those containing a mixture of salt and freshwater such as estuaries and coastal lagoons. Examples of important wetlands include saline coastal lagoons in West Africa, freshwater lakes scattered throughout the continent, brackish-water lakes in East Africa, the Okavango Delta and Kafue flats in Southern Africa, the marshland along the White Nile in Central Sudan, and the large floodplain wetlands of the savannah region that flow into Lake Chad (Stock 2004, Haller and Merten 2008, Ramberg and Wolski 200, Etile and others 2009). Figure 1.4 shows Africa's main lakes, rivers and wetlands.

Figure 1.4: Surface water showing major natural lakes, rivers and wetlands (Source: UNEP-WCMC 2006)

Estuaries

Estuaries are special types of wetlands found where rivers such as the Congo, Zambezi, Nile, Niger and Senegal discharge into oceans. They normally have a unique combination of physical features associated with their shape, catchment area and connection to the sea and tidal regime (Khedr 1998). This interface between saline waters from the sea and freshwater from rivers is rich in biological diversity. Lake St Lucia in South Africa is an example of an important estuary; it is the largest estuary on the east coast of Africa and is recognized as a wetland of international importance by the Ramsar Convention (Crook and Mann 2002).

Groundwater

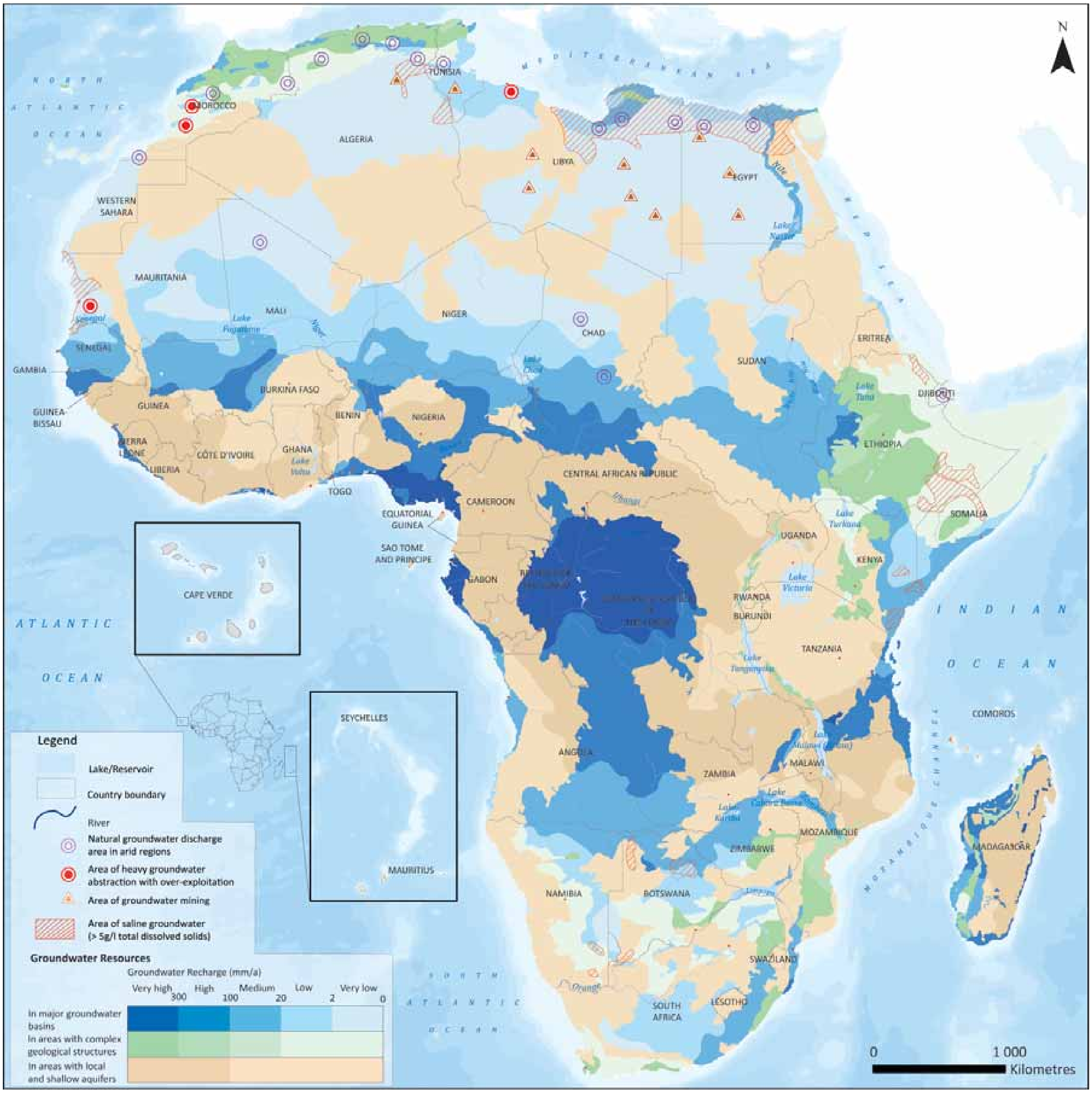
Aquifers and groundwater are highly important in Africa, especially for dry countries in the northern and southern sub-regions. Widespread but limited groundwaters represent only 15 per cent of the continent's renewable water resources, but the source of drinking water for three quarters of the continent's population (UNECA and other 2000). The cities of Lusaka, Windhoek, Kampala, Addis Ababa and Cairo are highly dependent on groundwater for municipal water, and groundwater contributes to the supply of other cities such as Lagos, Abidjan, Cape Town and Pretoria (Robins and others 2006).

Groundwater plays an important role in providing water for people and animals in rural areas

of Africa and may be the only practical means of meeting rural community needs in its arid and semi-arid regions (Robins and others 2006). Groundwater is generally cheaper to develop compared to alternatives. Aquifers are usually protected from contamination; however pollution from human activities on the surface is a growing concern. In addition, naturally occurring fluoride [F] and arsenic [As] can cause significant problems. Groundwater is less prone to evaporation than are surface water bodies, so it is a more reliable water source, especially during droughts (Calow and others 2010). Finally, groundwater is a source of seepage into water bodies such as rivers and lakes, and this interaction in the water cycle is important for maintaining the integrity of ecosystems.

Most countries in the desert areas of Africa such as Libya, Egypt, Algeria, Tunisia, Namibia and Botswana receive very little precipitation and therefore rely heavily on groundwater resources. For example, groundwater provides 80 per cent of domestic and livestock demands in Botswana (SADC and others 2008), and is the source of livelihood for 80 per cent of Namibia's rural population needs (Ndengu 2002). In general, groundwater represents the only source of water in North Africa (Braune and Xu 2010). Some of Africa's important aquifers are losing water faster than the rate of recharge, such as those found in large sedimentary basins of Lake Chad, and under the Sahara desert (Stock 2004). Figure 1.5 shows Africa's surface and groundwater features.

Figure 1.5: Surface and groundwater features (Source: BGRM/UNESCO Paris 2008)



Key Facts

Africa's climate is characterized by an overall unreliability of rainfall

There are two rainfall extremes, ranging from near zero in dry regions such as the Sahara Desert, to extremely high rainfall in the Congo-Guinean rainforests

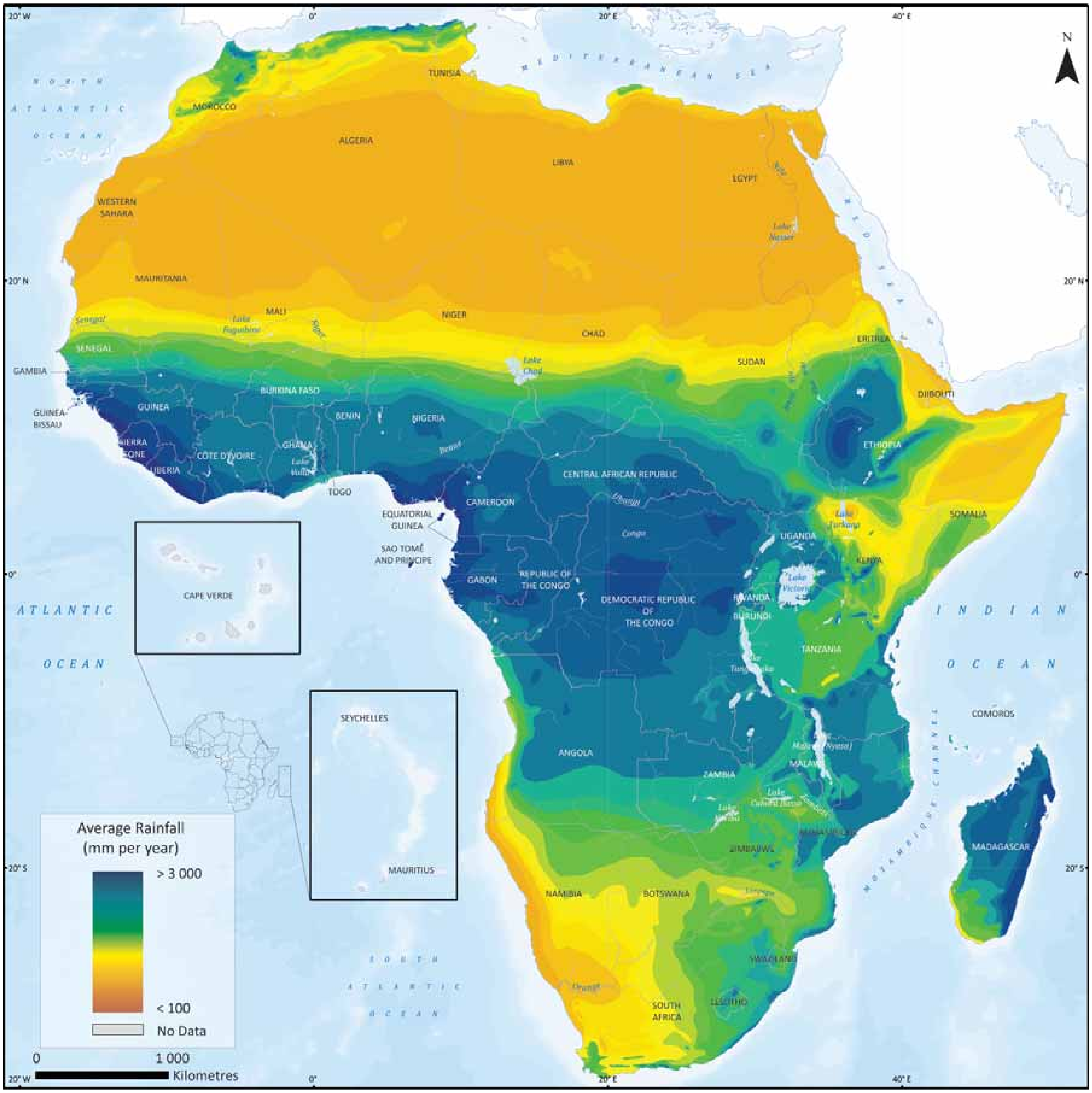
There are pronounced seasonal variations in precipitation in many African regions

Water and the Physical Environment

Climate

The distribution of rainfall varies in space and time, with a consequent overall unreliability of water supplies. In some places there are temporal variations as high as 40 per cent around the mean (UNECA and others 2000). The climate varies from humid equatorial to seasonally arid and tropical and sub-tropical Mediterranean-type climates. The continent's northern and southernmost extremes have temperate Mediterranean climates; in between are the subtropical Sahara and Kalahari deserts. Rainfall varies considerably by season, with some regions, such as the drought-prone areas of the

Figure 1.6: Rainfall map (Period data collected: 2003–2007, UNEP 2004)



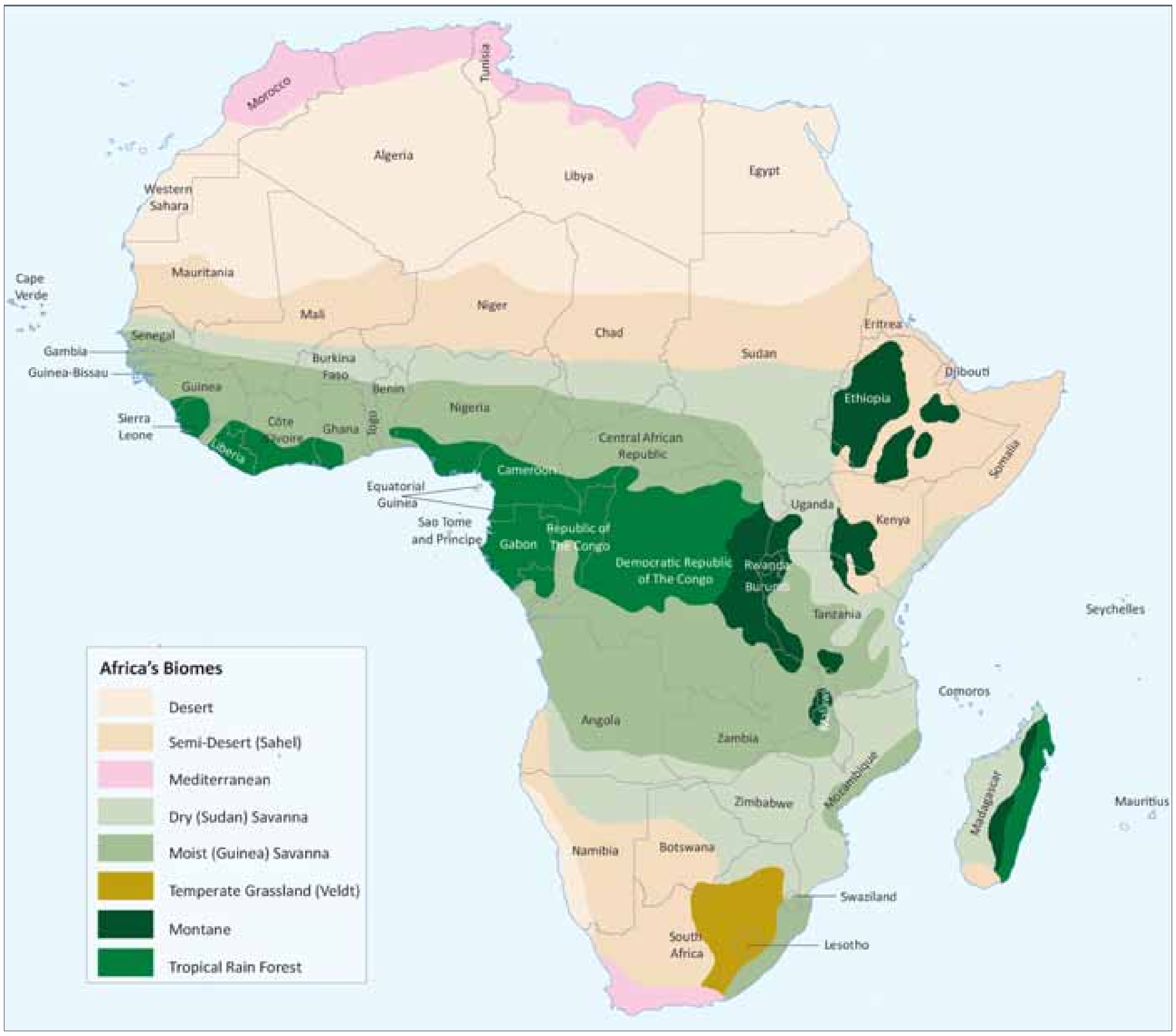


Figure 1.7: Africa's Biomes (Source: Chi-Bonnardel 1973)

Sahel, Southern and Eastern Africa, experiencing pronounced seasonal wet and dry periods (Hulme and others 2001) (Figure 1.6). Topographical features and differences in sea-surface temperatures influence climatic differences between the eastern and western parts of the continent.

The highest rainfall is observed in the Indian Ocean Islands and Central African states, while Northern African states receive the lowest. Overall, annual rainfall reliability is low, and in most sub-regions except Central Africa, it is less than potential evapotranspiration, with a highly variable picture across Indian Ocean Island States (UNEP and WRC 2008). Historical records show that during the 20th century, rainfall has been decreasing over large portions of the Sahel, while rainfall has increased in East Central Africa (Nicholson 2005).

Major influences on the climate come from prevailing wind movements, which are found in the equator region, the two tropics and the two largest deserts: the Sahara in the north, and the Kalahari in the south-western part. Circulation of these air masses brings rainfall to different parts of the continent, and seasonal, inter-annual and long-term circulation dynamics are instrumental to changes in local climate zones (Dinar and others 2008).

Key Facts

Arid lands cover about 60 per cent of Africa

Precipitation, primary productivity and biodiversity are correlated

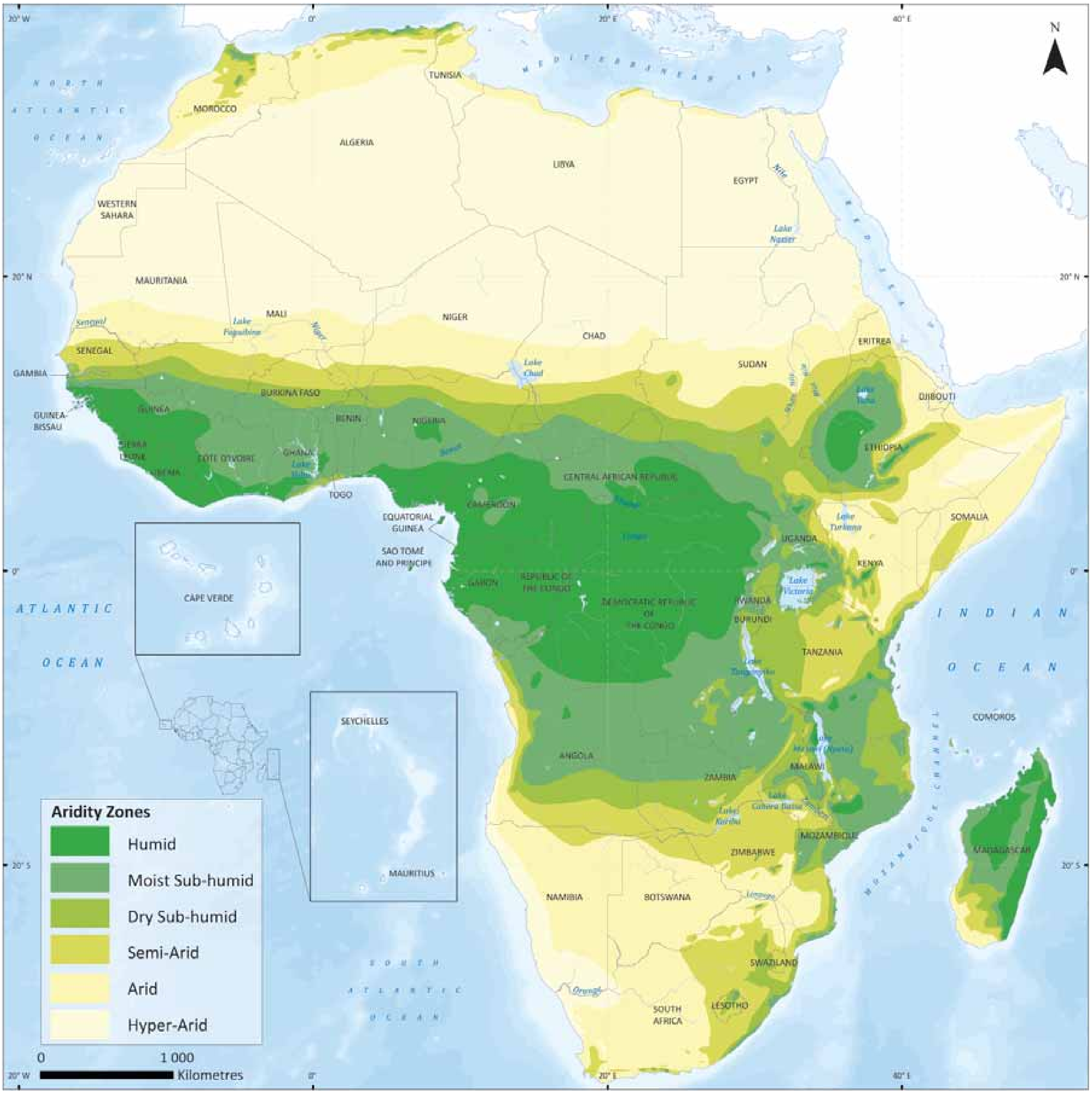
More than 40 per cent of Africa's population lives in arid, semi-arid and dry sub-humid areas

Africa's Biomes

Generally, the pattern of vegetation in Africa largely mirrors its climatic zones, with areas of high rainfall producing the greatest volume of biomass, or primary productivity. On a broad scale, UNEP (2008) has defined the vegetation of Africa in terms of eight major biomes—large areas with similar patterns of vegetation, soils, fauna and climate (Figure 1.7).

Approximately 66 per cent of Africa is classified as arid or semi-arid (Figure 1.8), with extreme variability in rainfall (UNEP 2002). There are three main deserts: the Sahara in the north, and the Kalahari and the Namib deserts in southern Africa. They are situated around the Tropic of Cancer in North Africa and the Tropic of Capricorn in the south. Other arid to semi-arid areas include the belt along

Figure 1.8: Aridity zones (Source: UNEP 2004)



the eastern coast of Africa, and up to the Horn of Africa. More than 40 per cent of Africa's population lives in the arid, semi-arid, and dry sub-humid areas where demand for water and other ecosystems services is on the rise (Ingram and others 2002, De Rouw 2004, Sultan and others 2005).

Droughts during the past three decades and land degradation at the desert margins, particularly the Sahara, have raised concerns about expanding desertification (Herrmann and Hutchinson 2005). The full nature of this problem and the degree to which human activities and climate change are contributing to it are still being determined. However, the negative impact that these degraded lands have on the livelihoods of the people who attempt to utilize them is well documented (UNEP 2008).

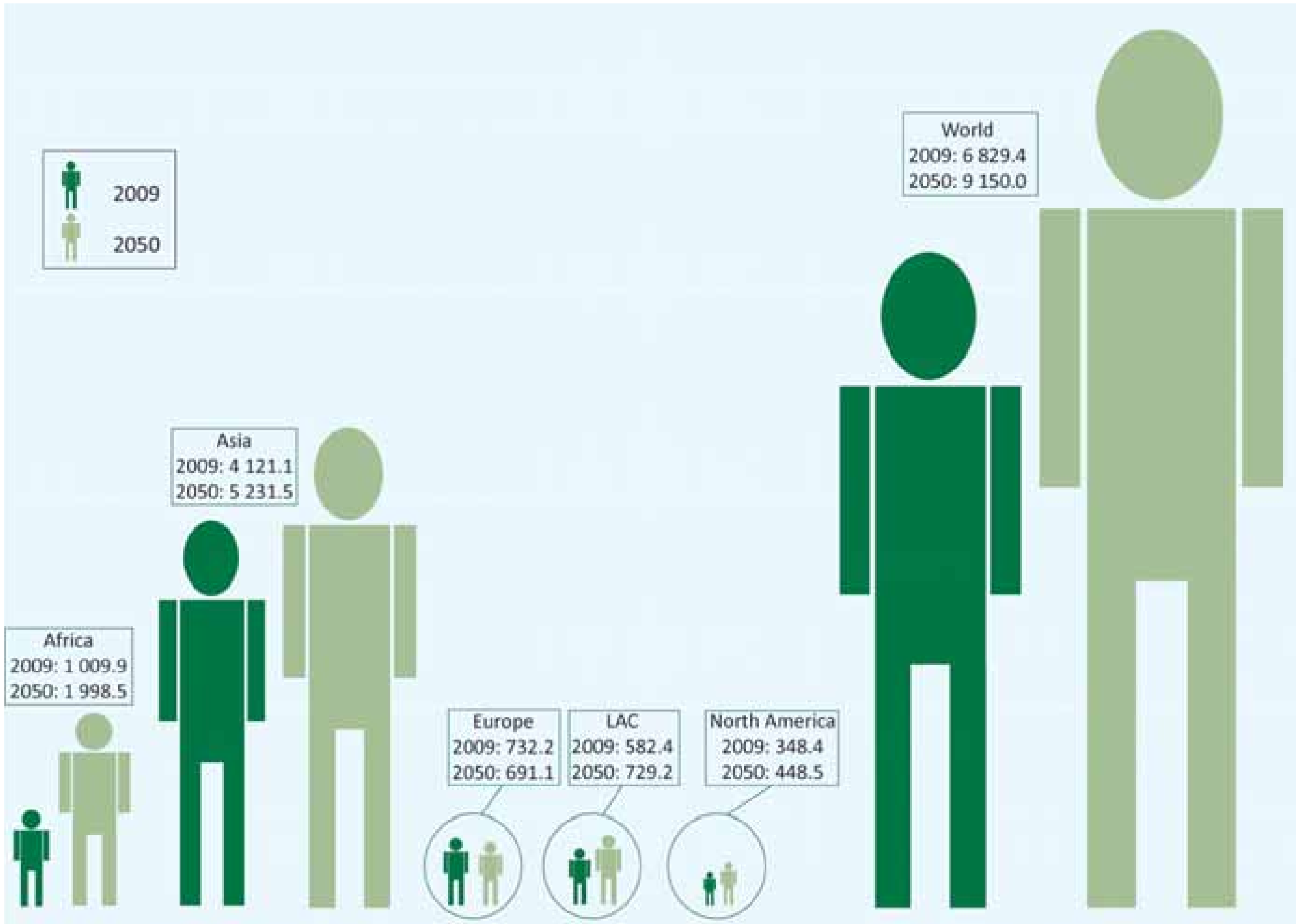


Figure 1.9: Comparative population numbers by world region in 2009 and projected population for the year 2050 (Data Source: UNFPA 2009)

Water and Population

Africa's rising population is one of the main drivers behind the slow progress in water and sanitation provision and in the increasing demand for, and degradation of water resources. Among the world's regions, the continent's average population growth rate of 2.3 per cent for the period 2005 to 2010 was the highest (UNFPA 2009). Africa is the second-most populous continent after Asia (Figure 1.9). Africa also had the highest urban growth rate for the period 2005-2010, although on average it also had the largest proportion of rural population in 2009 (UNFPA 2009). About 40 per cent of Africa's population now lives in cities. Between 2005 and 2010, Africa's urban population grew at a rate of 3.4 per cent, or 1.1 per cent more than the rural population. The urban growth rate over that time was highest in Central, Eastern and Western Africa, although at 58 per cent in 2009, Southern Africa had the highest proportion of urban population (Figure 1.10).

Permanent settlements are sparse in areas such as the Sahara and the western part of Southern Africa, but there are some places, such as the Nile delta, which are densely populated. Unlike biodiversity and primary productivity, which are generally correlated to rainfall availability, the distribution of people in Africa is also influenced by many natural and human induced factors that include availability of land for agricultural activities, the prevalence of natural disasters and disease, conflicts over natural resources, and historical reasons, among others. Nevertheless, people have tended to settle in areas of adequate water, and even the emergence of early civilizations along the Nile River was closely tied to

Key Facts

Africa's population growth rate of 2.3 per cent from 2005 to 2010 was the world's highest

Over that time, Africa's urban population grew at a rate of 3.4 per cent

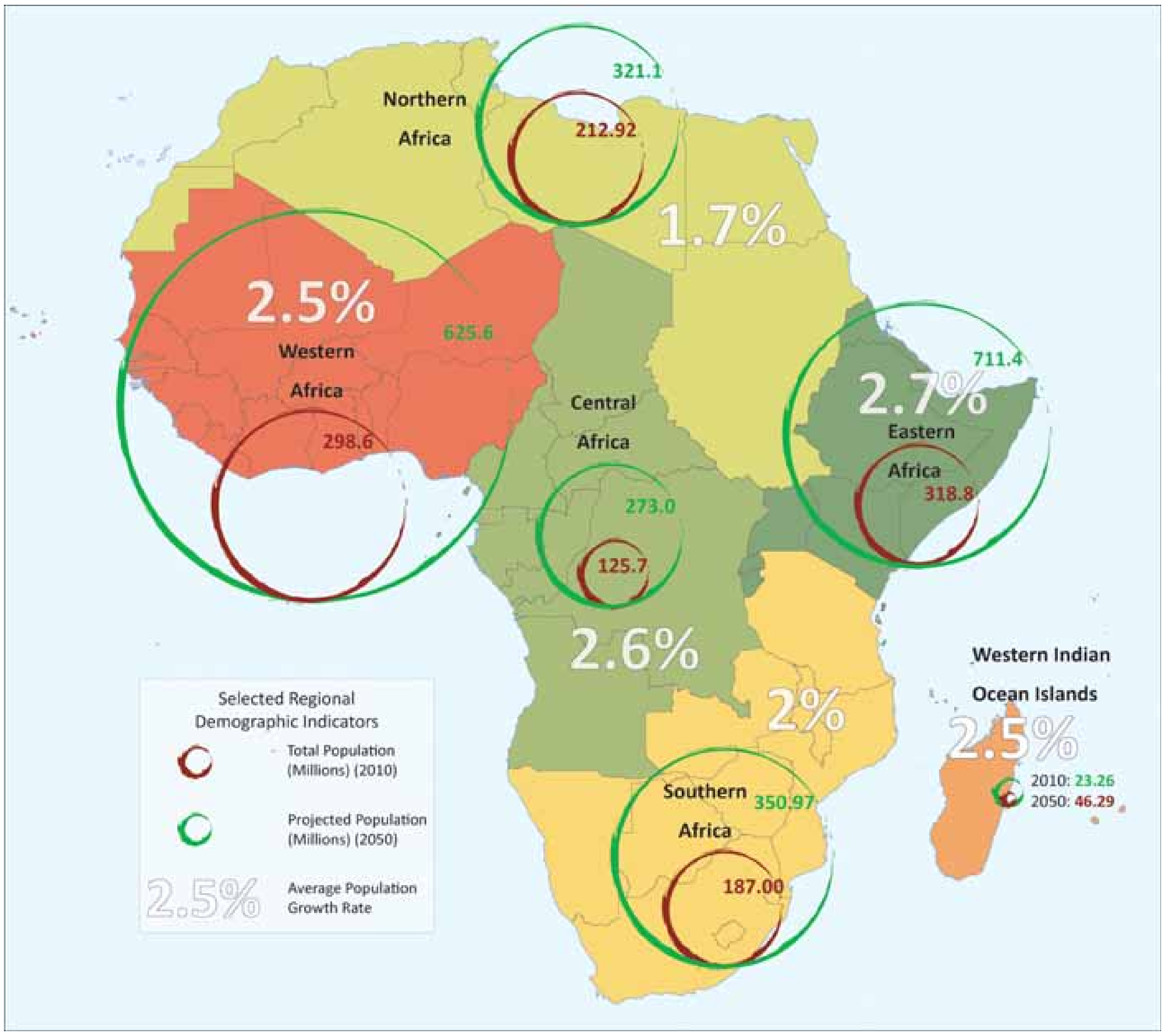


Figure 1.10: Selected demographic indicators for African regions (Data source: UNFPA 2009)

the availability of this critical resource. Countries with high population densities include Nigeria in West Africa, which is also the most populous nation on the continent with more than 150 million people (166 people per km^2) and the Central African nations of Rwanda (394 people per km^2) and Burundi (314 people per km^2) (World Bank 2010). It is estimated that the West Africa sub-region will still be the most populous by the year 2050 (Figure 1.10).

World Bank Group

Water and Poverty

Africa is widely acknowledged as the poorest and least developed continent in the context of the following selected issues:

- Nearly half of the entire population of Africa lives on less than one dollar a day per person (AfDB 2009);
- Malaria remains the leading cause of child mortality and anaemia in pregnant women in Africa, and is endemic in 46 countries (AfDB 2009);
- The prevalence of undernourishment in the total population was 25.5 per cent for the period of 2000-2007 (AfDB 2009), and 30 per cent of Africa's children less than five years of age suffer from moderate to severe malnutrition (Kolo 2009).

Key Facts

Africa is widely acknowledged as the world's poorest and least developed continent

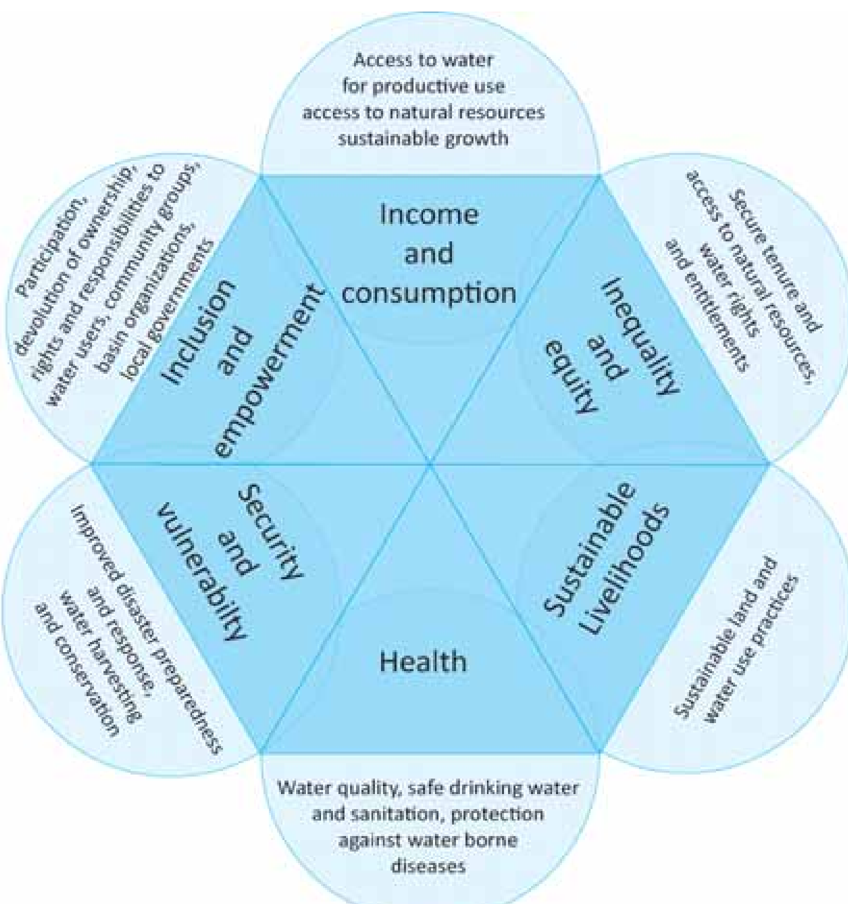
There are significant linkages between water, the environment and poverty

Many of these issues can be linked to Africa's water-related problems, which are compounded to include food shortages, diseases spread by water and other vectors, and flood damage, among other risks (Van Koppen and Schreiner 2003). Chapter 3 discusses water stress, vulnerability, physical and economic water scarcity and the lack of water for food security in greater depth.

Poverty is a large part of the reason for low levels of access to safe water and sanitation, as well as for lack of other water-related needs such as irrigation. Poverty is widespread in Africa and although it is rapidly urbanizing, the majority of its population is still rural-based and dependent on mostly rain-fed agriculture (as explained in the next section). Poverty is a cross-sectoral issue that is normally defined in different contexts. However, it is widely acknowledged that there are linkages between water, the environment and poverty (Faurès and others 2008, Chowdhury and Ahmed 2010) (Figure 1.11).

While poverty is a contributing factor in the widespread lack of access to improved water sources, wealth is often linked to the

Figure 1.11: Linkages between poverty, water, and the environment (Data Source: Hirji and others 2002)



overconsumption of water resources. For example, a family of eight living in a squatter camp in the Cape Town area of South Africa uses about 120 litres of water a day collected from a tap a few hundred metres away. In contrast, a couple in a nearby rich neighbourhood who have a big garden to water, can use 2 000 litres per day (Pallett 1997). Figure 1.11 shows an example of a framework for summarizing linkages between poverty, water and environment, where the cross-sectoral nature of poverty is shown to cover aspects well beyond income and consumption. The different dimensions of poverty are shown in the triangles, and examples of water and environmental linkages are shown in the semi circles.

Water and Gender

Economically and socially vulnerable groups such as women, the elderly and children often experience considerable negative effects related to the natural environment, such as droughts and floods, and demographic-related factors that include high population densities and land degradation (Saleth and others 2007). The issue most directly related to gender and water is the fact that traditionally, women and young children, especially girls, are instrumental in providing water for their families, particularly in rural Africa. They are thus more adversely affected when there is limited access to water resources. They often fetch and carry water in containers from long distances, spending large amounts of time and energy that could otherwise be used for other productive tasks. Women often perform between 65 and 72 per cent of water collection duties (Black and King 2009, WHO/UNICEF 2008), and some African women spend as much as 40 per cent of their daily nutritional intake travelling to collect water (Chenje 2000) (Figure 1.12).

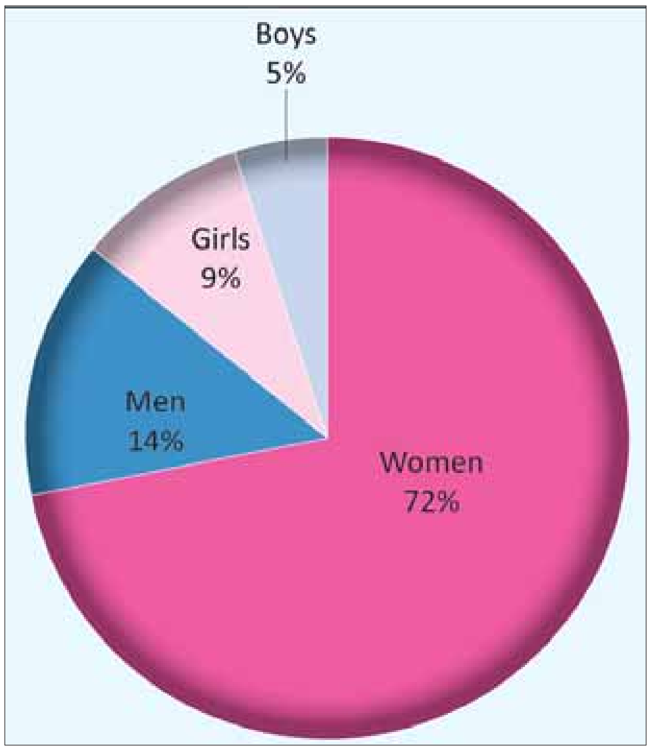


Figure 1.12: Average water collection responsibilities in Africa (Data Source: WHO/UNICEF 2008)

Key Facts

Women and girls are instrumental in providing water for their families

African women often perform between 65 and 72 per cent of water collection duties

Khym54/Flickr.com

Water and Transport

Rivers serve as channels for transportation. The quest for cheaper and efficient methods of transporting goods has seen governments all over Africa increasingly recognize the value of inland waterways in promoting trade between nations, and for the need to integrate different forms of transport networks across the continent (Ford 2007). Examples of the current continental impetus to utilize water transport more include the 20-year rehabilitation and upgrade plan for ports on Lakes Malawi and Tanganyika being carried out by the Tanzania Ports Authority (TPA) to improve the handling of imports and exports of coal, coffee, sugar, tea, timber, tobacco and other commodities through the Tanzanian sea port of Mtwara on the east coast; and the signing of a memorandum of understanding to promote shipping on the Zambezi-Shire water system by the governments of Zambia, Malawi and Mozambique (Mzunzu 2002, Ford 2007).

There are extreme navigation problems on most of Africa's major rivers (Winkley 1995). There is also uncoordinated development between different water use sectors (Toro 1997, Nzewi 2005) and inadequate funding to develop or make improvements to the important river navigation systems. Only a few of the waterways, mainly in the Congo, the Nile and Zambezi basins, are internationally navigable (UNECA 2009). Navigation issues on the Benue River in West Africa illustrate some of the challenges associated with the development of navigation and of Africa's water resources in broader terms.

Case study: Challenges of navigation on the Benue River between Cameroon, Chad and Nigeria

River traffic on the Benue River increased steadily from 1945 and peaked around 1964 with a trade volume of more than 64 000 tonnes of commodities. Major imports included cement, fuel, salt and fertilizer, while cotton fibre, other by-products of cotton and peanuts were the major exports from the Benue River Basin countries. Since 1965, various factors have conspired to reduce river transport to almost nothing. Fuel imports stopped in 1965 and the export of peanuts ceased in 1966. The decline has been attributed to a combination of the following factors:

(1) Irregular natural hydrological regimes. The natural variability of precipitation has meant that navigation has never exceeded a period of sixty days, due to low river flows at certain times.

(2) Environmental pressures. There has been a rapid and uncontrolled increase in the area of cultivation adjacent to the river and insufficient soil conservation practices in the Benue River Basin. This has led to soil erosion and subsequent river siltation, resulting in the stalling of boats in water too shallow to float vessels.

(3) Internal conflicts. Trade was stopped after the 1967 outbreak of the Biafran War and resumed in 1970 but stagnated to around 15 000 to 20 000 tonnes of commodities per year, mainly meeting the needs of cotton companies. In 1980, trade declined again following the outbreak of war in Chad and the impoundment of the Lagdo Dam.

(4) The emergence of other forms of transport. The uncertainty and unreliabilty of river transport saw other forms of transport such as rail and road growing significantly and gaining a substantial portion of the market share. However, the loss of vehicles on roads, problems related to the operation of the railway, and rising cotton production in both Chad and northern Cameroon meant that transport problems persisted.

(5) Human management issues. The long-term management issues of a major link between the Chad Basin and Benue with the Niger Delta is another water transport problem.

(6) Dam construction on the Benue River and its tributaries. In addition to the lowering of water levels due to silting, the overall hydrology of the region has also been affected by the construction of the Lagdo Dam on the Benue, the Shiroro Dam on its tributary in Kaduna and also the Jebba and Kanji dams on the Niger River.

Source: Enoumba 2010

Provisioning services	Regulating service	Cultural services	Supporting Services
Food	Air quality regulation	Spiritual and religious values	Soil Formation
Fiber	Climate regulation	Cultural diversity	Photosynthesis
Fuel	Water regulation	Knowledge systems	Nutrient cycling
Genetic Resources	Erosion regulation	Education values	Water cycling
Biochemicals, natural medicines, pharmaceuticals	Water purification and waste treatment	Recreation and ecotourism	Primary production
Fresh water	Disease regulation	Cultural heritage values	
Ornamental Resources	Pest regulation	Inspiration	
	Pollination	Aesthetic values	
	Natural hazard regulation	Social relations	
		Sense of place	

Table 1.8 Examples of ecosystem services linked to water (Source: MA 2005)

Key Facts

Agriculture—largely rain-fed—is the main source of income for 90 per cent of the rural population

Compared to other sectors, stimulating economic growth through agriculture is four times more effective in raising incomes of poor people; investing in agricultural water has even higher potential multipliers

Figure 1.13: Employment by sector for Africa in 2008 (Data source: ILO 2009, for population: WRI 2009)

Water and Agriculture

Most economies in Africa are closely tied to natural resources. Water is directly or indirectly used in almost every economic sector including agriculture, manufacturing, trade, mining, tourism, transport, and telecommunications, among others.

Agriculture—largely rain-fed—is the single most important driver of economic growth for most African countries (Webersik and Wilcon 2009) (Figure 1.13). The agricultural sector accounts for about 20 per cent of Africa's GDP, 60 per cent of its labour force and 20 per cent of the total merchandise exports, and is the main source of income for 90 per cent of the rural population (UNECA 2007). Compared to other sectors, GDP growth originating in agriculture is about four times more effective in raising incomes of poor people, with even higher potential multipliers from investing in agricultural water (World Bank 2009).

Water is both an ecosystem "good", providing drinking water, irrigation and hydropower, and an ecosystem "service", supplying people, whether they are aware of it or not, with functions such as cycling nutrients and supporting habitat for fish and other aquatic organisms, as well as "cultural services" such as scenic vistas and recreational opportunities.

Table 1.8 provides examples of ecosystem services that have direct or indirect linkages to water, classified under four broad categories defined by the Millennium Ecosystem Assessment, 2005: provisioning, regulating, cultural, and supporting services.

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References

Special Section

Barron, J. (2004). Dry spell mitigation to upgrade semi-arid rainfed agriculture: Water harvesting and soil nutrient management for smallholder maize cultivation in Machakos Kenya. Doctoral Thesis – Department of Systems Ecology, Stockholm University.

Barry, B., Olaleye, A., Zougmoré, R., Fatondji, D. (2008). Rainwater harvesting technologies in the Sahelian zone of West Africa and the potential for outscaling. Colombo, Sri Lanka: International Water Management Institute. (IWMI Working Paper 126)

DRSRS and KFWG. (2006). "Changes in Forest Cover in Kenya's Five Water Towers, 2003-2005". Available online at: http://www.unep.org/dewa/assessments/EcoSystems/Land/mountain/pdf/forest_catchment_2 005_report.pdf (Last Accessed on September 10, 2010)

Devitt, P. and Hitchcock, R. (2010). Who drives resettlement? The case of Lesotho's Mohale Dam. African Study Monographs 31 (2):57-106.

FAO. (2006). Sustainable Rural Development and Food Security: The Role of Mountain Development in Africa; FAO Regional conference for Africa. Food and Agriculture Organization of the United Nations. Available online at: http://www.fao.org/docrep/meeting/004/y6056e.htm#1 (Last Accessed on June 14, 2010)

GoK. (2010). Rehabilitation of the Mau Forest Ecosystem – Programme Document. Prepared by the Prepared by the Interim Coordinating Secretariat, Office of the Prime Minister, on behalf of the Government of Kenya, with support from the United Nations Environment Programme. Governement of Kenya.

Hoover, R. (2001). Pipe Dreams, The World Bank's Failed Efforts to Restore Lives and Livelihoods of Dam-Affected People in Lesotho. International Rivers Network. Available online at: http://www.irn.org/programs/lesotho/pdf/pipedreams.pdf (Last Accessed on September 27, 2007)

IUCN. (n.d.). The Lesotho Highlands Water Project: environmental flow allocations in an international river. Available online at: http://www.iucn.org/themes/wani/flow/cases/Lesotho.pdf (Last Accessed on September 20, 2007)

Kahinda, J., Taigbenu, A., Boroto, J. (2007). Domestic rainwater harvesting to improve water supply in rural South Africa. Physics and Chemistry of the Earth 32:1050-1057.

Kabo-Bah, A. Andoh, R., Odai, N. , Osei, K. (2008). Affordable Rainwater Harvesting Systems: A Collaborative Research Effort. 11th International conference on Urban Drainage. Edinburgh, Scotland, 2008. Available online at: http://plc.hydro-intl.com/index2.php?option=com_docman&task=doc_view&gid=30&Itemid=88 (Last Accessed on August 27, 2010)

LHDA (n.d.). Lesotho Highlands Water Project. Lesotho Highlands Development Authority. Available online at http://www.lhda.org.ls/news/archive2004/apr04/inauguration_report.htm (Last Accessed on September 10, 2010)

MA (2005). Ecosystems and Human Well-being: Volume 2 – Current State and Trends. "Mountain Ecosystems." Millennium Ecosystem Assessment, Island Press: Washington D.C.

Matete, M. (2006). The ecological economics of inter-basin water transfers: The Case of the Lesotho Highlands Water Project. PhD Thesis University of Pretoria. Available online at: http://upetd.up.ac.za/thesis/available/etd-06052006-145825/unrestricted/00front.pdf (Accessed September 20, 2007)

Nicholson, S. (1998). Interannual and interdecadal variability of rainfall over the African continent during the last two centuries. Proceedings of the Abidjan '98 conference, Abidjan, Côte d'Ivoire, November, 1998. IAHS Publication no. 252, 1998. Available online at: http://iahs.info/redbooks/a252/iahs_252_107.pdf (Accessed on June 7, 2010)

Nicholson, S. (2000). The nature of rainfall variability over Africa on time scales of decades to millennia. Global and Planetary Change. 26:137-158.

ORNL. (2008). LandScan Global Population Database 2008. Oak Ridge National Laboratory. Available online at: http://www.ornl.gov/sci/landscan/index.html (Last Accessed on June 7, 2010)

Pachpute, J., Tumbo, S., Sally, H., Mul, M. (2009). Sustainability of Rainwater Harvesting Systems in Rural Catchment of Sub-Saharan Africa. Water Resources Management 23:2815-2839.

Peel, M., McMahon, T., Finlayson, B., Watson, F. (2001). Indentification and explanation of continental differences in the variability of annual runoff. Journal of Hydrology. 250:224-240.

Rockström, J. (2000). Water Resources Management in Smallholder Farms in Eastern and Southern Africa: An Overview. Physics and Chemistry of the Earth (B). 25(3):275-283.

Rockström, J. and Karlberg, L. (2009) Zooming in on the Global Hotspots of Rainfed Agriculture in Water-constrained Environments. In Rainfed Agriculture: Unlocking the Potential. Eds. Wani, S.P., Rockström, J. and Oweis, T. (2009) Rainfed Agriculture Unlocking the Potential. CAB International. Available online at: http://www.iwmi.cgiar.org/Publications/CABI_Publications/CA_CABI_Series/Rainfed_Agriculture/Protected/Rainfed_Agriculture_Unlocking_the_Potential.pdf (Last Accessed on June 7, 2010)

Senay, G. and Verdin, J. (2004) Developing Index Maps of Water-Harvest Potential in Africa. Applied Engineering in Agriculture 20(6):789-799.

Senay, G., Pengra, B., Bohms, S., Singh, A., Verdin, J. (2010). Africa-wide water balance estimation using remote sensing and global weather datasets. American Geophysical Conference Fall Meeting. Submitted.

Tanner, A., Tohlang, S. and Van Niekerk, P. (2009). Civil Engineering – South African Institution of civil Engineering. 17(5):28-35.

Trabucco, A. and Zomer, R. (2009). Global Aridity Index (Global-Aridity) and Global Potential Evapo-Transpiration (Global-PET) Geospatial Database. CGIAR Consortium for Spatial Information. Published online, available from the CGIAR-CSI GeoPortal at: http://www.csi.cgiar.org. (Last Accessed on June 7, 2010)

UNEP (2010) Multimillion Dollar Response to Mau Appeal Brings Restoration Hope to Kenya and the Region Accessed August 13, 2010 at: http://www.unep.org/Documents.Multilingual/Default.asp?ArticleID=6549&DocumentID=624&l=en

USAID. (2009). Success Story: Defending Against Drought in Kenya. Available online at: http://www.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/countries/kenya/template/files/Success_Story_123009.pdf (Accessed June 23, 2010)

Wani, S., Sreedevi, T., Rockström, J. and Ramakrishna, R. (2009). Rainfed Agriculture – Past Trends and Future Prospects. In Rainfed Agriculture: Unlocking the Potential. Eds. Wani, S.P., Rockström, J., Oweis, T. (2009). Rainfed Agriculture Unlocking the Potential. CAB International. Available online at: http://www.iwmi.cgiar.org/Publications/CABI_Publications/CA_CABI_Series/Rainfed_Agriculture/Protected/Rainfed_Agriculture_Unlocking_the_Potential.pdf (Last Accessed on June 7, 2010)

Willemse, N. E. (2007). Actual versus Predicted Transboundary Impact: A Case Study of Phase 1B of the Lesotho Highlands Water Project. Water Resources Development 23 (3):457-472.

Wolf, A. (2007) Shared Waters: Conflict and Cooperation. Annual Review of Environmental Resources 32:241-269.

Chapter1

AfDB. (2009). "Gender, Poverty and Environmental Indicators on African Countries." Economic and Social

Statistics Division Statistics Department, ADB: Tunis. African Development Bank. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/GenderPovertyE nvironmental_IndicatorsAfricanCountries2009_01_Full_Report.pdf (Last accessed on February 23, 2009).

Banerjee, S., Skilling, H., Foster, V., Briceño-Garmendia, C., Morella, E., Chfadi, T. (2008). "Africa Infrastructure

Country Diagnostic: Urban Water Supply Africa". World Bank and the Water and Sanitation Program. http://www.eu-africa-infrastructuretf.net/attachments/library/aicd-backgroundpaper-12-water-summary-en.pdf (Last accessed on June 23, 2010).

Batisani, N. and Yarnal, B. (2010). Rainfall Variability and Trends in Semi-Arid Botswana: Implications for Climate Change Adaptation Policy. Applied Geography In Press, Corrected Proof.

BGRM /UNESCO Paris (2008). World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP). http://www.whymap.org/cln_145/whymap/EN/Home/whymap_nodehtml?__nnn=true (Last accessed on June 20, 2010).

Black, M., and J. King. (2009). The Atlas of Water: Mapping the World's Most Critical Resource. University of California Press.

Bowen, R. (1982). Surface Water. Applied Science Publishers: London.

Braune, E. and Xu, Y. (2010). The Role of Ground Water in Sub-Saharan Africa. Ground Water, 48: 229–238. doi: 10.1111/j.1745-6584.2009.00557.x.

Calow, R., MacDonald, A., Nicol, A., Robins, N. (2010). Ground Water Security and Drought in Africa: Linking Availability, Access, and Demand. Ground Water. 48: 2, 246–256. http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2009.00558.xpdf (Last accessed on August 17, 2010).

Chenje, M. (2000). State of the Environment in the Zambezi Basin 2000. Southern African Research & Documentation Centre, Zimbabwe.

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

Chowdhury, M. and Ahmed, S. (2010). Poverty-environment nexus: an investigation of linkage using survey data. International Journal of Environment and Sustainable Development. 9(1-3): 91-113.

Conway, D., Persechino, A., Ardoin-Bardin, S., Hamandawana, H., Dieulin, C., Mahé, G. (2009). Rainfall and water resources variability in Sub-Saharan Africa during the Twentieth Century. Journal of Hydrometeorology 10(1): 41-59.

Crook, B., and Mann, B. (2002). A critique of and recommendations for a subsistence fishery, Lake St Lucia, South Africa. Biodiversity and Conservation 11: 1223-1235.

De Rouw, A. (2004). Improving yields and reducing risks in pearl millet farming in the African Sahel. Agricultural Systems. 81: 73-93.

Dinar, A., Hassan, R., Mendelsohn, R., Benhin, J. (2008). Climate change and agriculture in Africa: Impact assessment and adaptation strategies. Earthscan: London; VA.

Enoumba, H. (2010). Challenges of navigation on the Benue River between Cameroon, Chad and Nigeria. Unpublished.

Etile, R., Kouassi, A., Aka, M. , Pagano, M., N'Douba, V., Kouassi, N. (2009). Spatio-temporal variations of the zooplankton abundance and composition in a West African tropical coastal lagoon (Grand-Lahou, Côte d'Ivoire). Hydrobiologia. 624:171-189. DOI 10.1007/s10750-008-9691-7.

FAO. (2009). AQUASTAT database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/aquastat (Last accessed on May 11, 2010).

Falkenmark, M., Lundqvist, J., Widstrand, C. (1989). Macro- scale water scarcity requires micro- scale approaches: Aspects of vulnerability in semi- arid development, Nat. Resour. Forum, 13, 258–267.

Faurès, J., Santini, G., Nepveu de Villemarceau, A. (2008). A livelihood approach to water interventions in rural areas and implications for Multiple Use Systems' in Multiple-use Water Services (Eds. J, Butterworth, M. Keitjizer, I. Smout and F. Hagos) Proceedings of an international symposium held in Addis Ababa, Ethiopia, 4-6 November 2008. MUSGroup.

Ford, N. (2007). East African waterways offer cheap and easy transport. African Business 01413929, Aug/Sep2007, Issue 334.

Haller, T. and Merten, S. (2008). We are Zambians-Don't Tell Us How to Fish. Institutional Change, Power Relations and Conflicts in the Kafue Flats Fisheries in Zambia. Human Ecology. 36: 699-715.

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

Hirji, R., Johnson, P., Maro, P., Matiza-Chiuta, T. (2002). Defining and mainstreaming environmental sustainability in water resource management in southern Africa. Washington, DC: World Bank, 2002.

Hulme, M., Doherty, R., Ngara, T., New, M., Lister, D. (2001). African climate change: 1900-2100. Climate Research. 17:145-168.

ILO. (2009). "Global Employment Trends January 2009". International Labor Office: Geneva. http://www.ilo.org/wcmsp5/groups/public/---dgreports/--- dcomm/ documents/publication/wcms_101461.pdf (Last accessed on March 5, 2010).

Ingram, K., Roncoli, M., Kirshen, P. (2002). Opportunities and constraints for farmers of West Africa to use seasonal precipitation forecasts with Burkina Faso as a case study. Agricultural Systems. 74: 331-349.

Khedr, A. (1998). Vegetation zonation and management in the Damietta estuary of the River Nile. Journal of Coastal Conservation. 4: 79-86.

Kolo, J. (2009). Striving for results: Prescriptions for broadening the sustainable development principles for policy making and planning in Africa. Journal of Sustainable Development in Africa. 11(1): 78-97.

LeCoz, M., Delclaux, F, Genthon, P., Favreau, G. (2009). Assessment of Digital Elevation Model (DEM) aggregation methods for Hydrological modeling: Lake Chad basin, Africa. Computers and Geosciences. 35:1661-1670.

Lemoalle, J. (2004). Lake Chad: A changing environment. In: Nihoul, J.C.J., Zavialov, P.O., Micklin, P.P.(Eds.),Dying and Dead Seas. Kluwer Academic Publishers: Dordrecht, pp.321-340.

MA. (2005). Ecosystems and Human Well-being: Synthesis. Island Press: Washington, DC. Millennium Ecosystem Assessment.

Mzunzu, M. (2002). Hydrographic survey Lake Malawi: A bilateral co-operation (Malawi - Iceland) for safety of navigation on the third largest lake in Africa. Hydro International. 6 (4): 57-59.

Ndengu, S. (2002). International shared aquifers in Namibia. Proceedings of the International Workshop Tripoli, Libya, 2- 4 June 2002. http://www.isarm.net/ dynamics/modules/SFIL0100/view.php?fi l_Id=176. (Last accessed on May 10, 2010).

Nicholson, S. (2005). On the question of the "recovery" of the rains in theWest African Sahel. Journal of Arid Environments. 63:615-641.

Nzewi, E.(2005). Managing water resources systems for sustainable development in underdeveloped regions. World Water Congress 2005: Impacts of Global Climate Change - Proceedings of the 2005 World Water and Environmental Resources Congress, pp. 275.

Pallett, J. (Ed.). (1997). Sharing Water in Southern Africa. Desert Research Foundation of Namibia. Windhoek.

Ramberg, L. and Wolski, P. (2008). Growing islands and sinking solutes: processes maintaining the endorheic Okavango Delta as a freshwater system. Plant Ecology. 196 (2): 215-231.

Robins, N., Davies, J., Farr, J., Calow, R. (2006). The changing role of hydrogeology in semi-arid southern and eastern Africa. Hydrogeology Journal. 14: 1481-1492.

SADC, SARDC, IUCN, UNEP. (2008). Southern Africa Environment Outlook. Southern African Development Community. Southern African Research and Documentation Centre. IUCN-The World Conservation Union. United Nations Environment Programme. http://soer.deat.gov.za/State_of_the_Environment. html (Last accessed September 14, 2010)

Saleth, R., Samad, M., Molden, D., Hussain, I. (2003). Water, poverty and gender: An overview of issues and policies. Water Policy 5: 385-398.

Shiklomanov I. and Rodda, J. (Eds.). (2003). World water resources at the beginning of the twenty-first century. International Hydrology Series. UNESCO: Cambridge University Press. 423 pp.

Slimani, H., Aidoud, A., Rozé, F. (2010). 30 Years of Protection and Monitoring of a Steppic Rangeland Undergoing Desertification. Journal of Arid Environments 74, no. 6 (2010): 685-91.

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

Sultan B., Baron C., Dingkuhn M., Sarr B., Janicot S. (2005). Agricultural impacts of large-scale variability of the West African monsoon. Agricultural and forest meteorology. 128 (1-2) : 93-110.

Strobl, E. and Strobl, R. (2009). The Distributional impact of dams: Evidence from cropland productivity in Africa. Working Papers hal-00392381_v1, HAL. http:// halshs.archives-ouvertes.fr/hal-00392381/ (Last accessed on June 20, 2010).

Swenson, S. and Wahr, J. (2009). Monitoring the water balance of Lake Victoria, East Africa, from space. Journal of Hydrology. 370: 163-176.

The Ramsar Convention on Wetlands. (1996). " The Ramsar Convention definition of "wetland" and classification system for wetland type". Available online at http:// www.ramsar.org/cda/en/ramsar-activities-cepaclassification-system/main/ ramsar/1-63-69%5E21235_4000_0__ (Last accessed on June 20, 2010).

Toro, S. (1997). Post-construction effects of the Cameroonian Lagdo Dam on the River Benue. Journal of the Chartered Institution of Water & Environmental Management. 11(2): 109–113.

UNECA, AU and AfDB. (2000). "The Africa Water Vision for 2025: Equitable and Sustainable Use of Water for Socioeconomic Development". Economic Commission for Africa, African Union and African Development Bank. Addis Ababa. http://www.uneca.org/awich/African%20Water%20Vision%2025.pdf (Last accessed on June 20, 2010).

UNECA. (2007). Africa Review Report on Agriculture and Rural Development. United Nations Economic Commission for Africa. http://www.un.org/esa/sustdev/csd/ csd16/rim/eca_bg2.pdf (last accessed on September 14, 2010).

UNECA. (2009). The transport situation in Africa. Sixth session of the Committee on Trade, Regional Cooperation and Integration. 13-15 October 2009. Economic Commission for Africa, Addis Ababa, Ethiopia. http://www.uneca.org/eca_ resources/major_eca_websites/crci/6th/TransportSituationinAfrica.pdf (Last accessed on February 15, 2009).

UNEP. (2000). Water Sharing in the Nile River Valley. United Nations Environment Programme (UNEP/DEWA/GRID: Geneva). http://www.grid.unep.ch/activities/ sustainable/nile/nilereport.pdf (Last accessed on February 25, 2010).

UNEP. (2002). Africa Environment Outlook: Past, present and future perspectives. United Nations Environment Programme. Earthprint: UK.

UNEP. (2004). Annual Precipitation. Climate Research Unit. United Nations Environment Programme. http://geodata.grid.unep.ch (Last accessed on September 22, 2010).

UNEP. (2005). Mau Complex Under Siege, Continuous destruction of Kenya's largest forest. United Nations Environment Programme, Kenya Wildlife Service and Kenya Forests Working Group. June 2005.

UNEP. (2008). Africa: Atlas of Our Changing Environment. United Nations Environment Programme, Nairobi.

UNEP and WRC. (2008). Assessment of transboundary freshwater vulnerability in Africa to climate change. United Nations Environment Programme and Water Research Commission. http://www.unep.org/dewa/assessments/ecosystems/ water/Assessment_of_Transboundary_Freshwater_Vulnerability_revised.pdf (Last accessed on March 3, 2008).

UNEP-WCMC. (2006). Wetlands. United Nations Environment Programme-World Conservation Monitoring Centre. Available online at http://geodata.grid.unep. ch/mod_metadata/metadata.php (Last accessed on June 11, 2010).

UNFPA. (2009). State of world population 2009: Facing a changing world: women, population and climate. United Nations Population Fund. New York: UNFPA.

Walling, D. (1996). Hydrology and Rivers. In: The Physical Geography of Africa (W.M. Adams, A.S. Goudie and A.R. Orme, Eds.). Oxford, Oxford University Press, 103–121.

WCD. (1999). "Dam Statistics: Africa and the Middle East Regions. http://www. dams.org/kbase/consultations/afrme/dam_stats_eng.htm (Last accessed on September 4, 2010).

Webersik, C. and Wilcon, C. (2009). Achieving Environmental Sustainability and Growth in Africa: the Role of Science, Technology and Innovation. Sustainable Development, 17, 400-413.

WHO/UNICEF (2008). Progress on Drinking Water and Sanitation Special focus on Sanitation. Joint Monitoring Programme (JMP). http://www.who.int/ water_sanitation_health/monitoring/jmp2008/en/index.html (Last accessed on March 2, 2010).

Winkley, B. (1995). Navigation Problems on the Zaire River, Africa. International Water Resources Engineering Conference – Proceedings. 2: 1754-1758.

World Bank. (2009). Africa's Infrastructure: A Time for Transformation. World Bank: Washington, DC.

World Bank. (2010). World development report: Development and climate change. World Bank: Washington, DC.

WRI. (2009). Population, Health and Human Well-being. World Resources Institute. http://earthtrends.wri.org/searchable_db/index.php?theme=4 (Last accessed on September 14, 2010).

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2

TRANSBOUNDARY WATER RESOURCES

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Water systems occur at many scales from local to global and ultimately are all interlinked. While it is important to understand these linkages at all scales it is often most useful to view surface water at the level of the basin. Hydrological basins are an important unit of management for most of the ecosystem services upon which humans and natural systems depend. Surface water flows across basins and sub-basins unite areas by providing common water sources, aquatic habitats, transportation networks, quality water, hydropower potential and other shared goods and services. This is borne out by the formation of numerous multi-national basin management organizations worldwide, with several notable examples in Africa. The continent also has many transboundary aquifer systems, about which much less is known. While their connections are less obvious than are those of river and lake basins, their management is also well served by basin-scale management, and like surface water basins, the emerging formation of multi-national groundwater basin management organizations is testimony to this reality.

Most people in Africa live in rural areas and are still heavily dependent on agriculture for their livelihoods. This makes water an especially vital economic and social commodity. Along with a growing population, the extreme variability of rainfall on Africa's landscapes—from arid northern and southern regions to the continent's belt of tropical forests—poses many challenges to providing safe drinking water and sanitation for millions of people. Consequently, transboundary water resource management requires an enabling environment that encourages cooperation on numerous fronts.

An important part of this enabling environment is the availability of adequate information about surface and groundwater upon which policy makers can make informed management decisions. Data for Africa's water resources remain incomplete and inconsistent, particularly for groundwater resources. Building on a foundation of detailed, consistent, accurate and available data is one of the central challenges for Africa's water future. The emergence of transboundary basin organizations for many of Africa's large basins may provide a powerful opportunity to build part of this foundation.

Transboundary Surface Water Basins

Worldwide, there are 263 transboundary river basins, which can be defined as basins shared by two or more riparian states. Approximately 60 per cent of the world's population depends on these international water systems (UNU 2006). Transboundary river basins are also important because of the complex natural ecosystems they support. The potential increase in conflicts over shared water resources as well as the effects of climate change represent significant social, economic and environmental threats. In addition, there is a growing danger to human health from inadequate or unsafe water supplies (UNEP 2006a).

Africa's 63 international transboundary river basins cover about 64 per cent of the continent's land area and contain 93 per cent of its total surface water resources (Figure 2.1). They are also home to some 77


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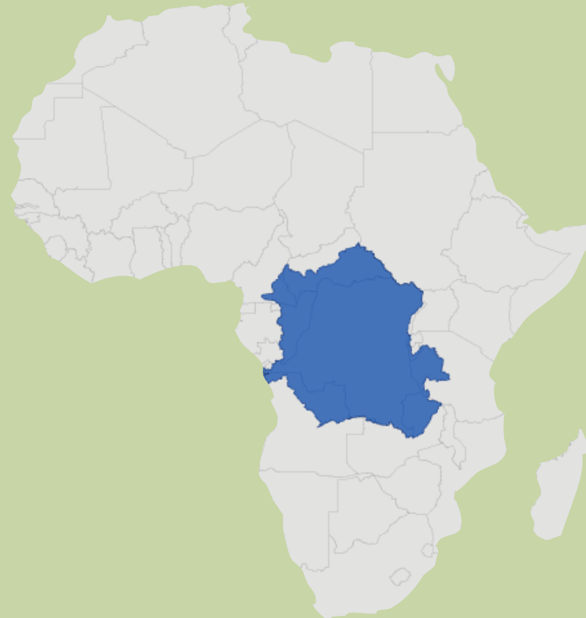
Figure 2.1: Africa's major transboundary river basins

per cent of Africa's population. The Nile River Basin is the most highly populated in all of Africa with over 220 million people—nearly a quarter of Africa's total population (SEDAC 2010). Fifteen principal lakes and 24 main watersheds also cross the political boundaries of two or more countries in Africa (UNEP 2006b). The catchment areas of the 17 largest river and lake basins on the continent exceed 100 000 km^2 in size and are therefore classified as large basins (UNU 2006).

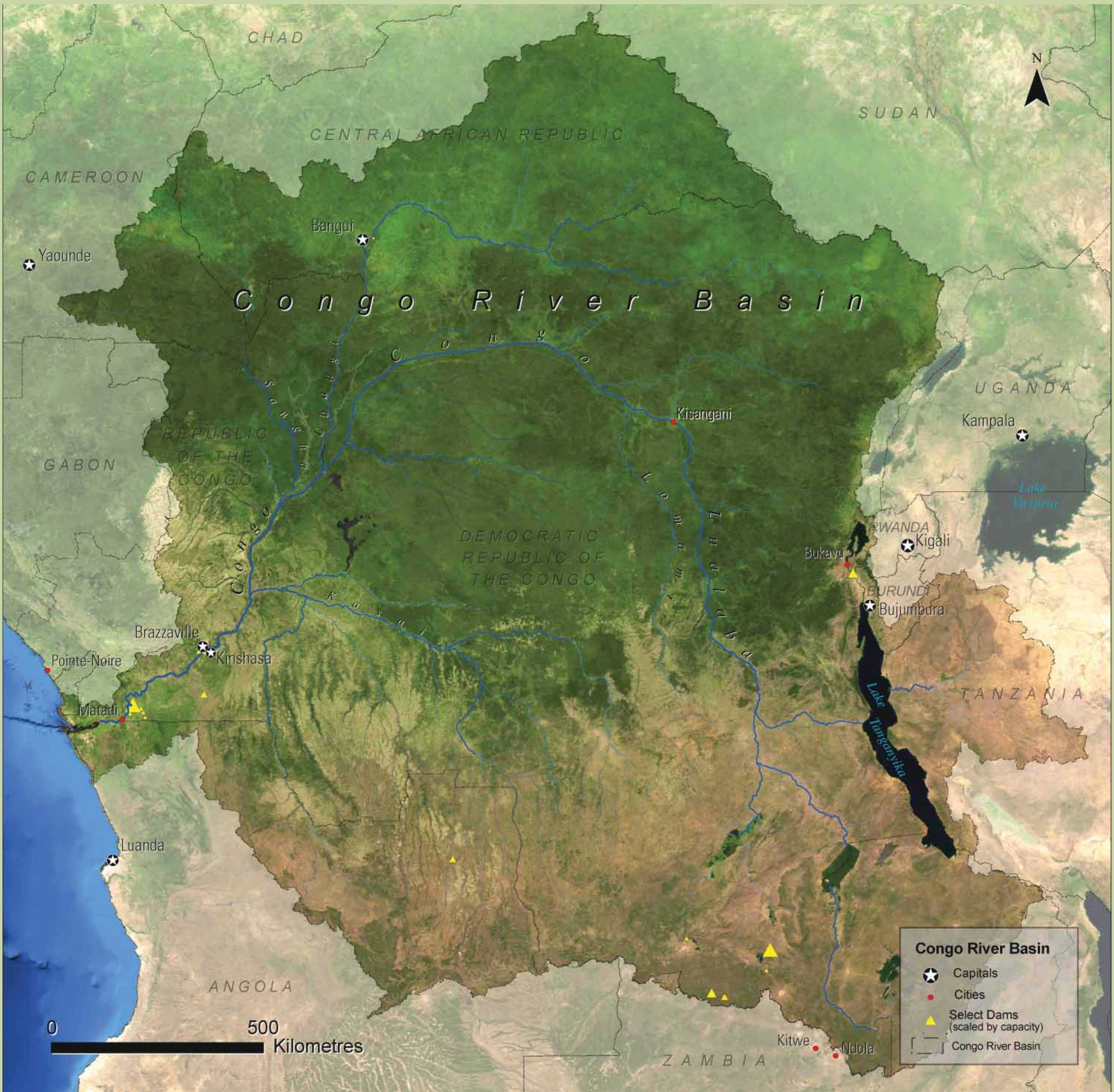
The complexity of the physical, political and human interactions within transboundary river basins can make equitable management of their risks, costs and benefits especially challenging. Quite often the resources are not evenly distributed by area or population. This often puts upstream areas or nations in a position of advantage over their downstream neighbours. Examples of this can be seen in the Niger Basin, Juba-Shabelle Basin, Okavango Basin and others. The degree and type of dependence on the common resources might also vary greatly within a basin. For example, on the Nile, Uganda is highly dependant upon the river for hydropower and manages it accordingly, however downstream it is water for agriculture that Egypt counts on most from the Nile.

The major transboundary basins of Africa present a variety of challenges and opportunities to the people and countries who share them. Each basin differs in many ways from the others but all share common attributes as well. The basin-scale profiles that follow present some of that diversity and commonality through common measures such as population and precipitation, and bring to life some of the management challenges and opportunities with specific cases within the basins.

Congo River Basin



The Congo Basin is a vast 3 700 000 km² depression extending nearly 2 000 km across both its north-south and east-west dimensions. It straddles the equator, gathering heavy precipitation that falls on the tropical rainforests covering much of its extent.



The Congo River runs 4 670 km in a counter-clockwise arc around eastern and northern Democratic Republic of Congo, finally turning west toward the Atlantic Ocean where it discharges 40 000 m^3 of water every second (Laraque and others 2001). Its volume is equal to 32 per cent of Africa's total renewable water resources. It is believed to be the deepest river in the world, with recent measurements showing a point over 200 m deep (USGS 2009). The river and its tributaries are a dominating feature in the basin's natural systems and in the livelihoods of the basin's population.

The Congo Basin river systems are an enormous resource for transportation and power generation. They have productive fisheries and potential for irrigation as well, but are widely seen as under-developed and under-managed. Sustainable development of the basin's vast potential will require effective transboundary cooperation among the countries that overlap the Congo River Basin—eleven in all. Four of the countries (Central African Republic, Cameroon, Democratic Republic of the Congo and Republic of the Congo) are already cooperating through the Commission Internationale du Bassin Congo-Oubangui-Sangha (CICOS) to further the development of the basin's potential. One of the keys to its goal of successful sustainable utilization will be improving data collection, processing, and management to provide the scientific basis for decision making.

Population

Approximately one hundred million people live in the Congo Basin with three-quarters of them living in the Democratic Republic of the Congo (DRC) (SEDAC 2010) (Figure 2.2.1). The most dense populations in the basin are along the DRC's border with Burundi and Rwanda on the basin's eastern edge and in the area between Kinshasa and Mbuji-Mayi. Rwanda's population density within the basin is around 400 persons per km^2 and Burundi's is just over 300 persons per km^2. Roughly seven million Tanzanians live within the basin on about five per cent of the basin's land area. Angola, Central African Republic and Congo each make up between seven and ten per cent of the basin's area, however all have sparse populations in their basin areas ranging from between eight and eleven people per km^2.

Precipitation

At around 1 100 mm/yr, Tanzania's portion of the basin has the lowest mean annual rainfall of any of the basin's countries. Congo has the highest in the basin at almost 1 700 mm/yr. Some parts of the Republic of the Congo and DRC receive an average of over 2 000 mm/yr (Figure 2.2.2). Because of the large area and heavy rainfall the DRC receives about two-thirds of all the rain in the basin and contributes about the same proportion of the basin's total runoff (Figure 2.2.3). Rainfall is seasonal in parts of the basin, however its size ensures that there is always some part of the watershed receiving heavy rains. At the mouth of the river these variations are averaged out to produce a relatively consistent flow with small peaks in November and May (Laraque and others 2001, Dai and Trenberth 2002).

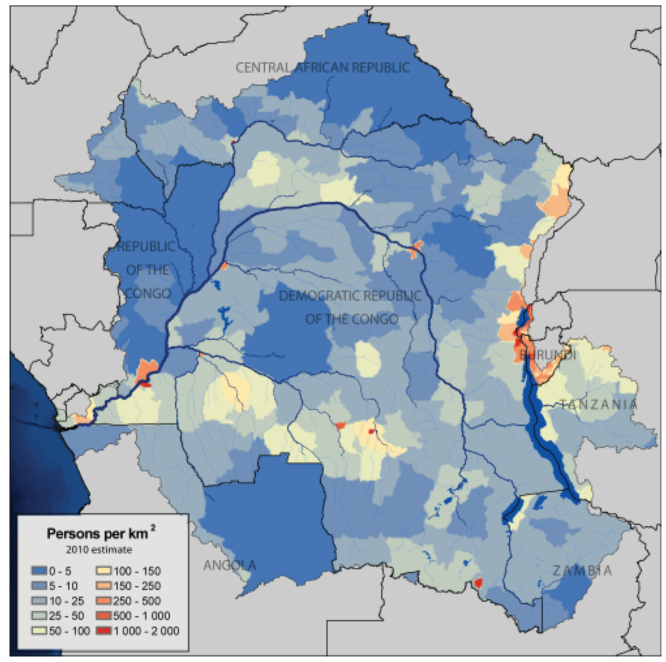


Figure 2.2.1 Congo Basin population density 2010

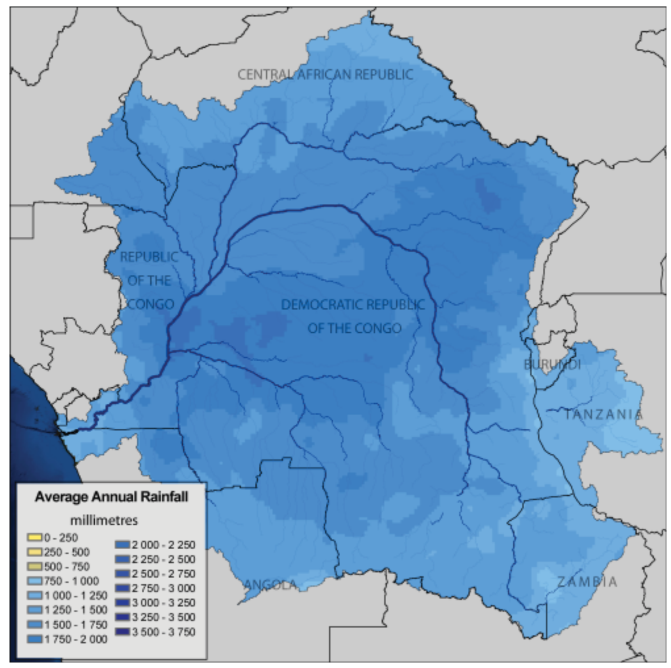


Figure 2.2.2 Congo Basin average annual rainfall

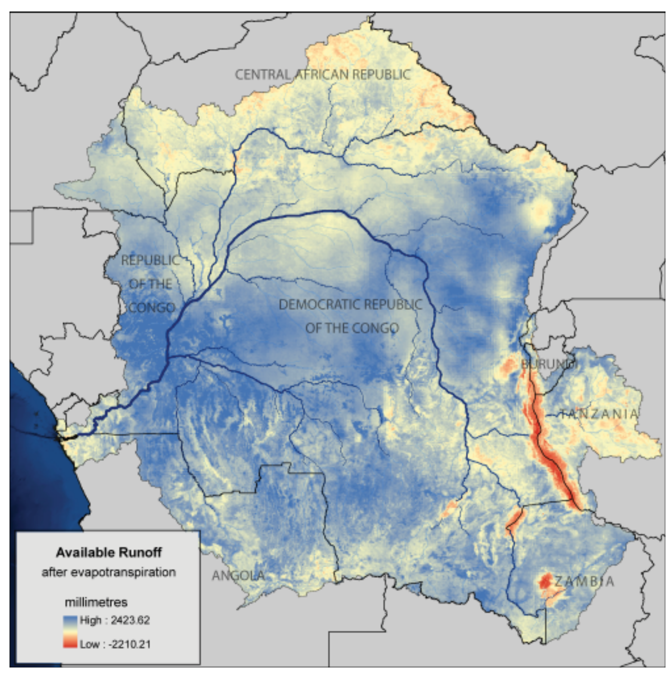


Figure 2.2.3 Congo Basin modeled available runoff

Transport

More than 1 000 km of the Congo River are navigable by large commercial vessels (UNEP 2008). Much of the basin's economic activity relies on these waterways for transport of principally timber, agricultural products, fuel and minerals. The three main routes converge at Kinshasa from Kisangani, Bangui (on the Ubangi) and Ilebo (on the Kasai) (Figure 2.2.4). The absence of roads in many parts of the basin makes these waterways crucial for transport and communication. Problems of low water levels, particularly in the Ubangi have increasingly interrupted navigation since the 1970s (Ndala 2009). This is consistent with precipitation trends during the same period, which show a decrease in average annual precipitation between 1970 and 2000 (NASA 2010) (Figure 2.2.5). Ironically, one of the proposed responses is an inter-basin transfer of water from the Congo Basin to the Lake Chad Basin. Proponents of the project cite "permanent navigability of the Ubangi River," as one of the benefits of a project that would include a dam on the Ubangi (near Palambo, CAR). The expectation is that the dam would even out the flow of the river and thus reduce the number of days that it is too low for large vessels to navigate (Musa 2008).

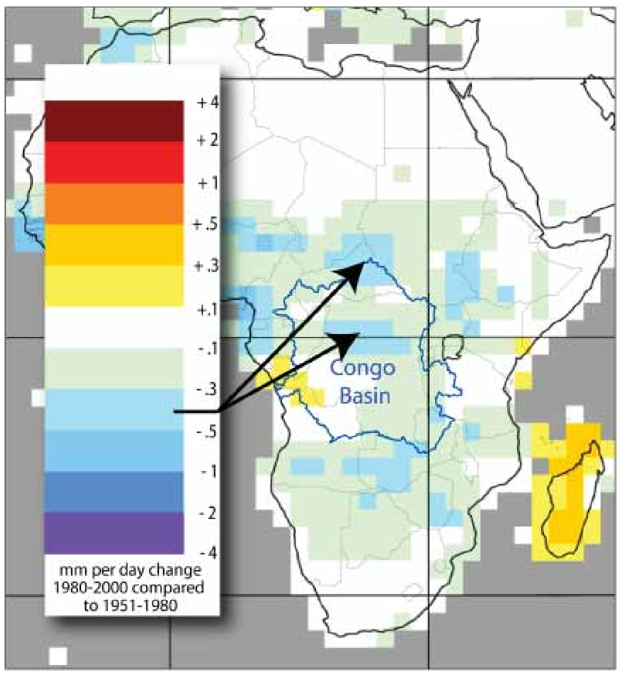
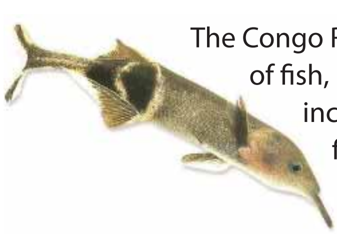


Figure 2.2.5: Precipitation data from NASA's Goddard Institute for Space Studies shows that there was a decrease in rainfall over parts of the Congo Basin between the period 1951-1980 compared to the period 1980 -2000

The Fisheries



The Congo River is home to nearly 800 species of fish, many of them endemic to the river, including the exotic lungfish and elephant fish (National Geographic 2010). The fisheries of the Congo River system's 33 000 km of streams provide high-quality protein for millions of people (Upper Congo Fishes Project n.d.). For many, it is a source of income as well (Bene and others 2009). Traditional fishing methods are generally used, including gillnets, seine nets, handlines and non-motorized canoes. However the use of a poisoning technique, utilizing toxic plants and even dynamite fishing have been reported (FAO 2001, Kashema 2006).

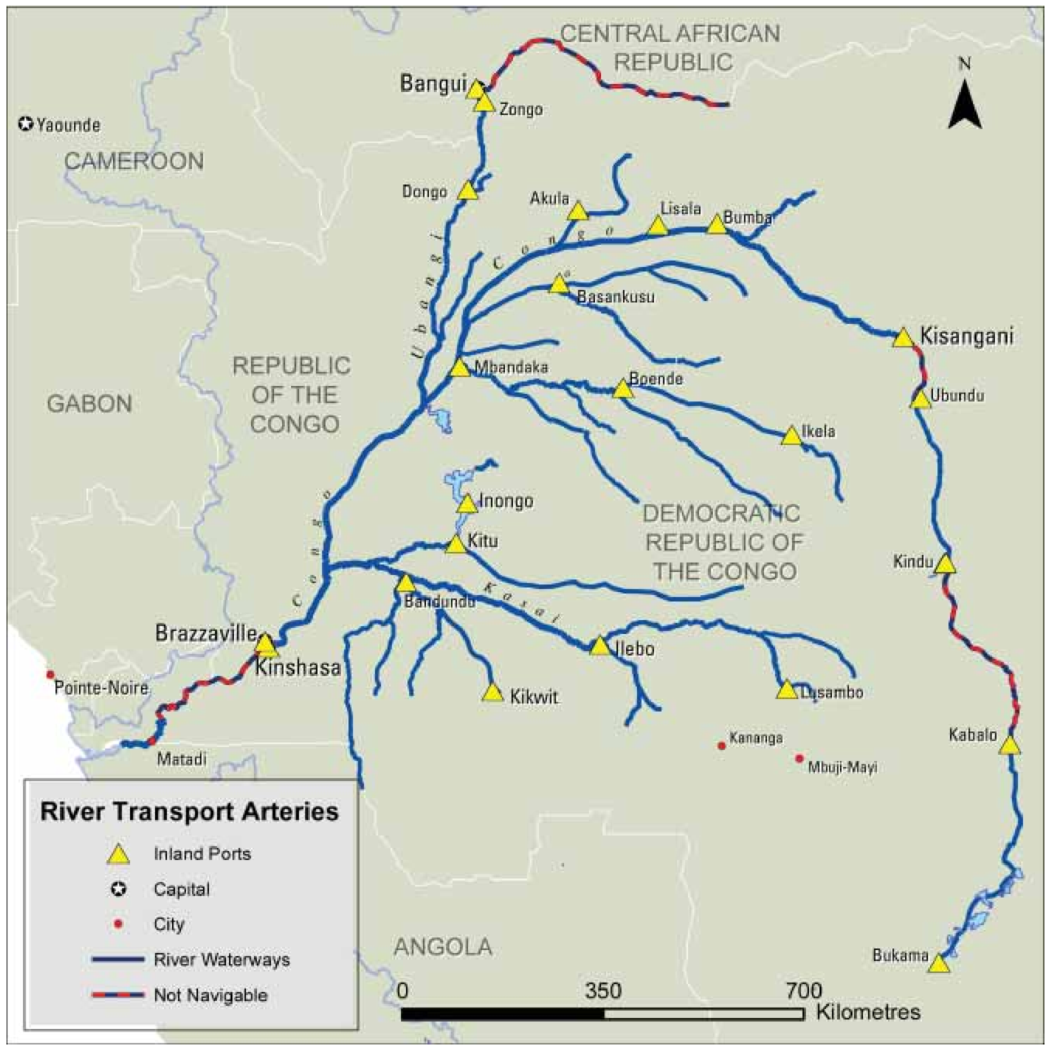


Figure 2.2.4: The absence of roads in many parts of the Congo Basin makes transport on the river's navigable waterways crucial for economic activity

Water Quality

Water quality is an issue in some cities along the river as well as some stretches of the navigable river and at the coast where there are oil refining facilities. Some of this pollution is also linked to transport activities and industrial facilities (FAO n.d.). Environmental impact assessments are not required for activities other than mining in the Democratic Republic of the Congo. DRC law requires an Environmental Impact Study, Mitigation and Rehabilitation Plan and an Environmental Management Plan for mining activities (SADC 2007); nevertheless, World Bank reports state that "Environmental impacts of mining operations in DRC are substantial and growing worse" (World Bank 2008). Katanga Province is the headwaters area of the Congo River and is also where much of the DRC's copper and cobalt are mined. Most of the mining areas in DRC have hydrological connections to the Congo River (Kirongozi 2008). Water quality concerns associated with copper mines include the release of processing chemicals, heavy metals and acids from tailings as well as erosion and sedimentation due to soil and rock disturbances caused by mining and the construction of associated infrastructure.

Agriculture

Transportation infrastructure is a greater factor in limiting agricultural development in the Congo Basin than is water; nevertheless, the amount of irrigated land within the basin is a very small fraction of the potential for irrigation based on water availability (FAO 1997). The potential for expanded lowland rice production within the basin is significant but is constrained by limited irrigation facilities and poor maintenance, among other things (FAO 2002).

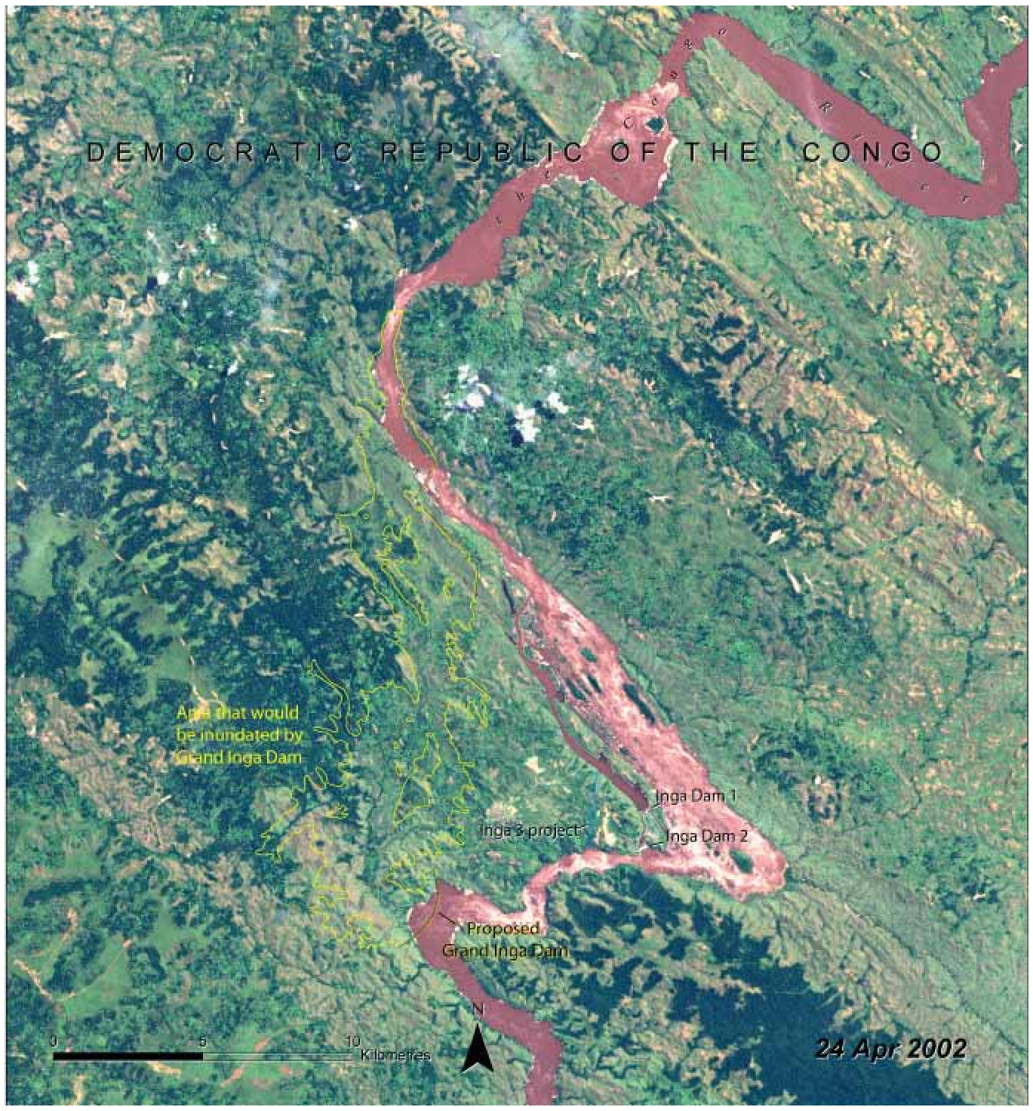


Figure 2.2.6: The reservoir of the proposed Grand Inga Dam would submerge roughly 55 km² of land if the project were to go forward as originally designed

Inga Dams and the Grand Inga Scheme

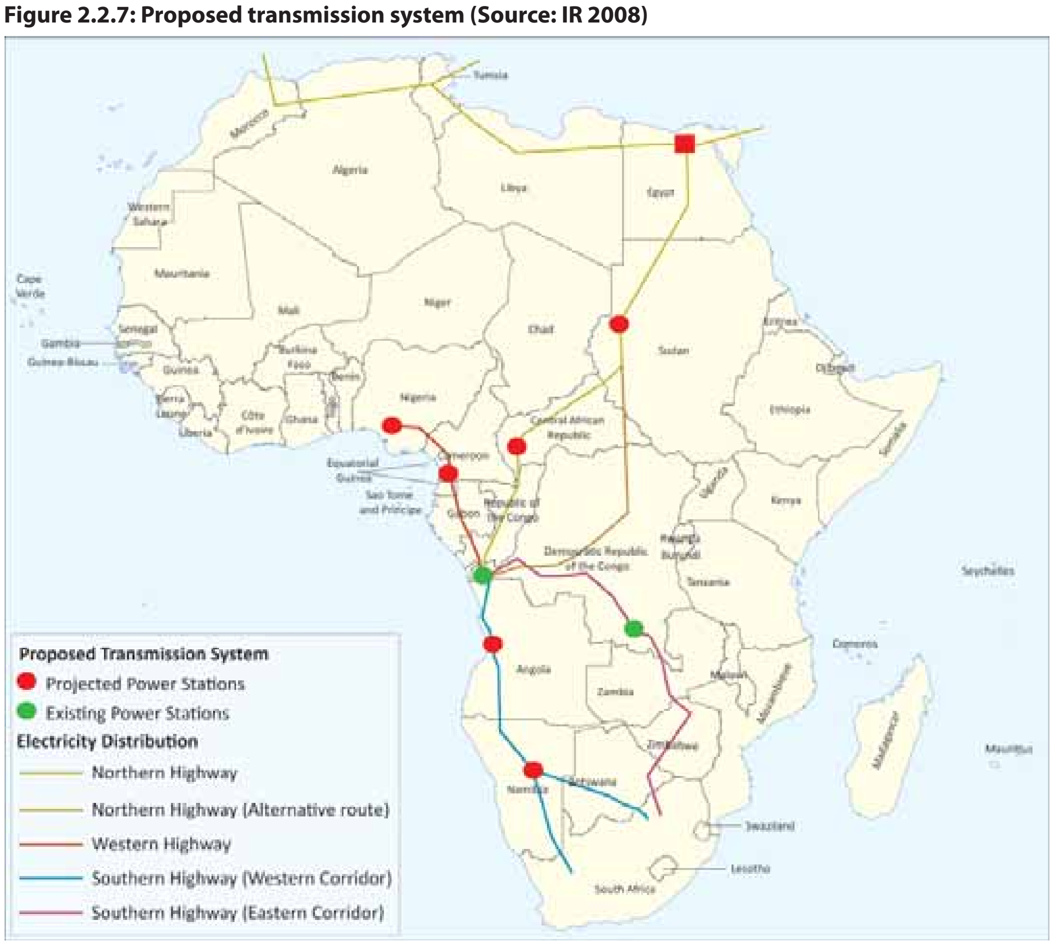
Interest in developing hydropower at Inga Falls in the Democratic Republic of the Congo dates back to the early 20th century when the high potential for generating electricity was first recognized (Showers 2009). The potential is created by a 102 m drop in the river's bed along just 15 km of its length. The Inga 1 Dam (commissioned in 1972) and the Inga 2 Dam (commissioned in 1983) realized some of that potential but fell into disrepair over the years. A project to rehabilitate Inga 1 and Inga 2 is under way at a cost of over US$500 million (IR n.d.a).

There are plans for additional development at the Inga Falls site (Figure 2.2.6). Inga 3 would draw water from the existing reservoir used by the Inga 1 and Inga 2 dams through eight 6 770 m tunnels—each tunnel driving two hydropower turbines (IR n.d.b). This phase is expected to cost approximately US$5 000 million. However, Inga 3 would be dwarfed in cost and scale, if the proposed Grand Inga Dam and related infrastructure are built at an estimated cost of US$50 000 million (IR n.d.c). Grand Inga would generate 44 000 MW of electricity— enough to power the entire continent of Africa.

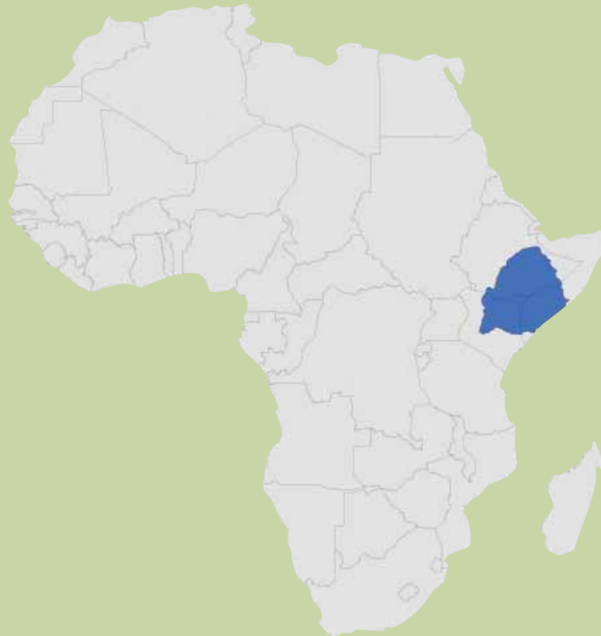
The value of cheap energy for development is undeniable. However, while the Inga 3 project qualifies for carbon-offset credits under the Kyoto Protocol (according to some involved in the project), and hydropower is relatively "green" from an environmental perspective, the Inga projects, and in particular Grand Inga, are not without serious unresolved questions regarding environmental impact and sustainability (Showers 2009, Counter Balance 2009). Serious and thorough environmental assessments and feasibility studies for Inga 3 and Grand Inga will be needed to avoid the unintended consequences that have plagued other large dam projects in Africa (Davies and others 2000, DeGeorges and Reilly 2006).

One of the project's controversial aspects is the proposed transmission system, which would supply power to a host of countries on the continent and potentially Europe as well (EIA 2002) (Figure 2.2.7). Critics have voiced concerns about the transmission line's environmental footprint and point out that in spite of its projected cost of US$40 000 million, it will not bring electricity to the majority of local people who are not already on the electrical grid (IR n.d.a).

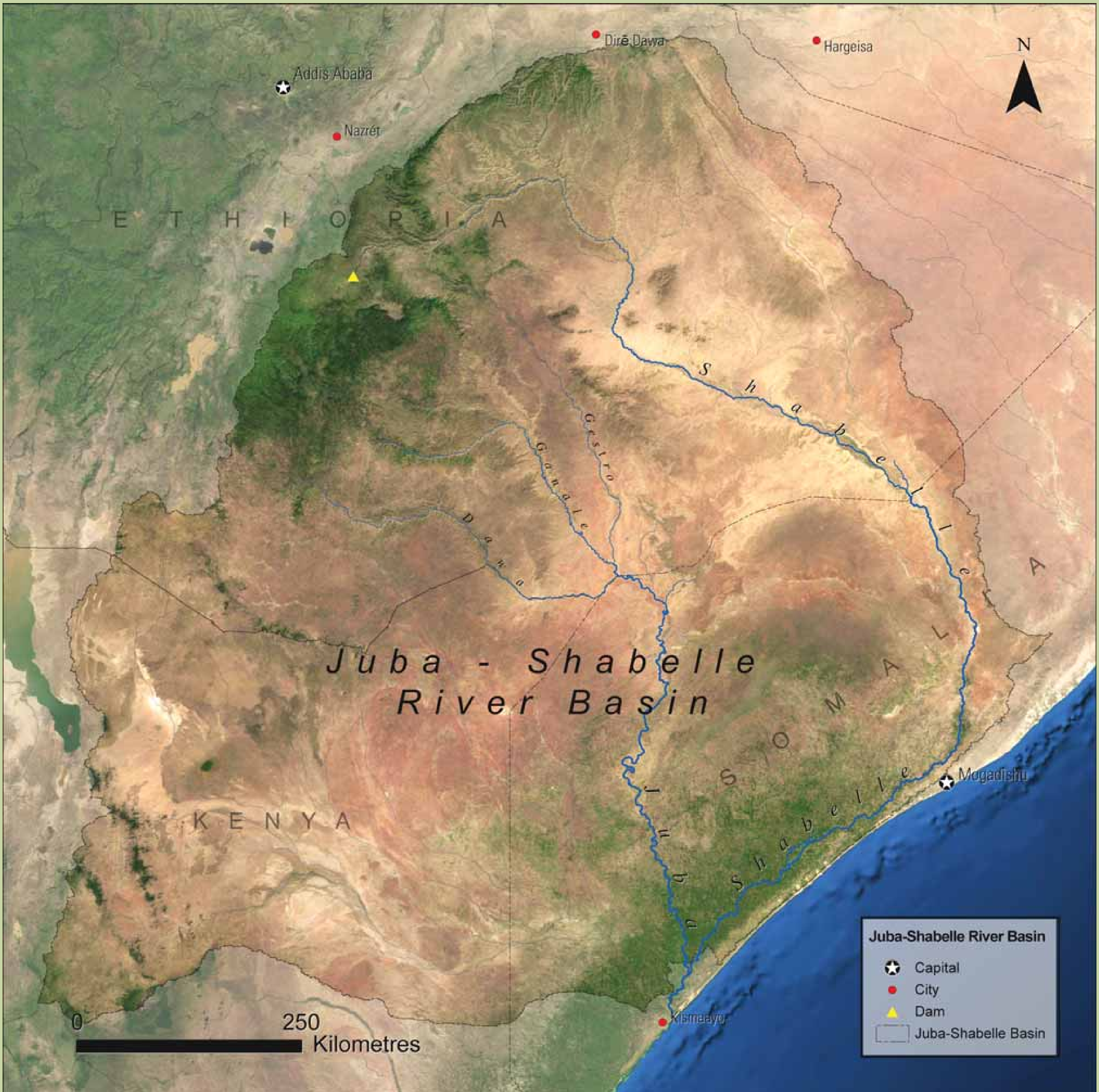
Figure 2.2.7: Proposed transmission system (Source: IR 2008)



Juba Shabelle Basin



Both the Juba and the Shabelle originate in the southeastern portion of the Ethiopian Highlands at over 3 000 m above sea level. The Juba has the smaller catchment area but receives heavier rainfall and has considerably higher runoff near its headwaters.



In most years, the Shabelle's discharge terminates in wetlands short of its confluence with the Juba

Both rivers lose discharge as they progress downstream due to a lack of rainfall in downstream areas, high evaporation and significant infiltration and withdrawals (Thiemig 2009). In most years, the Shabelle's discharge terminates in wetlands, short of its confluence with the Juba (FAO 2000).

Precipitation

The basin's rainfall comes in two rainy seasons with less pronounced dry seasons in the higher areas of Ethiopia than in lower areas throughout the rest of the basin. The primary rains occur from April to June delivering around 60 per cent of the annual rain. Lesser rains in October and November bring around one quarter of the year's precipitation (Artan and others 2007). Total annual rainfall in some areas of the Juba headwaters is over 1 400 mm. Much of the rest of the basin is arid or semi-arid and a lot of the lowland part of the basin receives less than 500 mm of rain annually and some parts as little as 200 mm (Figure 2.3.1, Figure 2.3.2). High temperatures, along with the limited rainfall, further reduce the contribution of most of the basin to the Shabelle-Juba River system. Ethiopia contributes the vast majority of the two rivers' flows, while Kenya has little influence and Somalia's portion of the basin has a negative net impact on the two rivers' water budget.

Agriculture is by far the largest water-user in most downstream areas, but relies predominantly on surface water (FAO 2005). Rainfall varies dramatically from year to year throughout the basin, however, causing severe droughts every seven to ten years (FAO 2005). This is catastrophic for rain-fed agriculture, which has increased in Somalia in recent decades as irrigation infrastructure has fallen into disrepair or been destroyed (FAO 2005). Somalia's heavy reliance on the Juba and Shabelle Rivers makes water development in Ethiopia, such as the Melka Wak Dam on the Shabelle, of great concern to Somalia.

Population

Approximately 13 million of the basin's roughly 20 million people live in the Ethiopian part of the basin. Kenya's quarter of the basin has a population of roughly 2.5 million. Somalia is estimated to have between 3.5 and 5.5 million people in its part of the basin (Figure 2.3.3).

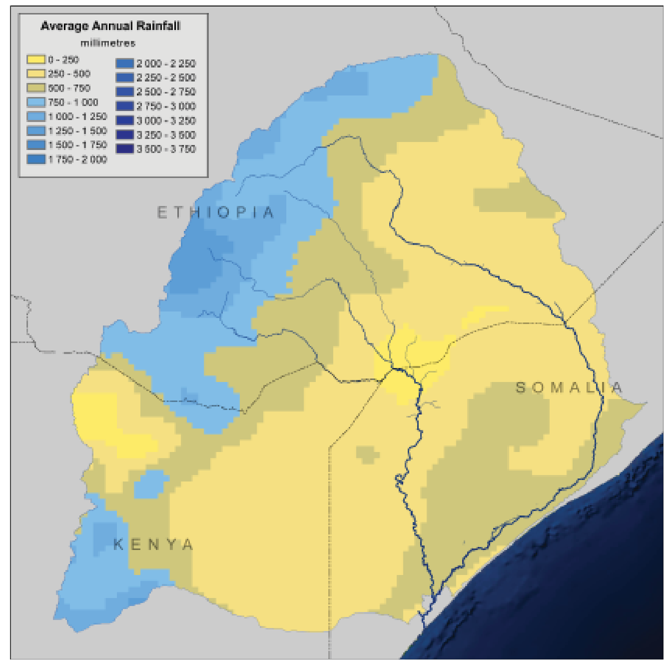


Figure 2.3.1 Juba-Shabelle River Basin average annual rainfall

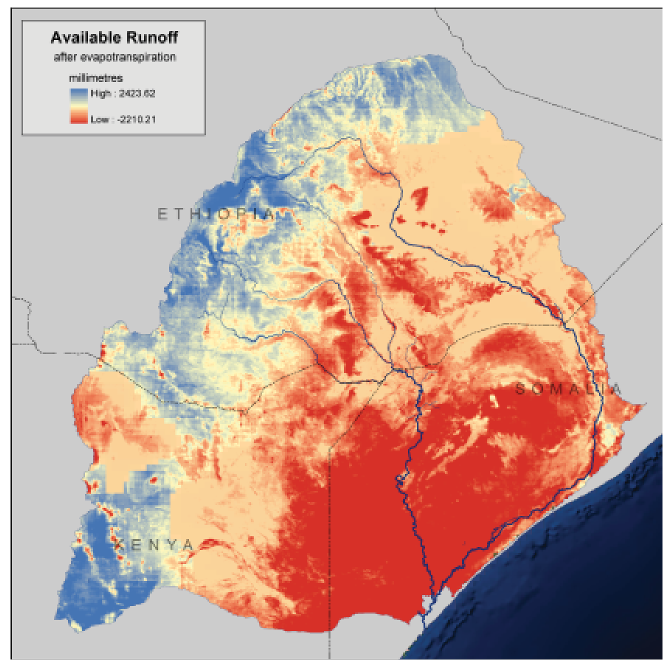


Figure 2.3.2 Juba-Shabelle River Basin modeled available runoff

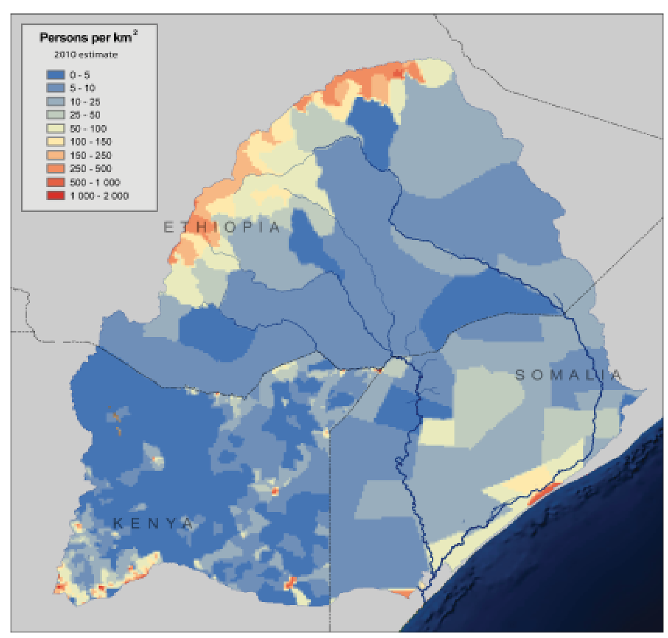
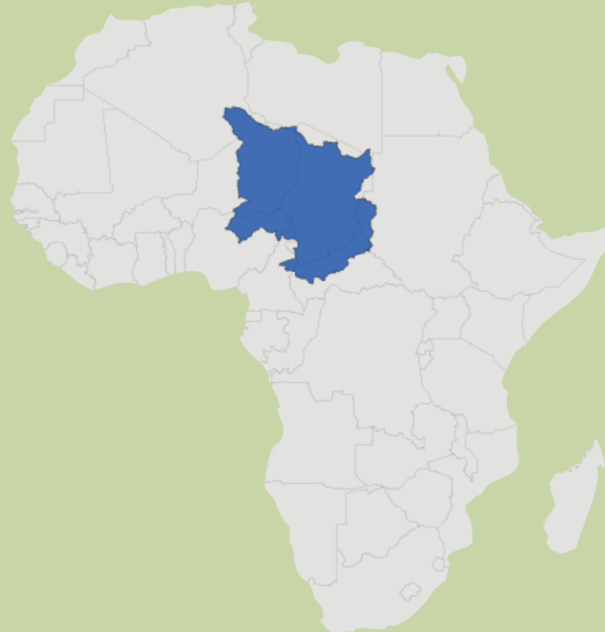
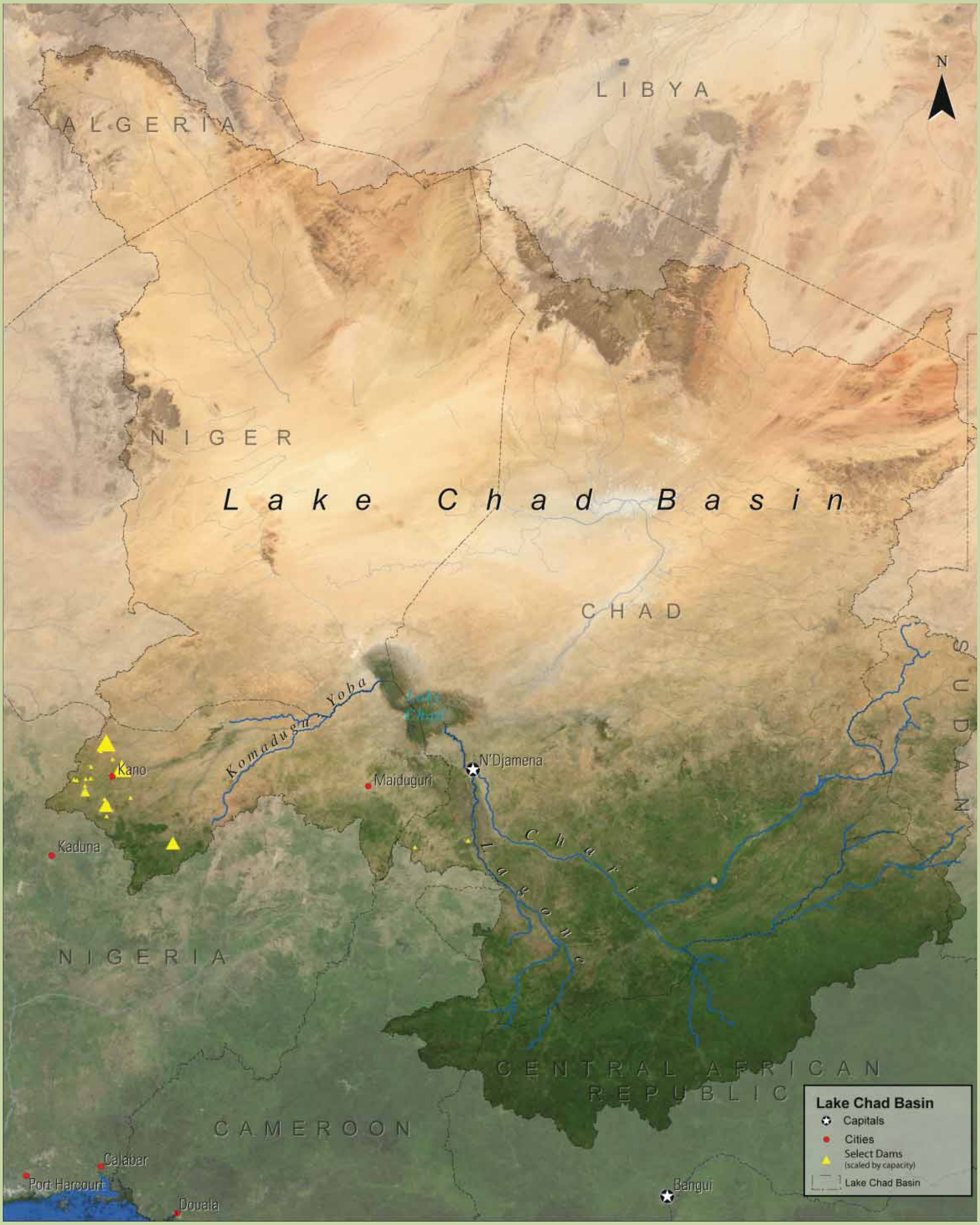


Figure 2.3.3 Juba-Shabelle River Basin population density 2010

Lake Chad
Basin



The watershed basin of Lake Chad makes up just over eight per cent of the surface area of Africa, and falls across the boundaries of eight countries—Algeria, Cameroon, Central African Republic, Chad, Libya, Niger, Nigeria and Sudan.



Lake Chad is among the largest freshwater reservoirs in the Sahel

It stretches across a range of landscapes north to south, from the barren core of the Sahara Desert in the north to heavily wooded savanna areas of northern Cameroon and the Central African Republic. Rainfall, vegetation, population and economic activity are all concentrated in the southern half of the basin with the lake itself falling along the transition from savannah to desert in the heart of the Sahel. The Chari, the Logone and the Komadougou Yobé rivers carry nearly all of the water in the basin. Nevertheless, even with no outlet to the sea, the basin's salinity remains low. Research has shown that the salts are controlled by seepage into the groundwater and to a lesser degree by sedimentation (Roche 1977, Isiorho and others 1996). The lake is among the largest freshwater reservoirs in the Sahel making it a focal point of human activity (Musa 2008). This is especially so for the more than three million people (SEDAC 2010) living within 200 km of the lake, many of whom make their living by farming, fishing and tending livestock (Musa 2008).

Population

Based on estimates of the 2010 population (SEDAC 2010), around 46 million people live within the larger Lake Chad basin, with most concentrated in the watershed's southwest corner (SEDAC 2010) (Figure 2.4.1). Nigeria, which makes up 7.5 per cent of the basin's area, is home to 26 million of the basin's people—well over half. Chad is the second-most populated with ten million of its people living in the basin, and Niger is third, with just under three million (SEDAC 2010). All three countries have had high estimated population growth rates over the past five years, ranging from 2.3 per cent annually in Nigeria to 3.5 per cent annually in Niger (UN-WPP 2006). Sudan and Cameroon each have around 2.5 million people living within the Chad Basin (SEDAC 2010).

Precipitation

Despite Chad's large size within the basin (46 per cent of its area) and the fact that it receives roughly 43 per cent of the basin's rainfall (Figure 2.4.2), it contributes well less than a third of the water balance, due to high evapotranspiration rates. Nigeria, with only 7.5 per cent of the basin's area, also contributes roughly 30 per cent of the basin's water balance (Senay and others 2010). Around a quarter of the total basin's runoff comes from the Central African Republic portion of the basin (Figure 2.4.3). While Niger makes up over one-quarter of the basin, it only receives 5.5 per cent of its precipitation and loses more than that to evapotranspiration, thus having a negative impact on the basin's water balance.

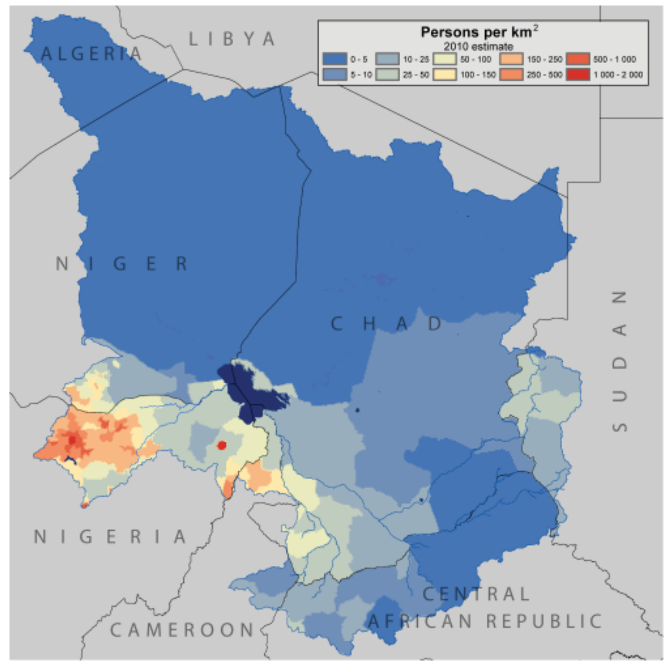


Figure 2.4.1 Lake Chad Basin population density 2010

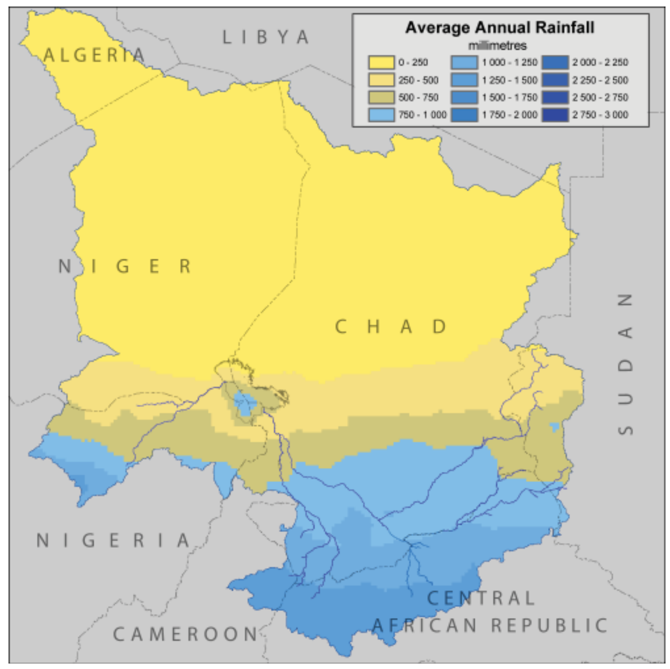


Figure 2.4.2 Lake Chad Basin average annual rainfall

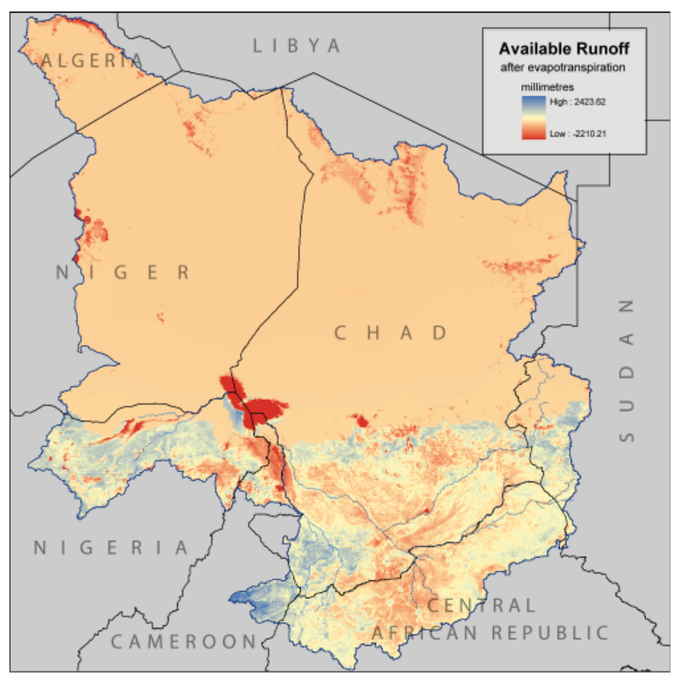


Figure 2.4.3 Lake Chad Basin average annual runoff

Lake Chad's Variability

Precipitation is highly variable across the Lake Chad watershed seasonally, from year to year, and over periods of several decades. This variability coupled with the shallowness of the lake makes its surface extent almost equally variable. The series of remote sensing images spanning the past 50 years shows the scale and pace of changes that have taken place (Figure 2.4.7, page 50-51). Between the early 1960s and the mid-1980s, surface area generally declined from a maximum of more than 25 000 km^2 to as small as 1 350 km^2. Determining long-term trends in surface area or lake levels (Figure 2.4.4 and 2.4.5) and attributing this change to specific causes has been complicated by this background of constant change. Nevertheless, some understanding of the trends and their causes is developing among scientists studying the lake.

It is well established that the overwhelming majority (85 to 90 per cent) of the water in the lake comes from the Chari-Logone River system (Figure 2.4.8, see page 52), with almost the entire remaining fraction derived from the Komadougou Yobé River and from direct rainfall (Coe and Foley 2001, Nihoul and others 2003). The discharge of the Chari-Logone system has decreased by nearly 75 per cent since the mid-1960s, due to drought and diversion (GIWA 2004). While some studies have indicated that

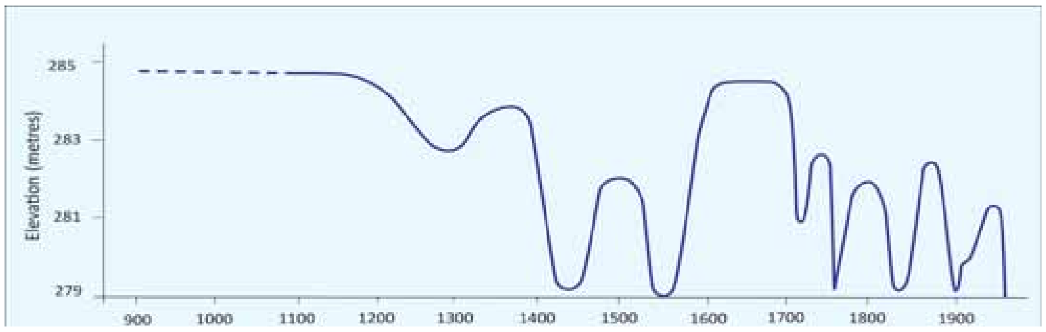


Figure 2.4.4: Long-term historical water levels of Lake Chad (Source: Olivry and others 1996)

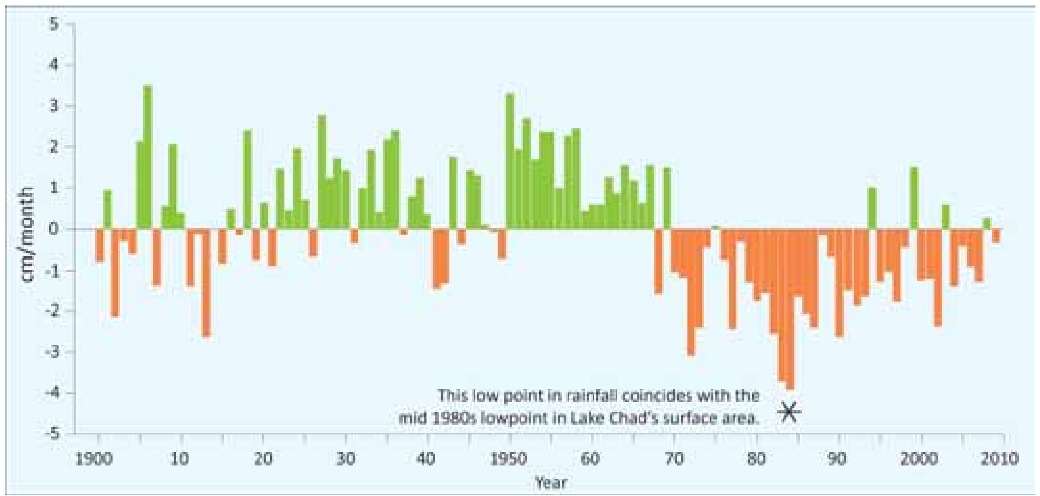


Figure 2.4.5: June to October, mean Sahel precipitation anomalies, 1900-2009 (Sources: University of Washington 2009)

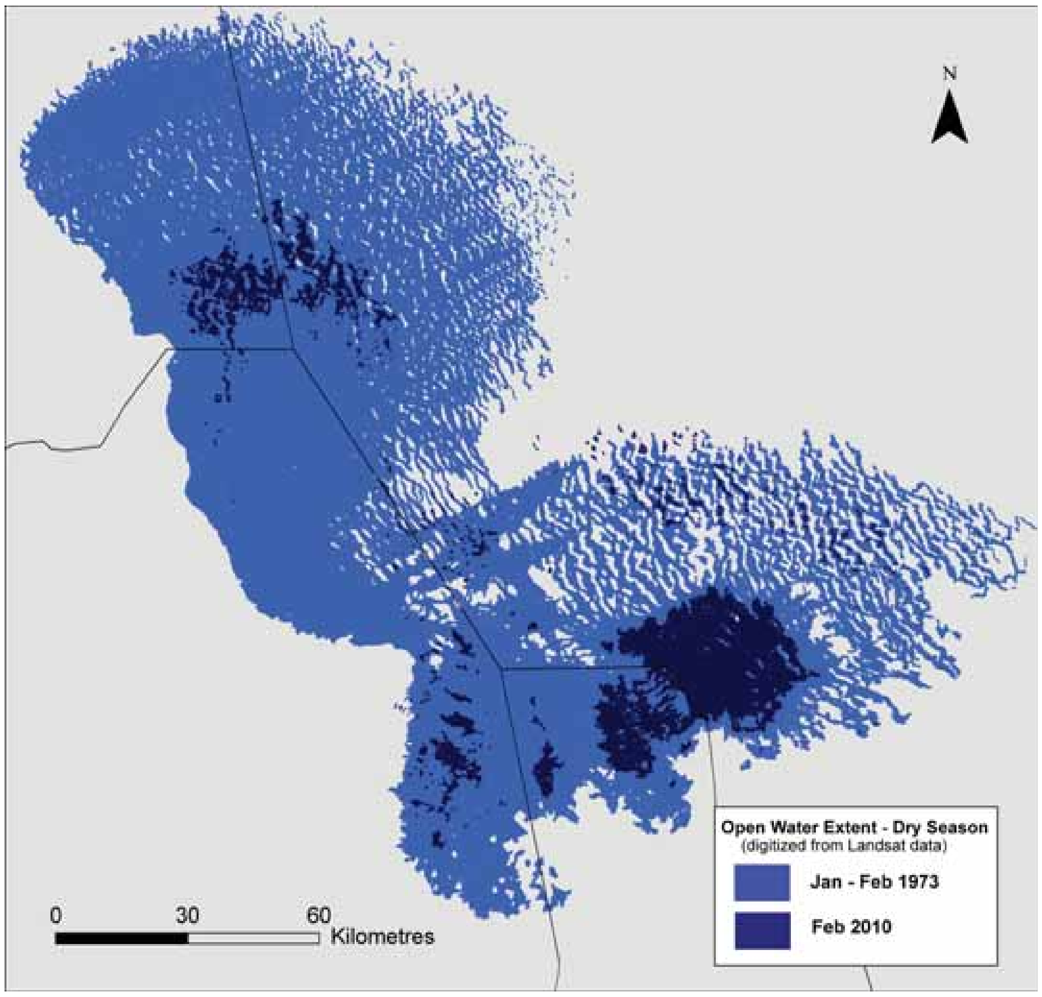


Figure 2.4.6: Approximate extent of open water in Lake Chad digitized from Landsat images, 1973-2010

irrigation that draws water from the Chari-Logone system has played a major role in the lake's declining size since the early 1970s (Coe and Foley 2001), the relative importance of irrigation is disputed (Lemoalle 2008, Nihoul and others 2003). Nevertheless, population is growing within the Chari-Logone Basin and as a result so is the demand for water (GIWA 2004), which will likely increase the importance of diversion in the Lake Chad water budget.

It is quite clear, however, that a decline in average rainfall following 1970 was a central cause of the drop in the lake level and areal extent during the same time frame (Lemoalle and others 2008) (Figure 2.4.6). The droughts of the 1970s and 1980s have in turn been linked to naturally occurring variation in Atlantic sea-surface temperatures (Shanahan and others 2009, Zhang and Delworth 2006, Giannini and others 2003). Recent research suggests that current patterns of drought driven by these variations are not anomalous, with evidence of much more extreme droughts across the Sahel as recently as 200-300 years ago and patterns of similar droughts extending back at least a few thousand years. Figure 2.4.5 raises the possibility that a drought more severe than the ones in the 1970s and 1980s could occur in the foreseeable future. In addition, it is suggested that global warming would likely make these droughts still more severe (Shanahan and others 2009).

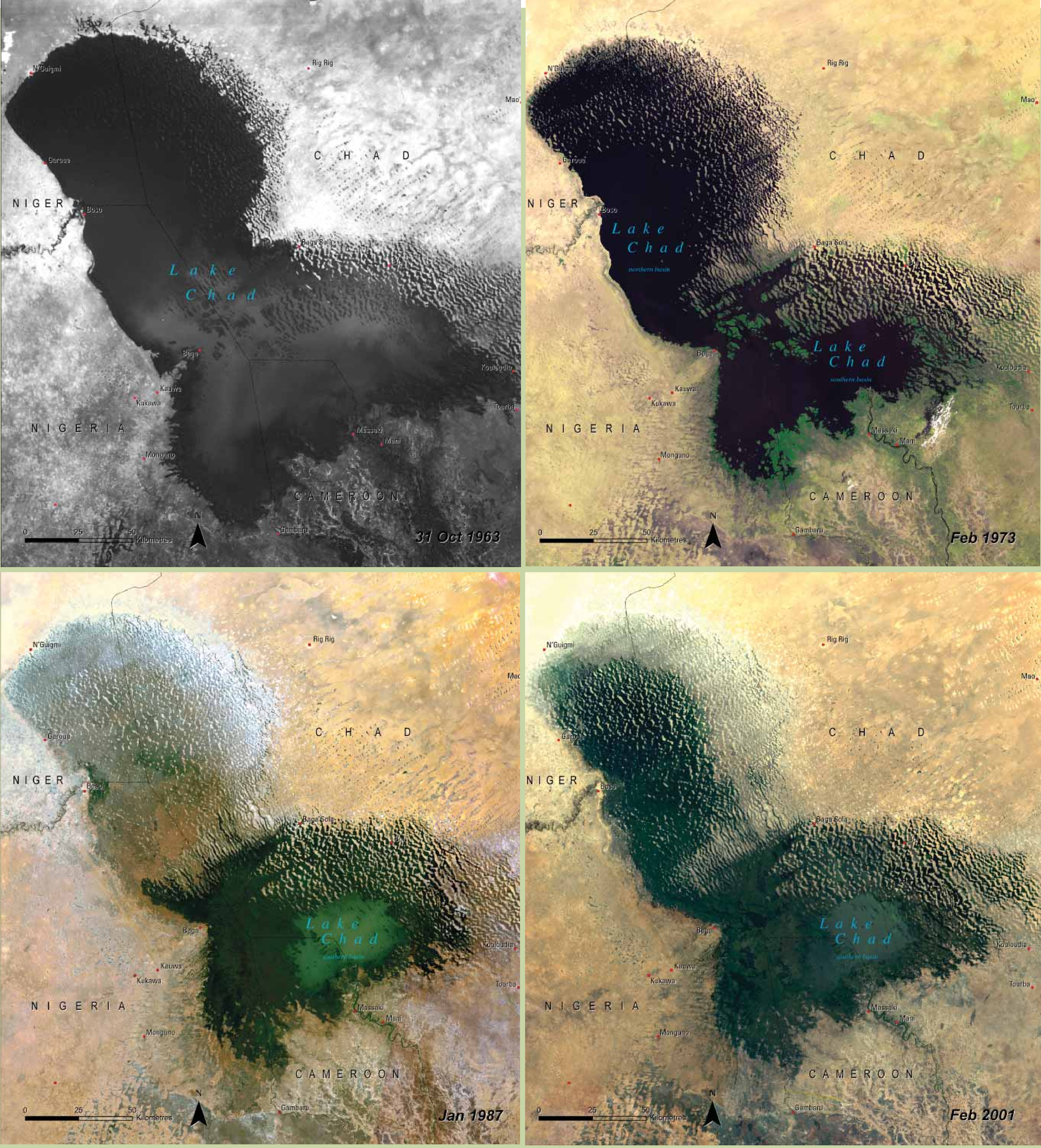
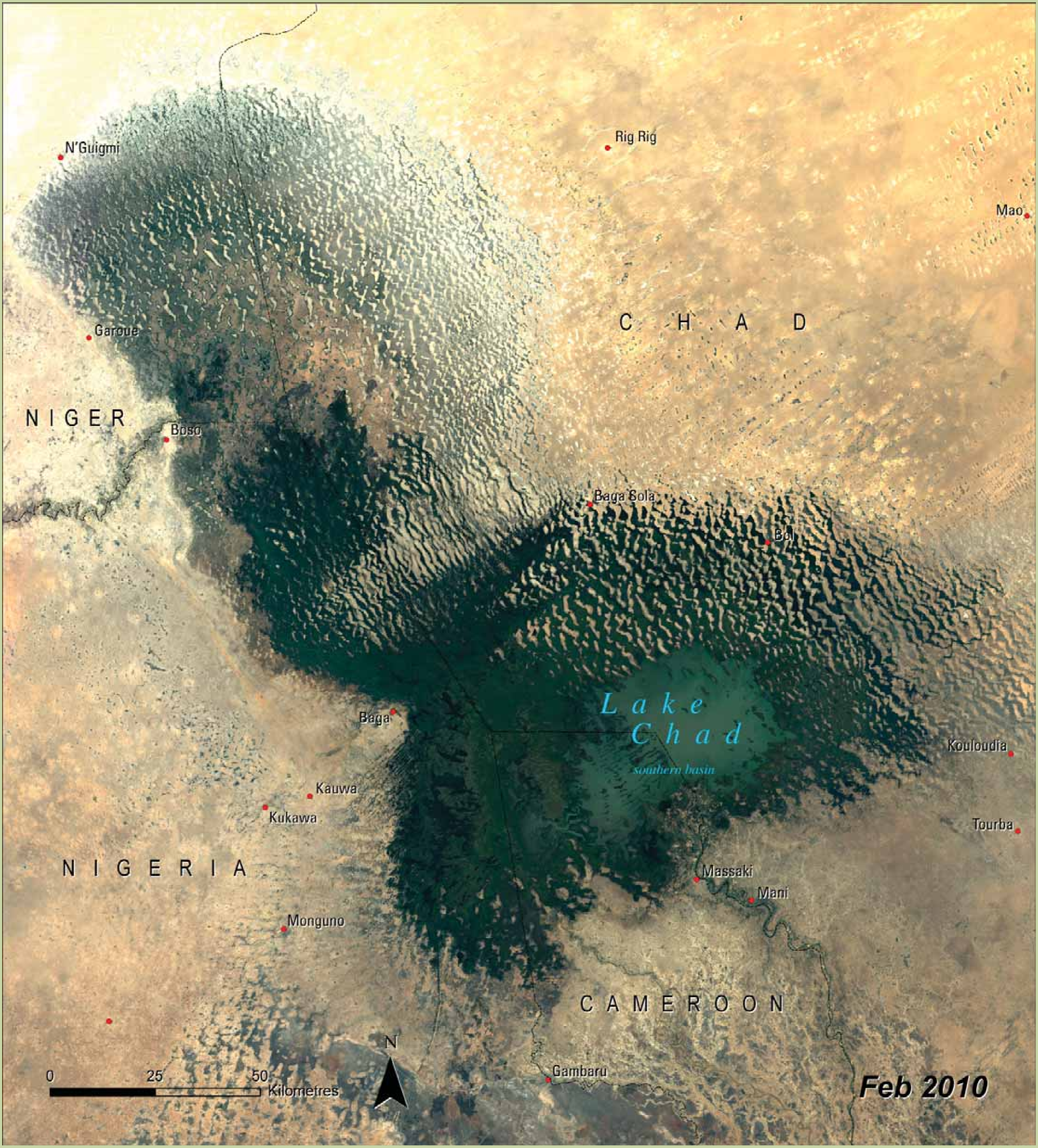


Figure 2.4.7: While Lake Chad's surface area fluctuates considerably with the seasonal rains, these dry-season images of Lake Chad show the long-term trend since the 1960s. Changes in rainfall during this period (Figure 2.4.5) have been a major factor as has diversion for irrigation (Coe and Foley 2001)


N'Guigmi
Rig Rig
Mao
C H A D
Garoue
N I G E R
Boso
Baga Sola
Bol
Lake
Chad
southern basin
Baga
Kouloudia
Kauwa
Kukawa
Tourba
N I G E R I A
Massaki
Mani
Monguno
C A M E R O O N
N
0
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50
Kilometres
Gambaru
Feb 2010

Decreased flow in the Chari-Logone system has dramatically decreased water supply to human and natural systems downstream (FAO 2009). The rate of change in the ecosystem has outpaced the rate at which the natural flora and fauna are able to respond and adapt (FAO 2009). The decline in Lake Chad has forced fishing communities to migrate to follow the receding lake waters (GIWA 2004). Reduced inundation of the Yaéré and Waza-Logone floodplains has had a negative impact on farming (GIWA 2004) and reduced the quality and area of dry-season grazing (IUCN 2003b). Wells must be dug deeper to reach the lower water table (GIWA 2004). The impact of drought and reduced lake area has already been profound for people living close to the lake and impacts extend to a lesser extent to the over 35 million people who live in the larger Chad Basin (GIWA 2004).

One response to the shortage of surface water has been increasing groundwater use. The Quaternary aquifer underlying the Lake Chad basin is the major groundwater source for the region (Ngatcha and others 2008). There is a lack of hydrogeological datasets for the area, which are needed for sustainable use of these groundwater assets (Ngatcha and others 2008). One recent study suggests that water levels in the Quaternary aquifer declined in response to the decrease in rainfall during the second half of the last century (Boromina 2008). This probability highlights the need for improved availability and completeness of hydrogeological datasets for policy makers looking for appropriate responses to the Lake Chad Basin's diminishing water resources.

Another proposed response that would directly address the lowering lake levels is the transfer of water from outside the Lake Chad Basin (see also page 42). A scheme to pump water from the Ubangi River to restore the Lake Chad and Chari River system was developed in the late 1980s (FAO 2009) (Figure 2.4.9). A dam would be built on the Ubangi at Palambo CAR from which water would then be pumped into the Fafa and Ouham Rivers. From there it would flow through a 1 350 km man-made channel to reach the Chari River and ultimately Lake Chad (FAO 2009). In November 2009, a US$6 million feasibility study was begun by a Canadian engineering firm on behalf of the Lake Chad Basin Commission. It is to be completed by late 2011 (CIMA n.d.).

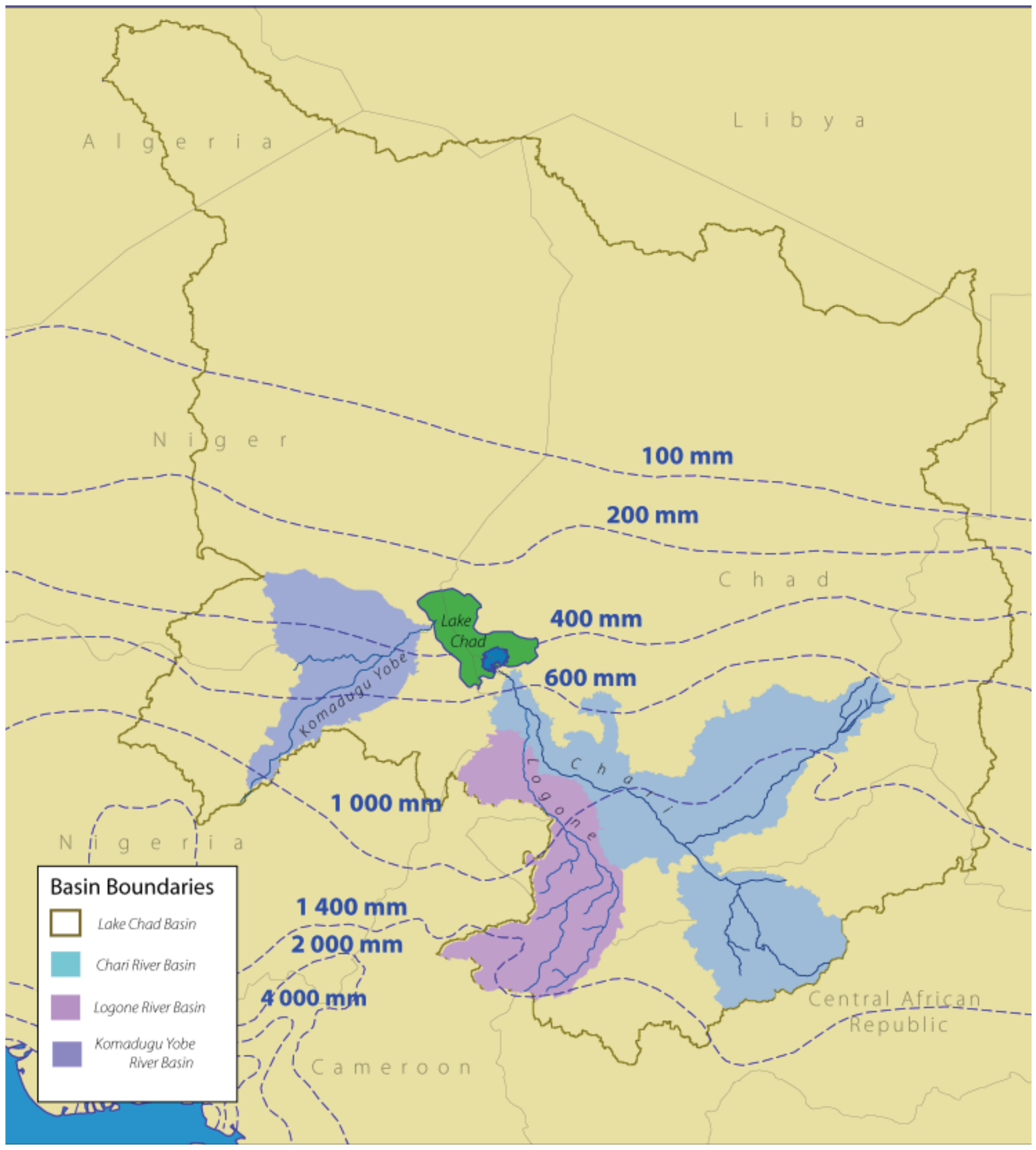


Figure 2.4.8: Rainfall averages only around 400 mm/yr at Lake Chad, but increases to the south where most of the Lake's inflow comes from—primarily from the Chari, Logone and Komadougou-Yobé Basins

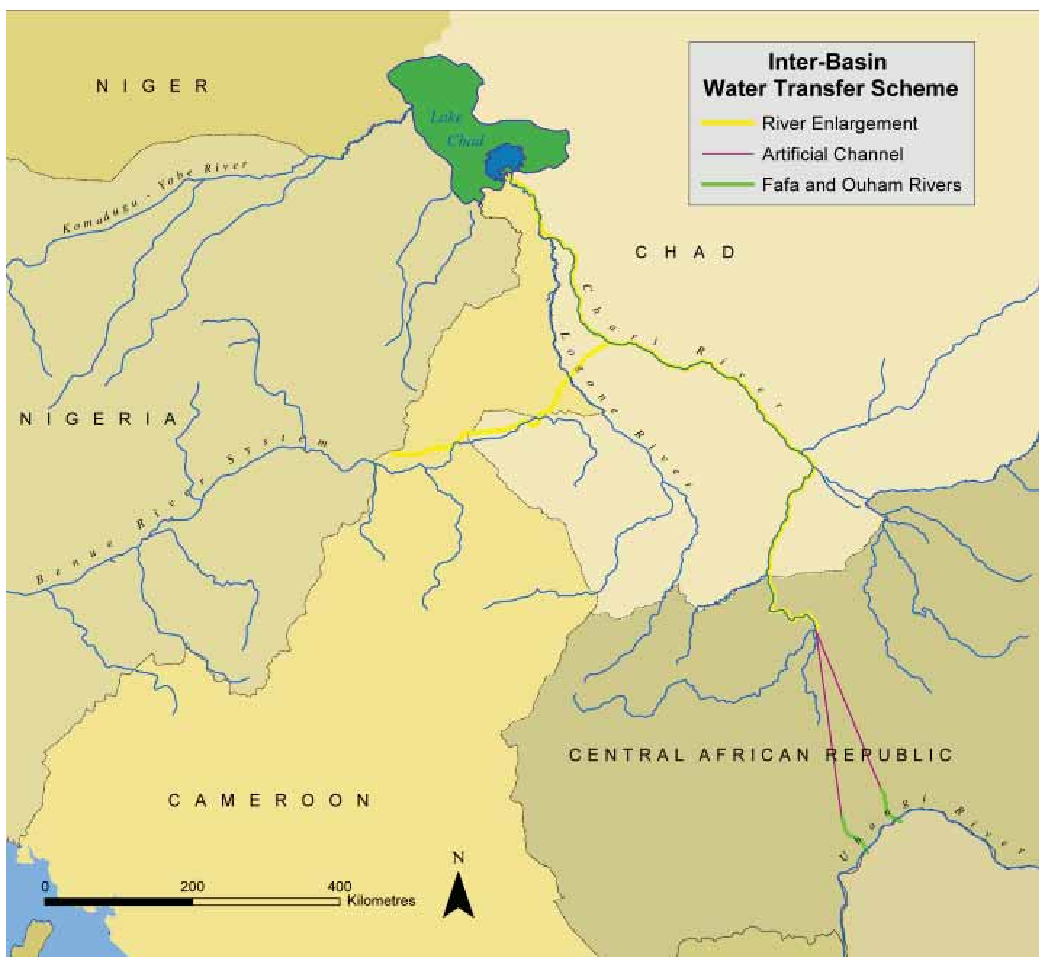


Figure 2.4.9: A proposed inter-basin transfer project would take water from the Ubangi River in the Congo River Basin and transfer it to the Lake Chad Basin

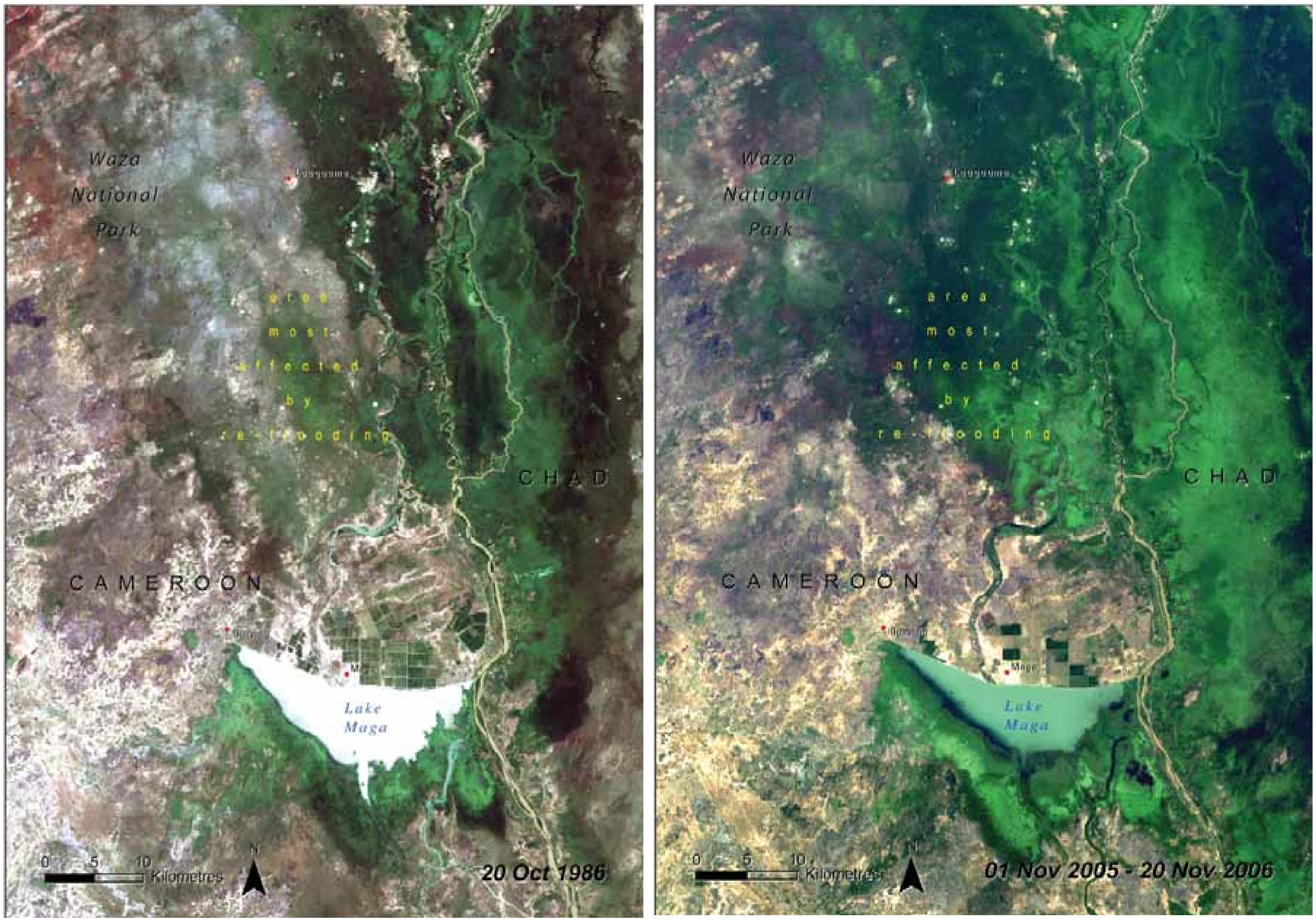


Figure 2.4.10: Damming of the Logone River in the 1970s coinciding with a period of drought reduced overbank flooding and disrupted local livelihoods on the Waza Logone Floodplain. Managed releases from the dam beginning in the 1990s restored some of the natural flooding, bringing improved grazing and return of other valuable ecosystem functions.

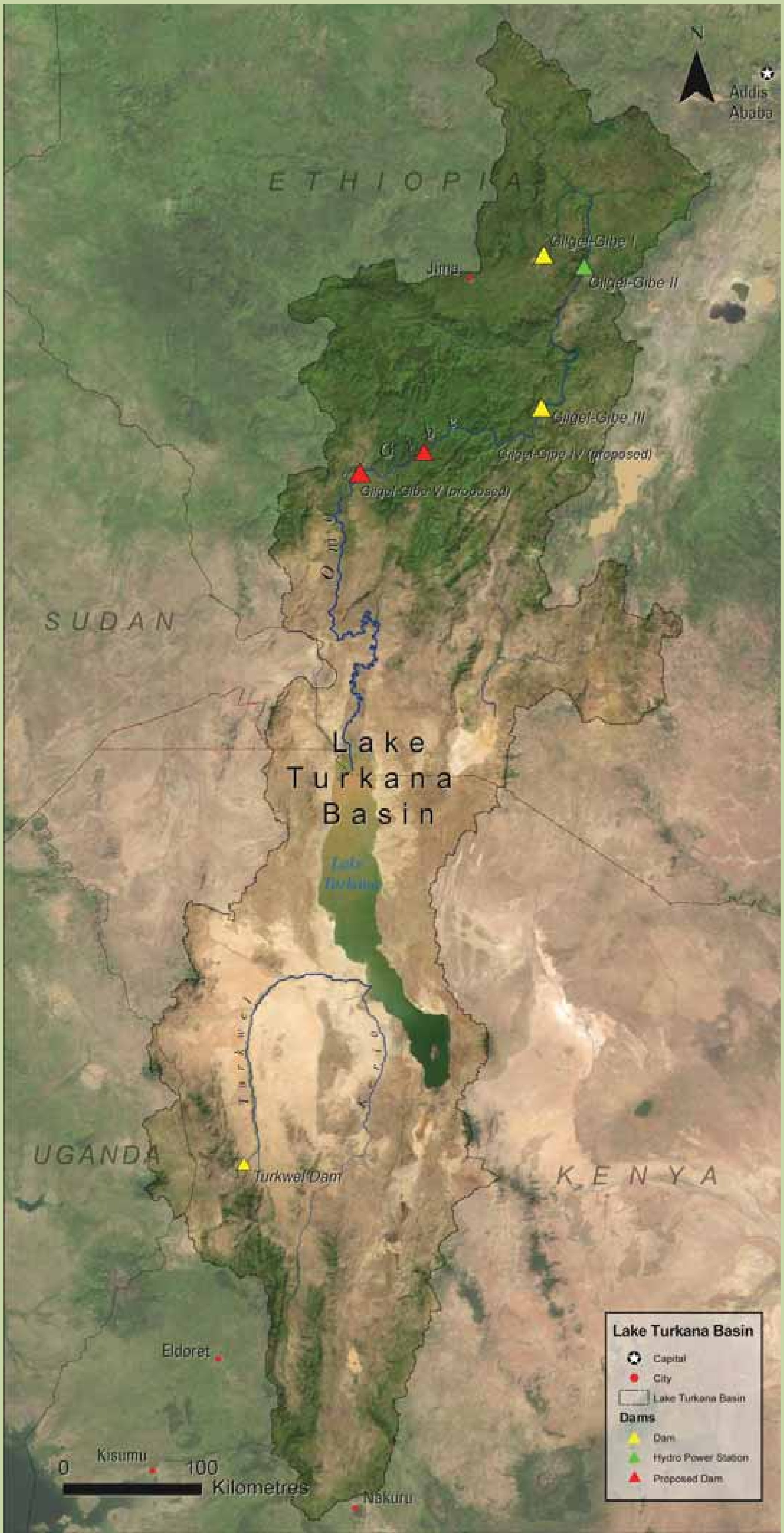
The Waza Logone Floodplain

The Waza Logone floodplain in northern Cameroon is a highly productive seasonal wetland with great biodiversity importance (IUCN 2004). It also provides livelihoods to approximately 135 000 people through recession agriculture, fishing, livestock and natural products and services such as honey, medicines and building materials (IUCN 2004). The high productivity and many of the ecosystem goods and services depend on overbank flooding from the rivers that feed into the wetland—primarily the Logone River but also the seasonal Tsanaga, Boula and Vrick Rivers. Many of these ecosystem services were lost on large parts of the floodplain following the construction of the Maga Dam and associated rice-irrigation schemes in the 1950s and late 1970s, which coincided with a period of below-average rainfall (Loth 2004). The drought, along with regulation of the Logone River for irrigation, greatly reduced natural flooding, which led to serious environmental damage and disrupted the lives of many local people who relied on the flooding for their livelihoods (Loth 2004).

The satellite image from late 1986 (Figure 2.4.10) flooding season shows little standing water and minimum wetland vegetation in the area just southwest of Waza National Park. In the 1990s, the management strategy of the Logone's flow was broadened to consider the viability of downstream resources (Loth 2004). Some channels that had been modified for the rice schemes were opened to allow water to flood roughly 200 km^2 (IUCN 2004). The integrated management of the floodplain's natural resources has allowed the return of some natural grasses that had been lost, enhanced productivity, increased bird numbers and improved grazing (Scholte 2005). Figure 2.4.10 from the 2005 and 2006 flooding seasons shows adequate flooding in the area southwest of Waza National Park along with heavy wetland vegetation.

Lake Turkana Basin

Although the Lake Turkana Basin occupies parts of four countries, 98 per cent of its area lies within just two of them. More than half (52 per cent) is in Ethiopia, where almost three-quarters of the basin's rain falls.



Lake Turkana is the largest desert lake in the world

Just less than half of the basin lies in Kenya, where the lake itself is located. The Turkwel and Kerio Rivers flow into the lake from the south, although their contribution to water levels is minimal. The lake receives nearly all of its inflow from the Omo-Gibe River, which drains part of Ethiopia's highlands. Lake Turkana itself is the largest closed-basin lake in the East African Rift (Haack 1996) and the largest desert lake in the world (Angelei 2009). It has remained relatively isolated since it is in Kenya's arid north where the average temperature is 30° C and average annual precipitation is less than 200 mm (Nyamweru 1989). Water levels in Lake Turkana varied within a 20 m range between 1885 and 2008 (ILEC n.d., Legos 2009) and there is evidence that the 20th century's fluctuations were smaller than those before 1900 (Nicholson 2001).

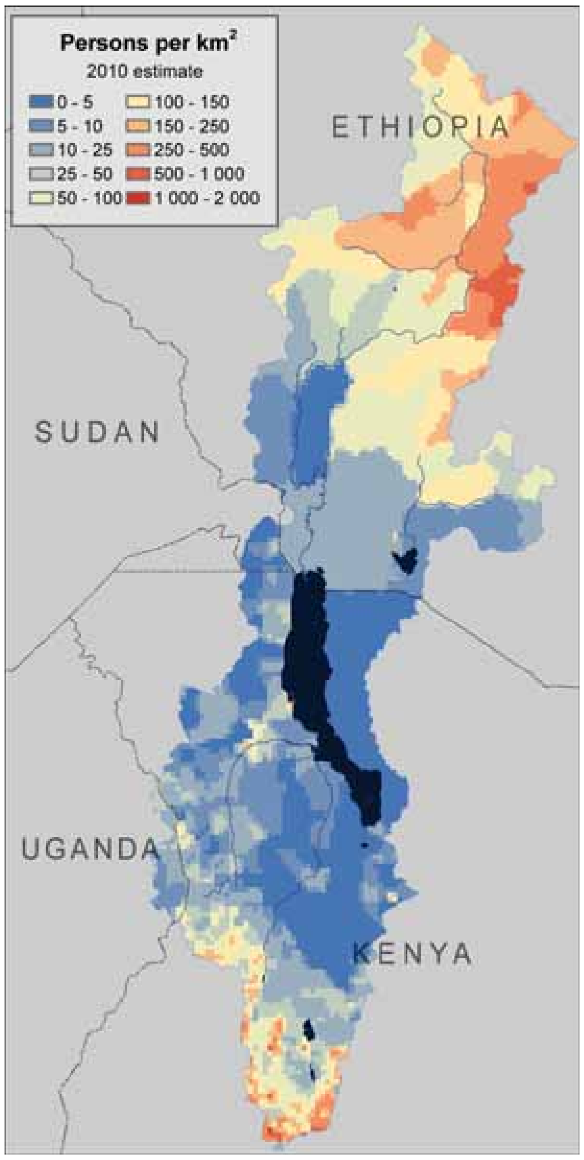


Figure 2.5.2 Lake Turkana Basin population density

Precipitation

Averaged across the entire Lake Turkana basin, mean annual precipitation is well over 900 mm (Figure

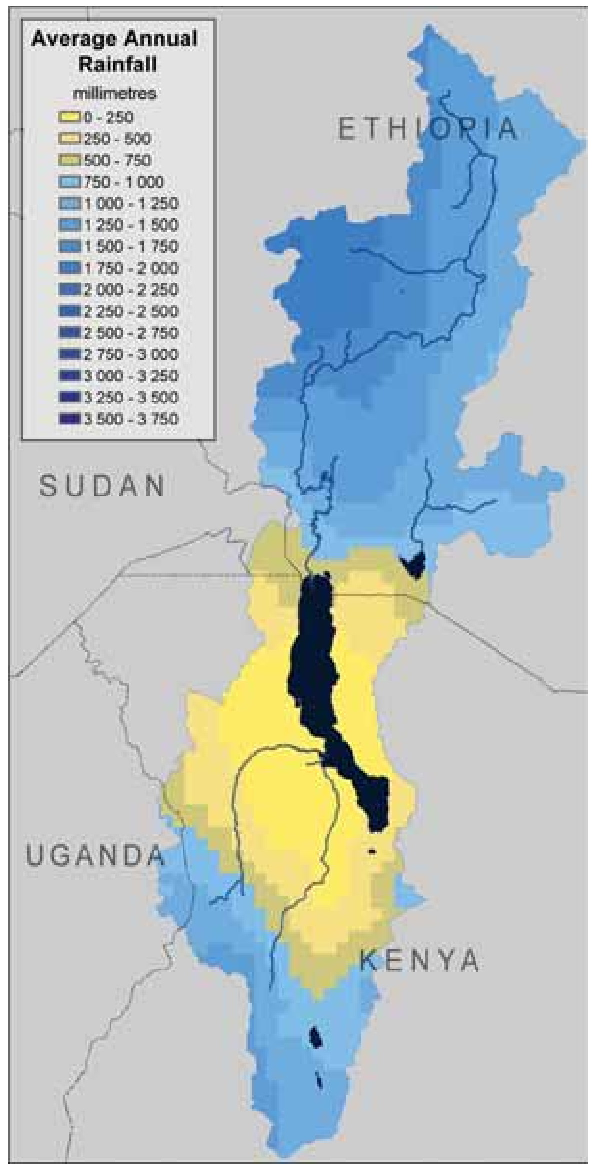


Figure 2.5.1: Lake Turkana Basin average annual rainfall

2.5.1). However, spatial variation is quite extreme with parts of Ethiopia approaching 2 000 mm of rain annually, while areas in northern Kenya receive less than 100 mm. In addition, high temperatures in northern Kenya and strong winds surrounding the lake quickly evaporate much of the erratic precipitation that does fall (ILEC n.d.). Lake Turkana receives 80 per cent of its inflow from the Omo River. The lower reaches of the Omo River as well as Lake Turkana and the communities that it supports rely on rainfall in the Ethiopian Highlands, which act as a "water tower." Recession-agriculture, flooding of grazing lands, fishing and recharge of shallow aquifers along the river's lower reaches all depend on the Omo River's volume and flow pattern.

Population

The total Ethiopian population in the basin is around nine million, while some 1.7 million people live in Kenya's portion of the basin. The number of people

living within 50 km of the lake, however, is estimated to be only around 215 000 (ORNL 2008). Population is concentrated in the upper fifth of the basin within Ethiopia and at the basin's southern-most limit in Kenya (SEDAC 2010) (Figure 2.5.2).

Hydropower Facilities

A series of five hydropower facilities are planned along the Omo-Gibe River. The first dam, Gilgel-Gibe I, has been completed and filled. The second hydropower facility, Gilgel-Gibe II is fed by a 25 km tunnel running east from Gilgel-Gibe I Reservoir through a mountain to where the Omo River is 700 m lower. Gibe III has been under construction since 2006 and when completed will be the second-largest reservoir in Africa. Construction has not yet begun on two additional planned hydropower facilities, Gibe IV and Gibe V.

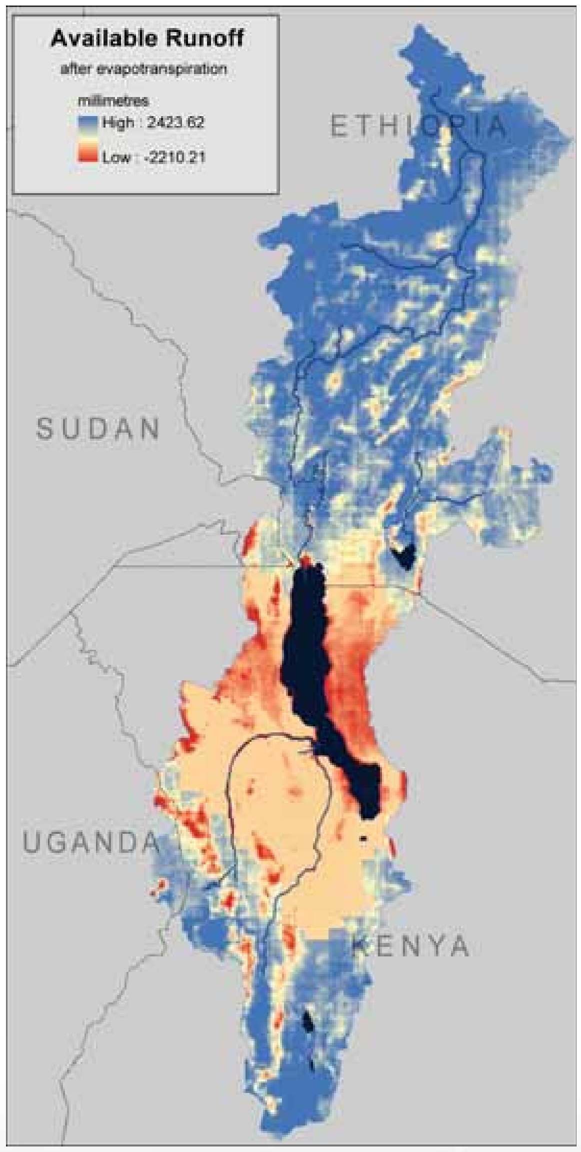


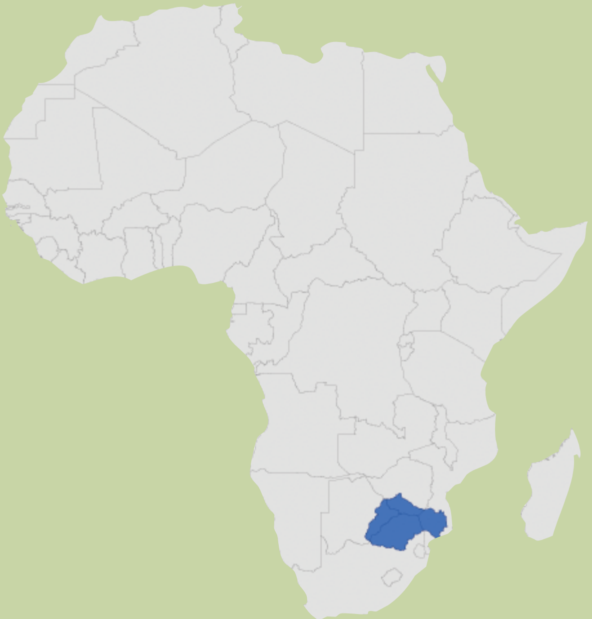
Figure 2.5.3: Lake Turkana Basin available runoff

Figure 2.5.4: The Gibe III dam was roughly one-third of the way to completion when this March 2009 image was acquired. It is expected to be finished around the end of 2013

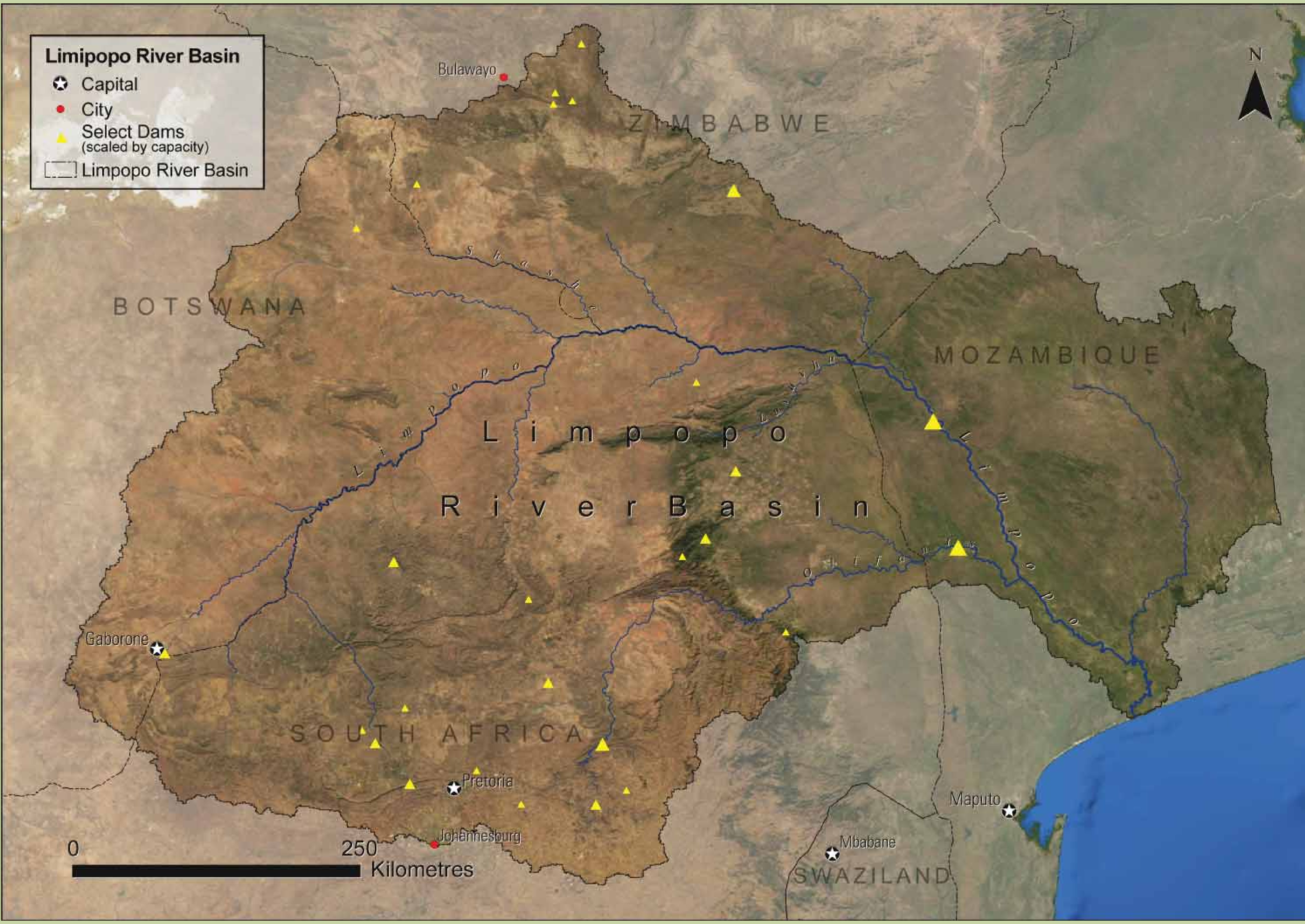
Public discussion of the potential impact of Gibe III

Proponents of the project, including the Ethiopia Electric Power Corporation (EEPCo) and to some degree funding organizations such as the African Development Bank have defended the project and its importance for development in Ethiopia. Several opponents have raised concerns about the dam's impact on the environment generally and on downstream communities in particular. These critics say that the Environmental and Social Impact Assessments (ESIA) produced to justify the project were inadequate and missed several key concerns (IR 2009). They cite several likely impacts including reduced inflow to Lake Turkana, risk of earthquakes and changes in the flow pattern that would prevent traditional recession agriculture and destroy riverine forests (ARWG 2009). The project's advocates defend the ESIA studies and point out the importance of electricity for development in Ethiopia. They assert that managing the flooding patterns will allow recession agriculture to continue and flooding will maintain many natural ecosystem functions (EEPCo 2009). Preliminary results from a study of the basin's water balance has found that the planned Gibe III Dam project is not likely to have a significant impact on lake levels once the initial filling phase is complete. This assumes that hydropower generation remains the principal purpose (as is currently planned), with minimal water diversion for irrigation.

Limpopo
River Basin



The Limpopo River's largely semi-arid catchment receives most of its rains in a short, intense rainy season during the austral summer (December – February). The rains vary considerably within and between seasons making the basin susceptible to severe drought and flood events.



The streamflow of the Limpopo is variable making irrigation unreliable

The Limpopo River's flow is variable, often making irrigation directly from streamflow (without any form of impoundment) unreliable (CGIAR 2003). Because the basin has a large rural population, many of whom practice rain-fed subsistence agriculture, this variability can be disastrous (Reasons and others 2005). Many areas also have very high sediment loads, which discourages the construction of dams and irrigation schemes that would quickly fill with silt (CGIAR 2003).

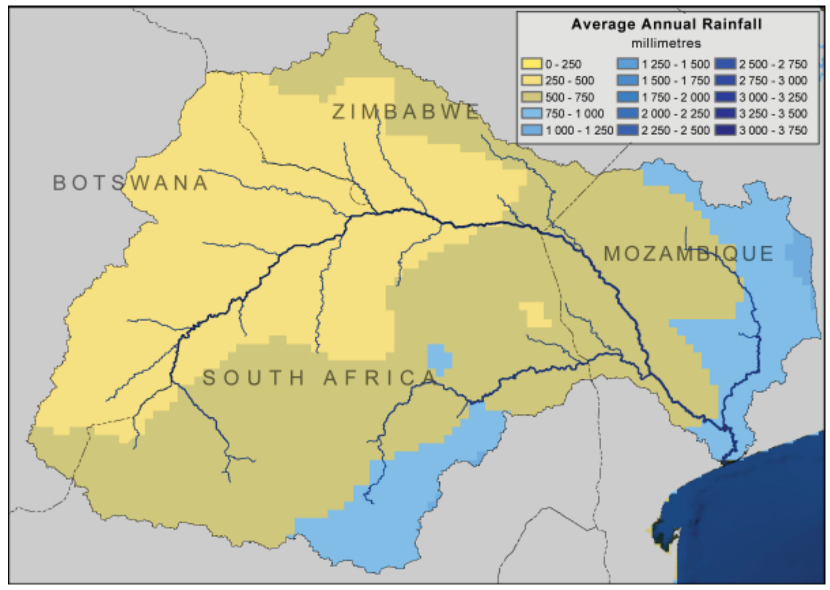


Figure 2.6.1 Limpopo River Basin average annual rainfall

Precipitation

The mean annual precipitation across most of the basin's northwestern half is below 500 mm/yr. The mean annual rainfall in Botswana's fifth of the basin is only 422 mm, while in Zimbabwe rainfall is just slightly higher at 469 mm. While parts of the basin's southeastern half also have somewhat limited rainfall, South Africa's mean annual precipitation is nearly 600 mm and Mozambique's is 729 mm, generally ample rain on an annual basis (Figure 2.6.1). The headwaters of the Limpopo's most significant tributaries, the Olifants and Crocodile Rivers, are in South Africa along the basin's southern edge and generally receive annual rains of 700 mm or more.

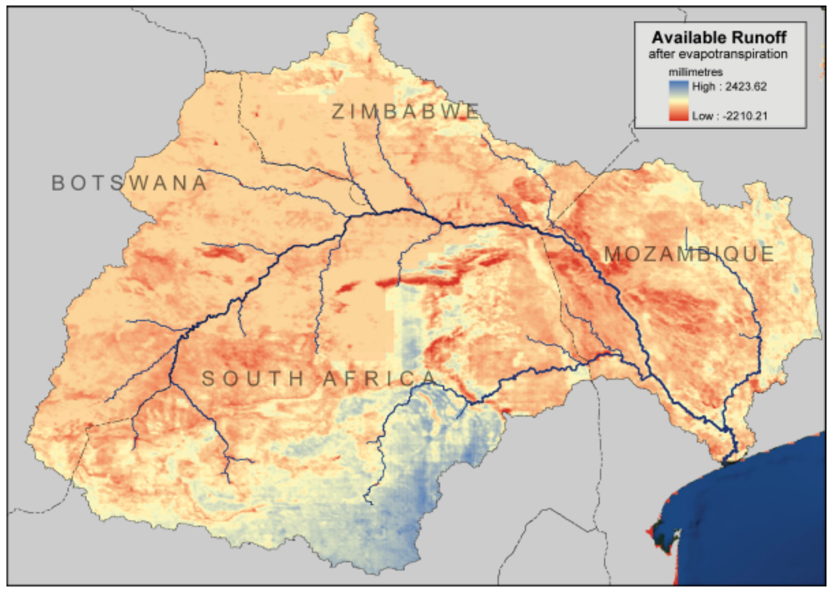


Figure 2.6.2 Limpopo River Basin modeled available runoff

Rainwater runoff in most of the basin is lost to high rates of evapotranspiration and make little contribution to the river's water budget. Botswana receives almost 15 per cent of the basin's rainfall, but because of the arid environment it is all lost to evaporation and transpiration (Figure 2.6.2). Mozambique receives over one-quarter of the basin's precipitation but also has a negative impact on the water budget because of losses to evapotranspiration. Some of Mozambique's highest rates of water loss are through transpiration occuring in the wetlands along the river's course through Mozambique. By far the largest contribution to the river's flow comes from the Crocodile and Olifants catchments in the higher-rainfall areas to the northeast and northwest of Pretoria.

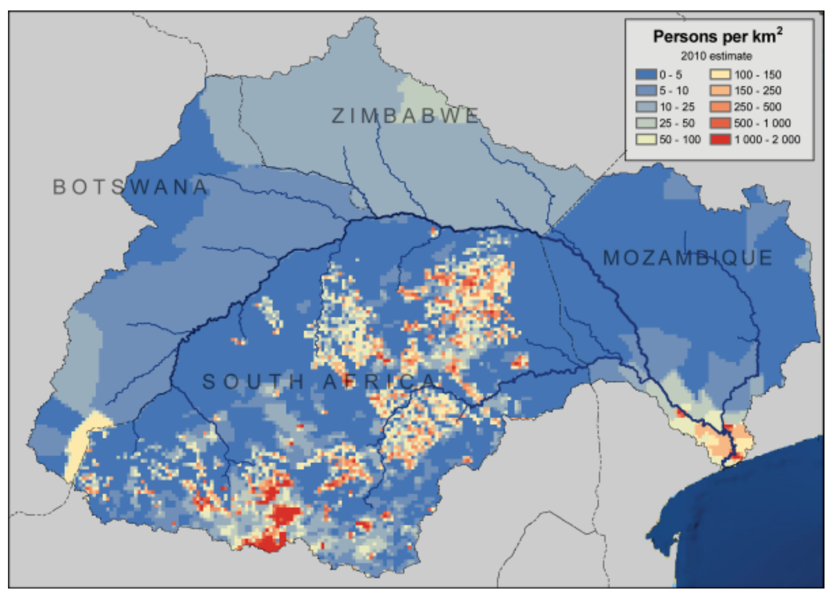


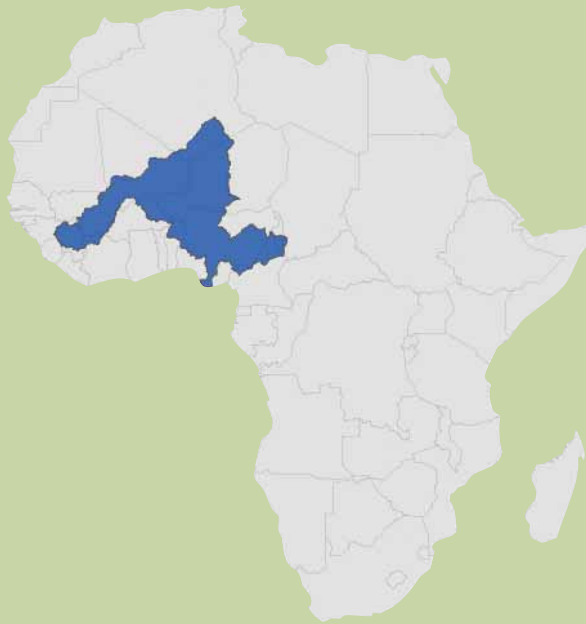
Figure 2.6.3 Limpopo River Basin population density

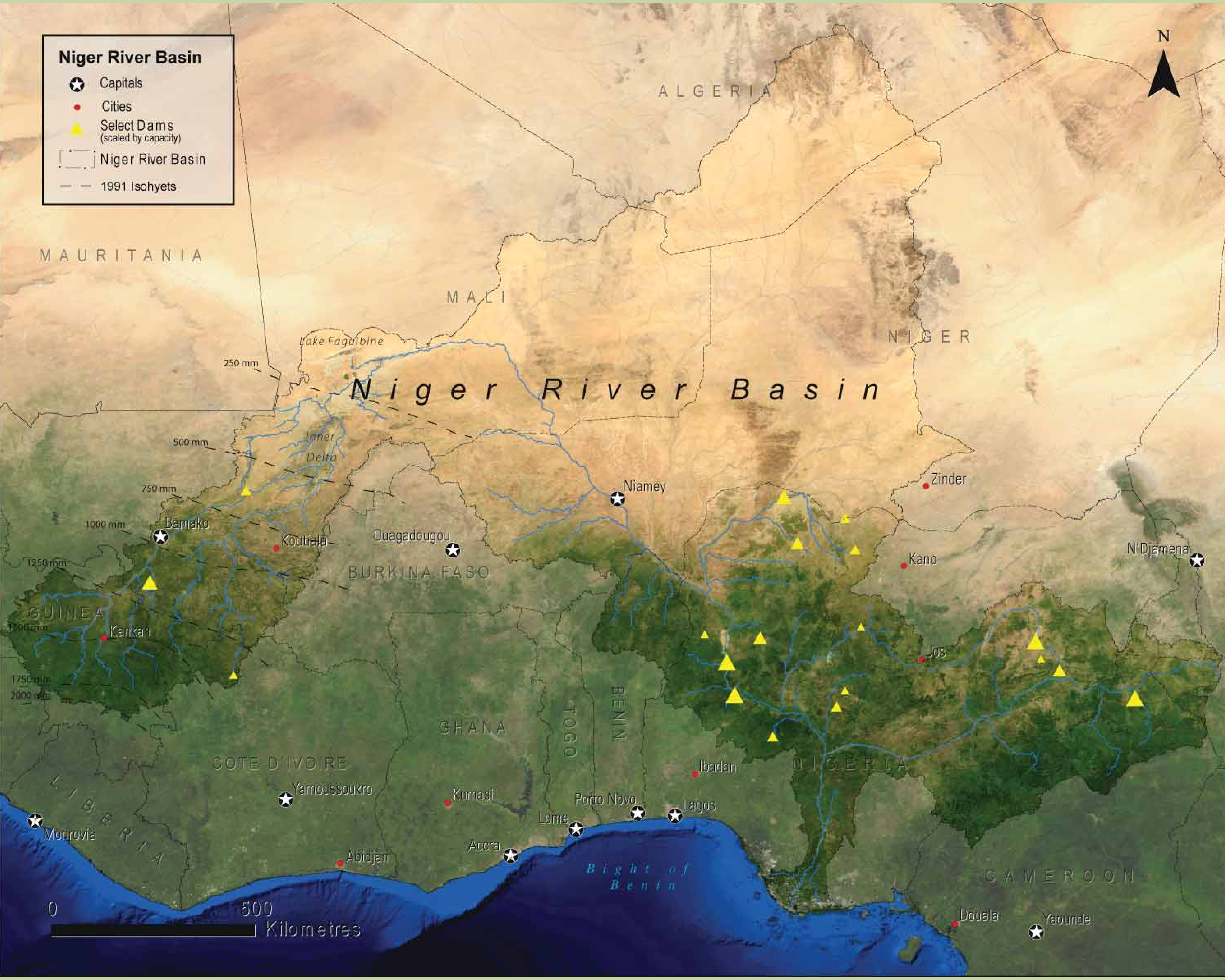
Population

Almost 80 per cent of the basin's over 15 million people live in the South African portion of the catchment, which includes Pretoria and much of Gauteng Province. Botswana, Mozambique and Zimbabwe each have roughly one million people living within the basin. Overall, the basin's population is around 60 per cent rural (CGIAR 2003). Growth rates were slower from 2005 to 2010 than in the previous decade for all of the countries sharing the basin (World Development Indicators 2010).

Niger
River Basin

The Niger River begins in the Fouta Djallon highlands in eastern Guinea and in the extreme north-western corner of Côte d'Ivoire. At 1 635 mm/yr in Guinea and 1 466 mm/yr in Côte d'Ivoire, the mean annual precipitation is the heaviest in the basin (FAO 1997).





The Niger River sustains an island of vegetation and life in the harsh Sahel

As it flows northeast, the Niger River passes through the Inner Niger Delta in Mali where it sustains an island of vegetation and life in the harsh Sahel with its life giving water and seasonal flooding. Flowing further northward, it then passes through the southern edges of the Sahara Desert. Roughly 100 km northwest of Gao, Mali, the river turns to the south, toward Niger, Nigeria and eventually the Gulf of Guinea. The river has collected the flow of ten tributaries before it reaches Nigeria but arrives there with less water then when it left Guinea almost 2 000 km upstream (FAO 1997). Through Nigeria, rainfall increases from north-to-south as the river approaches the Niger Delta where it empties into the Gulf of Guinea.

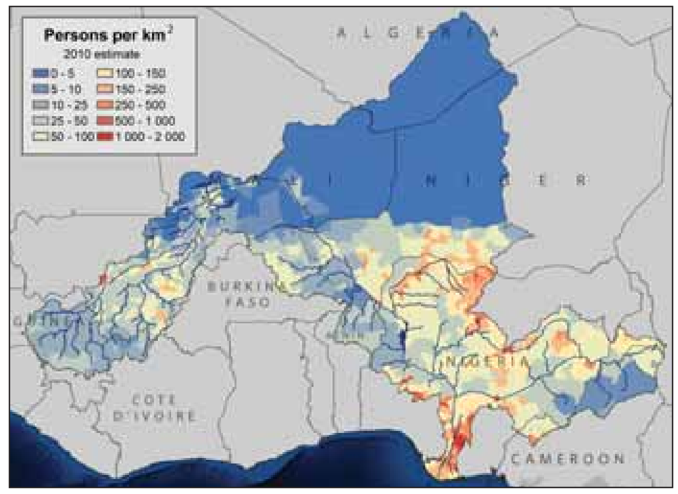


Figure 2.7.1 Niger Basin population density

Population

The Niger Basin's total population is approximately 100 million, with a growth rate of around three per cent. Of this population, 67 million people live in Nigeria, just less than eight million in Mali and just over eight million in Niger (Anderson and others 2005) (Figure 2.7.1). There has been a rapid rate in urbanization throughout most of West Africa since the 1950s (AFD n.d.). Several of the resulting urban agglomerations fall within the Niger Basin, some of them located on the banks of the river, such as Niamey and Bamako. Access to improved water sources is an issue throughout most of the basin and projected population growth for the next few decades will increase the need.

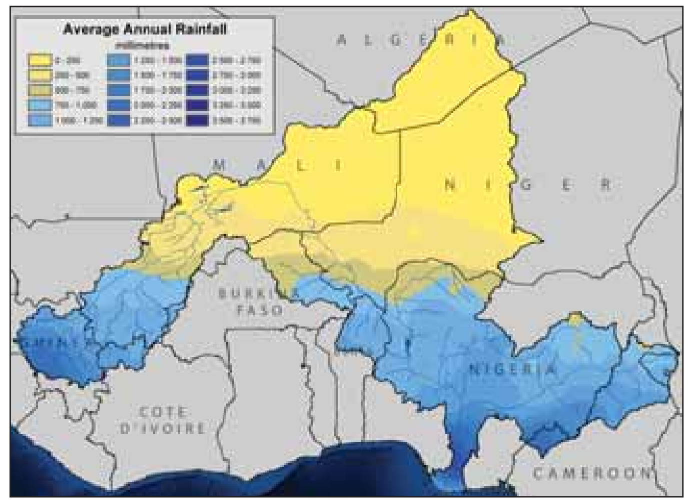


Figure 2.7.2 Niger Basin average annual rainfall

Precipitation

Guinea makes up less than five per cent of the basin by area but it contributes nearly one-third of the basin's water balance and almost all of the flow in the river's upper and middle reaches. Mali makes up nearly a quarter of the basin but because of its high average temperature and mean annual rainfall of only around 400 mm, it uses more water than it contributes to the river, much of it through evapotranspiration from the Inner Niger Delta. Niger and Nigeria each account for roughly a quarter of the basin's area. Niger's part of the basin receives an average of less than 300 mm/yr of rain and provides little runoff to the river. Nigeria's average rainfall within the basin approaches 1 200 mm and increases to over 2 000 mm near the coast (Figure 2.7.2, Figure 2.7.3).

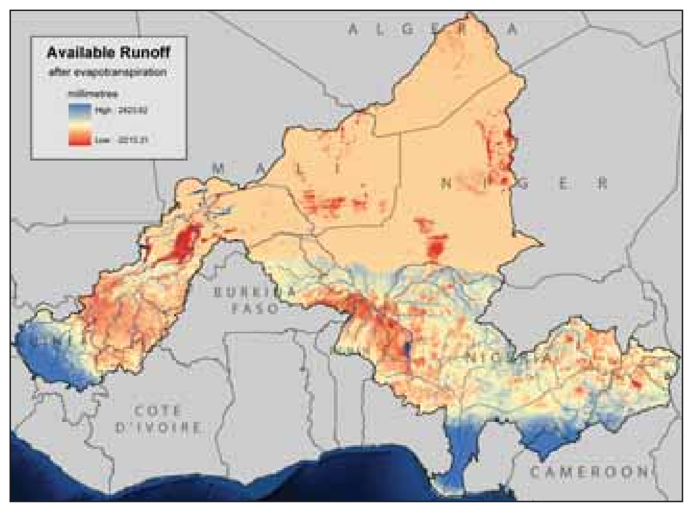


Figure 2.7.3 Niger Basin modeled available runoff

Benoit Rivard/Flickr.com

Water Quality

For the most part, cities along the river have not developed collection and treatment plants for either industrial or domestic wastewater. In addition to urban pollution sources, agricultural runoff, particularly fertilizers, have been found at several sites (Anderson and others 2005). At the coastal delta, oil production has been the source of a host of environmental issues. Millions of barrels of oil have been spilled in the delta's oil producing region.

Groundwater

High-quality aquifers can be found in the middle and lower reaches of the basin, including the Iullemeden Aquifer System, and there are several very good quality aquifers in parts of Nigeria (Anderson and others 2005, Ludec and others 2001, OSS 2008). Studies of recharge rates and resource mapping have been carried out in some areas, but in many cases, they are lacking (Lutz and others 2009). Assessment and sustainable development of groundwater resources will require building systems for mapping and monitoring of resources as well as the institutional capacity to manage resources and enforce policy (BGR n.d.).


Flickr.com

Drought

A period of reduced rainfall across the Sahel began in the early 1970s and continued through the 1990s, with two periods of very severe drought in the early 1970s and early 1980s (L'Hôte and others 2002). Rainfall was more than 30 per cent below average for three consecutive years in the mid-1980s. The Niger River's mean annual discharge declined to less than one-third of its average flow at some gauging stations (Anderson and others 2005) decreasing at almost twice the rate of the drop in rainfall during the 1970-2000 period (Descroix and others 2009, Andersen and others 2005, Lebel and others 2003). Paradoxically, as the rainfall decreased, changes in the land surface appear to have increased the rate of groundwater recharge, raising the water table in several areas of the Niger Basin. This is likely due to increased runoff caused by loss of surface vegetation and changes in land use. This rise in runoff is believed to have increased the number of ponds as well as their size and duration leading to increased infiltration (Descroix and others 2009).

The Sahelian droughts of the 1970s and 1980s spanned the Niger Basin (Nicholson 1983) causing famine, forcing dislocation of people and destroying livelihoods. Droughts are not uncommon in the Sahel and as already discussed on page 49, recent evidence suggests that much more severe droughts occurred as recently as 200 to 300 years ago with a pattern of similar droughts extending back at least a few thousand years (Shanahan and others 2009). It is becoming widely accepted that variations in sea-surface temperatures in the Atlantic and Indian Oceans are linked to these changes in rainfall patterns over Western Africa (Shanahan and others 2009, Zhang and Delworth 2006, Giannini and others 2003). It is not certain what impact global warming would have on future precipitation in the Niger Basin. Studies suggest possible scenarios of negative and positive impact but do not make predictions (Zhang and Delworth 2005, Giannini and others 2003).

Dams and development projects

Many opportunities for investment and development in the Niger Basin are dependent upon developing and managing sustainable water projects, including hydropower, irrigation and flood management (Anderson and others 2005). Existing dams in the Niger Basin in Mali (Sélingué Dam) and Nigeria (Kanji, Jebba and Shiroro Dams) provide large-scale hydropower for their respective countries (Mbendi n.d.). Further dams are planned, including Tossaye Dam in Mali, (under construction) and Kandadji Dam in Niger (funded but not yet begun) (Figure 2.7.4). Irrigation is minimal in Guinea where successful rain-fed agriculture is predominant. In Mali, Sélingué Dam and two diversion dams—Sotuba and Markala —can provide water for 114 000 ha of irrigated crops

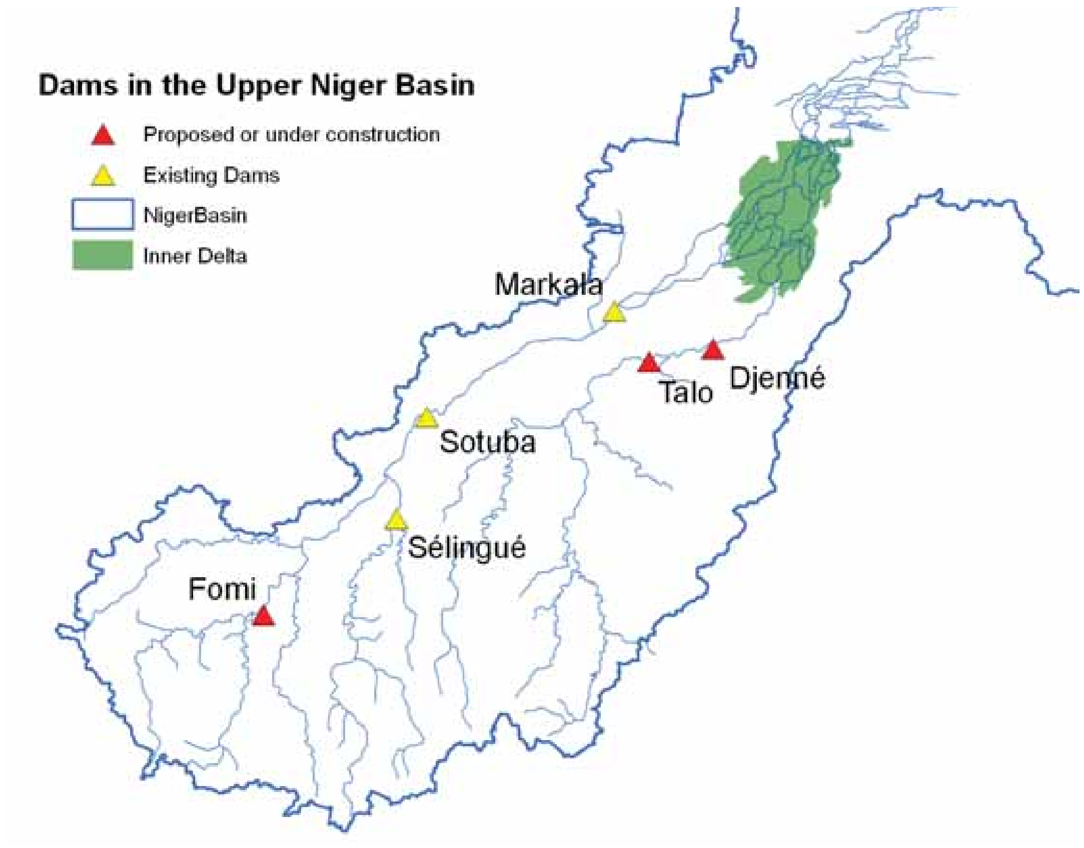


Figure 2.7.4: Dams in the Upper Niger Basin (Source: Zwarts and others 2005)

(FAO 1997). Only a fraction of the area equipped for irrigation in Mali is cropped (Zwart and Leclert 2009), and the ample availability of water in recent years has led to poor infrastructure maintenance (Vandersypen and others 2009). The construction of Tossaye Dam in Mali will bring 150 GWh/yr of hydropower capacity as well as irrigation to an additional 8 300 ha of land (Zwarts and others 2005) (Figure 2.7.4). In Niger, the Kandadji Dam, which has been under study for three decades is moving forward. It will increase the country's electricity supply by as much as 50 per cent, provide drinking water for Niamey and enable an irrigation scheme of 6 000 ha (AfDB 2008). Among the dam's negative impacts are the relocation of approximately 35 000 people living in the project area and the loss of around 7 000 ha of agricultural land that the reservoir would flood (UNEP 2007). The dam's potential effects, however, were identified early in the project's planning, allowing mitigation measures to be drawn up in subsequent phases of the planning process (UNEP 2007).

Fomi Dam

Other dams are under study for the Niger Basin including one in northeastern Guinea on the Niandan River, an important tributary of the Niger River. The proposed Fomi Dam (Figure 2.7.4) would have 2.9 times the storage volume of Sélingué Dam, currently the largest dam above the Inner Niger Delta. Cost-benefit analysis of the existing Sélingué Dam found that significant costs, which included the loss of grazing and agricultural land and some change in downstream flow, were balanced by many positive benefits. Among them were a productive fishery, some irrigation, new avian habitat, and a stable electricity production. The same study found that the Fomi Dam was likely to have a greater negative impact downstream and that if Fomi was operated on a similar basis as Sélingué, its impact on flow would be proportional to its larger storage volume—or roughly three times as much impact on flow. It is estimated that this loss of flow would reduce rice production on the Inner Delta by 34 500 tonnes, 40 per cent of the current average production (Zwarts and others 2005). The analysis found that in addition to an unfavorable overall cost-benefit ratio, the benefits would disproportionately accrue to the upstream stakeholders while more of the costs would fall upon downstream ones (Zwarts 2005b).

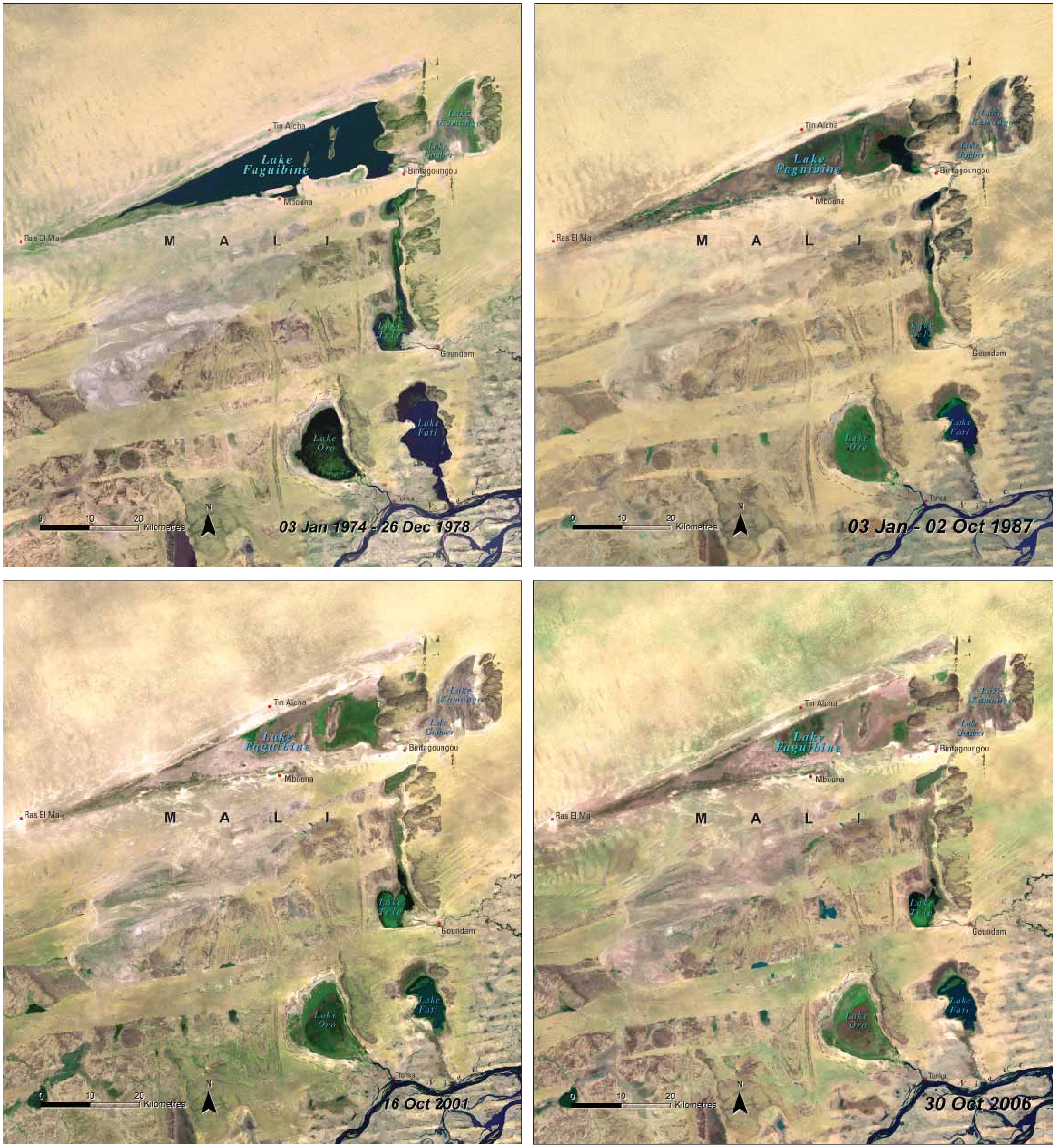


Figure 2.7.5 After drying up in the 1990s Lake Faguibine has not refilled significantly, however some pooling has occurred during wet years. Work is underway to clear debris from channels that feed the lake

Lake Faguibine

Lake Faguibine is located in the Sahelian sub-desert zone to the west of Timbuktu in northern Mali. Annual precipitation in the Faguibine area is in the range of 250 mm/yr, with the rainy season beginning in mid-June and lasting three to four months. When Lake Faguibine is full, as it was in the 1970s satellite image (Figure 2.7.5), it is among the largest lakes in West Africa, covering approximately 590 km^2 (Duvail and Hamerlynck 2009). During the great droughts of the 1970s and 1980s, Faguibine began declining and in the 1990s it dried up completely. With the lake all but gone, many local livelihoods also dried up including agriculture, fishing, and dry-season grazing (Duvail and Hamerlynck 2009).

The sparse rainfall is not enough to support rain-fed agriculture and cannot fill the lake without inflow from distant parts of the Niger Basin where the rainfall is heavier. The lake receives most of its water through two channels that carry water from the Niger River when its levels are high enough (CNEARC 2004). Despite some better rainfall years since the great droughts (Descroix and others 2009), Lake Faguibine has not significantly refilled, only forming

a small pond for a few years during the wet seasons since the 1990s. The 2010 wet season satellite image shows a pool of about 35 km² (six per cent of the 1974 surface area).

During the extended droughts of the 1970s and 1980s, the channels that carry water between the Niger and Lake Faguibine had become clogged with sand and vegetation (UNEP n.d., BBC 2009). The government of Mali has been working to clear the channels and recently received a commitment of US$15 million from the United Nations Environment Programme to help support that work. A government official working with the project says that conditions are already improving with a dramatic increase in farming around the lake between 2006 and 2010 (BBC 2009).

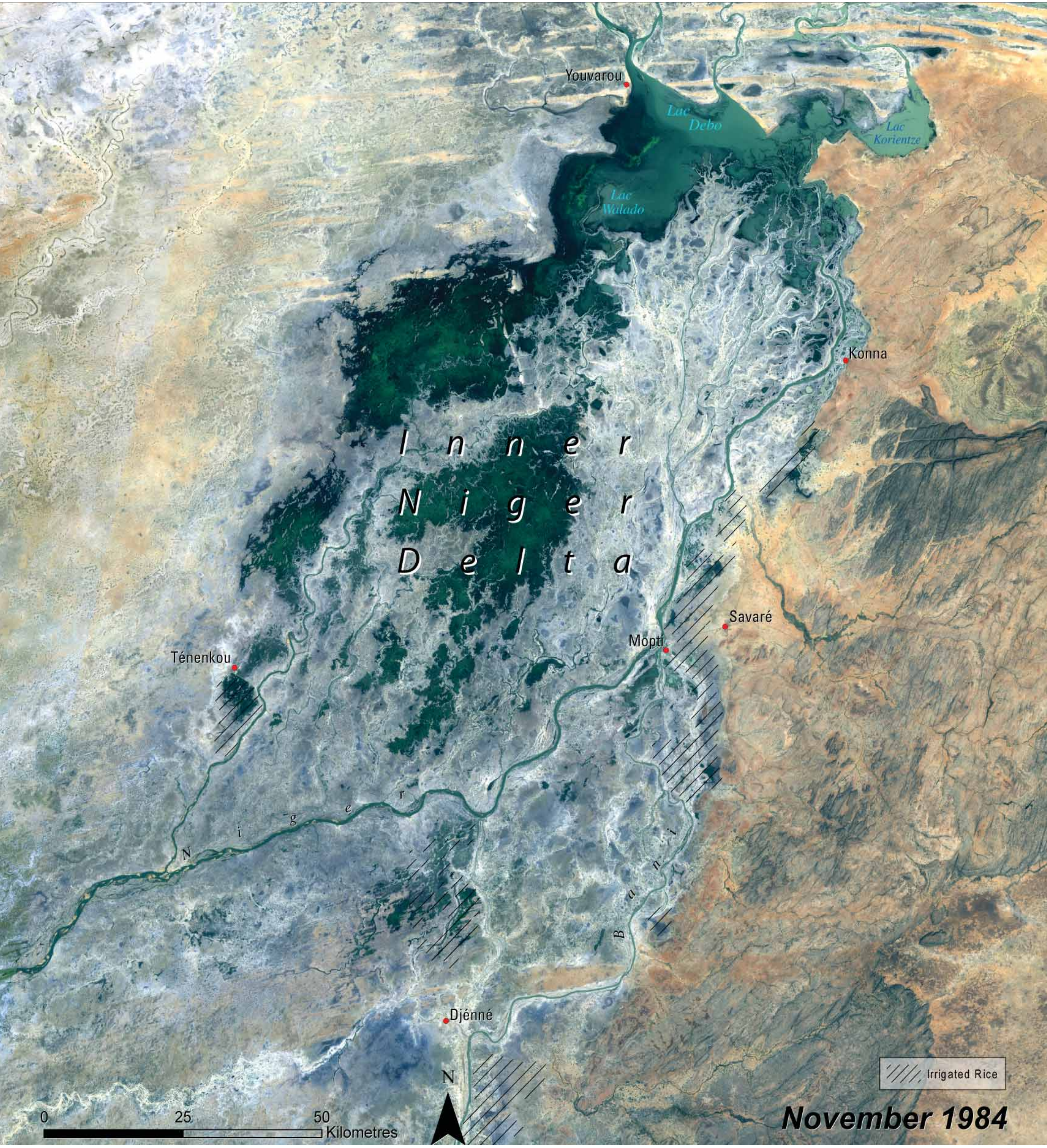


Figure 2.7.6: The Inland Niger Delta's annual floods were dramatically reduced during the great droughts of the 1970s and 1980s. In 2009, precipitation and flooding were more normal

Inner Niger Delta

The Inner Niger Delta lies roughly 400 km northeast of Bamako, Mali where the Niger River divides into innumerable channels and is met by the Bani River. It is the largest wetland in Western Africa (Ramsar 2004) spreading out along a very flat 200-km reach of the Niger River as it passes through the Sahel on its way north to the southern edges of the Sahara Desert. The Inner Delta is crucial to Mali's economy, its people and its natural environment. The delta supports about one million people, and a variety of ecosystem goods

and services, including a productive fishery, pasture for sheep and cattle, land and water for agriculture and habitat for natural flora and fauna. These attributes have earned it the designation as a Wetland of International Importance by the Ramsar Convention (Ramsar 2010).

The delta's water budget is complex and includes a significant groundwater component, which causes prolonged dry periods to extend beyond the resumption of more normal precipitation until groundwater levels have rebounded. In addition, as much as 48 per cent of the delta's water is lost to evaporation (Mahe 2009). Flooding of the delta is dependant on rainfall over the upper reaches of the Niger River in the Guinean Highlands and to a lesser extent in the Bani in northern Côte d'Ivoire while rainfall over the delta

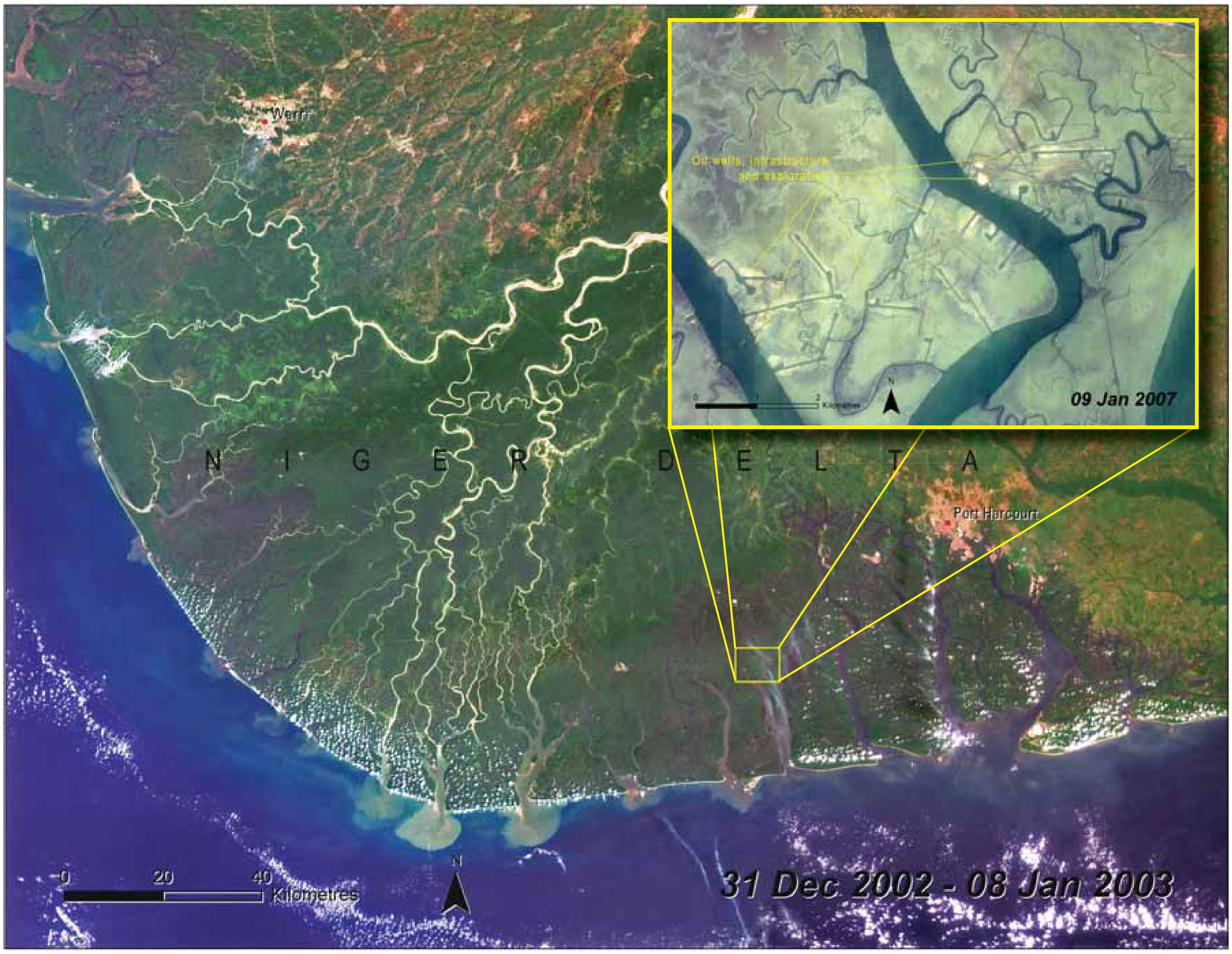


Figure 2.7.7: Oil wells and pipelines can be seen across much of the delta and spills here are a common occurrence

contributes only five to ten per cent of its water (Mahe 2009, Zwarts 2005). During the droughts of the 1970s and 1980s, flooding of the Inner Delta declined dramatically as can be seen in the pair of satellite images from the late-wet seasons of 1984 and 2009 (Figure 2.7.6, previous page). The 1984 image was taken during the prolonged drought while the 2009 image follows a more normal precipitation year.

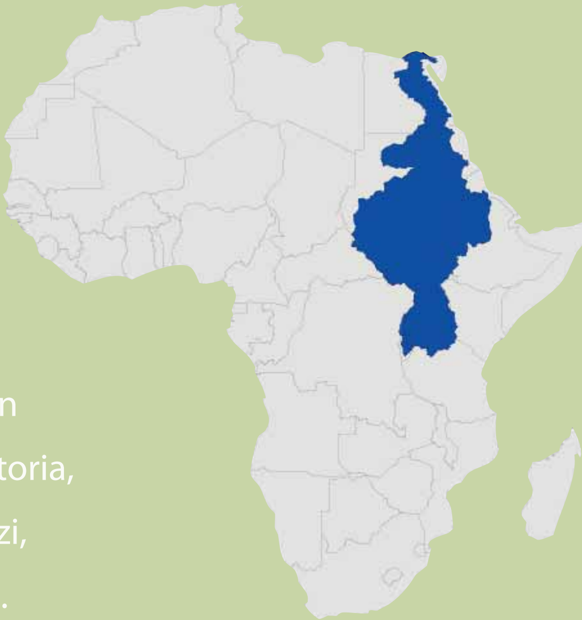
Niger Coastal Delta

The Niger Marine Delta (Figure 2.7.7) has formed over millions of years where the Niger River discharges into the Gulf of Guinea. The delta is home to approximately 31 million people (Amnesty International 2006). The delta is also widely recognized as an important natural

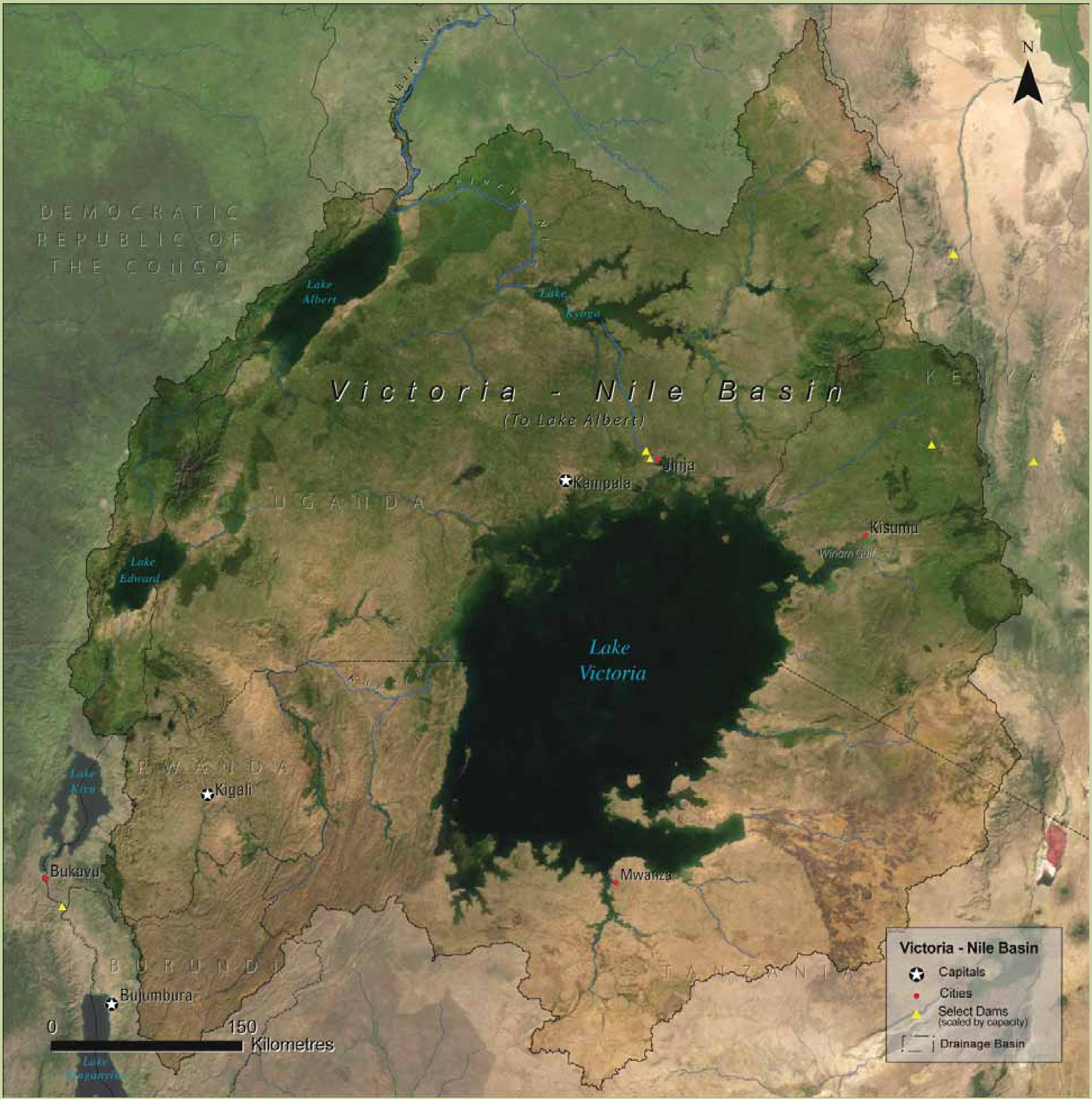
system supporting an array of plant and animal biodiversity—particularly in the delta's 20 000 km^2 of mangrove forests (IUCN n.d.). The delta's people, and the natural systems many of them rely on, co-exist with the vast majority of Nigeria's 896 oil and gas wells (NNPC 2009) and the associated storage facilities, refineries and thousands of kilometres of pipelines (IUCN n.d.). Thousands of oil spills, totaling over three million barrels of oil (Yo-Essien 2005) and wastewater from oil production (Ajao and Anurigwo 2002, Adedeji and Ako 2009) are among the primary causes of a serious decline in water quality in the delta region. Flaring of natural gas, which results in acid rain, is also a contributing factor.

Surface runoff from agricultural land and increased use of agricultural chemicals is also a significant problem (Adedeji and Ako 2009). Other key contributors are disposal of untreated sewage and effluents from domestic and industrial sources and poorly designed sanitary landfills (Ajao and Anurigwo 2002).

Nile
River Basin



The Nile begins its 6 800-km journey to the sea 1 600 m above sea level in northern Burundi. The Kagera is one of many rivers flowing into Lake Victoria, which include the Mara, Nzoia, Katonga, Kagera, Yala, Isanga, Sondu, Ruizi, Kibos, Simiyu and Sio; only one river flows out, however, the Victoria Nile.




Al-Iskandariyah
Al-Qahirah
Al-Jizah
Al-Uqsur
EGYPT
LIBYA
Nile
administrative boundary
Red Sea
Nile River Basin
(from Lake Albert to the delta)
Atbarah
CHAD
SUDAN
ERITREA
Al-Khartum
Asmera
Atbarah
Blue Nile
White Nile
Addis Ababa
ETHIOPIA
CENTRAL AFRICAN REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
KENYA
0
500
Kilometres
N
Nile River Basin
middle and lower
Capitals
Cities
Select Dams
(scaled by capacity)
Nile Drainage Basin

The catchments of most of the inflowing rivers have dense rural populations where much of the land is used for subsistence agriculture. Outflow is controlled by the Nalubaale and Kiira Dams at Owens Falls, eight kilometres downstream from the Victoria shoreline. After leaving the lake, the river flows through Lake Kyoga, a shallow wetland complex that is an important fishery for Uganda (ILEC n.d.), then east to Lake Albert, which also collects inflow from the Semliki River. Flowing north across the Uganda-Sudan border, the river splits into two channels—the Bahr al-Jabal and the Bahr az-Zaraf. Flowing across broad flat plains, the rivers expand into a vast wetland, the Sudd Swamp. Covering around 8 000 km^2 during the dry season, the swamp seasonally overflows, flooding an area many times this size (Ahmad 2008). The vast surface area, heavy vegetation and high temperatures of the Sudd lead to the loss of roughly half the total White Nile's inflow through evaporation and transpiration (Sutcliffe and Petersen 2007). The remaining outflow moves north where it meets the Blue Nile, 500 km downstream at Khartoum.

The Blue Nile originates at Lake Tana, 1 800 m above sea level in the Ethiopian Highlands, where average annual rainfall is high and evaporation and transpiration are relatively low. It gathers more than 20 tributaries between Lake Tana and Khartoum, including the Rahad, Didessa, Dabus and Dinder Rivers (Sutcliffe and Petersen 2007). By the time it reaches the Roseires Dam 80 km into Sudan, it begins to lose more water to evaporation and transpiration than it receives in rainfall; nevertheless, it has collected enough water to provide around 65 per cent of the Nile's flow at Khartoum where it joins the White Nile. Additional inflow from the Ethiopian Highlands comes through the Atbara River, which enters the Nile 300 km downstream.

From this point on, the combined effect of large and small irrigation schemes, increased temperatures and diminishing rainfall cause the river to lose more water than it receives. In northern Sudan, the Merowe Dam forms an artificial lake that will be 174-km long when full (Hildyard 2008). The Nile in Egypt begins with Lake Nasser, a reservoir created by the Aswan High Dam. One of the largest pumps in the world forces water from Lake Nasser into a channel that transports it onto the Western Desert where Egypt has begun a large irrigation and resettlement project (WaterTech n.d.).

As the Nile flows on from Aswan toward the Mediterranean Sea, it is lined with irrigation canals. Almost all of Egypt's population of 78 million people live along the river and depend heavily on its resources. By the time the river reaches the sea, much of its water has been diverted for irrigation. Along with the water, sediments that have not already been trapped behind the river's many dams are diverted as well. As a consequence, erosion at the delta's margins and subsidence or compaction of the delta's soil is outpacing new deposition, leading the delta to sink and erode (Bohannon 2010).

Almost 78 million people in Egypt depend heavily upon the Nile

Population

The Nile Basin has three of the heaviest population concentrations in Africa; surrounding Lake Victoria in Kenya and Uganda; in the Ethiopian Highlands surrounding the Blue Nile; and along the banks of the Nile in Egypt. While Egypt only accounts for nine per cent of the basin's area, it holds almost one-third of its population. In contrast, almost 64 per cent of the Nile Basin falls in Sudan but a little less than 36 million people, or about half as many as in Egypt, live there (CIESEN 2010). The 35 million Ugandans within the basin live on only 7.6 per cent of the basin's area. Kenya's 1.6 per cent of the basin has a still-higher population density, averaging about 320 people per km^2. Ethiopia has about 35 million people within the Nile basin, but with 363 315 km^2 in area, population density is lower at about 97 people per km^2.

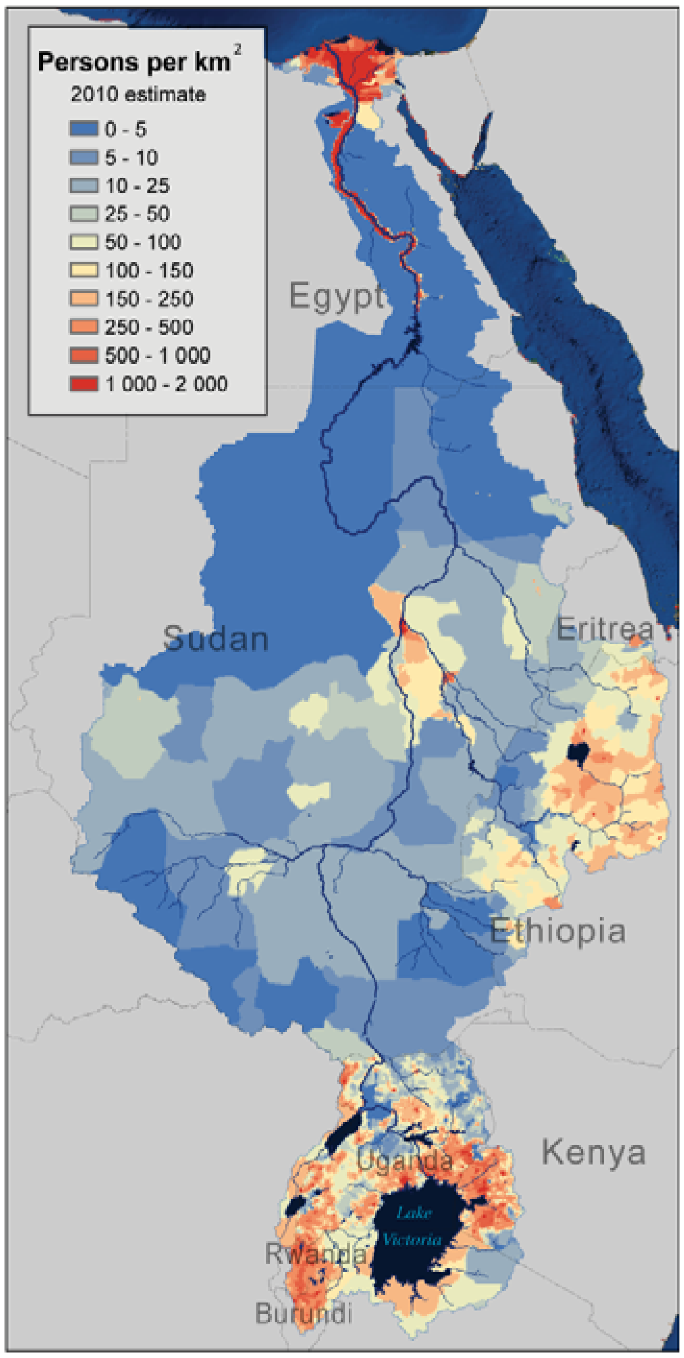


Figure 2.8.1 Nile Basin population density

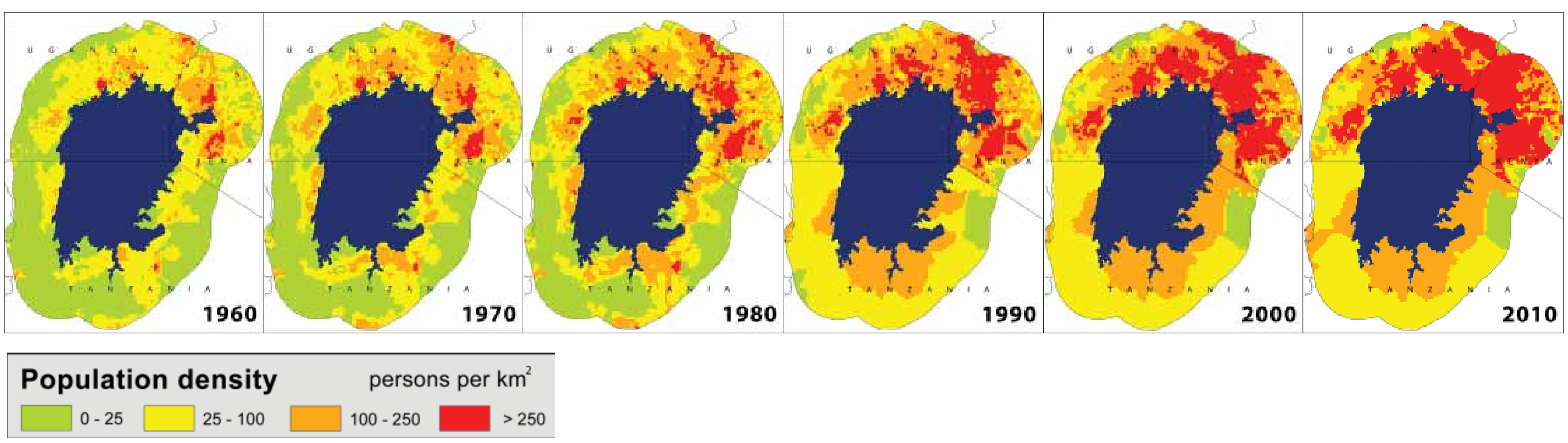
In total, almost 224 million people live within the basin—almost one-quarter of Africa's population. Four of the basin's 11 countries have population growth rates in the top ten globally; all but two are above the mean growth rate for Africa and all are well above the global average (UNESA 2008). While growth rates within the basin are expected to decline, most projections are still well above two per cent per year over the next two decades.

Urban populations are growing rapidly throughout the basin. Burundi is the most rural of any of the basin countries with only 11 per cent of its people in cites, although its urban areas are growing at 6.8 per cent/yr (UNESA 2007). Sudan and Egypt are the most urban of the Nile Basin countries with 45.2 per cent and 42.8 per cent of their respective populations living in cities. By 2030, it is expected that in half of the basin's countries, the majority of their people will live in cities.

The dense population surrounding Lake Victoria has grown faster than Africa's overall population during every decade since 1960. One estimate of the population in 2010 shows over 35 million people living within 100 km of the lake and twice that many people living within Lake Victoria's watershed, which extends across Rwanda, Burundi, Tanzania, Uganda and Kenya (CIESEN 2010)(Figure 2.8.2). The lake's resources are crucial to the livelihoods of many of these people and significant to all of them. The expanding population has led to increased deforestation, land conversion, agriculture, livestock numbers, industrialization, waste disposal and fishing pressure (Lehman 2009). This dense population and consequent changes in the surrounding environment have had a profound impact on the lake and the ecosystems of which it is a part.

With 11 countries and 224 million people sharing the Nile's waters across very different climatic regions, water management, particularly transboundary water management is very complex. In an area characterized by water scarcity and poverty, rapid population growth will likely compound the difficulty for the foreseeable future.

Figure 2.8.2: The dense rural population surrounding Lake Victoria has grown dramatically since 1960 (SEDAC 2010)



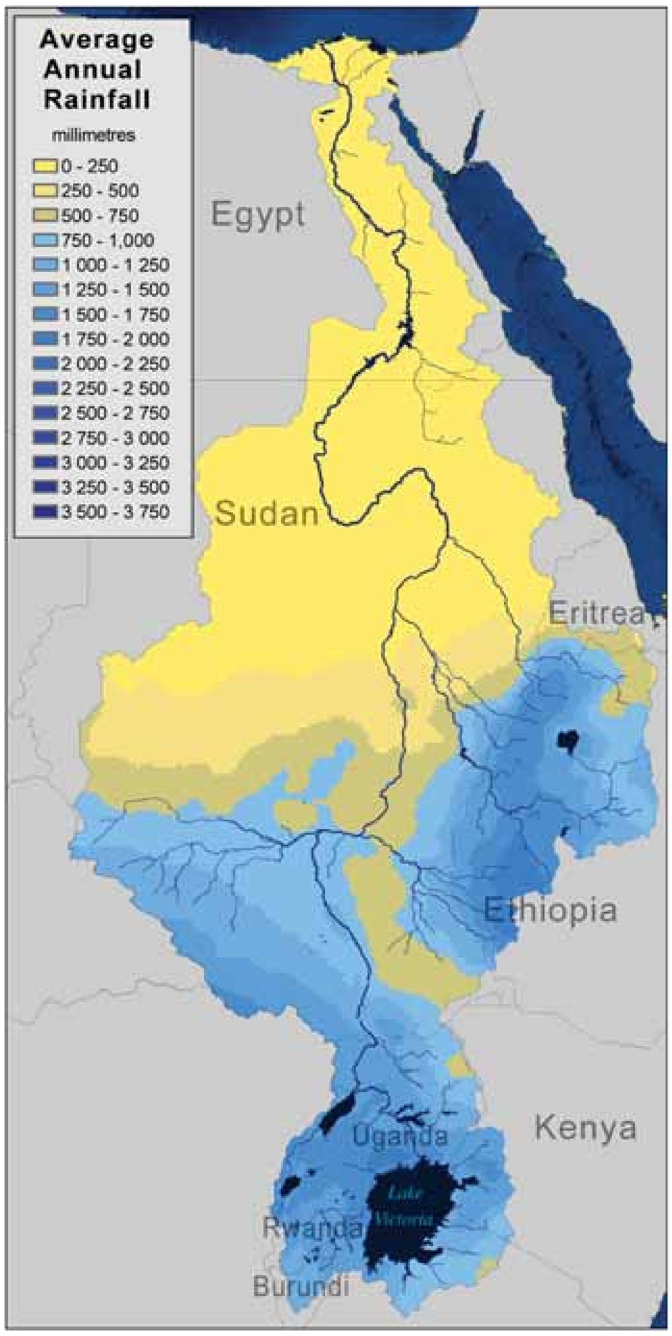


Figure 2.8.3 Nile Basin average annual precipitation

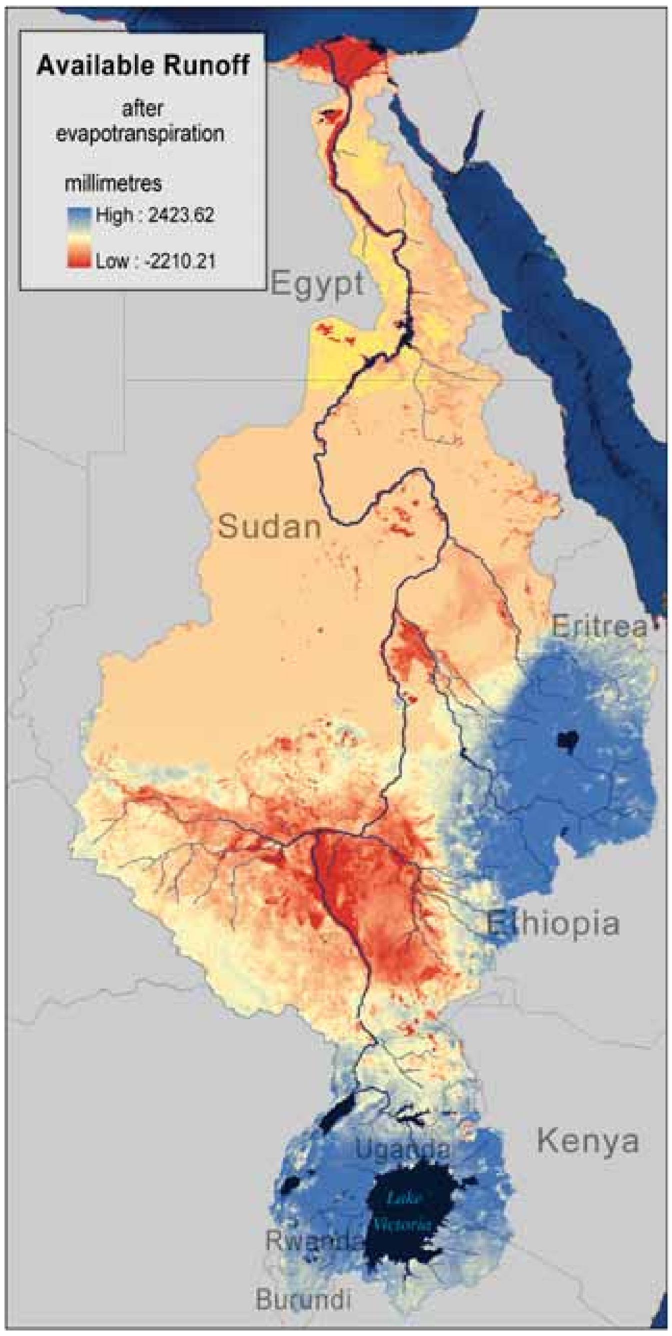


Figure 2.8.4 Nile Basin modeled available runoff

Precipitation and Water Budget

Great extremes in average annual precipitation and evapotranspiration divide the basin's countries into net users of water and net contributors to the water budget, with extremes at both ends of the continuum. Egypt receives an average of around ten mm of rain annually within its part of the basin. In addition, the heat of the desert and the consequence of water transpiration over the vast areas of irrigation make Egypt a net user of water. It relies entirely on water from upstream wetter countries to survive. Sudan is also a net user of water. Although it receives 46 per cent of the basin's total rainfall, high temperatures, irrigation, and the Sudd Swamp create enormous water losses to evapotranspiration.

At the other extreme, Ethiopia receives only 22 per cent of the basin's total rainfall but lower temperatures and evapotranspiration in the highlands allow much of that water to run off. Thus, Ethiopia contributes well over half of the Nile River's total water budget. Uganda, Tanzania and Kenya also contribute significant runoff to the Nile, although much of this water is lost in the Sudd Swamp in southern Sudan before it reaches Khartoum.

Dams, Irrigation and Water Agreements

While the amount of water in the Nile Basin may fluctuate due to climate change and climate variability, it can be safely assumed that water availability will not increase. Since the projected population growth in the basin will be above average, this limited resource must be divided among more and more people. This makes it even more crucial to manage water sustainably, both within and among the basin's countries. Development projects are underway in several of the basin's countries and are being considered in others. They include hydropower dams, irrigation projects, and other water-diversion projects (Figure 2.8.5). All of them have implications for resource use throughout the basin, irrespective of regional and national boundaries.

Regulation of Lake Victoria's outflow at Jinja, Uganda, has a clear effect on the lake's water levels (Kull 2006, Swenson and Wahr 2009, Kiwango and Wolanski 2008, Sutcliffe and Petersen 2007) and less direct impacts on many of the lake's other ecosystem functions (Kiwango and Wolanski 2008, Minakawa and others 2008). These effects are also experienced by Tanzania and Kenya, who share the lake with Uganda, and to a lesser extent by all of the downstream countries in the basin. Deliberations about construction of the Jonglei Canal in southern Sudan continues (Sudan Tribune 2009) in spite of concerns about serious environmental impacts (Howell and others 1988, Krishnamurthy 1980, Laki 1994) on a wetland that is listed as a Ramsar Wetland of International Importance (UN News Centre 2006). The water the canal would save from evaporation and transpiration, however, could be of immense value for agriculture to the downstream communities in Egypt and Sudan. In Egypt, large volumes of water are being diverted onto the desert to irrigate crops and create a new area of settlement and jobs for Egypt's growing population. The demands for water that this will create, however, have very important implications for water development in both upstream and downstream locations.

The literature often predicts that water scarcity will be a future source of conflict between countries that share it. If this is so, the Nile Basin would be a very likely trouble spot with its many riparian countries and unequal distribution of water resources. However, recent scrutiny of the history of disputes over water resources suggests that violent international conflict is rare. Rather, countries are more likely to cooperate in managing shared water resources (Barnaby 2009, Yoffe and others 2003). The formation of the Nile Basin Initiative in 1997 is just the latest of many attempts to work together to manage the Nile's resources across national boundaries; it remains a work in progress (Cascão 2009) as countries continue to review hydropower and irrigation project proposals (IR 2006).

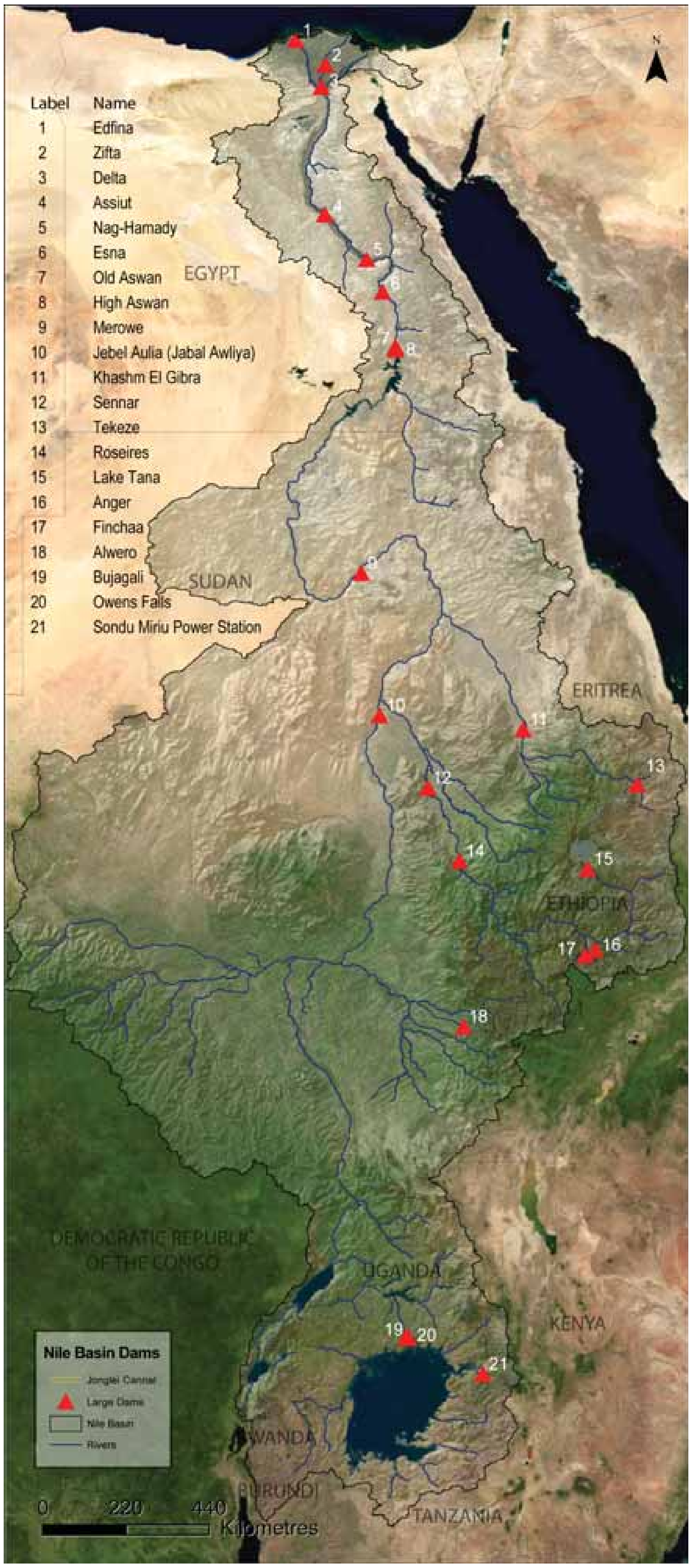


Figure 2.8.5 Dams and Water Projects

Marc de St Pern/Flickr.com

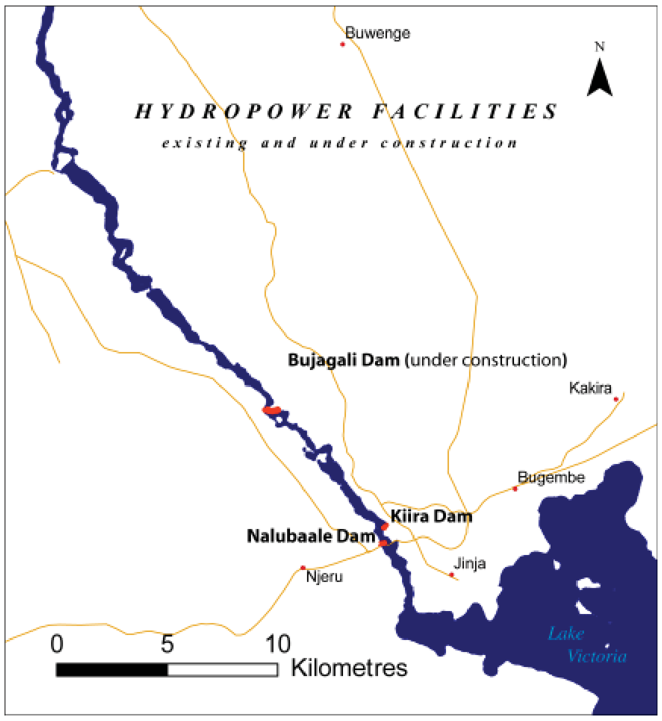


Figure 2.8.6: Hydropower facilities

Figure 2.8.7: Location of the Nalubaale and Kiira dams

Lake Victoria, Owens Falls Dams, and Water Levels

The majority of the input to Lake Victoria's water budget derives from rainfall directly over the lake (82 per cent of inflow) and evaporation (76 per cent of outflow) (Kiwango and Wolanski 2008). The primary inflowing stream is the Kagera River, which enters at the lake's southwest corner. There are several smaller streams that enter along the lake's eastern and southern shores. The only out-flowing stream is the Victoria Nile at Jinja, Uganda. Since 1959, the Nalubaale Dam has controlled the outflow at Jinja (Kull 2006) (Figure 2.8.6).

Water levels in Lake Victoria declined by two metres (GRLM 2010) between the time the Kiira Dam was built at the same location in 1999 until the end of 2006, raising questions about the possible connection with water releases through the dams at Jinja (Kull 2006). Multiple studies have found that as much as half the decline in the lake's level during this time period was due to outflow at the Jinja Dams in excess of rates stipulated in an agreement with Egypt; these rates were designed to maintain the relationship between the outflow and lake levels that existed before the dams were built (Kull 2006, Swenson and Wahr 2009, Kiwango and Wolanski 2008, Sutcliffe and Petersen 2007). A third dam, Bujagali Dam, is now under construction approximately ten kilometres downstream from the existing dams. Assumptions about future water levels are necessary in planning these dams and their current and future operation. Recent scientific investigations have found dramatic and sometimes rapid changes in the lake's level over the past two centuries (Sutcliffe and Peterson 2007, Nicholson and Yin 2000). The future viability of hydropower from the Victoria Nile is generally as uncertain and variable as the climate. The lake's water level may also affect other ecosystem services, such as fisheries, wetlands, invasive species as well as water quality (Kiwango and Wolanski 2008) and malarial mosquito habitat (Minakawa and others 2008).

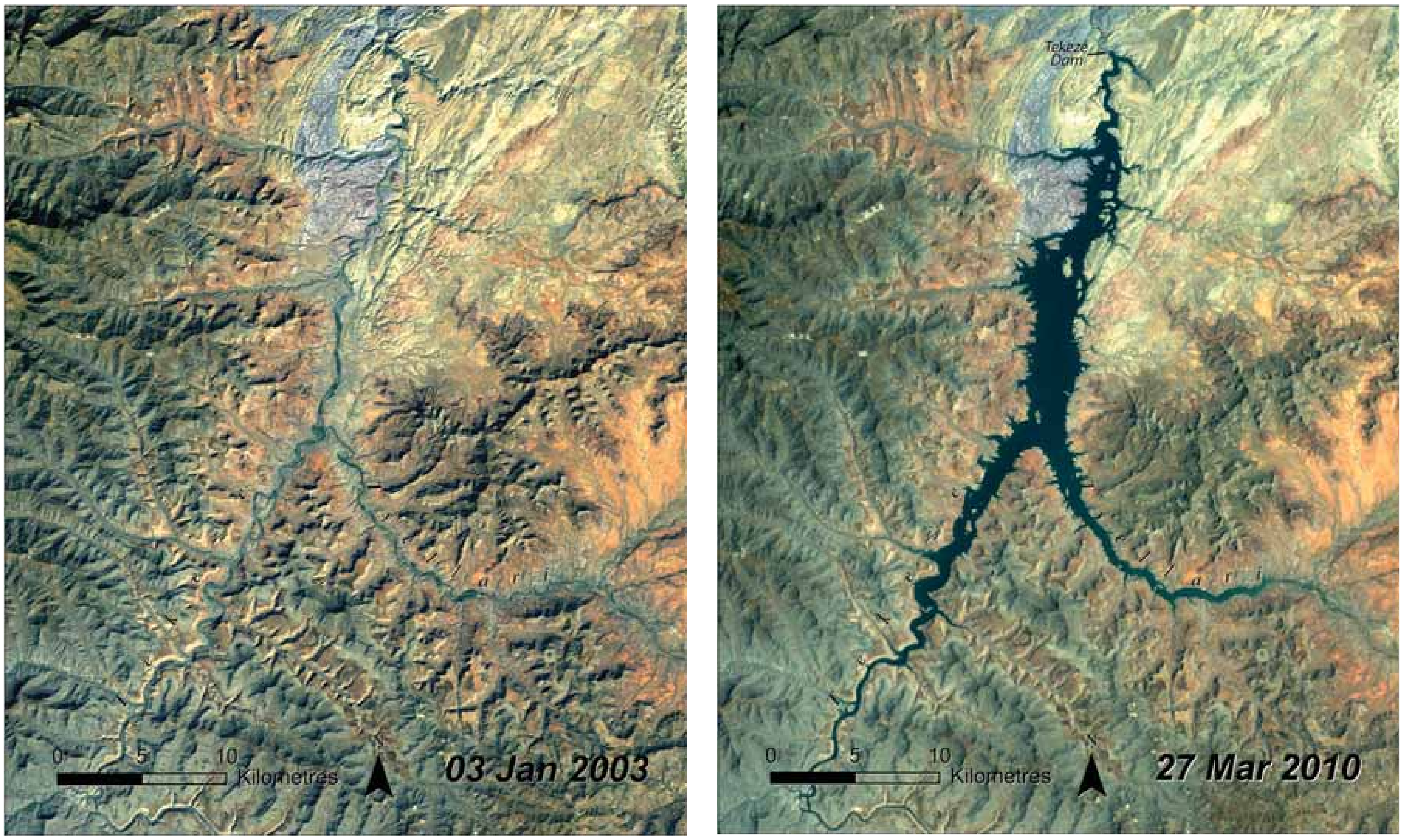


Figure 2.8.8: Tekezê Dam site, before and after the closing of the dam construction

Tekezé Dam in Northern Ethiopia

Tekezé Dam

The Tekezé River in northern Ethiopia is a tributary of the Atabara River, which joins the main course of the Nile 300 km north of Khartoum. In early 2009, a Chinese contractor completed the Tekezé Dam, which rises 188 m from the river bed, at a final cost of around US$365 million. The dam is intended primarily for hydropower generation and is expected to produce 300 MW when fully operational. Undertaken without the endorsement of the nascent Nile Basin Initiative, the Ethiopian Electric Power Corporation (EEEPCo) partnered with the Chinese National Water Resources and Hydropower Engineering Corporation for the project. As with many other large hydropower dams, concerns have been raised about the dam's environmental impacts. In 2008, a large landslide necessitated the addition of massive retaining walls to keep the slopes from eroding, adding an additional US$42 million to the project's cost.

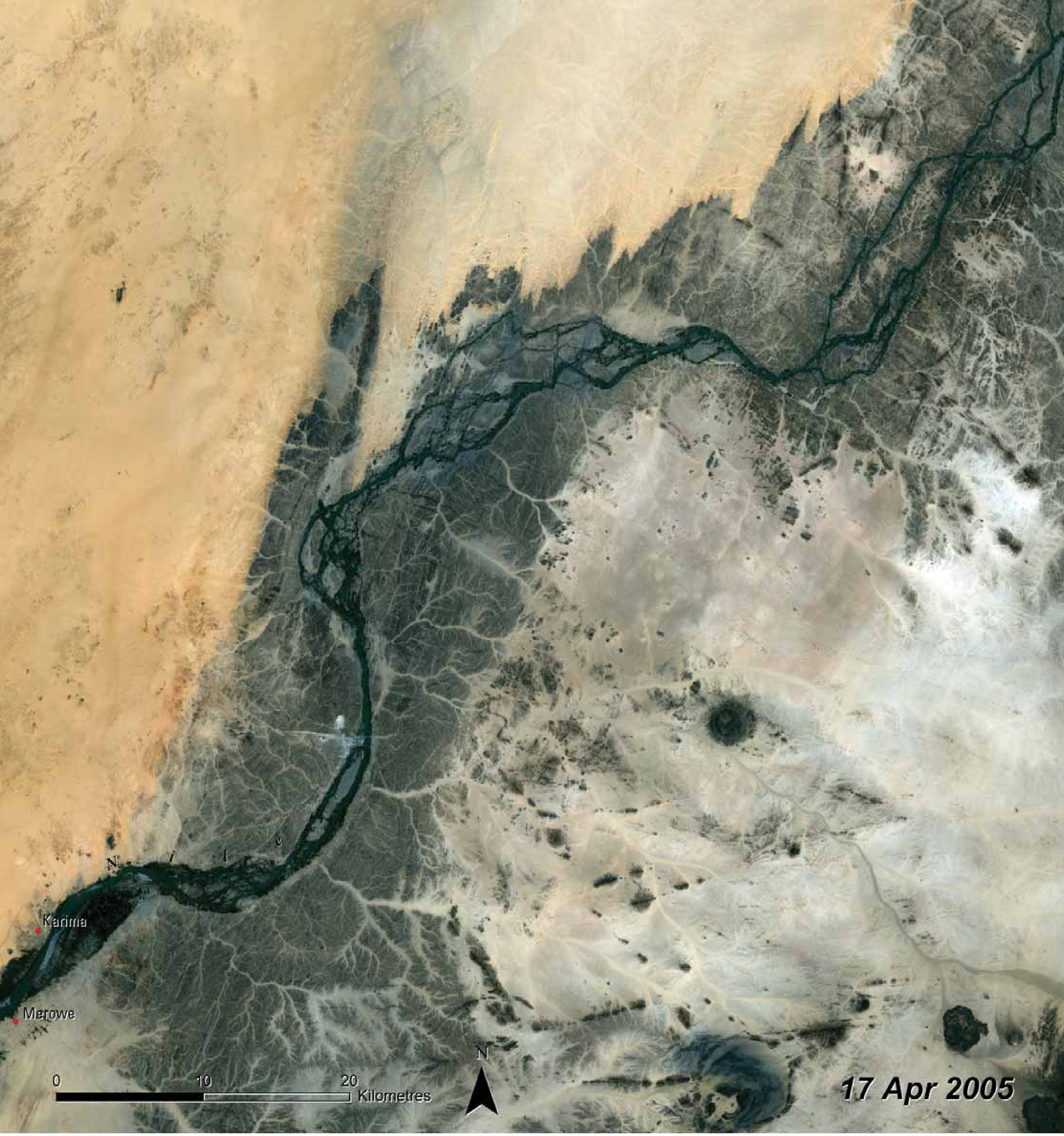
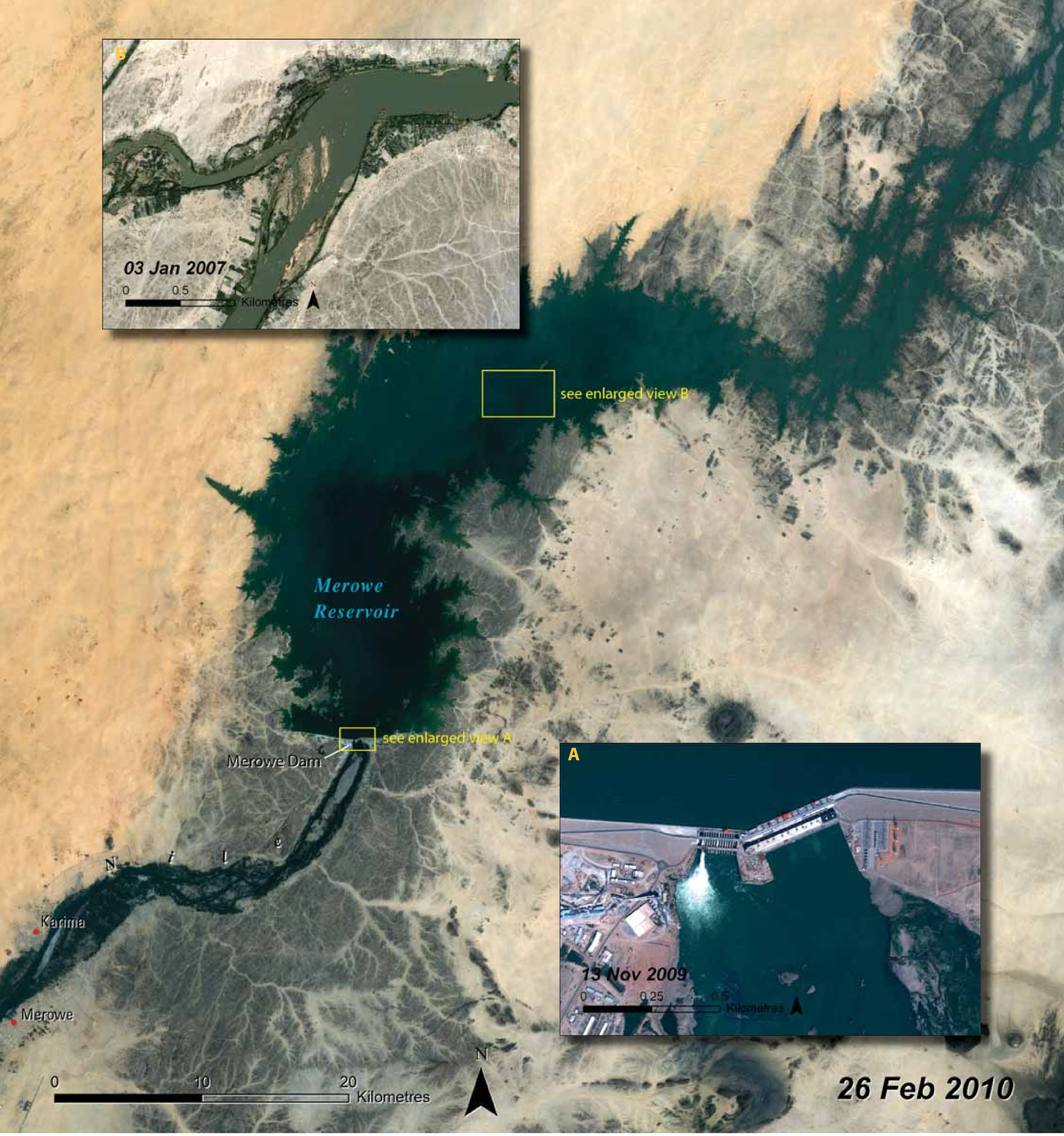


Figure 2.8.9: Merowe Dam on the Nile's fourth cataract was completed in March 2009

Merowe Dam

Merowe dam in north-central Sudan near the Nile's fourth cataract is among Africa's largest hydroelectric projects. When complete, it will generate nearly 6 000 GWh of electricity annually and will have the potential to irrigate around 400 000 ha of crops (Lahmeyer Int n.d.). Even by regional standards, Sudan is in dire need of greater electricity generating and distribution capacity to support much-needed development (Moussa and Bethmann 2007). However, the human, environmental and archeological costs of the Merowe Dam have been substantial and have raised complaints from NGOs and the UN (EAWAG



2006, IR n.d., UN News Centre 2006). It has been reported that when the dam began filling in August 2006 (IR 2006b), it affected 10 000 families forcing tens of thousands of people to relocate their homes and livelihoods (Hildyard 2008). The dam submerged a substantial area of agricultural land, as can be seen in the high resolution satellite image from January 2007 (Inset B, Figure 2.8.9), 18 months before the dam was closed. Like many of the Nile Basin countries, Sudan has considered plans for several dams along its length of the river (Independent 2008, UNEP 2007). The most controversial of these has been the Kajbar Dam proposed for the Nile's second cataract.

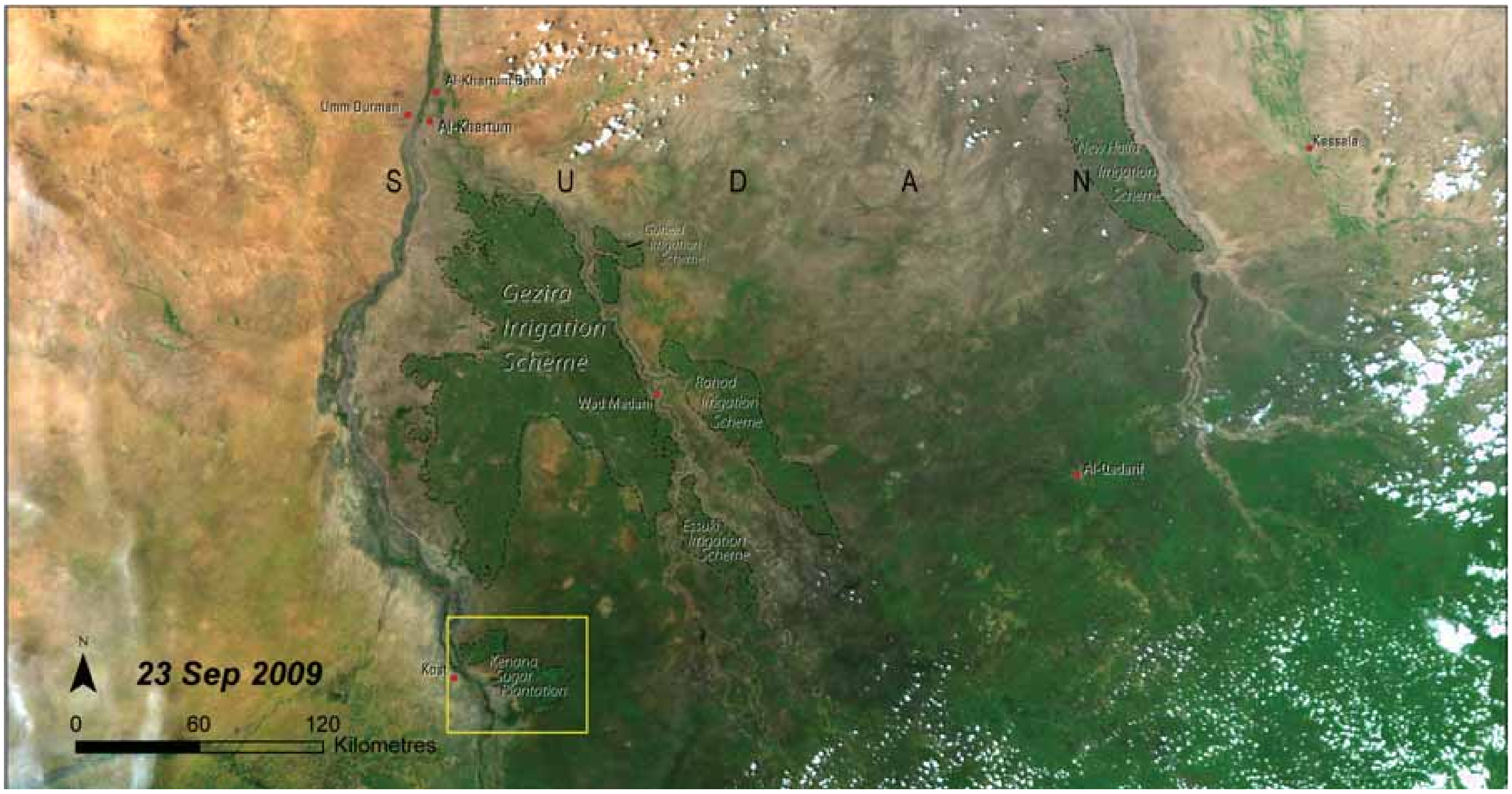


Figure 2.8.10: Sudan has the second-highest amount of land under irrigation in Africa after Egypt, including the massive Gezira Irrigation Scheme built in the early 20th century

Sudan Irrigation

Sudan has an estimated 48 000 km^2 of land with irrigation potential, but water limitations constrain the area that can actually be developed. Currently, 16 800 km^2 is under large-scheme irrigation and a total of just under 20 000 km^2 is irrigated land (Figure 2.8.10). Plans to increase the irrigated area are based on the amount of water that would be available if the Jonglei Canal is completed.

Several problems, including inefficiency and poor maintenance, have reduced the productivity of Sudan's existing irrigation. The Gezira Irrigation Scheme built in the early 20th century is one of the world's largest at nearly 9 000 km^2. Other schemes such as Rahad, New Halfa and the Kenana Sugar Plantation were built in the 1960s and 1970s (Figure 2.8.10). While the Kenana scheme is generally seen as efficient and environmentally sound, Sudan's irrigation overall is ranked last among the Nile Basin countries in efficiency and use of best practices (Figure 2.8.11).

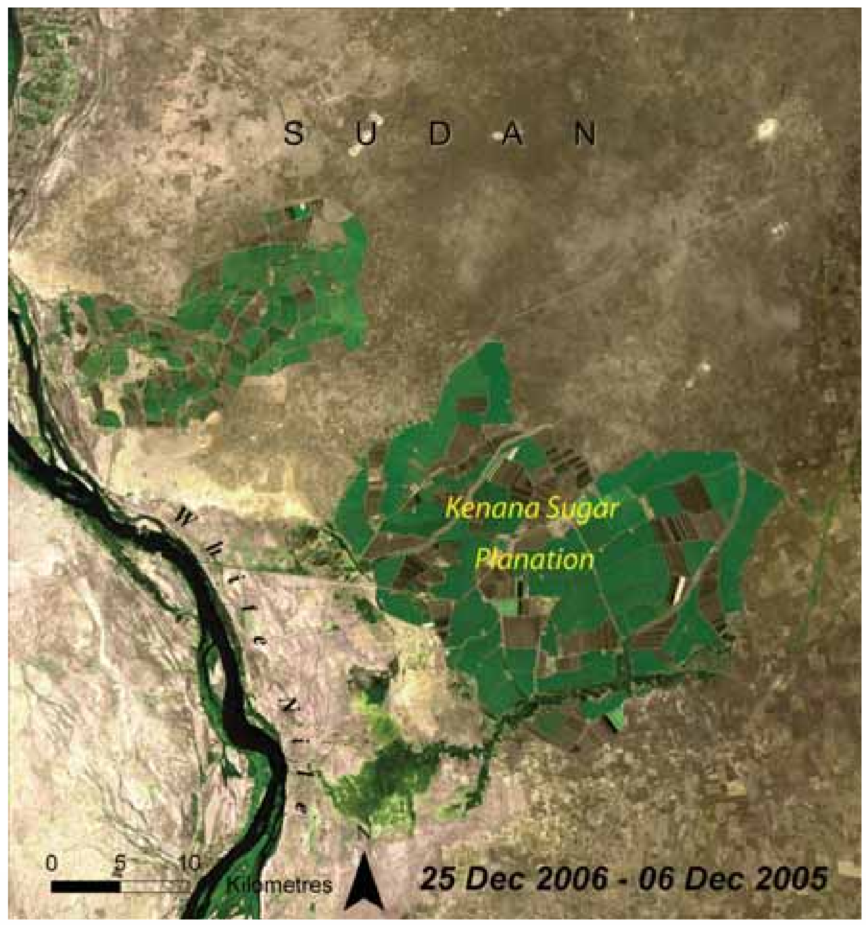


Figure 2.8.11: While Sudan has had problems with efficiency at many of its irrigation facilities, the Kenana Sugar Plantation is widely seen as efficient and environmentally sound

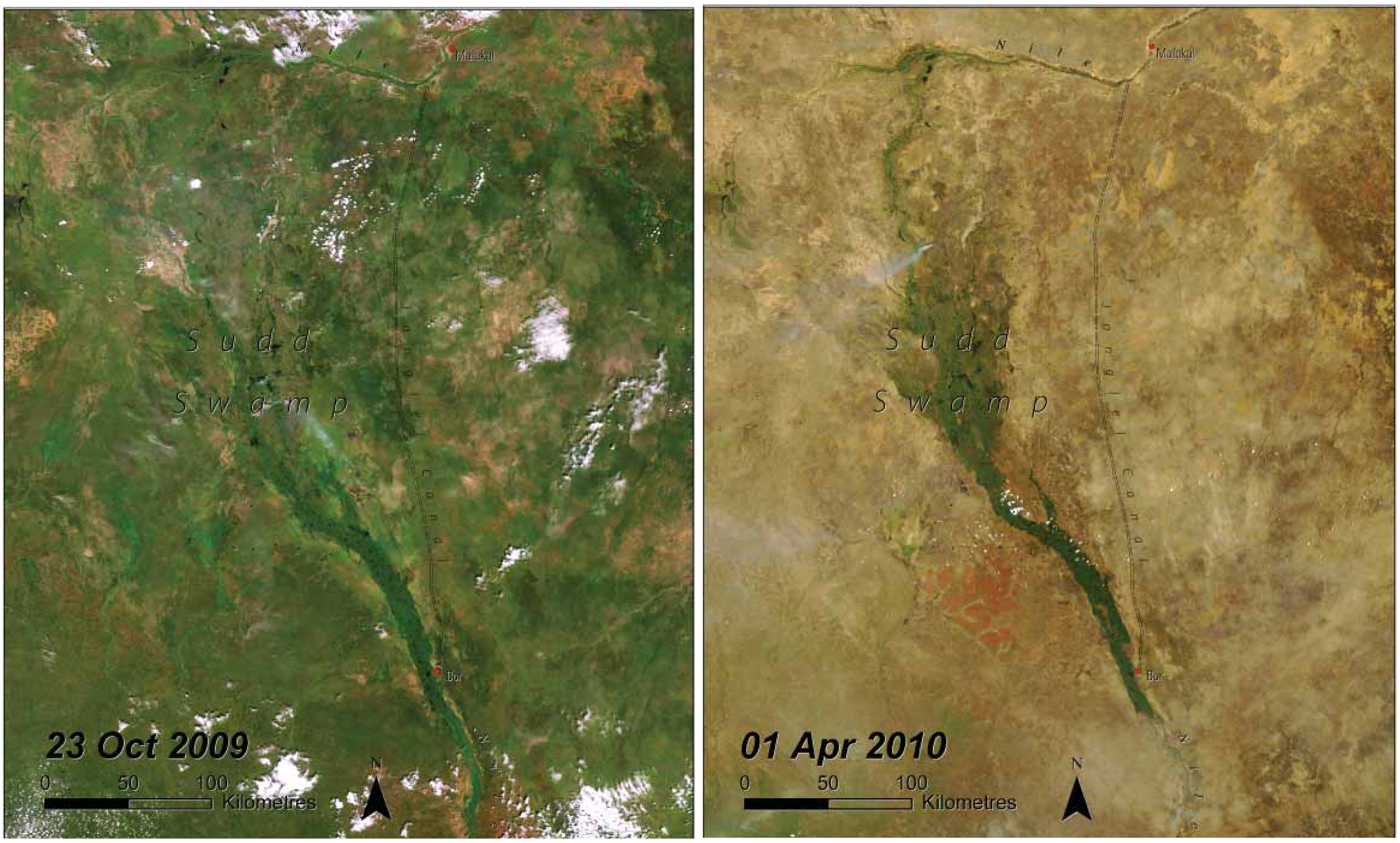


Figure 2.8.12: Wet season and dry season images of the Sudd Swamp. Annual overbank flooding creates an enormous wetland that is an integral part of the local ecosystem as well as the livelihoods of local people

Construction of the canal ended in 1983 and the digger has remained here since

The Sudd Swamp and Jonglei Canal

The Sudd is a vast wetland in southern Sudan where the Nile River wanders for nearly 644 km, losing much of its flow to evaporation (Howell and others 1988). During the dry season, the wetlands contract to approximately 8 300 km^2 of permanent swamp (Krishnamurthy 1980). During the wet season from April to October, the Sudd overflows into the surrounding area to cover 80 000 km^2. This annual pattern of flooding is an integral part of the ecosystem and is crucial to the local flora and fauna and to the local Nilotic people's way of life (Krishnamurthy 1980, Laki 1994).

The Jonglei Canal project is designed to reroute a portion of the Nile's flow around the wetland, thus reducing evaporative loss and increasing the water available downstream for irrigation. The project has been at a standstill since November 1983 when military conflict in the area stopped construction (Laki 1994). This conflict has now ended and there are plans to resume construction.

A 1954 study, The Equatorial Nile Project and its Effects on the Anglo-Egyptian Sudan, identified many concerns with the Jonglei Canal that are still a source of controversy today. It concluded that a canal diverting 55 million m^3 of the White Nile's water per day would mean the loss of 36 per cent of pasture and 20 000 metric tonnes of fish. It would also significantly reduce agricultural production (Laki 1994). The pastoralists who depend on the area's seasonal flooding will lose the grasses for their cattle and access to drinking water; in addition, the canals will impede their seasonal migration. Several studies support these concerns and a little-studied second phase of the project will almost certainly further affect the area. Environmentalists have voiced concern that the project could have drastic effects on the ecosystem, potentially affecting the climate, groundwater recharge, water quality, fisheries and the local people (FAO 1997).

The proponents of the canal claim that its benefits will outweigh impacts on the wetlands. In addition to enhancing of downstream irrigation, supporters say that travel from Khartoum to Juba, the main city in the south, will be reduced by 300 km. The impact of this project is difficult to predict and further study is needed to ensure that decisions are based on sound up-to-date science.

Figure 2.8.13: Overflow from the Lake Nasser spillway created a chain of enormous lakes in the middle of Egypt's Western Desert between 1998 and 2002 which have since largely evaporated

Toshka Lakes

In the mid-1990s, water levels in Lake Nasser on the Nile River approached the reservoir's storage capacity of 183 m above sea-level. Excess water was released through a spillway that flowed into the Toshka Depression in the Western Desert. Over the next several years, continued overflow created a series of lakes on some of Egypt's most arid land.

After peaking at 182 m above sea level in 1998, levels declined and flow through the spillway ceased in 2001. Since that time, levels in the Toshka Lakes have been declining as well—primarily by evaporation and to a lesser degree by infiltration. At the current rate, the remaining water will be lost to evaporation as the lakes disappear in the next few years (Figure 2.8.13).

The New Valley Project

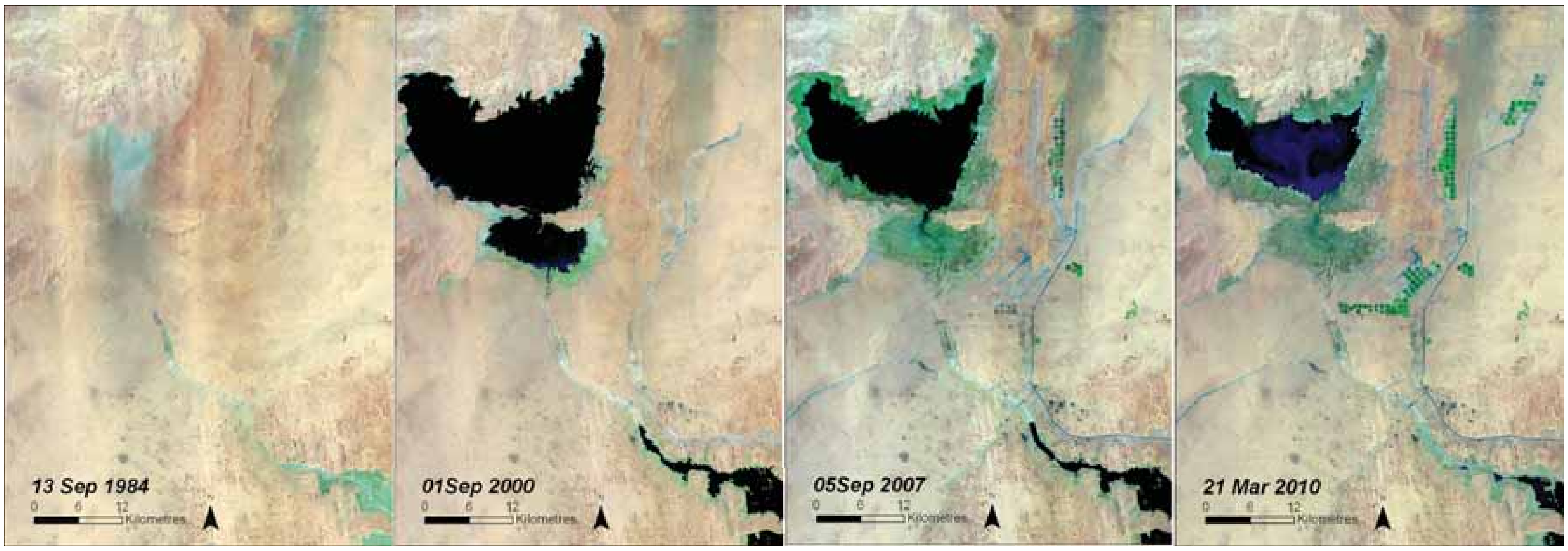
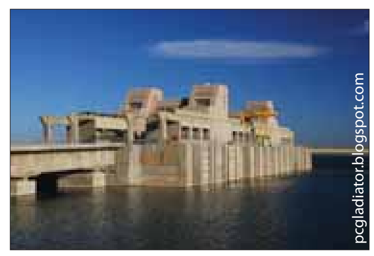


Figure 2.8.14: The New Valley Irrigation Project uses water from Lake Nasser to grow crops in the desert including wheat, tomatoes, grapes and citrus. The goal is to irrigate over 3 300 km^2 of desert land and attract settlers away from the densely populated Nile Valley

In January 1997, the Egyptian government began building a network of canals to continue carrying Lake Nasser water to the eastern portion of the Toshka Depression with the goal of irrigating 3 360 km^2 of land in the Western Desert. The New Valley Project was intended to relieve overcrowding within the densely populated Nile Valley and provide economic development to Egypt.

Among the many challenges the developers faced was the fact that only about ten per cent of the area's soils are suitable for sustained irrigation without extensive management. In addition, the area is prone to wind erosion and dune formation, which present significant constraints on sustainable development and settlement in the area. There is also a considerable cost to create infrastructure to entice and support the needed labour away from the less challenging Nile Valley area.

The project is an enormous undertaking with a cost of over US$1 billion. Critics are concerned that the anticipated withdrawal of five billion cubic metres of water per year will reduce water available to farmers on the delta, leave Egypt more economically vulnerable to drought and reduce resources available for other development opportunities. Much of the needed infrastructure is already in place and crops are already being produced, including grapes, cantaloupe, tomatoes, cucumbers, citrus fruits, and wheat.



pcgladiator.blogspot.com

The Mubarak Pumping Station pumps water from Lake Nasser into the irrigation channels

Bruce Pengra/UNEP

The Fishery

Lake Victoria has the most important inland fishery in Africa (Njiru and others 2008). Historically, the lake supported a large variety of native fish including hundreds of *haplochromine cichlid* species (Baskin 1992). The release of non-native, predatory Nile perch in the lake in 1954 and its later deliberate introduction in 1962 led to a rapid decline in the endemic haplochromine species and a matching explosion of the Nile perch population in the 1970s and 1980s (Goudswaard and others 2008). The success of the Nile perch experiment led to an economic boom in the fishing industry. The annual catch rose from 30 000 metric tonnes in the late 1970s to 560 000 metric tonnes in the early 1990s (Njiru and others 2008). The benefits of this growth accrued predominantly to larger commercial wholesalers and processors rather than to the small operators, comprised largely of local women, who had historically dominated the fish trade (Njiru and others 2008). The fish catch has declined somewhat since the early 1990s but is still around 500 000 metric tonnes—valued at between US$300 and US$500 million per year (Yongo and others 2005).

Fishing is not a major source of food or livelihoods for Sudan with only 1.7 kg of fish consumed per person annually (FAO 2008), although the sector has been growing steadily for decades. The Nile, along with its tributaries and artificial lakes, are the source of roughly 90 per cent of that production. There are as many as 100 species in the inland fisheries, the most commercially important of which are Nile Perch, Black Nile Catfish, and Silver Catfish. Most fishing is small-scale artisan activity using gillnets, seine nets, long lines, cast nets, and baskets (FAO 2008).

Figure 2.8.15: Surface runoff from the Entebbe area south of Kampala can be seen as greenish clouds expanding out into the water. Heavy runoff of domestic, industrial and agricultural waste as well as eroded soil is degrading the water quality of Lake Victoria

Egypt has significant marine and freshwater fisheries. Its inland fisheries are generally associated with the Nile, including the river itself, some brackish coastal lagoons, irrigation canals, and the reservoirs on the Nile, the most significant of these being Lake Nasser (FAO 2008). The inland fisheries account for almost 70 per cent of the country's total catch. The most economically important species are tilapia, catfish, and the Nile perch (FAO 2008). Egypt's fish capture production has declined somewhat since it peaked at over 400 000 tonnes in the late 1990s and early 2000s (FAO 2008).

Water Quality

Agricultural runoff, industrial waste and untreated municipal and domestic waste have led to seriously degraded water quality in Lake Victoria over the past few decades (Scheren and others 2000, USAID 2009) (Figure 2.8.15). While industrial waste is generally confined to urban areas (Kampala, Mwanza, and Kisumu among others), untreated sewage and agricultural runoff occur all along the heavily populated shoreline. Phosphorous, and to a lesser extent nitrogen from untreated waste, put excessive nutrients into the water driving algae blooms and contributing to the water-hyacinth invasion seen in the mid-1990s (Scheren and others 2000, Williams and others 2005, Albright and others 2004). In addition, accelerated erosion from deforestation and agricultural conversion of natural areas has led to greatly increased sediment loads being carried into the lake (Machiwa 2003).

As the river flows through Sudan it also picks up substantial non-point source agricultural and urban runoff (NBI 2005a). While water quality has generally been found to be within World Health Organization standards (NBI 2005a) there are some localized high chemical pollution concentrations especially in the Khartoum area (NBI 2005a).

In Egypt, water quality is under pressure from intense populations and accompanying agricultural and industrial activity concentrated along the banks of the Nile. In Upper Egypt, this comes primarily from agro-industries particularly sugar cane (NBI 2005b, Wahaab 2004). Downstream, where populations are more concentrated, a wide range of industrial pollution and wastewater enters the river from Cairo and Lower Egypt's other urban centres (NBI 2005b, Wahaab and Badawy 2004). While Egypt has made significant efforts to construct additional wastewater treatment capacity, population growth has outstripped capacity and considerable domestic wastewater enters the Nile with no treatment (NBI 2005b). Intense agriculture and some mixing of industrial and domestic wastewater in irrigation-drainage canals are a source of multiple contaminants in Lower Egypt (NBI 2005b).

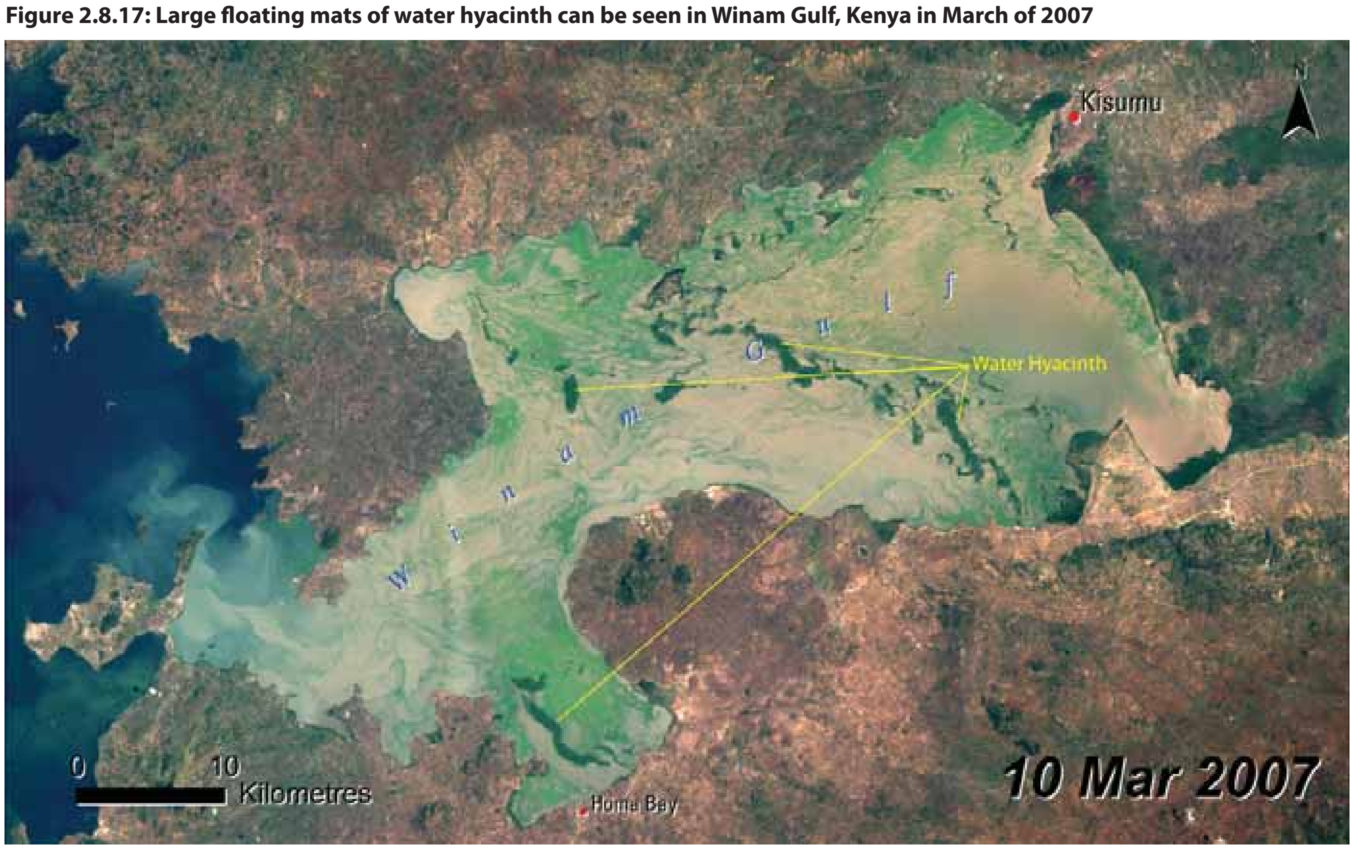
Invasive Water Hyacinth

Water hyacinth is an invasive aquatic plant originating in South America. It first appeared in Lake Victoria in 1989 and subsequently invaded much of the lake's shoreline over the next seven or eight years with the heaviest infestations occurring along the north shore and in Winam Gulf in Kenya (Williams and others 2005, Albright and others 2004) (Figure 2.8.16). The infestation reportedly caused several serious problems including fouled drinking water, clogged city-water intakes, impeded fishing and boating, altered fish populations, fish kills, reduced tourism, increased mosquito habitat and clogged drainage ditches, irrigation canals and culverts (Cavalli and others 2009, Williams and others 2005). Physical removal and limited chemical controls proved inadequate in reversing the invasion (Albright and others 2004). In December 1996, a weevil that feeds on the hyacinth was introduced as a biological control agent (Williams and others 2005). By the late 1990s, the weed began a rapid decline and was largely eradicated by early 2001 (Albright and others 2004). The causes of the rapid decline are not clear but likely include several factors in addition to the weevils, including changed weather conditions from the El Niño Southern Oscillation (ENSO) event of 1997 and 1998 (Williams 2007).

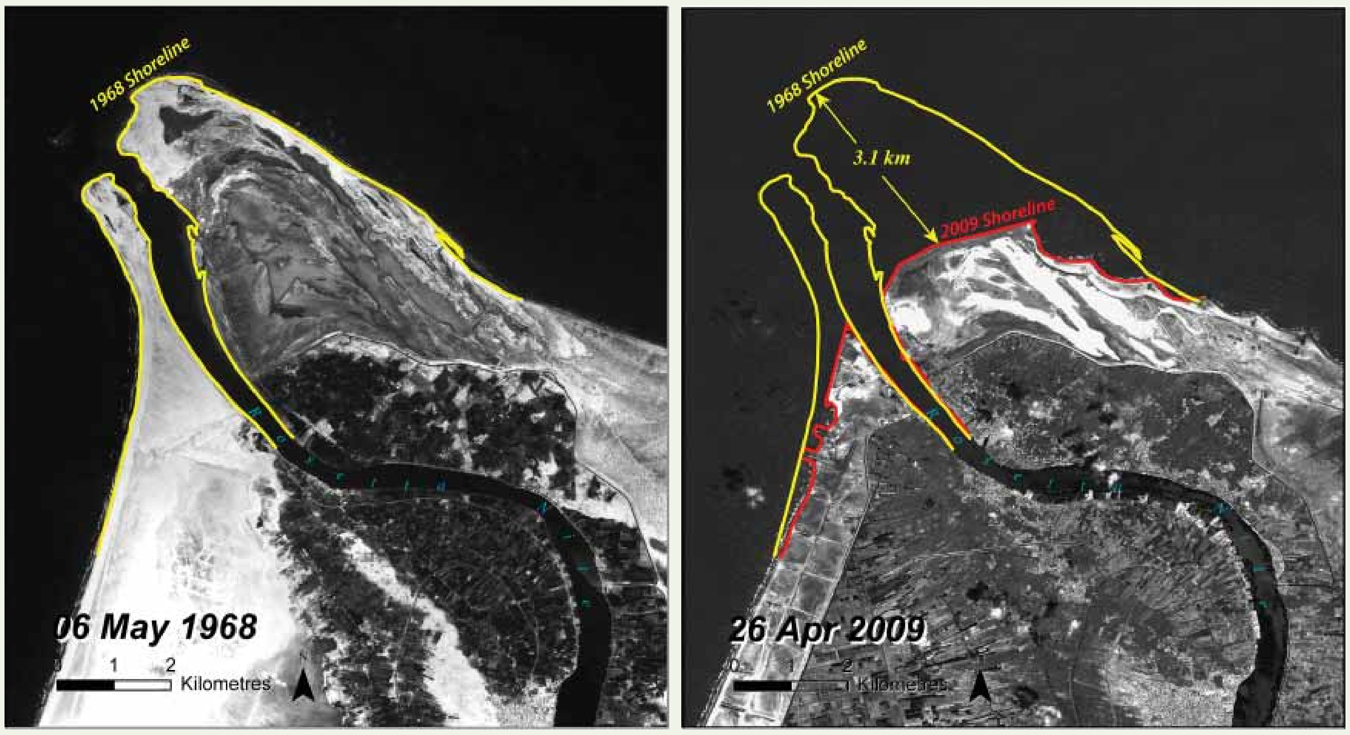
Figure 2.8.16: The dense rural population just north of Winam Gulf in Kenya increases the eroded soil, agricultural runoff and domestic waste that run into Lake Victoria

In 2006, water hyacinth was beginning to return to some of the areas affected by the 1990s invasion. Winam Gulf in Western Kenya saw very heavy infestation in early 2007 (Figure 2.8.17).

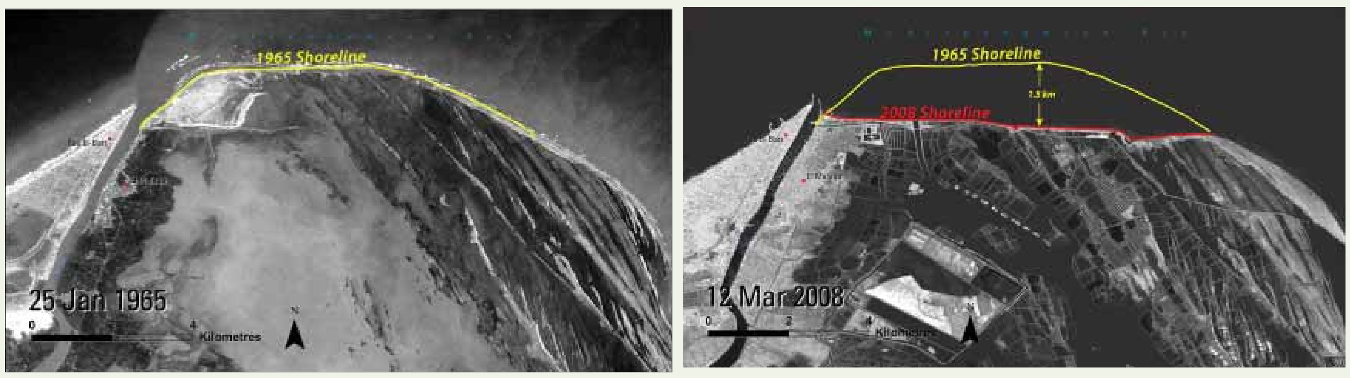
Figure 2.8.17: Large floating mats of water hyacinth can be seen in Winam Gulf, Kenya in March of 2007



Case Study: Coastal Erosion and the Sinking Nile Delta



Rosetta Promontory lost over 3 km to erosion between 1968 (left image, yellow line) and 2009 (right image, red line)



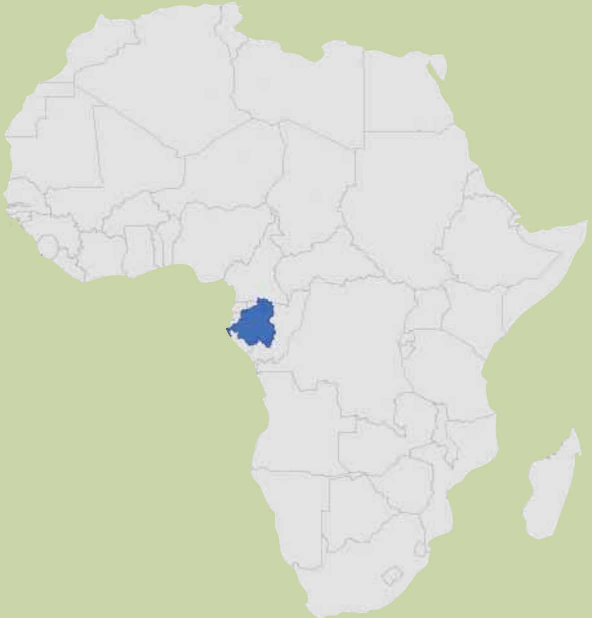
Damietta Promontory, formed by one of the two principle outlets of the Nile River, eroded 1.5 km between 1965 (yellow line) and 2008 (red line)

The Nile Delta is built of sands carried to Egypt's Mediterranean coast by the Nile River, primarily since the end of the last ice age. Dams along the river and sediment trapped in a vast network of irrigation canals have led to a dramatic decrease in the flow of water and sediment to the delta's edge. Since the closing of the Aswan High Dam in 1964, the forces of erosion have outstripped the balancing effect of sediment deposition (Stanley and Warne1993).

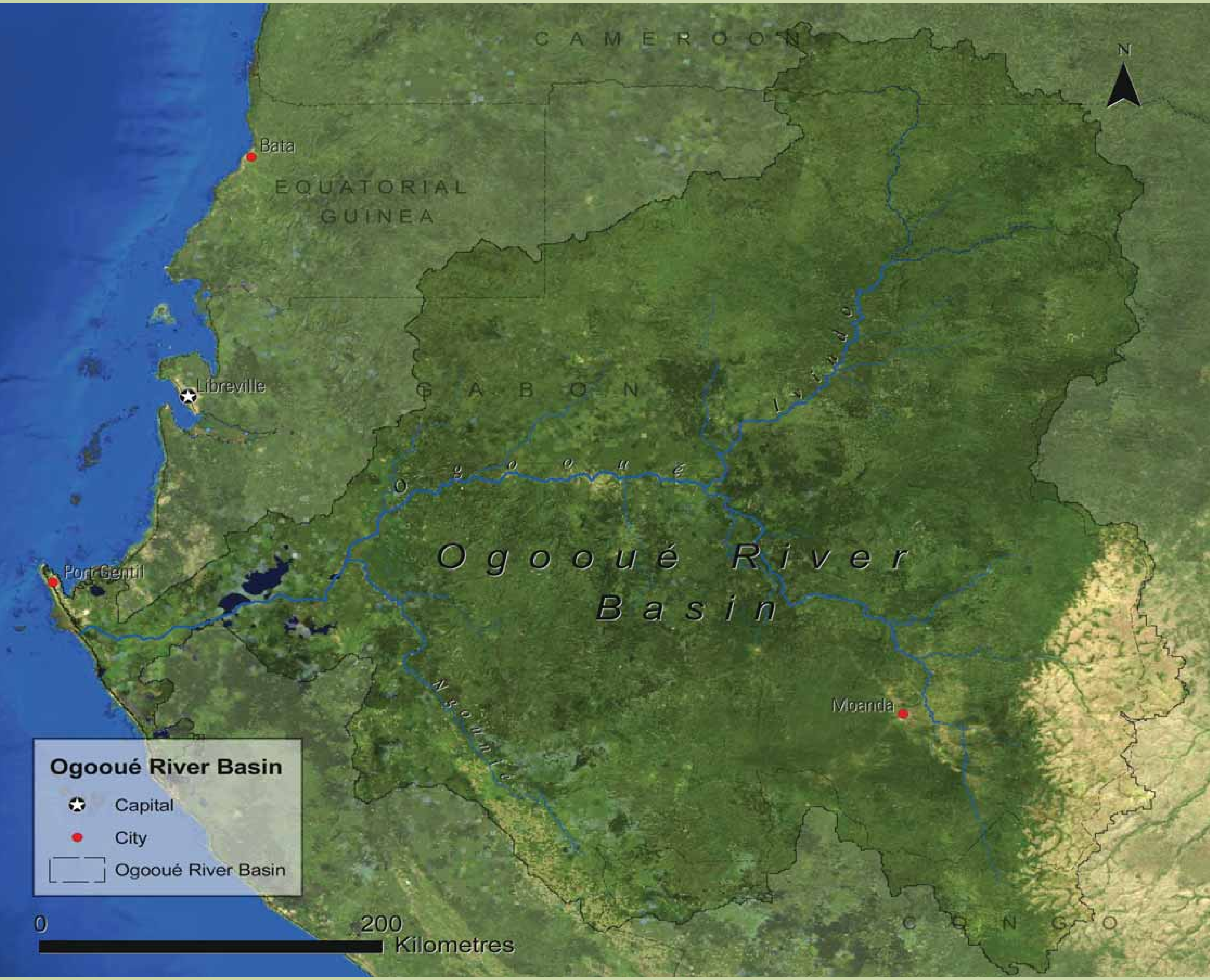
While there are some local areas of accumulation, on balance the delta is now receding (Stanley and Warne 1993). Damietta Promontory and Rosetta Promontory have eroded dramatically as waves and currents have stripped their sands faster than the river can replenish them. The images show the changes from shortly after Aswan High dam was built to recent years. The point of Rosetta Promontory has receded as much as three kilometres since 1968.

Prior to the construction of the Aswan High Dam, freshwater from annual floods influenced salinity and circulation patterns up to 80 km offshore from the delta (El Din 1977). In contrast, current discharge patterns allow salt water from the Mediterranean to reach dams up to 26 km inland (Frihy and Lawrence 2004). Diminished freshwater and sediment delivery to the delta also affects the ecology of coastal lagoons and soil fertility. In addition, the delta is sinking as new deposits of soil no longer offset the natural effect of soil compaction. Coastal protection structures, regulated irrigation, and increased groundwater exploitation may mitigate the delta's decline, but the current population growth rate threatens to outstrip these measures.

Ogooué River Basin



The Ogooué River originates at relatively low elevations near the edges of Gabon. Approximately 85 per cent of the basin lies within Gabon with about 12 per cent in Congo and the remaining area in Cameroon and Equatorial Guinea. The river is fed by a dense network of permanent streams. The two largest tributaries are the Ivindo and the Ngounié.



Much of the basin's population is concentrated along river courses

Precipitation

Average annual rainfall is heavy throughout the basin exceeding 2 100 mm in a few parts of Gabon and averaging over 1 700 mm in Gabon, Republic of the Congo, and Equatorial Guinea's portions of the basin (Figure 2.9.1, Figure 2.9.2).

Population

Approximately 650 000 people live in the basin giving it a population density of less than three people per km^2. Roughly 80 per cent of the basin's residents live in Gabon with another 12 per cent in Congo and about four per cent each in Equatorial Guinea and Cameroon's portions of the basin (SEDAC 2010) (Figure 2.9.3). Much of the basin's population is concentrated along the basin's river courses, particularly so in Gabon where French colonial policy relocated villages and towns along major roads and rivers (Laurence and others 2006).

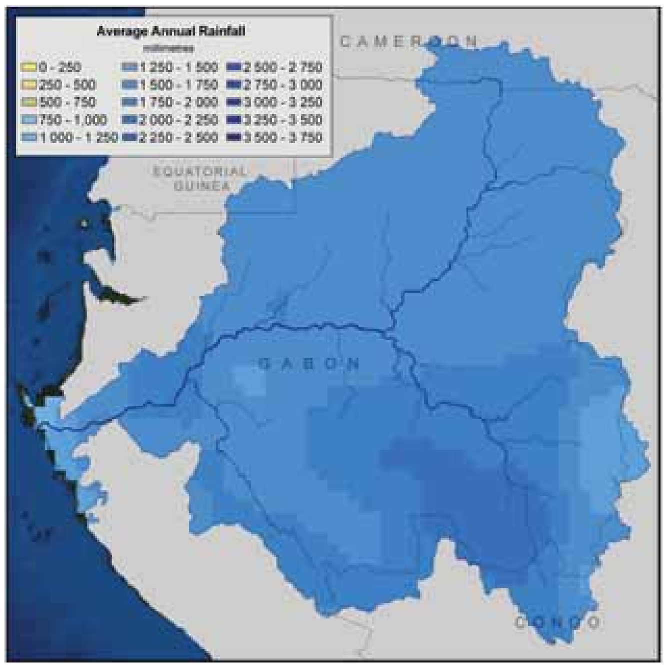


Figure 2.9.1: Ogooué River Basin average annual rainfall

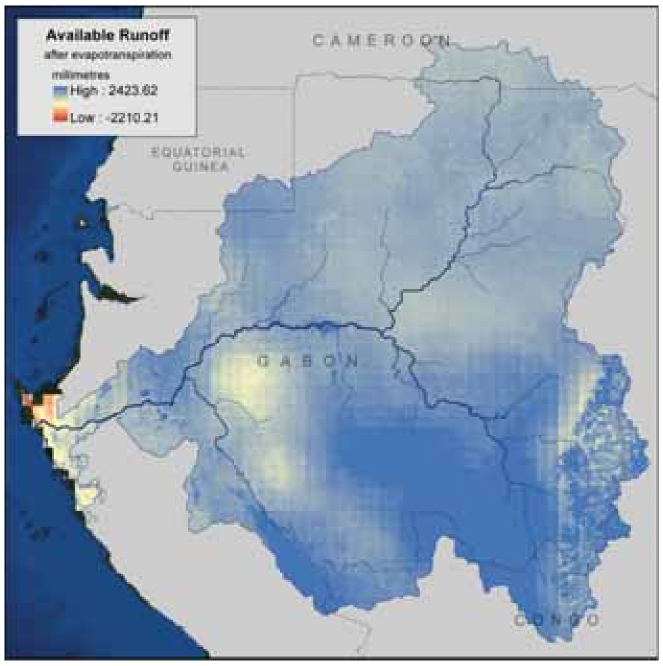


Figure 2.9.2: Ogooué River Basin modeled available runoff

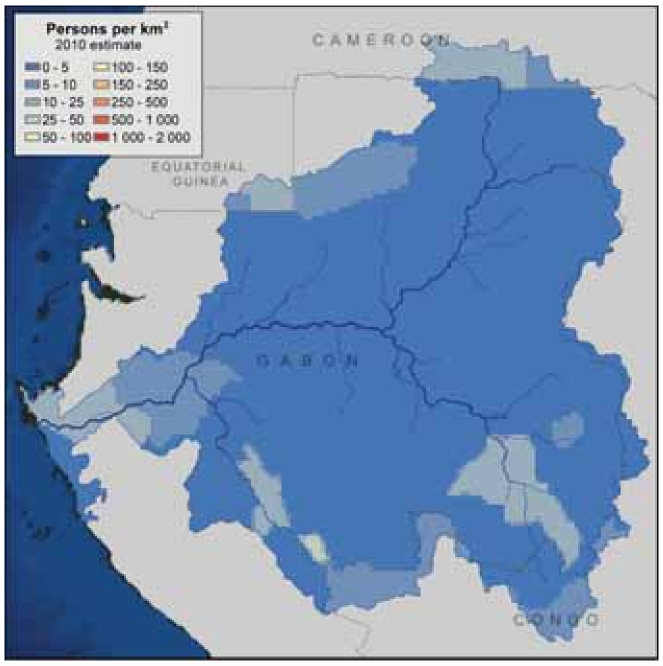
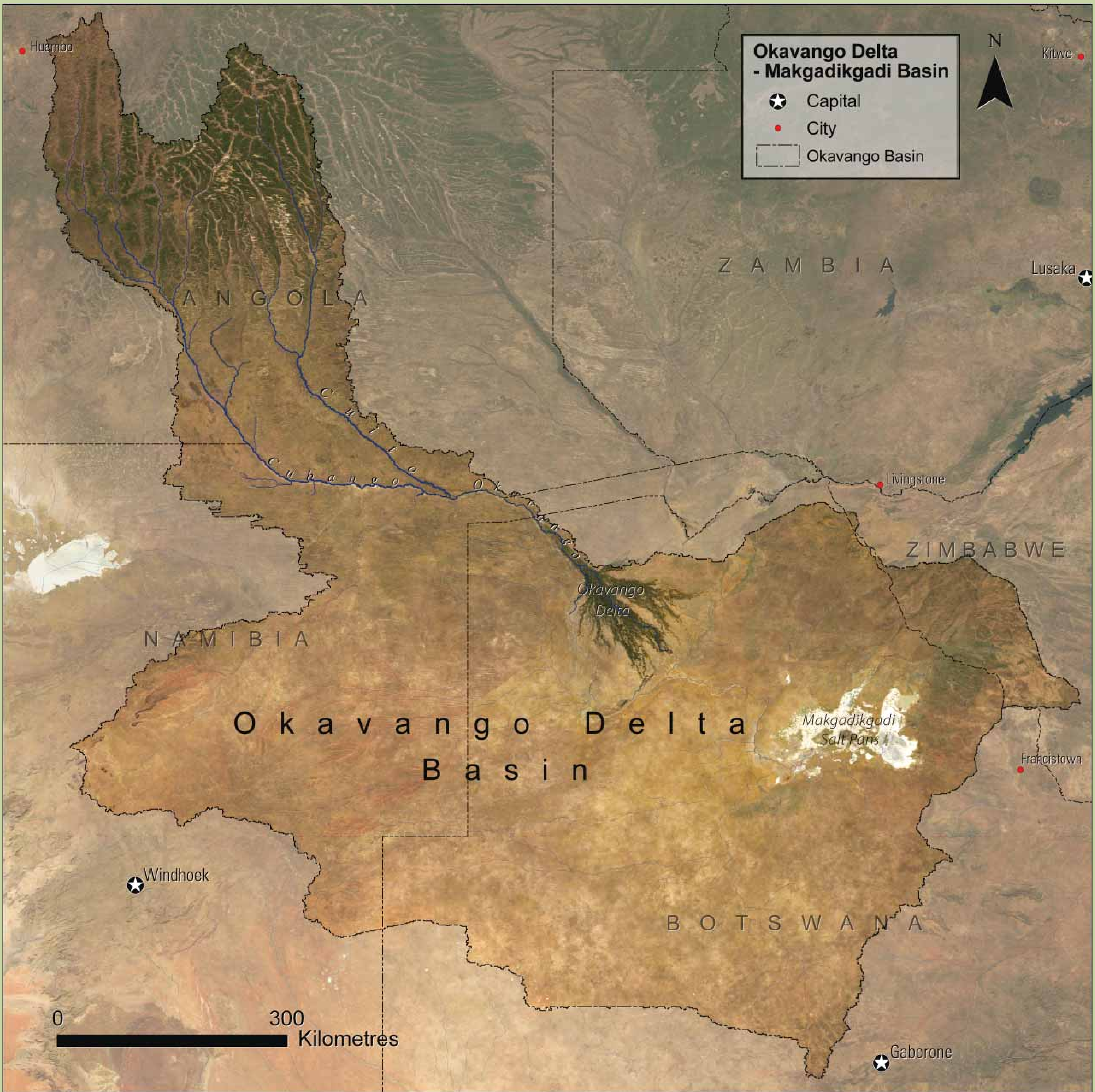


Figure 2.9.3: Ogooué River Basin population density

Wikipedia

Okavango Delta
Makgadikgadi Basin

The Okavango Delta Basin is a sub-catchment of a larger drainage basin that empties into the Makgadikgadi Salt Pans. The pans are only seasonally flooded, however, and the majority of the basin's water resources are within the Okavango system.



There are no major dams on the Okavango's tributaries and no significant water diversions

Outflow from the Okavango Delta to the Boteti River and the Makgadikgadi Pans is minimal since about 98 per cent of its water is lost to evapotranspiration (Gieske 1997).

Almost all of the inflow to the Okavango Delta comes from the Cubango and Cuito Rivers that capture rains in the more elevated Miombo woodlands of south-central Angola. There are currently no major dams on the Okavango's tributaries and no significant water diversions (Scudder 2008). Proposals to build a dam at the Popa Falls site in Namibia have apparently been shelved following a pre-feasibility study that found that the high cost outweighed the benefits (SAIEA 2009).

The Okavango Delta is among the most valuable wetlands in the world (Scudder 2008) with an extraordinary rich variety of terrestrial and aquatic habitat (Ramberg 2006). The variety and variability of habitat created by the unique hydrological patterns of the Okavango Basin have played a primary role in giving rise to and sustaining its myriad species—1 300 plant, 71 fish, 33 amphibian, 64 reptile, 444 bird and 122 mammal (Ramberg 2006).

Population

Population is sparse across the Makgadikgadi-Okavango Basin, averaging just over two persons per km^2 for a total basin population of less than 1.5 million. One-third of these people live in Angola. Another third live in Botswana, spread across a much larger area with a population density of approximately 1.2 persons per km^2. There are no large cities within the basin (Figure 2.10.1).

Precipitation

More than half of the basin falls in northwestern Botswana where mean annual rainfall is around 425 mm. Very little of this rainfall makes its way into streamflow. Namibia occupies about one-quarter of the basin and receives a little more rain on average and makes a significant contribution to the basin's water budget, accounting for about 18 per cent of the larger Makgadikgadi Basin's total runoff. Angola, with a mean annual rainfall around 940 mm and some locations that receive as much as 1 339 mm of rain each year, contributes the vast majority (over 70 per cent) of the basin's runoff.

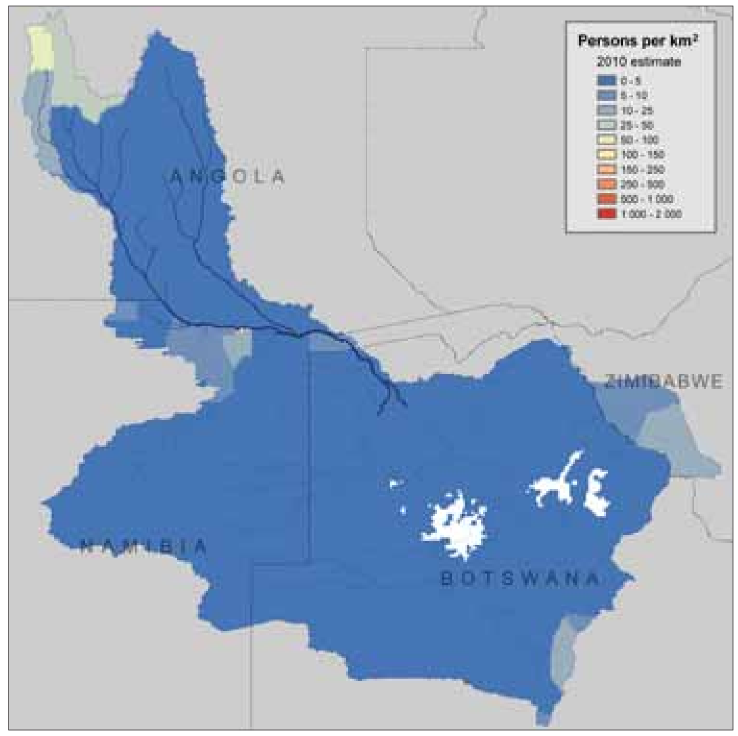


Figure 2.10.1: Okavango Basin population density

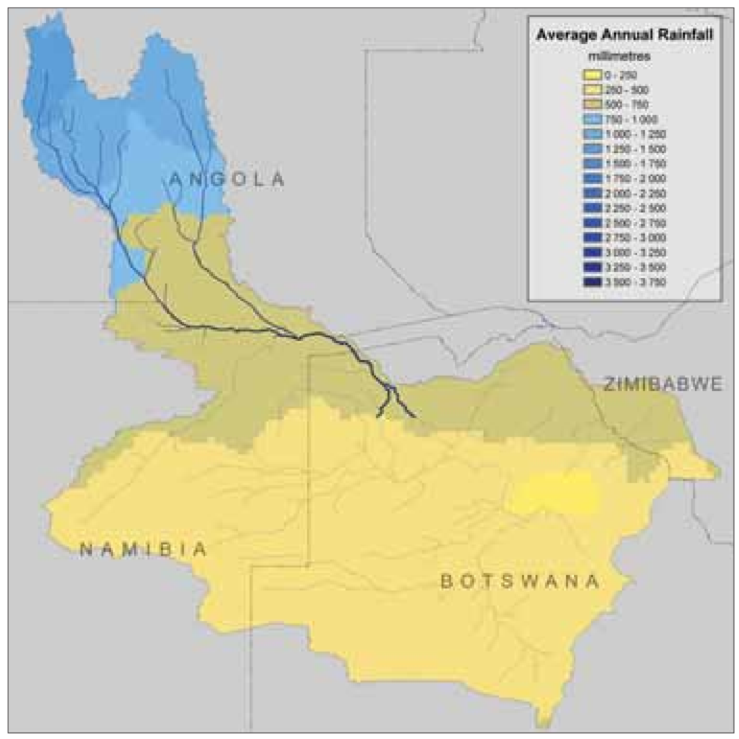


Figure 2.10.2: Okavango Basin average annual rainfall

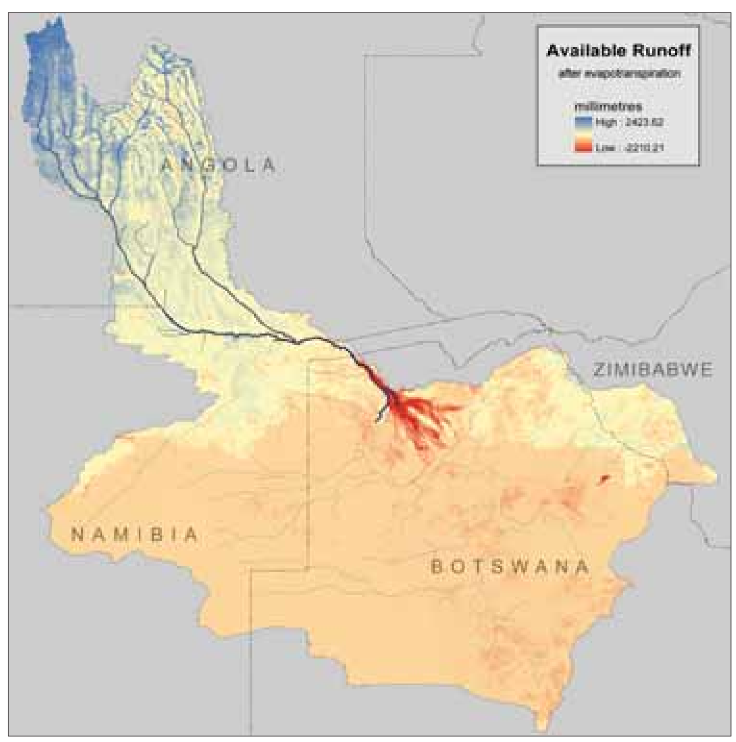
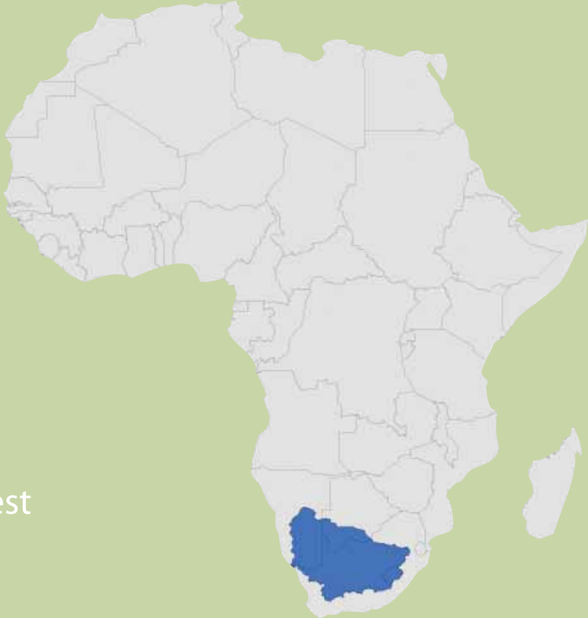


Figure 2.10.3: Okavango Basin modeled available runoff

Orange River Basin



The Orange River originates in Lesotho where its tributary, the Senqu, begins high in the Drakensberg Mountains. While only three per cent of the basin lies in Lesotho the country's highlands have some of the highest mean annual rainfall in the basin and Lesotho contributes nearly 17 per cent of the Orange River's water budget (Senay and others 2010).

While only three per cent of the basin lies in Lesotho, the country's highlands contribute nearly 17 per cent of the water budget

The Vaal River drains the wetter eastern portion of South Africa, which occupies 60 per cent of the basin and contributes most of South Africa's 76 per cent share of the basin's water. Namibia (25 per cent) and Botswana (13 per cent) each make up significant shares of the basin's area but because of high evapotranspiration of limited rainfall, make only minor contributions to the river's flow.

Precipitation in the basin declines from east-to-west with some areas of Lesotho and South Africa receiving over 1 000 mm of rain annually while western areas of South Africa and Namibia receive less than 200 mm (Figure 2.11.1, Figure 2.11.2)

Population

Population also follows an east-to-west gradient with the majority of people living in the eastern third of the basin. Nearly 12 million South Africans live within the Orange Basin, most of them in and around the cities of Gauteng Province. Lesotho's average population density of around 67 persons per km^2 is the highest in the basin. Populations in the Namibia and Botswana portions of the basin are quite sparse with densities near one person per km^2 (Figure 2.11.3).

Dams, Irrigation and Development

The Orange River Basin is highly developed, with many dams and transfer schemes, particularly in the South African share of the basin. The largest-capacity dams are the Gariep and Vanderkloof on the Orange River, the Sterkfont Dam on the Nuvejaars River, and the Vaal Dam on the Vaal River. The Katse Dam and Mohale are the largest dams outside of South Africa. Both are in Lesotho and are a part of the world's largest inter-basin water transfer scheme, the Lesotho Highlands Water Project, which transfers water north to Gauteng Province to help meet the Johannesburg area's rapidly growing water needs (Earle and others 2005). Irrigation developments line the river banks. In the Vaal River catchment's heavily populated upper reaches, large volumes of water are utilized for domestic, industrial, and mining purposes. In the western regions where population is sparse, water schemes draw on the river to provide water for livestock, irrigation, and mining (SADC-GTZ 2007).

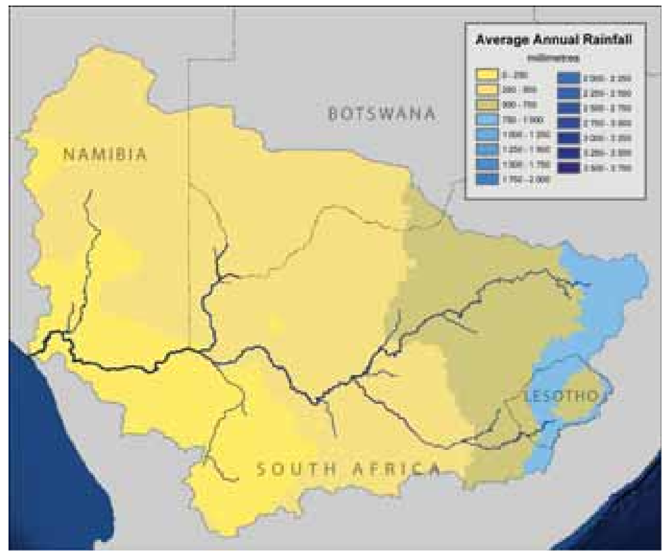


Figure 2.11.1: Orange River Basin average annual rainfall

Figure 2.11.2: Orange River Basin modeled available runoff

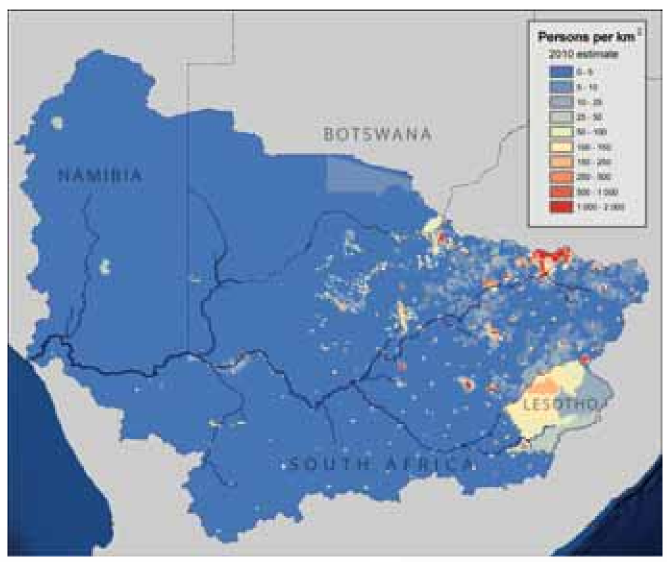
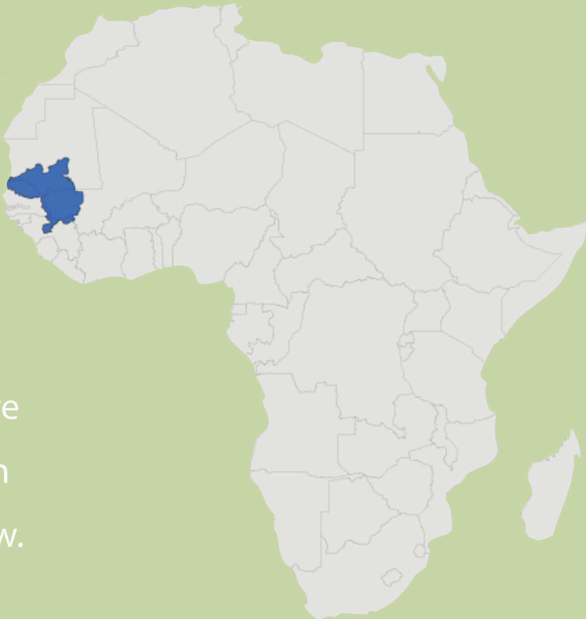
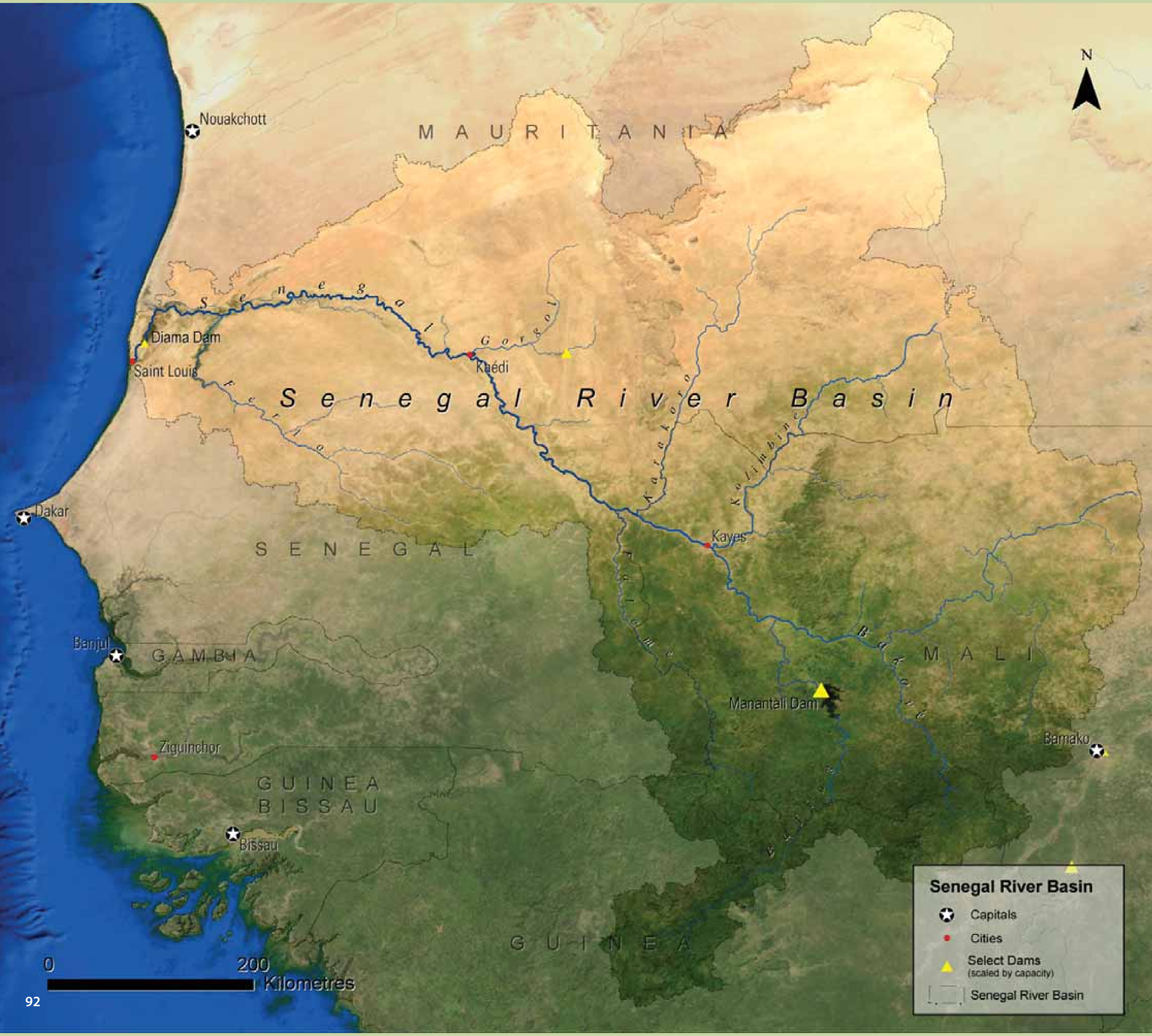


Figure 2.11.3: Orange River Basin population density

Senegal
River Basin



The Senegal River's two primary tributaries are the Bafing and the Bakoye Rivers, both originating in the Guinea Highlands. The Bafing originates in the Fouta Djallon at 800 m and is the source of most of the Senegal's flow. The Bakoye begins on the Manding Plateau about 250 km to the east.



The river's transboundary nature makes managing the Senegal River Basin's water resources very complex and challenging

Temperatures rise and rainfall decreases as the two rivers flow north through southern Mali where nearly one-third of the Senegal River's catchment basin is located. The Manantali Dam in Mali retains over 11 000 million m^3 of the Bafin for irrigation and hydropower generation (IR 1999). One hundred and twenty-five kilometres downstream of Manantali Dam, the Bafing and the Bakoye meet to form the beginning of the Senegal River. The river forms the border between Senegal and Mauritania for the rest of its journey to the Atlantic Ocean. Roughly half of the river's basin lies in Mauritania where rainfall is very limited. The river accumulates the flow of several lesser tributaries, including the Gorgol, Karakoro, Kolimbine, Falémé and Ferlo Rivers.

The transboundary nature of the river, the variety of ethnic groups living along its banks, differing rural and urban priorities, conflicting local and national interests, and challenging natural conditions that include limited and highly variable rainfall, conspire to make managing the Senegal River Basin's water resources very complex and challenging.

Population

The Senegal Basin's population is approximately seven million. Rural population in the basin is concentrated along the river and its tributaries and includes several ethnic groups including Wolof, Fulani, Tukulor and Moor (Lahtela 2003). The river is an important resource for most of the rural population, supporting pastoral, agricultural and fishing livelihoods. By country, 2.7 million of Mali's population live within the basin, 1.9 million of Mauritania's, and 1.5 million of Senegal's, while less than one million of Guinea's population lives in its seven per cent of the basin (Figure 2.12.1). Population within the basin is growing very rapidly at three per cent per year—high even by West African standards. Urbanization is also high throughout the basin, with many medium and small cities located beside the river itself (UNESCO 2003). According to UNDP's Human Development Index (HDI), many among this growing population are living in difficult conditions. Of the 182 countries ranked on the HDI, Mali ranks 178th, Senegal 166th, and Mauritania 154th (UNDP 2009).

Precipitation

At the river's source in the Guinean Highlands precipitation within the Senegal watershed averages over 1 400 mm/yr. As the Bafing and Bakoye Rivers flow out of Guinea and through southern Mali, rainfall remains above an average 850 mm/year. Shortly after the two merge to form the Senegal River, north of Manantali Reservoir, rainfall drops to below 500 mm/yr, a level at which rain-fed agriculture becomes very difficult. Roughly half of the basin lies in Mauritania where rainfall is even more limited. At the far reaches of the Gorgol, Karakoro, and Kolimbine Rivers in Mauritania, average annual rainfall is below 140 mm/yr. Precipitation in Senegal's 15 per cent of the basin averages approximately 500 mm/yr (Figure 2.12.2, Figure 2.12.3).

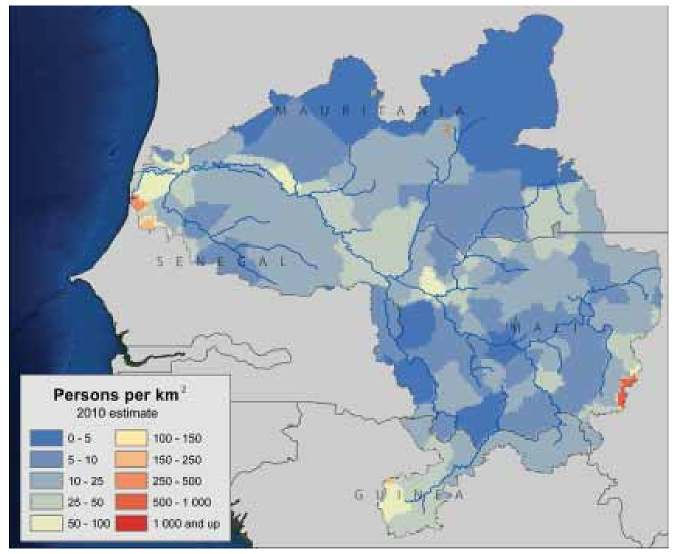


Figure 2.12.1: Senegal Basin population density

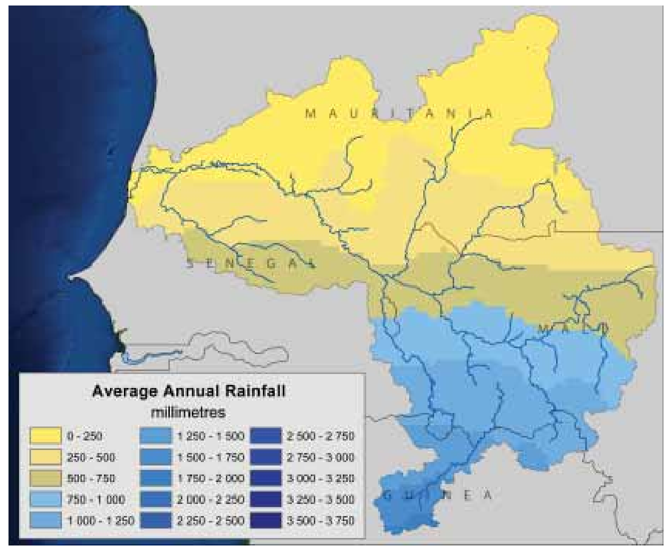


Figure 2.12.2: Senegal Basin average annual rainfall

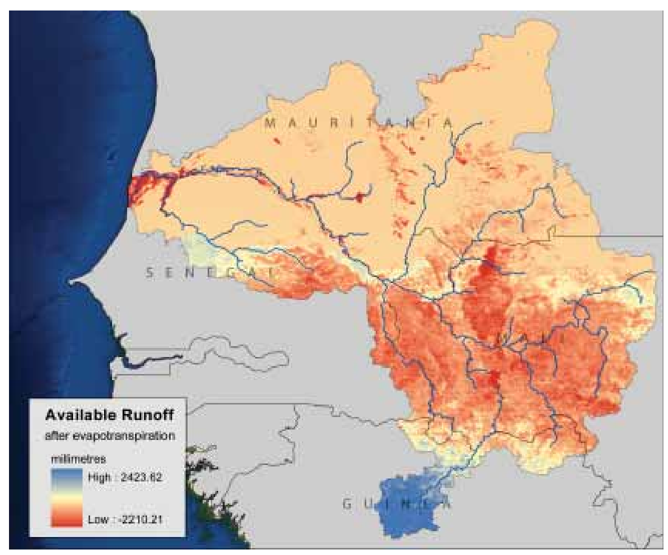


Figure 2.12.3: Senegal Basin modeled available runoff

Rainfall along the Sahel is highly variable seasonally, inter-annually and over periods of decades, but on average it declines from south-to-north. During the great droughts of the 1970s and 1980s, this rainfall pattern shifted to the south by approximately 100 km (Lebel and Ali 2009) (Figure 2.12.4). Various studies have conflicting conclusions as to whether the drought has ended although it is clear that precipitation has not returned to levels that occurred during the relatively wet periods of the 1950s and 1960s. This is particularly the case in the western Sahel—including the Senegal Basin—where average annual precipitation over the past two decades resembles rainfall levels from1970 to 1989 when the great droughts occurred (Lebel and Ali 2009).

Irrigation

Large irrigation schemes in the Richard Toll area along the Senegal River in Mauritania and Senegal date back to at least the 1940s and can be seen to cover a significant area at the north end of Lac de Guiers in satellite images from November of 1965 (Figure 2.12.5). The great droughts of the 1970s and 1980s prompted massive investments in large irrigation schemes across the Sahel (Van Asten and others 2003). Rice is the most suitable crop for the soils, climate and available irrigation infrastructure in the Senegal Valley (Verheye 1995) and is the predominant crop on large irrigation developments. Other crops include tomatoes, potatoes, sweet potatoes, onions, melons, okra, maize, and sorghum (UNESCO 2003, OMVS n.d.).

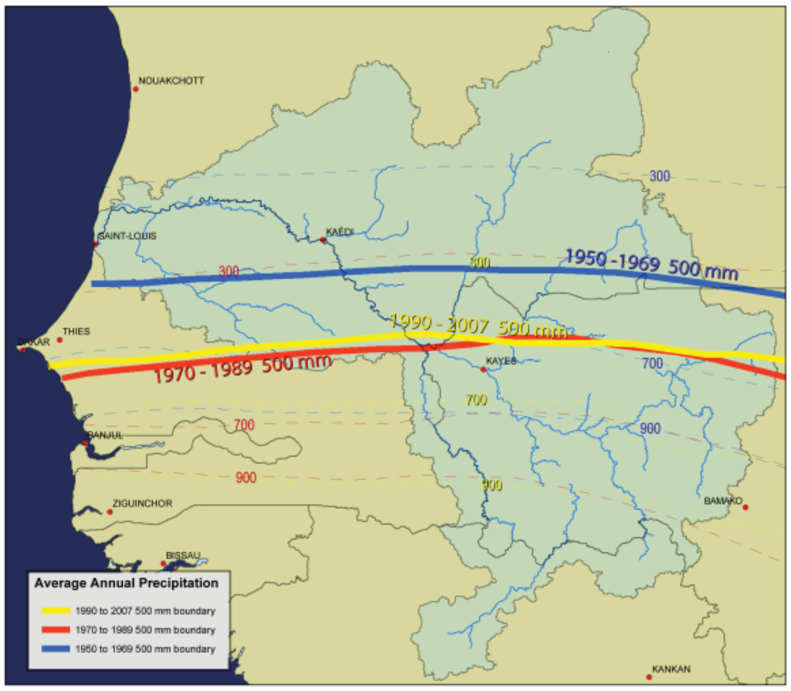


Figure 2.12.4: In the western Sahel, the northern limit of 500 mm annual precipitation shifted over 100 km to the south between the 1950-1969 period and the 1973-1989 period

With the construction of the Manantali Dam in Mali in 1981 and the Diama Dam in Senegal in 1986, an estimated 375 000 (OMVS n.d.) to 420 000 ha (FAO 1997) could now potentially be irrigated within the Senegal Basin. Current irrigation development is well below that figure and the area actually cultivated annually is generally well below the approximately 120 000–140 000 ha that are managed for irrigation in Mali, Senegal, and Mauritania (OMVS n.d., FAO 1997). This is generally attributed to inadequate maintenance of drainage and other infrastructure (Connor and others 2008, Verhaye 1995, Van Asten and others 2003, Boivin and others 1998).

With little dissolved salt, the quality of water in the Senegal River is generally good for irrigation. Without proper drainage, however, its alkaline content can accumulate in soils increasing alkalinity in the root zone (Van Asten and others 2003). This is an issue from just upstream of lac de Guiers to just below Kaédi in Mauritania (Wopereis and others 1998). In the delta region, downstream of lac de Guiers, neutral soil salinity and salinity of the water table are the result of interactions with the Atlantic Ocean (Wopereis and other 1998, Barbeiro and others 2004). While this generally provides a good buffer against alkalinization, localized areas of saline soils and the rise of saline water where the water table is near the surface can present problems to irrigation

Figure 2.12.5: Areas of large-scale irrigation had already been developed along the Senegal River before 1965

in the delta area. In both cases, proper design of drainage systems and appropriate cropping schedules can mitigate these issues (Wopereis and others 1998).

The benefits of large-scale irrigation developments in the Senegal Basin have not come without significant ecological and human costs. Among those cited in studies of the irrigation projects and related dams are the displacement of thousands of people from their land and traditional livelihoods, alteration of important natural habitats and biodiversity loss, reduced riverine woodlands and unequal benefits distribution (Duvail and Hamerlynck 2003, DeGeorges and Reilly 2006, Horowitz and Salem-Murdock 1993, Tappan and others 2004).

The two satellite images in Figure 2.12.6 show the dramatic changes in a segment of the middle river valley. In 1984, there was considerable irrigation development. Outside of the irrigated areas, the landscape had little vegetation because of the droughts during 1984 and preceding years. During the same season in 2009, areas of irrigation had expanded significantly, identified by the straight lines of bunds, which are built to retain the irrigation water. Abundant vegetation grows outside the irrigated areas as the rains had been more normal in recent years.

Figure 2.12.6: Irrigation development in the Senegal River Basin

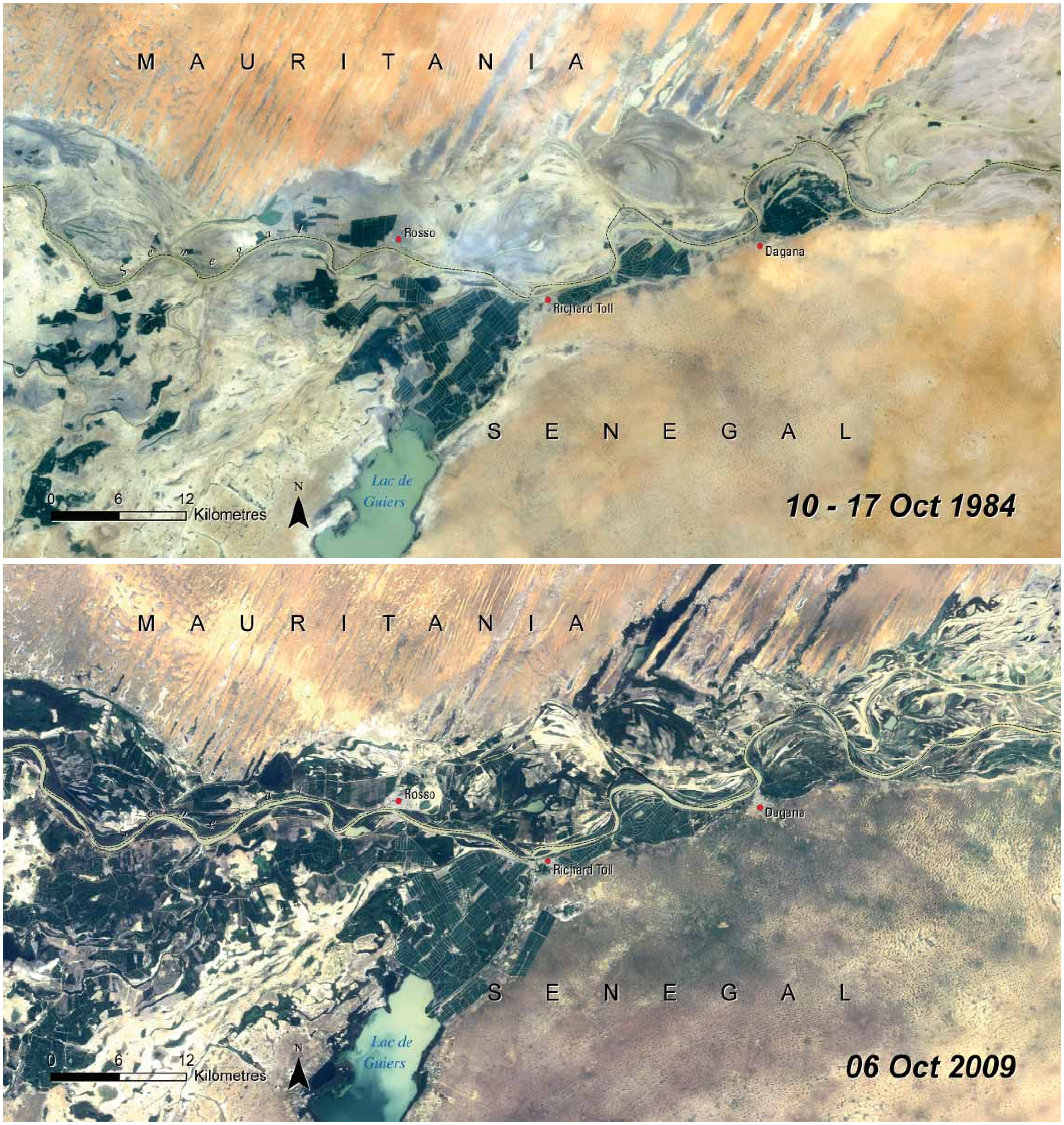
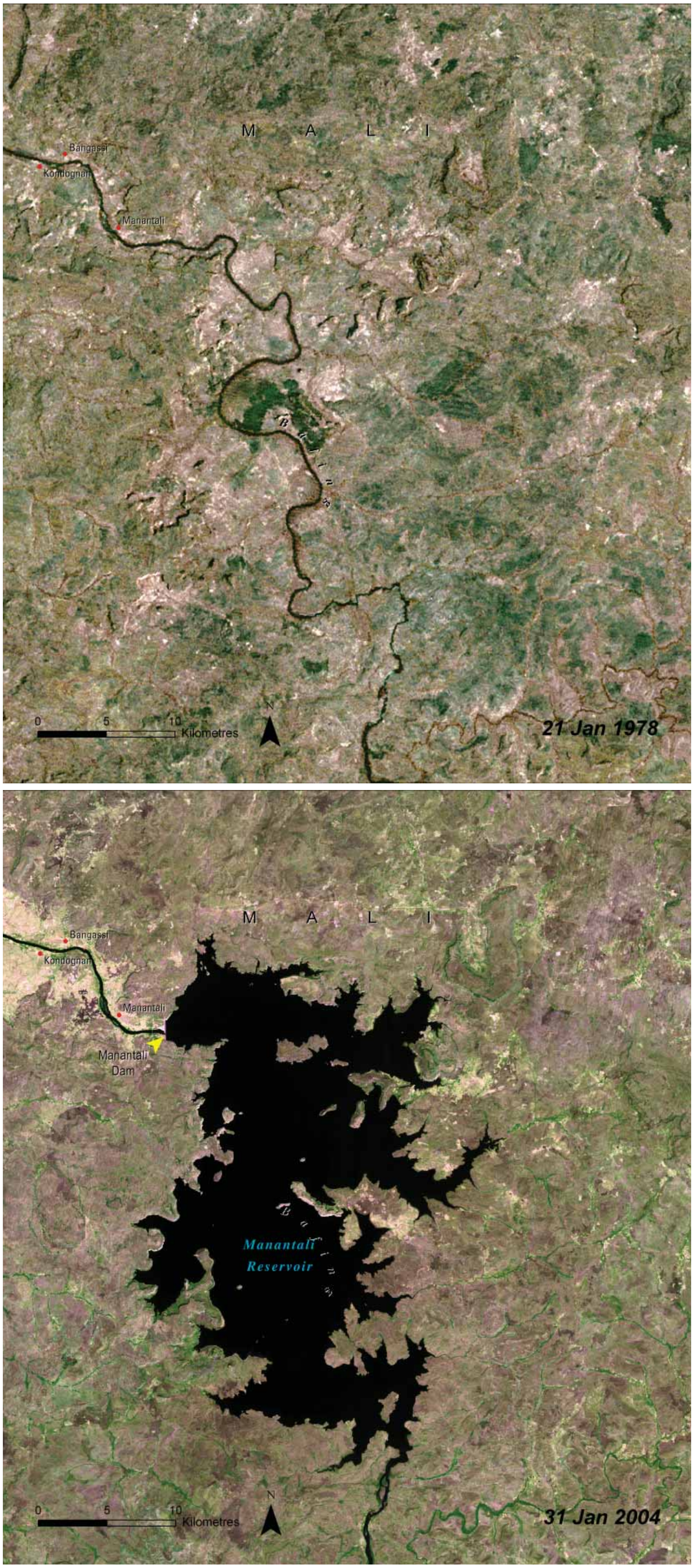


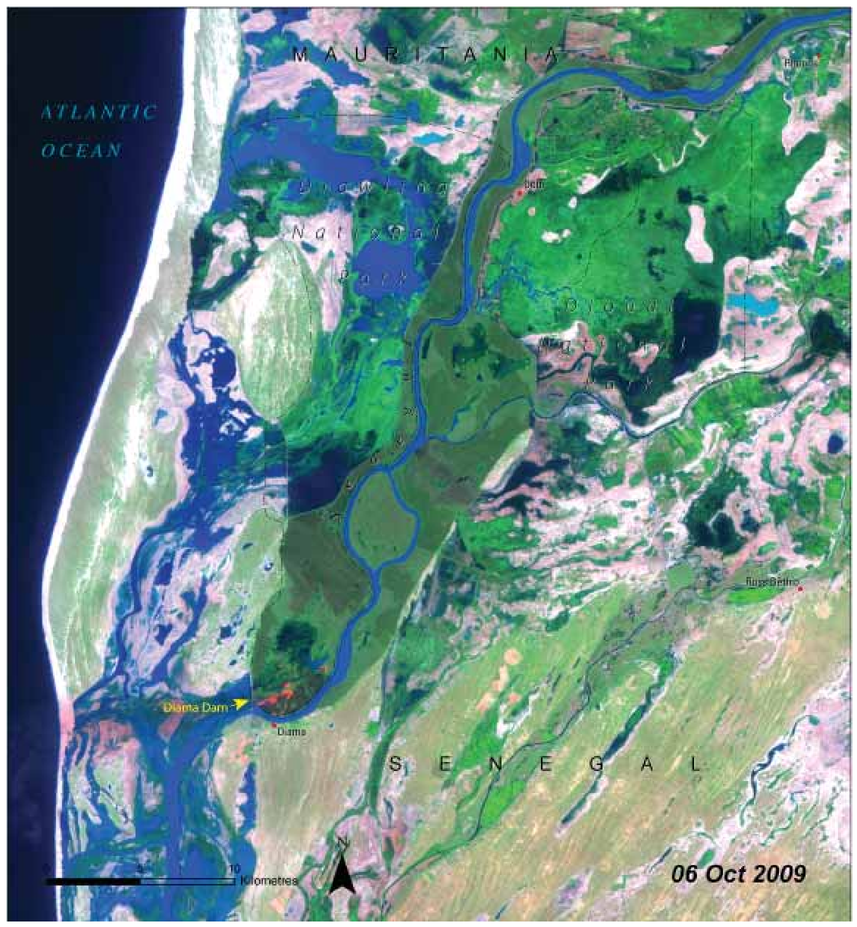
Figure 2.12.7: The Manantali Dam in the Senegal River Basin



Manantali Dam

Prior to 1981, the Bafing River flowed through western Mali, rising and falling with the seasonal rainfall at its headwaters in the Guinea Highlands. The Manantali Dam in western Mali was one of two large dams built in the Senegal River Basin in the 1980s by the Organisation for the Development of the Senegal River (OMVS). By collecting the highly seasonal waters of the Bafing River, the dam limits extreme floods, stores wet-season flow for irrigation, and provides hydropower to OMVS-member countries (Figure 2.12.7). However, it has also displaced approximately 12 000 people, contributed to the loss of riverine forest along the lower reaches of the river and disrupted traditional flood-recession agriculture (IR 2009, Tappan and others 2004).

Figure 2.12.8: Years of drought and the construction of two dams brought the Djoudj and Diawling wetlands to a low point in the 1980s. After changes in artificial impoundments and water flows, the wetlands rebounded



Djoudj and Diawling Wetlands

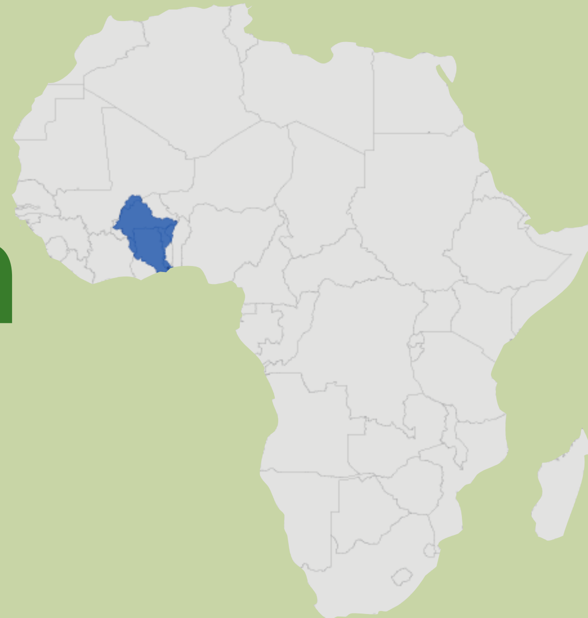
Prior to construction of the Diama and Manantali dams, dry season tides could be detected up to 470 km upstream of the ocean bringing salt water influence up to 300 km inland of the Senegal River mouth (Isupova and Mikhailov 2008). Then, in August of each year during the Senegal River's peak flow, floods would flush much of the delta with freshwater from the annual monsoons (Duvail and Hamerlynck 2003). The alternating brackish and freshwater environment created a unique wetland system that supported rich natural habitats and traditional livelihoods including fishing, grazing, agriculture, and the production of artisanal mat-making (Duvail and Hamerlynck 2003, Fall and others 2003). Natural habitats thrived throughout history under this hydrological regime, including mangroves, saltmarshes, lagoons, acacia woodlands, and floodplain grasses (Fall and others 2003, WMO 2004, Isupova and Mikhailov 2008).

In Figure 2.12.8, the 1984 satellite image of the Diawling and Djoudj area shows the wetlands in decline under the influence of the 1970s and 1980s droughts, which also created a food crisis. The Senegal Basin countries in response to this crisis proposed to develop intensive-irrigated rice production by building two dams on the river. The dams, completed in 1985 and 1988, were to facilitate development of irrigated agriculture, hydropower and river transport, although irrigation in the delta has been less widespread and less productive than planned (Duvail and Hamerlynck 2003, Poussin and Boivin 2002, OMVS n.d., FAO 1997).

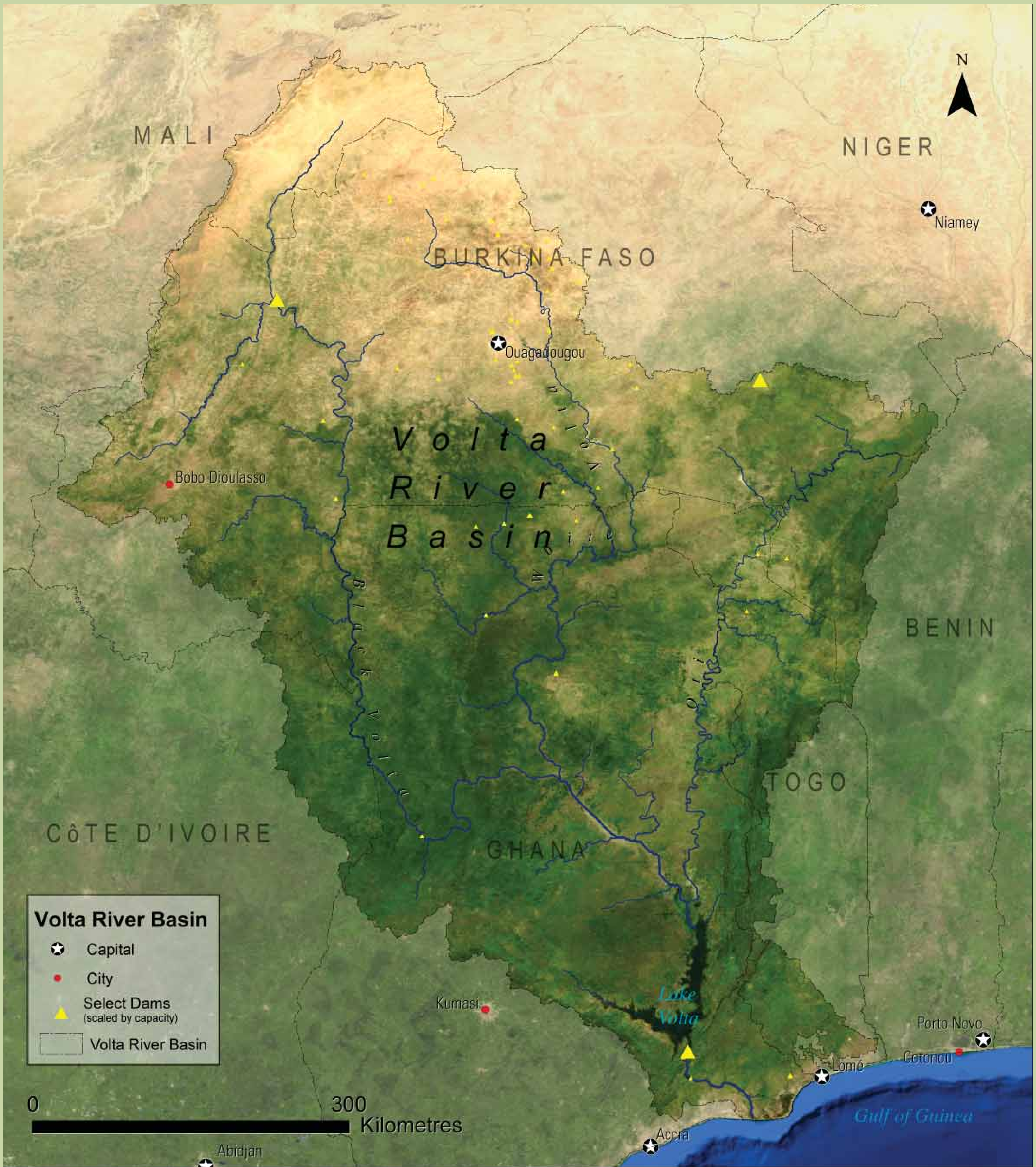
The dams also change the delta's natural hydrological patterns with several negative impacts on the natural environment and the local communities that relied on their ecosystem products and services (Duvail and Hamerlynck 2003). In the area of Diawling, fish stocks decreased and much of the wetland vegetation disappeared (Bâ Amadou 2004). Upstream of Diama Dam, the change to an all-freshwater regime led to invasive plant species overtaking much of the natural vegetation (Mietton and others 2007). Invasive species posed such a threat that UNESCO listed Djoudj on its List of World Heritage in Danger (UNESCO n.d).

Beginning in the early 1990s, changes in the hydraulic infrastructure and dam management allowed controlled water releases to better mimic previously existing conditions (Duvail and Hamerlynck 2003b). The wetlands in the Diawling area have substantially recovered. While invasive species in Djoudj continue to be a concern, UNESCO removed Djoudj National Park from its List of World Heritage in Danger in 2006 following mitigation efforts that include biological controls. In the 2009 image, the wetlands on both sides of the river are lush with vegetation following changes in the dams and their operation and a period of improved rainfall.

Volta River Basin



The Volta Basin lies across parts of six countries in West Africa. Burkina Faso and Ghana each make up approximately 40 per cent of the basin. About eight per cent lies in Togo and the remaining 12 per cent is divided between Benin, Côte d'Ivoire and Mali.



The Volta Basin lies across parts of six countries in West Africa

Akosombo Dam

Despite their relatively small area in the basin, Benin and Togo make significant contributions to the river's water budget by virtue of their location in areas where rainfall exceeds evapotranspiration.

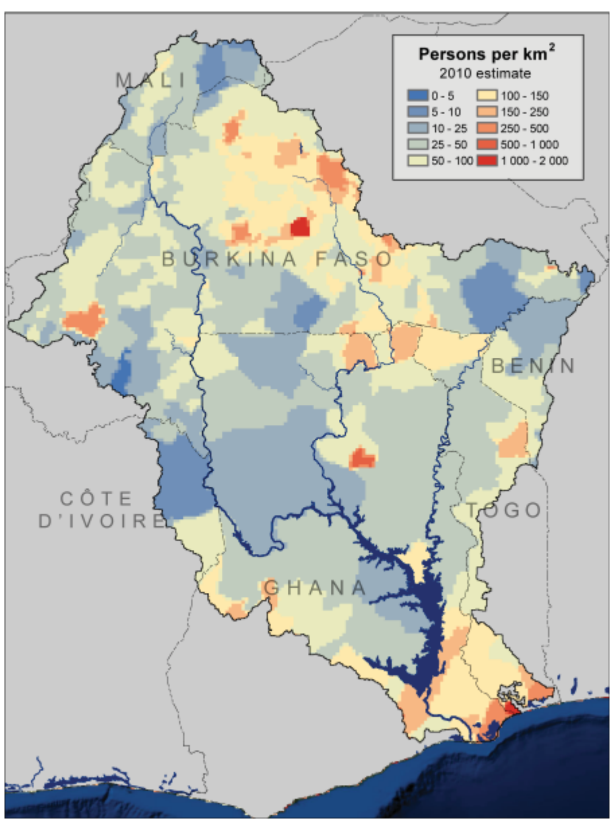
The Volta River has many tributaries but the principal streams feeding its flow are the Oti (Pendjari) River, The Black Volta, Red Volta, and White Volta. The largest of these is the Oti, which originates in northwest Benin where annual rainfall is generally above 1 000 mm. It yields around one-third of the Volta River System's annual flow (Barry and others 2005). The Black and White Volta Rivers originate in Burkina Faso. Many of the smaller tributaries dry up during arid periods of most years. All of the major streams converge in Ghana and eventually in Lake Volta, the largest man-made lake in the world, formed by the Akosombo Dam built in the 1960s.

Precipitation

The basin has pronounced wet and dry seasons with two distinct rainy seasons in the more humid south and a single rainy season peaking in August further north (Boubacar 2005). Average annual rainfall generally decreases from south-to-north with areas in eastern Ghana and Western Togo receiving some of the heaviest rainfall—as high as 1 500 mm/yr in some locations. Togo's portion of the river basin receives the highest mean annual precipitation with an average of 1 262 mm. Ghana also receives over 1 200 mm/yr across its part of the basin. The driest part of the basin lies in Mali at the far northern extreme where rainfall averages about 540 mm/yr (Figure 2.13.1).

High rates of evapotranspiration across most of Burkina Faso and Ghana leave little excess runoff to contribute to the river's flow. The largest contributions come from Togo and Mali followed by Ghana and Benin. Both Burkina Faso and Côte d'Ivoire have a negative impact on the basin's water budget due to evapotranspiration rates that exceed annual rainfall (Figure 2.13.2).

Figure 2.13.3: Volta River Basin population density



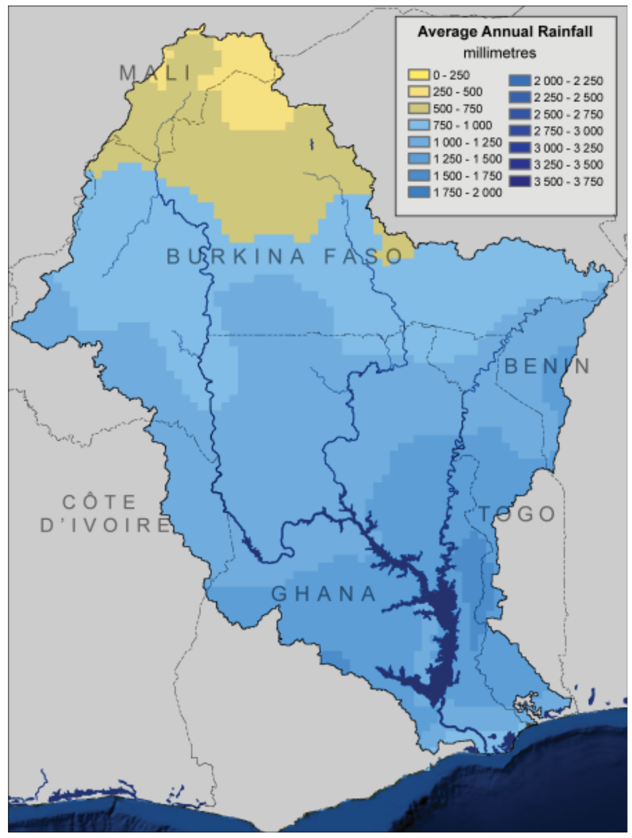


Figure 2.13.1: Volta River Basin average annual rainfall

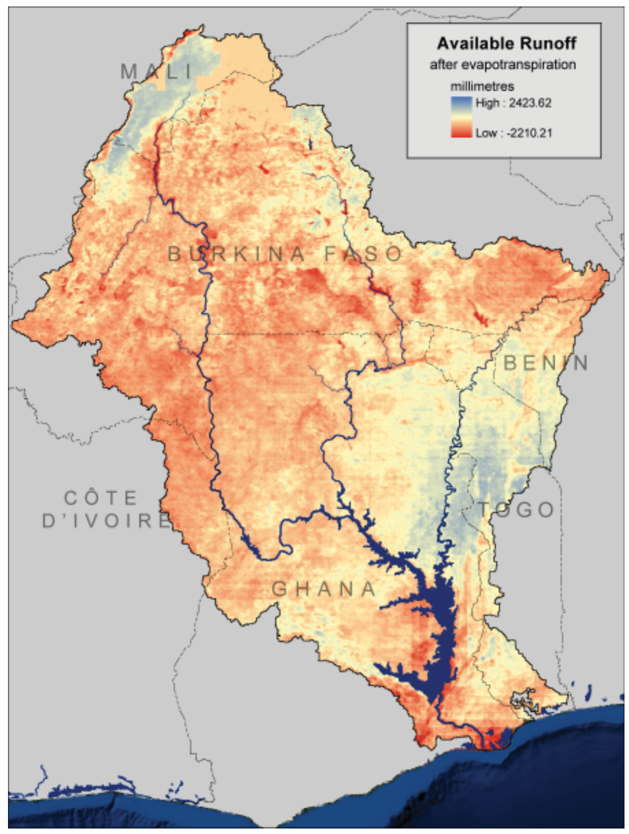


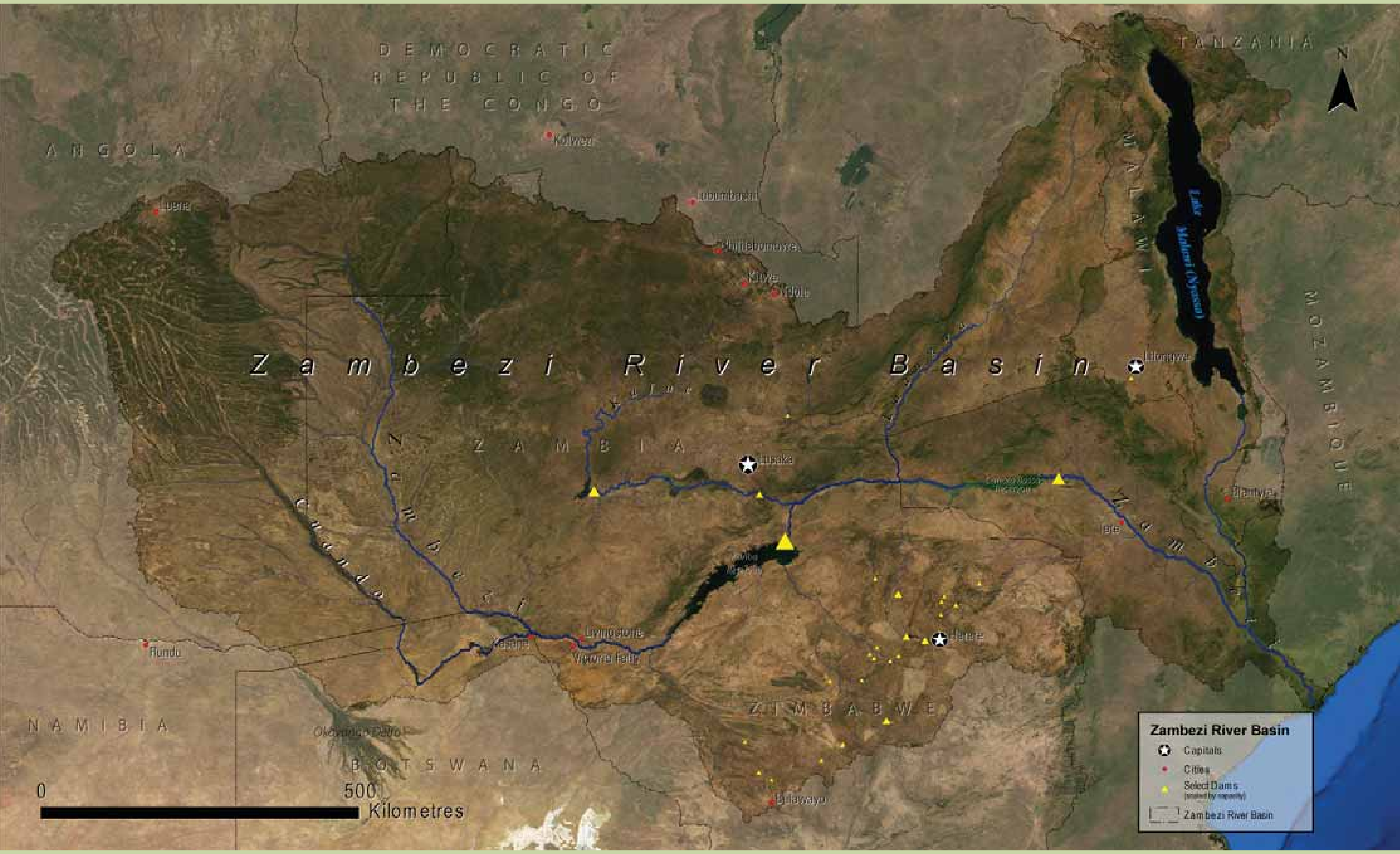
Figure 2.13.2: Volta River Basin modeled available runoff

Population

Approximately 28 million people live in the Volta Basin. The two countries with the largest area in the basin also have the most people—Burkina Faso with 13 million and Ghana with almost 10 million people. Togo has the highest population density in its portion of the basin at 116 persons per km² while Côte d'Ivoire's part of the basin has only 26 persons per km² (Figure 2.12.3).

Zambezi River Basin

The Zambezi River begins approximately 1 200 m above sea level in the Kalene Hills, where the borders of eastern Angola, northwestern Zambia and southern DRC meet. As it flows through Angola and northwestern Zambia, the landscape is generally dominated by miombo woodlands with networks of grassy wetlands along drainage lines and riverine forests along larger streams.



Over 40 million people make their home within the Zambezi basin

Tributaries enter along both banks, draining portions of eastern and southeastern Angola and northern Zambia onto a low-gradient area that forms the Barotse floodplain. Following the Ngonye Falls, the river steepens as it continues to collect tributaries, including the Cuando-Chobe River that drains southern Angola and Namibia's Caprivi Strip. Three hundred kilometres downstream, the river drops a dramatic 100 m forming Victoria Falls and marking the beginning of the river's middle section. Below Victoria Falls, the gradient steepens sharply, the flow accelerates, rapids rise, and the river makes a series of sharp turns for several kilometres (Moore and others 2007). It then widens and continues along the border between Zambia and Zimbabwe, expanding dramatically as it enters Kariba Reservoir. Downstream by 200 km, the Zambezi enters Mozambique and flows into the Cahora Bassa Reservoir. Below this, the gradient levels out again as the river crosses the coastal plain. Below the Shire River, the Zambezi crosses another area of floodplains before reaching the delta and emptying into the Indian Ocean.

Population

A total of over 40 million people make their home within the Zambezi basin. While only eight per cent of the basin's area is in Malawi, over 13 million people or one-third of the basin's mostly rural population lives there. Both Zambia and Zimbabwe have roughly ten million of their people living within the basin. Several of the region's largest cities and urban agglomerations are within the basin including Lusaka and the copperbelt cities of Zambia as well as Harare and Bulawayo in Zimbabwe and Lilongwe and Blantyre in Malawi. Countrywide growth rates in Malawi, Tanzania, and Angola are high by global standards. Most growth within the basin since 1990 has occurred in Malawi, however, and in the already large urban areas. Malawi's population growth rate peaked in the late 1980s at over six per cent annually but has since declined to a little over 2.5 per cent (Figure 2.14.1).

Precipitation

Annual precipitation throughout most of the basin is adequate to support rain-fed agriculture. It generally decreases to the south and west from a high of over 1 700 mm/yr in northern Malawi to parts of Botswana, Namibia and Zimbabwe where the average is just over 500 mm/yr. Rainfall is quite variable spatially and from year-to-year, especially in parts of the eastern edge of the basin and particularly in eastern Malawi and western Mozambique. Over 42 per cent of the Zambezi Basin falls within Zambia, and occupies about three-quarters of the country. Zambia's annual average rainfall ranges from over 1 500 mm in some northern areas to the 650 mm range across its southern border. Precipitation averages 950 mm across Zambia's portion of the basin, contributing nearly half of the river's inflow. Angola accounts for roughly one-fifth, with Malawi, Mozambique and Zimbabwe supplying nearly all the remaining inflow (Senay 2009) (Figure 2.14.2, Figure 2.14.3).

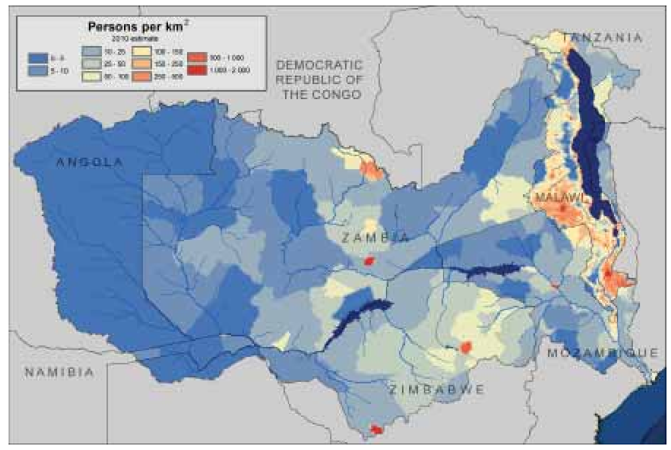


Figure 2.14.1: Zambezi Basin population density

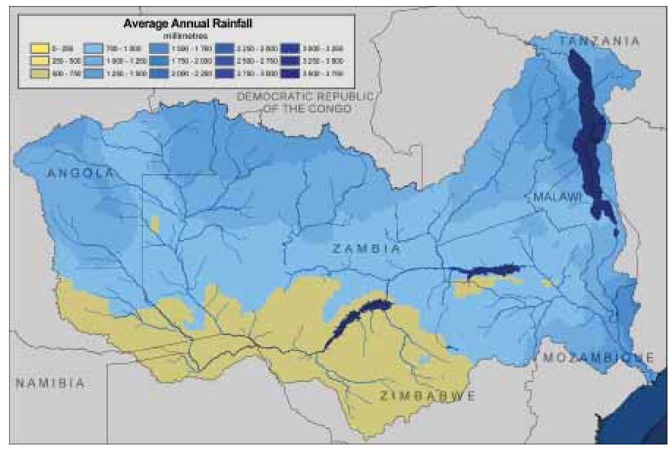


Figure 2.14.2: Zambezi Basin average annual rainfall

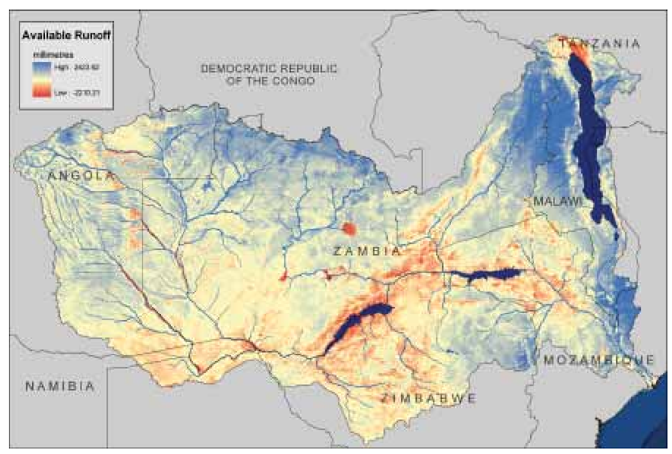


Figure 2.14.3: Zambezi Basin modeled available runoff

Rainfall is very seasonal throughout the basin, peaking in December and January, and declining to very little precipitation during the austral winter months (Chenje 2000). The timing and amount of rainfall has a very significant impact on the region's highly agriculturally based economies (Manatsa and others 2008, IFPRI 2009). The 20th century precipitation records indicate that drought was frequent and severe, following a broad 10 to 15 year precipitation cycle (Manatsa and others 2008, Nicholson and Kim1997).

Kariba Dam viewed from the Zimbabwe side of the Zambezi

Kariba Dam

Kariba was the first of the large dams built on the Zambezi River. The river's water began filling it at the end of 1958 (Beilfuss 2006). The dam has an installed power capacity of 1 350 MW and creates a reservoir covering 5 580 km^2 (Magadza n.d.). It is so large that it has increased seismic activity in the valley, causing many small earthquakes since the lake was filled (Magadza n.d.). The filling of Kariba displaced 57 000 people (ETH 2004, McDermott-Hughes 2006, Scudder 2006). Relocation is generally considered to have been poorly handled leaving most of the displaced much worse off (Magadza 2006, Magadza n.d., ETH 2004, Scudder 2006).

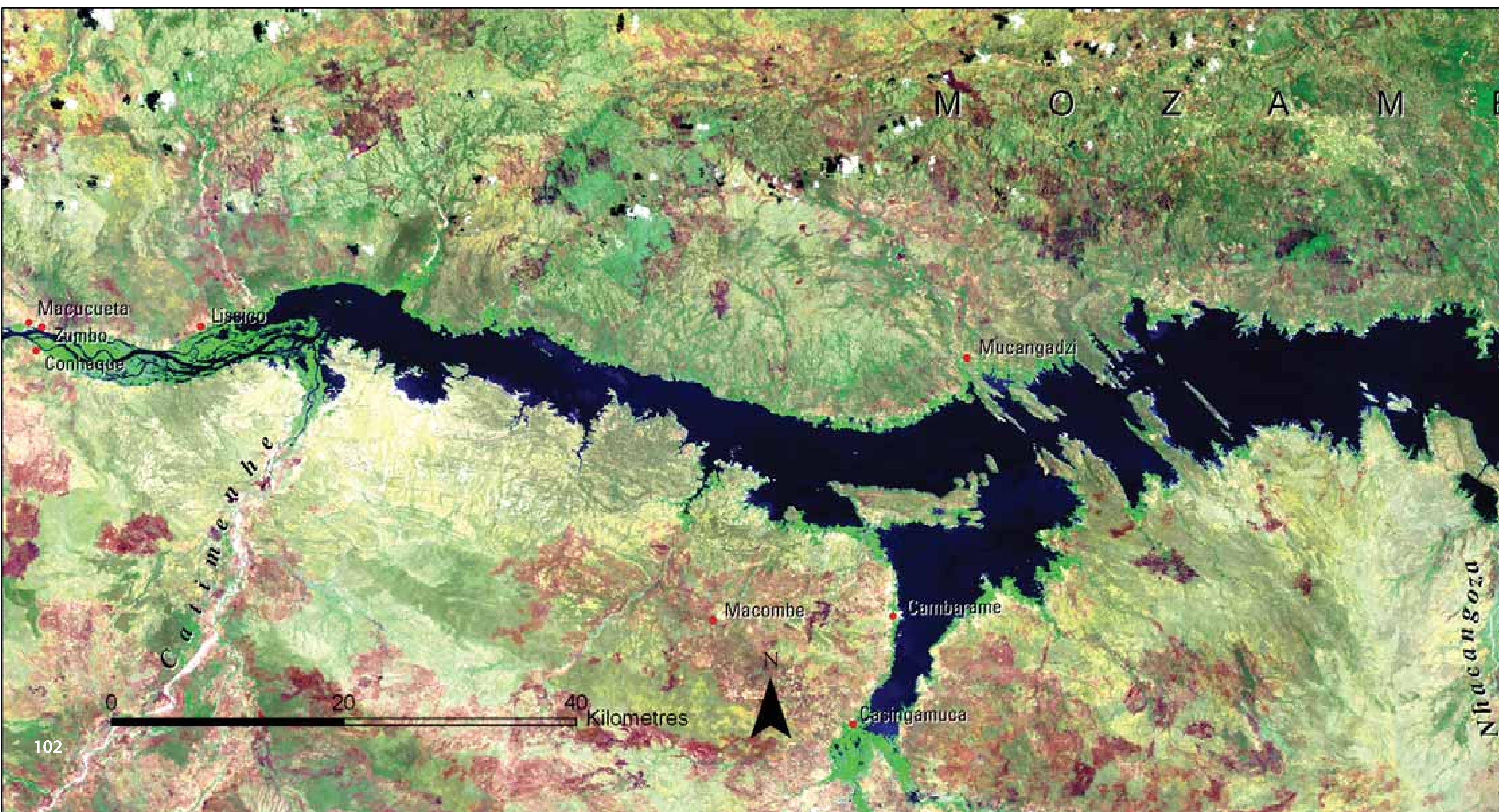
Kariba Dam regularized the river's flow and began changing downstream flooding patterns. This had a negative impact on several natural systems downstream of the dam, especially wetlands, including the delta area (Scudder 2005, Beilfuss 2006). The loss of natural flooding patterns also adversely affected the coastal shrimp fishery in Mozambique (Scudder 2005). In addition, the reservoir has suffered invasions of *Salvinia molesta* and water hyacinth (Marshall 1981, Magadza 2006).

Kariba's power generation has been very important for Zambia and Zimbabwe's development, supporting large industries such as the mines in Zambia's copperbelt (Magadza 2006). In addition, a productive artisanal and industrial fishery has been developed in Lake Kariba (Ngalande 2004). The new large water environment was not ideal for the native fish species and left large parts of the new habitat unutilized. A species of fish from Lake Tanganyika, known locally as kapenta, was introduced into the lake and quickly colonized the open niche (Magadza 2006). While the fisheries benefits have not fallen equally to all groups, the catch has been substantial, averaging around 9 000 metric tonnes between the mid 1980s and 2000 (Ngalande 2004).

Water Development

Four major dams in the Zambezi Basin regulate the river's flow and generate much of the area's electricity. The Cahora Bassa Dam and the Kariba Dam are on the Zambezi itself, while the Kafue Gorge Dam and Itezhi-Tezhi Dam are on the Kafue River in Zambia—one of the Zambezi's main tributaries. All four dams have generated some degree of controversy regarding their environmental and human impact (IR 2006). Proponents argue that the electricity generated is crucial to the development of basin countries. This fact is generally not disputed but opponents argue that the environmental and human costs have been unnecessarily high due to improper planning and management, and that the costs and benefits have not accrued equally to all stakeholders (Morrissey 2006).

Figure 2.14.4: Cahora Bassa dam and reservoir



Cahora Bassa Dam in western Mozambique

Cahora Bassa Dam

Cahora Bassa Dam was constructed in 1974 under the control of the Zambezi Valley Planning Authority. It was intended to provide hydropower generation, navigation, irrigation and water for mining and industry. Cahora Bassa's closure, along with other upstream impoundments, further regularized the flow. The dam has primarily been managed to produce hydroelectric power, most of it for sale to South Africa and to a lesser extent to Zimbabwe. This hydropower will likely to be reduced to below optimal levels should all the dams along the Zambezi be managed to mimic natural flooding to benefit affected ecosystems (Beilfuss 2006) (Figure 2.14.4).

The dam's human and environmental costs include a decline in coastal fisheries, loss of mangroves along the coast, changes in wetland vegetation, increased disease carrying insects and invasive plants. Project evaluations prior to the dam's closing anticipated these impacts and recommendations that would have minimized these costs were not followed in the early days of the dam's operation. Recent studies recommended flow management to restore some of the river's pre-impoundment functions by simulating natural flow variations (Davies 2000, Beilfuss 2006).

Further dams are planned, including the Mphanda Nkuwa Dam roughly113 km downstream of Cahora Bassa. Its hydroelectric facility will have an installed capacity of 1 300 MW (UTIP n.d.). This electricity is intended to facilitate development in Mozambique but initially the bulk of it will be sold to South Africa (IR 2006). Several NGOs and researchers have raised concerns over the project's environmental and human costs (Beilfuss 2006, IR 2006).

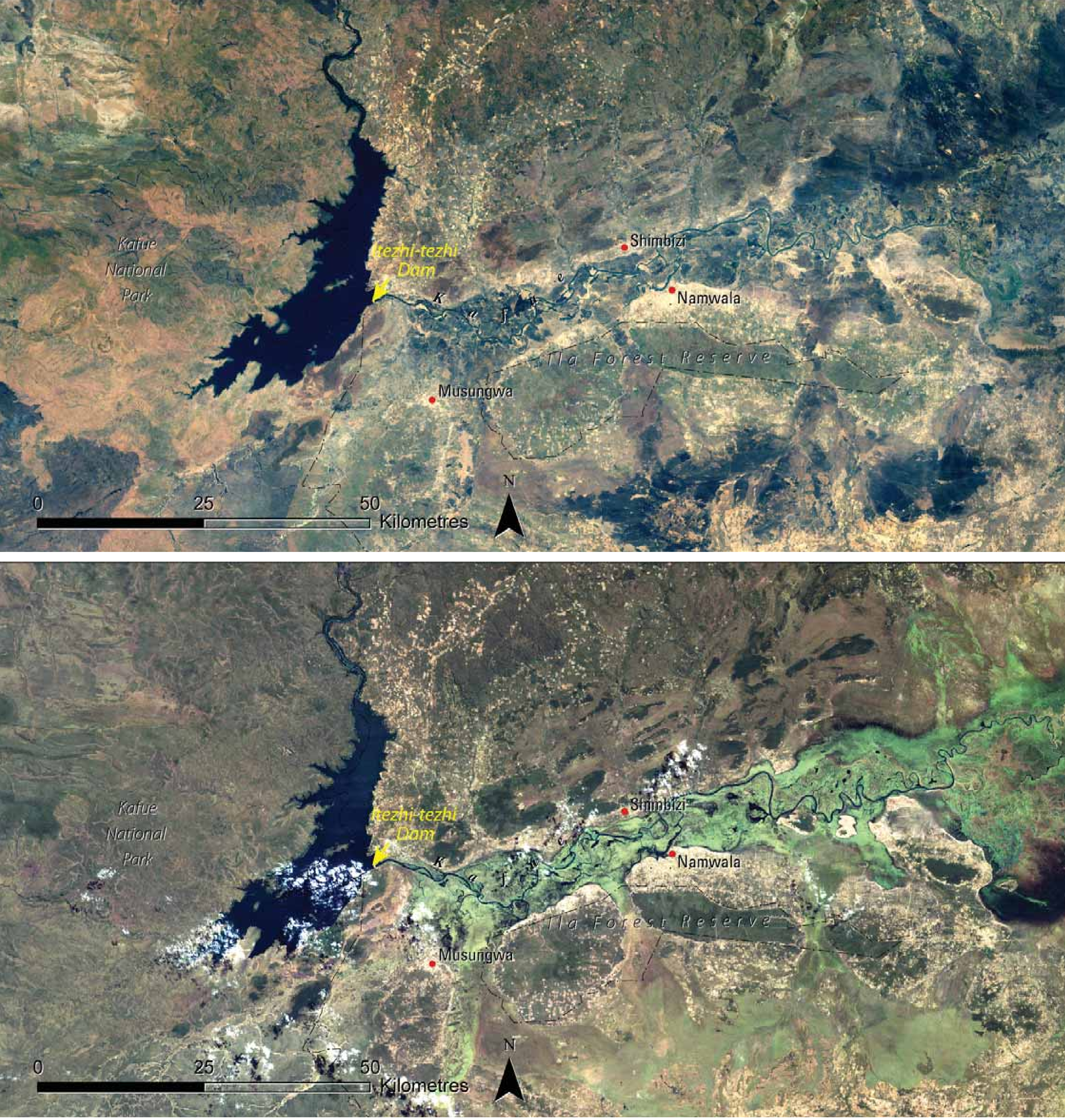
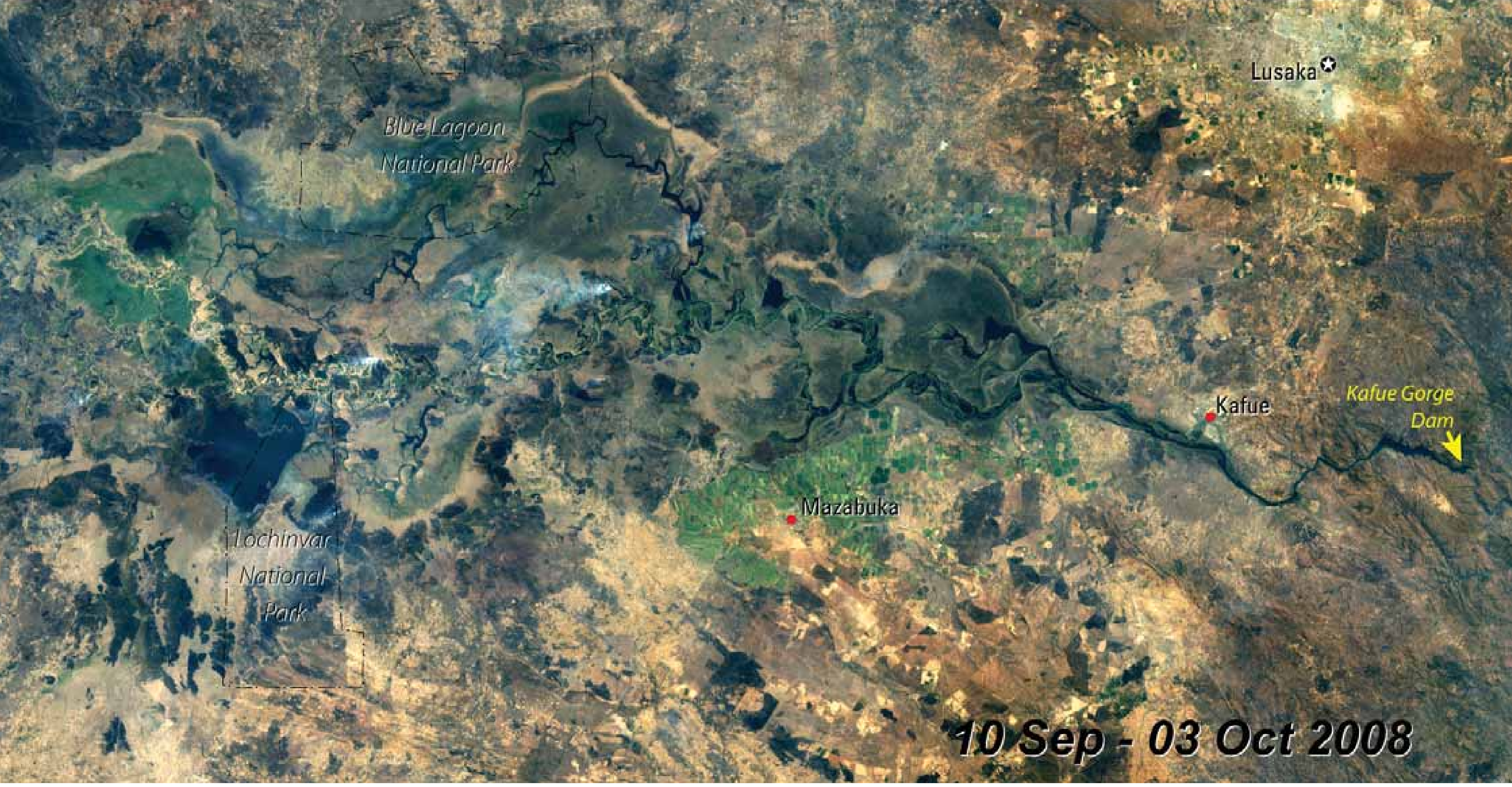
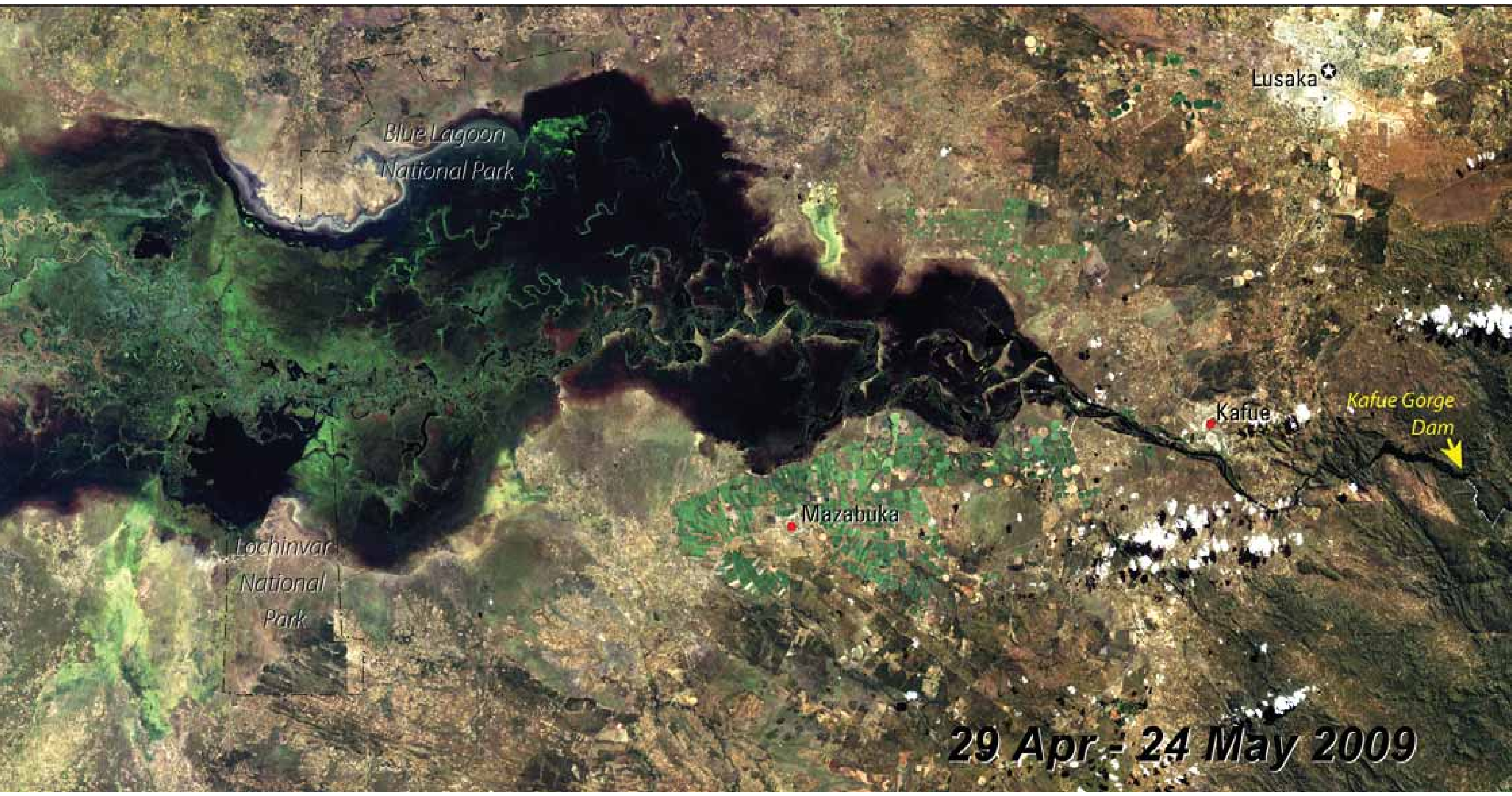


Figure 2.14.5: Kafue Flats before and after water release

Kafue Flats

The Kafue River, one of the Zambezi's main tributaries, crosses a broad floodplain roughly 255 km long as it passes between the Itezhi-tezhi dam and the Kafue Gorge Dam. Before the Itezhi-tezhi Dam was built on the river in 1978, flooding began in December and would cover much of the plain well into the dry season. Although the dam was built to allow the release of sufficient water to mimic natural seasonal flooding, it is not clear to what extent this was done in the past. This floodplain provides important habitat for rare and endemic species, including the Kafue lechwe and wattled crane, and supports local livelihoods, especially cattle-raising and fishing (Schelle and Pittock 2005). Limited





seasonal flooding following the dam's construction has been linked to a decline in fish production and reduced numbers of Kafue lechwe. The number of lechwe fell from around 90 000 before the dam was built to around 37 000 in 1998 (CEH 2001).

In 2004, a partnership between World Wildlife Fund, the Zambian Ministry of Energy and Water Development, and the Zambian Electricity Supply Company put new rules in place so that water releases from the dam mimic natural flooding patterns (WWF 2007).

The 2008 satellite image in Figure 2.14.5 is from the dry season when floodwaters have generally receded. The 2009 image from seven months later shows the extent of the annual floods during the wet season, aided by managed releases.

Transboundary Aquifers

Just as there are internationally shared river basins, there are also internationally shared, or transboundary, water resources and aquifers hidden underground. Some of the world's transboundary aquifers contain huge freshwater resources, enough to provide safe and good-quality drinking water for the needs of all humanity for decades (UNESCO 2001) (Figure 2.15.1). Generally, aquifer systems contain excellent quality water, due in part to their relative isolation from surface impacts. The hidden nature of transboundary groundwater and lack of legal frameworks to manage them, however, also invite misunderstanding by many policy makers. Not surprisingly therefore, transboundary aquifer management is still in its infancy, since groundwaters are difficult to evaluate and there is a lack of institutional will and finances to collect the necessary information. Although there are fairly reliable, detailed estimates of the water resources in rivers shared by two or more countries, no equivalent estimates exist for transboundary aquifers (Salman 1999).

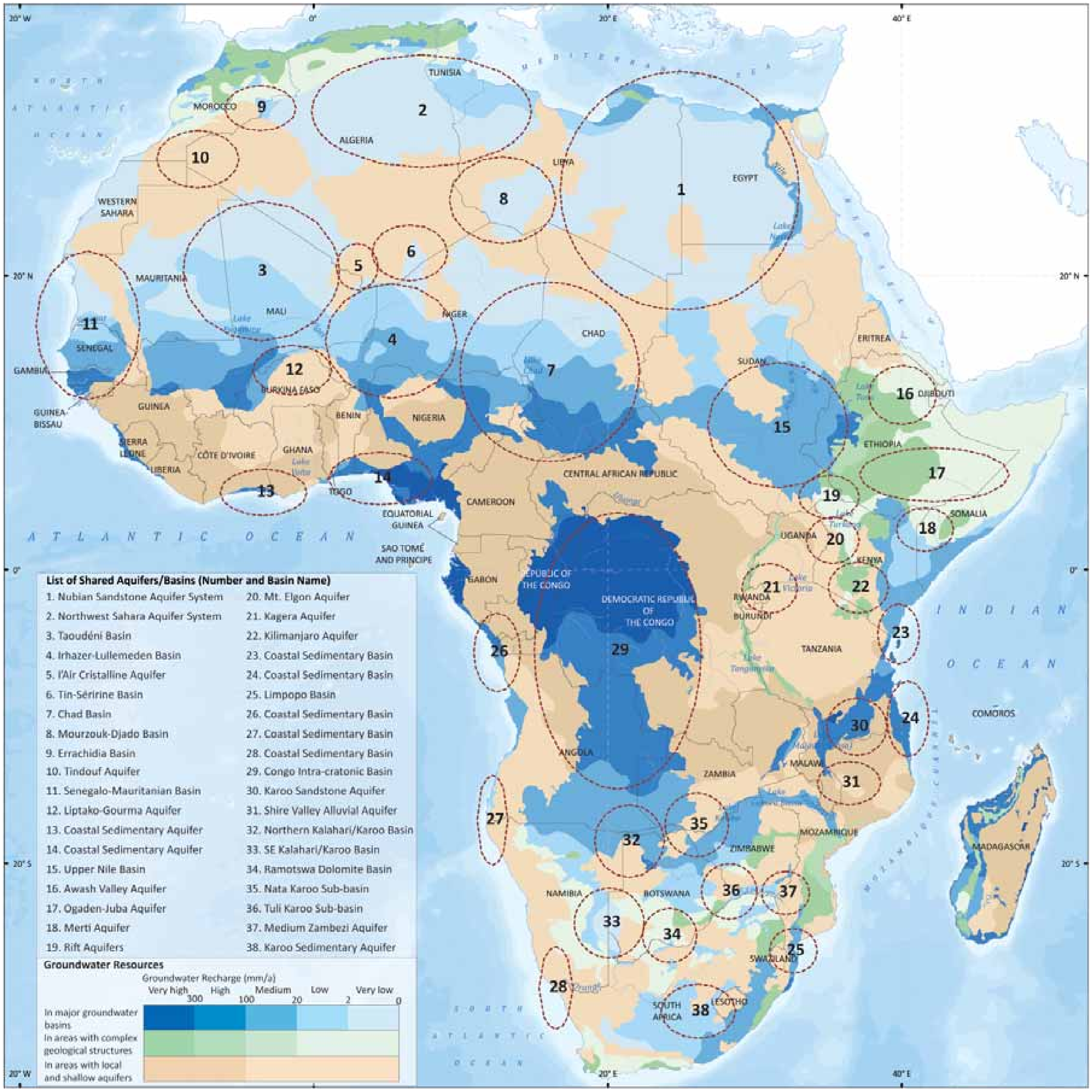
In Africa, groundwater is an important source of freshwater and it is essential to supplement the surface water resources in a region that is increasingly

Erwin Bolwidt/Flickr.com

affected by recurrent drought. Africa is endowed with large and often under-utilized aquifer resources, predominantly in the large shared subregional sedimentary systems of the Sahara and Central and Southern Africa. There are also significant shared coastal aquifer resources that supply the large urban populations concentrated in rapidly growing coastal areas (Figure 2.15.2).

Large shared aquifer resources often represent the only source of drought security and life sustenance for large populations in semi-arid areas. While the linkages between surface water and groundwater are critical to aquifer recharge, the watersheds in many aquifer recharge zones are threatened by accelerated land degradation and

Figure 2.15.1: Transboundary aquifers (Source: adapted from UNESCO-IHP/ISARM 2004)



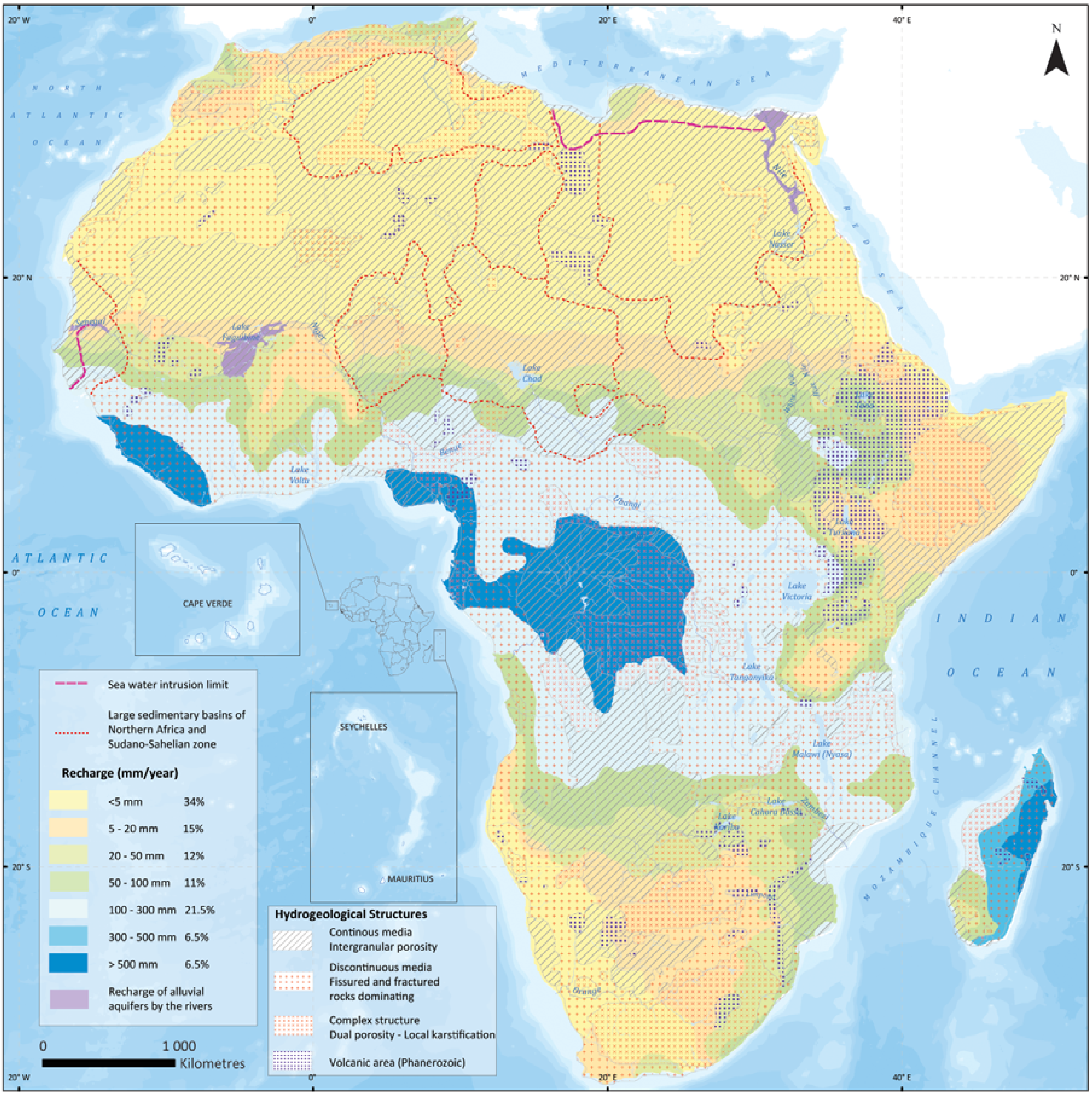
desertification, reduced seepage and in irrigated areas, by water logging and salinization. These threats, which affect very large land areas, have reached a sub-regional and transboundary scale in Africa (UNESCO 2004).

The Sahara and central and southern African sub-regional sedimentary systems dominate transboundary aquifers in Africa. From north-to-south the systems include the Saharan-Libyan, the Sahel Basin with the Taoudenni, the Iullemeden, the Chad and the Congo, and in southern Africa, the Kalahari and the Karoo. These largest aquifer systems are predominantly located—and are of highest importance—in the continent's arid and semi-arid dryland zones, which are continuously threatened by accelerated land degradation, loss of productive land, and human-induced desertification. Thus, management issues and the transboundary implications extend beyond water balance and control of the hydraulic systems to include land use and protection in recharge and discharge areas. In addition to sub-regional aquifers, there are also a multitude of local transboundary systems shared by two or more adjacent countries (UNESCO 2004).

Groundwater Case Studies

As with surface water basins, it is useful to approach groundwater at a basin scale. While aquifer systems are generally not as well defined as river and lake basins, there are many common interests among people living over shared groundwater resources. These include developing an adequate scientific basis of understanding of the resource, protecting water quality and ensuring sustainable and equitable use.

Figure 2.15.2: Hydrogeological structures (Source: adapted from BRGM 2005)



Nubian
Sandstone Aquifer

The Nubian Sandstone Aquifer System underlies virtually all of Egypt, much of eastern Libya, and significant areas of northern Chad and northern Sudan (CEDARE 2001). It can be broadly described as two distinct aquifer systems vertically separated by layers of lower permeability that allow some upward leakage (Alker 2008). The deeper Nubian Sandstone Aquifer System is older and extends to the entire area while the Post Nubian Aquifer System lies above that in more recent geological formations and covers roughly the northern half of the larger system (CEDARE 2001).

People have been extracting groundwater to a limited degree for thousands of years in the North African desert (Shahin 1987). Historical rates of use, however, are relatively insignificant compared to the current rate of abstraction in the Nubian Sandstone Aquifer System, which has increased by roughly 500 per cent since the early1960s when large-scale development began (Bakhbakhi 2006) (Figure 2.16.2). Models of the aquifer's water budget show that the current scale of groundwater use and the increased rate

Figure 2.16.1: Nubian Sandstone Aquifer

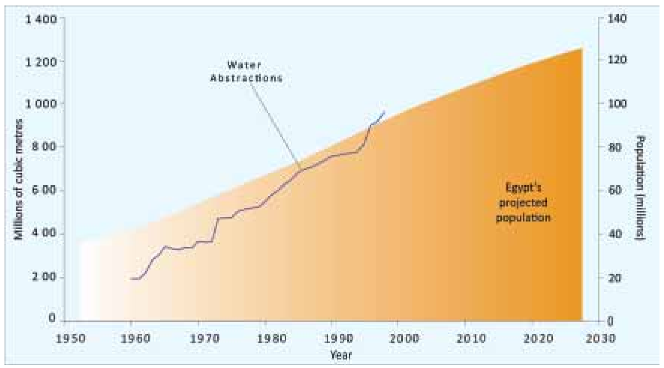


Figure 2.16.2: Water abstraction by population (Source: CEDARE 2001)

of groundwater decline will significantly exceed historical rates (Ebraheem and others 2003).

While it is clear that the aquifer system holds an enormous reserve of water, estimates vary considerably as to the amount—from as little as 15 000 km^3 (Alker 2008) to 135 000 km^3 (Gossel and others 2004), to as much as 457 570 km^3 (Bakhbakhi 2006). It is generally believed that the aquifer's water dates from wetter climates in the past (5 000–10 000 and 20 000–25 000 years BP) and that no significant recharge is taking place under current climate conditions (Gossel and others 2004, CEDARE 2001, Ebraheem and others 2003). Experts generally accept that the system has not been in equilibrium for thousands of years and that groundwater levels were already declining well before artificial extraction began (Heinl and Brinkman 1989, Gossel and others 2004). Thus, any water withdrawal from the aquifer under the current climate would be considered "water mining," or a rate that exceeds recharge.

Precipitation

Arid and hyper-arid climate conditions in most of the region dramatically magnify the aquifer's importance. Almost all of the water used by people living above the aquifer comes either from groundwater abstraction or diversion from the Nile. The average annual mean rainfall is less than 50 mm and on average vast areas over the aquifer system receive no measurable precipitation. The wettest area at the northernmost tip of Libya receives around 425 mm of rain. Northern Darfur in Sudan is the wettest area to the south but sees only an average of around 200 mm each year (Figure 2.16.4).

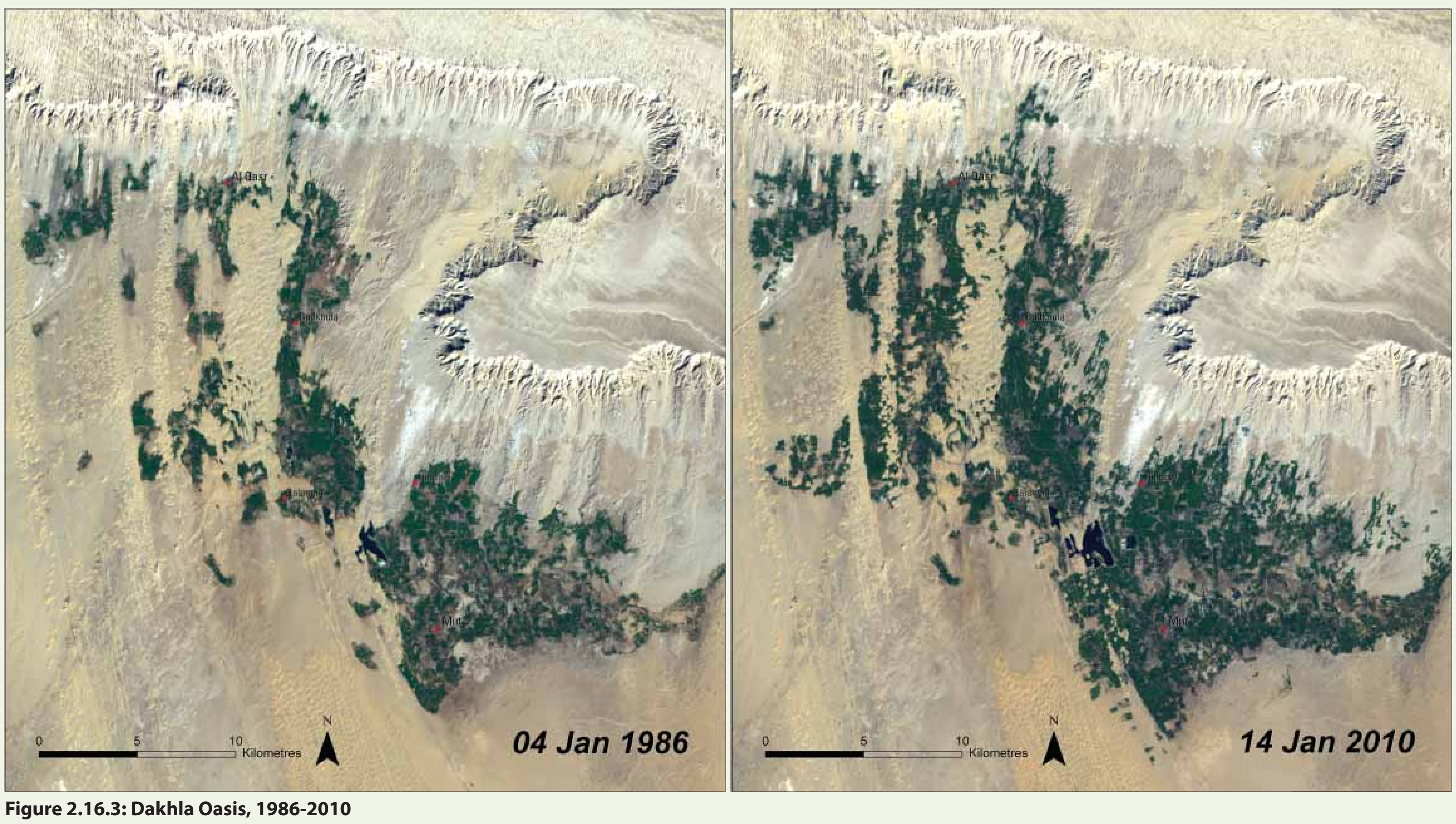


Figure 2.16.3: Dakhla Oasis, 1986-2010

Desert Oasis Development – Dakhla Oasis

Dakhla Oasis lies 300 km west of the Nile and is surrounded by the driest of desert landscapes. Its location over the southern edge of the Post Nubian Aquifer, however, provides access to both shallow and deep wells within the Nubian Sandstone Aquifer System. While it is currently home to fewer than 100 000 people, archeologists believe that the Dakhla Oasis has been continuously settled for around 8 000 years (Dakhleh Project n.d.). Water extraction from the deeper Nubian Sandstone Aquifer at the Oasis has grown ten-fold since 1960 (CEDARE 2001). The related growth in agriculture can be seen in the pair of satellite images that span just a few of those years—1986 to 2010 (Figure 2.16.3). Faced with increasingly crowded populations along the Nile, the Egyptian government has been further developing settlement and agriculture in the Western Desert's oasis. Some studies suggest that the planned rate of abstractions for these areas is unsustainable, however, because it will lead to local depressions in the water table making water more and more expensive to access (Ebraheem and others 2003).

Figure 2.16.4: Nubian Sandstone Aquifer System average annual rainfall

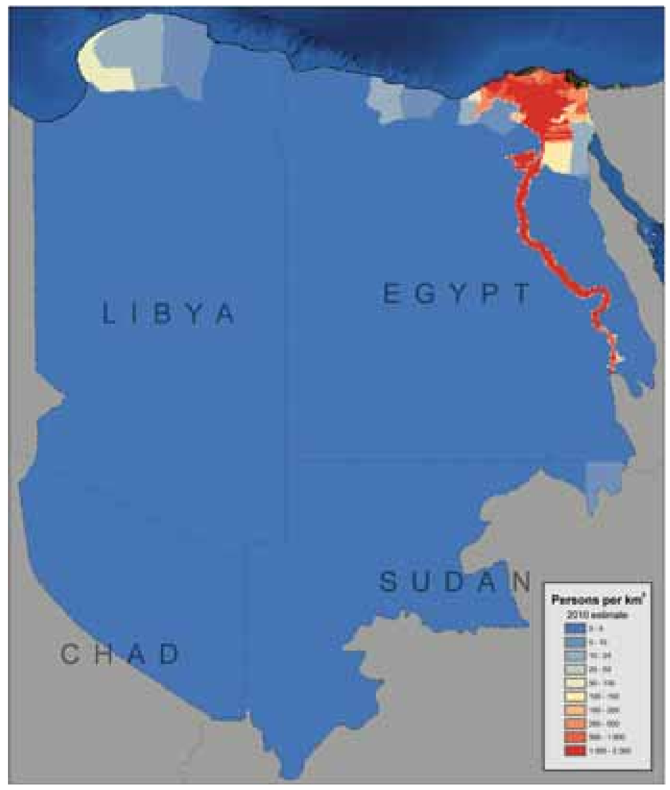


Figure 2.16.5: Nubian Sandstone Aquifer System population density

Population

Egypt's population of over 80 million people makes up almost 98 per cent of the entire population living over the Nubian Sandstone Aquifer System (NSAS) (Figure 2.16.5). Egypt's population has doubled since 1975 and is projected to grow to over 129 million by 2050 (UNESA 2008). This situation alone would mean that by the second half of this century, five times as many people will be sharing the same water resources as in 1960. Because of the Nile Valley's intense concentration of people, the Egyptian Government has been seeking ways to attract people to areas away from the river including regions of well-field development or expansion at East Oweinat, Bahariya, Farafra, and Dakhla, which will rely on water from the Nubian Sandstone Aquifer System (Ebraheem and others 2003).

In addition to the increasing number of users, however, less water will be available to share as levels decline. Modeling of the aquifer system's water balance shows that present extraction rates are responsible for measurable changes in water storage (Ebraheem and others 2003). Furthermore, where heavy pumping occurs, the areas develop depressed cones in the groundwater level, which could make it prohibitively expensive to pump for irrigation in the future (Ebraheem and others 2003).

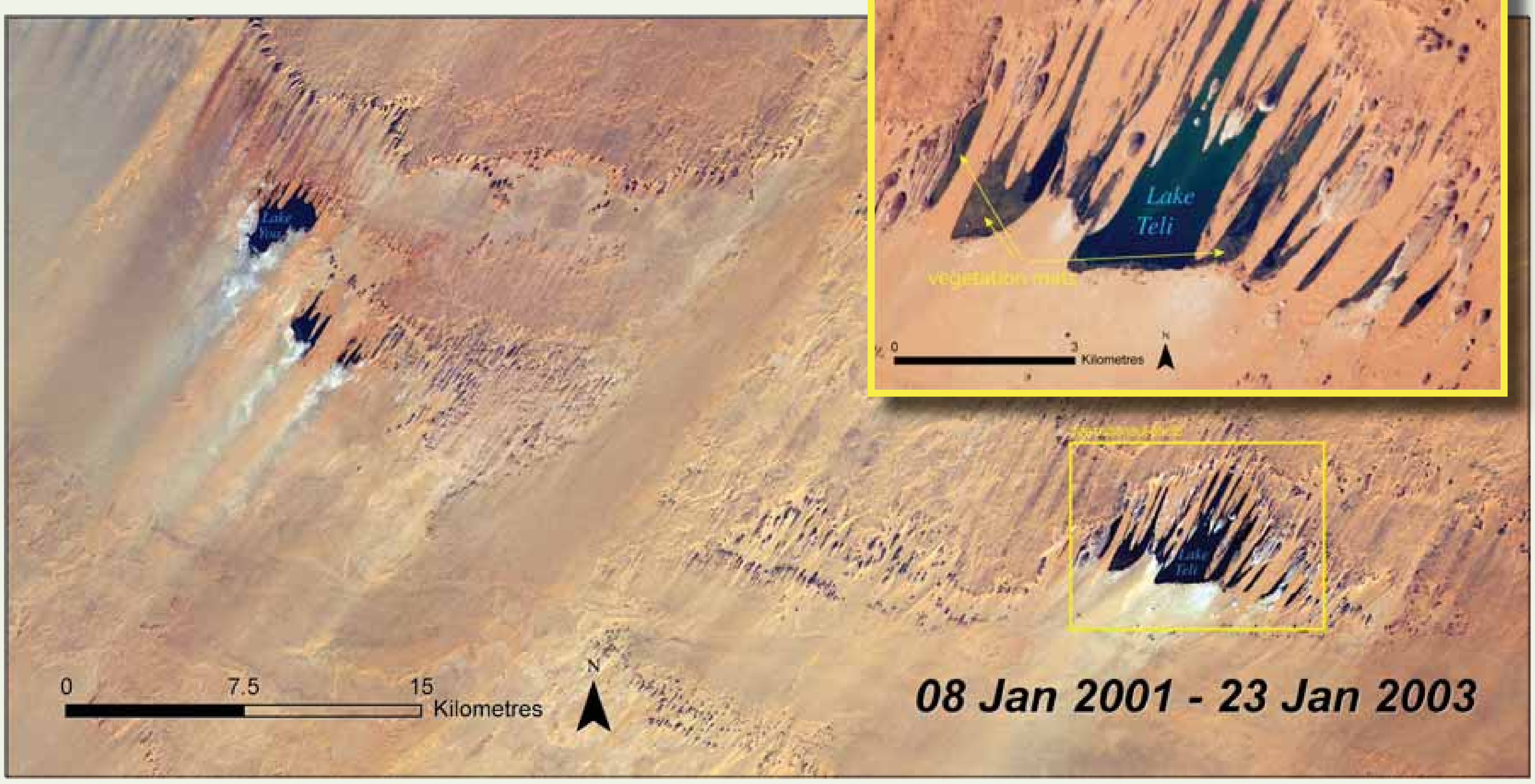
Lake Yoa in the Ounianga Serir Basin lies in the hyper-arid Sahara Desert but is replenished with water from the Nubian Sandstone Aquifer System

Ounianga Basin Lakes in the Sahara

The Ounianga Depression lies in northeastern Chad between the Tibesti and Ennedi mountains, in the middle of the Sahara Desert. The area receives an average of only a few millimetres of rain annually but has an evaporation potential of over 6 000 mm—among the highest in the world (Kröpelin 2009). Nevertheless, a series of lakes survive in the desert here, fed by a continuous supply of water from the Nubian Sandstone Aquifer System (Eggermont and others 2008, Grenier and others 2009, Kröpelin and others 2008). Extreme evaporation in this type of hyper-arid environment typically concentrates dissolved salts making lakes very saline, and the two largest lakes are Lake Yoa and Lake Teli. Several of the smaller lakes surrounding Lake Teli, however, have freshwater due to a unique combination of factors including vegetative mats that reduce evaporation and a pattern of flow that draws freshwater through smaller lakes on its way to the large saline Lake Teli (Kröpelin 2007). The vegetation mats can be seen covering much of the surface of the smaller lakes (Figure 2.16.6).

In spite of the extreme conditions people still live in the Ounianga Serir basin. A village, Ounianga Kebir, is located on the west shore of Lake Yoa (western most lake in satellite image). Salt extraction, date-palm cultivation, and grazing cattle are sources of livelihood (Hughes and Hughes 1992).

Figure 2.16.6: Ounianga Basin Lakes, 2001-2003



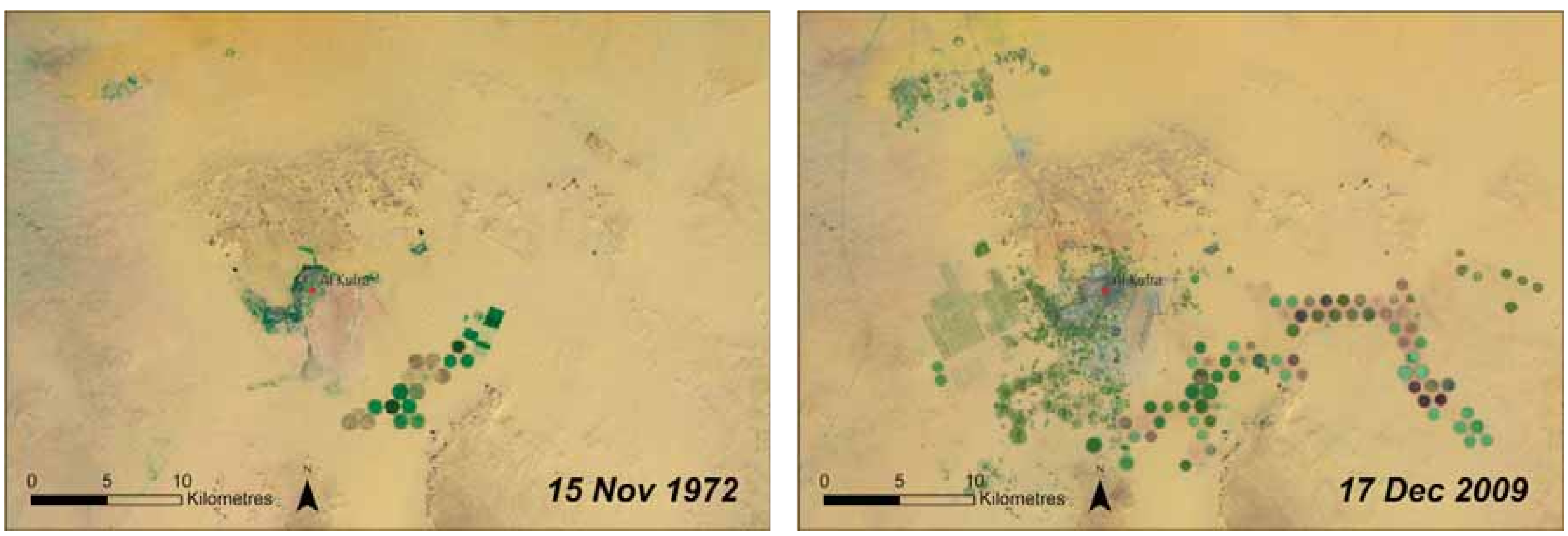
The Great Man-Made River Project

Libya is one of the African countries with the least amount of renewable water. It relies on groundwater to meet 95 per cent of its water requirements. The water is primarily "fossil water" from non-recharging aquifers such as the Nubian Sandstone Aquifer System, the North-Western Aquifer System and the Murzuq Basin Aquifer System (Alker 2008). While Libya has some aquifers in the north with limited recharge, salt-water intrusion due to over-pumping and growing demands have made it necessary for Libya to look elsewhere to meet its water needs (Ghazali and Abounahia 2005). In the 1960s, the discovery of water in deep aquifers located under Libya's southern desert inspired an enormous water-transfer scheme—the Great Man-Made River Project.

Work on the Great Man-Made River Project in Libya began roughly 30 years ago. The project brings water from well fields in the Sahara to Libya's population, which is generally concentrated in the northern plains along the Mediterranean Coast. The

Figure 2.16.7: The East and North East Jabal Hasaouna well fields supply water for irrigation on the Murzuq Basin and to Tripoli and the Jeffara Plain in the north

Figure 2.16.8: The expansion of center-pivot irrigation (green and brown circles) between 1972 and 2009 is supplied by water from wells drawing from the Nubian Sandstone Aquifer System, which are a part of the Great Man-Made River Project



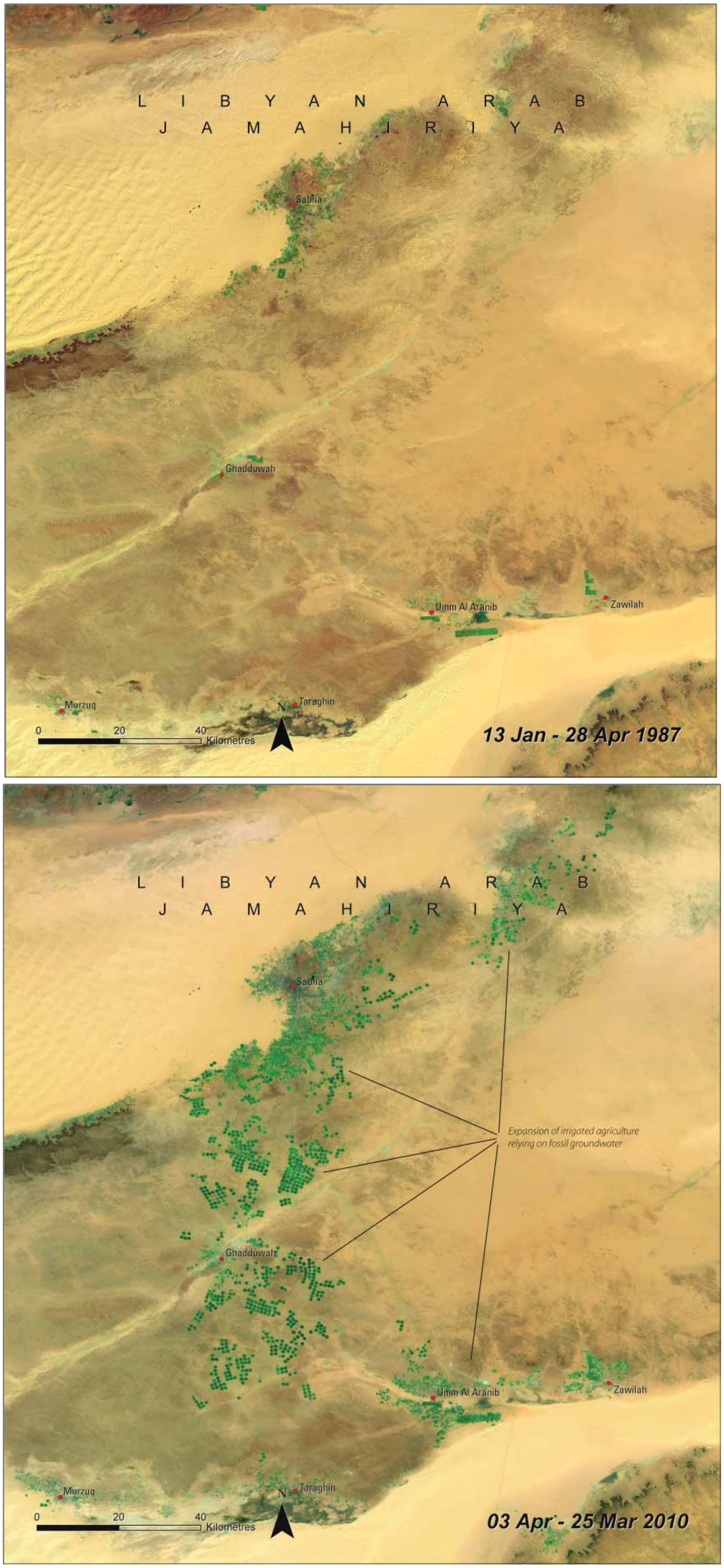


Figure 2.16.9: Expansion of irrigated agriculture relying on fossil groundwater

water is for industry, domestic use and to support irrigated farms that feed Libya's growing population. The system is among the largest civil engineering projects in the world.

The majority of the system's water comes from Libya's two largest groundwater resources—the Murzuq and Kufra groundwater basins (Alghariani 2007). Located in Libya's southern desert, they hold over two-thirds of Libya's groundwater reserves (Alghariani 2007). Neither aquifer system receives significant recharge; consequently any withdrawal of water reduces the total reserves. While the total volume of water in the two aquifers is enormous, drawdown of the water levels under heavy usage could eventually make extracting water prohibitively expensive (Shaki and Adeloye 2006, Alghariani 2003). The July 2010 image (Figure 2.16.7, previous page) shows some of the wells of the East and North East Jabal Hasaouna well fields, which abstract around two million m^3 of water daily from the Murzuq Basin Aquifer (Abdelrhem and others 2008).

The satellite image pairs (Figure 2.16.9) show the large increase in centre pivot irrigation at two locations —one drawing from the Kufra Basin in the southeast and the other from the Murzuq Basin in the southwest. The majority of Libya's groundwater, as much as 80 per cent (Alghariani 2003), is used for agriculture including wheat, alfalfa, vegetables and fruits. Water and agricultural demands are driven by Libya's population, which was growing at just over two per cent per year in 2008, down from five per cent per year in the early eighties (World Bank 2010). Since the project's initiation in 1983 the cost of alternative sources of water, particularly by desalinization, has become competitive with water delivered by the Great Man-Made River transfer scheme (Alghariani 2003) and will likely become less expensive in the foreseeable future.

The project is being built in several stages. Phase One provides two million cubic metres per day from wells at Sarir and Tazerbo to the Northern Cities of Benghazi and Sirte. The second phase delivers water to the Jeffara Plain and to Tripoli. The third phase of the project has begun construction, although some parts of that phase have been cancelled (WaterTechnologyNet n.d.).

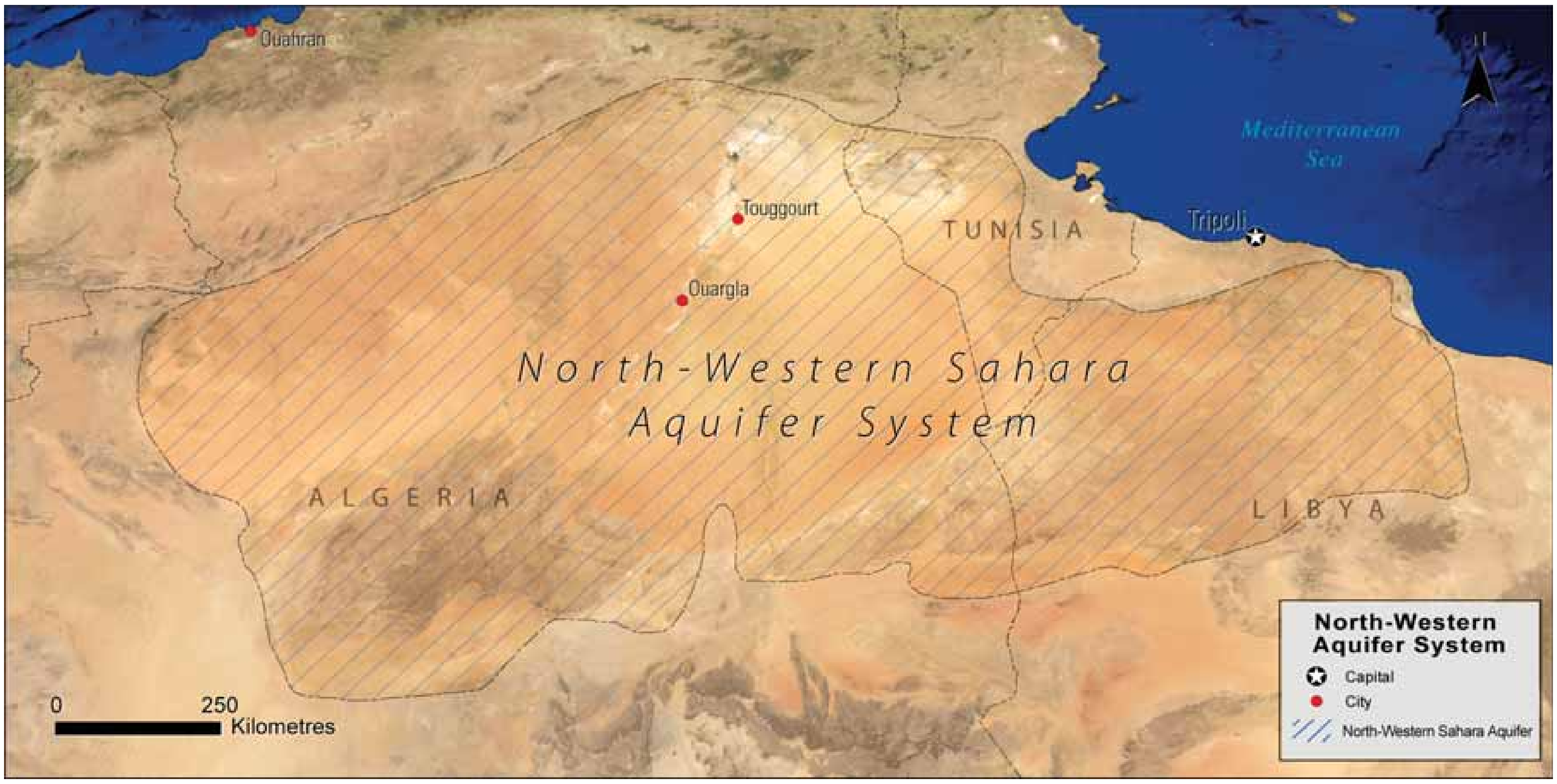
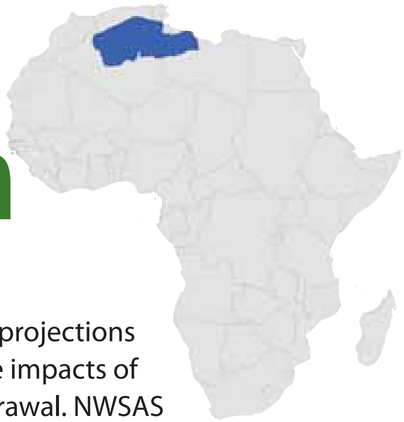


Figure 2.17.1: North-Western Sahara Aquifer System

North-Western Sahara Aquifer System



The North-Western Sahara Aquifer System (NWSAS) covers a total area of over one million km²: 700 000 km² in Algeria, 80 000 km² in Tunisia and 250 000 km² in Libya (Figure 2.17.1). It contains sedimentary deposits that have two main levels of aquifers, the Intercalary Continental (IC) and the Terminal Complex (TC). The three NWSAS countries have embraced an approach of joint management. This approach is based on an in-depth knowledge of the aquifer, including projections and simulations of the impacts of intensive water withdrawal. NWSAS is crucial to development in the north-western part of the Sahara desert, especially to secure food for a growing population close to, and even far beyond its borders, and to meet the demands of agriculture, industry, and construction.

Argeberg/Flickr.com

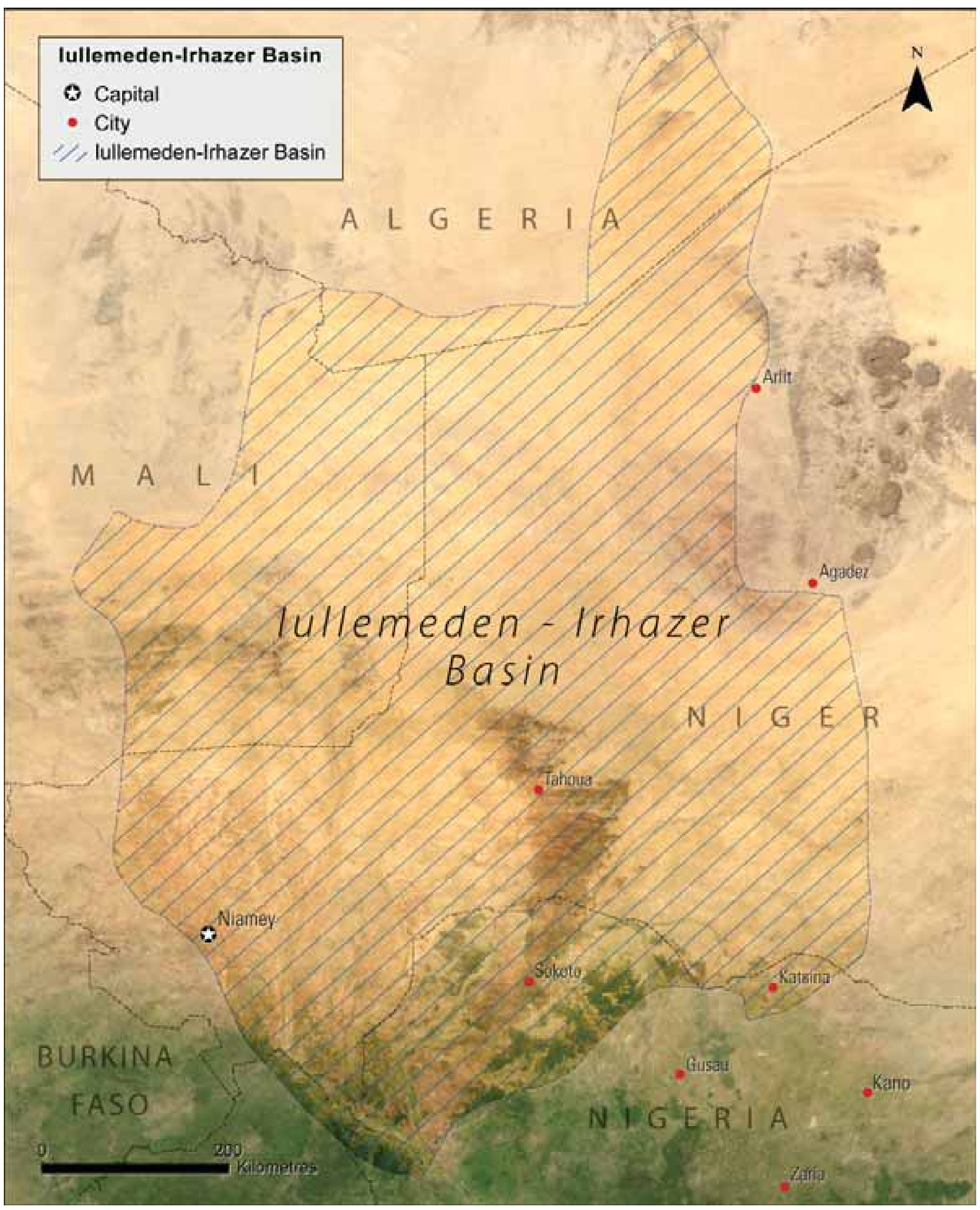
Iullemeden-Irhazer Groundwater Basin

The Iullemeden sedimentary groundwater basin (IAS) is located in Mali, Niger and Nigeria with minor, non-connected sections in Algeria and Benin. The aquifer system, which covers an area of 525 000 km^2 with 31 000 km^2 in Mali, 434 000 km^2 in Niger and 60 000 km^2 in Nigeria, represents one of West Africa's major freshwater reservoirs and is linked to many humid areas and ecosystems (Figure 2.18.1).

With high demographic growth (from six million in 1970 to about 15 million in 2000 and probably 30 million by 2025) and the impacts of climatic change and variability, including regional drought over the last several decades, the Iullemeden aquifer system increasingly suffers from environmental stress. Annual water withdrawals of about 50 million m^3 in 1970 increased to about 170 million m^3 in 2004 and the IAS is changing from a strategic regional resource to an increasingly well-used aquifer system. Total abstractions now exceed the annual aquifer recharge and there are visible impacts of declining water tables, loss of artesian pressure and aquifer pollution in local hotspots and border areas. The IAS interacts with the regional Niger River through seepage inflows that support the river's water resources during periods of low flow and extended drought.

A number of environmental threats to the aquifer and the related ecosystems have been identified including land-use change in recharge areas and humid zones of the IAS; climatic change; over-extraction; human-induced water pollution, and land salinization. To address these threats and risks, joint mechanisms and cooperative frameworks have been established. Scientific uncertainty about the aquifer system and the impacts of climate change, however, constrain the scope for managing transboundary risk and conflict in the IAS.

Figure 2.18.1: Iullemeden-Irhazer Basin



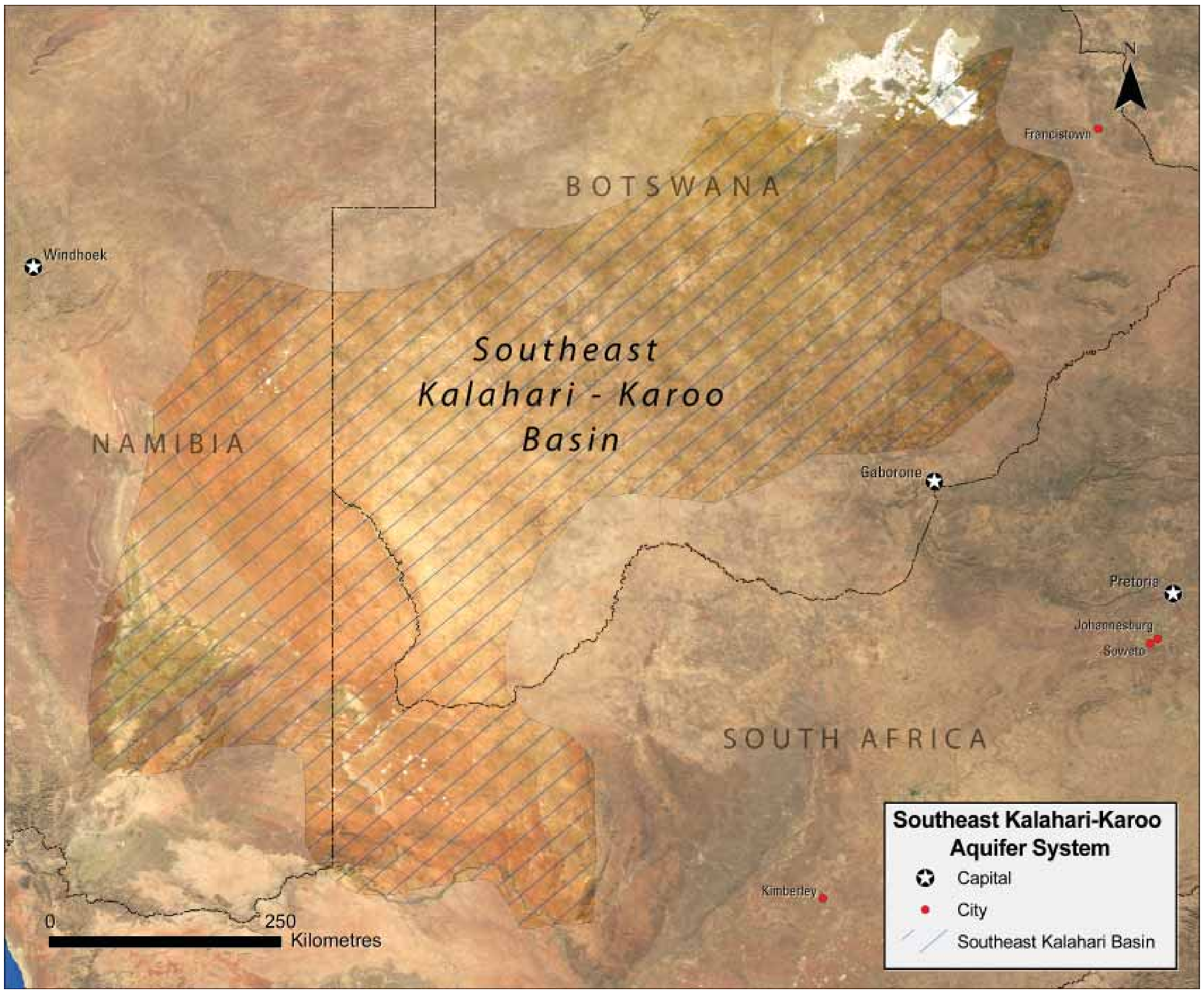


Figure 2.19.1: Southeast Kalahari Karoo Aquifer

Southeast Kalahari Karoo Aquifer

The Southeast Kalahari Karoo aquifer is shared by Namibia, Botswana, and South Africa, although it is predominantly used in Namibia where most recharge probably occurs (Figure 2.19.1). There is a comparatively good understanding of the aquifer's geology and hydrogeology in Namibia. Water occurs in the Auob and Nossob sandstones of the Ecca Group (lower Karoo Sequence), as well as in the overlying Kalahari. The dip of the formations is slightly towards the southeast and in general the water quality deteriorates also in that direction (by about three degrees).

Population on the Namibian side is generally sparse; water usage is therefore primarily for irrigation and stock farming. Although the system is large, because of present uncertainty about recharge it is not known if it can sustain large irrigation schemes, so the appropriate balance between irrigation and sustainability is currently unresolved.

The Southeast Kalahari Artesian aquifer is bordered by the south-west part of Botswana, the South African Kalahari National Game Park, and the Gordonia District. In Gordonia, water quality of the Karoo aquifers appears to be very poor, as in the so-called Salt block in the southeastern part of the Artesian basin in Namibia. At present, water is used in Namibia for stock watering and increasingly for irrigation purposes. The system also supplies five smaller towns with water. By far the largest portion of the aquifer falls within Namibia, which is expected to have the largest demand from the system and where need is expected to rise in the future.

Significant issues concerning the shared aquifer

The major issue at this stage is for all three countries to obtain a proper understanding of the aquifer for joint management of the resource. The countries can then work out a legal framework for a common abstraction policy.

Coastal Aquifers

As with any groundwater resource, the rate of abstraction in coastal aquifers cannot exceed the rate of recharge indefinitely without exhausting supply. About 2.7 per cent of Africa's population lives within 100 km of the coast (UNEP 2008). While this degree of concentration is lower than on the other continents (Hinrichsen 1995), Africa's coastal population is growing rapidly (UNEP 2008). In many cases, this rising pressure on coastal groundwater resources has exceeded sustainable levels (Steyl and others 2010). In addition, excessive abstraction from coastal aquifers can also lead to saltwater intrusion as seawater replaces the extracted water.

Twelve of Africa's coastal groundwater aquifers are shared by two or more of the continent's 32 coastal countries. The shared hydrogeology in these cases makes management a joint concern of the populations and governments of all countries involved.

Across North Africa, dependence on groundwater is magnified by the arid environment and the lack of alternative freshwater sources. Nearly half of all groundwater withdrawn in Africa comes from aquifers in this region. Tunisia obtains 95 per cent of its freshwater supply from groundwater. The arid environment also means that recharge is minimal outside of the coastal zone where some rainfall occurs and away from rivers that provide some recharge to shallow aquifers. Consequently, several North African locations are experiencing serious seawater intrusion including the Nile Delta, Tunisia, Libya, Algeria, and Morocco. Several factors have contributed to an alarming drop in water tables in the Maghreb including drought, urbanization, and abstraction for agriculture (Steyl and others 2010).

The Siwa Oasis in Egypt and the Jaghbub Oasis in Libya are located at the margins of the saltwater-freshwater interface in the Nubian Sandstone Aquifer System (Figure 2.20.1). Modeling of the aquifer's response to current water abstraction at Siwa shows a slight cone of depression in the surrounding water table's surface (Elbadawy 2007). The original plans for the Great Man-Made River Project in Libya included a well-field south of Jaghbub and south of the freshwater-saltwater interface. Research that modeled the impact this would have on the sea-water intrusion in the area has raised concern and further research has been recommended before proceeding with this part of the project (Schlumberger Water Services 2007).

Figure 2.20.1: Abstraction of freshwater from coastal aquifers can lead to saltwater intrusion as sea water replaces the water that is withdrawn. A thorough understanding of the underlying hydrogeology is needed to manage this risk

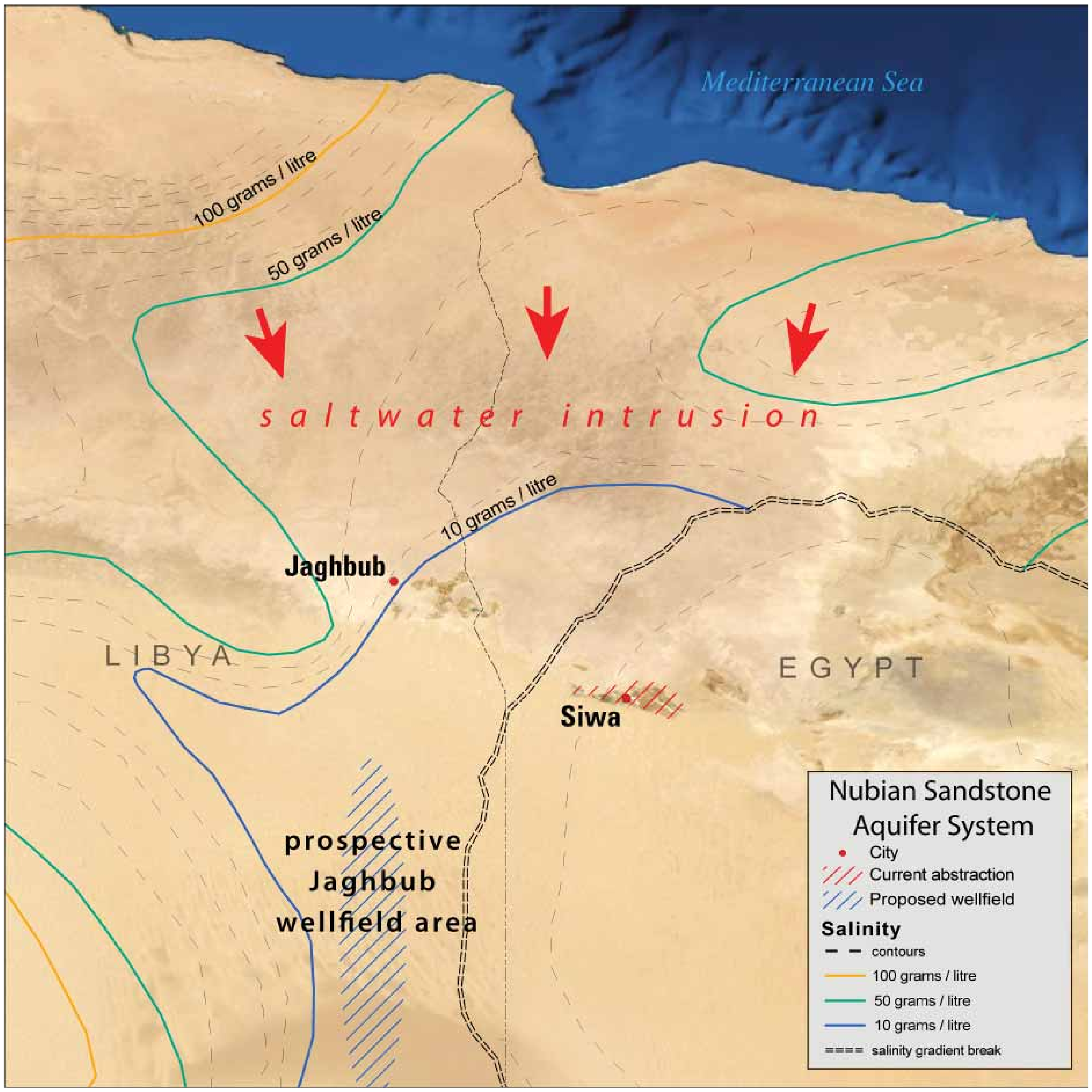


Figure 2.21.1: Map of Tano Groundwater Basin/Abidjan Aquifer

Tano Basin
Abidjan Aquifer

Western Africa's aquifer systems are generally complex with a variety of hydrogeological settings and varying levels of utilization. Coastal aquifers at several locations in Western Africa have been found to be deteriorating due to over-exploitation, and in some cases due to the infiltration of domestic, agricultural, and industrial pollutants.

Sedimentary aquifers straddling the border between Côte d'Ivoire and Ghana are the principal water source for several urban areas along the Gulf of Guinea including Abidjan, Côte d'Ivoire—a city of around four million people (Oga and others 2008). There are two aquifers in a regional unconfined system: the Quaternary Aquifer along the coast and the more important Continental Terminal Aquifer just inland of the Quaternary (Oga and others 2008).

The aquifers are under intense pressure from domestic, industrial, and agricultural use in this area where population growth is around two per cent annually. In some places water quality has deteriorated as over-abstraction has led to sea-water intrusion, although salinity in the aquifers remains relatively minor (Oga and others 2008). There are also some areas where domestic waste disposal and agricultural pollution have degraded water quality creating high concentrations of nitrates (Oga and others 2008). There is currently no transboundary management of this important groundwater resource.

References

Transboundary Surface Water Basins

SEDAC. (2010). Gridded Population of the World: Future Estimates. Socioeconomic Data and Applications Center (SEDAC); collaboration with CIESIN, UN-FAO, CIAT. http://sedac.ciesin.columbia.edu/gpw (Last accessed on August 10, 2010).

UNU. (2006). International Rivers and Lake Basin Management, United Nations University. http://www.unu.edu/env/water/transboundary-water.html (Last accessed on September 10, 2010).

UNEP. (2006a). Global Deserts Outlook. United Nations Environment Programme, Nairobi, Kenya.

UNEP. (2006b). Africa's Lakes: Atlas of Our Changing Environment. United Nations Environment Programme, Nairobi, Kenya.

Congo River Basin

Béné, C., Steel, E., Luadia, B., Gordon, A. (2009). Fish as the "bank in the water" –Evidence from chronic-poor communities in Congo. Food Policy. 34:108-118.

Counter Balance. (2009). Conrad's Nightmare, The World's Biggest Dam and Development's Heart of Darkness. http://www.counterbalance-eib.org/component/option,com_datsogallery/Itemid,98/func,detail/id,128/ (Last Accessed on February 25, 2010).

Dai, A. and Trenberth. (2002). Estimates of Freshwater Discharge from Continents: Latitudinal and Seasonal Variations. Journal of Hydrometeorology. 3:660-687.

Davies, B., Beilfuss, R., Thoms, M. (2000). Cahora Bassa restrospective, 1974-1997: effects of flow regulation on the Lower Zambezi River. Verh. Internat. Verein. Limnol. 27:1-9.

DeGeorges, A. and Reilly, B. (2006). Dams and Large Scale Irrigation on the Senegal River. Impacts on Man and the Environment. Case Study for 2006 Human Development Report. UNDP.

EIA. (2002). Inga Hydroelectric Facility. Energy Information Administration. Food and Agriculture Organization of the United Nations. http://www.eia.doe.gov/emeu/cabs/inga.html (Last Accessed on February 26, 2010).

FAO. (1997). Irrigation potential in Africa: A basin approach – FAO Land and Water Bulletin – 4. Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/w4347e/w4347e00.htm (Last Accessed on February 25, 2010).

FAO. (2001). Information on fisheries management in the Democratic Republic of the Congo. Food and Agriculture Organization of the United Nations. http://www.fao.org/fi/oldsite/FCP/en/COD/BODY.HTM (Last Accessed on February 25, 2010).

FAO. (2002). FAO Rice Information. Democratic Republic of the Congo. Food and Agriculture Organization of the United Nations. http://www.fao.org/DOCREP/005/Y4347E/Y4347E00.HTM (Last Accessed on February 26, 2010).

FAO. (n.d.). Aquastat Country Profile - République démocratique du Congo. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/congo_dem_r/indexfra.stm (Last Accessed on February 26, 2010).

IR. (n.d.a.). "Inga 1 and Inga 2 dams". International Rivers. http://www.internationalrivers.org/en/node/2877 (Last Accessed on February 26, 2010).

IR. (n.d.a.). "Inga 3". International Rivers. http://www.internationalrivers.org/en/africa/grand-inga-dam-dr-congo/inga-3 (Last Accessed on February 26, 2010).

IR (n.d.c). Grand Inga, Grand Illusions. World Rivers Review. 20(2):6-7. http://www.internationalrivers.org/files/WRR.V20.N2.pdf (Last Accessed on September 10, 2010).

IR. (2008). "Pimping Inga". International Rivers. http://www.internationalrivers.org/blog/terri-hathaway/pimping-inga-0 (Last Accessed on August 10, 2010).

Kirongozi, H. (2008). Sustaining Congo River and its Communities: Congolese Mining Industry to Grow Green. International River Symposium 2008 paper presentation. http://www.riversymposium.com/index.php?page=2008 (Last Accessed on February 26, 2010).

Kashema, J. (2008). How the DRC could become self-sufficient in fish production. Agricultural International Magazine /KUL-Belgium pp.1-45.

Laraque, A., Mahe, G., Orange, D. and Marieu, B. (2001). Spatiotemporal variations in hydrological regimes within Central Africa during the XXth Century. Journal of Hydrology 245:104-117.

Musa, I. (2008). Saving Lake Chad – Based on Proceedings of Sirte Roundtable, Libya, 17 Dec. 2008. Lake Chad Basin Commission and International Commission of Irrigation and Drainage. http://www.afrwg.icidonline.org/save_lakechad.pdf (Last Accessed on August 10, 2010).

NASA. (2010). GISS Precipitation Data. National Aeronautics and Space Administration. http://data.giss.nasa.gov/precip_cru/maps.html (Last Accessed on February 25, 2010).

National Geographic. (2010). Fish of the Congo River, National Geographic Website.http://channel.nationalgeographic.com/series/explorer/3826/Overview (Last Accessed on February 25, 2010).

Ndala, B. (2009). Congo River Basin: challenges and current initiatives. Presented at the 5th World Water Forum, 2009. http://www.riob.org/IMG/pdf/03_CICOS-PO.pdf (Last Accessed on February 25, 2010).

SADC. (2007). Handbook on Environmental Assessment Legislation in the SADC Region. Development Bank of Southern Africa & SAIEA, Midrand. Southern African Development Community. http://www.saiea.com/dbsa_book/index.htm (Last Accessed on February 26, 2010).

Showers, K. (2009). Gongo River's Grand Inga hydroelectricity scheme: linking environmental history, policy and impact. Water History 1:31-58.

UNEP. (2008). Freshwater Under Threat, Africa. United Nations Environment Programme.

Upper Congo Fishes Project. (n.d.). Discovering the Fishes of a Great River. http://www.congofishes.net/Site/Welcome.html (Last Accessed on February 25, 2010).

USGS. (2009). A Field Trip to the Congo, Hydroacoustic measurements in "the river that swallows all rivers." Online lecture by John Shelton, Associate Director, Hydrologic Data South Carolina Water Science Center. United States Geological Survey. http://www.usgs.gov/public_lecture_series/archive_lectures.asp (Last Accessed on February 25, 2010).

World Bank. (2008). Democratic Republic of Congo Growth with Governance In the Mining Sector. Report No. 43402. http://siteresources.worldbank.org/INTOGMC/Resources/336099-1156955107170/drcgrowthgovernanceenglish.pdf (Last Accessed on February 25, 2010).

Juba Shabelle Basin

Thiemig, V. (2009). Early Flood Warning in Africa: Are the Methodologies of the European flood Alert System (EFAS) Transferable to African Basins? – A Feasibility Study in the Juba-Shabelle River Basin. Masters Thesis, Radboud University Nijmegen, Nijmegen, The Netherlands. http://floods.jrc.ec.europa.eu/flood-research-at-jrc/flood-forecasting-in-africa (Last Accessed on May 21, 2010).

FAO. (2005). FAO Aquastat Country Profile, Somalia. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/somalia/index.stm (Last Accessed on May 21, 2010).

Artan, G., Gadain, H., Muthusi, F., Muchiri, P. (2007). Improvingflood forecasting and early warning in Somalia – a feasibility study. FAO-SWALIM Project publicationi No W-10. http://www.faoswalim.org/subsites/frrmis/downloads/W-10%20Improving%20Flood%20Forecasting%20and%20Early%20Warning%20in%20Somalia.pdf (Last Accessed on May 21, 2010).

Lake Chad Basin

Boronina, A. and Ramillien, G. (2008). Application of AVHRR imagery and GRACE measurements for calculation of actual evapotranspiration over the Quaternary aquifer (Lake Chad basin) and validation of groundwater models. Journal of hydrology 348:98-109.

CIMA Webpage. (n.d.). "CIMA International in Lake Chad". http://www.international.cima.ca/cgics/cs.waframe.content?click=105396&lang=2 (Last accessed on February 9, 2010).

Coe, T. and Foley, A. (2001). Human and natural impacts on the water resources of the Lake Chad basin. Journal of Geophysical Research 106(4):3349–3356.

FAO. (2009). Adaptive Water Management in the Lake Chad Basin, Addressing current challenges and adapting to future needs, World Water Week, Stockholm, August 16-22, 2009. Food and Agriculture Organization of the United Nations.

Giannini, A., Saravanan, R. and Chang, P. (2003). Ocean Forcing of Sahel Rainfall on Interannual to Interdecadal Time Scales. Science 302:1027-1030.

GIWA. (2004). Lake Chad Basin, GIWA Regional assessment 43 GIWA Regional assessment reports [GIWA Reg. Assess. Rep.] Global International Waters Assessment. http://www.unep.org/dewa/giwa/publications/r43.asp (Last Accessed on August 10, 2010).

Isiorho, S., Matisoff, G., Wehn, K. (1996). Seepage Relationships Between Lake Chad and the Chad Aquifers. Groundwater 34(5):819-826.

IUCN. (2003). Waza Logone Floodplain, Cameroon: Economic benefits of wetland restoration. Integrating Wetland Economic Values into River Basin Management. International Union for Conservation of Nature. http://www.iwlearn.net/abt_iwlearn/events/ouagadougou/readingfiles/iucn-restoration-benefits-waza-cameroon.pdf (Last accessed on February 9, 2010).

IUCN. (2004). Case Studies in Wetland Valuation #4, Waza Logone Floodplain Cameroon: economic benefits of wetland restoration. International Union for Conservation of Nature. http://cmsdata.iucn.org/downloads/casestudy04waza.pdf (Last accessed on March 29, 2010).

Lemoalle, J., Bader, J., and Leblanc, M. (2008). The variability of Lake Chad: hydrological modelling and ecosystem services. In: 13th IWRA World Water Congress 2008, 01-04 September 2008, Montpellier, France. http://eprints.jcu.edu.au/4918/ (Last accessed on February 8, 2010).

Loth, P. (Ed.).(2004). The Return of the Water: Restoring the Waza Logone Floodplain in Cameroon. IUCN, Gland, Switzerland and Cambridge, UK. http://www.wou.edu/~moritzm/return_water.pdf (Last accessed on March 29, 2010).

Musa, I. (2008). Saving Lake Chad – Based on Proceedings of Sirte Roundtable, Libya, 17 Dec. 2008. Lake Chad Basin Commission and International Commission of Irrigation and Drainage. http://www.afrwg.icidonline.org/save_lakechad.pdf (Last Accessed on August 10, 2010).

Ngatcha, B., Budry, J., Leduc, C. (2008). Water resources management in the Lake Chad basin: Diagnosis and action plan. In Applied Groundwater Studies in Africa: IAH Selected Papers on Hydrogeology, volume 13 Editor(s): Segun Adelana, University of Ilorin, Nigeria; Alan MacDonald, British Geological Survey, Edinburgh, Scotland.

Nihoul, C., Zavialov, P., Micklin, P. (2003). Dying and Dead Seas: Climatic versus anthropic causes. North Atlantic Treaty Organization Scientif Affairs Division, NATO Science Series IV, Earth and Environmental Sciences – Vol. 36. 2003. Kluwer Academic Publishers.

Roche, M. (1977). Lake Chad: A subdesertic terminal basin with freshwaters. ORSTOM. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/b_fdi_35-36/41578.pdf (Last accessed on September 10, 2010).

Scholte, P. (2005). Floodplain rehabilitation and the future of conservation & development: Adaptive management of succes in Waza-Logone, Cameroon, PhD. Thesis, Leiden University, The Netherlands. https://www.openaccess.leidenuniv.nl/handle/1887/4290 (Last accessed on March 29, 2010).

SEDAC. (2010). Gridded Population of the World: Future Estimates. Socioeconomic Data and Applications Center (SEDAC); collaboration with CIESIN, UN-FAO, CIAT http://sedac.ciesin.columbia.edu/gpw (Last Accessed on August 10, 2010).

Senay, G., Pengra, B., Bohms, S., Singh, A., Verdin, J. (2010). Africa-wide water balance estimation using remote sensing and global weather datasets. American Geophysical Conference Fall Meeting. Submitted.

Shanahan, T., Overpeck, J., Anchukaitis, K., Beck, J., Cole, J., Dettman, D., Peck, J., Scholz, C., King, J. (2009). Atlantic Forcing of Persistent Drought in West Africa. Science 324:377-380.

UN-WPP (2008) World Population Prospects: The 2008 Revision, United Nations Population Division. http://esa.un.org/UNPP/ (Last accessed on July 20, 2010).

University of Washington. (2009). Joint Institute for the Study of the Atmosphere and Ocean (2009) Sahel rainfall index (20-10N, 20W-10E), 1900 - August 2009. Available online at: http://jisao.washington.edu/data/sahel/ (Last Accessed on February 9, 2010)

Zhang, R. and Delworth, T. (2006). Impact of Atlantic multidecadal oscillations on India/Sahel rainfall and Atlantic hurricanes. Geophysical Research Letters 33:L17712

Lake Turkana Basin

Angelei, I. (2009) Another African Lake on the Endangered List, Ethiopian Dam Endangers Kenya's Lake Turkana. World Rivers Review 24(1):6-7

ARWG. (2009) A Commentary on the Environmental, Socioeconomic and Human rights Impacts of the Proposed Gibe III Dam in the Lower Omo river Basin of Ethiopia by African Resources Working Group. http://www.arwg-gibe.org/ (Last accessed on April 6, 2009).

EEEPCo. (2009). GIBE III Hydroelectric Project, Environmental and Social Impact Assessment. Ethiopian Electric Power Corporation, 2009.

Haack, B. (1996). Environmental Auditing, Monitoring Wetland Changes with Remote Sensing: An East African Example. Environmental Management 20(3):411-419.

ILEC. (n.d.). World Lakes Database. International Lake Environment Committee. http://www.ilec.or.jp/database/afr/afr-20.html (Last accessed on April 6, 2009).

Legos. (2005). Fleuves et Lacs du Monde – Veille hydrologique par satellite. http://www.legos.obs-mip.fr/soa/hydrologie/hydroweb/StationsVirtuelles/Turkana.html (Last accessed on April 6, 2009).

Nicholson, S. (2001). Climatic and environmental change in Africa during the last two centuries. Climate Research 17:123-144.

Nyamweru, C. (1989). New evidence for the former extent of the Nile drainage system. The Geographical Journal 155:179-188.

ORNL. (2008). LandScan dataset 2008, Oak Ridge National Laboratory. http://www.ornl.gov/sci/landscan/index.shtml (Last Accessed on August 10, 2010).

SEDAC. (2010). Gridded Population of the World: Future Estimates. Socioeconomic Data and Applications Center (SEDAC); collaboration with CIESIN, UN-FAO, CIAT. Accessed http://sedac.ciesin.columbia.edu/gpw (Last Accessed on August 10, 2010).

Limpopo River Basin

CGIAR. (2003). Limipopo Basin Profile – ARC-Institute for Soil Climate and Water/ARC-Institute for Agricultural Engineering/IWMI. Consultative Group on International Agricultural Research. http://www.arc.agric.za/limpopo/pdf/basin_profile_intro.pdf (Last accessed on May 21, 2010).

Reason, C., Hachigonta, S., Phaladi, R. (2005). Interannual variability in rainy season characteristics over the Limpopo region of southern Africa. International Journal of Climatology 25:1835-1853.

World Bank (2010). World Bank Development Indicators. http://www.google.com/publicdata?ds=wb-wdi&met=sp_pop_grow&idim=country:AGO&dl=en&hl=en&q=Angola+population+growth+rate#met=sp_pop_grow&idim=country:MOZ:BWA:ZAF (Last accessed on May 21, 2010).

Niger River Basin

Adedeji A. and Ako, R.(2009). Towards achieving the United Nations' Millennium Development Goals: The imperative of reforming water pollution control and waste management laws in Nigeria. Desalination 248:642-649.

AfDB. (2008). "Kandadji" Ecosystems Regeneration and Niger Valley Development Programme, Detailed Environmental and Social Impact Assessment – Executive Summary. African Development Bank. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Environmental-and-Social-Assessments/ADF-BD-IF-2008-51-EN-NIGER-KANDADJI-ECOSYSTEMS-REGENERATION-DETAILED-POPULATION-RESETTLEMENT-PLAN.PDF (Last accessed on July 20, 2010).

AFD. (n.d.). Africapolis: Urbanization study in West Africa (1950-2020) Report from Agence Française de Développement. http://www.afd.fr/jahia/Jahia/lang/en/home/publications/NotesetEtudes/Africapolis# (Last accessed on February 24, 2010).

Ajao, E. and Anurigwo, S. (2002). Land-based Sources of Pollution in the Niger Delta, Nigeria. Ambio 31(5):442-445.

Amnesty International. (2009). Petroleum, Pollution and Poverty in the Niger Delta. http://www.amnesty.org/library/asset/AFR44/017/2009/en/e2415061-da5c-44f8-a73c-a7a4766ee21d/afr440172009en.pdf (Last accessed on February 24, 2010).

Anderson, I., Dione, O., Jarosewich-Holder, M., Olivry, J. (2005). The Niger River Basin, A Vision for Sustainable Management. Edited by K.G. Golitzen. Washington D.C.; The World Bank.

BBC. (2009). "Mali villagers fight back against Sahara". http://news.bbc.co.uk/2/hi/8408568.stm (Last accessed on September 20, 2010)

BGR. (n.d.). Capacity Building for Groundwater Management in West and Southern Africa. W/Downloads/pbgw__executivesummary,templateId=raw,property=publicationFile.pdf/pbgw_executivesummary.pdf (Last accessed on February 24, 2010).

CNEARC. (2004). Le lac Faguibine, un espace agropastoral au Nord Mali : Centre National d'Etudes Agronomiques des Régions Chaudes, 1101, avenue Agropolis – BP 5098 - 34033 Montpellier Cedex 01. http://www.cariassociation.org/gtd/?section=documentation&subsection=gtd (Accessed on December 15, 2006).

Descroix,L., Mahéb,G., Lebel,T., Favreau,G., Galle, S., Gautier,E., Olivry J-C., Albergel, J., Amogu, O., Cappelaere, B., Dessouassi, Diedhiou, R., Le Breton, E., Mamadou, I., and Sighomnou, D. (2009). Spatio-temporal variability of hydrological regimes around the boundaries between Sahelian and Sudanian areas of West Africa: A synthesis. Journal of Hydrology 375(1-2): 90-102.

Giannini, A., Saravanan, R. and Chang, P. (2003). Ocean Forcing of Sahel Rainfall on Interannual to Interdecadal Time Scales. Science 302:1027-1030.

Hamerlynck, O., Chiramba, T., Pardo, M. (2009). Gestion des écosystèmes du Faguibine (Mali) pour le bien-être humain : adaptation aux changements climatiques et apaisement des conflits. http://www.dialoguebarrages.org/dialoguebarrages/index2.php?option=com_docman&task=doc_view&gid=25&Itemid=39 (Last accessed on March 30, 2010).

L'Hôte, Y., Mahé, G., Somé, B., Triboulet, J. (2002). Analysis of a Sahelian annual rainfall index from 1896 to 2000; the drought continues. Hydrological Sciences 47(4):563-572.

Ludec, C., Favreau, G., Schroeter, P. (2001). Long-term rise in a Sahelian water-table: the Continental Terminal in South-West Niger. Journal of Hydrology 243:43-54.

Lutz, A., Thomas, J., Pohll, G., Keita, M., McKay W. (2009). Sustainability of groundwater in Mali, West Africa. Environmental Geology 58:1441-1450

Mahé, G., Bamba, F., Soumaguel, A., Orange, D., and Olivry, J. (2009). Water losses in the inner delta of the River Niger: water balance and flooded area. Hydrological Processes 23:3157-3160.

Nicholson, S. (1983). Sub-Saharan Rainfall in the Years 1976-80: Evidence of Continued Drought. Monthly Weather Review. 111:1646-1654

NNPC (2009) 2009 Third Quarter Petroleum Information – Nigerian National Petroleum Corporation. http://www.nnpcgroup.com/ (Last accessed on February 24, 2010).

OSS. (2008). Iullemeden Aquifer System (Mali, Niger, Nigeria): concerted management of shared water resources of a sahelian transboundary aquifer. Tunis, Tunisia; Sahara and Sahel Observatory (OSS).

Ramsar. (2004). Mali designates Inner Niger Delta for the Ramsar List. http://www.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-63-78%5E18383_4000_0__ (Last accessed on February 24, 2010).

Ramsar. (2010). The List of Wetlands of International Importance – 28 January 2010. http://www.ramsar.org/pdf/sitelist.pdf (Last accessed on February 23, 2010).

Shanahan, T., Overpeck, J., Anchukaitis, K., Beck, J., Cole, J., Dettman, D., Peck, J., Scholz, C., King, J. (2009). Atlantic Forcing of Persistent Drought in West Africa. Science 324:377-380.

UNEP. (n.d.). Rehabilitating Lake Faguibine Ecosystem – Project Fact Sheet. United Nations Environment Programme. http://www.unep.org/Themes/freshwater/PDF/Factsheet_LakeFaguibine.pdf (Last accessed on March 30, 2010).

UNEP. (2007). Dams and Development Project Compendium on Relevant Practices, Social Impact Assessment of Affected People. http://www.unep.org/DAMS/includes/compendium.asp United Nations Environment Programme. (Last accessed on February 23, 2010).

Vandersypen, K., Verbist, B., Keita, A., Raes, D.,Jamin, J. (2009). Linking Performance and Collective Action-the Case of the Office du Niger Irrigation Scheme in Mali. Water Resource Management 23:153-168.

Yo-Essien, L. (2008). Oil Spill Management in Nigeria: Challenges of Pipeline Vandalism in the Niger Delta Region of Nigeria. Presented at 15th Annual International Petroleum & Biofuels Environmental Conference, Nov. 10-13 2008, Albuquerque, NM. http://ipec.utulsa.edu/Conf2008/Manuscripts%20&%20presentations%20received/Eyo_Essien_2.pdf (Last accessed on February 23, 2010).

Zhang, R. and Delworth, T. (2006). Impact of Atlantic multidecadal oscillations on India/Sahel rainfall and Atlantic hurricanes. Geophysical Research Letters 33:L17712.

Zwarts, L., Van Beukering, P., Kone, B. & Wymenga, E. (2005). The Niger, a Lifeline: Effective Water Management in the Upper Niger Basin. Lelystad, Sévaré, Amsterdam, Veenwouden: RIZA, Wetlands International, Institute for Environmental Studies (IVM), Altenburg & Wymenga Ecological Research.

Zwart, S. and Leclert, L. (2009). A remote sensing based irrigation performance assessment: a case study of the Office du Niger in Mali. Irrigation Science (in press)

Nile River Basin

Ahmad, A. (2008). Post-Jonglei planning in southern Sudan: combining environment with development. Environment and Urbanization 20:575-586.

Albright, T.P., Moorhouse, T.G. and McNabb, T.J. (2004). The Rise and Fall of Water Hyacinth in Lake Victoria and the Kagera River Basin, 1989-2001. Journal of Aquatic Plant Management 42:73-84.

Barnaby, W. (2009). Do nations go to war over water? Nature 458:282-283.

Baskin, Y. (1992). Africa's troubled waters. BioScience 42(7):476-481.

Bohannon, J. (2010). The Nile Delta's Sinking Future, Climate change and damming the Nile threaten Egypts's agricultural oasis. Science 327:1444-1447.

Cascão, A. (2009). Changing Power Relations in the Nile River Basin: Unilateraism vs. Cooperation? Water Alternatives 2(2):245-268.

Cavalli, R.M., Laneve, G., Fusilli, L., Pignatti, P., Santini, F. (2009). Remote sensing water observation for supporting Lake Victoria weed management. Journal of Environmental Management 90:2199-2211.

EAWAG. (2006). Teodoru, C., Wuest, A., Wehrli, B., Independent review of the environmental impact assessment for the Merowe Dam project (Nile River, Sudan). EAWAG: Swiss Federal Institute of Aquatic Science and Technology. http://www.wrq.eawag.ch/media/2006/20060323/Independent-Review-20060323.pdf (Last accessed on August 10, 2010).

El Din, S. (1977). Effect of the Aswan High Dam on the Nile flood and on the estuarine and coastal circulation pattern along the Mediterranean Egyptian coast. Limnology and Oceanography, 22(2):194-207.

FAO. (2008). Fishery Country Profile – February 2008. Food and Agriculture Organization of the United Nations. ftp://ftp.fao.org/FI/DOCUMENT/fcp/en/FI_CP_SD.pdf (Last accessed on September 20, 2010).

Frihy, O. and Lawrence, D. (2004). Evolution of the modern Nile delta promontories: development of accretional features during shoreline retreat. Environmental Geology 46:914-931.

GRLM. (2010). Global Reservoir and Lake Monitor -United States Department of Agriculture. http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/index.cfm (Last accessed on September 30, 2010).

Goudswaard, K., Witte, F., Katunzi, E. (2008). The invasion of an introduced predator, Nile perch (Lates niloticus, L.) in Lake Victoria (East Africa): chronology and causes. Environmental Biology of Fishes 81:127–139.

ILEC. (n.d.). "Lake Kyoga".International Lake Environment Committee. http://www.ilec.or.jp/database/afr/afr-15.html (Last accessed on September 27, 2010).

Independent. (2008). Death on the Nile: new dams set to wipe out centuries of history by Boulding, C. http://www.independent.co.uk/news/world/africa/death-on-the-nile-new-dams-set-to-wipe-out-centuries-of-history-817236.html (Last accessed on September 27, 2010).

IR. (n.d.). "Merowe Dam, Sudan". International Rivers Website. http://www.internationalrivers.org/en/africa/merowe-dam-sudan (Last accessed on September 20, 2010).

IR. (2006). "Ethiopia's Water Dilemma". International Rivers Website. http://www.internationalrivers.org/node/2492 (Last accessed on September 20, 2010).

IR. (2006b). "Hundreds Forced to Flee Homes as Merowe Dam Reservoir Waters Rise Without Warning". International Rivers Website. http://www.internationalrivers.org/en/africa/hundreds-forced-flee-homes-merowe-dam-reservoir-waters-rise-without-warning (Last accessed on September 20, 2010).

Hildyard, N. (2008). Bystanders and Human Rights Abuses: The case of Merowe Dam. Sudan Studies 37, April 2008, published by the Sudan Studies Society of the United Kingdom.

Howell, P., Lock, M., Cobb, S. (1988). Jonglei Canal: Impact and Opportunity (Cambridge: Cambridge University Press).

Kiwango, Y. and Wolanski, E. (2008). Papyrus wetlands, nutrients balance, fisheries collapse, food security, and Lake Victoria level decline in 2000-2006. Wetlands Ecology Management 16:89-96.

Krishnamurthy, V. (1980). The Impact Forseen of the Jonglei Canal Scheme on The Fisheries on the Sudd Region: The Problems and Solutions. In CIFA Technical Paper No. 8: Seminar on River Basin Management and Development, Blantyre, Malawi, 8-10 December.

Kull, D. (2006). Connections Between Recent Water Level Drops in Lake Victoria, Dam Operations and Drought. Hydrologic Engineer, Nairobi, Kenya.

Laki, S. (1994). The impact of the Jonglei Canal on the economy of the local people. International Journal of Sustainable Development and World Ecology, 1:89-96

Lahmeyer Int. (n.d). Merowe Dam and Hydropower Plant - Lahmeyer International Engineering and Consulting Services Website. http://www.lahmeyer.de/en/projects/details/browse/0/project/298/mode/1/show/showAll/ (Last accessed on September 20, 2010).

Lehman, J. (2009). Lake Victoria. In: Dumont, H.J. (ed) The Nile: Origin, Environments, Limnology and Human Use, Springer Science, 2009.

Machiwa, P. (2003). Water quality management and sustainability: the experience of Lake Victoria Environmental Management Project (LVEMP)––Tanzania. Physics and Chemistry of the Earth 28:1111-1115.

Minakawa, N., Sonye, G. Dida, G.O., Futami, K., Kaneko S. (2008). Recent reduction in the water level of Lake Victoria has created more habitats for Anopheles funestus. Malaria Journal 7:119.

Moussa, A. and Bethmann F. (2007). Case study Merowe / Hamdab Dam Project. From the seminar The Science and Politics of Large Dam Projects – Swiss Federal Institute of Aquatic Science and Technology. http://www.eawag.ch/research_e/apec/seminars/Case%20studies/2006/Merowe-dam.pdf (Last accessed September on 20, 2010).

NBI. (2005a). National Nile Basin Water Quality Monitoring Baseline Report for Sudan. Nile Basin Initiative. http://nile.riverawarenesskit.com/French/NRAK/Resources/Document_centre/WQ_Baseline_report_Sudan.pdf (Last accessed on July 20, 2010).

NBI. (2005b). National Nile Basin Water Quality Monitoring Baseline Report for Egypt. Nile Basin Initiative. http://nile.riverawarenesskit.com/French/NRAK/Resources/Document_centre/WQ_Baseline_report_Egypt.pdf (Last accessed on July 20, 2010).

Nicholson, S. and Yin, X. (2000). On the feasibility of using a lake water balance model to infer rainfall: an example from Lake Victoria. Hydrological Sciences 45(1):75-95.

Njiru, M., Kazungu, J., Ngugi, C.C., Gichuki, J., Muhoozi, L. (2008). An overview of the current status of Lake Victoria fishery: Opportunities, challenges and management strategies. Lakes and Reservoirs: Research and Management 13:1-12.

SEDAC. (2010). Gridded Population of the World: Future Estimates. Socioeconomic Data and Applications Center (SEDAC); collaboration with CIESIN, UN-FAO, CIAT. http://sedac.ciesin.columbia.edu/gpw (Last accessed on August 10, 2010).

Scheren, P., Zanting, H., Lemmens, A. (2000). Estimation of water pollution sources in Lake Victoria, East Africa: Application and elaboration of the rapid assessment methodology. Journal of Environmental Management 58:235-248.

Stanley, D. and Warne, A. (1993). Nile Delta: Recent Geological Evolution and Human Impact. Science 260:628-634.

Sudan Tribune. (2009). Jonglei canal project needs to be revised, South Sudan says. http://www.sudantribune.com/spip.php?article32062 (Last accessed September on 20, 2010)

Sutcliffe, J. and Petersen, G. (2007). Lake Victoria: derivation of a corrected natural water level series. Hydrological Sciences 52(6):1316-1321.

Swensen, S. and Wahr, J. (2009). Monitoring the water balance of Lake Victoria, East Africa from space. Journal of Hydrology 370:163-176.

UN News Centre (2006). UN agency hails inclusion of vast wetlands in south Sudan on conservation list. UN News Centre. http://www.un.org/apps/news/story.asp?NewsID=20439&Cr=sudan&Cr1 (Last accessed on December 14, 2007).

UNESA. (2007). The 2006 Revision and World Urbanization Prospects: The 2007 Revision. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: http://esa.un.org/unup (Last accessed on September 20, 2010).

UNESA. (2008). Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision, http://esa.un.org/unpp (Last accessed on September 20, 2010).

UNEP. (2007). Sudan Post-Conflict Environmental Assessment. United Nations Environment Programme, Nairobi, Kenya.

USAID. (2009). Cooperation and competition: Managing Transboundary Water Resources in the Lake Victoria Region. United States Agency for International Development. Working Paper No. 5.

Yoffe, S., Wolf, A., Giordano, M. (2003). Conflict and Cooperation over international freshwater resources: Indicators of Basins at Risk. Journal of the American Water Resources Association 39(5):1109–1126.

Yongo, E., Keizire, B., Mbilinyi, B. (2008). Socio-economic Impacts of Fish Trade. In The State of the fisheries Resources of Lake Victoria and Their Management – Proceedings of the Regional Stakeholders' conference, Entebbe, 24th-25th February 2005).

Wahaab, R. and Badawy M. (2004). Water Quality Assessment of the river Nile System: An Overview. Biomedical and Environmental Sciences 17:87-100.

WaterTech. (n.d.). "Toshka Project – Mubarak Pumping Station / Sheikh Zayed Canal, Egypt." http://www.water-technology.net/projects/mubarak/ (Last accessed on September 20, 2010).

Williams, A., Duthie, H., Hecky, R. (2005). Water hyacinth in Lake Victoria: Why did it vanish so quickly and will it return? Aquatic Botany 81:300-314.

Ogooué River Basin

SEDAC. (2010). Gridded Population of the World: Future Estimates. Socioeconomic Data and Applications Center (SEDAC); collaboration with CIESIN, UN-FAO, CIAT. http://sedac.ciesin.columbia.edu/gpw (Last accessed on August 10, 2010).

Laurance, W., Alonso, A., Lee, M., Campbell, P. (2006). Challenges for forest conservation in Gabon Central Africa. Futures 38:454-470.

The Okavango Delta Basin

Gieske, A. (1997). Modelling outflow from the Jao/Boro River System in the Okavango Delta, Botswana. Journal of Hydrology 193:214-239.

Scudder, T. (2008). Okavango River Basin. In, Water Resources Development and Management Management of Transboundary Rivers and Lakes. Eds. Varis, O., Tortajada, C. and Biswas, A.K. http://www.springerlink.com/content/l0184t6h40l31v85/fulltext.pdf (Last accessed on May 21, 2010).

Ramberg, L., Hancock, P., Lindholm, M., Meyer, T., Ringrose, S. Sliva, J., Van As, J., VanderPost, C. (2006). Species diversity of the Okavango Delta, Botswana. Aquatic Sciences 68:310-337.

SAIEA. (2009). Pre-Feasibility Study for the Popa Falls Hydro Power Project: Preliminary Environmental Assessment - Impact Assessment Case Studies from Southern Africa. http://www.saiea.com/case_studies09/08%20PopaFallsHydropower.pdf (Last accessed on May 21, 2010).

Orange River Basin

Earle, A., Malzbender, D., Turton, A., Manzungu, E. (2005). A Preliminary Basin Profile of the Orange/Senqu River. AWIRU, University of Pretoria, South Africa. http://www.acwr.co.za/pdf_files/05.pdf. (Last accessed on May 21, 2010).

SADC-GTZ. (2007). Orange River Integrated Water Resources Management Plan, Prepared for the Orange Senqu River Commission (ORASECOM). http://www.orasecom.org/publications/iwrm+plan.aspx (Last accessed on May 21, 2010).

Senay, G., Pengra, B., Bohms, S., Singh, A., Verdin, J. (2010). Africa-wide water balance estimation using remote sensing and global weather datasets. American Geophysical Conference Fall Meeting. Submitted.

Senegal River Basin

Bâ, A. (2004). Case 1: Parc National Du Diawling. In: Report of the African Pre-Conference on water for food and ecosystems, Addis Ababa, 4-6 Nov. 2004. http://www.fao.org/ag/wfe2005/docs/annex_d.pdf (Last accessed on October 17, 2007).

Barbiéro, L., Mohamedou, A., Laperrousaz, C., Furian, S., Cunnac, S. (2004). Polyphasic origin of salinity in the Senegal delta and middle valley. Catena 58:101-124.

Boivin, P., Maeght, J., Hammecker, C., Barbiéro, L., Favre, F., Wopereis, M. (1998). Evolution of irrigated soils in the Senegal river valley:alcaline or neutral salinization process? Paper presented at: 16e ISSS World Congress, August, 1998. http://natres.psu.ac.th/Link/SoilCongress/bdd/symp29/1260-t.pdf (Last accessed on March 8, 2007).

Connor, D., Comas, J., Gómez-Macpherson, H., Mateos, L. (2008). Impact of small-holder irrigation on the agricultural production, food supply and economic prosperity of a representative village beside the Senegal River, Mauritania. Agricultural Systems 96:1-15.

DeGeorges, A. and Reilly, B. (2006). Dams and Large Scale Irrigation on the Senegal river. Impacts on Man and the Environment. Case Study for 2006 Human Development Report. UNDP.

Duvail, S. and Hamerlynck, O. (2003). Mitigation of negative ecological and socio-economic impacts of the Diama dam on the Senegal River Delta wetland (Mauritania), using a model based decision support system. Hydrology and Earth System Sciences 7(1):133-146.

Fall, O., Hori, N., Kan, H., Diop, M. (2003). Toward an Integrated Management Plan of the Djoudj Park Water Resources: Senegal River Mouth. Environmental Management 31(1):14-28.

FAO. (1997). Irrigation potential in Africa: A basin approach – FAO Land and Water Bulletin – 4. Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/w4347e/w4347e00.htm (Last accessed on February 24, 2010).

Horowitz, M. and Salem-Murdock, M. (1993). Development-Induced Food Insecurity in the Middle Senegal Valley GeoJournal 30(2):179-184.

IR. (1999). A Case Study on the Manantali Dam Project (Mali, Mauritainia, Senegal). International Rivers. http://www.internationalrivers.org/en/africa/case-study-manantali-dam-project-mali-mauritania-senegal (Last accessed on March 8, 2010).

Isupova, M. and Mikhailov, V. (2008). Hydrological and Morphological Processes in Senegal River Mouth Area. Water Resources 35(1):30-42.

Lahtela, V. (2003). Managing the Senegal River: National and Local Development Dilemma. Water Resources Development 19(2):279-293.

Lebel, T. and Ali, A. (2009). Recent trends in the Central and Western Sahel rainfall regime (1990-2007). Journal of Hydrology 375:52-64.

Mietton, M., Dumas, D., Hamerlynck, O., Kane, A., Coly, A., Duvail, S., Pesneaud, F., Baba, M. (2007). Water management in the Senegal River Delta: a continuing uncertainty. Hydrological Earth Systems Sciences Discussions 4:4297-4323.

OMVS. (n.d.). Aménagements hydroagricoles. L'Organisation pour la mise en valeur du fleuve Sénégal website. http://www.omvs.org/fr/realisations/irrigation.php (Last accessed on September 27, 2010).

Poussin, J. and Boivin, P. (2002). Performances des systemes rizicoles irrigues saheliens. Cahiers Agricultures 11:65-73.

Tappan, G., Sall, M., Wood, E., Cushing, M. (2004). Ecoregions and land cover trends in Senegal. Journal of Arid Environments 59(3):427-462.

Van Asten, P., Barbiéro, L., Wopereis, M., Maeght, J., van der Zee, S. (2003). Actural and Potential salt-related soil degradation in an irrigated rice scheme in the Saheliann zone of Mauritania. Agricultural Water Management 60:13-32.

Verheye, W. (1995). Impact of climate and soil conditions on conception and implementation of irrigation schemes in the Senegal River basin. Agricultural Water Management 28:73-94.

Wopereis, M., Ceuppens, J., Boivin, P., Ndiaye, A., Kane, A., (1998). Preserving soil quality under irrigation in the Senegal River Valley. NJAS wageningen. Journal of Life Sciences, Vol 46(1):1-8.

UNDP. (2009). Human Development Report – Overcoming Barriers: Human mobility and development. United Nations Development Programme. http://hdr.undp.org/en/reports/global/hdr2009/ (Last accessed on March 8, 2010).

UNESCO. (2003). World Water Report: Water for People, Water for Life-Chapter 20 Senegal River Basin, Guinea, Mali, Mauritania, Senegal. United Nations Educational, Scientific and Cultural Organization. http://www.unesco.org/water/wwap/wwdr/wwdr1/table_contents/index.shtml (Last accessed on March 8, 2010).

UNESCO. (n.d.) List of World Heritage in Danger. United Nations Educational, Scientific and Cultural Organization. http://whc.unesco.org/archive/repcom00.htm#djoudj (Last accessed on March 8, 2010).

WMO. (2004). Integrated Flood Management Case Study Mauritania: Managed Flood Releases and Livelihoods – Lower Delta Senegal river. World Meteorological Organization. http://www.apfm.info/pdf/case_studies/cs_mauritania.pdf (Last accessed on March 8, 2010).

Volta River Basin

Barry, B., Obuobie, E., Andreine, M., Andah, W. Pluquet, M. (2005). The Volta River Basin, Comprehensive Assessment of Water Management in Agriculture – Comparative study of river basin development and management. IWMI. http://www.iwmi.cgiar.org/assessment/files_new/research_projects/River_Basin_Development_and_Management/VoltaRiverBasin_Boubacar.pdf (Last accessed on September 20, 2010).

Zambezi River Basin

Beilfuss, R., and Brown, C. (2006) Assessing Environmental Flow Requirements for the Marromeu complex of the Zambezi Delta. Museum of Natural History – University of Eduardo Mondlane, Maputo, Mozambique. http://www.internationalrivers.org/files/Beilfussfinalreport.pdf (Last accessed on March 25, 2010).

CEH. (2001). Managed Flood Releases: A working conference on guidelines for managed flood releases and lessons learned from Itezhi-tezhi. Lusaka 13-14 March 2001. Center for Ecology and Hydrology, Workshop Report.

Chenje, M. (2000) State of the Environment Zambezi Basin 2000. SADC/IUCN/ZRA/SDRDC, Maseru/Lusaka/Harare, 2000.

Davies, B., Beilfuss, R., Thoms, M. (2000). Cahora Bassa restrospective, 1974-1997: effects of flow regulation on the Lower Zambezi River. Verh. Internat. Verein. Limnol. 27:1-9.

ETH. (2004). Zambezi River Basin, from: ETH Seminar: Science and Politics of International Freshwater Management 2003/2004. Swiss Federal Institute of Technology Zurich. http://www.eawag.ch/research_e/apec/seminars/Case%20studies/2003/Zambezi.pdf (Last accessed on March 25, 2010).

IR. (2006). "Damning the Zambezi – Risks outweigh benefits of proposed Mphanda Nkuwa Dam." International Rivers. http://www.internationalrivers.org/en/node/846 (Last accessed on March 25, 2010).

IFPRI. (2009) The Impact of climate Variability and change on Economic Growth and Poverty in Zambia. International Food Policy Research Institute. http://www.ifpri.org/publication/impact-climate-variability-and-change-economic-growth-and-poverty-zambia (Last accessed on March 25, 2010).

Magadza, C. (n.d.). Kariba Reservoir, Experience and Lessons Learned Brief. http://www.worldlakes.org/uploads/14_Kariba_Reservoir_27February2006.pdf (Last accessed on March 25, 2010).

Magadza, C. (2006). Kariba Reservoir: Experience and lessons learned. Lakes and Reservoirs: Research and Management 11:271-286.

Manatsa, D., Chingombe, W.,Matarira, C. (2008). The impact of the positive Indian Ocean dipole on Zimbabwe droughts. International Journal of Climatology 28:2011-2029.

Marshall, B. and Junor, F. (1981). The decline of Salvinia molesta on Lake Kariba. Hydrobiologia 83:477-484.

McDermott-Hughes, D. (2006). Whites and Water: How Euro-Africans Made Nature at Kariba Dam. Journal of Southern African Studies 32(4):823-838.

Moore, A., Cotterill, F., Main, P., Williams, H. (2007). The Zambezi River. In Large Rivers: Geomorphology and Management. Edited by A Gupta, Chichester, UK. 2007, John Wiley & Sons.

Morrissey, J. (2006). Livelihoods at Risk: The case of the Mphanda Nkuwa Dam - Community risk assessment for the proposed Mphanda Nkuwa hydroelectric dam. http://www.internationalrivers.org/files/MphandaRA2006.pdf (Last accessed on March 25, 2010).

Ngalande, P. (2004) Country Review Zambia. In: Proceedings of the International Workshop on the Fisheries of the Zambezi Basin, Livingstone, Zambia 31 May – 2 June 2004. http://www.worldfishcenter.org/resource_centre/CP75_301007.pdf (Last accessed on March 25, 2010).

Nicholson, S. and Kim, J. (1997). The Relationship of the El Niño-Southern Oscillation to African Rainfall. International Journal of Climatology 17:117-135.

Schelle, P. and Pittock, J. (2005). Restoring the Kafue Flats, A partnership approach to environmental flows in Zambia. Presented at 10th International Riversymposium & Environmental Flows Conference, Brisbane, Australia, September 3, 2005.

Scudder, T. (2005). The Kariba Case Study. Social Science working Paper 1227 – California Institute of Technology.

UTIP. (n.d). Unidade Técnica de Implementação Dos Projectos Hidroeléctricos. http://www.utip.org.mz/home/index.htm (Last accessed on March 25, 2010).

WWF. (2007). Towards Effective Conservation Strategies – The application of strategic principles to increase the impact and sustainability of WWF conservation efforts. Prepared by AID Environment for WWF Netherlands, WWF US & WWF UK. World Wildlife Fund. http://assets.panda.org/downloads/wwf_nl_strategic_principles_03_29_07.pdf (Last accessed on June 6, 2007).

Transboundary Aquifers

BRGM. (2005). Hydrogeological Map of Africa: a prototype at 1/10 000 000 scale. Bureau de Recherches Géologiques et Minières. http://www.sigafrique.net/datawebmaster/doc/Carte_Hydro_Afrique.pdf (Last accessed on July 15, 2010).

Salman, S. (1999). Groundwater, Legal and Policy Perspectives. Proceedings of a World Bank seminar (November 1999). Washington, World Bank. WBTP 456.

UNESCO. (2001). Internationally Shared (Transboundary) Aquifer Resources Management. Their significance and sustainable management. A framework document. IHP-VI, IHP Non Serial Publications in Hydrology. November 2001, UNESCO, Paris.

UNESCO. (2004). Managing shared aquifer resources in Africa. United Nations Educational, Scientific and Cultural Organization.

UNESCO - IHP/ISARM. (2004). Managing Shared Aquifer Resources in Africa. IHP-VI, Series on Groundwater 8. United Nations Educational, Scientific and Cultural Organization International Hydrologocal Programme. Internationally Shared Aquifer Resources Management. http://www.isarm.net/publications/299 (Last accessed on July 15, 2010).

Nubian Sandstone Aquifer

Abdelrhem, I., Rashid, K., Ismail, A. (2008). Integrated Groundwater Management for Great Man-Made River Project in Libya. European Journal of Scientific Research 22(4):562-569.

Alghariani, S. (2007). Reducing Agricultural Water Demand in Libya through Improving Water Use Efficiency and Crop Water Productivity. Proceedings of WRM 2007, Honolulu Hawaii.

Alker, M. (2008). The Nubian Sandstone Aquifer System. In: Conceptualizing cooperation on Africa's transboundary groundwater resources. Ed: Waltina Scheumann and Elke Herrfahrdt-Pähle. German Development Institute. http://www.isn.ethz.ch/isn/Current-Affairs/Security-Watch/Detail/?q51=Mali&ots591=0c54e3b3-1e9c-be1e-2c24-a6a8c7060233&lng=en&id=103285 (Last accessed on May 21, 2010).

Bakhbakhi, M. (2006). Nubian Sandstone Aquifer System. In: Non-Renewable Groundwater Resources – A guidebook on socially-sustainable management for water-policy makers. Eds. S. Foster and D. Loucks. UNESCO 2006.

CEDARE. (2001). Regional Strategy for the Utilisation of the Nubian Sandstone Aquifer System – Executive Summary. Centre for Environment and Development for the Arab Region and Europe – International Fund for Agricultural Development. Cairo, CEDARE 2001.

Dakhleh Oasis Project (n.d.)) Dakhleh Oasis Project – Monash University Department of Archaeology webpage. http://arts.monash.edu.au/archaeology/excavations/dakhleh/index.php (Last accessed on May 21, 2010).

Ebraheem, A., Riad, S., Wycisk, P., Seif El-Nasr, A. (2003). Simulation of impact of present and future groundwater extraction from the non-replenished Nubian Sandstone Aquifer in southwest Egypt. Environmental Geology 43:188-196.

Eggermont, H., Verschuren, D., Fagot, M., Rumes, B.,Van Bocxlaer, B. (2008). Aquatic community response in a groundwater-fed desert lake to Holocene desiccation of the Sahara. Quaternary Science Reviews 27:2411-2425.

Ghazali, A. and Abounahia, M.(2005). An Optimum Approach for the Utilization of the Great Man-Made River Water in Libya. Proceedings Ninth International Water Technology converence, IWTC9, 2009 Sharm El-Sheikh, Egypt.

Gossel, W., Ebraheem, A., Wycisk, P. (2004). A very large scale GIS-based groundwater flow model for the Nubian sandstone aquifer in Eastern Sahara (Egypt, northern Sudan and eastern Libya) Hydrogeology Journal 12:698-713.

Grenier, C., Paillou, P. and Maugis, P. (2009). Assessment of Holocene surface hydrological connections for the Ounianga lake catchment zone (Chad). C.R. Geoscience 341:770-782.

Heinl, M. and Brinkman, P. (1989). A groundwater model of the Nubian aquifer system. Hydrological Sciences Journal 34(4):425-447.

Hughes, R. and Hughes, J. (1992). A Directory of African Wetlands. IUCN, Gland, Switzerland/UNEP, Nairobi, Kenya/WCMC, Camberidge, U.K.

Kröpelin, S. (2007) The Saharan lakes of Ounianga Serir-A unique hydrological system. In: Bubenzer, O., Bolten, A. & Darius, F. (eds.) (2007): Atlas of Cultural and Environmental Change in Arid Africa. Africa Praehistorica 21. Cologne.

Kröpelin, S., Verschuren, D., Lézine, A.-M., Eggermont, H., Cocquyt, C. Francus, P., Cazet, J.-P., Fagot, M., Rumes, B., Russell, J., Darius, F., Conley, D., Schuster, M., von Suchodoletz, H. Engstrom, D. (2008). Climate-Driven Ecosystem Succession in the Sahara: The Past 6000 Years. Science 320:765-768.

Kröpelin, S. (2009). Lakes in the Sahara. German Research February 2009.

Shahin, M. (1987). Groundwater resources in Egypt: potentials and limitations. Water for the Future: Hydrology in Perspective (Procedings of the rome Symposium, April 1987). IAHS Publ. no. 164.

Shaki, A. and Adeloye, A. (2006). Evaluation of quantity and quality of irrigation water at Gadowa irrigation project in Murzuq Basin, southwest Libya. Agricultural Water Management. 84:193-201.

UNESA. (2008). World Population Prospects: The 2008 Revision Population Database. Department of Economic and Social Affairs. http://esa.un.org/unpp/index.asp?panel=3 (Last accessed on May 21, 2010).

Water Technology.net (n.d.) "GMR (Great Man-made river) Water Supply Project, Libya." http://www.water-technology.net/projects/gmr/ (Last accessed on May 21, 2010).

World Bank. (2010). World Bank Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators?cid=GPD_WDI (Last accessed on July 21, 2010).

Coastal Aquifers

Elbadawy, O. (2007) Management of Shared Aquifer using GIS: A regional case study, Nubian Sand Stone Aquifer. Environmental technologies, including GIS, environmental simulation and process simulation. December 10-12 2007, Tunis, Tunisia.

Hinrichsen D. 1995. Coasts in Crisis. American Associate for the Advancement of Science (AAAS), Washington D.C. USA. http://www.aaas.org/international/ehn/fisheries/hinrichs.htm (Last accessed on May 21, 2010).

Schlumberger Water Services. (2007). Groundwater Modeling in the Al Kufrah Basin and the Al Jaghbub Area – Case Study. http://www.waterloohydrogeologic.com/e_news/guest_articles/Kufra-Jaghboub-Case-Study.pdf (Last accessed on May 21, 2010).

Steyl, G. and Dennis, I. (2010). Review of coastal-area aquifers in Africa. Hydrogeology Journal 18:217-225.

UNEP. (2008). Africa Atlas of Our Changing Environment. United nations Environment Programme. Division of Early Warning and Assessment. Nairobi.

Tano Basin Abidjan Aquifer

Oga, M., Marlin, C., Dever, L., Filly, A., Njitchoua, R. (2008). Hydrochemical and isotopic characteristics of coastal groundwater near Abidjan (southern Ivory Coast). In Applied Groundwater Studies in Africa – Sequn Adelana and Alan MacDonal editors, Taylor and Francis 2008.

3

CHALLENGES & OPPORTUNITIES

Curt Carnemark / World Bank

Improving the Quantity, Quality and Use of Africa's Water

Africa faces mounting challenges in providing enough safe water for its growing population, especially for the huge numbers of people migrating to peri-urban areas, where municipal water services are often non-existent. Many African nations will fail to achieve the Millennium Development Goal's safe water target to reduce by half the proportion of the population without sustainable access to safe drinking water by 2015, and many more will miss the sanitation target that stipulates that by that date, they reduce by half the proportion of the population without sustainable access to basic sanitation. Other challenges include avoiding potential conflicts over water in the 63 water basins on the continent shared by two or more countries; adapting to the impacts of climate change on water resources, which will be greater than most other regions because Africa already suffers from extreme rainfall variability; and developing water resources that are adequate for local needs but that are unavailable due to political and economic constraints.

On the other hand, there are clear opportunities for Africa to overcome these and other water-related challenges. One of them is the huge opportunity to develop its untapped water resources. In 2005, only about five per cent of the development potential of these resources—irrigation, industry, tourism and hydropower—was expected to be utilized (UNECA and others 2000). This chapter proposes exciting potential solutions to some of Africa's other water challenges, including revolutionizing toilets so they are as desirable as mobile phones, promoting a greener Green Revolution, investing in small hydroelectricity developments and fostering the greening of the Sahel.

This chapter underscores the following nine major challenges that Africa faces in addressing its water resource issues:

CHALLENGE 1

PROVIDE SAFE DRINKING WATER

The Challenge: *Attain the MDG water provision target: By 2015, reduce by half the proportion of the population without sustainable access to safe drinking water.*

The Situation: *Africa as a whole is not expected to meet this MDG drinking water target; of its 53 countries, only 26 are on track to meet it. The high incidence of water-related and waterborne diseases related to the lack of safe drinking water is a drain on human and financial resources.*

The Constraints: *Exploding peri-urban and slum areas; economic growth and higher demand; geographical isolation; dearth of public utilities and regulation; and high costs of water provision.*

The Opportunities: *Improve financing; encourage privatization through concessions; subsidize connections; target informal settlements; institute or improve regulation; target rural communities; and employ simple solutions.*

The Challenge

The Millennium Development Goal's safe water target is to reduce by half the proportion of the population without sustainable access to safe drinking water by 2015.

The Situation

- *Africa as a whole will not reach the MDG drinking water target*: Worldwide, 884 million people have no access to drinking water from improved sources (Figure 3.1.1). Sub-Saharan Africa accounts for more than third of that number, with about 330 million people without access to safe drinking water. Africa's progress towards the MDG drinking water target is slow and uneven, and the continent as a whole will not reach the goal. Although the proportion of people in sub-Saharan Africa using improved sources of drinking water increased by 14 per cent from 1990 to 2008, only 60 per cent of its population had such access by the end of that period (WHO/UNICEF 2010). Based on current trends, sub-Saharan Africa will not reach the MDG water target until 2040 (UNDP 2006a). A recent survey revealed a bleak future in which only two countries (Kenya and South Africa) are estimated to have more than 75 per cent of what is needed to achieve the sanitation target, and five countries are estimated to have more than 75 per cent of what is needed to achieve the MDG target for drinking water (WHO and UN-Water 2010).
- *There are large disparities in the provision of safe water*: sub-Saharan Africa has by far the lowest coverage rates of piped water among world regions (50 per cent) (WHO/UNICEF 2010). The increase in numbers of people with access to other improved sources of drinking water was 3.5 times higher than the rise in people with piped water on premises. Only five per cent of the rural population receives piped water in their homes compared to 35 per cent of urban dwellers (WHO/UNICEF 2010).

Figure 3.1.1: Number of people without access to an improved source of drinking water (millions) (Source: WHO/UNICEF 2010)

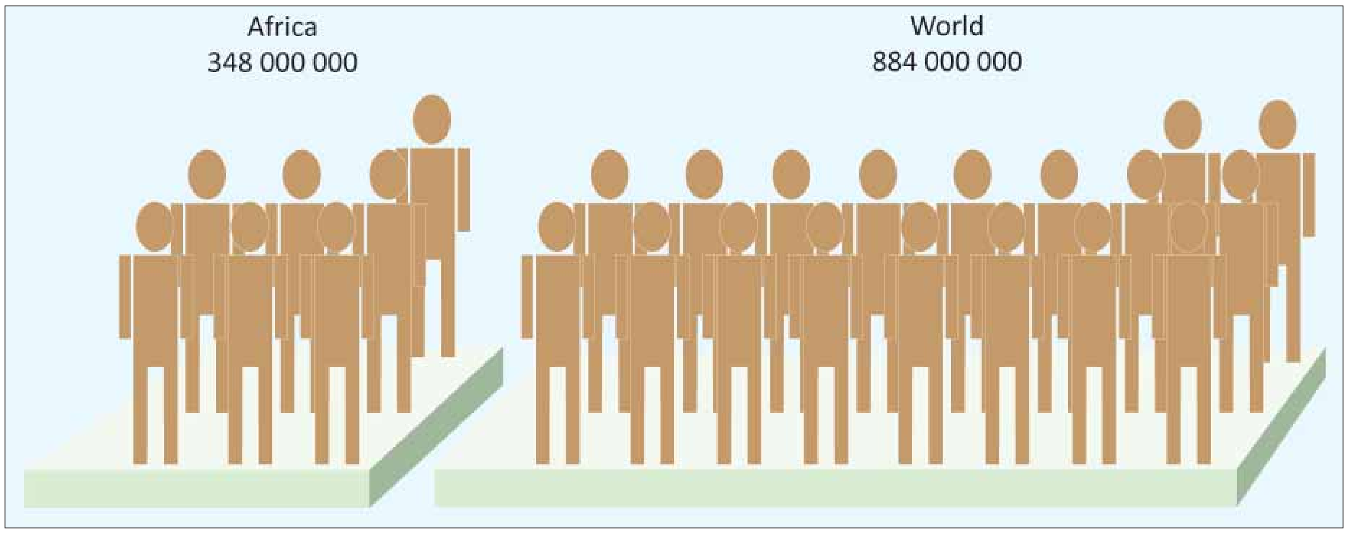


Figure 3.1.2: Percentage loss in GDP due to diseases and productivity losses linked to water and sanitation (Source: UNDP 2006a)

- *Limited access to water means that Africa has a high incidence of water-related disease:* The incidence of water-related and waterborne diseases such as cholera, malaria, Guinea worm and river blindness is high in Africa, mainly due to limited access to water and sanitation. Schistosomiasis (or bilharzia) is endemic in a total of 46 countries (Boelee and Madsen 2006). During the wet season in 2005, 14 303 cases of cholera were diagnosed and 252 people eventually died in Guinea-Bissau alone (Bordalo and Savva-Bordalo 2007). The World Health Organization (WHO) estimates that there are 0.75 cases of diarrhoea per person worldwide every year. This rate varies between regions. Sub-Saharan Africa has the highest rate, with 1.29 cases per person annually. In contrast, rates in Europe and the United States are 0.18 and 0.07 cases per person per year, respectively (Lewin and others 2007) (Figure 3.1.3).

- *The lack of safe water is debilitating to the economy:* In economic terms, the lack of proper water and sanitation services in developing countries translates into the loss of revenues and the inability to generate and sustain livelihoods, due in large part to the debilitating effects of water-related disease (Figure 3.1.2). In addition, the time and energy lost in hauling water from long distances, predominantly undertaken by women and girls, deprives them of time to engage in livelihood generating activities and attending school.

The Constraints

There are many reasons for the lack of progress in providing the people of Africa with safe drinking water, including the following:

- *Exploding peri-urban areas and more affluent consumers:* In some regions, growing populations have caused the ranks of the destitute to swell. In Cairo and other large cities on the continent, sprawling city limits and rapidly growing populations (from both natural growth and in-migration from rural areas) have created extensive squatter settlements or slums, challenging the abilities of water management institutions to provide adequate water and sanitation infrastructure. On the other hand, as some city dwellers become more affluent and industrial development expands with economic growth, the demand for better and more water services also grows. Consequently, water scarcity is not entirely a natural phenomenon. It can also be attributed to low levels of investment in water resources services and the inability to cope with the growing demand for water in response to population growth and economic development (Mwanza 2003).

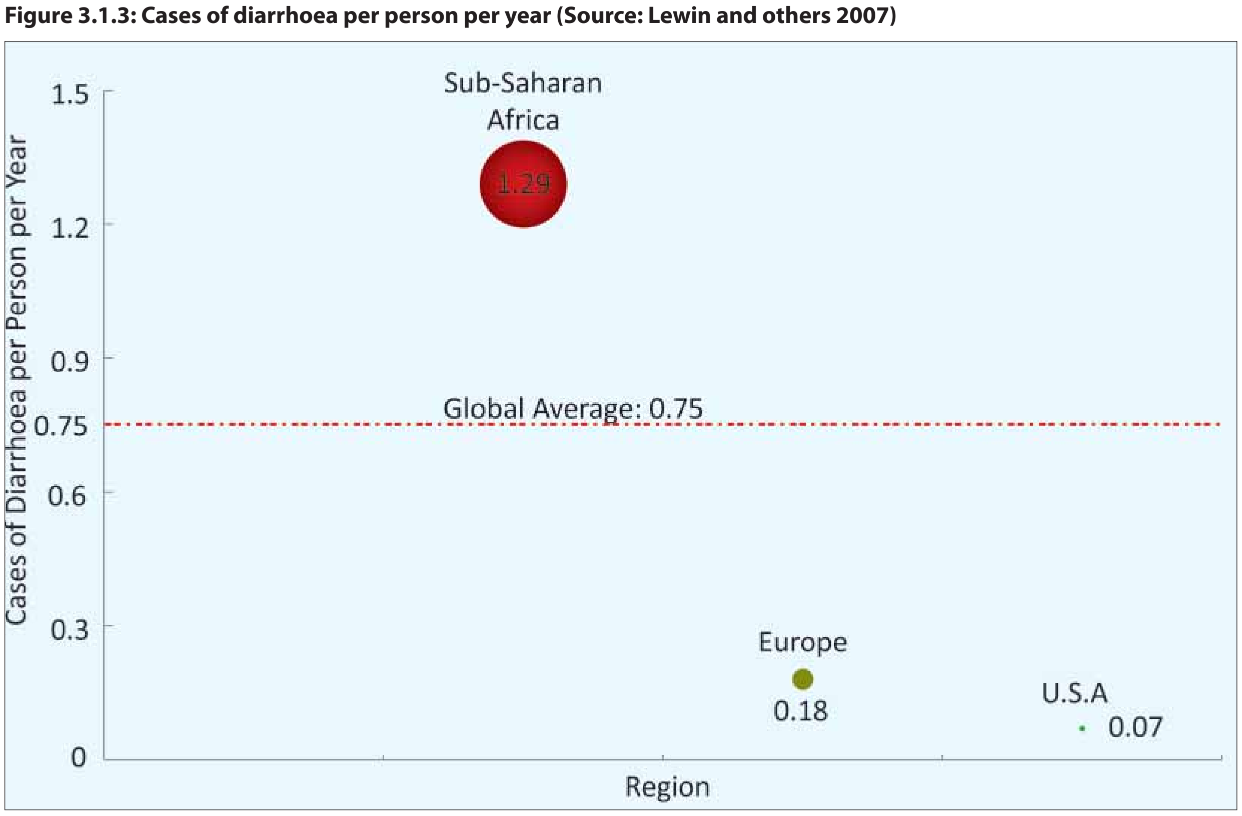
- *Lack of access, regulation and public utilities:* Throughout Africa, there are areas where water and sanitation services are more easily accessible than others. This can be due to geography, climate and the economic and political history of the countries. In poor and conflict-prone areas, water services are meager and most areas have no infrastructure at all. This dilemma has been recognized as a major

African Countries with Human Schistosomiasis

- ***Northern**: Algeria, Egypt, Libya, Morocco, Tunisia, Sudan*
- ***Western**: Burkina Faso, Chad, Gambia, Mali, Mauritania, Niger, Senegal, Benin, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Sierra Leone, Togo*
- ***Central**: Angola, Cameroon, Central African Republic, Congo, Democratic Republic of Congo, Gabon*
- ***Eastern:** Burundi, Ethiopia, Kenya, Rwanda, Uganda, Somalia*
- ***Western Indian Ocean Islands:** Comoros, Madagascar, Mauritius*
- ***Southern**: Tanzania, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe*

(Source: Boelee and Madsen 2006)

Figure 3.1.3: Cases of diarrhoea per person per year (Source: Lewin and others 2007)



challenge to South Africa's Department of Water Affairs and Forestry, for example (Dungumaro 2007). Small-scale private providers (that is, excluding community or publicly operated water schemes) supply 50 per cent of the urban population in Africa. High prices per unit of water supplied, poor water quality and difficulty in regulating the providers are important issues that challenge progress in safe water provision.

- *High cost of water provision*: The financial cost to users is a less obvious barrier to the provision of safe drinking water. The per capita costs of providing clean water are highest in urban areas and in sparsely populated rural areas; on average, however, expanding coverage costs less in rural areas than in high-density urban areas. In much of sub-Saharan Africa, higher-income households with connections to utilities derive the greatest gains from water sold at prices far below the level needed to cover operations and maintenance costs. People living in the slums of Kenya pay five to ten times more for water per unit than those in high-income areas, and more than consumers pay in London or New York. In Benin, Kenya and Uganda, connection fees for access to water provision from formal network providers exceeds US$100 (UNDP 2006a).

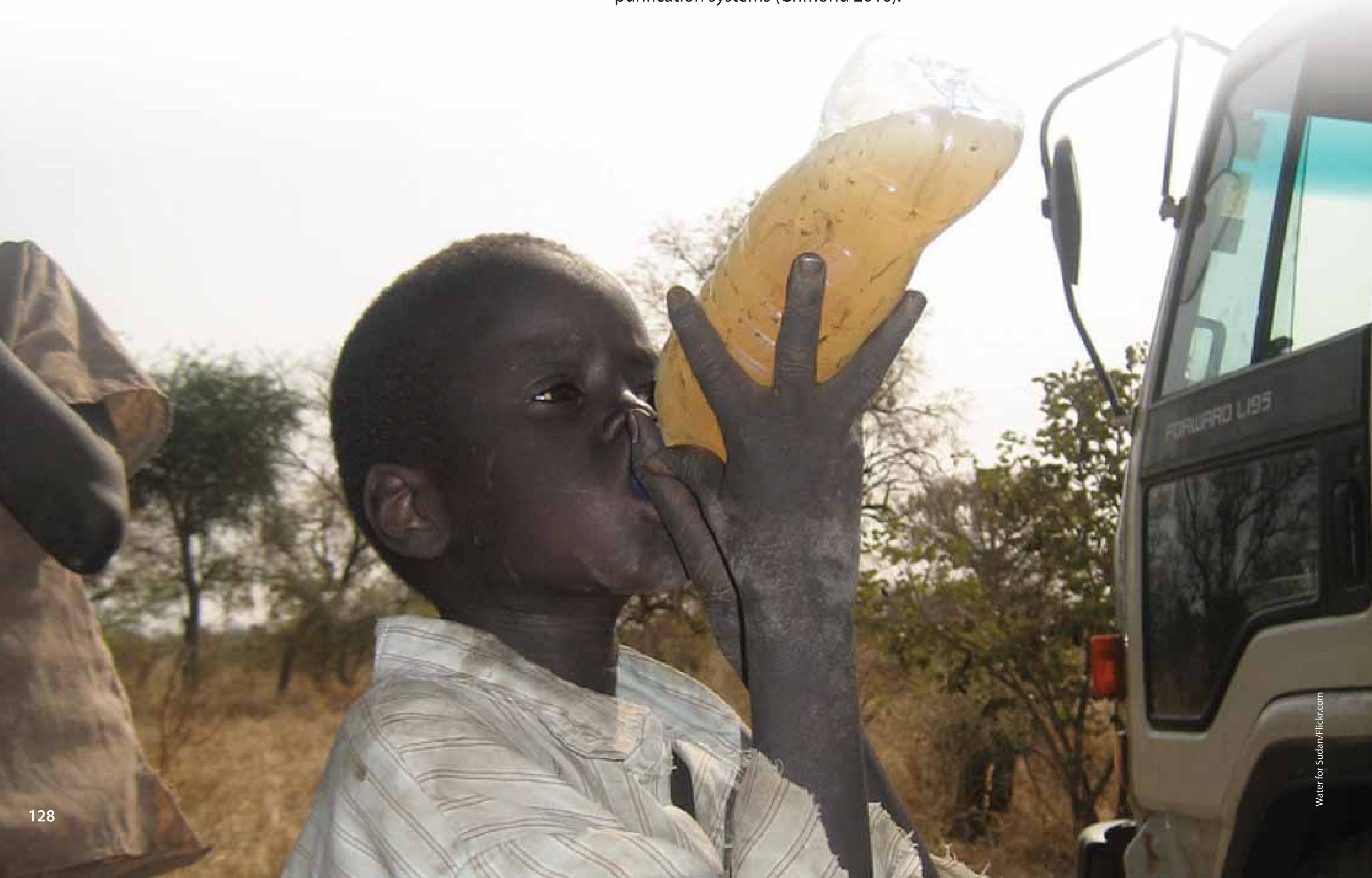
In 2008, aid commitments for large sanitation and drinking water systems was US$4.6 billion, compared to US$1.2 billion in aid to basic systems. Basic drinking water systems are defined as drinking water supply through low-cost technologies such as hand pumps, spring catchment, gravity-fed systems, rainwater collection, storage tanks and small distribution systems. Basic sanitation systems are defined as latrines, small-bore sewers and on-site disposal. Large drinking water systems include treatment, drinking water conveyance and distribution and large sanitation systems include sewerage collection systems and wastewater treatment plants (WHO and UN-Water 2010).

The Opportunities

In spite of the situation and formidable challenges, there are opportunities to improve safe water availability in Africa and lessons can be learned from some African countries that have seen the most progress. The strongest performers in terms of piped water-service expansion are Benin, Burkina Faso, Chad, Ethiopia, Mali and Senegal, all showing growth rates of four to eight per cent per year (Banerjee and others 2009). While rural populations continue to lag behind urban populations globally, countries as diverse as Morocco and Uganda have sustained rapid increases in rural coverage (UNDP 2006a).

- *Improve financing:* According to the 2006 UNDP Human Development Report, governments need to spend about one per cent of GDP on water and sanitation. Additionally, increased international aid would play a very crucial role in catalyzing access to improved water sources. More funding from tariffs, taxes and transfers, in the right mix, can help meet national goals for sustainable water access (Hashimoto Action Plan 2010).
- *Encourage concessions in privatization schemes:* Private investment by domestic and foreign companies that assume responsibility for financing and operating water systems can improve efficiency, reduce water losses, increase supply, extend meters and revenue collection and enlarge coverage. In Morocco, which created four concessions between 1997 and 2002, coverage increased as did consumer satisfaction scores (UNDP 2006a). In 1995, another programme to supply water to rural areas called PAGER was established in Morocco, which required public participation in its planning and implementation. Access to drinking water increased from 14 per cent before PAGER, to 16 per cent in 1995 and to 61 per cent in 2004 (Tortajada 2006). The crucial consideration in the introduction of any system, however, is the need to be sensitive to customer's needs, a lesson learned by the failure of some water-privatization schemes (Grimond 2010).
- *Subsidize connections for the poor*: Subsidising connections for poor households and implementing innovative payment strategies may remove an important barrier to expanding the water-supply network. In Côte d'Ivoire, for example, a Water Development Fund surtax is included in bills, with about 40 per cent of the proceeds used for connection subsidies (UNDP 2006a).

- *Target informal settlements:* Some utilities have shown an unwillingness to extend services to households lacking legal title, fearing that it could jeopardize their revenue collection. Using creativity to deal with this dilemma may solve water access problems for people in these settlements. For example, a utility in Manila has extended underground water lines to the perimeter of slums and allowed households to make above-ground connections through small plastic pipes linked to meters that are maintained by residents associations and non-governmental agencies. Such arrangements can improve equity; efficiency increases also by reducing the revenue losses associated with illegal connections. In Manila, for example, it reduced water costs by 25 per cent in the slum areas now being served (UNDP 2006a).
- *Institute or improve regulation:* Regulatory authorities are important to ensure that providers are managed in a way that secures both equity and efficiency independent of politics. Where administrative capacity and regulatory institutions are lacking, citizens can take a pro-active role, pressing for more information and publicizing underperformance by water utilities (UNDP 2006a).
- *Target rural communities:* Opportunities in rural communities include adoption of free-standing small-scale systems capable of treating water; recovering wastewater for re-use and capturing resulting gases as a source of energy for power, lighting and cooking—support to community-level projects on water resources management, water supply and sanitation in over 30 countries has demonstrated this. In Rajasthan, India, such support aided in the construction of 7 500 community water harvesting structures in the form of dams and ponds to eliminate water shortages in the area (UNDP 2006b).
- *Encourage entrepreneurship for simple water purification techniques:* Solutions using local ingenuity and simple tools and mechanisms have been shown to improve access to safe drinking water. For example, a Swiss-pioneered water-disinfection program is being used all over the world to provide drinking water for about four million people. The main components of the system are discarded plastic bottles, which are filled with any water that is not too murky and then placed on a piece of metal in full sunlight. In six hours, the UVA radiation is able to kill viruses, bacteria and parasites in the water, making it safe to drink. Since the beginning of the program in Tanzanian schools, promising results include less absenteeism due to diarrhoea (Jenkins 2010). There is now a large market for water purifiers and many entrepreneurs are inventing more affordable models to bring safe water to the poor. Subsidies may be required to initiate new programs, but a local commercial incentive by private enterprise is needed to grow and sustain the adoption of simple and efficient water purification systems (Grimond 2010).



Water for Sudan/Flickr.com

CHALLENGE 2

ENSURE ACCESS TO ADEQUATE SANITATION

The Challenge: *Attain the MDG sanitation target: By 2015, reduce by half the proportion of the population without sustainable access to basic sanitation.*

The Situation: *Africa as a whole is not expected to meet this MDG sanitation target; of its 53 countries, only nine are on track to meet it. The high incidence of water-related and waterborne disease related to unsanitary conditions is debilitating to African economies and human livelihoods and well-being.*

The Constraints: *Exploding peri-urban and slum areas; economic growth and higher demand; geographical isolation; dearth of public utilities and regulation; and high costs of water provision.*

The Opportunities: *Recognize the potential to generate revenues from sanitation technologies; revolutionize toilets so they are as desirable as mobile phones; learn from the extraordinary expansion of mobile phones; encourage and support simple solutions from entrepreneurs; introduce urban water tariffs; increase sanitation's share in total aid; adopt system financing; build partnerships between the government and civil society for educational campaigns; and seek international funding.*

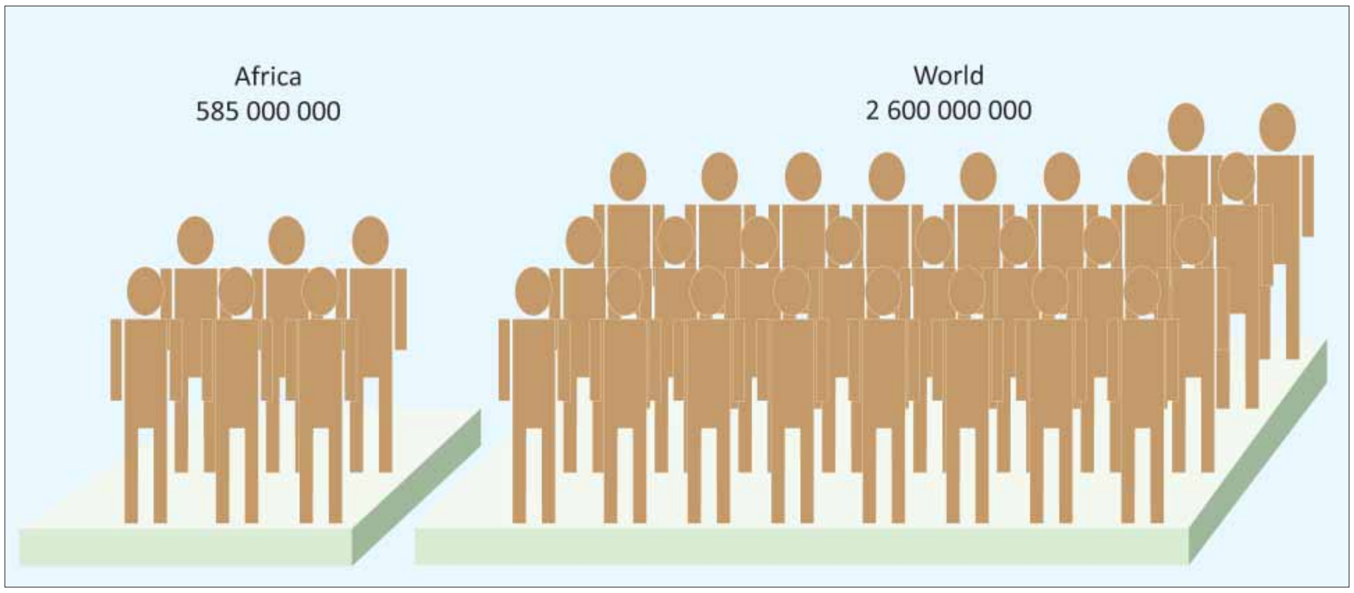
The Challenge

The Millennium Development Goal's sanitation target is to reduce by half the proportion of the population without sustainable access to basic sanitation by 2015. Increasing people's access to water will help Africa reach this target, while ensuring that water sources are not contaminated by sanitation facilities will help it to reach the MDG safe drinking water target.

The Situation

- *Africa as a whole will not meet the MDG sanitation target:* There are about 2.6 billion people in the world who do not have access to improved sanitation facilities of which about 585 million people are in Africa (Figure 3.2.1). Less than half of the people living in 35 African countries do not have such access. Use of improved sanitation facilities in sub-Saharan Africa is very low, at an overall 31 per cent, with great disparities between urban and rural areas. The MDG target requires that 63 per cent of the region's population has access to improved sanitation by 2015. That amounts to 370 million more people than the estimated 242 million who were using such facilities in 2006 (WHO/UNICEF 2010). Most African countries will not meet the target. Only nine countries (Algeria, Morocco, Tunisia, Libya, Rwanda, Botswana, Angola, South Africa and Egypt) of the 53 in Africa will achieve the MDG target for basic sanitation (WHO/UNICEF 2010). The 2006 Human Development Report predicts that under a business-as-usual scenario, it would only be possible to reduce the population using unimproved sanitation facilities by half by 2076 (UNDP 2006).
- *Access to sanitation is rising in Africa, but there are large disparities in its provision:* The coverage rates for sanitation are far lower than those for water, even in higher-income groups. The proportion of the population using improved sanitation facilities, however, is increasing in all the developing regions (UNDP 2006). Notable increase in the use of improved sanitation facilities has been made in North Africa, but

Figure 3.2.1: Number of people without access to improved sanitation facilities (Source: WHO/UNICEF 2010)



throughout the continent, regional disparities are still very apparent. Sub-Saharan Africa is the only region where more than half the population still does not have any access to better sanitation, with a striking contrast between urban areas, which are better served, and rural ones (WHO/UNICEF 2010). Even so, less than ten per cent of the urban population is connected. In Zambia, for example, only three-quarters of the richest quintile of households have access to a flush toilet (UNDP 2006).

- *Although sanitation coverage is rising, population growth is outpacing provision efforts:* Although Africa had one of the world's lowest sanitation coverage rates in 1990, the number of people using improved sanitation facilities in sub-Saharan Africa has improved over the years. The sanitation coverage in sub-saharan Africa as a whole increased from 28 per cent in 1990 to 31 per cent in 2008. The number of people without access to latrines and toilets in sub-Saharan Africa, however, increased by 194 million people during the same period. Similarly, the proportion of people practicing open defecation declined by 25 per cent, but population growth has meant that the absolute number increased from 188 million (in 1990) to 224 million (in 2008) (WHO/UNICEF 2010). Efforts to reach the MDG sanitation target have been unable to catch up with the population growth.

- *Lack of sanitation is a cause of waterborne disease:* Cholera epidemics are a major risk in areas with high concentrations of people and poor sanitation. Heavy rains can flood latrines, contaminating water and exposing populations to cholera bacteria. Groundwater can also become contaminated by improper sanitation. In Côte d'Ivoire, and in Dar es Salaam, Tanzania, for example, groundwater contaminated by inadequate sanitation facilities has caused cholera outbreaks and other water-borne diseases in informal settlements around these areas (Dagdeviren 2009). In 2005, West Africa suffered more than 63 000 cases of cholera, leading to 1 000 deaths. Senegal was severely affected following rainy season flooding in Dakar. During the first half of 2006, one of the worst epidemics to sweep sub-Saharan Africa in recent years claimed more than 400 lives in a month in Angola (UNDP 2006).

- *Economies and human livelihoods suffer from the lack of sanitation:* Lack of sanitation hurts local economies when resulting poor health leads to lost working days, school absenteeism and increased time to take care of the sick. A cost-benefit analysis by the WHO demonstrated an estimated economic return of between US$3 and US$34 for every US$1 invested in water and sanitation (WHO and UN-Water 2010).

The Constraints

The obstacles to providing proper sanitation facilities are the same as those faced in the provision of safe drinking water: exploding peri-urban and slum areas, economic growth and higher demand, geographical isolation, dearth of public utilities and regulation, and the high costs of water provision. In addition, talking about toilets is taboo, making it difficult for people, especially women who lack a voice in Africa, to demand better services.

- *Lack of financial and technical resources:* Sanitation investments have lagged behind water supply by almost a decade. Poor economic performance and associated financial and technological limitations continue to be at the root of the slow progress in supplying adequate sanitation services, which suffers from

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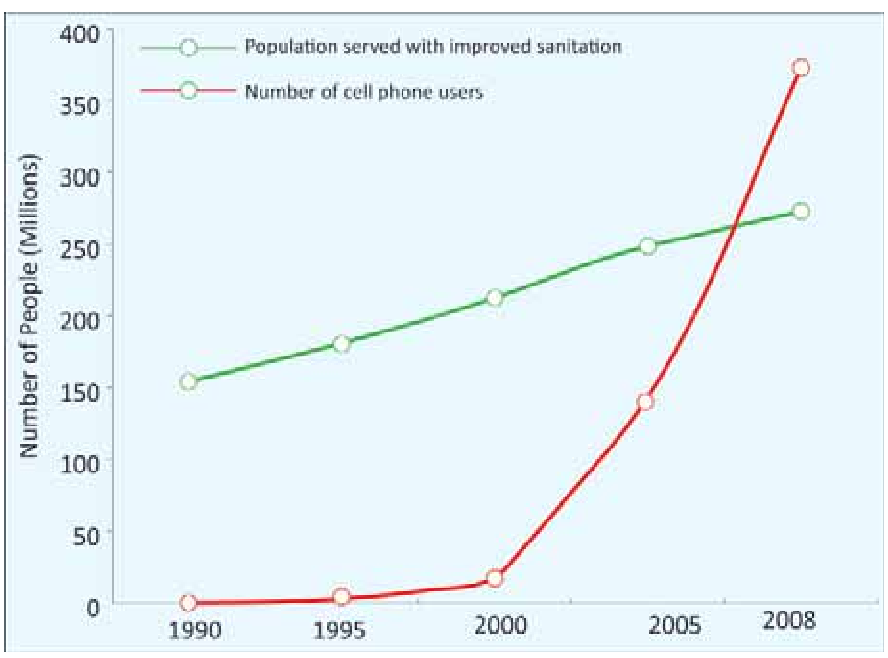
chronic under-funding. Public spending on water and sanitation is typically less than 0.5 per cent of GDP. The infrastructure for an effective nationwide water and sanitation system—from water pipes to pumping stations to sewerage works—requires investment on a scale beyond what the poorest countries can begin to afford. Moreover, it requires large upfront investments as well as longer-term maintenance costs. Given the high proportion of people in developing countries that lack access to water and sanitation and survive on less than U$1 a day, it is not feasible to meet these upfront costs through user fees (UNDP 2006).

The Opportunities

The improvement of sanitation services is inextricably linked to the improvement of water provision. Thus, the same opportunities outlined in the previous section apply here and there are lessons to be learned from countries that have made the most strides in increasing sanitation coverage. As well, the vast improvements being made in access to communications technologies provides an example of how innovation and entrepreneurship in sanitation technologies could also reap economic benefits in addition to improving health and well-being. The World Toilet Organisation (WTO) offers an alternative and radical approach to accelerate progress towards the MDG sanitation target by encouraging the perception of toilet ownership as a status symbol.

Figure 3.2.2: Number of cellphone users against the population served with improved sanitation (Source: UNSD 2009, WHO/UNICEF 2010)



- *Recognize the potential to generate revenues from sanitation technologies:* The business opportunities afforded by investing in sanitation is now being recognized and Africa could benefit by market-based approaches (Lane 2010). The World Toilet Organisation (WTO) offers such an approach, arguing that businesses that provide affordable toilets can make profits (WTO 2010). The products of properly composted human faeces can also be a commercial commodity rather than a waste product, as has been demonstrated by the Chinese for centuries (Lane 2010).
- *Revolutionize toilets so they are as desirable as mobile phones:* The WTO also promotes a sanitation revolution in which toilets will become as desirable as mobile phones, simply by selling them—"Once people have invested some of their own money in a loo, they will use it" (Grimond 2010). Since the poor have not been motivated to invest in toilets through promotion on health grounds, the WTO aims to emotionally connect with the poor by branding toilets as a status symbol and an object of desire (WTO 2010).
- *Learn from the extraordinary expansion of mobile phones:* The number of mobile phone users in Africa has grown exponentially, while sanitation adoption has only increased mathematically. The number of mobile cell phone subscribers in Africa reached 448.1 million in 2009, representing an increase of 75 million new users since the previous year and a growth of 20 per cent in the customer base since 2008. The adoption of improved sanitation, on the other hand, has grown at a much slower rate (Figure 3.2.2).

Public-private partnerships have helped to drive the recent exponential growth of mobile phone subscribers in Africa. The combination of the public sector's knowledge and expertise in development with the technical expertise and innovation of private companies has fostered the rapid, efficient and sustainable communications business (Aker 2008). Improving sanitation can also provide an opportunity for such partnerships. Marginal costs can be reduced by the private sector's innovation for cheaper alternatives to improved sanitation facilities while the public sector can be responsible for equity and inducing behavioural changes.

- *Encourage and support simple solutions from entrepreneurs*: Entrepreneurs are increasingly bringing out low technology and affordable toilets. In Tanzania, for example, a concrete slab to install above pit latrines is now available for about US$5.00. A Swedish company is manufacturing a hygienic, single-use personal toilet bag of biodegradable plastic that breaks down the contents into marketable fertilizer (Grimond 2010).The most efficient way of designing integrated water and sanitation projects, especially for remote rural areas, is to use plug-in technologies that are flexible, compact, mobile and solar powered. More importantly, these technologies should be easily transferable to local communities so that local stakeholders can be responsible for maintaining and operating these facilities themselves. This local approach is suitable whereas large-scale solutions to the sanitation crisis are not practical due to lack of capacity in engineering, business development and fiscal management; it is also more donor-friendly for funding cycles of one-to-two years (UNU 2010).
- *Introduce urban water tariffs:* A study in Egypt showed that if urban water tariffs were raised to cover operations and maintenance costs, enough financial resources could be freed up to finance urgently required investment in sanitation infrastructure (UNDP 2006).
- *Increase sanitation's share in total aid:* Aid for sanitation and drinking water is increasing in absolute terms, but its share of total aid decreased from eight per cent in 1997 to five per cent in 2008 (WHO and UN-Water 2010). If water and sanitation targets were achieved, sub-Saharan Africa would save about US$2 per capita—equivalent to about 12 per cent of public health spending. Reduced spending would release resources for other priorities, including addressing HIV/AIDS (UNDP 2006).
- *Adopt system financing:* This opportunity is especially relevant if national plans include clear funding estimates for attaining their targets. All financing ultimately comes from government budgets (a category that includes aid) or users. The appropriate mix between the two varies. In low-income countries with limited coverage and high levels of poverty, a benchmark indicator is public spending on water and sanitation of about one per cent of GDP (depending on per capita income and the ratio of revenue to GDP), with cost-recovery and community contributions providing an equivalent amount (UNDP 2006).
- *Build partnerships between the government and civil society for educational campaigns:* There is an opportunity to increase capacity building through stronger partnerships between the government and civil institutions. For example, ten years ago Bangladesh's rural areas had one of the lowest levels in the world of access to proper sanitation. Despite being one of the world's poorest countries, it is now on target to achieve nationwide sanitation coverage by 2010, thanks to a "total sanitation campaign" promoted by NGOs and local authorities. The campaign appeals to three drivers of change: disgust, self-interest and a sense of individual responsibility for community welfare (UNDP 2006). An example from Burkina Faso in the mid-1990s demonstrates the success of an educational campaign conducted in partnership between the Ministry of Health and community groups related to sanitation: In Bobo-Dioulasso, children were still at risk from poor hygiene despite the presence of pit latrines in most households. The partnership promoted behavioural changes that reduced the incidence of diarrhoea—for example, by encouraging mothers to wash their hands with soap and water after changing diapers. Over three years, the programme averted some 9 000 diarrhoea episodes, 800 outpatient visits, 300 hospital referrals and 100 deaths—at a cost of US$0.30 per inhabitant (UNDP 2006).

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CHALLENGE 3

FOSTER COOPERATION IN TRANSBOUNDARY WATER BASINS

The Challenge: *Reduce potential conflicts over water resources by enhancing cooperation in transboundary water basins.*

The Situation: *Africa has 63 shared water basins. There is a potential for conflict over shared water resources; but there are already at least 94 international water agreements in Africa to cooperatively manage them.*

The Constraints: *Population growth is diminishing shared water supplies; climate change threatens to stress shared waters; water is declining in shared aquifers; there are seasonal differences in water supplies, and inadequate joint management laws and conflicting national interests stress joint management capacities.*

The Opportunities: *Recognize and build on water as a binding factor between otherwise hostile states; and learn from successful transboundary cooperation efforts and agreements among African states.*

The Challenge

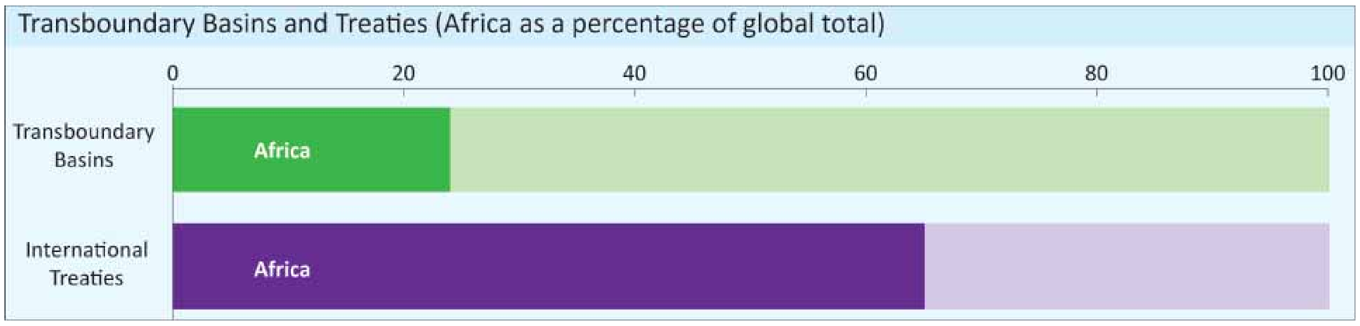
Given the many watersheds shared by numerous African nations and the potential for discord over water management in them, there is a need and an opportunity to avoid conflict by cooperating in transboundary water basins.

The Situation

- *Africa has a large number of shared watersheds:* There are 263 international river basins covering almost one half of the total land surface of the globe and affecting 40 per cent of the world's population. Of these, Africa has 63 shared basins covering about 64 per cent of the continental area (Figure 3.3.1). Africa has more rivers shared by three or more countries than any other continent. Every country in Africa has at least one international river, with the Congo basin shared by as many as 11 countries (Sadoff and others 2002).

- *There is a potential for conflict over water resources*: There are a number of ways in which disagreements over water use can arise among parties that share the resource: where one country transfers or threatens to transfer water outside the basin (for example, there is a planned project to transfer water from the Ubangi River to Lake Chad); when activities in upstream sections of a basin threaten downstream users and vice-versa (in the Okavango Transboundary watershed, for example, there is the potential for disputes between users in Angola and Namibia in the upper part of the river and those in Botswana downstream); where development outside a river basin threatens the river's water availability or quality, or vice-versa (for example, urban and industrial developments outside the Congo basin watershed make demands on the basin's waters); where there is competition for the same water among different economic sectors both within and between countries, including irrigation, hydroelectricity, industry, navigation, tourism, mining, etc.; and finally, when richer countries or large corporate development projects threaten water use by poorer users in another part of the basin (Roy and others 2010).

Figure 3.3.1: Number of transboundary basins and international treaties worldwide and in Africa (Source: UNEP 2006, OSU 2007)



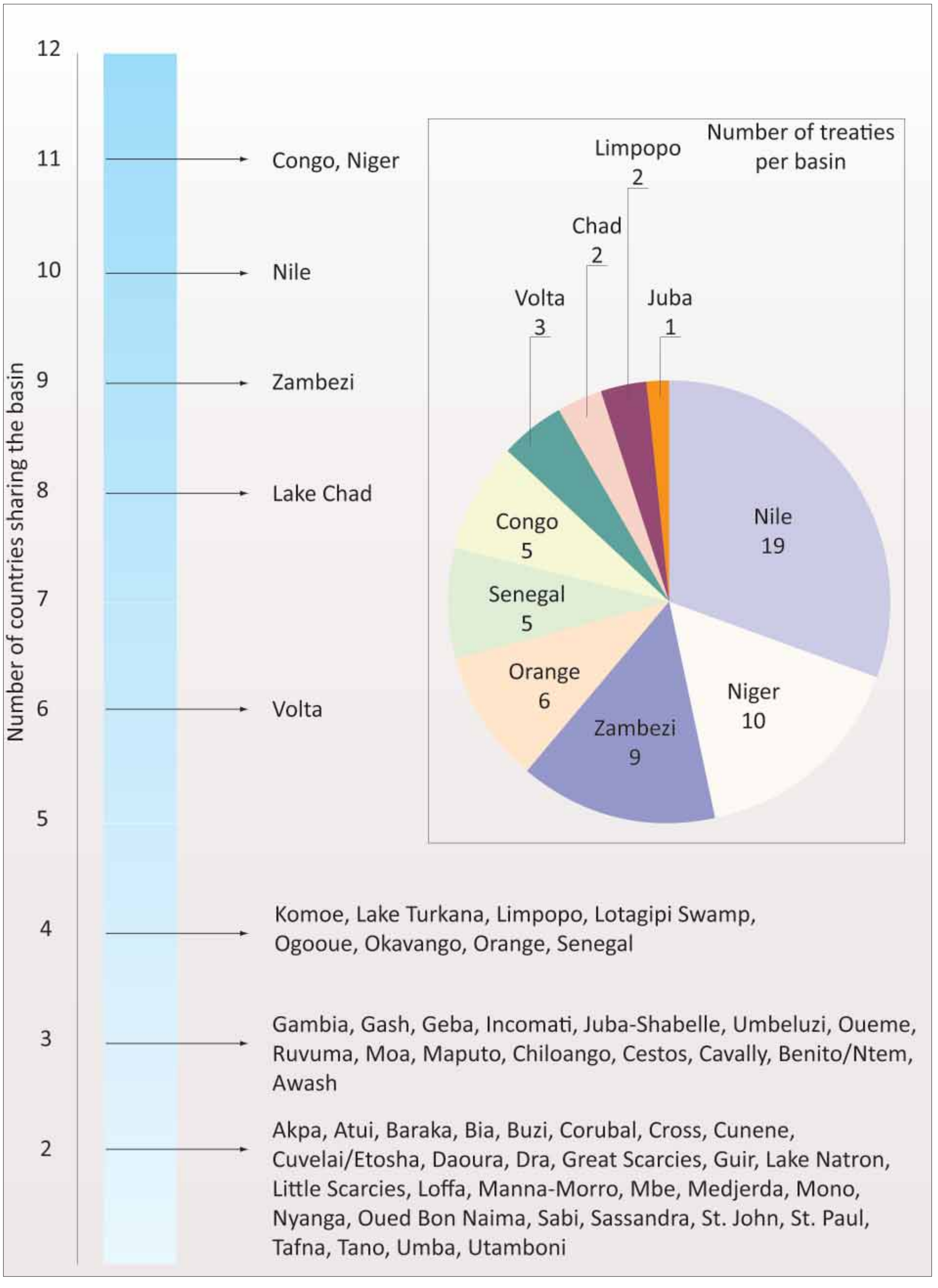
- *There are at least 94 international water agreements in Africa:* Worldwide, about 3 600 international waters treaties have been signed between 805 AD and 1984. Out of 145 international agreements signed between two or more states sharing water-basins in the last century, about 94 occurred in Africa, dating back from late 1800s (Wolf 1998). Figure 3.3.2 shows the number of countries sharing river basins in Africa's top shared basins and the number of transboundary treaties in those watersheds. It also illustrates the number of treaties in each of Africa's major basins.

The Constraints

- *Population growth is diminishing shared water supplies:* Perpetual population growth and existing hydro-political complexities in Africa's international river basins will inevitably place high stress on shared water resources and on the agreements that govern them (Turton 2008a). Africa's ever-growing population will certainly increase the demand for water. As demand increases and water supply decreases, the possibility for conflicts between transboundary nations could rise. For example,

*"**Water conflict**" refers to any disagreement or dispute over or about water, where external social, economic, legal, political or military intervention is needed to resolve the problem. A "**water war**" is an armed conflict that is fought between countries with the sole or primary purpose of gaining access to water, or where water forms the central weapon of offence in the arsenal of an aggressor (Ashton 2007).*

Figure 3.3.2: Number of countries in top-most shared basins and number of treaties for each of the major basins (Source: Wolf and others 2005, OSU 2007; Source 2 (for treaties): Number of treaties by Africa's major basins. Source: UNEP 2006, UNEP 2002, OSU 2007)



there is unprecedented demand for water in the Okavango River Basin, in part due to the increase in returning refugees and renewed commerce and trade as a result of the Angola peace process; water scarcity in the future could severely constrain economic development and possible elevate the issue of how to manage water to a national security issue (Roy and others 2010).

- *Climate change threatens to stress shared waters:* Predicted climate changes may have negative impacts on supply and demand, and may further exacerbate situations in which water is shared among countries (Cooley and others 2009).
- *Water is declining in shared aquifers:* Africa's aquifers contain large amounts of fossil water, which is thousands of years old. Their recharge rate is now much less than the withdrawal rate (UNEP 2006). A drop in groundwater levels or a decline in its quality may threaten the political stability of the region, especially where numerous countries share the resource (Turton 2008b).
- T*here are seasonal differences in water supplies:* Conflicts can also occur between upstream and downstream users due to large seasonal variations in water flows and periodic droughts and floods that are characteristic in Africa (Turton and others 2006).
- *Inadequate joint management laws and conflicting national interests stress joint management capacities*: Given that Africa's national boundaries are not aligned with water bodies, water resource management needs to include regional considerations rather than just national objectives (Ashton 2007). Vague or inadequate international laws regarding joint management of shared waters, however, make it hard for riparian states to manage both a single basin with other states and multiple basins in the same state. The water needs and economic situation in each country also varies (Turton 2008b). Conflicting interests and inequity in capacities between riparian states further constrain negotiations on international watershed management (Van der Zaag 2007). The Southern African Development Community (SADC) and the Senegal River Development Organization (OMVS) are the only two organizations that operate basin-wide shared water management (Kliot and others 2001). Issues among other organizations include lack of legitimacy and effectiveness, a "not-invented-here" syndrome (referring to models not developed in Africa) and inadequate consideration of the realities and needs of the local people (Merrey 2009). A mixture of these issues can lead to tense relations among riparian countries and increased potential for conflict. The "War of the Well" in Somalia is one example. Two clans clashed over the control of a water well, leading to the killing of 250 people over a period of two years as drought gripped the region (Jarvis 2006).

The Opportunities

International water cooperation presents an opportunity to deal with these challenges and constraints through negotiated basin sharing for both withdrawal and in-stream water uses. The sustainability of water available within a river basin that crosses two or more countries may be assured and even increased via transboundary agreements. Such agreements help ensure equity in the provision of water for all and help maintain peace and security. There are several examples of transboundary water agreements and other sharing mechanisms that have been successful in helping riparian African nations negotiate equitable water sharing and that illustrate the potential for such agreements to be a catalyst for wider political cooperation.

- *Recognize and build on water as a binding factor between otherwise hostile states:* Although water has generally been described as a cause of political tension and armed conflicts, in reality, water has seldom been the primary cause of a transboundary war. Contrary to common perceptions, water has been a binding factor between otherwise hostile states. The Indus Water Treaty, for example, has survived three wars between India and Pakistan and Iraq gave Kuwait water "in brotherhood" without compensation. In Africa, confrontation between Swaziland, South Africa and Mozambique on water sharing within the Incomati River Basin because of competing interests ended after negotiations between 1964 and 2002. The deadlock was broken when the management of the adjacent Maputo River Basin was included so that some of the benefits were tradable between the parties (Van der Zaag 2007, Van der Zaag and Carmo Vaz 2003). A case study of competition and cooperation in the Incomati water issue concluded that: "The hypothesis that water drives peoples and countries towards cooperation is supported by the developments in the Incomati basin. Increased water use has indeed led to rising cooperation" (Van der Zaag and Carmo Vaz 2003).

  In the case of transboundary groundwater, conflicts are often attributed to the lack of information about the boundaries of the physical resource, resource capacity and conditions that suggest water quality. Yet, with all of these potential triggers for conflict, there are no documented cases where intensive groundwater use in a medium or large-sized aquifer has caused serious social conflicts (Jarvis 2006). Thus, there appears to be no historical reason to suggest that the problem of sharing water among riparian countries is likely to be a cause of future conflict in Africa or elsewhere; rather, it can be the catalyst for cooperation.

- *Learn from successful transboundary cooperation efforts and agreements among African states:* Successful transboundary water distribution is inherently dependent on political cooperation between the involved riparian states. In the absence of strong rules and laws, treaties are the best form of formal river basin management. These regimes define implicit and explicit principles, norms, rules and decision-making procedure to help meet actors' expectations. The formation of such institutions, including liability and sanctions in case of non-compliance, can help shift "negative peace" (absence of war) into "positive peace" (cooperation and confidence) (Turton 2003). Such cooperation in managing shared or competing interests in common water basins can promote many benefit-sharing possibilities, including international trade in water. For example, Lesotho and South Africa entered into a multi-billion-dollar water transfer and hydropower project on the Orange/Senqu river basin called The Lesotho Highlands Project (see page 91). It includes mechanisms such as direct payments for water, purchase agreements and financing arrangements and has enabled Lesotho to earn valuable foreign exchange from the water it sells to South Africa (Ashton 2000, Roy and others 2010). In the case of the Senegal River, a burden-sharing formula enabled Senegal, Mali and Mauritania to agree on how to share the development costs and benefits of infrastructure they jointly operate on the river. There has been a decided change from top-down to cooperative management approaches to managing transboundary water resources in Africa, as illustrated by the formation of OKACOM in the Okavango River Basin, which brought the riparian nations together under the slogan "Three Nations, One River" in a new model of water sharing (Roy and others 2010).

  Other examples of successful water-sharing bodies or mechanisms in Africa that hold lessons in cooperative management are the Nile Basin Initiative, in which ten riparian nations have met amicably for more than a decade, and the Senegal River group, including Mali, Senegal, Guinea and Mauritania, which refuses to argue about water entitlements in favour of distributing projects equitably such that a dam may be built in one country but the electricity generated is distributed elsewhere in exchange for another benefit (Grimond 2010).

  Common interests in transboundary rivers and basins, like water quality, supply, flood control, effects of climate change, etc., are potential arenas in which to build institutional capacity through collaboration among co-riparian states. Joint efforts in collecting data, understanding impacts and improving socio-economic models can bring the actors together and thus avoid potential conflicts. Transboundary cooperation can broaden the knowledge base, enlarge the range of measures available for prevention, preparedness and recovery, develop better responses and offer more cost-effective solutions.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CHALLENGE 4

PROVIDE WATER FOR FOOD SECURITY

The Challenge: *Provide African agriculture with enough water to ensure long-term food security.*

The Situation: *Agricultural growth is the mainstay of most African economies; agriculture is the greatest user of water in Africa; there is inadequate water use for sustainable food production; Africa suffers from food insecurity and 30 per cent of the population lives with chronic hunger.*

The Constraints: *Per capita food intake is rising; food production is not increasing; green water efficiency is very low; and irrigation capacity is underdeveloped.*

The Opportunities: *Learn from the 1960-1990 Green Revolution; promote a greener, Green Revolution in Africa; increase irrigation to increase food security; avoid the pitfalls of over-irrigation; invest in simple and inexpensive irrigation technologies; tie irrigation development to issues of social equity and environmental sustainability; secure sustainable investment for the Green Revolution; invest in targeted breeding of drought tolerant varieties.*

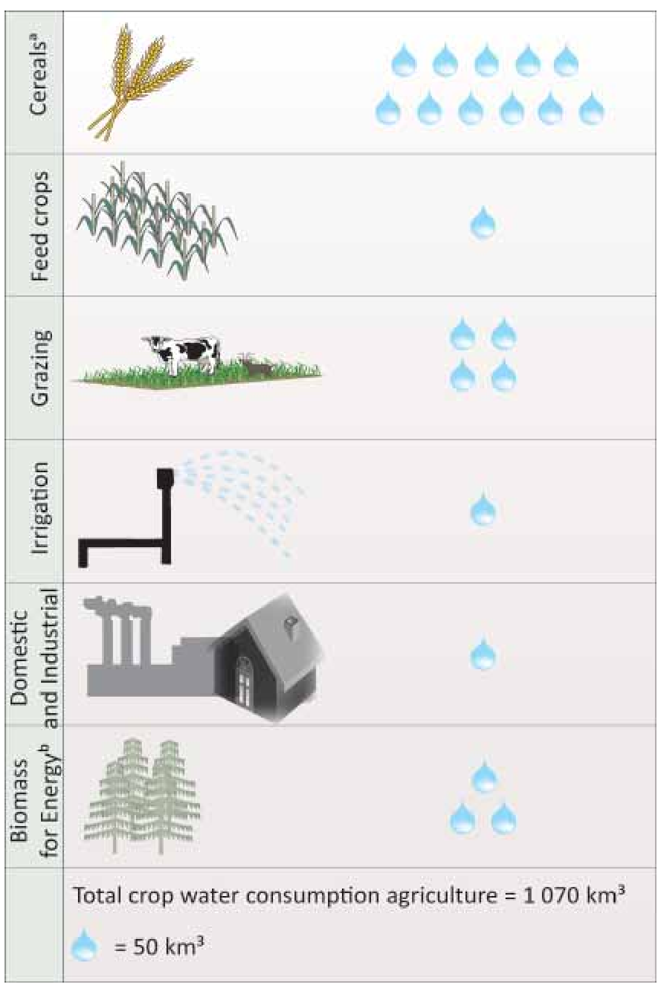
The Challenge

With a growing population, Africa needs more food and must secure the water needed to ensure its supply at the same time as water resources are becoming scarcer. How can Africa squeeze more food out of each drop of scarce water?

The Situation

- *Agricultural growth is the mainstay of most African economies:* Farming is the source of livelihood for about 70 per cent of Africa's population that are rural-based. In sub-Saharan Africa, mostly small-scale farming represents about 30 per cent of GDP and at least 40 per cent of export value. In a number of Africa's smaller nations, agriculture plays a much greater role, accounting for 80 per cent or more of export earnings (Nwanze 2010). Studies have shown that other economic sectors on the continent tend to perform well when there is positive growth in the agricultural sector (Wik and others 2008).

Figure 3.4.1: Water depletion from main agricultural activities for sub-Saharan Africa (Source: Adapted from de Fraiture and Wichelns 2010) [a]Includes cereals used for feed; [b]includes all biomass (mostly firewood)



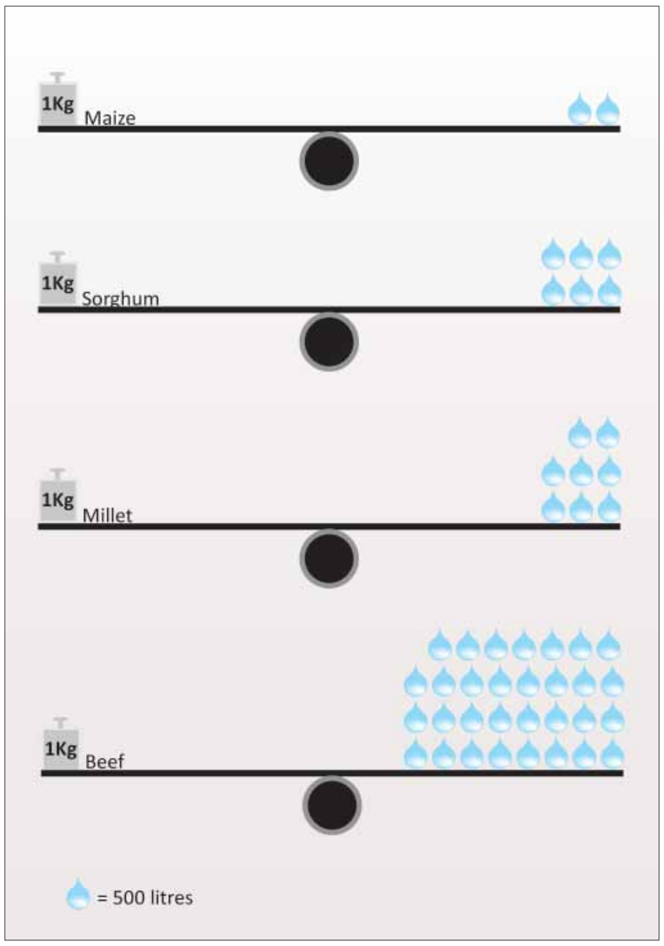
- *Agriculture is the greatest user of water in Africa:* Globally, agriculture accounts for 70 per cent of water consumption (UNEP 2008) but in Africa, as much as 86 per cent of total annual freshwater withdrawal goes to agriculture (Frenken 2005). Thus, the demand for food is the most important driver of water use in Africa. Figure 3.4.1 shows the amount of water used for various agricultural activities in sub-Saharan Africa.
- *There is inadequate water use for sustainable food production:* Inadequate water for food production continues to compromise the well-being and economic productivity of Africa's people, thus curtailing their ability to generate revenue required for improving the availability and access to water for food.
- *Africa suffers from food insecurity and 30 per cent of the population lives with chronic hunger:* Lack of water contributes to the situation of food insecurity, a situation in which people lack adequate physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life (Mwaniki 2006). Economic water scarcity is a contributing factor to food insecurity, especially in sub-Saharan Africa (see Challenge 9). This refers to a condition in which water resources are abundant relative to water use, with less than 25 per cent of water from rivers withdrawn for human purposes, but malnutrition exists (UNEP GRID/Arendal 2008). In sub-Saharan Africa, overall per capita agricultural yields declined from 1970 to 1980,

and since then have stagnated. The number of poor people is increasing, 30 per cent of the population lives with chronic hunger, and similar levels of malnutrition in children under the age of five persist (IAASTD 2009). Sub-Sahara Africa alone accounts for 25 per cent of the undernourished people in the developing world and it has the highest proportion (one-third) of people suffering from chronic hunger (World Bank 2008). In East and Southern Africa, the number of food-insecure people almost doubled from 22 million in the early 1980s to 39 million in the early 1990s. Furthermore, no single sub-region in Africa can attain food security without recourse to food imports or external food aid (UNECA 2006).

The Constraints

- *Per capita food intake is rising:* As Africa's population rapidly becomes more urbanized (UNFPA 2009), increasingly large amounts of water are needed to meet food requirements. Not only are there more people to feed in cities, but urbanization is also generally accompanied by a rise in personal income and an increase in per capita food intake. In addition, people tend to shift away from staples towards richer diets containing products that require more water to produce such as meat, fruits, vegetables, sugars and oils (Pingali 2007) (Figure 3.4.2).
- *Food production is not increasing:* About one-third of the continent's people live in drought-prone areas, and the rising population and increasing affluence and demand for different foods has not been matched by a corresponding increase in food production.

Figure 3.4.2: Water requirements of selected agricultural products (Data sources: Hoekstra and Chapagain 2008, Water Footprint n.d.)



- *Green water efficiency is very low:* A large portion of water for crop production in Africa comes from rainfall that is eventually transpired by crops as soil moisture (green water), while 68 km^3 or around six per cent is from surface and groundwater sources (blue water). Green-water use efficiency is still very low, with studies showing that only 15 per cent of the terrestrial rainwater is used by plants for the production of food, fodder and fibre in sub-Saharan Africa, partly due to excessive losses caused by poor land management practices (Rockström and others 2009, Stroosnijder 2009).
- *Irrigation capacity is underdeveloped:* There is underinvestment in water infrastructure for irrigation across the continent, with only seven per cent of cultivated land equipped for irrigation in 2005 (FAO 2005). In sub-Saharan Africa, the proportion was only 3.8 per cent of arable land. By comparison, 28.7 per cent of the Near East and North Africa's cultivated land was irrigated, and in South Asia, the proportion was as high as 39 per cent (Figure 3.4.3). Water-managed areas in national agriculture vary from less than one per cent of cultivated land in such countries as the Democratic Republic of the Congo, Comoros, Ghana, Togo and Uganda to 100 per cent in the most arid countries such as Egypt and Djibouti where agriculture is impossible without irrigation (UNECA 2006). The lack of investment in irrigation in most countries contributes to the expansion of rain-fed agriculture on to marginal lands with uncertain rainfall. This is forcing millions of impoverished people to farm in ecologically fragile areas. Without adequate water, farmers have little incentive to invest in quality seed and inputs (FAO 2002).

The Opportunities

- *Learn from the 1960-1990 Green Revolution:* There are lessons to be learned for Africa from the Green Revolution, which saw the yield of major cereals (rice, wheat and maize) more than double during the period 1960-1990 in Asia and Latin America, arresting the threat of famine and lowering the prices of staple crops (FAO 2005). By focusing on small farmer-based agriculture, countries that were food deficit 40 years ago are now food exporters. National governments controlled their own agricultural policies and the main focus of agricultural research was to promote local and appropriate technologies. Although there are natural, social and economic differences, the Asian food crisis at that time was described in the same breadth and in terms used for Africa today: high population growth rates, widespread poverty, hunger and malnutrition.
- *Promote a greener, Green Revolution in Africa:* By initiating a green (ecological friendly), Green Revolution, Africa has an opportunity to grow more food from the same amount of water or grow the same amount of food using less

Water and food insecurity in Africa: some statistics

- *The depth of water across Sudan, Africa's largest country by land area, is 43 cm, which is equivalent to the amount consumed annually by crops on the continent (De Fraiture and Wichelns 2010).*
- *Africa's irrigated area of over 13 million hectares represents six per cent of its total cultivated area, compared to 35 per cent in Asia and 11 per cent in Latin America (FAO 2009).*
- *Two-thirds of sub-Saharan Africa's over six million hectares of irrigated land is found in only three countries: Madagascar, South Africa and Sudan (AfDB and others 2007).*
- *At least US $4.7 billion is required per year to ensure food security in Africa (AfDB 2006).*

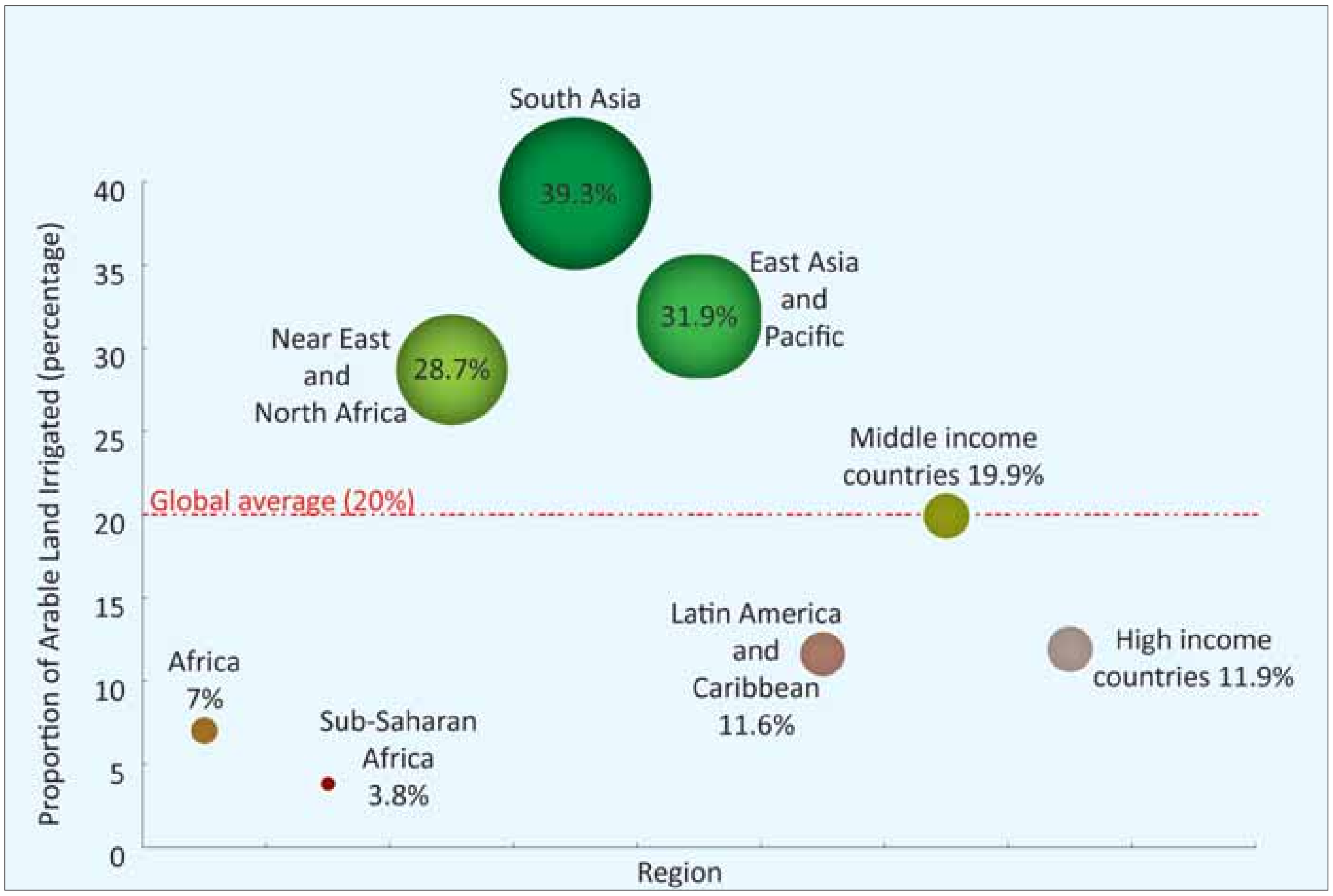


Figure 3.4.3 Proportion of arable land irrigated—regional and global (Data Source: FAO 2005)

water. The use of irrigation, synthetic fertilizers, chemical pesticides, early maturing and high yielding dwarf seed varieties (the dwarf varieties of rice and wheat were less susceptible to falling over, enabling the application of large amounts of water and fertilizer to boost yields) were critical components of the Green Revolution technology package in Asia (Ringler and others 2010). Record yields were realized but higher rates of poisonings from the chemical pesticides were also recorded in many areas, in addition to intense eutrophication of aquifers and waterways (Bai and others 2008, Jhamtani 2010). In Asia, the ecological costs of the Green Revolution have risen and a growing number of farmers are turning back to non-chemical or less-chemical agriculture (Jhamtani 2010). Alternative sustainable farming practices include agroforestry and intercropping cereals with legumes to improve nitrogen deficient soils and reduce reliance on synthetic fertilizers and pesticides. Increasing productivity on existing cropland is fundamental if Africa is to avoid destroying vital ecosystems such as its biodiversity-rich wetlands and rainforests. Africa can avoid the environmentally damaging aspects of such a revolution by focusing on a green, Green Revolution.

- *Increase irrigation to increase food security:* The estimated rate of agricultural output increase needed to achieve food security in Africa is 3.3 per cent per year. The potential for meeting this estimate exists, since two-thirds of African countries have developed less than 20 per cent of their agricultural production and less than 5 per cent of the cultivated area is under irrigation in all but four countries (UNECA 2006). Without investment in irrigation, it will be difficult to increase food production, reduce the financial burden of agricultural imports and increase food security. Irrigation increases yields of most crops by 100 to 400 per cent. In sub-Saharan Africa, only four per cent of cropland is irrigated (Figure 3.4.4), so farmers need to make significant investments in irrigation to increase their productivity. Irrigation makes it possible to:
  - Control soil moisture and therefore exploit an extended cropping season to boost agricultural yields and outputs;

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Figure 3.4.4: Map of Irrigated Areas (Source: FAO 2006)

- Supplement unreliable rainfall, and grow a wider range of crops, including high value crops for the export market;
- Maintain food production levels and contribute to price stability through control over production levels;
- Achieve food security at local levels through increased income and improved health and nutrition; and
- Bridge national gaps between production and demand of food crops (Ringler and others 2010).

• *Avoid the pitfalls of over-irrigation:* Irrigation development was an important component of the Asian Green Revolution, used to double yields by supplementing unreliable rainfall. Critics argue that over-irrigation led to steep drops in the water table, while thousands of hectares of productive land have been lost to salinization and waterlogged soils. A typical example is India where dams and canals constructed by the government and tube wells drilled by individual farmers saw the net irrigated area increase from 21 million ha in the 1950s, to 39 million ha, or roughly 20 per cent of the world's irrigated land in 1980 (Fitzgerald-Moore and Parai 1996). This expansion resulted in not only higher agricultural production, but also excessive groundwater depletion, waterlogging and salinization of formerly productive cropping areas (Ringler and others 2010).

- *Invest in simple and inexpensive irrigation technologies:* These offer the best advantages for increasing irrigation for food production, but they must be managed carefully to avoid environmental damage, which is already extensive, and the spread of water-borne diseases. Parts of sub-Saharan Africa have large untapped reserves of groundwater and there is great potential for harvesting water runoff and for farming lowlands and valley bottoms that catch it naturally (Figure 3.4.5). With investment, this potential could be unleashed (FAO 2002). Other water conservation techniques include switching from surface to "smarter" irrigation techniques like micro-irrigation and mulching and using cover crops to minimize the loss of available green water.

Increases in the level of irrigation can come from both surface and ground water, drawing lessons from within and outside the region on viable small to medium scale irrigation techniques that require limited infrastructural development and can reach many farmers. Methods such as pumping from rivers on an individual and small group basis, and locally manufactured drip systems are still to be fully exploited (IAASTD 2009).

Surface irrigation is easy to operate and maintain, and can be developed at the farm level with minimal capital investment, with an indicative field application efficiency of around 60 per cent. Most energy requirements for surface irrigation systems come from gravity, and the systems are less affected by climatic and water quality characteristics (FAO 1989a, 1989b).

Sprinkler irrigation has a high irrigation field application efficiency of around 75 per cent, and is easy to design and simple to install and operate. It can be adapted for all types of soils, many kinds of field crops and small irregular plots, and is less expensive than many other modern irrigation systems (FAO 1989b, 2007a). Drip irrigation is the most advanced irrigation method with the highest field application efficiency of around 90 per cent. Water is applied to each plant separately in small, frequent, precise quantities through dripper emitters. Switching from sprinkler irrigation to drip systems has resulted in a reduction in water use by 30-60 per cent (FAO 1989b, 2003, 2007a).

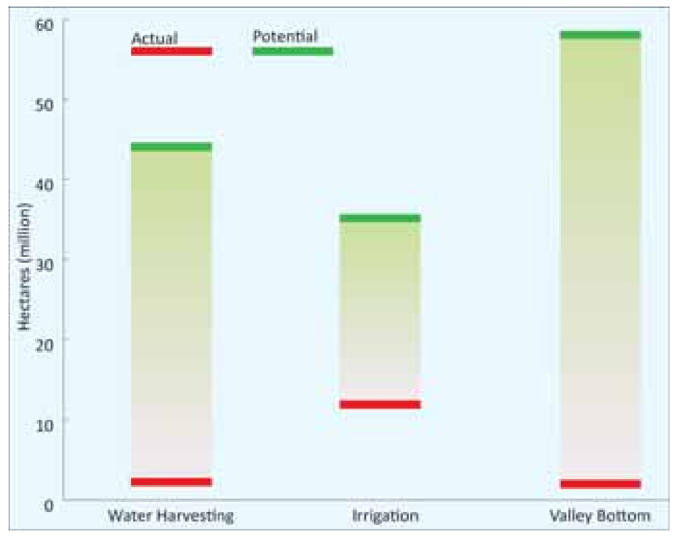


Figure 3.4.5: Water management potential in Africa (area in millions of hectares) (Source: FAO 2010)

Box 3.4.1: Small-scale irrigation projects bring multiple benefits

A recent study of selected small-scale irrigation projects in Burkina Faso, Mali and the United Republic of Tanzania shows the potential for these initiatives to increase farm productivity. Small dams, wells and canals built in the villages increased agricultural productivity and generated income that allowed people to cope better with "hungry periods" of the year. The projects included nonagricultural activities such as nutrition education. The benefits extended beyond increased agricultural productivity, giving women time to start market gardens and helping families reduce debt, increase school attendance, limit seasonal migration for work and earn cash to pay for health care.

Source: FAO 2002

- *Tie irrigation development to issues of social equity and environmental sustainability:* The large-scale irrigation schemes of the past have lost favour because of their social, environmental and financial costs. Now, project planners are seeking the participation of farmers in designing and managing irrigation plans. In implementing small-scale irrigation projects, there are opportunities to extend benefits to enhance social and environmental sustainability (Box 3.4.1). One of these benefits should be providing opportunities for rural women; given their central role not only as mothers and caregivers, but also as farmers, they hold the key to food security (Nwanze 2010).
- *Secure sustainable investment for the green, Green Revolution:* Technologies such as the development of underutilized irrigation potential, and the development of high yielding and more drought tolerant varieties can work for Africa if there is good investment (World Bank 2008). African farmers can reduce reliance on food imports and protect against the import of low-price grains. Governments in Africa are taking ownership of their own agricultural policies through initiatives such as the Comprehensive Africa Agriculture Development Programme (CAADP), which provides the framework for supporting the design and implementation of national agriculture and food security strategies (MDG Africa Steering Group 2008). This initiative presents an opportunity for development partners and the private sector to support national governments, and to reduce donor fragmentation so that financing can be channeled to effectively support the implementation of national-scale agriculture strategies within the framework.
- *Invest in targeted breeding of drought-tolerant varieties:* For example, the AfDB funded and African Rice Initiative coordinated project contributed to a six per cent increase in the continent's rice output during 2007 (World Bank 2008). Such targeted breeding can produce crop varieties that are higher yielding, more drought tolerant, utilize fertilizers more efficiently, and are more resistant to pests. It is important to note that genetically modified organisms (including crops) are still considered an emerging issue in Africa since they present the following concerns and uncertainties in light of increasing cooperation and trade:
- The issues of bio-safety;
- The impact of GMOs on the environment;
- Trade with non-GMO partners;
- Ethics issues;
- Intellectual property rights; and,
- Access to seeds by small-scale farmers (SADC and others 2008).

CHALLENGE 5

DEVELOP HYDROPOWER TO ENHANCE ENERGY SECURITY

The Challenge: *Develop Africa's water resources for hydroelectricity to boost energy security.*

The Situation: *Hydroelectricity supplies 32 per cent of Africa's energy; electricity consumption in Africa is the lowest in the world; access to electricity is uneven; electricity supply is often unreliable; wars have destroyed existing electricity service in some areas; and Africa's hydro potential is underdeveloped.*

The Constraints: *The capacity to generate hydropower is unequal across the continent; climate change will exacerbate rainfall variability and hinder hydro potential; and hydro dams will need to avoid the environmental and social impacts historically characteristic of large dam developments.*

The Opportunities: *Recognize that Africa has enormous hydroelectricity potential; develop hydropower because it will boost the economy and human well-being, invest in hydroelectricity rather than fossil fuels, which makes sense in an era of climate change; learn from the many African countries that have developed hydropower successfully; learn from and copy successful regional power pools; and develop small-scale hydropower projects to avoid the environmental and human costs associated with large dams.*

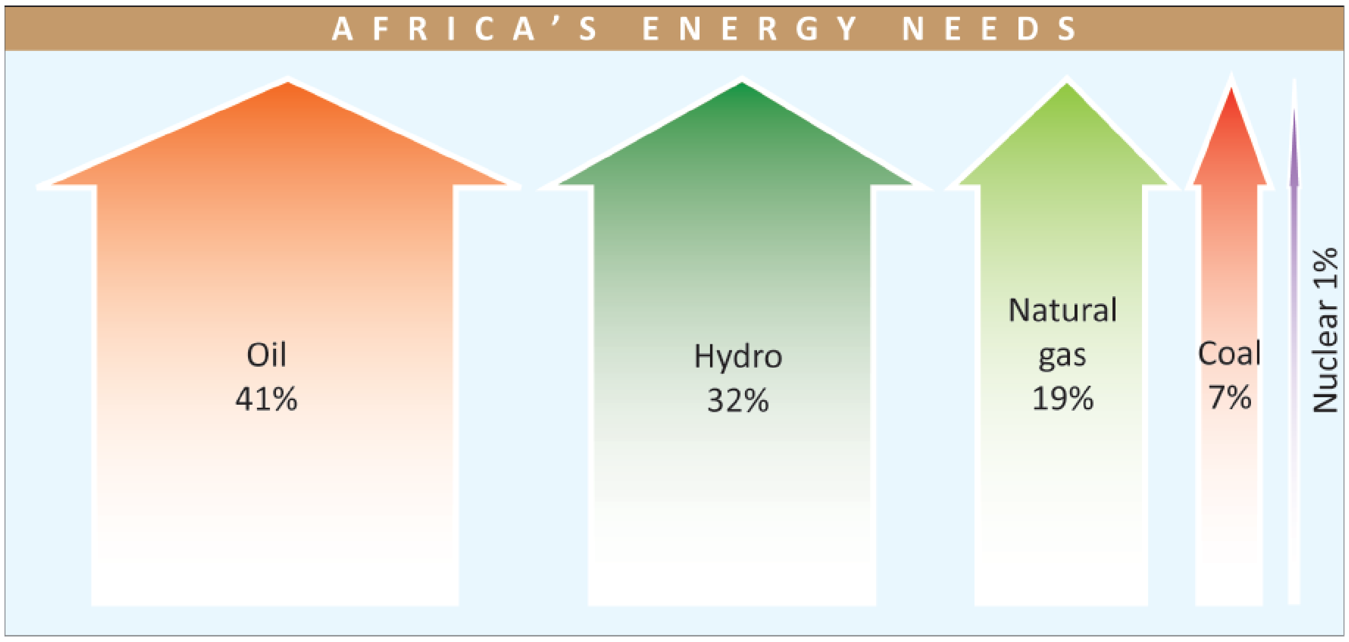
The Challenge

Africa has plentiful water resources for hydroelectricity and can boost energy security by increasing hydro development.

The Situation

- *Hydroelectricity supplies 32 per cent of Africa's energy* (Figure 3.5.1);
- *Electricity consumption in Africa is the lowest in the world:* Although Africa has the second-largest population after Asia, it has the lowest energy consumption per capita of any continent (Figure 3.5.2, next page). Many African nations have a per capita electricity consumption of less than 80 kWh/yr (Figure 3.5.3, next page), compared to 26 280 kWh/yr in Norway, 17 655 kWh/yr in Canada, and 13 800 kWh/yr in the United States (Bartle 2002).
- *Access to electricity is low and uneven:* More than 90 per cent of the rural population relies on biomass energy sources that include wood, crop waste, charcoal and manure for cooking and heating, and candles and kerosene for lighting (Bartle 2002, Tshombe and others 2007). Only one in four people in Africa has access to electricity, and this figure is barely 10 per cent in rural areas (MDG Africa Steering Group 2008). There are major disparities in levels of electrification between North Africa (93.6 per cent) and sub-Saharan Africa (23.6 per cent) (Kauffman 2005).
- *Electricity supply is often unreliable:* Even where access to electricity is available, it does not necessarily mean that electricity is available on demand. People frequently have to cope with unreliable supply and this disrupts economic activity at all levels and hampers progress. There are many reasons for the frequent and extended

Figure 3.5.1: Hydro contribution to Africa's primary energy needs, 2002 (Source: Kalitsi 2003)



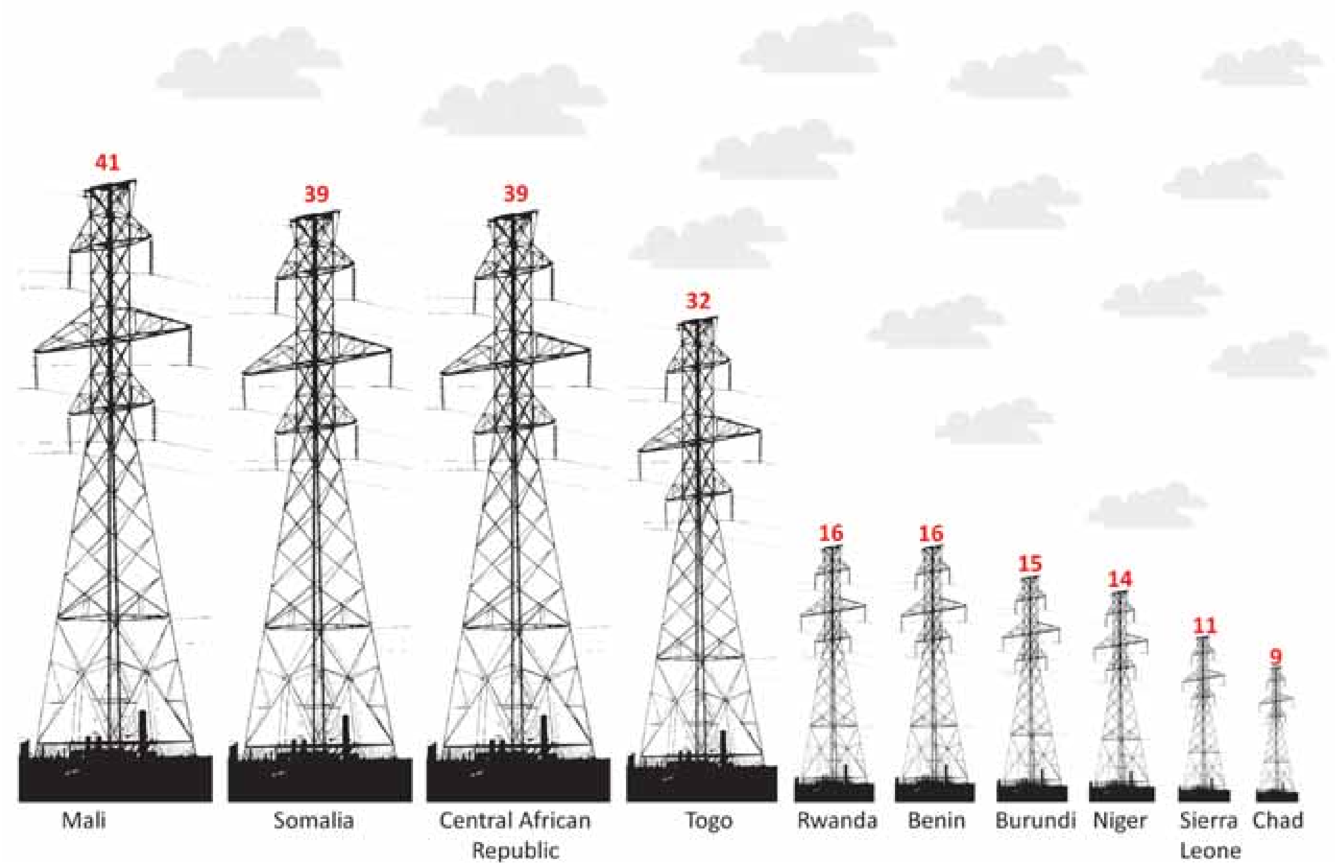


Figure 3.5.3. African countries with less than 80 kWh per capita electricity consumption (Source: Adopted from Bartle 2002)

interruptions, including conflicts that have damaged infrastructure, lack of government funds or treating hydro as a low priority, and aging equipment. Nigeria, for example, operates at about one-third of its installed capacity due to aging facilities. In addition, unpredictable and variable climatic conditions affect the constancy of electricity supply. The 1999-2000 East African drought had a serious impact on hydroelectric facilities, especially in Kenya and Ghana (MBendi n.d.). Rising demand is another reason. In 2007, frequent and extended electricity interruptions affected nearly two-thirds of the countries in sub-Saharan Africa, and although conflict and drought were to blame in several instances, electricity supplies failing to keep pace with growing demand was the cause in most cases (IMF 2008).

- *Wars have destroyed existing electricity service in some areas*: Infrastructure for electricity distribution and transmission has been

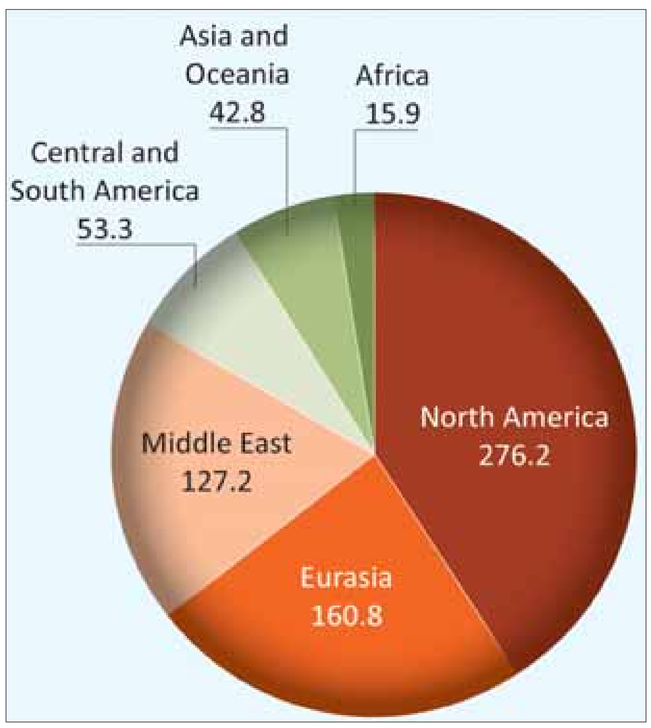


Figure 3.5.4: World per capita total primary energy consumption, 2006 (Million Btu) (Source: IEA 2008)

Africa is the "underdammed" continent. Only three per cent of its renewable water is used, against 52 per cent in Asia. So there is plenty of scope for an African dam-building boom.

—The Economist 2010

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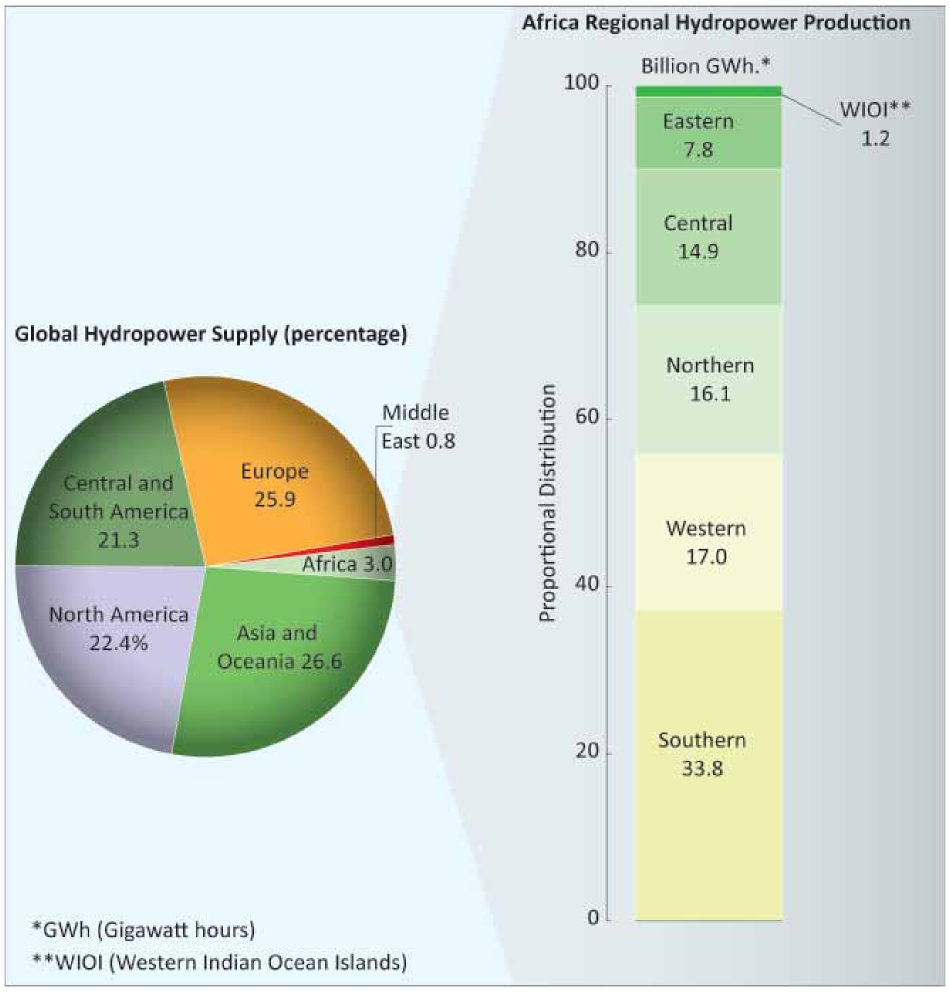


Figure 3.5.4: Regional shares in hydropower supply, 2004 (Data source: IEA 2007)

destroyed by war in countries such as Angola, Congo, Côte d'Ivoire, Chad and Sudan. According to the IEA (2008), it is more costly to restore service than the average cost of serving new customers in a stable environment.

- *Africa's hydro potential is underdeveloped:* Only three per cent of its renewable water resources are exploited for hydroelectricity, compared to an average of 45 per cent in OECD countries and 21 per cent in Latin America (Figures 3.5.4 and 3.5.5, and Box 3.5.1).

Box 3.5.1: How much hydro potential has Africa developed?

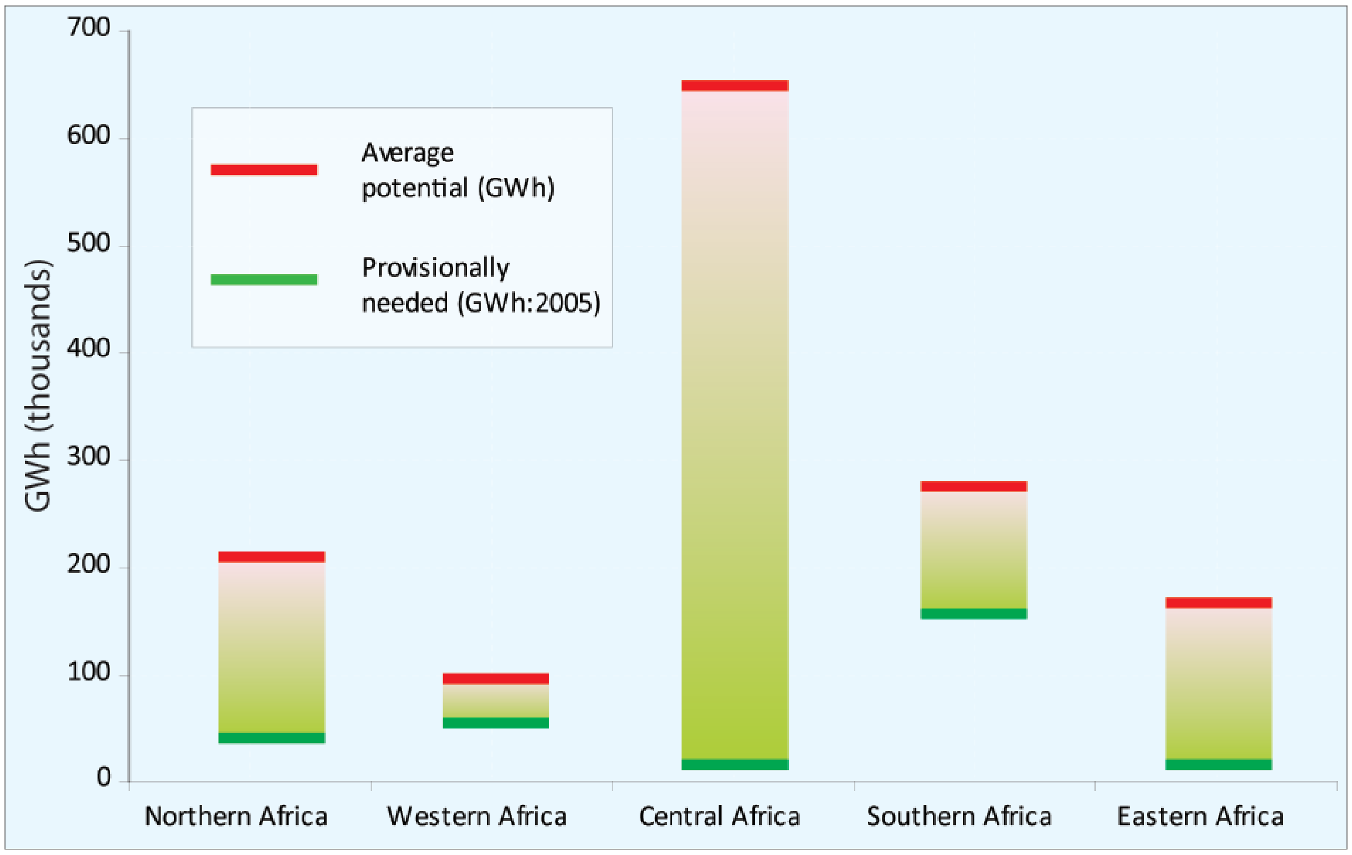
Various estimates regarding the extent of hydropower development in Africa have been given by different sources in the last decade. Despite these variations, as shown in this box, one underlying message is clear: Africa's vast hydropower potential is yet to be tapped.

Capacity Developed	Source
4 per cent	Bartle (2002); Blyden and Akiwumi (2008)
8 per cent	World Bank (2010a)
Less than 8 per cent	AfDB (2006)
4 per cent**	World Water Assessment Programme (2009)
7 per cent	AfDB (2006)

*Figure provided as "renewable water use", which covers other sectors in addition to hydropower.

**Figure covers annual renewable flows for irrigation, food production and hydroelectricity for sub-Saharan Africa only.

Figure 3.5.5: Regional development of economically feasible hydropower potential (Source: Modified from Hammons 2006)



The hardest bit is hydrology. Rainfall estimates are often wrong. Some countries must rent costly diesel generators to boost hydropower in years of drought. Climate change makes hydrology trickier still. Reservoir water sometimes falls too low to turn the turbines

—The Economist 2010

The Constraints

Constraints to hydropower development in Africa include the unavailability of suitable sites, large capital requirements, long lead times to develop, concerns over social and environmental impacts, political instability, and the impacts of climate variability on water resources (World Bank 2010). Low demand and dispersed populations also hinder rapid exploitation as well as the increase in demand from population and economic growth that challenge the ability of countries to provide increased power (Kalitsi 2003, MBendi n.d.).

- *The capacity to generate hydropower is unequal across the continent:* Across Africa, available sites for hydro development are unevenly distributed. For example, the average potential in North Africa is 41 000 GWh compared to 653 361GWh in Central Africa (Figure 3.5.6). In spite of its enormous hydroelectric potential, the Central Africa sub-region is the least electrified with only 2.6 per cent power production, while the Southern Africa sub-region is the most electrified (MDG Africa Steering Group 2008).

- *Climate change will exacerbate rainfall variability and could hinder hydro potential in some areas:* Challenge 8 outlines how and where climate change is expected to affect Africa's water resources.

- *Hydro dams will need to avoid the environmental and social impacts historically characteristic of large dam developments:* Africa has over 1 270 large dams (WCD 1999). In most cases, they brought considerable hardship to the local communities who reaped few benefits, but often sacrificed their land and livelihoods to make way for the projects. Such were the impacts of large hydro dams in Sudan, Senegal, Kenya, Zambia/Zimbabwe and Ghana. In most cases, benefits are inequitably shared and the dams feed centralized power grids that benefit industry and elite groups. Africa faces the challenge of developing hydro facilities that do not inflict damage on the environment or people's lives (Hathaway and Pottinger 2010).

Figure 3.5.6. Regional power production in Africa (Source: Hammons 2006)

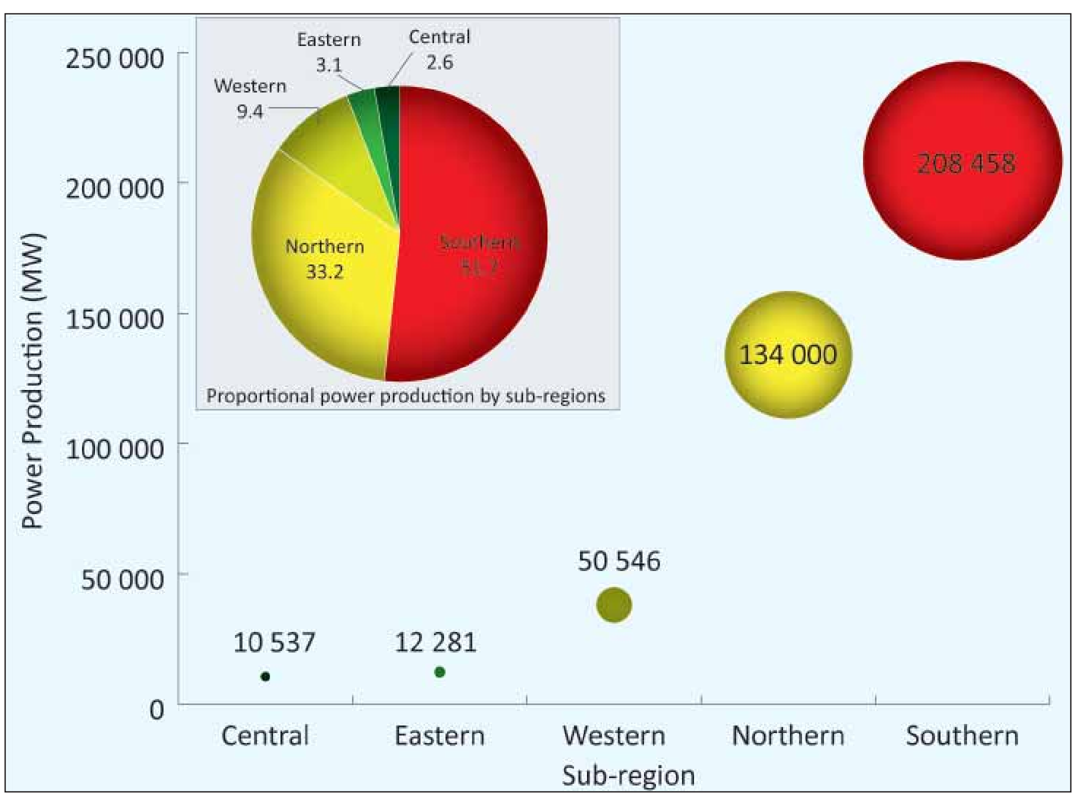


Table 3.5.1: Overview of proposed hydro developments in selected African countries. (Sources: Bartle 2002, Kalitsi 2003, Export-Import Bank of the United States 2008, Hydroworld website 2010, World Bank 2010)

Country	Proposed Developments
Benin	Hydro supplies 80 per cent of electricity; planning to increase country's installed capacity by more than 100 per cent to improve on 49 kW h annual per capita electricity consumption.
Niger	Per capita consumption is 25 kW h/yr; planning for first hydro plant, Kanadji, with a capacity of 125 MW.
Chad	Per capita consumption 14 kW h/yr; only 11 MW of 32 MW national capacity in service; planning for 6 MW capacity first hydro plant.
Burkina Faso	Water management programme for the Nakanbe river to lead to further hydro-development, regarded as a high priority for socio-economic development.
Mali	Detailed financial studies conducted for four of several medium-sized projects at the feasibility stage; Up to 800 MW new hydro-capacity planned for the long-term.
Ghana	Hydro is the main priority in economy; 400 MW Bui scheme under construction and scheduled for 2012 completion.
Liberia	Most power facilities damaged or destroyed due to long-term civil war; Large hydro-potential development regarded as basis for economic recovery.
Democratic Republic of the Congo	Largest potential in Africa with technically and economically feasible potential around 419 TW h/yr; and future plans include La Grande Inga, with capacity between 6 and 39 GW. Many more medium scale (40–100 MW) and small schemes planned; More than 3 000 MW expected from refurbishing existing plants.
Sudan	4 800 MW technically feasible hydro projects identified; two medium-scale schemes at the feasibility study stage.
Ethiopia	Exploitation of potential in the Nile basin regarded a priority; Nearly 200 sites identified for hydro-development; 18 proposed and two projects, Gilgel Gibe and Tis Abbay II, recently completed. Gibe III under construction.
Nigeria	5 000 MW planned for the medium and long-term, including the Zungeru (950 MW) and Mambila (3 900 MW) projects.
Mozambique	2 000 MW planned for implementation.
Tanzania	180 MW of capacity construction; Seven future schemes at the feasibility study stage; Stigler's Gorge (1 400 MW) the largest; others are 40–250 MW capacity.
Zambia	Two major binational schemes planned with Zimbabwe; Batoka Gorge to include 181 m-high dam and twin 800 MW power plants for each country; Devil's Gorge to provide 600 MW each. Major refurbishment schemes completed at Kafue Gorge, Kariba and Victoria Falls.
Zimbabwe	Two major binational schemes planned with Zambia; Batoka Gorge to include 181 m-high dam and twin 800 MW power plants for each country; Devil's Gorge to provide 600 MW each.
Cameroon	Hydro a major priority for rural electrification; Plans for several hundred megawatts of new hydro-capacity, and refurbishment of several schemes.
Kenya	Several new schemes totaling 460 MW planned.
Malawi	Could implement 365 MW of hydro-capacity, including the 90 MW Lower Fufu scheme.
Uganda	Hydro provides 99 per cent of electricity; Several private schemes planned, including the 290 MW Bujagali scheme on the Nile, now going ahead; Extension of Owen Falls project completed; Four more capacities 180- 642 MW in the longer term.
Egypt	Installing about 200 MW hydropower at its Nile barrages; Power sector capacity has doubled in the last few years.
Sierra Leone	Plans have been delayed by civil war.
Eritrea	Development impeded by economic difficulties; has ideal conditions for hydro schemes but lacks the necessary infrastructure.

The Opportunities

- *Recognize that Africa has enormous hydroelectricity potential:* Africa has vast hydropower potential—enough to meet all the continent's electricity needs (Lubini and others 2006), and even to export to Europe (Tshombe and others 2007). In fact, this is illustrated by the many proposed hydro developments in numerous African countries (Table 3.5.1).
- *Develop hydropower because it will boost the economy and improve human welfare*: Energy supply is vital for economic growth, stability and human welfare. As a factor of production, it directly affects the prices of other goods and services and hence, the competitiveness of businesses (Tshombe and others 2007). None of the Millennium Development Goals can be attained without more energy development (Hathaway and Pottinger 2010). Greater access

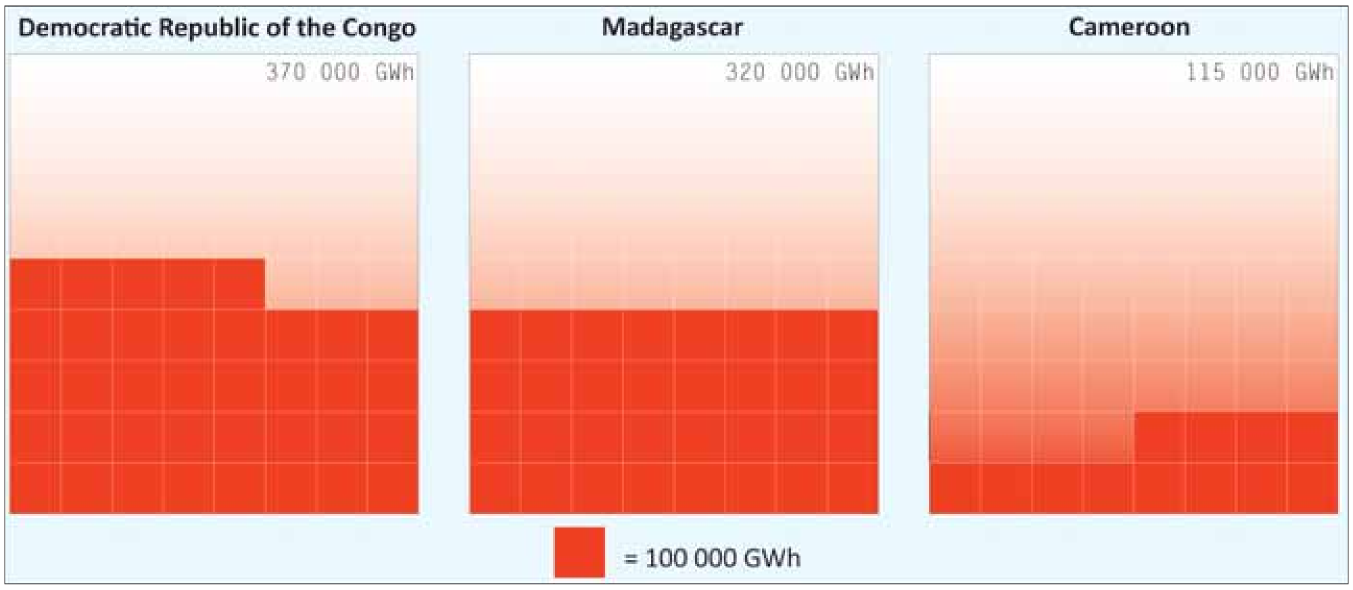


Figure 3.5.7: Top three potential electricity generating nations (Source: Tshombe and others 2007)

to energy will improve food security and health through refrigeration, while electric lighting promotes educational development and lengthens working hours. Improved access to energy also increases economic development through industrialization and communications technologies, among other benefits. The advent of electricity in rural homes reduces the human costs of fetching wood for fuel, freeing women's and girl's time for more productive and educational pursuits (Kauffman 2005).

- *Invest in hydroelectricity rather than fossil fuels, which makes sense in an era of climate change:* Fuel shares of world total primary energy supply were 10 345 Mtoe (Million tonnes of oil equivalent) in 2004. The global energy market is currently dominated by fossil fuel consumption. Concern about global warming is one of the major drivers behind recent interests in renewable and clean sources such as hydropower and biofuels (Ringler and others 2010). According to the World Bank (2010), regional hydropower trade could offer Africa the least-cost energy supply with zero carbon emissions.

- *Learn from the many African countries that have developed hydropower successfully:* Despite the low level of exploitation of technically feasible hydro potential, many African countries have shown that it is possible to develop that potential: hydroelectricity contribution is more than 50 per cent in 25 countries, and greater than 80 per cent in Angola, Benin, Burundi, Cameroon, Central African Republic, Congo, Democratic Republic of Congo, Ethiopia, Guinea, Lesotho, Malawi, Mozambique, Namibia, Rwanda, Tanzania, Uganda and Zambia (Bartle 2002) (Figure 3.5.7).

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Box 3.5.2. Regional power pools and the Grand Inga Project

A regional power pool is a "framework for pooling energy resources and power exchanges between utilities in a given geographic area base in an integrated master plan and pre-established rules." Such pools are meant to allow countries to secure their own power supply while they reduce costs, foster mutual help when power systems fail, bring social and environmental benefits, and strengthen relationships among nations (Hamad 2010). Africa's regional power pools are at very different stages of development, both technically and institutionally. The South African Power Pool (SAPP) was the first operational power pool in Africa, sponsored under the authority of the Southern African Development Community (SADC). The political process is also well advanced in the West African Power Pool (WAPP), supported by political agreements at the head of state level through the Economic Community of West African States (ECOWAS). The pools, particularly the SAPP and WAPP, have facilitated significant cross-border power exchanges.

Inga Hydroelectric Plants (Source: Tshombe and others 2007)

Element of Hydropower	Inga 1	Inga 2	Inga 3 Planned	Grand Inga Planned
Number of unit	6	8	7	5
Total installed capacity	351 MWh	1 424 MWh	1 344 MWh	244 000 MWh
Height of water head	50 metres	58 metres	60 metres	150 metres
Gross energy capacity	2 400 GWh	10 400 GWh	9 900 GWh	324 900 GWh

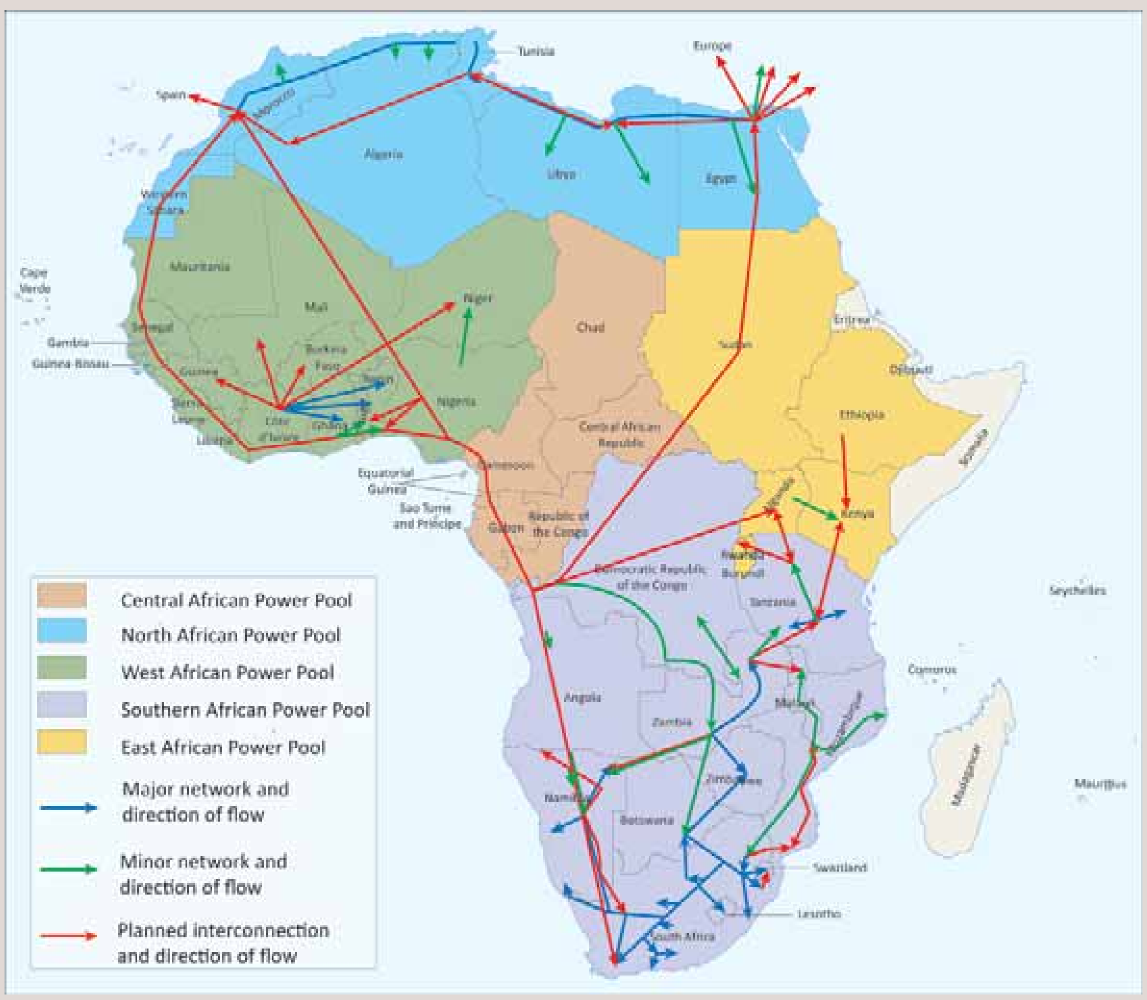
Regional power pools are able to reduce costs and improve conditions on the supply side. Operational costs are lower, due to investment in least-cost power generation plants on a regional basis. Benefits on the supply side, all contributing to increased reliability, include reduced coincident peak loads on the regional power pool, compared with the sum of the individual peak loads for each national power grid; shared power generation reserves for the interconnected power grids; and increased robustness to deal with local droughts or other unexpected events.

The Grand Inga dam in the Democratic Republic of Congo (DRC) is one of the key projects that will support regional pools. The project is estimated to cost US$80 billion and to have a total installed capacity of 44 000 MWh. Difficulties associated with the project include an absence of political consensus and legal harmonization. Nigeria is expected to be the largest consumer. The carbon-emission reduction potential is expected to help attract necessary investment.

Most of the power will be used for industry or for export. Inga 1 and Inga 2 were commissioned in 1972 and 1982, as part of an industrial development scheme in the DRC. The two dams currently operate at only 40 per cent capacity because they have never received maintenance. The World Bank is partially financing a project to rehabilitate these dams. When Inga 2 was built, a 1 800-km transmission line was also built to transport the power to state-owned copper mines in the Katanga province, bypassing nearly every city and village underneath. A component of the Grand Inga project could be expanded for household electricity access, particularly in the DRC, where access is estimated to be 13 per cent in urban areas and only three per cent in rural areas.

Sources: Tshombe and other 2007, IEA 2008

Africa's Regional Power Pools: CAPP, EAPP, SAPP and WAPP (Source: SAPP n.d.)



Box 3.5.3: The Tungu-Kabiti hydro scheme

A 1998 pilot project initiated by Practical Action (previously Intermediate Technology Development Group (ITDG) and the Kenyan Ministry of Energy (MoE), with funding from the UNDP, illustrates the potential for small hydro projects to boost electricity supplies in Africa in a sustainable manner. About 200 members of the Tungu-Kabiti community 185 km north of Nairobi formed a company to own, operate and maintain the plant, with each member buying a share in the company and contributing to building the plant. Community ownership has been central to the project's success. The project generates 18 kW of electricity that is generally sold to users for micro-enterprizes, such as a welding unit, a battery-charging station and a beauty salon. The project demonstrates that communities are willing to invest in improving energy generation and delivery and that micro hydropower can effectively meet poor, off-grid community energy needs.

Sources: UNEP 2006, Hydro4Africa n.d.

- *Develop small-scale hydropower projects to avoid the environmental and human costs associated with large dams:* With the current global financial crisis making it difficult to raise financing for large-scale hydropower that require large capital requirements, and considering the environmental and social impacts of large dams, small hydropower (generally less than 10MW of installed capacity) has been touted as an attractive proposition, especially in the rural areas of Africa. The technology can be connected to the main grid, isolated grids or as a stand-alone option, or combined with irrigation systems (Klunne 2007). Box 3.5.3 is a case study example of such a project.

Mait Juriado/Flickr.com

CHALLENGE 6

MEET GROWING WATER DEMAND

The Challenge: *Meet Africa's growing demand for water in a time of ever-scarcer water resources.*

The Situation: *More than 40 per cent of Africa's population lives in the arid, semi-arid and dry sub-humid areas; the amount of water available per person in Africa is far below the global average and is declining; groundwater is falling; and rainfall is also declining in some regions.*

The Constraints: *Demand for water is increasing with population growth and economic development; development of water resources is inadequate; prices to access water are generally distorted; and water provision is highly inefficient.*

The Opportunities: *Further develop and manage water resources sustainably; improve water use productivity; improve urban planning for better water provision; rationalize water prices; and protect Africa's water towers.*

The Challenge

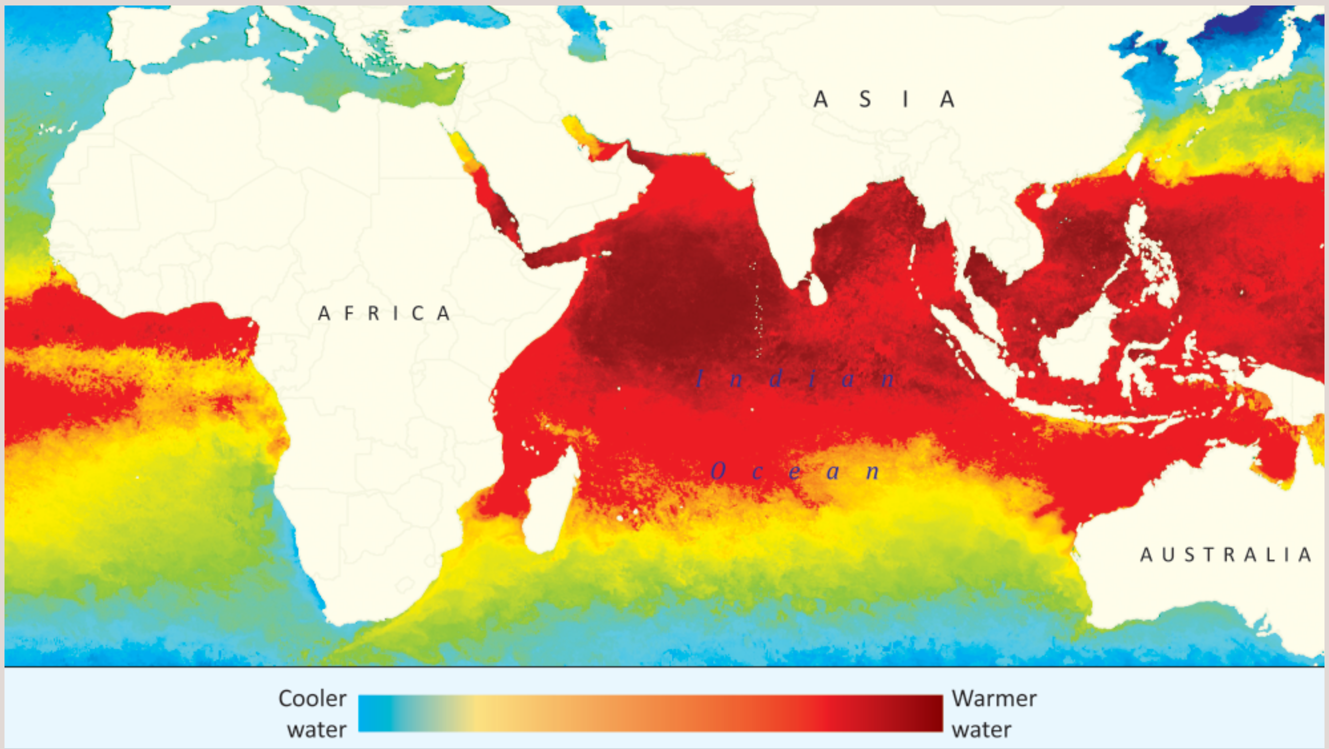
Africa faces the challenge of providing enough water for its people and ecosystems in a time of growing demand and increased scarcity. How can it ensure that access to water does not remain a pipe dream for millions?

The Situation

Chapter 1 provides the background water situation in Africa—the physical, meteorological and socio-economic conditions that contribute to making water so scarce on the continent. The main points are outlined below and in the following section that underscores other constraints Africa faces in meeting its growing demand for water.

- *More than 40 per cent of Africa's population lives in arid, semi-arid and dry sub-humid areas:* In these areas, annual rainfall reliability is low (de Rouw 2004, Sultan and others 2005). The uncertainty of water supplies has implications for Africa's people in terms of food security and public health, seasonal and permanent rural-to-urban migrations, and political instability and conflicts over scarce water resources (le Blanc and Perez 2008).
- *The amount of water available per person in Africa is far below the global average and is declining:* The continental annual average water availability per person is 4 008 m^3/capita/year, well below the global average of 6 498 m^3/capita/year (FAO 2009). Annual per capita water availability has declined from 37 175 m^3 in 1750 to 4 008 m^3 in 2008. It has been predicted that the proportion of the African population at risk of water stress and scarcity will increase from 47 per cent in 2000 to 65 per cent in 2025, affecting 18 countries (Bates and others 2008).
- *Groundwater is declining*: Some of Africa's important aquifers are losing more water than the rate of recharge. Water withdrawal in North Africa has greatly surpassed the rate of natural replenishment of aquifers from precipitation and countries will not be able to support current irrigation rates.
- *Rainfall is also declining in some regions:* Rainfall during the growing season is declining in Southern and Eastern Africa and research indicates that it is associated with warming in the Indian Ocean (Box 3.6.1).

"Scratching" for water. Muddy seep in a dry river bed in rural Chikomba District, Zimbabwe. Due to growing water scarcity, people end up scouring river beds to find water for drinking and for their livestock.



Visualization of sea-surface temperatures over the Indian Ocean, created with data from 1994 to 2005 from the Pathfinder satellite dataset

Box 3.6.1: Warming Indian Ocean associated with rainfall decline in Southern and Eastern Africa

A study of sea-surface temperatures and rainfall has linked anthropogenic warming in the Indian Ocean to decreasing growing-season rainfall in eastern and southern Africa. The link to anthropogenic global warming implies that rainfall decreases are likely to continue or intensify, contributing to increased food insecurity in the region.

According to the study, the combination of evidence from models and historical data strongly suggests that human-induced warming of the Indian Ocean leads to an increase in rainfall over the ocean, which, in turn, adds energy to the atmosphere. The added energy then creates a weather pattern that reduces the flow of moisture onshore and brings dry air down over the African continent, which decreases rainfall.

The study observed that rainfall in eastern and southern African countries decreased about 15 per cent since the 1980s and reports that rainfall over the Indian Ocean would likely continue to increase through the year 2050, with impacts on moisture movement on the continental shelf. This disruption would reduce much needed continental rainfall by around 15 per cent every 20-25 years.

Source: NASA Earth Observatory 2010

The Constraints

- *Demand for water is increasing with population growth and economic development:* With population projected to reach nearly two billion people by the year 2050 (UNFPA 2009), water supplies will be stretched to provide adequately for all uses. Africa's average population growth rate between 2005 and 2010 was 2.3 per cent, the highest in the world (UNFPA 2009).

- *Development of water resources is inadequate:* Water scarcity in Africa is partly a consequence of the very low level of development and exploitation of its water resources, which combined with physical water scarcity, deprives millions of people in Africa of adequate access to water. The growth in water demand is not being matched by a corresponding development of water resources at both national and transboundary levels, mainly due to lack of financial resources (AfDB 2009). Africa has the world's lowest per capita water withdrawal at about 170 m^3, due not only to poor water resource availability but also to underdeveloped water infrastructure and inefficient water management (AICD 2009). For example, less than 25 per cent of Africa's average annual river runoff is being utilized for human developmental activities (Couet and Maurer 2009), and total annual withdrawals for the three major water-use sectors of agriculture, municipalities and industries is only 5.5 per cent of internal renewable resources (FAO 2005). Agriculture is mostly rain-fed and less than 10 per cent of the continent's cultivated land of 185 million ha or 6 per cent of the total land area is irrigated. Nevertheless, agriculture is the largest user of water, accounting for about 85-88 per cent of total water use. This is believed to be due, in part, to the very low levels of technology and efficiency in agricultural production (UNECA n.d.). Similarly, Africa has exploited less than ten per cent of its low-cost hydropower potential even though it suffers from chronic shortages and high power costs (AICD 2009).

- *Prices to access water are generally distorted:* Access to water often remains free of charge, even to the rich, and in places where people

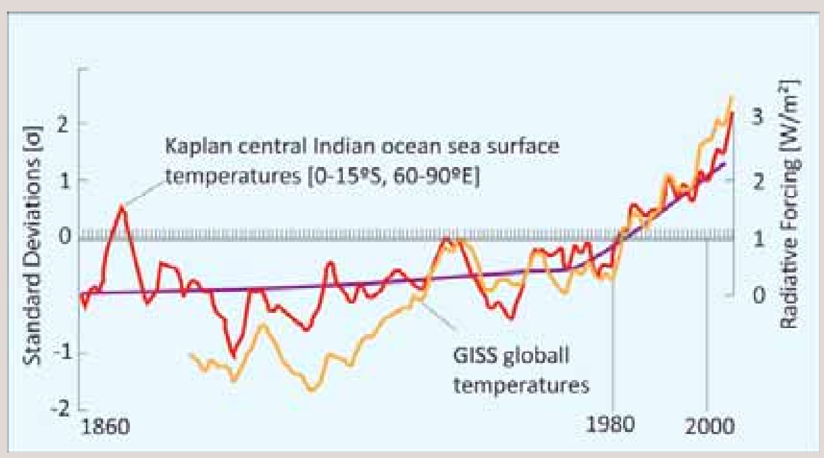
are charged for water, the poor pay more for it than do the rich (IWMI 2008). In some instances, the poor, who spend labour time and cash to access water, pay ten times as much as the rich. Distorted prices are also evident in agriculture. For example, farmers in Gauteng province, South Africa, pay a high price for water to grow export crops for Zambia, where water costs far less and similar crops could be grown. In addition, the cost of water access and long-run marginal costs continue to grow (Grey 2000).

- *Water provision is highly inefficient:* One of the constraints in providing people of Africa with adequate and sustainable water supplies is the high level of water wastage through leakages in all major water-use sectors: agriculture, municipalities and industry. Most of the losses are due to delayed maintenance of infrastructure resulting from funding constraints (Frenken 2005). In some cities, as much as 40-60 per cent of the water introduced into distribution systems cannot be accounted for (Gumbo 2004). Water availability is also constrained by the pollution of existing water due to the lack of comprehensive wastewater management to treat the huge volumes of domestic wastewater generated by fast-growing urban populations (UNEP 2002, IWMI 2006). Water wastage is also encouraged by the use of contumacious or perverse incentives—water pricing mechanisms that do not promote a culture of saving; an example is the provision of subsidies for irrigation water.

The Opportunities

- *Further develop and manage water resources sustainably:* Given the presence of ample available water resources and their underdevelopment, one of the opportunities for addressing Africa's water scarcity is to further develop and manage its water sustainably (UNECA 2006). Economic development is needed to ensure a sustainable flow of funds for water infrastructure. There is also considerable scope for improved agricultural production and food security through irrigation and rain-fed agriculture, which does not necessarily lead to increased demand for water (UNECA n.d.). The African Water Vision specifically recommends an increase in the development of water resources potential by five per cent in 2005, 10 per cent in 2015, and 25 per cent in 2025 to meet increased

Box 3.6.2: Global surface temperatures and Indian Ocean temperatures, 1860-2000



Analyses show a negative relationship between seasonal continental rainfall and precipitation over the Indian Ocean. The analysis of historical seasonal rainfall data over the Indian Ocean and Africa's eastern seaboard from 1950 to 2005 showed that declines in rainfall in Ethiopia, Kenya, Tanzania, Zambia, Malawi and Zimbabwe were linked to increases in rainfall over the ocean, and that the trend was likely to continue.

Although differing in approach, the study's broad conclusions generally agree with those of the IPCC's Fourth Assessment Report finding that semi-arid Africa may experience water-stress and yield reductions by 2030. The IPCC assessment, however, anticipates precipitation increases over the Eastern African region, highlighting the fact that climate models are still not yet able to make precise predictions.

The same study showed that modest increases in agricultural capacity could reduce the number of undernourished people by 40 per cent by the year 2030. The challenge for Africa is to determine how best to mitigate the impacts of the likely increased water scarcity through investments in water for food and in agricultural development.

Sources: Funk and others 2008, Hansen 2008

David Trainer/Flickr.com

"The consequences of doing nothing, or waiting too long, can lead to situations where physical and economic resource scarcities converge, including geopolitical hotspots…."

– Bergkamp 2009

demand from agriculture, hydropower, industry, tourism and transportation at national levels (UNECA n.d.). "Hard" water development requires infrastructure such as dams, weirs, interbasin transfer pipelines, aqueducts and centralized treatment plants (Gleick 2003).

- *Improve water-use productivity:* In addition to developing more water resources, Africa will need to follow the "soft" path in water resource development, management and use by improving water-use productivity as opposed to seeking more sources of new supply (Gleick 2003). In this instance, water is acquired through a combination of Integrated Water Resources Management (IWRM) measures that include managing by water basin rather than within national boundaries; conserving water through efficiency approaches; making decisions at the appropriate level of public participation; investing in technology that is suitable for targeted communities; protecting aquatic ecosystems; pricing water appropriately; improving governance, including the operation of farmers markets; training people to maintain their own water infrastructure; managing aquifers more efficiently; analysing what farmers grow and encouraging change if appropriate; implementing drip irrigation to save fuel and water; and harvesting water (Gleick 2003).
- *Improve urban planning for better water provision:* Africa's increasing population and the unreliability of its water resources presents an opportunity for forward planning and learning new adaptation mechanisms. An example is the facilitation of migration from rural to urban areas (World Bank 2010). The availability of long-term historical rainfall patterns and various scenario analyses means urban planners can already factor in future contingent measures to handle rural-to-urban migration well before water systems get overwhelmed.
- *Rationalize water prices:* Given the contradiction between adequate water supplies and the lack of acceptable access, the economic, social and environmental values of water need to be defined and reconciled (UNECA 2006). Improved water pricing is necessary to indicate rising water scarcity and its value, force water towards high-value uses, encourage investment and improve water services. Water access and rights for the poor must also be protected, since water is a social good. Economic instruments can be used to ensure water allocation is productive, equitable and environmentally sustainable (IWMI 2008). Rational pricing approaches can be implemented that help the poor to access water at the same time as reducing costs. For example, in South Africa a levy was used to finance rural water supply and sanitation upstream, in a scheme in which urban areas supported protection measures upstream with economic benefits for those downstream (Grey 2000).

CHALLENGE 7

PREVENT LAND DEGRADATION AND WATER POLLUTION

The Challenge: *Prevent water pollution, and address land degradation related to rainfall variability and the impacts of such degradation on water resources.*

The Situation: *The Sahel has been subject to enormous rainfall fluctuations. Over the last three decades, the Sahel has suffered from land degradation; groundwaters are being polluted by saltwater intrusion, and Africa's scarce water supplies are being polluted by point sources.*

The Constraints: *Lack of valuing of ecosystem services; political instability and conflict within and between countries; poor agricultural practices and farming on marginal lands that affect water use or water resources; and lack of structured water monitoring and governance.*

The Opportunities: *Maintain vital ecosystem functions; foster the greening of the Sahel by encouraging adaptation to drought; and support scientific assessments of both land degradation and water quality.*

The Challenge

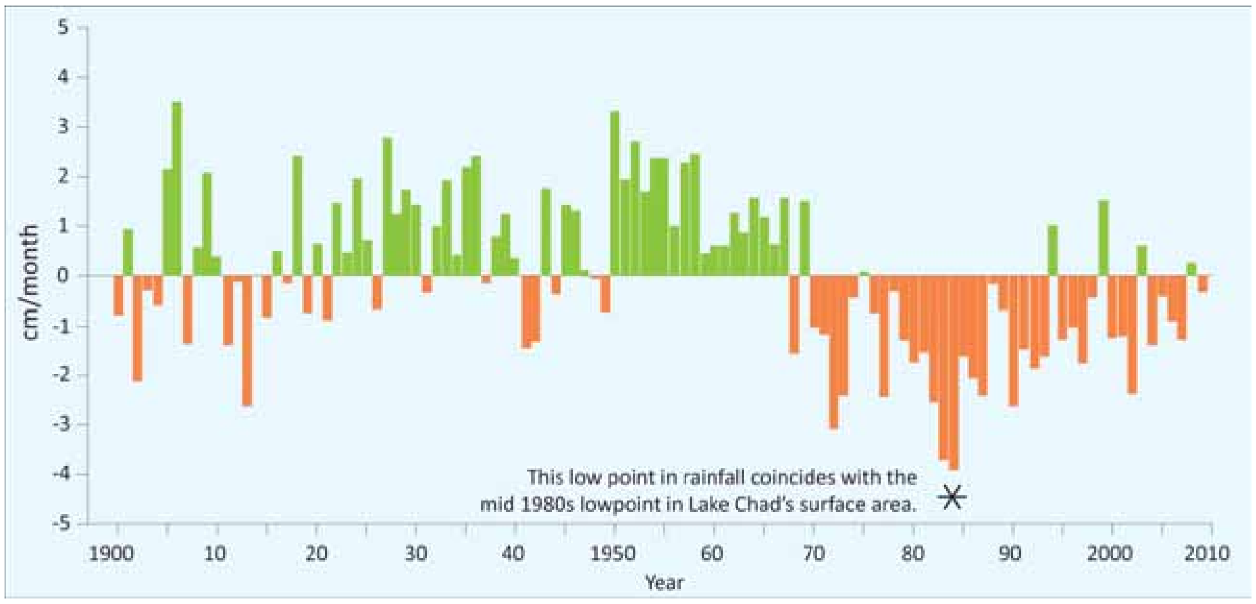
Rainfall variability, drought and land mis-management contribute to land degradation in Africa, while improperly managed water released to the environment can pollute land and water bodies; there are many opportunities for African countries to protect land and water resources from both.

The Situation

- *The Sahel has been subject to enormous rainfall fluctuations:* The Sahel is an arid to semi-arid ecoregion in northern Africa that spans 3 800 km from the Atlantic Ocean in the west to the Red Sea in the east, in a belt that varies from several hundreds to thousands of kilometres in width, covering an area of 3 053 200 km²; it is sandwiched between the Sahara desert to the

Tim Brauhn/Flickr.com

Figure 3.7.1: Rainfall index values in the Sahel, 1900-2004



The positive rainfall index values from more than a century of rainfall records in the Sahel show an unusually wet period from around 1950 to 1970. This period was followed by extremely dry years from the early 1970s to 1990, shown by the negative rainfall index values. Rainfall from 1990 to 2004 exhibited high inter-annual variability, but the levels were slightly below the 1898–1993 average (Sources: NASA Earth Observatory n.d., University of Washington 2009)

north and the wooded Sudanian savannas to the south (Frappart and others 2009). It includes parts of Senegal, Mauritania, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, Somalia, Ethiopia and Eritrea, and is often referred to as the transition zone between the Saharan desert and the rainforests of Central Africa and the Guinean Coast (Held and others 2005).

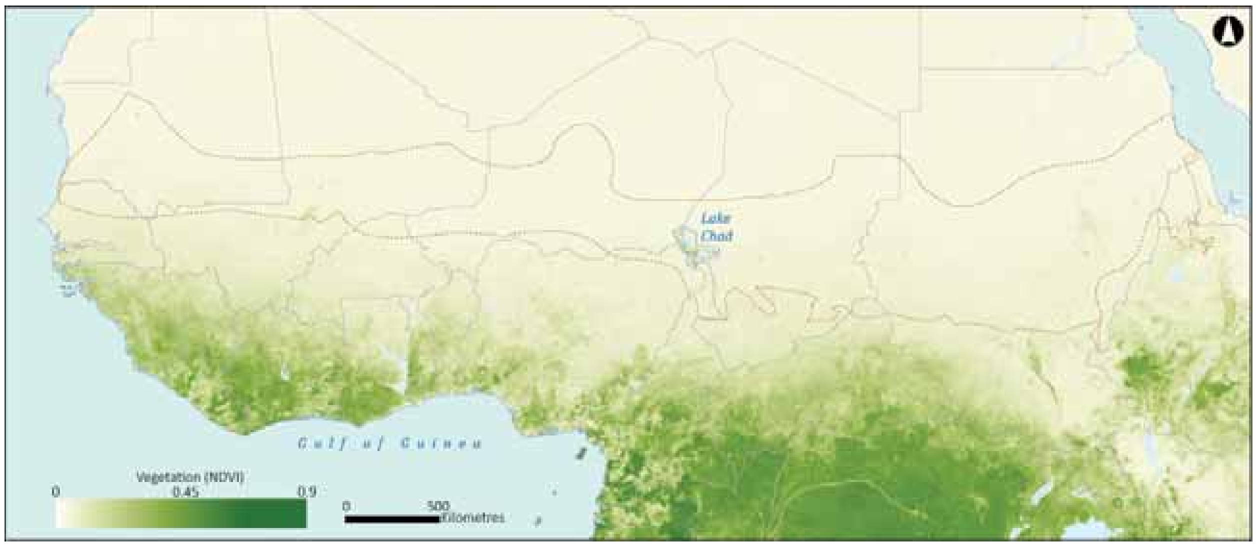
Historically, the Sahel has been subject to great rainfall fluctuations, characterized by extreme and prolonged droughts, especially during the last half of the 20th century (Figure 3.7.1). During the thirty-year periods between 1931-1960 and 1968-1997, mean rainfall declined by 25-40 per cent. Extreme differences occurred during the 1950s and 1980s, the wettest and driest decades, which affected the whole of Africa and point to large-scale general atmospheric circulation as the main driver of rainfall variability, albeit partially affected by variations in sea-surface temperatures. Dry conditions persisted from the late-1960s into the mid-1990s (Nicholson 2003). Patterns in the long-term human use of the land may have changed in response to rainfall variation. Substantial changes in climate conditions have seen the rainy season starting late and becoming shorter, forcing Sahelian farmers and pastoralist communities to adapt to declining water resources (Pedersen and Benjaminsen 2008, Biasutti and Sobel 2009). The drying trend has also been attributed to human factors such as increased aerosol loading and greenhouse gases (Held and others 2005). Both human and climatic conditions have contributed to land degradation in the Sahel, but satellite and ground data have not provided enough evidence for a consensus on the direction of change (ICRSE 2003). Figure 3.7.2 shows the extreme difference in vegetation between wet and dry periods, as illustrated in the Sahel.

Studies of global tropical carbon balance using a vegetation model are consistent with a recent trend toward a greener Sahel, showing that the region accumulated an average of 8.4 g $C/m^2/y$, or 50 million tonnes of carbon per year for the entire region for the period 1983-1999 (Olsson and Hall-Beyer 2008). Spatial

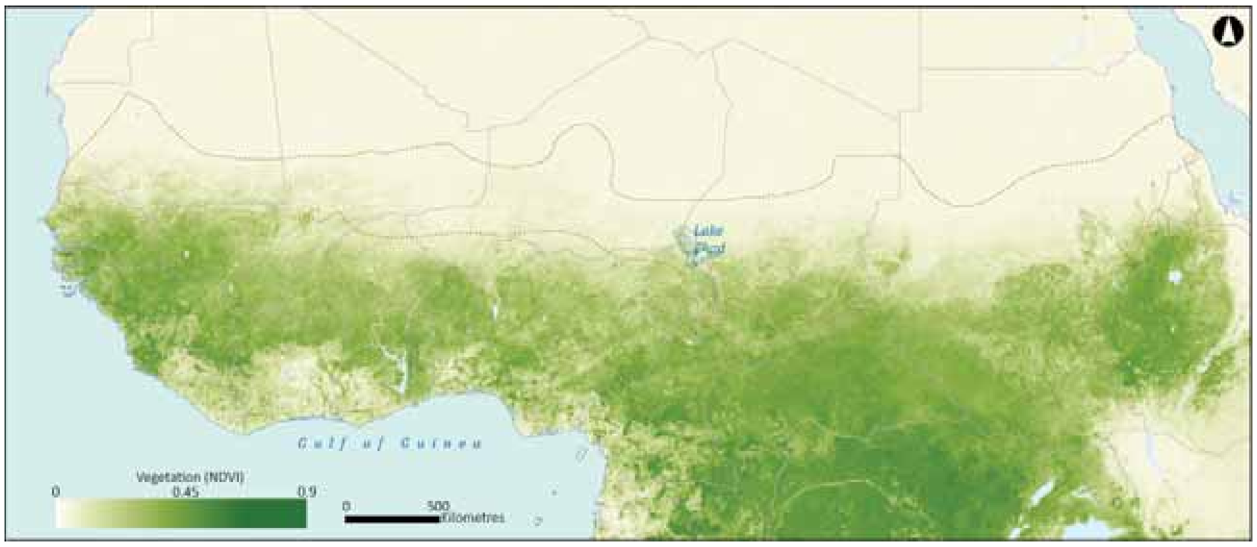
Radio Nederland Wereldomroep/Flickr.com

Figure 3.7.2: Dry and wet seasons in Senegal (Source: NASA Earth Observatory n.d.)

(a) March 2010 (Dry)

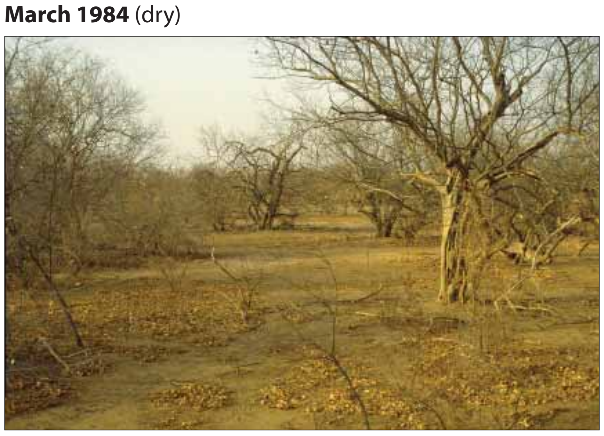


(b) September 2009 (Wet)



Vegetation in the Sahel region is generally coupled to seasonal rainfall and land use. In March, during the dry season, rainfall and lush vegetation do not extend north of the Gulf of Guinea (Figure 3.7.2a). September brings rain and vegetation into the Sahel as far north as the northern edge of Lake Chad (Figure 3.7.2b)

March 1984 (dry)



September 1982 (wet)

Vegetation in the Sahel region is generally coupled to seasonal rainfall and land use, as demonstrated by photographs from Senegal showing the difference in vegetation between the dry (left) and wet (right) seasons

vegetation patterns in the Sahel region, showing an increasing greenness, are an indication of variability of primary productivity (vegetation) in response to inter-annual rainfall variations (Hiernaux and Le Houérou 2006, Giannini and others, 2008, Mahé and Paturel 2009).

- *Over the last three decades, the Sahel has suffered from land degradation:* According to estimates by the Millennium Ecosystem Assessment (2005), 10-20 per cent of the world's drylands—an area more than twice that of India—have been significantly degraded. These include the Sahel region where the impacts of both rainfall variability and human uses have led to spatial and temporal changes and variability in landscape features such as tree-crop patterns and forest cover, and severe degradation of soils and fragile ecosystems (Sadio 2003). There are 500 million ha of moderately or severely degraded land in Africa, which represents 27 per cent of global land degradation (UNECA

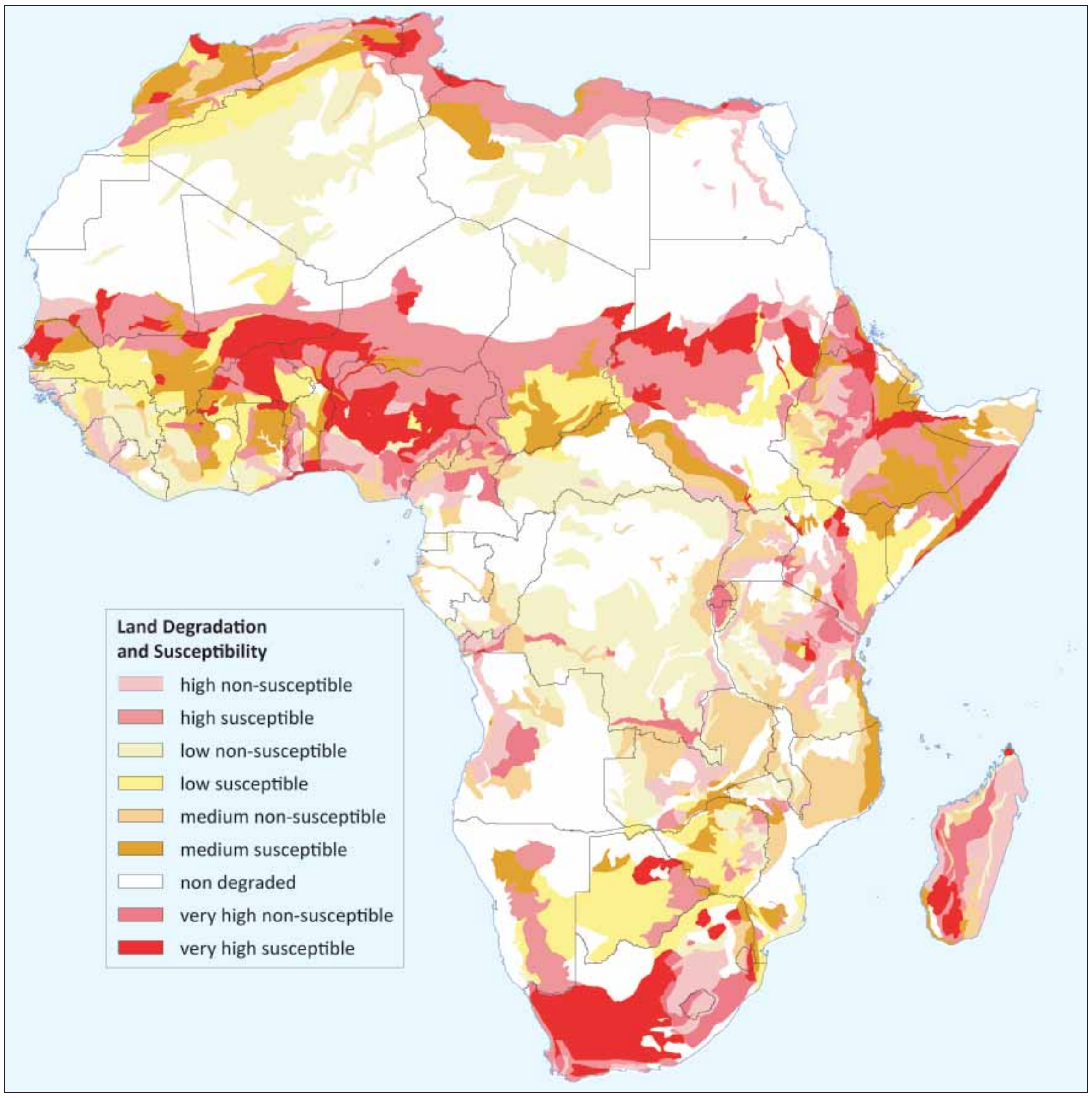
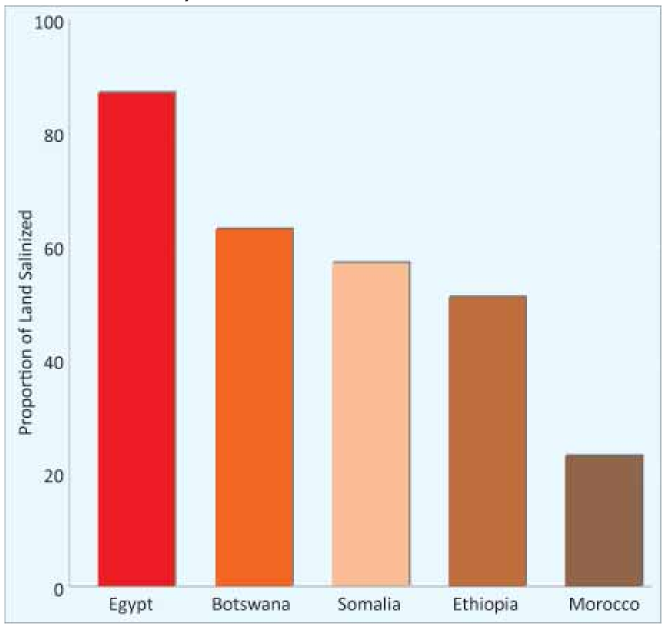


Figure 3.7.3: Land degradation susceptibility in Africa (Source: UNEP 2006)

2009) (Figure 3.7.3). "Land degradation is a long-term loss of ecosystem function and services, caused by disturbances from which the system cannot recover unaided" (UNEP 2007). Water contributes to land degradation through erosion (as a result of both human causes such as deforestation and poor agricultural practices, and from natural causes, such as flooding, often combined) and it suffers the consequences of land degradation in the form of the disruption of the water cycle, pollution and sedimentation. The degradation can reduce water availability and quality and alter the flows of rivers, all leading to serious downstream consequences (Barr and Mafuta 2007).

Figure 3.7.4: Salinization in African countries (Source: Barr and Mafuta 2007)



- *Groundwaters are being polluted by saltwater intrusion:* Agricultural production in Africa comes from predominantly rain-fed lands and irrigation. Inappropriate management of irrigation can result in land degradation in the form of waterlogging and saliniszation of formerly productive cropping areas (Figure 3.7.4).
- *Africa's scarce water supplies are being polluted by point sources:* Africa's available water and land resources are being increasingly polluted through people's actions that include discharge of industrial effluent, poor sanitation practices, release of untreated sewage, disposal of solid wastes, release of liquid from refuse dumps and the discharge of food-processing waste. These actions are affecting water quality and quantity and leading to an increase in the cost of developing water resources. Many water bodies receive waste at rates that are much higher than their natural ability to assimilate it and as a result there are widespread water-borne and water-related diseases. Water quality in sub-Saharan Africa is especially threatened. There are unacceptable levels of toxic substances such as heavy metals, persistent organic pollutants and biological contaminants in many important water bodies that provide drinking, sanitation and irrigation water for local people (PACN 2010).

Box 3.7.1: Environmental reserves in South Africa maintain the basic ecological functions of aquatic ecosystems

In 1998, South Africa established the National Water Act to set aside or allocate water of a certain quantity and quality to maintain the basic ecological functions of aquatic ecosystems. This amount of water is called an Environmental or Ecological Reserve. In other words, they protect the legitimate right of rivers and other ecosystems to their own water when water allocation decisions are made.

Although stakeholders sometimes interpret such protection or allocation as being in direct competition with human needs, the Environmental Reserve represents an opportunity to maintain the health of rivers and other ecosystems that provide water-related ecosystem goods and services

(maintaining water flows, for example) for the benefit of society. Sustaining various ecological functions through the Reserve in turn guarantees and prolongs the sustainability of ecosystems.

Sources: Republic of South Africa 1998, Van Wyk and others 2006, Digby and others 2007

The Constraints

The challenges Africa faces in addressing water issues related to land degradation include the impacts of the socioeconomic drivers already mentioned in other sections of this chapter, including rising populations, rapid growth of peri-urban areas and economic development, as well as improper or lack of sustainable water management practices. As the continent develops, for example, non-point sources such agricultural fertilizers and pesticides will rise with increased food demands from a growing population, while point sources from industries and municipalities will also increase. There are also risks of future threats to water from land-based activities such as petroleum refineries and tailing ponds from mining ventures (PACN 2010). Other constraints include the obvious rapid and often extreme rainfall fluctuations and continued change in the scientific debate about the causes (ICRSE 2003).

- *Poor agricultural practices and farming on marginal lands that affect water use or water resources:* Agricultural drought (drought in the root zone) is much more frequent than meteorological drought (a period when there is not enough water to grow crops because average rainfall is well below average) because most rainfall on cultivated land runs off the surface, and soil-water storage is diminished by soil erosion, resulting in poor soil structure, loss of organic matter, unfavourable texture and impediments to rooting. Farmers' field -water balances show that only 15-20 per cent of rainfall actually contributes to crop growth, falling to as little as five per cent on degraded land (UNEP 2007). Despite the reduced productivity of eroded soil, many African farmers are forced to continuously use the same land because of factors such as population pressure, inequitable land ownership and poor land-use planning. There is a strong relationship between population density and soil erosion (Barr 2007). The impacts of land degradation on water include the depletion of water availability through destruction of catchments and aquifers while increased siltation fills up dams and leads to flooding in rivers and estuaries. In Sudan, for example, the total capacity of the Roseires reservoir, which generates 80 per cent of the country's electricity, fell by 40 per cent in 30 years, due to siltation of the Blue Nile (Barr and Mafuta 2007).
- *Lack of structured water monitoring and governance:* Water pollution statistics are lacking because many African countries lack effective water quality monitoring programmes due to underinvestment and poor or absent water governance structures (PACN 2010).

The Opportunities

Maintain vital ecosystem functions: There is an opportunity in Africa for governments to set aside water for the environment in order to maintain ecological functions that contribute to water quantity and quality. Box 3.7.1 provides an example.

- *Foster the greening of the Sahel by encouraging adaptation to drought:* While rainfall has been deemed the primary driver of the

Box 3.7.2: Helping reverse land degradation in Africa

According to researchers at a meeting organized by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger (23-25 September 2006), the degradation of drylands in Africa can be reversed. Rehabilitation does not necessarily lead to full land recovery, but it may restore the land to 50-75 per cent of its former productivity, depending on soil and economic conditions. Through rehabilitation by tree planting, sustainable farming practices and groundwater replenishment, the land can become more productive again. Farmer-led rehabilitation initiatives in the Sahel in the past 30 years have started paying dividends:

Niger: Three million hectares of severely degraded land were rehabilitated at the initiative of local farmers, resulting in 20 to 150 trees per hectare in areas where few trees could were growing in the mid-1980s. The farmers focused on actions such as protecting the re-growth of natural vegetation, which improved soil fertility and led to the breaking down of the hard crust that forms over soils. They also integrated agriculture, livestock and forestry, resulting in a significant increase in farm productivity. The initiative reversed the spiral of degradation that characterized the region in the 1970s and 1980s.

Burkina Faso: Farmers were able to improve the productivity of 200 000 ha of degraded land.

Ethiopia: Regrowth of vegetation occurred in the northern parts of the country, spurred by tree planting and soil conservation measures over a ten-year period. The farmers were reportedly earning extra income through selling wood.

Source: Hebden 2006

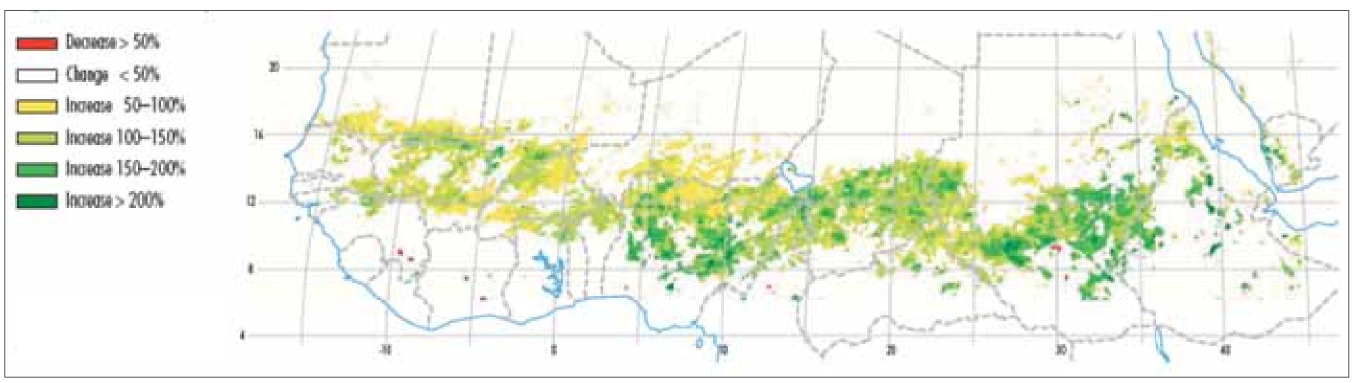
recent greening of the Sahel (Herrmann and Hutchinson 2005, Hickler and others 2005), the non-uniformity of greenness (greenness in certain areas but desertification in others) (Figure 3.7.5) suggests the interplay of factors in addition to rainfall, including land mangament practices, rural-to-urban migration and the displacement of people due to conflict (Mahé and Paturel 2009).

A number of studies (in Niger, Nigeria, Burkina Faso and Senegal) now indicate that some farmers and communities have improved the way they manage water in response to changes experienced during drought in the Sahel. When productivity and incomes rise as a result of the adaptive strategies, the farmers have been able to invest in more methods, such as inputs or crop diversification, that improve both their land and their livelihoods. Benefits have included higher cereal yields, tree densities and groundwater tables and reduced rural poverty and outmigration. These success stories suggest models that others may pursue. The emphasis on controlling land degradation could be changed to allow more focus on encouraging adaptation that would take advantage of good years and build up insurance against bad ones, since it is certain that drought will return (ICRSE 2003). Box 3.7.2 illustrates how degraded land has presented an opportunity to showcase what people can do on a local scale to rehabilitate degraded land.

To address land degradation by water and the impacts on water, it is necessary to manage freshwater resources from the moment rainwater hits the land surface. The type of soil management determines whether rain runs off the surface, carrying topsoil with it, or infiltrates the soil to be used by plants or to replenish groundwater and stream flows (UNEP 2007).

- *Support scientific assessments of both land degradation and water quality:* There is a need for both systematic global and national assessments of land degradation and desertification focusing on slow variables to understand long-term trends in land degradation and the potential for recovery. Such studies could allow the planning of effective responses to long-term drought (UNEP 2007). There is considerable knowledge and expertise among scientists in Africa to help plan and implement sustainable water strategies to address land degradation and pollution. Establishing centres of excellence staffed with African scientists networking with other water research and management experts would build Africa's capacity to monitor water quality, collect data and identify good water management approaches (PACN 2010).

Figure 3.7.5: Distribution of the greenness index in the Sahel, 1982-1999 (Source: Olsson and others 2005)



CHALLENGE 8

MANAGE WATER UNDER GLOBAL CLIMATE CHANGE

The Challenge: *Manage Africa's water under the impacts of global climate change.*

The Situation: *Global warming and its human cause are undeniable; warming patterns in Africa are consistent with global ones; Africa is already subject to important spatial and temporal rainfall variability; drought in Africa is common and some regions are becoming drier; Africa's repeated drought cycles kill thousands of people each event; and floods also occur regularly with severe impacts on peoples' livelihoods.*

The Constraints: *Africa is one of the most vulnerable continents to climate change and climate variability; the convergence of multiple stressors limits Africa's capability to address climate change impacts; increased rainfall variability contributes to Africa's economic limitations in adapting to climate change impacts; population growth in peri-urban areas will exacerbate flooding events; climate change will likely increase aridity, with important impacts on food production; climate change will increase water stress in Africa; climate variability and change could result in low-lying lands being inundated; climate change impacts in productive aquatic ecosystems will be costly economically and in terms of food supplies; and it is likely that climate change will affect disease vectors.*

The Opportunities: *Reinforce traditional adaptation mechanisms; provide early warning; introduce adaptation measures informed by a more reliable system of seasonal predictions; support public-private partnerships that develop innovative adaptation measures; and improve physical infrastructure.*

The Challenge

The impacts of climate change will be felt in Africa more than in most other regions, while its resources to adapt are much more limited. Africa faces the enormous challenge of managing increasingly uncertain water supplies as the global climate changes.

The Situation

- *Global warming and its human cause are undeniable:* The International Panel on Climate Change (IPCC) confirms that warming of the climate system is unequivocal. Furthermore, it confirms that human emissions of greenhouse gases are the primary cause. There is increasing evidence of a rise in global average air and ocean temperatures (Figure 3.8.1), widespread melting of snow and ice (Box 3.8.1) and an increase in global average sea level (IPCC 2007a). The impacts are expected to have great risks for environmental, social and economic well-being in both developed and developing world-regions. In developing regions, especially Africa, they are likely to reverse decades of development efforts.
- *Warming patterns in Africa are consistent with global ones:* The continent of Africa is warmer than it was about 100 years ago (Hulme and others 2000). Warming throughout the 20th

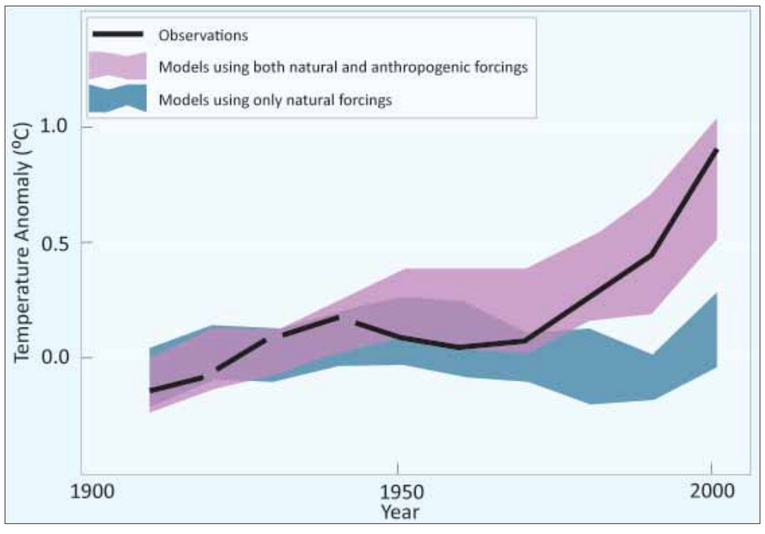
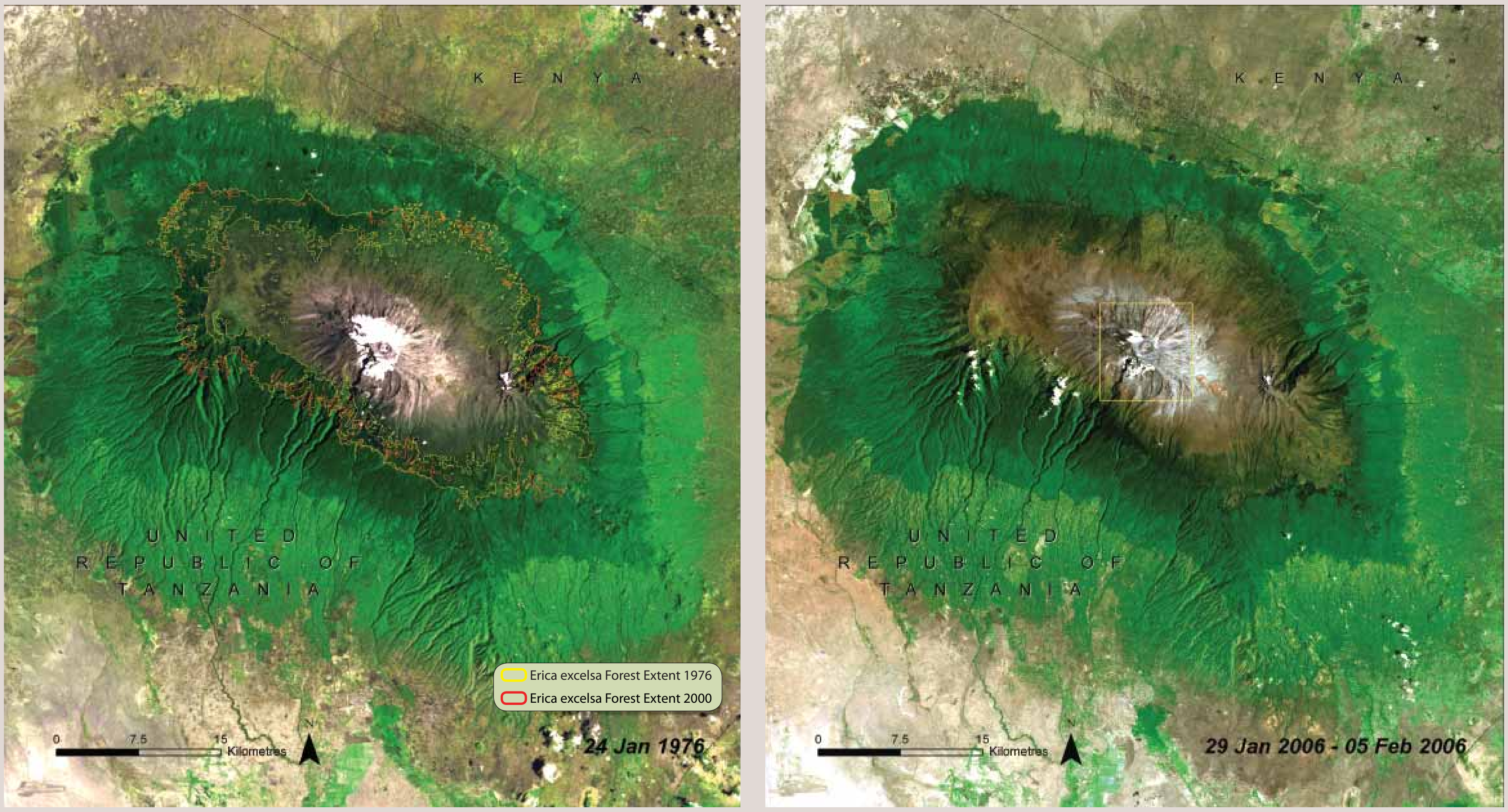


Figure 3.8.1 Comparison of observed continental-scale changes in surface temperature with results simulated by climate models using either natural or both natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906-2005 (black line) plotted against the centre of the decade and relative to the corresponding average for the 1901-1950. Lines are dashed where spatial coverage is less than 50 per cent. Blue shaded bands show the 5- 95 per cent range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Purple shaded bands show the 5- 95 per cent range for 58 simulations from 14 climate models using both natural and anthropogenic forcings (Source: IPCC 2007a)



Box 3.8.1: Mount Kilimanjaro's glaciers are melting

Glaciers on the summit of Mount Kilimanjaro have decreased in area by 80 per cent since the early 20th century. While glacial retreat globally has been linked to rising air temperatures, there is evidence that the decline of Kilimanjaro's glaciers (above images), along with changes in the boundaries of vegetation zones on the mountain, may be due in large part to a more local trend of decreasing precipitation that began in the 1880s.

It has also been found that water from the melting of Mount Kilimanjaro's glaciers provide little, if any, water to lower elevation streams. Most ice is lost through sublimation—water from the small amount of melting evaporates very quickly. A greater impact on the mountain's hydrology has resulted from increased burning under the drier conditions since 1880. The upper limit of the forest zone has descended significantly, as fire has destroyed nearly 15 per cent of Kilimanjaro's forest cover since 1976. In the 1976 image above, the upper limit of the Erica excelsa forest is shown in yellow. By 2000, the upper limit had moved noticeably downslope (red line) as a result of frequent fires. Changes in the hydrological and ecological functioning of Kilimanjaro affect a growing population living on and around the mountain.

Source: UNEP 2008

century has been at the rate of 0.5 degree Celsius/century, with slightly larger warming in the June-August and September-November seasons than in December-February and March-May. The warming patterns in Africa are similar to those globally, with the most rapid warming periods occurring in the 1910s to 1930s and the post-1970s (Hulme and others 2000). Although these trends seem to be consistent over the continent, the changes are not always uniform. For instance, decadal warming rates of 0.29°C in the African tropical forests and 0.1 to 0.3°C in South Africa have been observed. In South Africa and Ethiopia, minimum temperatures have increased slightly faster than maximum or mean temperatures (IPCC 2007a). Additionally, deep-water temperatures (which reflect long-term trends) of the large East African lakes (Edward, Albert, Kivu, Victoria, Tanganyika and Malawi) have warmed by between 0.2 and 0.7°C since the early 1900s (Bates and others 2008).

- *Africa is already subject to important spatial and temporal rainfall variability:* The situation is more complicated in the case of precipitation, with notable spatial and temporal variability. Inter-annual rainfall variability is large over most of Africa and multi-decadal variability is also substantial in some regions. In West Africa (4°-20°N; 20°W-40°E), a decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20-40 per cent noted between the periods 1931-1960 and 1968-1990. Increased inter-annual variability, however, has been observed in the post-1970 period, with higher rainfall anomalies and more intense and widespread droughts reported. In different parts of southern Africa, such as in Angola and Namibia, a significant increase in heavy rainfall events has also been reported, including evidence of changes in seasonality and weather extremes (IPCC 2007a).

Box 3.8.2: Late-twentieth-century warming in Lake Tanganyika unprecedented since AD 500

According to a study led by geologists at Brown University, Lake Tanganyika, the world's second-largest (by volume) and second-deepest lake after the Lake Baikal, has become warmer. The changes in temperature of Lake Tanganyika during the last century, which are considered to be unprecedented, have been attributed to anthropogenic climate change.

Tanganyika is a rift lake, situated in the Great Rift Valley in Eastern Africa, bordering Burundi, Tanzania, Zambia and the Democratic Republic of Congo. It is estimated that the lake provides 25-40 per cent of animal protein in the local population's diet. Fisheries employ around one million people.

The research team found that Lake Tanganyika experienced rising lake-surface temperatures throughout the past 1 500 years. However, it has only been in the past few decades that changes in the lake's temperature have surpassed natural variability.

Changes in the lake-surface temperature have affected its ecosystem, which heavily relies on nutrient recharge from the depths, the lake's base of the food chain. With rising temperatures at the surface, Lake Tanganyika becomes increasingly stratified, which diminishes this essential mixing of waters.

Lacking the basic nutrients, algae are unable to reproduce, which leads, in turn, to lower productivity of the lake, including fish stocks. If this trend continues, it will likely have major implications for the millions of people in the region that depend on these fish stocks.

Source: Tierney and others 2010

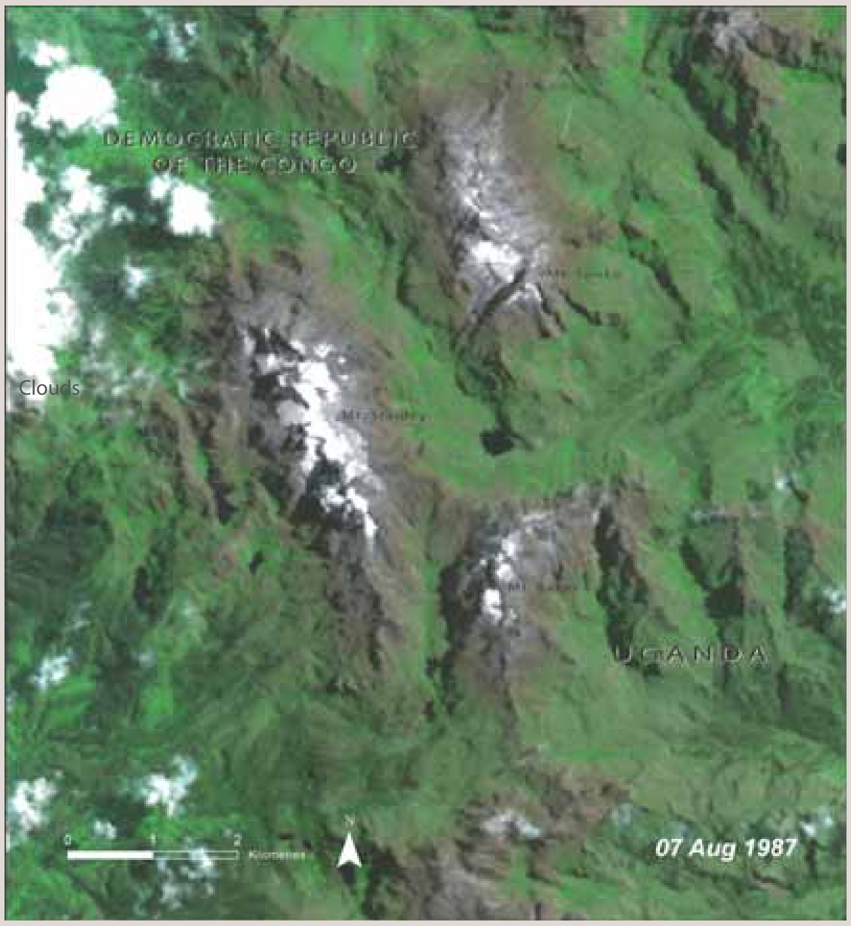
- *Drought in Africa is common and some regions are becoming drier:* Historically, the Sahel has experienced at least one severe drought every century. Since the 1950s, precipitation levels have decreased in the sub-tropics and tropics, making regions like the Sahel and Southern Africa even drier (Box 3.8.3).
- *Africa's repeated drought cycles kill thousands of people each event:* Drought is Africa's principal type of natural disaster, and in terms of number of people affected, Africa is second only to the world's most populous continent of Asia. Estimates suggest that one third of African people live in drought-prone areas and that around 220 million people are annually exposed to drought (UNFCCC 2006). Figure 3.8.2 (next page) shows the number of people killed and affected by Africa's most severe droughts. Droughts have particularly affected the Sahel, the Horn of Africa and Southern Africa since the end of the 1960s (UNFCCC 2006). The

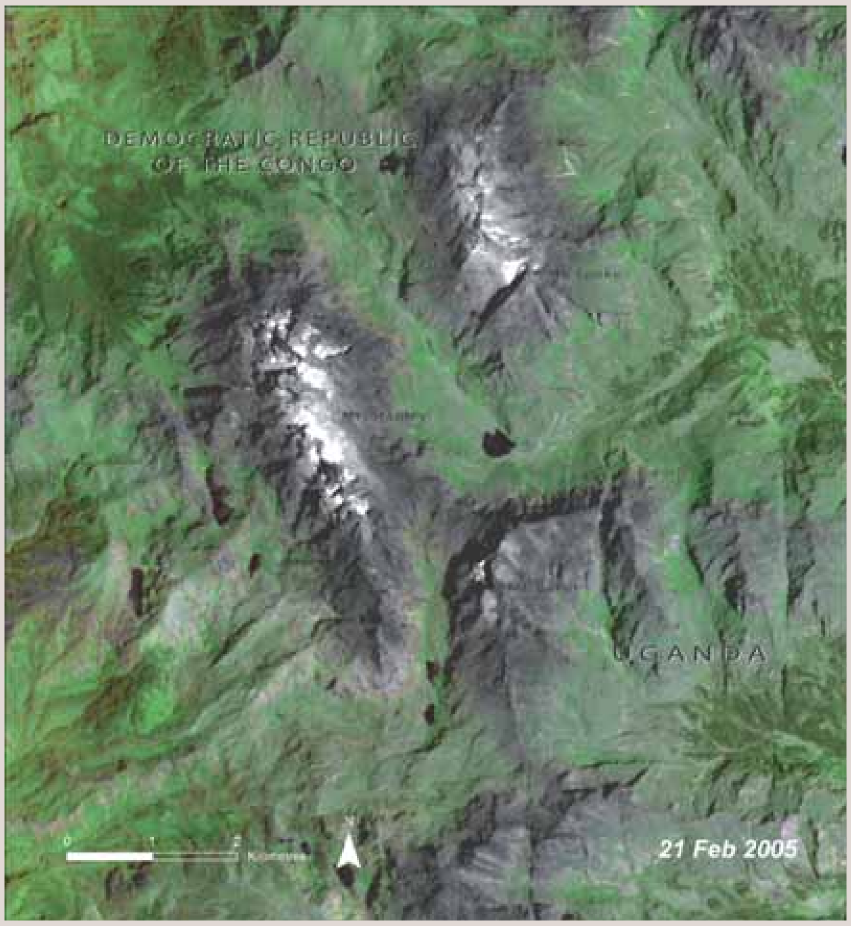
Box 3.8.3: The Sahel and Southern Africa are becoming drier

Historically, about 20 per cent of the earth's land surface experiences drought at any one time, but this has now risen to 28 per cent and will reach 35 per cent by the year 2020 (Calow and others 2010).

Since the 1950s, precipitation levels have increased in Africa's higher northern latitudes and decreased in the sub-tropics and tropics, making regions like the Sahel and Southern Africa even drier. Globally, very dry land areas have almost doubled since the 1970s, due to decreased El Niño-Southern Oscillation (ENSO)-related precipitation on land, which has been further augmented by surface warming. It is still not apparent if the recent multi-decadal droughts in the Sahel region are anomalous, or a part of a cyclic process. It has been argued that long-lasting intervals of dry and wet spells have been a feature of West African Monsoons for at least the past three millennia, and that this variability is associated with changes in circulation of the Atlantic. A much more severe drought than that witnessed by the African climate system in the last century occurred only 200-300 years ago. Hence, this recurring pattern of the hydrologic cycle suggests that there might be a gradual shift back into the period of centennial-scale drought of much greater severity, which would only be enhanced by rising temperatures (Trenberth 2005, Shanahan and others 2009). In the Sahelian region, warmer and drier conditions have reduced the length of growing seasons with detrimental effects on crops (IPCC 2007b).

Drought in the 1970s resulted in a dramatic alteration of the hydrological regime of rivers in the Sahel region due to land-use/cover change, while a rise in rainfall from the mid-1990s to the level of the 1970s caused an impermeable crust on the surface, resulting in less infiltration of water into the ground, and higher and earlier flood peaks in the rivers (Mahe and Paturel 2009).





Box 3.8.4: Glacial Recession in the Rwenzori Mountains

A comparison of satellite images from 1987 and 2005 shows a decrease in the extent of glaciers on Speke, Stanley and Baker peaks in the Rwenzori Mountains, which lie on the equator between Uganda and the Democratic Republic of the Congo. They are a major source of water for the lower plains like Kasese. Seasonal changes in snow and ice cover prevent simple visual analysis from conclusively measuring the decline of these glaciers. However, scientific findings from studies in 2003 and 2006 show that the glaciers at the tops of the Rwenzori Mountains are rapidly receding. The glaciers declined by 50 per cent between 1987 and 2003. This glacial recession is generally attributed to increased air temperature and decreased snow accumulation during the 20th century. It has recently been suggested that decreasing cloud cover during that same time period has contributed to a higher rate of sublimation (vaporization of ice without melting) of these glaciers as well. A century ago the glaciers of the Rwenzori Mountains covered nearly 6.5 km^2. If the glaciers continue to recede, as they have since 1906, researchers estimate they will be gone in the next 20 years.

Source: UNEP 2008

worst African drought in terms of fatality killed 300 000 people in Ethiopia in 1984, and the 1972 drought in Kenya caused severe damage to livestock and a 40 per cent decline in maize harvest (EM-DAT 2010).

- *Floods also occur regularly with severe impacts on people and livelihoods*: Floods recur in some African countries; even communities located in dry areas have been affected by floods (UNFCCC 2006). Unlike most of the tropics where the

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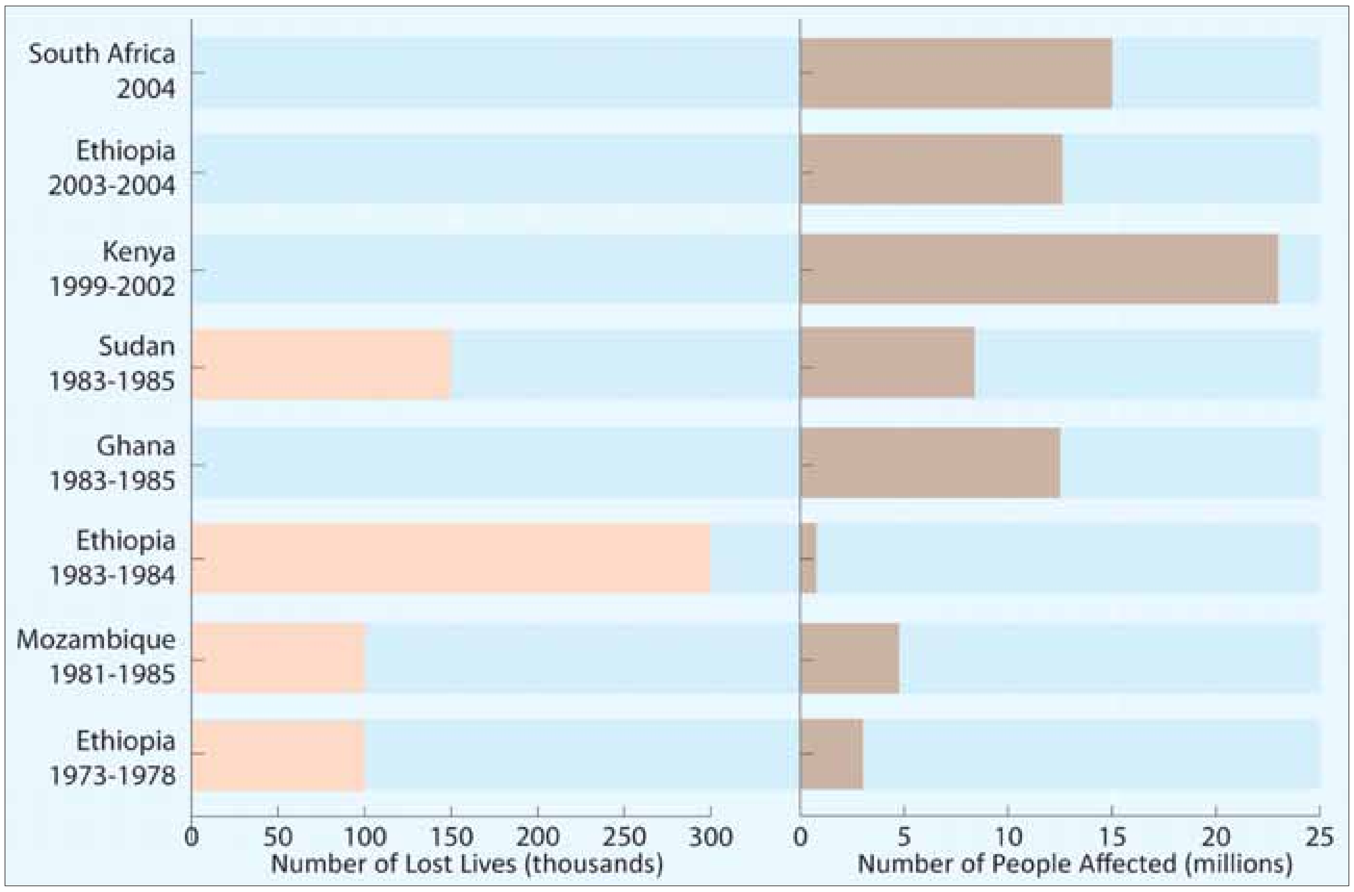
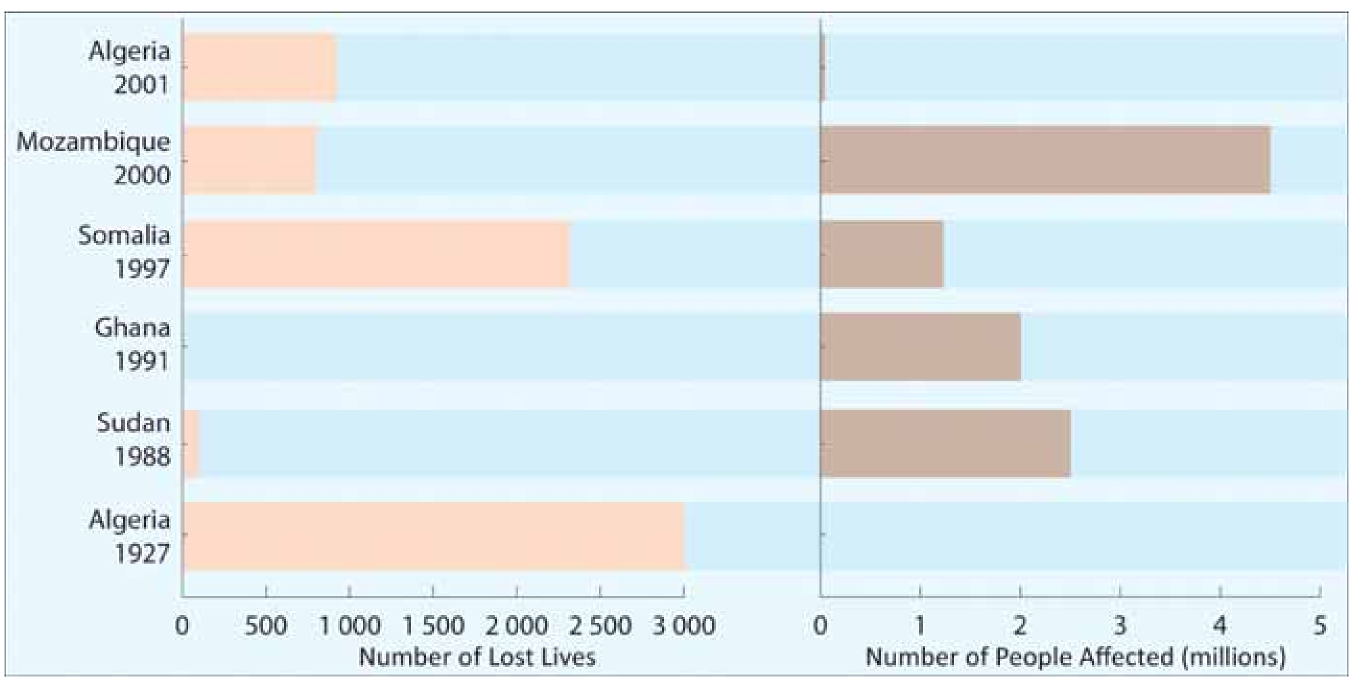


Figure 3.8.2: Number of people killed and affected by Africa's worst droughts (Source: EM-DAT 2010)

distribution and timing of floods is said to be dependent on the cycle of ENSO events, flooding in East Africa is mostly attributed to Indian Ocean Dipole (Behera and others 2005, Trenberth 2005). Floods have resulted in loss of life (Figure 3.8.3) and costly destruction of infrastructure on the African continent, with low-lying and densely populated coastal areas the most vulnerable.

The 1997-1998 floods in the Greater Horn of Africa caused extensive loss of life and property, and the loss of both field crops and food stocks in Somalia seriously affected food security in the region (Verdin and others 2005). In 2001, Mozambique was hit by both floods and drought in different parts of the country. In 2009, heavy and intense rainfall in western Africa set off massive flooding that affected 100 000 people, while torrential rain affected

Figure 3.8.3: Number of people killed and affected by Africa's worst floods (Source: EM-DAT 2010)



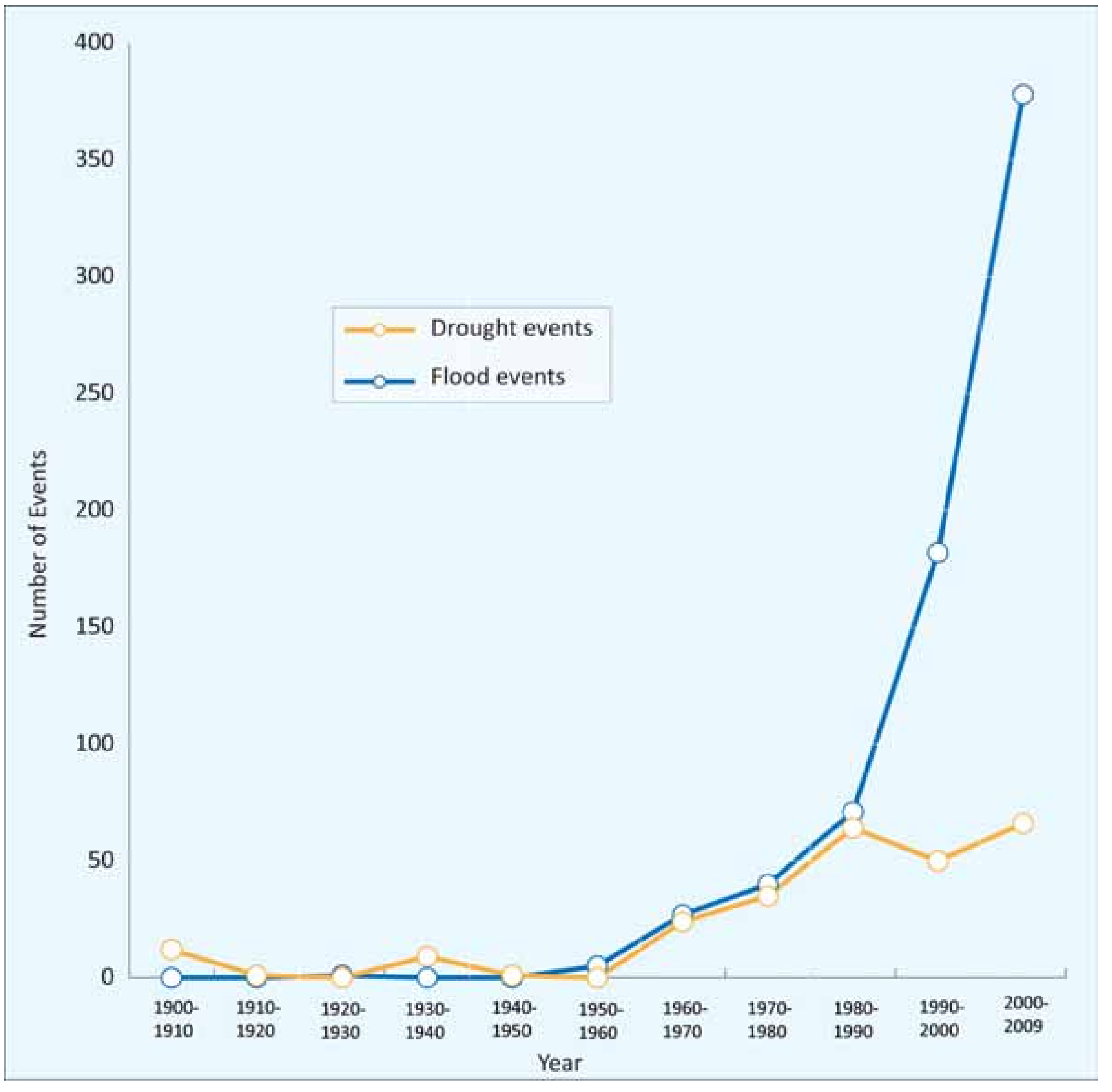


Figure 3.8.4: Trend in the number of recorded flood and drought events in Africa (Source: EM-DAT 2010)

about a million people in Zambia and Namibia (WMO 2009). Figure 3.8.4 shows a rising trend in the number of recorded flood and drought events in Africa.

The Constraints

A combination of various factors that include widespread poverty makes it difficult for most African communities to draw on financial, human, social, physical and natural capital to minimize their vulnerability to the impacts of climate change, including the possibility of more severe and frequent droughts and floods. Population growth is an additional strain on scarce resources to adapt to climate change impacts. Faced with existing low adaptation capacity, Africa will be further constrained by the direct and indirect impacts of climate change and a lack of the financial means to cope. These include increased water stress in some areas and inundation in others, a rise in food insecurity and the potential for an increase in water-related disease vectors.

- *Africa is one of the most vulnerable continents to climate change and climate variability:* This situation is aggravated by the interaction of multiple stresses, occurring at various levels (IPCC 2007a).

- *The convergence of multiple stressors limits Africa's capability to address climate change impacts:* The African continent contains the poorest and least developed nations of the world with low per capita GDP, low life expectancy and high infant mortality, weak governance structures and a low capacity to respond proactively to changes. A number of factors explain this very low adaptive capacity, including a deteriorating ecological base, widespread poverty, inequitable land distribution, a high dependence on the natural resource base, the ravages of HIV/AIDS and a reduced ability to cope with consecutive dry years due to less recovery and preparation time between events (UNFCCC 2006).

- *Increased rainfall variability contributes to Africa's economic limitations in adapting to climate change impacts:* A research study by Brown and Lall (2006) showed a statistically significant relationship between greater rainfall variability and lower per capita GDP and concluded that there is need for more infrastructure to secure water in the study's poorer countries, the majority of which are located in Africa. In Ethiopia, it found that the occurrence of droughts and floods reduced economic growth by more than one-third. Losses in Kenya due to flooding associated with El Niño in 1997-1998 and the La Niña drought in 1998-2000 caused annual damage ranging from 10 to 16 per cent of GDP during this period. The transport sector suffered the most damage, with 88 per cent of flood losses, while foregone hydropower and industrial production totaled 84 per cent of the drought losses (Brown and Lall 2006).

- *Population growth in peri-urban areas will exacerbate flooding events:* A surge in rural-to-urban migration in most areas of the continent has exerted pressure on urban areas, which are often not prepared to accommodate the extra numbers in the short term, resulting in informal settlements. About 72 per cent of Africa's urban population lives in such settlements that are quite frequently found in cities located in low-lying and poorly drained catchment areas, and thus most subject to flooding (GAR 2009).

- *Climate change will likely increase aridity, with important impacts on food production:* The IPCC (2007a) reports with high confidence that agricultural production and food security (including access to food) in many African countries and regions are likely to be severely compromised by climate change and climate variability. A number of countries in Africa already face semi-arid conditions that make agriculture challenging, and climate change will likely increase aridity and reduce the length of the growing season as well as force large regions of marginal agriculture out of production. Projected reductions in yield in some countries could be as much as 50 per cent by 2020, and crop net revenues could fall by as much as 90 per cent by 2100, with small-scale farmers being the most affected. This would adversely affect food security on the continent.

- *Climate change will increase water stress in Africa:* The IPCC reports with very high confidence that water stress currently faced by some countries is likely to increase, while some countries that currently do not experience water stress will become at risk. Even without climate change, several countries in Africa, particularly in northern Africa, will exceed the limits of their economically usable land-based water resources before 2025. About 25 per cent of Africa's population (about 200 million people) currently experience high water stress. The population at risk of increased water stress in Africa is projected to be between 75-250 million and 350-600 million people by the 2020s and 2050s, respectively (IPCC 2007a).

- *Climate variability and change could result in low-lying lands being inundated:* Climate change induced inundation will result in important impacts on coastal settlements (IPCC 2007a). Regionally, the most flood risk occurs in North, West and Southern Africa (Warren and others 2006). The numbers affected will be largest in the mega-deltas of Africa while small islands are especially vulnerable. Towards the end of the 21st century, projected sea-level rise will affect low-lying coastal areas with large populations.

- *Climate change impacts in productive aquatic ecosystems will be costly economically and in terms of food supplies:* Natural climate variability, coupled with human-induced changes, may affect ecosystems such as mangroves and coral reefs, with consequences for fisheries and tourism. The cost of adaptation could amount to at least 5-10 per cent of GDP (IPCC 2007a). Any changes in the primary production of large lakes will have important impacts on local food supplies. Lake Tanganyika currently provides 25-40 per cent of animal protein intake for the surrounding populations, and climate change is likely to reduce primary production and possible fish yields by roughly 30 per cent (Warren and others 2006).

- *It is likely that climate change will affect disease vectors:* Africa is already vulnerable to a number of climate-sensitive diseases (UNFCCC 2006). Climate change will no doubt alter the ecology and transmission of some disease vectors with links to water in Africa, and consequently the spatial and temporal transmission of such diseases. Most assessments of health have concentrated on malaria and there are still debates on the attribution of malaria resurgence in some African areas. There is a need to examine the vulnerabilities and impacts of future climate change on other infectious diseases such as dengue fever, meningitis and cholera, among others.

The Opportunities

With the knowledge that Africa will face significant impacts on its water resources due to climate change, the international community has begun to devote considerable attention and resources to climate change adaptability on the continent. It has identified many opportunities for managing water to overcome those impacts and the constraints in addressing them, some of which are highlighted below.

- *Reinforce traditional adaptation mechanisms:* Although Africa as a whole, especially its governments, have a low capacity for adaptation, many African communities in arid and semi-arid areas have developed traditional adaptation strategies to face great inter-annual climate variability and extreme events. An unusually persistent drought may increase people's vulnerability in the short term, but it can encourage adaptation in the medium to long term. This is particularly true for the drought-prone area in the Sahel region, which is susceptible to frequent climatic hazards (UNFCCC 2006).

- *Provide early warning:* It is as important for local communities to have early warning systems as it is to be supplied with relief, because at the onset of adverse environmental changes the critical decisions are made at the household level. Better forecasting and early warning systems are a prerequisite for adaptation, particularly to predict and prevent the effects of floods, droughts and tropical cyclones as well as for indicating the planting dates to coincide with the beginning of the rainy season and predicting whether there will be disease outbreaks in areas that are prone to epidemics (UNFCCC 2006). Improved early warning systems and their application will reduce vulnerability to future risks associated with climate variability and change (IPCC 2007a).

- *Introduce adaptation measures informed by a more reliable system of seasonal predictions:* Such measures include managing agriculture and water resources better, diversifying livelihoods and improving production efficiencies in arid lands and marginal areas by intensifying livestock densities, using natural fertilizers and practicing soil and water conservation, for example (UNFCCC 2006, IPCC 2007a). Improvement in present-day rain-fed agriculture can enhance resilience for future periods of drought stress through technological steps like water-harvesting systems, dam building, water conservation and agricultural practices, drip irrigation, and developing drought resistant and early-maturing crop varieties and alternative crop and hybrid varieties. Biotechnology research could also yield tremendous benefits if it leads to drought- and pest-resistant rice, drought-tolerant maize and insect-resistant millet, sorghum and cassava, among other crops (IPCC 2007a).

- *Support public-private partnerships that develop innovative adaptation measures:* Innovations for managing climate-related risks are being developed and deployed with private sector participation. In Malawi, for example, a private sector initiative that bundles insurance based on an established relationship between lack of rainfall and crop failure and a loan to help farmers purchase seeds and fertilizers has received strong support from farmers. With more variable and intense climate, weather-related crop insurance may have more limited prospects (APF 2007).

- *Improve physical infrastructure:* Improvements to physical infrastructure may improve adaptive capacity. Building improved communication and road networks for better exchange of knowledge and information, for example, gives people an opportunity to migrate more easily in case of extreme events due to climate change. On the other hand, general deterioration in infrastructure threatens the supply of water during droughts and floods (IPCC 2007a).

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CHALLENGE 9

ENHANCE CAPACITY TO ADDRESS WATER CHALLENGES

The Challenge: *Enhance Africa's capacity to address its water challenges.*

The Situation: *Africa faces a situation of economic water scarcity; and current institutional, financial and human capacities for managing water are lacking.*

The Constraints: *Inadequate and unsustainable funding arrangements for water resources management; insufficient knowledge base; lack of an effective research and technology base; and weak institutional arrangements and legal frameworks for the ownership, allocation and management of water resources.*

The Opportunities: *Reform water institutions; improve public-private partnerships; and improve the knowledge base through human capacity building.*

The Challenge

To address Africa's mounting challenge of economic water scarcity, it will need to strengthen and sustain financial, human and institutional capacities to effectively develop and utilize water resources.

The Situation

- *Effective institutional, financial and human capacities for managing water are lacking:* There is a lack of sustainable financing mechanisms for water-related investments, including transboundary water resources development, water supply, sanitation, hydropower and irrigation, among others and under financing of the water and sanitation sector in many countries has led to deterioration and potential collapse of infrastructure (Carles 2009). The situation is exacerbated by competition for public funding between sectors, and heavy public debt burdens in most countries (OECD 2010).

The Constraints

Insufficient knowledge base : There is generally a lack of data due to the underdeveloped human capacity for research, collection, assessment and dissemination of water resources data, and no motivation and retention of skilled staff. The planning and monitoring of water development activities need data, information, and managed knowledge. This is especially evident in the deficiency of climate change data on Africa, as identified in the G8 Gleneagles plan of action (2005), which is still relevant. It identifies the following gaps:

- Low institutional and human capacity levels.
- Limited comprehensive studies on vulnerability analysis.
- Equally limited studies on possible adaptation measures and their cost-benefit analysis.
- Lack of quantification of the different components of Africa's water balance. While estimates are available in the literature for continental average annual rainfall and evapotranspiration, research data are lacking for other components such as surface runoff, infiltration, groundwater storage and groundwater discharge, among others.
- Groundwater quantity and quality monitoring is very irregular in most countries due to a lack of expertise to collect and analyze the data for the continent's development.
- Wide gaps in ground and surface water information and knowledge in the water sector across Africa.
- Lack of earth observation systems and lack of in-country and regional capacity for analyzing and interpreting observational data.
- Data on economically exploitable small-scale hydropower potential is limited or not available for most African countries, and there are wide variations on how much hydropower potential has been exploited overall.
- Lack of decision-support systems and tools that are relevant to Africa's local water resources management needs.
- Lack of real-time data collection and transmission technology to facilitate sharing, such as through the Internet for meteorological and hydrological data.
- Lack of a coordinated, effective and financially sustainable continental system or database for data collection, assessment and dissemination for national and transboundary water basins, and for supporting strategic development decisions on the continent.
- Lack of commitment in the mobilization and leveraging of financial resources by African countries also affects the above data issues directly or indirectly. A typical example is the

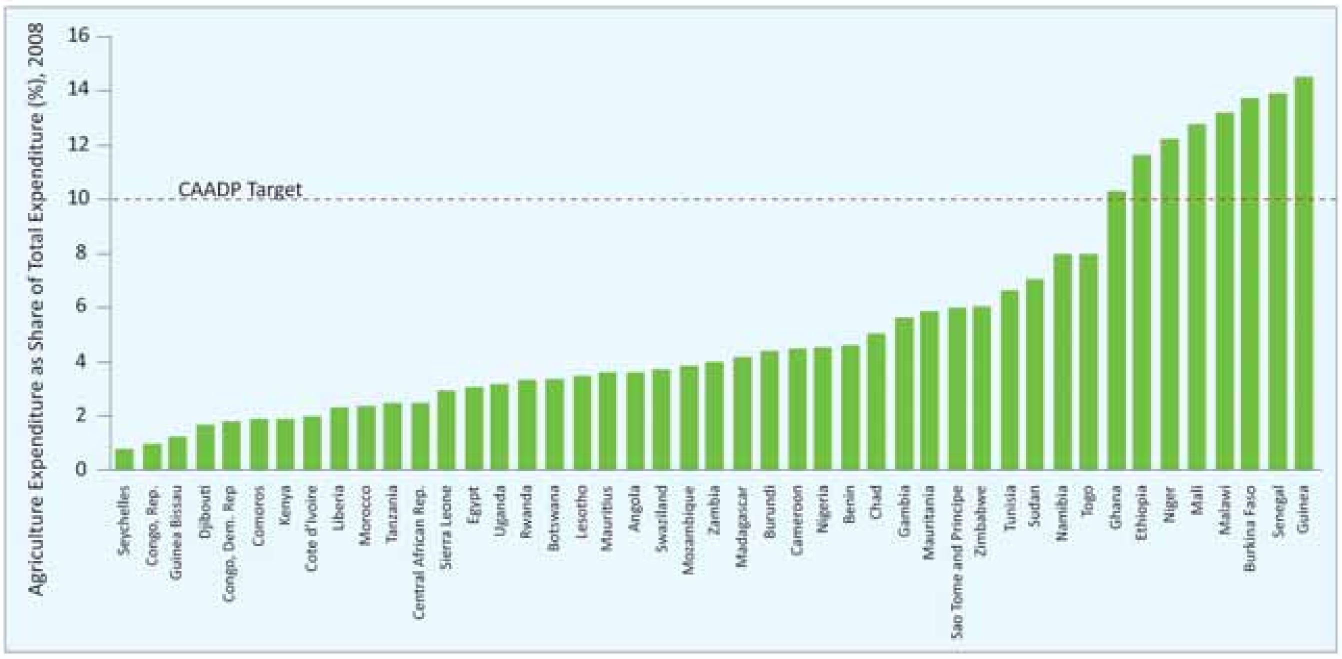

Figure 3.9.1: Agricultural expenditure (as percentage of total) compared to CAADP 10 per cent target, 2008 (Source: Bekunda 2010)

implementation of the 2003 Comprehensive Africa Agriculture Development Programme (CAADP), the Africa-owned and Africa-led initiative to boost agricultural production on the continent through irrigation and water management, among other measures. In 2003, member countries made a commitment to spend ten per cent of their total national expenditures on agriculture, but by the year 2008, only a handful of countries had implemented what they promised (Figure 3.9.1).

The Opportunities

Although there is a general lack of institutional, financial and human capacity to effectively manage water resources in Africa, at the individual country level, many African nations have made progress in improving water policies, strategies and institutional arrangements that highlight the opportunities to improve water management capacities in Africa. These include an increased awareness of, and political commitment to Integrated Water Resources Management (IWRM). Many countries are also increasingly committed to water-policy reform and the decentralization of water institutions. And many are taking steps towards financial sustainability in the water sector and recognize the importance of treating water as an economic good, while providing a safety net for the poor (UNECA 2006). Based on their progress and on recommendations from the Africa Water Vision, the following are some of the opportunities for African nations to improve their capacity to manage water resources.

- *Reform water institutions:* There is potential to enhance human resources and the capacity of water resource institutions, including the decentralization of water resource management activities to the most appropriate levels for stakeholders, as well as strengthening existing initiatives. Several countries, including South Africa and Namibia, reformed their water sectors and these initiatives provide lessons for establishing comprehensive water sector

Eugene Apindi Ochieng

policy and strategy reforms and setting up appropriate legal frameworks, including those that protect the interests of the more vulnerable in society such as the poor. The capacity to manage water in Africa in an integrated and coordinated fashion can be improved through maintaining a centralized institutional structure that can better govern the complex and multi-disciplinary nature of water resources management and planning, especially given the challenges of pollution and environmental degradation (UNECA 2006). National water management institutions can be improved if their responsibilities include helping to unify perceptions about domestic water concerns, establishing a national water management framework, providing data to enable the forecasting of water demand and potential problems, cooperating with regional and international water bodies to manage shared water, and coordinating training programmes (UNECA 2006).

- *Improve public-private partnerships:* Governments have the opportunity to improve public-private partnership arrangements for the development of water infrastructure. The financial model of Public-Private Partnerships (PPPs) involves a sharing of risk and responsibility between the state and private firms, while the state retains control of the assets. Although such partnerships were expected to improve services without the disadvantages of privatization (unemployment, higher prices and corruption), they have fallen short of expectations; costs are often greater for the consumer, the private sector may not always be more efficient and big government contracts are often abused. If governments improve the system for dealing with the private sector by being disciplined and using highly transparent procedures, there is the potential for gains in efficiency and effectiveness in water management. There is evidence that PPPs in Africa have been most successful when planning, communication and commitment are strong, and when governments have implemented effective monitoring, regulation and enforcement. Governments must also perform thorough feasibility studies to examine affordability, value for investment and risk transfer. An example of a successful PPP is a 20-year concession contract between the government of Gabon and a private firm for the provision of water and electricity services; its relative success is due to the government's strong political commitment (Farlam 2005).

- *Improve the knowledge base through human capacity building*: Opportunities to identify training needs for water resources assessment and management, and to train a cadre of water professionals need to be fostered and acted upon to improve the level of information about Africa's water resources, uses and needs. Training should aim to ensure that staff is retained and that their knowledge and skills are frequently upgraded (UNECA 2009.). Governments need to ensure that information and education programmes are an integral part of the development process, and to provide water specialists with the training and means to implement IWRM (INPIM 1992). The proper policy frameworks for planning, developing and managing water resources that implement recent advancements in the science and technology of water management also need to be in place to take advantage of available knowledge and skills. This knowledge includes local and indigenous knowledge and wisdom about water resources (UNECA 2006). Box 3.9.1 illustrates the richness of indigenous knowledge of water that should not be lost.

Box 3.9.1: Indigenous Knowledge of Water

The Fulani of Mauritania have a detailed art of detecting groundwater. Their indicators are based on topography (e.g., shallow aquifers can be found near natural ponds or in depressions of mountains), on plant species (especially tap-rooted trees) and the health or vigour of the plants, such as the greenness of leaves during the year. Other indicators are based on fauna (e.g., wild boars only live where they can dig and find moist soil; other animals that prefer to stay around moist places are caimans, amphibious lizards, tortoises, bands of butterflies, some bird species, and many termite hills). The Fulani also are familiar with the geological strata in their area, and that they must dig through the whole layer of red or grey clayey soil and arrive at the sandy layer before finding ground water. A good quality ground water that is clear, sweet and has a good mineral content, is indicated by the presence of *Guiera senegalensis, B. rufescens*, termite hills, and deep-water wells (the deeper, the better the quality). The best quality natural ponds are indicated by the presence of water lilies, followed by *Acacia nilotica* and *Mitragyna inermis*. Bad, diseased water is indicated by the presence of the grass *Echinochloa pyramidalis*. Water quality is also tested by immersing a leather container in it. The best water leaves the leather intact, and as water quality deteriorates, the intensity and duration of the leather's colour will change to white, black, red or finally yellow/orange. Water quality is also evaluated by its effect on livestock, especially their behaviour after drinking (whether they are content or not) and the yield of milk.

Source: UNECA 2006

References

UNEP. (2006). Africa Environment Outlook 2: Our Environment Our Wealth. United Nations Environment Programme. Earthprint: UK.

1. Provide Safe Drinking Water

Banerjee S., Diallo A., Foster V., Wodon Q. (2009). Trends in Household Coverage in Modern Infrastructure Services in Africa. World Bank Policy Research. World Bank. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1372957##. (Last accessed on May 2, 2010).

Boelee E. and Madsen H. (2006). Irrigation and Schistosomiasis in Africa: Ecological Aspects. IWMI Research Report 99. International Water Management Institute. Colombo. Sri Lanka.

Bordalo A. and Savva-Bordalo, J. (2007). The quest for safe drinking water: An example from Guinea-Bissau (West Africa). Water Research. 41: 2978-2986.

Dungumaro E. (2007). Socioeconomic differentials and availability of domestic water in South Africa. Physics and Chemistry of the Earth. 32:1141-1147.

Grimond, J. (2010). For want of a drink. Economist. LONDON, UK, 20 May 2010. http://www.economist.com/node/16136302?story_id=16136302&source=hptextfeature (Last accessed on August 17, 2010).

Hashimoto Action Plan. (2010). Strategy and Objectives through 2012. The United Nations Secretary-General's Advisory Board on Water and Sanitation.

Jenkins, M. (2010). High marks for clean water. National Geographic Magazine. 217(4): 28. http://blogs.ngm.com/blog_central/2010/04/high-marks-for-clean-water.html (Last accessed on May 19, 2010).

Lewin S., Norman R., Nannan N., Thomas E., Bradshaw D., and the South African Comparative Risk Assessment Collaborating Group. (2007). Estimating the burden of disease attributable to unsafe water and lack of sanitation and hygiene in South Africa in 2000. South African Medical Journal. 97:755-762.

Mwanza D.D. (2003). Water for Sustainable Development in Africa. Environment, Development and Sustainability. 5: 95-115.

Tortajada C. (2006). "Teaching the Poorest: Rural Water Supply in Morocco. Case Study for the 2006 HDR". http://hdr.undp.org/en/reports/global/hdr2006/papers/cecilia_tortajada_morocco_casestudy.pdf (Last accessed on May 10, 2010).

UNDP. (2006a). Human Development Report 2006. United Nations Development Programme. http://hdr.undp.org/en/reports/global/hdr2006/ (Last accessed on May 2, 2010).

UNDP (2006b). "Human Development Report 2006 Presskit". United Nations Development Programme. http://hdr.undp.org/en/media/HDR_2006_Presskit_EN.pdf, (Last accessed on May 2, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking Water- 2010 Update. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. http://whqlibdoc.who.int/publications/2010/9789241563956_eng_full_text.pdf (Last accessed on May 20, 2010).

WHO and UN-Water. (2010). UN-Water Global Annual Assessment of Sanitation and Drinking-Water. World Health Organization and United Nations. http://www.who.int/water_sanitation_health/publications/UN-Water_GLAAS_2010_Report.pdf (Last accessed on May 20, 2010).

2. Ensure Access to Adequate Sanitation

Aker J. (2008). Can you hear me now? How cell phones are transforming markets in sub-Saharan Africa. CGD Notes. Center for Global Development. Washington D.C.

Dagdeviren, H. and Robertson, S. (2009). Access to water in the slums of the developing world. Policy Centre for Inclusive Growth Working Paper 57. UNDP. http://www.ipc-undp.org/pub/IPCWorkingPaper57.pdf (Last accessed on May 08, 2010).

Grimond, J. (2010). "For want of a drink". Economist. LONDON, UK, 20 May 2010. http://www.economist.com/node/16136302?story_id=16136302&source=hptextfeature (Last accessed on August 17, 2010).

Lane, J. (2010). "Don't let disputes over data get in the way of safe water for billions". The Guardian, 6 May. http://www.guardian.co.uk/commentisfree/2010/may/06/water-sanitation-millenium-development-goals (Last accessed on May 22, 2010).

UNSD. (2009). Number of Mobile cellular telephone subscriptions data by country. United Nations Statistical Division. http://mdgs.un.org/unsd/mdg/Data.aspx (Last accessed on April 21, 2010).

UNDP. (2006). Human Development Report 2006. United Nations Development Programme. http://hdr.undp.org/en/reports/global/hdr2006/ (Last accessed on May 2, 2010).

UNU. (2010). Sanitation as a Key to Global Health: Voices from the Field. United Nations University. Ontario. Canada.

WHO/ UNICEF. (2010). Population with Improved Sanitation data. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. http://www.wssinfo.org/datamining/introduction.html (Last accessed on April 21, 2010).

WHO and UN-Water. (2010). UN-Water Global Annual Assessment of Sanitation and Drinking-Water. World Health Organization and UN-Water.

WTO (2010). "Vision and Approach". World Toilet Organization. http://www.worldtoilet.org/aboutus2.asp (Last accessed on September 10, 2010).

3. Foster Cooperation in Transboundary Water Basins

Ashton, P. (2000). Southern African Water Conflicts: Are they inevitable or Preventable. The African Dialogue Lecture Series. Pretoria University. South Africa.

Ashton, P. (2007). Disputes and Conflicts over Water in Africa. In Violent conflicts, Fragile Peace: Perspectives on Africa's Security. Adonis and Abbey. London.

Cooley, H., Christian-Smith, J., Gleick, P., Allen, L., Cohen, M. (2009). Understanding and reducing the risks of Climate change for Transboundary Waters. Pacific Institute and UNEP.

Grimond, J. (2010). "For want of a drink". Economist. LONDON, UK, 20 May 2010. http://www.economist.com/node/16136302?story_id=16136302&source=hptextfeature (Last accessed on August 17, 2010).

Jarvis, W. (2006). Transboundary Groundwater: Geopolitical Consequences, Commons Sense, and the Law of the Hidden Sea. Dissertation presented at Oregon State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Kliot, N., Shmueli, D., Shamir, U. (2001). Institutions for management of transboundary water resources: their nature, characteristics and shortcomings. Water Policy 3: 229-255.

Merrey, D. (2009). African models for transnational river basin organizations in Africa: An unexplored dimension. Water Alternatives 2(2): 1-22.

OSU. (2007). International Freshwater Treaties Database. Program in Water Conflict Management and Transformation. Oregon State University. http://www.transboundarywaters.orst.edu/database/interfreshtreatdata.html (Last accessed on April 30, 2010).

Roy, D., Barr, J., and Venema, H. (2010). Ecosystem Approaches in Transboundary Integrated Water Resources Management (IWRM): A Review of Transboundary River Basins. (Unpublished report). IISD, Winnipeg, Canada and UNEP, Nairobi.

Sadoff, C., Whittington D., Grey, D. (2002). Africa's International Rivers. In Africa's International Rivers: An Economic Perspective, pp 3-14. The International Bank for Reconstruction and Development/The World Bank. Washington D.C.

Turton, A., Earle, A., Malzbender, D., Ashton, P. (2006). Hydroplitical Vulnerability and Resilience along Africa's International Waters. In Hydropolitical Vulnerability and Resilience along International Waters: Africa pp 19-67. United Nations Environmental Programme. http://www.awiru.up.ac.za/pdf/C_CH%202%20UNEP%20Africa.pdf. (Last accessed on April 30, 2010).

Turton, A. (2003). The Hydropolitical dynamics of cooperation in Southern Africa: A strategic perspective on institutional development in international river basins. In Hydropolitical dynamics of cooperation in Southern Africa, pp. 83-103. http://www.anthonyturton.com/admin/my_documents/my_files/2BA_Chapter_4.pdf (Last accessed on April 30).

Turton A. (2008a). The Southern African Hydropolitical Complex. Management of Transbounday Rivers and Lakes pp. 21-79.

Turton A. (2008b). A South African perspective on a possible benefit-sharing approach for transboundary waters in the SADC Region. Water Alternatives (1) 180:200.

UNEP. (2002). Atlas of International Freshwater Agreements. United Nations Environment Programme.

UNEP. (2006). Hydropolitical Vulnerability and Resilience along International Waters: Africa. United Nations Environment Program.

Wolf, A. (1998). Conflict and cooperation along the international waterways. Water Policy 1(2): 251-265.

Wolf A., Kramer A; Carius A.,Dabakelko, G. (2005). Managing Water Conflict and Cooperation. In State of the World 2005: Redefining Global Security pp. 80-99. Worldwatch Institute. Washington D.C. http://tbw.geo.orst.edu/publications/abst_docs/wolf_sow_2005.pdf. (Last accessed on April 20, 2010).

Van der Zaag P. (2007). Asymmetry and equity in water resources management; Critical institutional issues for Southern Africa. Water Resource Management 21:1993–2004.

Van der Zaag P. and Carmo Vaz A. (2003). Sharing the Incomati waters: cooperation and competition in the balance. Water Policy 5:349-368.

4. Provide Water for Food Security

AfDB. (2006). African Regional Document – "Water Resources Development in Africa". African Development Bank. http://www.reliefweb.int/rw/lib.nsf/db900sid/RURI-6N4NFJ/$file/afdb-gen-mar06.pdf?openelement. (Last accessed on March 10, 2010).

AfDB, FAO, IFAD, IWMI and World Bank. (2007). Investment in Agricultural Water for Poverty Reduction and Economic Growth in Sub-Saharan Africa: Synthesis Report. African Development Bank, Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, International Water Management Institute. http://siteresources.worldbank.org/RPDLPROGRAM/Resources/459596-1170984095733/ synthesisreport.pdf. (Last accessed on April 10, 2010).

Bai, Z. , Dent, D.,. Olsson, L., Schaepman, M. (2008). Global assessment of land degradation and improvement. Identification by remote sensing. Report 2008/01, ISRIC – World Soil Information, Wageningen. http://www.isric.org/isric/webdocs/docs/Report%202008_01_GLADA%20international_REV_Nov%202008.pdf. (Last accessed on April 30, 2010).

De Fraiture, C., and Wichelns, D. (2010). Satisfying Future Water Demands for Agriculture. Agricultural Water Management 97(4):502-511.

FAO. (1989a). Guidelines for designing and evaluating surface irrigation systems. Food and Agriculture Organization of the United Nations.FAO Irrigation and Drainage Paper 45. Rome.

FAO. (1989b). Irrigation Water Management: Irrigation scheduling. Food and Agriculture Organization of the United Nations.FAO Training manual number 4. Rome.

FAO. (2002). Water and food security. World Food Summit: Five Years Later. Food and Agriculture Organization of the United Nations, 10-13 June. http://www.fao.org/worldfoodsummit/english/fsheets/water.pdf (Last accessed on April 25, 2010).

FAO. (2003). Improving irrigation technology. Food and Agriculture Organization of the United Nations. http://www.fao.org/ag/magazine/0303sp3.htm. (Last accessed on May 23, 2010).

FAO. (2005). Special Event on Green Revolution in Africa. Background document. Committee on World Food Security 31st Session – 23-26 May 2005. Food and Agriculture Organization of the United Nations. http://www.fao.org/unfao/bodies/cfs/cfs31/cfs2005_events_en.htm. (Last accessed on April 25, 2010).

FAO. (2006). Database of African dams. Food and Agriculture Organization of the United Nations. http://www.fao.org/geonetwork/srv/en/metadata.show?id=280&currTab=summary (Last accessed on June 14, 2010).

FAO. (2009). AQUASTAT database. Food and Agriculture Organization of the United Nations http://www.fao.org/nr/aquastat. (Last accessed on January 13, 2010).

FAO. (2010). "Water and Food Security". Food and Agriculture Organization of the United Nations. http://www.fao.org/worldfoodsummit/english/fsheets/water.pdf (Last accessed on September 15, 2010).

Fitzgerald-Moore, P. and Parai, B. (1996). Unpublished. The Green Revolution. http://people.ucalgary.ca/~pfitzger/green.pdf. (Last accessed on May 13, 2010).

Frenken, K. (Ed.), 2005. Irrigation in Africa in figures - AQUASTAT Survey – 2005. FAO Water Reports no.29. FAO, Rome. ftp://ftp.fao.org/agl/aglw/docs/wr29_eng.pdf. (Last accessed on February 2, 2010).

Hoekstra, A. and Chapagain, A. (2008). Globalization of water: Sharing the planet's freshwater resources; Oxford, UK.: Blackwell Publishing.

IAASTD. (2009). "Summary for Decision Makers of the Sub-Saharan Africa (SSA) Report". International Assessment of Agricultural Knowledge, Science and Technology for Development. Island Press.

Jhamtani, H. (2010). "The Green Revolution In Asia: Lessons for Africa". http://www.fao.org/docrep/012/al134e/al134e02.pdf. (Last accessed on May 7, 2010).

MDG Africa Steering Group. (2008). Achieving the Millennium Development Goals in Africa. Recommendations of the MDG Africa Steering Group. June 2008. http://www.mdgafrica.org/pdf/MDG%20Africa%20Steering%20Group%20Recommendations%20-%20English%20-%20HighRes.pdf. (Last accessed May 9, 2010).

Mwaniki, A. (2006). "Achieving Food Security in Africa: Challenges and Issues". UN Office of the Special Advisor on Africa (OSAA) http://www.un.org/africa/osaa/reports/Achieving%20Food%20Security%20in%20Africa-Challenges%20and%20Issues.pdf (Last accessed on May 9, 2010).

Nwanze, K. (2010). "Change Africa from Within". World Economic Forum. http://worldeconomicforum.ning.com/profiles/blogs/change-africa-from-within (Last accessed on May 9, 2010).

Pingali, P. (2007). Westernization of Asian diets and the transformation of food systems: Implications for research and policy. Food Policy, Volume 32, Issue 3. 281-298.

Ringler, C., Biswas, A., Cline, S. (Eds.). (2010). Global Change: Impacts on Food Security. Springer-Verlag Berlin Heidelberg.

Rockström, J., Kaumbutho, P., Mwalley, J., Nzabi, A., Temesgen,M., Mawenya, L., Barron, J., Mutua, J., Damgaard-Larsen, S. (2009). Conservation Farming Strategies in East and Southern Africa: Yields and Rain Water Productivity from on-Farm Action Research. Soil and Tillage Research 103(1): 23-32.

SADC, SARDC, IUCN, and UNEP. (2008). Southern Africa Environment Outlook. Gaborone/Harare/Nairobi.

Stroosnijder, L. (2009). Modifying Land Management in Order to Improve Efficiency of Rainwater Use in the African Highlands. Soil and Tillage Research 103(2): 247-256.

UNECA. (2006). "African Water Development Report. Economic Commission for Africa." United Nations http://www.uneca.org/awich/AWDR_2006.htm (Last accessed on 30 May 2010).

UNEP/GRID-Arendal (2008). Areas of physical and economic water scarcity, UNEP/GRID-Arendal Maps and Graphics Library, http://maps.grida.no/go/graphic/areas-of-physical-and-economic-water-scarcity (Last accessed on 30 May 2010).

UNFPA. (2009). State of world population 2009: Facing a changing world: women, population and climate. United Nations Population Fund. New York: UNFPA.

Waterfootprint. (n.d.). "Water footprint and virtual water". http://www.waterfootprint.org/?page=files/home. (Last accessed on April 20, 2010).

Wik, M., P. Pingali, Broca, S. (2008). Global Agricultural Performance: Past Trends and Future Prospects. Background Paper for The World Development Report 2008. The World Bank: Washington, DC.

World Bank. (2008). "New, high yield rice spells millions in savings for African countries". http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/0,,contentMDK:21844287~menuPK:258657~pagePK:2865106~piPK:2865128~theSitePK:258644,00.html. (Last accessed on April 26, 2010).

5. Develop Hydropower to Enhance Energy Security

Bartle, A. (2002). Hydropower potential and development activities. Energy Policy. 30(14): 1231-1239.

Export-Import Bank of the United States. (2008). Power Projects in Africa. 2008 Annual Conference, April 17 & 18. http://www.exim.gov/products/special/africa/pubs/Power_Projects_Africa_April2008.pdf. (Last accessed on March 16, 2010).

Hamed, S. (2010). Eastern Africa Power Pool. Energy Efficiency Workshop Washington-March, 2010. http://www.usea.org/Programs/EUPP/gee/presentations/Egypt_eastafricapowerpool.pdf (Last accessed on September 15, 2010).

Hammons, T. (2006). Status, plans of action, further developments, and recommendations for power pools in Africa, IEEE Transactions on Power Systems 21 (2006) (2).

Hathaway, T. and Pottinger, L. (2010). Big Dams: Bringing Poverty, Not Power to Africa. Progress: the Sustainable Development Quarterly, IV, 38-42.

Hydro4Africa. (n.d.). African Hydropower News. http://hydro4africa.net/index.php (Last accessed on September 15, 2010).

Hydroworld website. (2010). Africa News and Information. http://www.hydroworld.com/index/world-regions/africa.html (Last accessed on May 23, 2010).

IMF. (2008). Africa's Power Supply Crisis: Unraveling the Paradoxes. MFSurvey Magazine: Countries & Regions. International Monetary Fund. http://www.imf.org/external/pubs/ft/survey/so/2008/CAR052208C.htm (Last accessed on September 15, 2010).

IEA. (2008). World Energy Outlook 2008. International Energy Agency. http://www.iea.org/textbase/nppdf/free/2008/weo2008.pdf. (Last accessed on April 16, 2010).

IEA. (2007). Renewables in Global Energy Supply: An IEA Fact Sheet. Paris: OECD/IEA. International Energy Agency. https://www.iea.org/papers/2006/renewable_factsheet.pdf. (Last accessed on April 16, 2010).

Kalitsi, E. (2003). Problems and prospects for hydropower development in Africa. Report prepared for the Workshop for African Energy Experts on Operationalizing the NEPAD Energy Initiative, 2 – 4 June 2003, Novotel, Dakar, Senegal. United Nations, Republic of Senegal.

Kauffman, C. (2005). Energy and Poverty in Africa. Policy Insights, No. 8. http://www.oecd.org/dataoecd/39/54/34961237.pdf (Last accessed on September 15, 2010).

Klunne, J. (2007). Small hydropower development in Africa. ESI Africa 2: 2007. http://renewables4africa.net/klunne/publications/ESI2007_2_SMALL_HYDROPWER_PG36-37_Jonker_Klunne.pdf . (Last accessed on April 29, 2010).

Lubini, I., Kitoko, L., Lamfel, F., Muyingi, H. (2006). Southern Africa can contribute to solving the global warming problem with its huge hydropower potential. AC and DC Power Transmission, 2006. ACDC 2006. The 8th IEE International Conference on , vol., no., pp. 210- 214, 28-31 March 2006.

MBendi. (n.d.). "Electrical Power in Africa". MBendi Information Services. http://www.mbendi.com/indy/powr/af/p0005.htm#20 (Last accessed on September 15, 2010).

MDG Africa Steering Group. (2008). Achieving the Millennium Development Goals in Africa. Recommendations of the MDG Africa Steering Group. June 2008. http://www.mdgafrica.org/pdf/MDG%20Africa%20Steering%20Group%20Recommendations%20-%20English%20-%20HighRes.pdf. (Last accessed on May 9, 2010).

Ringler, C., Biswas, A., Cline, S. (Eds.). (2010). Global Change: Impacts on Food Security. Springer-Verlag Berlin Heidelberg.

SAPP. (n.d) "Overview of the Sothern African Power Pool". Southern Africa Power Pool. http://www.sapp.co.zw/docs/SAPP%20Overview%20RT%20Presentation%20July%202009.pdf. (Last accessed on April 29, 2010).

Tshombe, L., Ferreira, I., Uken, E. (2007). Nepad Vision and the Inga hydro-electric scheme. Journal of Energy in Southern Africa. 18(4): 19-25.

The Economist. (2010). Tap that water: Controversy surrounds the argument for dam-building in Africa. The Economist. Saturday, May 8, 2010.

UNEP (2006). Description of Best Practice: Community Micro Hydro Project (Energy) – Kenya. 9th Special Session of the Governing Council / Global Ministerial Environment Forum 7-9 February 2006, Dubai, UAE. http://www.unep.org/GC/GCSS-IX/Documents/Kenya-Theme-1B.pdf (Last accessed on September 10, 2010).

World Bank. (2010). Africa's Infrastructure, A Time for Transformation: Overview. http://siteresources.worldbank.org/INTAFRICA/Resources/aicd_overview_english_no-embargo.pdf. (Last accessed on April 29, 2010).

WCD. (1999). "Dam Statistics: Africa and the Middle East Regions. http://www.dams.org/kbase/consultations/afrme/dam_stats_eng.htm (Last accessed on September 4, 2010).

6. Meet Growing Water Demand

AfDB. (2009). Africa regional paper: Bridging divides in Africa's water security: An agenda to implement existing political commitments. 5th World Water Forum, Turkey, Istanbul. March 2009. African Development Bank (http://portal.worldwaterforum5.org/wwf5/en-us/worldregions/Africa/Consultation%20Library/Regional%20Position%20Paper%20-%20Final%20V6%2016%20Feb%2009.pdf (Last accessed on March 10, 2010).

AICD (2009). Africa's Infrastructure: A Time for Transformation - Water resources are underutilized in Africa across the board, yet conflicts between water uses are common. Africa Infrastructure Country Diagnostic. http://www.infrastructureafrica.org/aicd/key-msg/sector/water-resources-are-underutilized-africa-across-board-yet-conflicts-between-water-use (Last accessed on March 10, 2010).

Bates, B., Kundzewicz, Z., Wu, S., Palutikof, J. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Bergkamp, G. (2009). A table for 9 billion please: Building global water, food and energy resilience. In. Briscoe, J. et al. 2009. (Eds.). Water and Agriculture: Implications for Development and Growth. Essays from the CSIS and SAIS Year of Water Conference. Washington, D.C.: Center for Strategic and International Studies.

de Rouw, A. (2004). Improving yields and reducing risks in pearl millet farming in the African Sahel. Agricultural Systems 81: 73–93.

FAO. (2005). Special Event on Green Revolution in Africa. Background document. Committee on World Food Security 31st Session – 23-26 May 2005. http://www.fao.org/unfao/bodies/cfs/cfs31/cfs2005_events_en.htm. (Last accessed on April 25, 2010).

FAO. (2009). AQUASTAT database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/aquastat. (Last accessed on January 13, 2010).

Frenken, K. (2005). Irrigation in Africa in figures - AQUASTAT Survey – 2005. FAO Water Reports no.29. FAO, Rome. ftp://ftp.fao.org/agl/aglw/docs/wr29_eng.pdf. (Last accessed on February 2, 2010).

Funk C, Dettinger M., Michaelsen, J., Verdin, J., Brown, M., Barlow, M., Hoell A. (2008). Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development Proc. Natl Acad. Sci. USA 105 11081–6.

Gleick, P. (2003). Global freshwater resources: Soft-path solutions for the 21st century. Science 302: 1524-1528.

Couet, T. and Maurer, T. (2009). Surface Freshwater Fluxes into the World Oceans / Thomas de Couet; Thomas Maurer. Global Runoff Data Centre. Koblenz: Federal Institute of Hydrology (BfG), 2009.

Grey, D. (2000). The Challenge of Water in Africa - A Perspective, 23 February 2000 – Overseas Development Institute (ODI) Public event, London. http://www.odi.org.uk/events/details.asp?id=2354&title=challenge-water-africa-perspective (Last accessed on September 13, 2010).

Gumbo, B. (2004). The status of water demand management in selected cities of southern Africa. Physics and Chemistry of the Earth 29(15-18): 1225-1231.

Hansen, K. (2008). NASA Data Show African Droughts Linked To Warmer Indian Ocean. Terra Daily: News About Planet Earth. http://www.terradaily.com/reports/NASA_Data_Show_African_Droughts_Linked_To_Warmer_Indian_Ocean_999.html. (Last accessed on March 10, 2010).

IWMI, (2006). Recycling Realities: Managing health risks to make wastewater an asset. IWMI Policy Briefing Issue 17. International Water Management Institute. Http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/wpb17.pdf. (Last accessed onApril 29, 2010).

IWMI (2008). Research Theme 4 : Water and Society. International Water Management Institute, Sri Lanka. http://www.iwmi.cgiar.org/Research_Impacts/Research_Themes/ (Last accessed on April 29, 2010).

le Blanc, D. and Perez. R. (2008). The relationship between rainfall and human density and its implications for future water stress in Sub-Saharan Africa. Ecological Economics 66(2-3): 319-336.

NASA Earth Observatory. (2010). "NASA Data Show Some African Drought Linked to Warmer Indian Ocean". http://www.nasa.gov/topics/earth/features/indian_ocean_warm.html (Last accessed on September 15, 2010).

Sultan B., Baron, C., Dingkuhn, M., Sarr B., Janicot, S. (2005). Agricultural impacts of large-scale variability of the West African monsoon. Agricultural and Forest Meteorology 128: 93–110, 2005.

UNECA (n.d.). The Africa Water Vision for 2025: Equitable and Sustainable Use of Water for Socioeconomic Development. United Nations Economic Commission for Africa., Addis Ababa, Ethiopia http://www.uneca.org/awich/African%20Water%20Vision%202025.pdf (Last accessed on September 15, 2010).

UNECA. (2006). African Water Development Report. United Nations Economic Commission for Africa. http://www.uneca.org/awich/AWDR_2006.htm (Last accessed on September 15, 2010).

UNEP.(2002). Africa Environment Outlook: Past, present and future perspectives. United Nations Environment Programme. Earthprint: UK.

UNFPA. (2009). State of world population 2009: Facing a changing world: women, population and climate. New York: UNFPA. United Nations Population Fund.

World Bank. (2010). World development report: Development and climate change. Washington, DC.

7. Prevent Land Degradation and Water Pollution

Barr, J. and Mafuta, C. (2007). Chapter 6: Regional Perspectives. In Global Environment Outlook 4. United Nations Environment Programme, Nairobi.

Biasutti, M., and Sobel, A. (2009). Delayed Seasonal Cycle and African Monsoon in a Warmer Climate. Submitted arXiv:0907.2735v1 [physics.ao-ph] 16 Jul 2009. http://www.citebase.org/abstract?id=oai:arXiv.org:0907.2735. (Last accessed on March 25, 2010).

Digby P. Cyrus, D., MacKay, C. (2007). The Environmental Reserve and its role in retaining the diversity of birds at the Thukela Estuary. Ostrich: The Journal of African Ornithology. 78(3): 621–631.

Giannini, M, Biasutti, M., Verstraete, M. (2008). A climate model-based review of drought in the Sahel: Desertification, the re-greening and climate change. Global and Planetary Change 64(3-4): 119-128. DOI: 10.1016/j.gloplacha.2008.05.004.

Frappart, F., P. Hiernaux, Guichard, F., Mougin, E., Kergoat, L., Arjounin, M., Lavenu, F., Koite, M., Paturel, J., Lebel, T. (2009). Rainfall Regime across the Sahel Band in the Gourma Region, Mali. Journal of Hydrology. 375(1-2): 128-42.

Hebden, S. (2006). "Africa's land degradation can be reversed". http://www.scidev.net/en/news/africas-land-degradation-can-be-reversed.html (Last accessed on September 16, 2010).

Held, I., Delworth, T., Lu, J., Findell, K., Knutson, T. (2005). Simulation of Sahel drought in the 20th and 21st centuries. Proc. Natl. Acad. Sci. USA 102(17891–17896).

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

Hickler, T., Eklundh, L., Seaquist, J., Smith, B., Ardö, J., Olsson, L., Sykes, M., Sjöström, M. (2005). "Precipitation controls Sahel greening trend." Geophysical Research Letters 32(21): 214-215.

Hiernaux, P., and Le Houérou, H. (2006). Les parcours du Sahel. Sècheresse 17 (1–2): 51–71.

ICRSE. (2003). UNEP/FAO/UNCCD Workshop on changes in the Sahel, International Center for Remote Sensing of Environment, Nairobi 14-16 October. http://www.icrse.org/sahel_report.html (Last accessed on September 15, 2010).

MA. (2005). Ecosystems and Human Well-being: Synthesis. Island Press: Washington, DC. Millenium Ecosystem Assessment.

Mahé, G., and Paturel, J. (2009). 1896-2006 Sahelian Annual Rainfall Variability and Runoff Increase of Sahelian Rivers. Comptes Rendus Geosciences 341(7): 538-546.

NASA Earth Observatory (n.d.) online. Temporary Drought or Permanent Desert? http://earthobservatory.nasa.gov/Features/Desertification/desertification2.php. (Last accessed on April 10, 2010).

Nicholson, S. (2003). Long-term precipitation variability in the Sahel. UNEP/FAO/UNCCD Workshop on changes in the Sahel, International Center for Remote Sensing of Environment, Nairobi 14-16 October. http://www.icrse.org/sahel_report.html (Last accessed on September 15, 2010).

Olsson, L., and Hall-Beyer, M. (2008). Greening of the Sahel. In: Encyclopedia of Earth. Eds. C. J. Cleveland. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment. [First published in the Encyclopedia of Earth January 30, 2008. http://www.eoearth.org/article/Greening_of_the_Sahel. (Last Accessed on February 17, 2010).

Olsson, L., Eklundh, L., Ardö, J. (2005). A Recent Greening of the Sahel – trends, patterns and potential causes. Journal of Arid Environment 63(3): 556–566.

PACN. (2010). Africa's Water Quality: A Chemical Science Perspective, A report by the Pan Africa Chemistry Network, March 2010. http://www.rsc.org/images/RSC_PACN_Water_Report_tcm18-176914.pdf (Last accessed on September 15, 2010).

Pedersen, J., and Benjaminsen, T. (2008). One leg or two? Food security and pastoralism in the Northern Sahel. Human Ecology. 36(1): 43–57.

Republic of South Africa. (1998). National Water Act. Act No. 36 of 1998. Pretoria, South Africa.

Sadio, S. (2003). Environmental and land cover changes in the Sahel region: lessons learned, challenges and priority actions. UNEP/FAO/UNCCD Workshop on changes in the Sahel, International Center for Remote Sensing of Environment, Nairobi 14-16 October. http://www.icrse.org/sahel_report.html (Last accessed on April 25, 2010).

UNECA. (2009). Economic Report on Africa 2009: Developing African Agriculture Through Regional Value Chains. United Nations Economic Commission for Africa, Addis Ababa, Ethiopia. http://www.uneca.org/era2009/ERA2009_ENG_Full.pdf. (Last accessed on May 25, 2010).

UNEP (2006). Africa Environment Outlook 2. United Nations Environment Programme, Nairobi.

UNEP. (2007). Chapter 3: Land. In Global Environment Outlook GEO4 Environment for development. . United Nations Environment Programme, Nairobi.

University of Washington. (2009). Joint Institute for the Study of the Atmosphere and Ocean (2009) Sahel rainfall index (20-10N, 20W-10E), 1900 - August 2009. http://jisao.washington.edu/data/sahel/ (Last Accessed on February 9, 2010).

Van Wyk, E. Breen, C., Roux, D., Rogers, K., Sherwill, T., van Wilgen, B. (2006). The Ecological Reserve: Towards a common understanding for river management in South Africa. Water SA 32(3): 403-409.

8. Manage Water Under Global Climate Change

APF. (2007). Climate Change and Africa. 8th Meeting of the African Partnership Forum. (AFP), Berlin. Germany. http://www.oecd.org/dataoecd/57/7/38897900.pdf (Last accessed on May 14, 2010).

Bates, B., Kundzewicz, Z., Wu, S., Palutikof, J. (2008) Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Behera S., Luo J., Masson S., Delecluse P., Gualdi S., Navarra A., Yamagata T. (2005). Paramount Impact of the Indian Ocean Dipole on East African Short Rains: A CGCM Study. Journal of Climate 18: 4514-4530.

Brown C. and Lall U. (2006) Water and economic development: The role of variability and a framework for resilience. Natural Resources Forum 30: 306-317.

Calow, R., MacDonald, A., Nicol, A., Robins, N. (2010). Ground Water Security and Drought in Africa: Linking Availability, Access, and Demand. Ground Water. 48: 2, 246–256. http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2009.00558.x/pdf (Last accessed on August 17, 2010).

EM-DAT. (2010). The International Disaster Database. Centre for Research on the Epidemiology of Disasters-CRED. http://www.emdat.be/disaster-list (Last accessed on March 22, 2010).

GAR. (2009). Chapter 3: Deconstructing Disaster: Risk Patterns and Poverty Trends at the Local Level. Global Assessment Report (GAR) on Disaster Risk Reduction. http://www.preventionweb.net/english/hyogo/gar/report/documents/GAR_Chapter_3_2009_eng.pdf (Last accessed on March 30, 2010).

Hulme M., Doherty R., Ngara T.,New M., Lister D. (2000). African Climate Change: 1900-2100. Climate Research 17:145-168.

IPCC. (2007a). Summary for Policymakers: Contribution of Working Group II to the Fourth Assessment. Intergovernmental Panel on Climate Change.

IPCC. (2007b). Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

Mahe G. and Paturel J. (2009). 1896-2006 Sahelian annual rainfall variability and runoff increase of Sahelian rivers. Geoscience 341: 538-546.

Shanahan T., Overpeck J., Anchukaitis K., Beck J., Cole J., Dettman D., Peck J., Scholz C., King J. (2009). Atlantic forcing of persistent drought in West Africa. Science 324: 377-380.

Tierney, J., Mayes, M., Meyer, N., Johnson, C., Swarzenski, P., Cohen, A. , Russell, J. (2010). Late-twentieth-century warming in Lake Tanganyika unprecedented since AD 500. Nature Geoscience. doi: 10.1038/ngeo865.

Trenberth K. (2005). The impact of climate change and variability on heavy precipitation, flood, and droughts. Encyclopedia of Hydrological Sciences. http://www.cgd.ucar.edu/cas/Trenberth/EHShsa211.pdf (Last accessed on March 29, 2010).

UNEP. (2008). Africa: Atlas of our changing environment. United Nations Environment Programme. Division of Early Warning, Nairobi.

UNFCCC. (2006). Background paper on Impacts, vulnerability and adaptation to climate change in Africa for the African Workshop on Adaptation Implementation of Decision 1/CP.10 of the UNFCCC Convention, Accra, Ghana, 21 - 23 September. United Nations Framework Convention on Climate Change.

Verdin J., Funk C., Senay G., Choularton R. (2005). Climate science and famine early warning. Philosophical Transactions of the Royal Society 360: 2155-2168.

Warren, R., Arnell, N., Nicholls, R., Levy P., and Price, J. (2006). Understanding the Regional Impacts of Climate Change. Research report prepared for the Stern Review on the Economics of Climate Change. Tyndall Centre.

WMO. (2009). Statement on the Status of the Global Climate in 2009. World Meteorological Organization. Geneva. Switzerland. http://www.wmo.ch/pages//publications/showcase/documents/1055_en.pdf (Last accessed on April 2, 2010).

9. Enhance Capacity to Address its Water Challenges

Bekunda, M. (2010). Climate Change, Food and Nitrogen in Smallholder Farming. Presentation at the second annual Brown International Advanced Research Institutes (BIARI) on Climate Change and Its Impacts. Providence, RI, United States. June 24, 2010.

Carles, A. (2009). Water Resources in Subsaharan Africa. Peace with Water, Bruxelles, 12-13 February 2009. European Parliament.

Farlam, P. (2005) Working Together: Assessing Public–Private Partnerships in Africa. NEPAD Policy Focus Series, South African Institute of International Affairs (SAIIA). http://www.oecd.org/dataoecd/44/4/34867724.pdf (Last accessed on September 16, 2010).

G8 Gleneagles. (2005). "The Gleneagles Communique". http://www.unglobalcompact.org/docs/about_the_gc/government_support/PostG8_Gleneagles_Communique.pdf. (Last accessed on June 19, 2010).

INPIM (1992). The Dublin Statement on Water and Sustainable Development. Dublin, Ireland, January 31, 1992. International Network on Participatory Irrigation Management. http://www.inpim.org/files/Documents/DublinStatmt.pdf (Last accessed on September 16, 2010).

OECD. (2010). Innovative mechanisms for the water sector. Organization for Economic Co-operation and Development. OECD: Paris.

CAADP. (2003). "The new partnership for Africa's Development". The Comprehensive Africa Agriculture Development Programme. http://www.nepad-caadp.net/ (Last accessed on June 24, 2010).

UNECA. (2006). "African Water Development Report". UN Economic Commission for Africa. http://www.uneca.org/awich/AWDR_2006.htm (Last accessed on September 15, 2010).

4

WATER PROFILE OF COUNTRIES

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Tracking Progress Towards Environmental Sustainability

In September 2000, building upon a decade of major United Nations conferences and summits, world leaders came together at the United Nations Headquarters in New York to adopt the United Nations Millennium Declaration, committing their nations to a new global partnership to reduce extreme poverty and setting out a series of time-bound targets—with a deadline of 2015—that have become known as the Millennium Development Goals (MDGs).

The eight MDGs, which range from halving extreme poverty to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015, form a blueprint agreed to by all the countries and all the world's leading development institutions. They have galvanized unprecedented efforts to meet the needs of the world's poorest. In September 2010, with only five years left until the 2015 deadline, world leaders met at a summit in New York to accelerate progress towards the MDGs.

Note: Material for this section has been drawn directly from WHO/UNICEF 2008 and WHO/UNICEF 2010 and may differ from country profiles drawn from UN Statistical Division data.

Apparent discontinuities between these two datasets may result from differences in date of collection, differences in data made available to WHO/UNICEF and UNSD as well as differences in metrics used to derive these two data sets.

Goal 7 relates to environmental sustainability and includes targets to address the issue of water. The targets are to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation.

Globally, some 1.7 billion people have gained access to safe drinking water since 1990. At this rate, the world is expected to meet the MDG target on drinking water. But about 884 million people still do not have access to safe drinking water, and 2.6 billion lack access to basic sanitation services. In Africa, most countries are still struggling to get on track to meet the water and sanitation targets.

Water-related diseases are a growing human tragedy, killing more than five million people each year—ten times the number of people killed in wars. About 2.3 billion people suffer from diseases linked to dirty water. Some 60 per cent of all infant mortality worldwide is linked to infectious and parasitic diseases, most of them water-related.

An improved drinking water source: *is protected from outside contamination, in particular from contamination with faecal matter. For monitoring purposes, the use of improved drinking water sources has been equated to access to safe drinking water, but not all improved sources in actual fact provide drinking water that is safe.*

An improved sanitation facility: *hygienically separates human excreta from human contact.*

Source: WHO/UNICEF 2010

Access to Improved Drinking Water

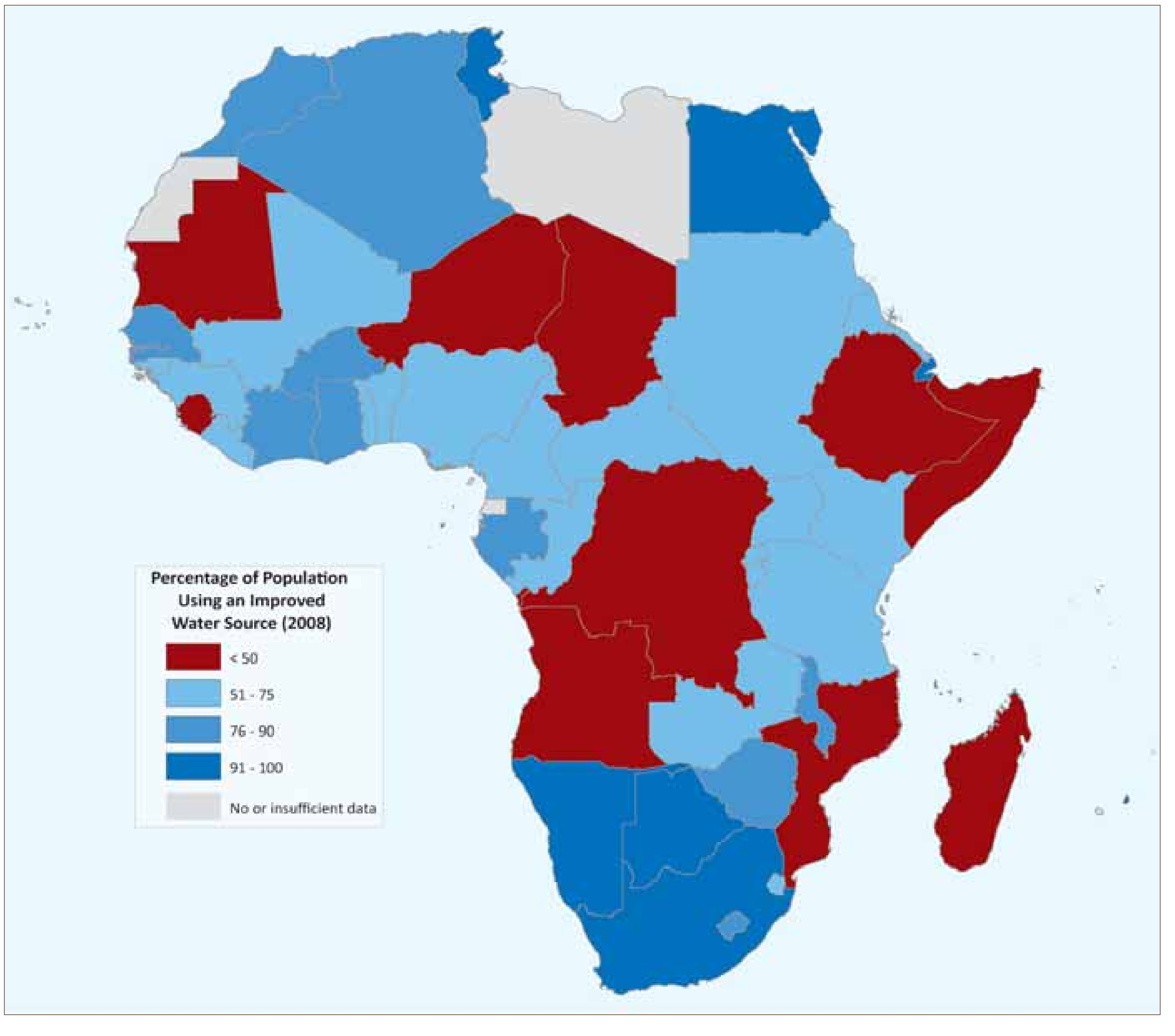
Globally, 884 million people still don't have access to an improved source of drinking water

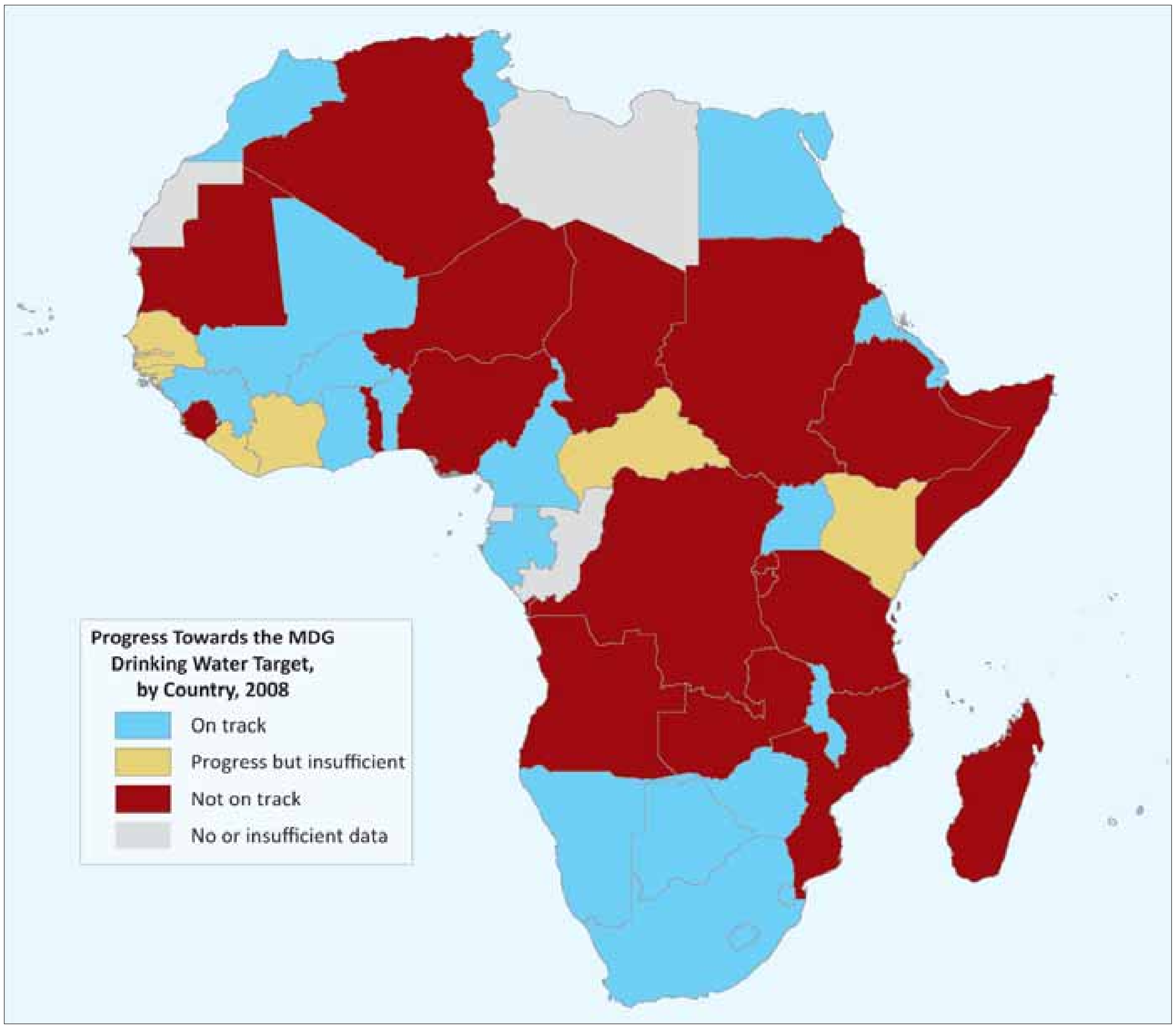
- In developing regions, 84 per cent of the population uses an improved source of drinking water.
- In urban areas the use of improved sources of drinking water has been maintained at 96 per cent since 2000, with over one billion more people now using such a source than in 1990. However, this increase is barely keeping up with urban population growth.
- The number of people living in rural areas who do not use an improved source of drinking water is over five times the number living in urban areas.

In Africa, increases in the use of improved drinking water sources are not keeping up with population growth

- Six hundred and two million people in Africa had access to improved drinking water sources in 2006. Coverage increased from 56 per cent in 1990 to 64 per cent in 2006. Thus, by 2006, nearly two in three people in Africa used an improved source as their main source of drinking water.
- The proportion of the population without access to an improved drinking water source has decreased across all regions in Africa from 44 per cent in 1990 to 36 per cent in 2006.
- In nine African countries, less than half the population has access to improved drinking water.
- The African population without access to improved drinking water sources increased by 61 million, from 280 million in 1990 to 341 million in 2006.
- Sub-Saharan Africa accounts for over a third of the 884 million people worldwide who still do not get their drinking water from improved sources.
- The number of people in sub-Saharan Africa using improved drinking water increased by 11 per cent since 1990.
- However, only 60 per cent of the population in sub-Saharan Africa, uses improved sources of drinking water.
- Coverage of improved drinking water sources is highest in Southern Africa (92 per cent) and Northern Africa (88 per cent).
- The number of people with a piped connection on their premises has increased by 60 per cent in urban areas and doubled in rural areas.
- Twenty-six per cent of the African population (244 million) has a piped connection on premises, while in northern and southern Africa almost two-thirds (166 million) enjoy piped connections.

Percentage of the population using an improved drinking water source, 2008 (Source: WHO/UNICEF 2010)





Progress Towards the MDG Improved Drinking Water Target by Country, 2008 (Source: WHO/UNICEF 2010)

Globally, the world is expected to reach the drinking water target

- At the current rate of progress, the world is expected to exceed the MDG target of halving the proportion of the population without sustainable access to safe drinking water.
- Even so, 672 million people will still lack access to improved drinking water sources in 2015.

Africa, however, is not expected to meet the drinking water target

- The rate at which people of Africa have gained access to improved drinking water sources—245 million people since 1990—falls short of that required to meet the 2015 MDG drinking water target.
- To meet the MDG drinking water target, coverage needs to increase from 64 per cent in 2006 to 78 per cent in 2015.
- Only 26 countries in Africa are on track to meet the MDG water target.
- To meet the target almost 300 million people need to gain access to an improved drinking water source. That is half as many as the current population with access in Africa.
- On average 33 million people of Africa need to gain access to an improved drinking water source every year until 2015.
- Even when the MDG drinking water target is met, 253 million people in Africa will still be without access to an improved drinking water source.

Access to Improved Sanitation

Globally, 2.6 billion people still do not use improved sanitation

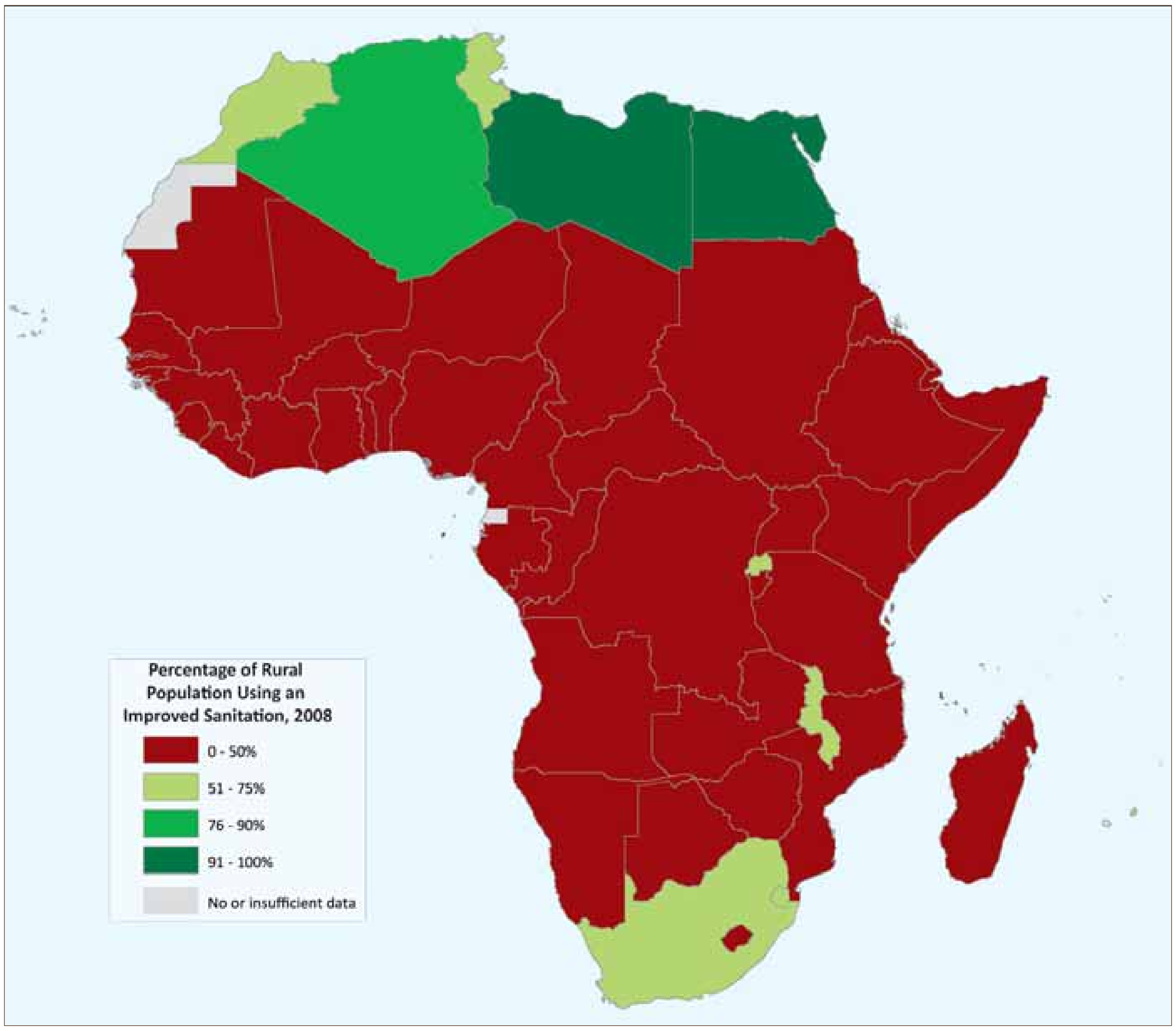
- Less than two thirds of the world's population uses improved sanitation facilities.
- In developing regions only around half the population uses improved sanitation.

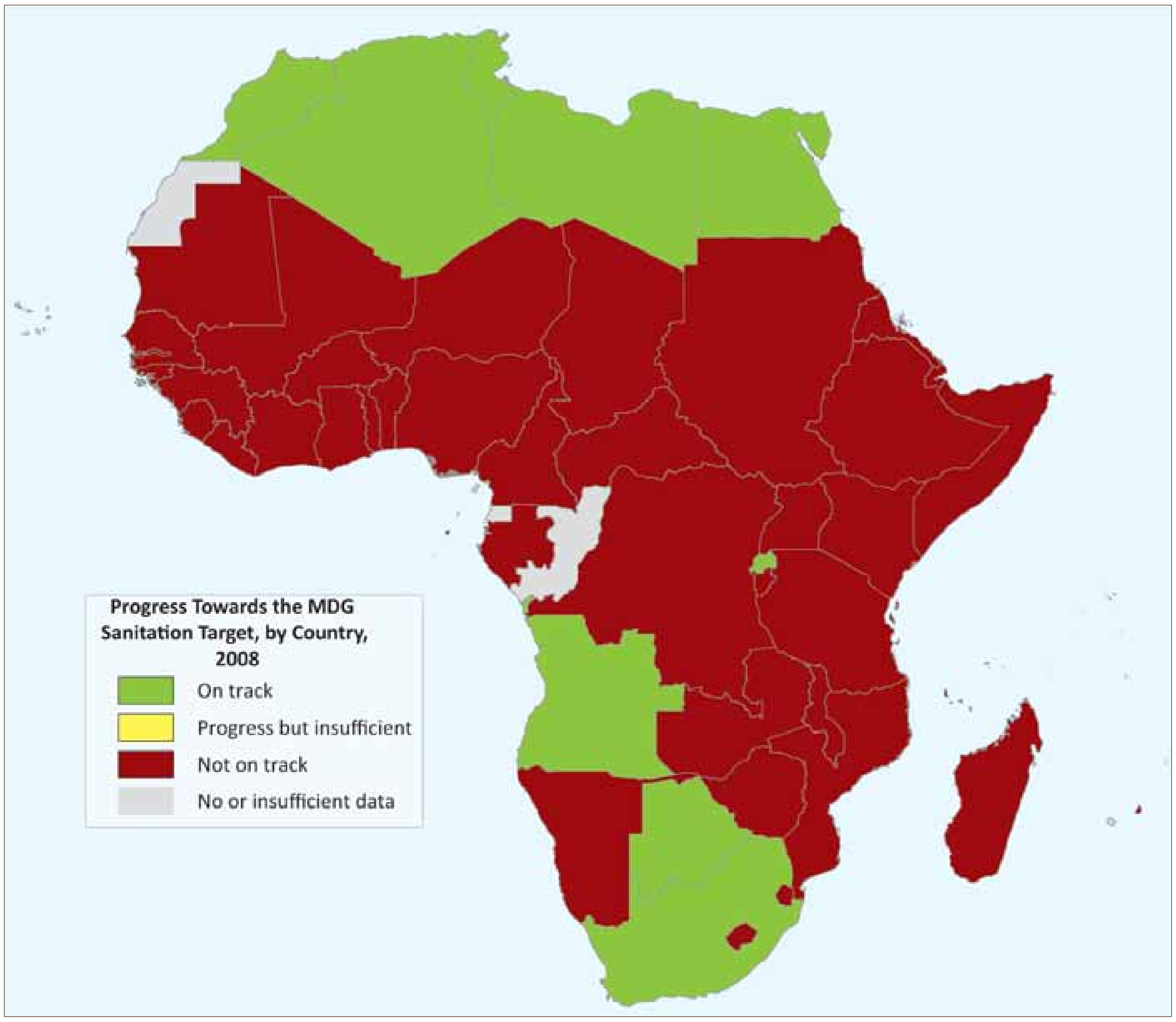
Tim Brauhn/Flickr.com

In Africa, half the population uses an improved or shared sanitation facility; but one in four practices open defecation

- Three hundred and fifty four million people of Africa had access to improved sanitation facilities in 2006. Coverage increased from 33 per cent in 1990 to 38 per cent in 2006.
- The African population without access to sanitation increased by 153 million—from 430 million in 1990 to 583 million in 2006. Increases in coverage are not keeping pace with population growth.
- In 38 countries in Africa sanitation coverage is less than 50 per cent.
- Open defecation in Africa has dropped from 33 per cent in 1990 to 24 per cent in 2006, although the absolute number of people practicing open defecation has increased by 20 million.
- Fifteen per cent of the African population (143 million) shares an otherwise adequate type of sanitation facility, while 23 per cent (212 million) uses an unimproved facility that does not meet minimal hygiene standards.
- Use of shared sanitation facilities is most common in Southern Africa.
- Sanitation coverage is highest in Northern Africa and lowest in Western Africa.

Proportion of rural population using improved sanitation facilities, 2008 (Source: WHO/UNICEF 2010)





Progress towards the MDG sanitation target by country, 2008 (Source: WHO/UNICEF 2010)

Globally, the world is off track for attaining the sanitation target

- Although 1.3 billion people have gained access to improved sanitation since 1990, the world is likely to miss the MDG sanitation target by a billion people at the current rate of progress.
- By 2015, there will still be 2.7 billion people without access to basic sanitation.

In Africa, most countries will not meet the MDG target for sanitation

- The rate at which people of Africa gained access to sanitation—153 million people since 1990—is insufficient to meet the MDG sanitation target.
- To meet the MDG sanitation target, coverage needs to increase from 38 per cent in 2006 to 67 per cent in 2015.
- Only nine countries in Africa are on track to meet the MDG sanitation target.
- To meet the MDG sanitation target, over 400 million people need to gain access to an improved sanitation facility. That is more than the current total population with access in Africa.
- On average 45 million people in Africa need to gain access to sanitation every year until 2015.
- Even when the MDG sanitation target will be met, 385 million people in Africa will still be without sanitation.

Rural-Urban Disparities

Access to Improved Drinking Water

Globally, the rural population without access to an improved drinking water source is over five times greater than that of urban areas

- Of almost 1.8 billion people who gained access to improved drinking water in the period 1990-2008, 59 per cent lived in urban areas.

In Africa, more than eight out of ten people without access to improved drinking water sources live in rural areas.

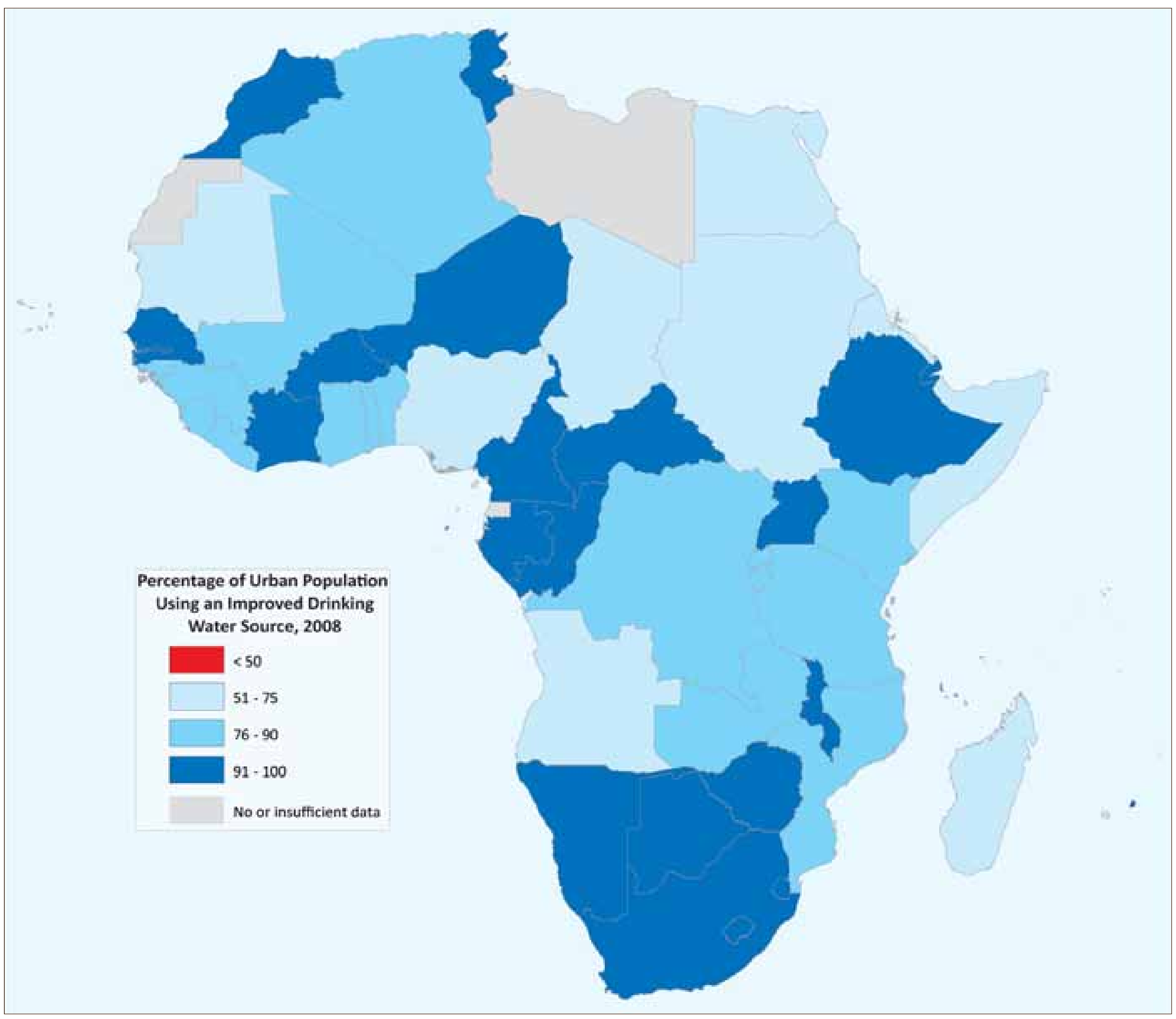
Urban

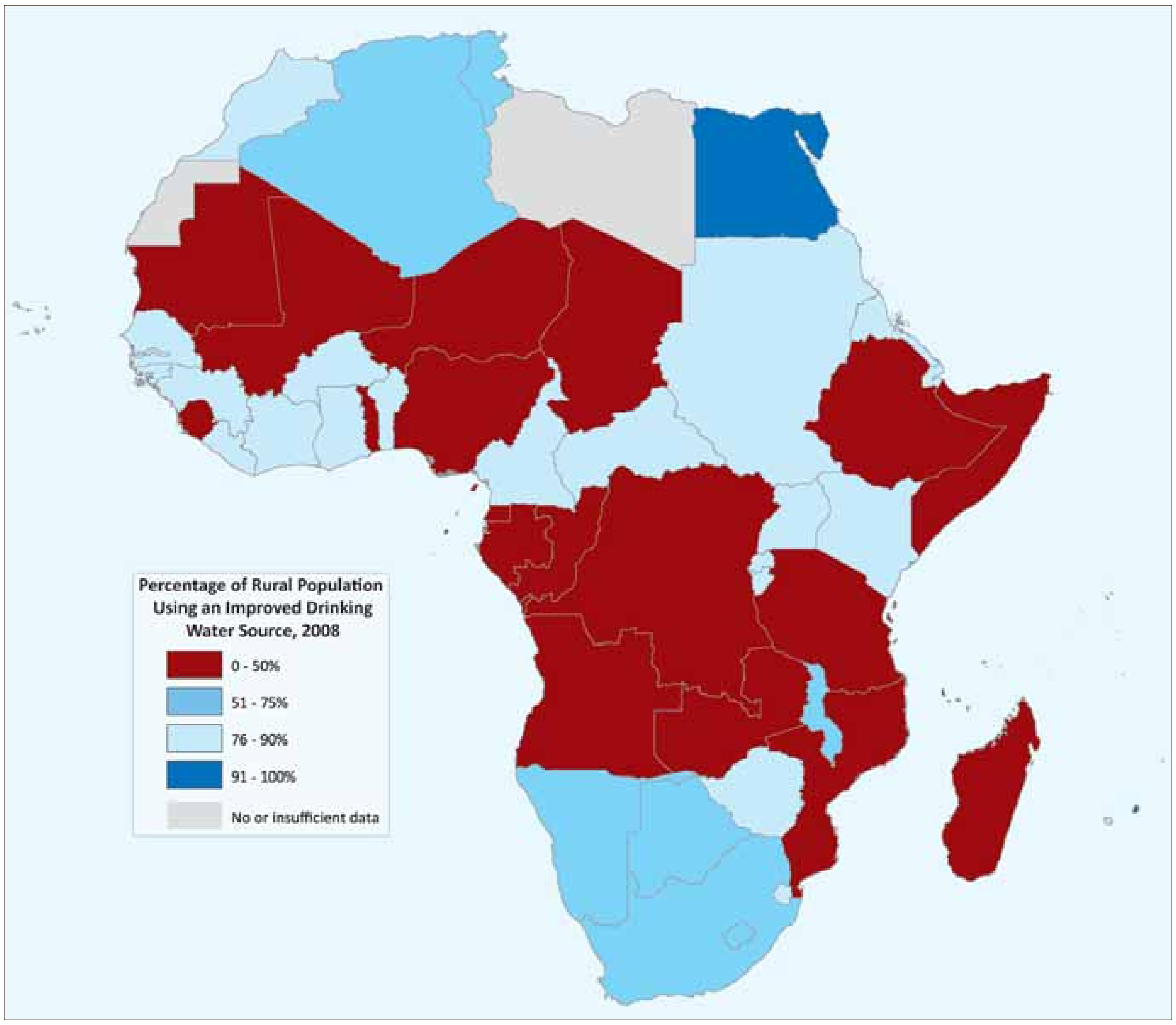
- Urban drinking water coverage in Africa is 85 per cent.
- Since 1990, 134 million people in urban areas have gained access to an improved drinking water source, but the increase in coverage is barely keeping pace with population growth.
- Between 1990 and 2006, the urban population without access to an improved drinking water source increased by 28 million people (to 57 million).
- Of the 366 million people in urban areas in 2006, 47 per cent have a piped connection on premises, down from 56 per cent in 1990.

Rural

- Rural improved drinking water coverage is 51 per cent.
- Since 1990, 112 million people in rural areas gained access to an improved drinking water source.
- Of the 577 million people in rural areas, about 70 million have a piped connection on premises while 225 million use other improved drinking water sources.
- Since 1990, the rural population without access to improved drinking water sources increased by 32 million people, to 284 million people in 2006.
- The urban-rural disparities are particularly striking in the sub-Saharan region.

Percentage of urban population using an improved drinking water source, 2008 (Source: WHO/UNICEF 2010)





Percentage of rural population using an improved drinking water source, 2008 (Source: WHO/UNICEF 2010)

Access to Improved Sanitation

Globally, more people use improved sanitation in urban areas than in rural ones

- With only 45 per cent of the rural population using improved sanitation, rural areas lag far behind urban areas, where the rate is 76 per cent.
- Of the approximately 1.3 billion people who gained access to improved sanitation during the period 1990-2008, 59 per cent live in urban areas.
- The number of people in urban areas without improved sanitation is increasing because of rapid growth in urban populations.

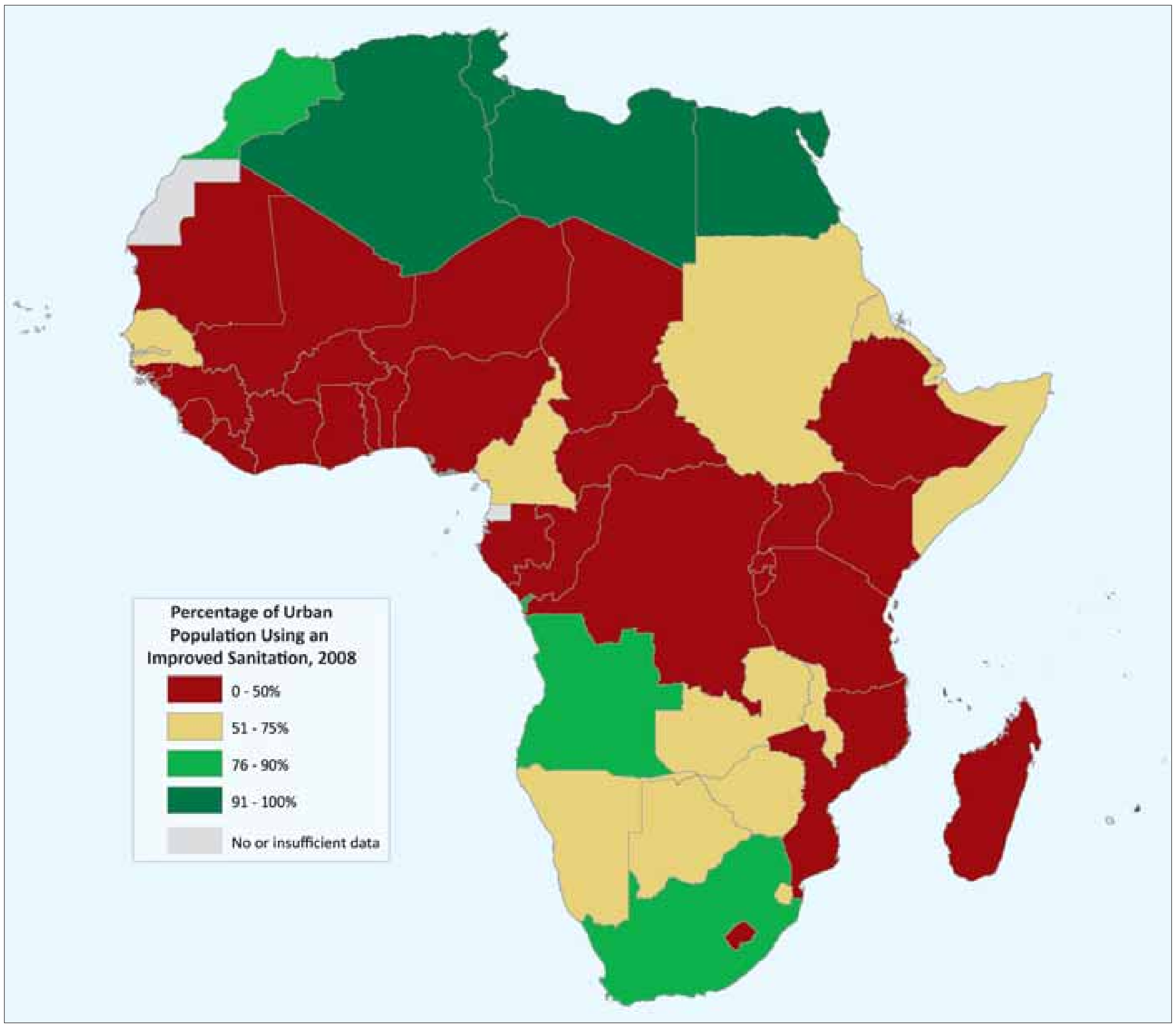
In Africa, seven out of ten people without sanitation facilities live in rural areas

Urban

- Urban sanitation coverage in Africa is 53 per cent.
- Since 1990, the urban population without improved sanitation increased by 73 million people.
- Eighty-five million people in urban areas share a sanitation facility of an otherwise acceptable type.
- Twenty-three million people in urban areas practice open defecation.

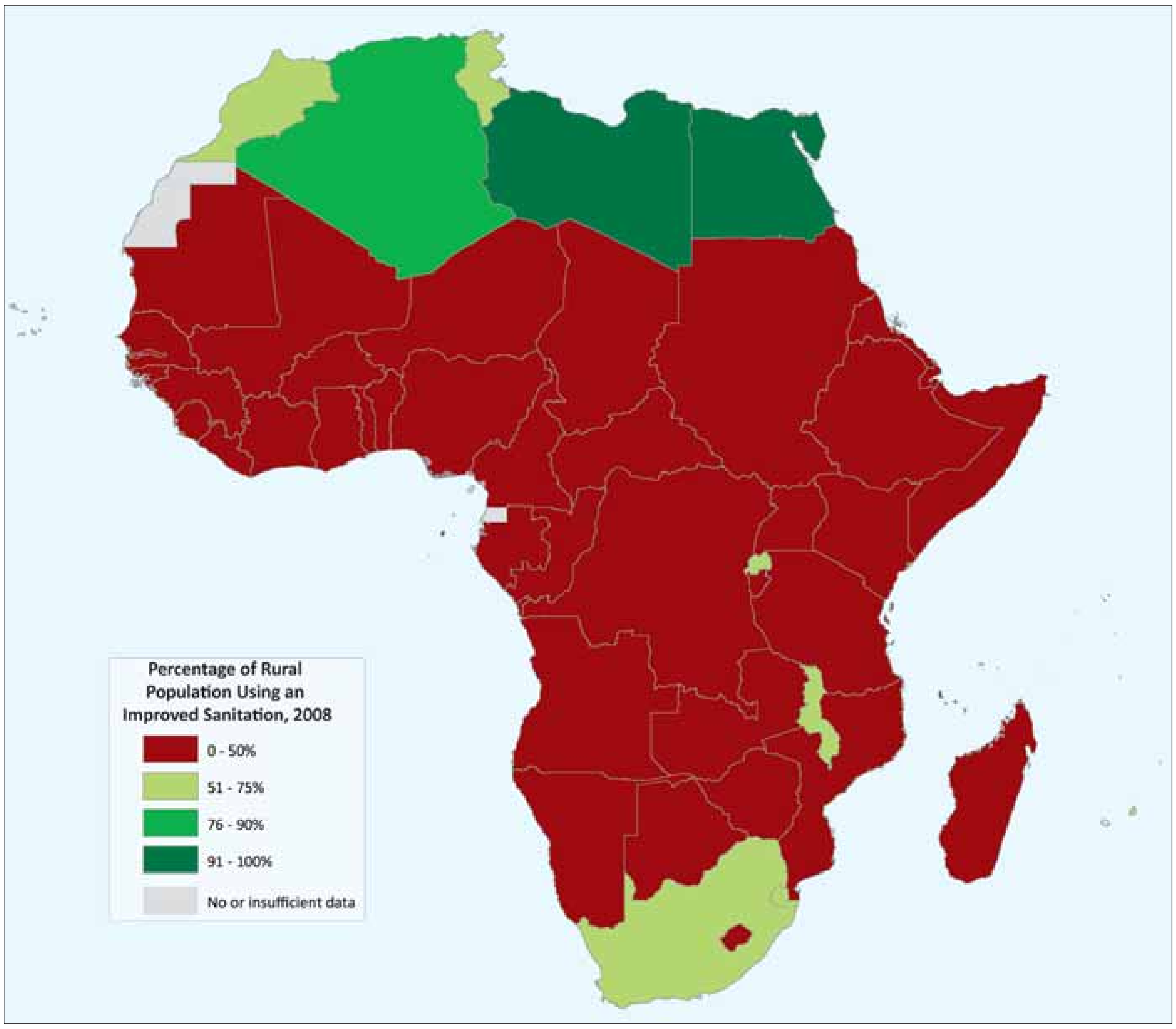
Rural

- Rural sanitation coverage in Africa is 29 per cent.
- Since 1990, the rural population without improved sanitation increased by 81 million people.
- 149 million people in rural areas use sanitation facilities that do not meet minimum hygiene standards.
- 228 million people in rural areas do not use any sanitation facility and practice open defecation.



Percentage of urban population using an improved sanitation facility, 2008 (Source: WHO/UNICEF 2010)

Percentage of rural population using an improved sanitation facility, 2008 (Source: WHO/UNICEF 2010)



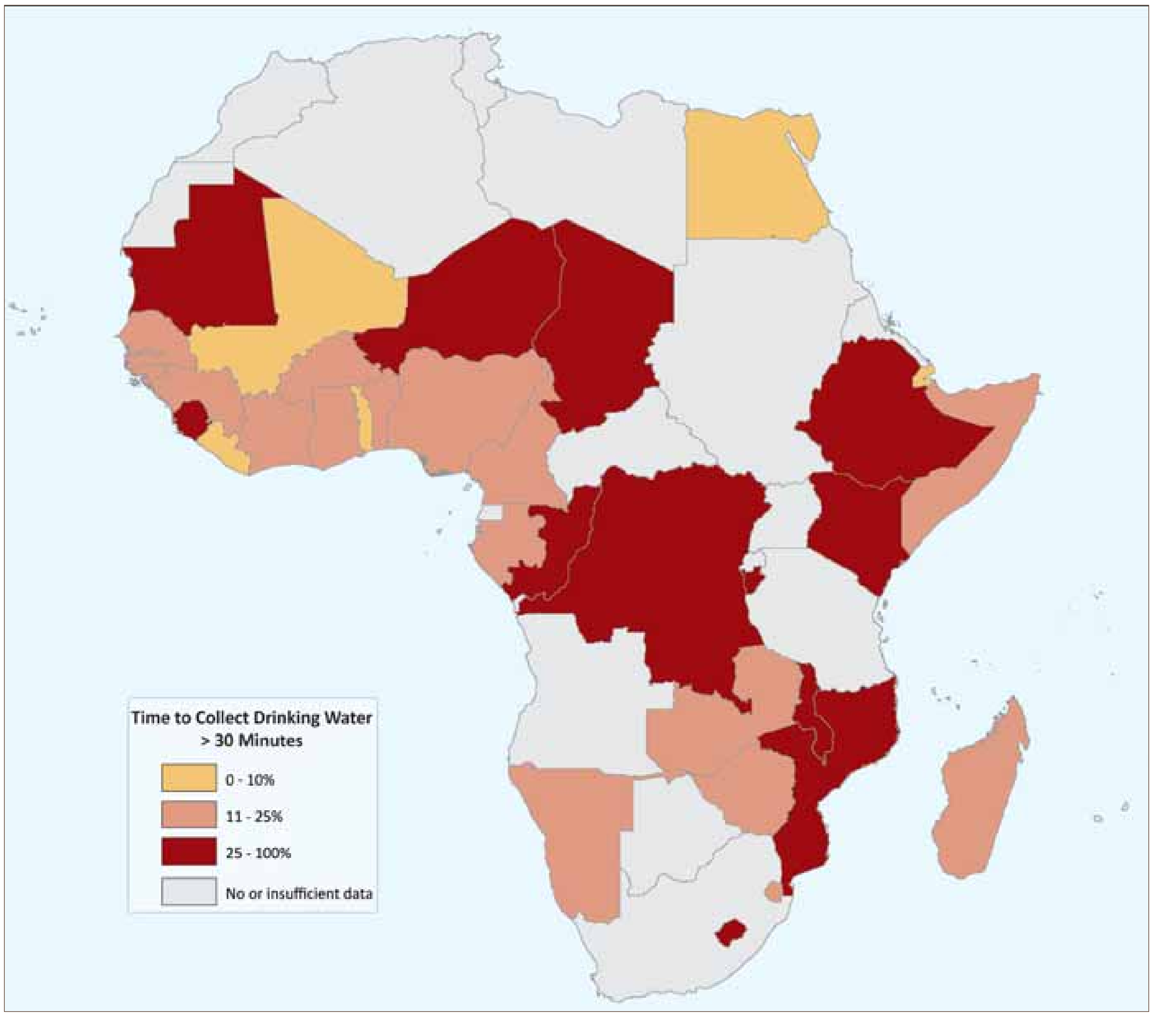
Time Collecting Drinking Water

Research has shown that those spending more than half an hour per round trip to fetch water progressively collect less water, and eventually fail to meet their families' minimum daily drinking water needs. Additionally, the economic costs of having to make multiple trips per day to collect drinking water are enormous.

Women shoulder the largest burden in fetching water, particularly in rural areas

For families without a drinking water source on the premises, it is usually women who go to the source to collect drinking water. Globally, this is the case in almost two-thirds of households, while in almost a quarter of households men usually collect the water. In 12 per cent of households, however, children carry

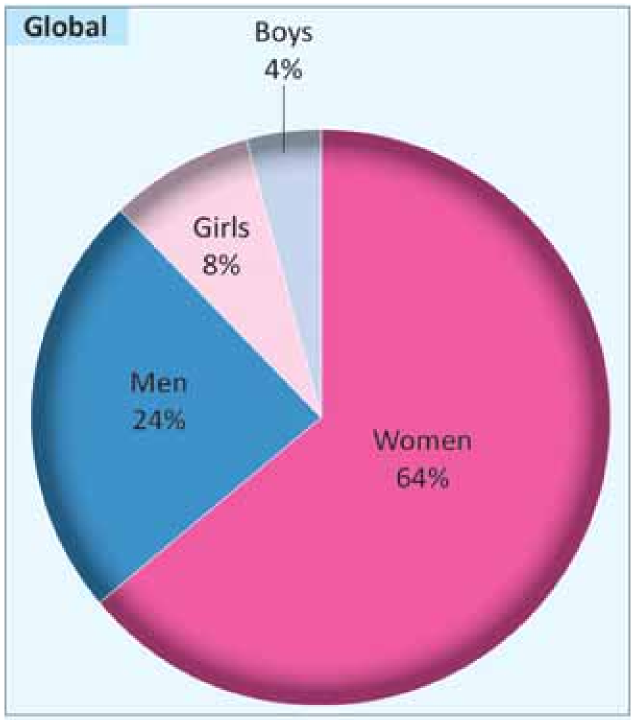
Time to collect drinking water, 2008 (Source: WHO/UNICEF 2010)



In Africa, water collection trips of over 30 minutes are common

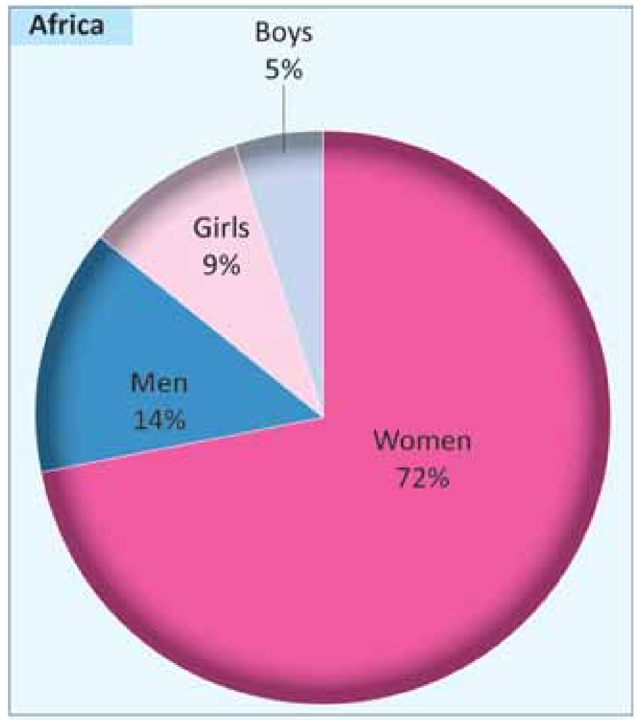
Water collection trips of over 30 minutes are most prevalent in Africa as well as in arid countries outside of Africa, such as Mongolia and Yemen. In various countries, most notably in sub-Saharan Africa, more than a quarter of the population spends more than half an hour per round trip to collect water.

Source: WHO/UNICEF 2010



Worldwide, women shoulder the largest burden in collecting drinking water

Source: WHO/UNICEF 2010



Women in Africa shoulder the largest burden in collecting water

Source: WHO/UNICEF 2010

the main responsibility for collecting water, with girls under 15 years of age being twice as likely to carry this responsibility as boys under the age of 15 years. The real burden on children is likely to be higher because in many households the water collection burden is shared, and children—though not the main person responsible—often make several round trips carrying water.

In Africa, women are more than five times as likely as men to usually collect drinking water for the household

In one out of seven households children (boys and girls) have the main responsibility for collecting drinking water, with girls almost twice as likely to be responsible than boys. On average, less than a fifth of households report that men and boys usually go to the source to collect water.

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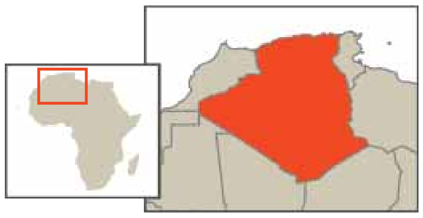
Northern Africa

Algeria
Egypt
Libyan Arab Jamahiriya
Morocco
Sudan
Tunisia



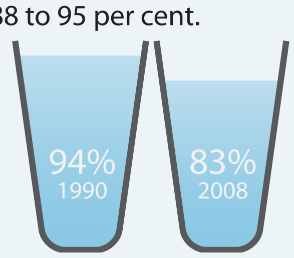
People's Democratic Republic of

Algeria

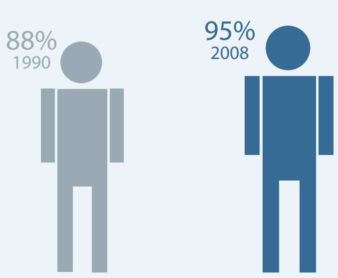
Total Surface Area: 2 381 741 km²
Estimated Population in 2009: 34 895 000

Progress Towards MDG Goal 7

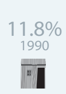
Algeria is Africa's second most water-scarce country (after Libya), with only 339.5 m³ available per person per year. Water shortages, aggravated by regular droughts, are a major problem and a limiting factor in the availability of safe drinking water. The proportion of people with improved drinking water declined from 1990 to 2008—from 94 to 83 per cent, no doubt associated with urban population growth. The proportion of people with improved sanitation, however, increased over the same period, from 88 to 95 per cent.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	89
Total renewable water (actual) (10^9 m³/yr)	2008	11.7
Total renewable per capita (actual) (m³/inhab/yr)	2008	339.5
Surface water: total renewable (actual) (10^9 m³/yr)	2008	10.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	1.5
Dependency ratio (%)	2008	3.6

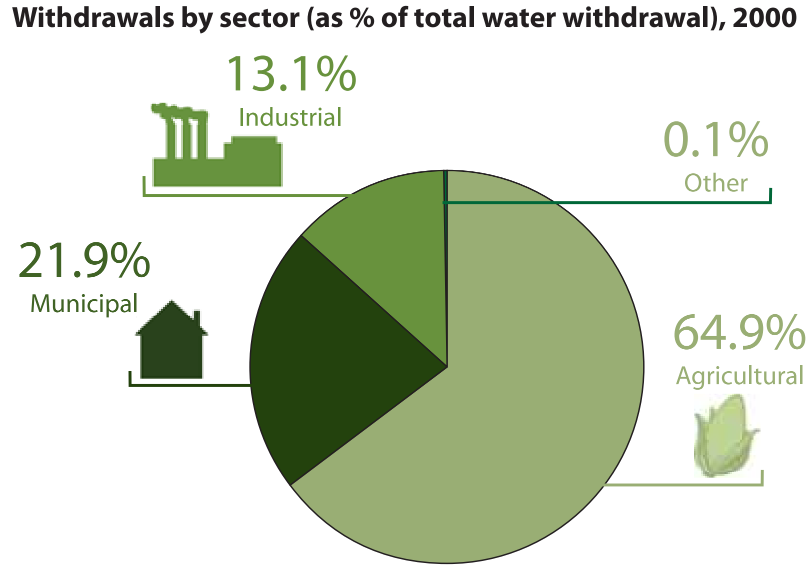
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	6.1
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	193.2
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	51.9

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

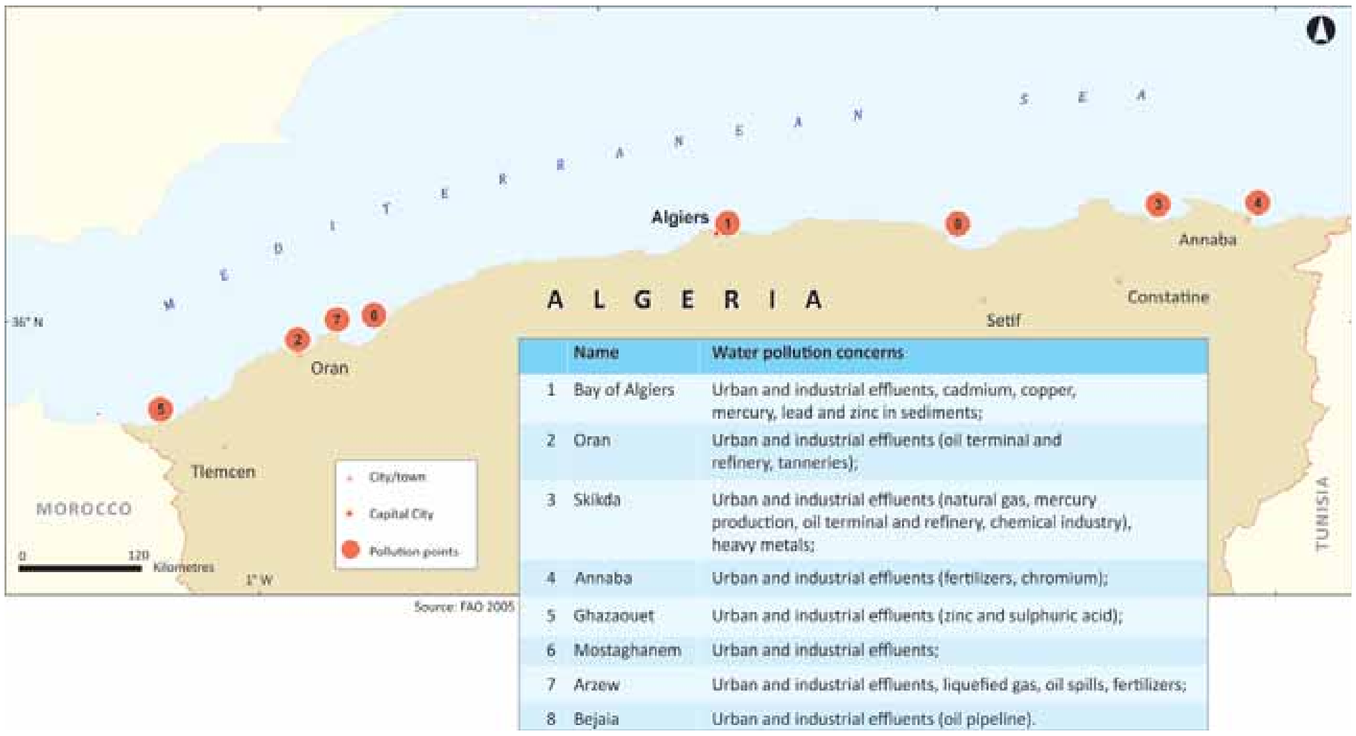
Withdrawals by sector (as % of total water withdrawal), 2000



Industrial Water Pollution

Algeria is the second-largest country in Africa covering almost 2.4 million km². Of this vast area, the fertile coastline, where most of the population is concentrated, only represents 1.8 per cent of the total land mass. However, more than a third of the population (12.5 million of the country's approximate 34 million inhabitants) is located in this area, as is the majority of the country's heavy industry. The effluents from both these sources compounded by insufficient water treatment puts a heavy burden on Algeria's water resources.

Most urban effluent is discharged untreated directly into the marine environment, causing water pollutants such as faecal microorganisms to accumulate on Algerian bathing beaches. An estimated 85 per cent of wastewater from sectors such as metallurgy, chemicals, petrochemicals, construction materials, minerals and agro-food industries is discharged into the sea and neighbouring wadis without proper treatment (EC 2006). The agro-food sector contributes the greater part of the organic load of industrial effluents, 55 per cent, with the textile sector accounting for 22 per cent. Petroleum hydrocarbon pollution is also very common along the Algerian coastline because of maritime oil traffic lines that pass close to the coast (EC 2006).



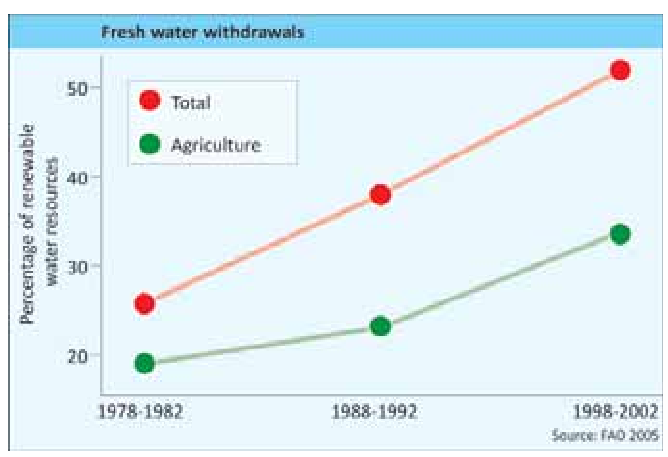
	Name	Water pollution concerns
1	Bay of Algiers	Urban and industrial effluents, cadmium, copper, mercury, lead and zinc in sediments;
2	Oran	Urban and industrial effluents (oil terminal and refinery, tanneries);
3	Skikda	Urban and industrial effluents (natural gas, mercury production, oil terminal and refinery, chemical industry), heavy metals;
4	Annaba	Urban and industrial effluents (fertilizers, chromium);
5	Ghazaouet	Urban and industrial effluents (zinc and sulphuric acid);
6	Mostaghanem	Urban and industrial effluents;
7	Arzew	Urban and industrial effluents, liquefied gas, oil spills, fertilizers;
8	Bejaia	Urban and industrial effluents (oil pipeline).

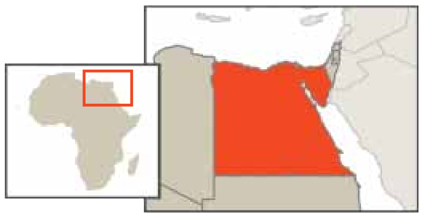
Water Scarcity

Water scarcity in Algeria is a major issue with only 340 m³ of water available annually per person, the second-lowest on the continent and well below the 1 000 m³/yr international water scarcity threshold (FAO 2008). About 84 per cent of the country is covered by the Sahara desert with most of the freshwater resources found in the north. However, even these limited resources are heavily dependent on precipitation, which is rare during the summer months, irregular during the winter and highly variable from year to year (FAO 2005). The national average rainfall hovers around 89 mm/yr, well below the level required to sustain rain-fed agriculture (FAO 2008). Over half of Algeria's total freshwater resources are withdrawn each year, with agriculture accounting for 64 per cent of this figure.

The lack of surface water resources has culminated in the overexploitation of coastal aquifers and their contamination from saltwater intrusion. The Oranie and the Chéliff water basins are the most affected by this phenomenon. Consequently, salinity affects irrigated agricultural land that, in some instances, has become irreversibly sterile (FAO 2005).

The lack of sufficient water resources compounded by water pollution, insufficient water treatment capacity, and the reuse of non-treated water has also contributed to water-related diseases, especially in children and young adults (FAO 2005).





Arab Republic of

Egypt

Total Surface Area: 1 001 449 km²
Estimated Population in 2009: 82 999 000

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	51
Total renewable water (actual) (10^9 m³/yr)	2008	57.3
Total renewable per capita (actual) (m³/inhab/yr)	2008	702.8
Surface water: total renewable (actual) (10^9 m³/yr)	2008	56
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	1.3
Dependency ratio (%)	2008	96.9

Withdrawals

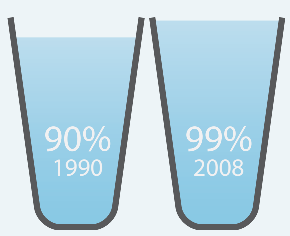
	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	54.3
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	937
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	94.7

Irrigation

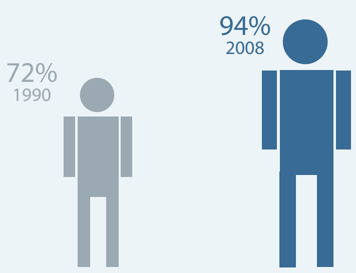
	Year	Value
Irrigated grain production as % of total grain production (%)	1993	100
Area salinized by irrigation (1000 ha)	2005	250

Progress Towards MDG Goal 7

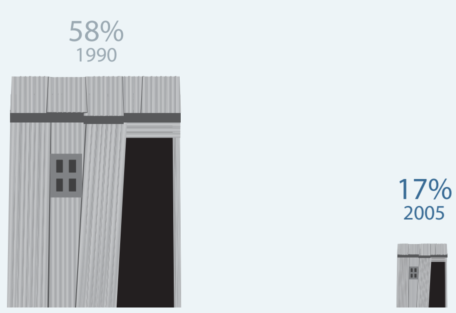
By 2008, almost all Egyptians were using improved drinking water. Remarkable progress was made in providing access to improved sanitation, with rates up from 72 per cent to 94 per cent of the population from 1990 to 2008. Progress was made from 1990 to 2008 in both urban and rural areas with an increase from 91 to 97 per cent in the former and from 57 to 92 per cent in the latter. Egypt has already the sanitation target, which requires that it provides sanitation to 77 per cent of its people by 2015.



Proportion of total population using improved drinking water sources, percentage

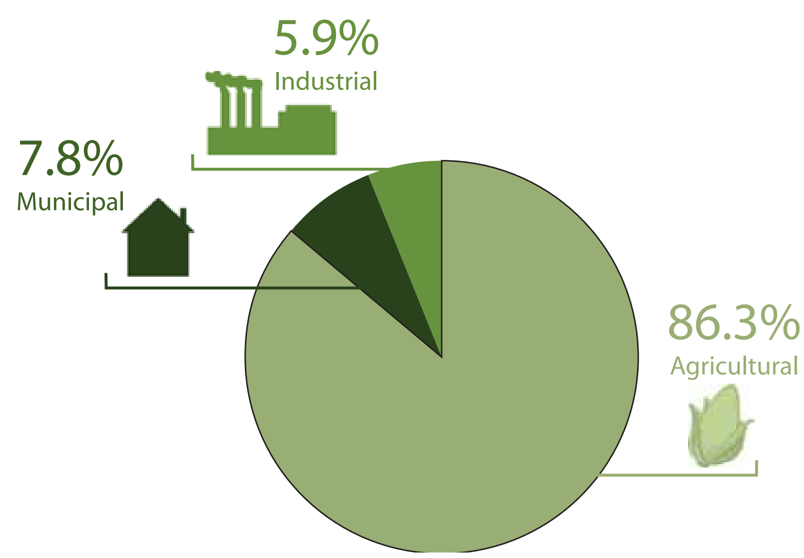


Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Withdrawals by sector (as % of total water withdrawal), 2000



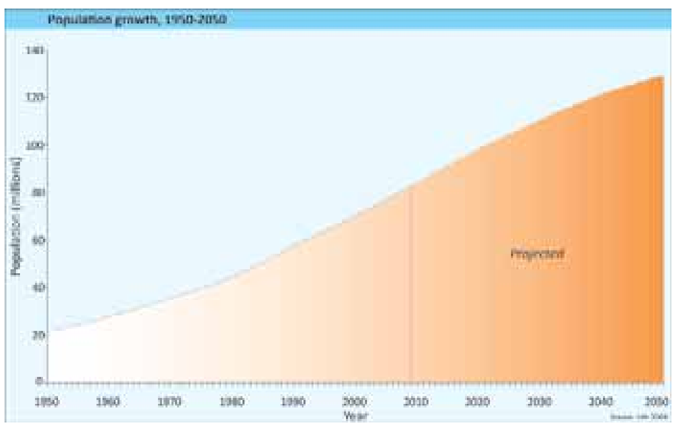
Vulnerability of the Nile Delta to Sea Level Rise

The Nile Delta is one of world's oldest intensely cultivated regions. It accounts for 24 900 km^2 of Egypt's one million km^2 area and has a high population density of up to 1 600 inhabitants per km^2. Despite its comparatively small area, 65 per cent of Egypt's agricultural land is found in the Nile Delta, land that is currently at risk because of climate-change related sea-level rise. River deltas are particularly vulnerable due to their low-lying nature and increases in sea level are often compounded by land subsidence and human interference such as sediment trapping by dams (AFED 2009) (see page 85).

With a one-metre rise in sea level, it is estimated that 34 per cent of the Nile Delta would be inundated, putting more than 12 per cent of Egypt's best agricultural land at risk. The coastal cities of Alexandria, Idku, Damietta and Port-Said would be directly affected, displacing roughly seven million Egyptian's or 8.5 per cent of the population. In the extreme case of a five metre sea-level rise, more than half (58 per cent) of the Delta would flood, devastating 35 per cent of Egypt's agricultural land and displacing roughly 11.5 million people from over 10 major cities. Along with the direct effect on people's livelihoods, Egypt's economic growth will also feel the repercussions. A one-metre rise would incur a six per cent drop in GDP while a three-metre rise would result in a 12 per cent drop (AFED 2009).

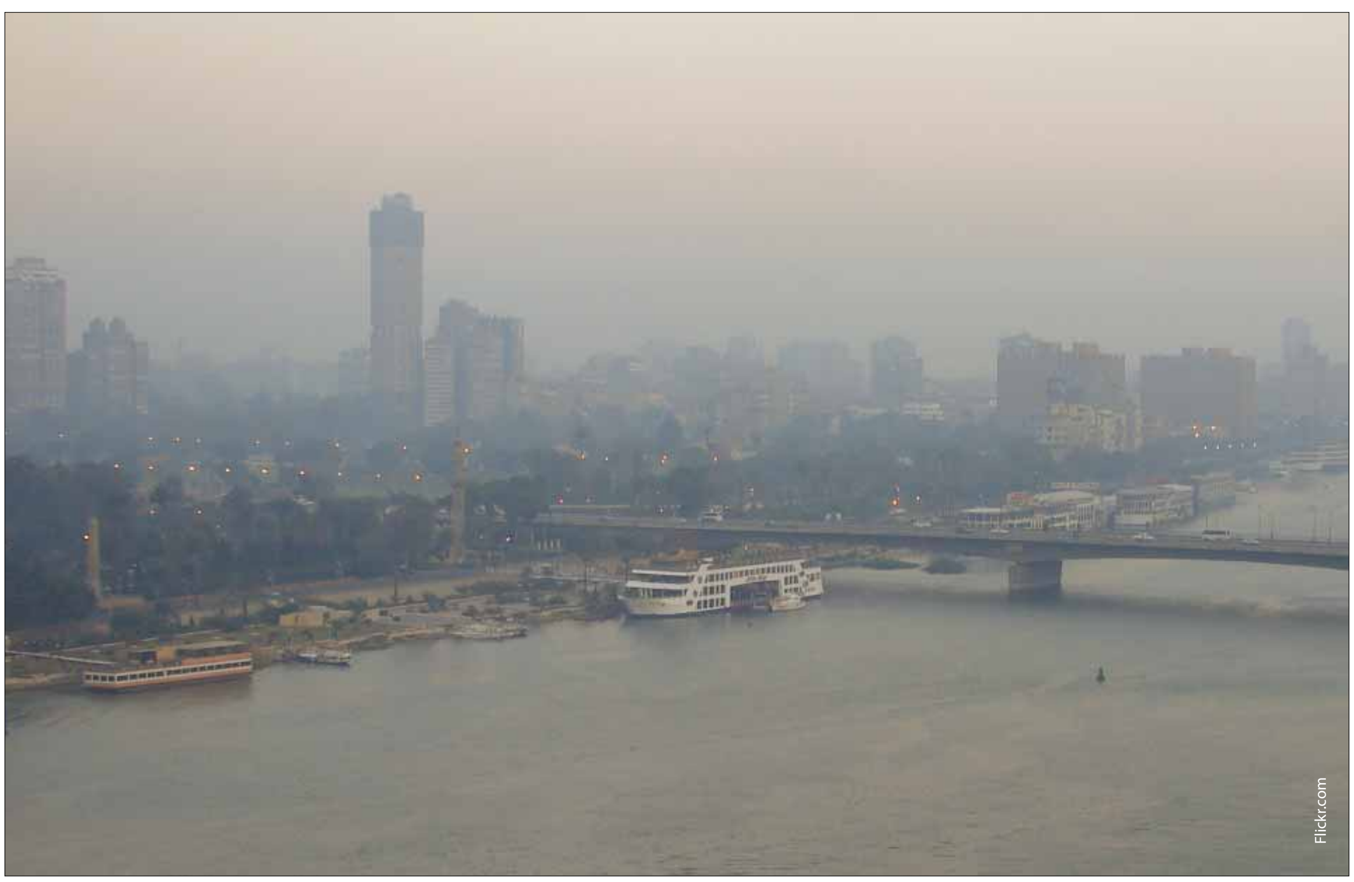
Water Pollution

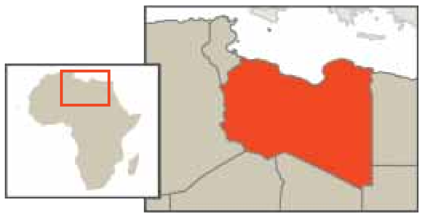
Egypt's population is increasing rapidly, growing from an estimated 21.5 million in 1950 to 84.5 million in 2010 and is projected to reach almost 130 million by 2050 (United Nations 2008). The vast majority (99 per cent) is concentrated along the Nile Valley and Delta, which accounts for just four per cent of Egypt's total land mass (EEAA 2008). The water quality in the Nile is generally assessed to be good until the river reaches Cairo where it divides into the Damietta and Rosetta branches. At this point the quality deteriorates as a result of municipal and industrial effluents and agricultural drainage (World Bank 2006).



In Egypt, only 53.6 per cent of households were connected to main sewage in 2004, with less than half the wastewater being collected and treated (EEAA 2008). This figure falls even further, to 11 per cent, in rural areas (EEAA 2008). Between the Damietta and Rosetta branches, fecal coliform bacteria concentration from human or animal feces, are 3-5 times higher than the permissible national standard (World Bank 2006).

Of the 129 industrial facilities located on the Nile, 102 of them discharge roughly 4.05 billion m^3 /yr of water containing heavy metals, organic and inorganic components directly or indirectly into the river (EEAA 2008). An intensive use of pesticides and fertilizers in agriculture adds to Egypt's water pollution concerns.

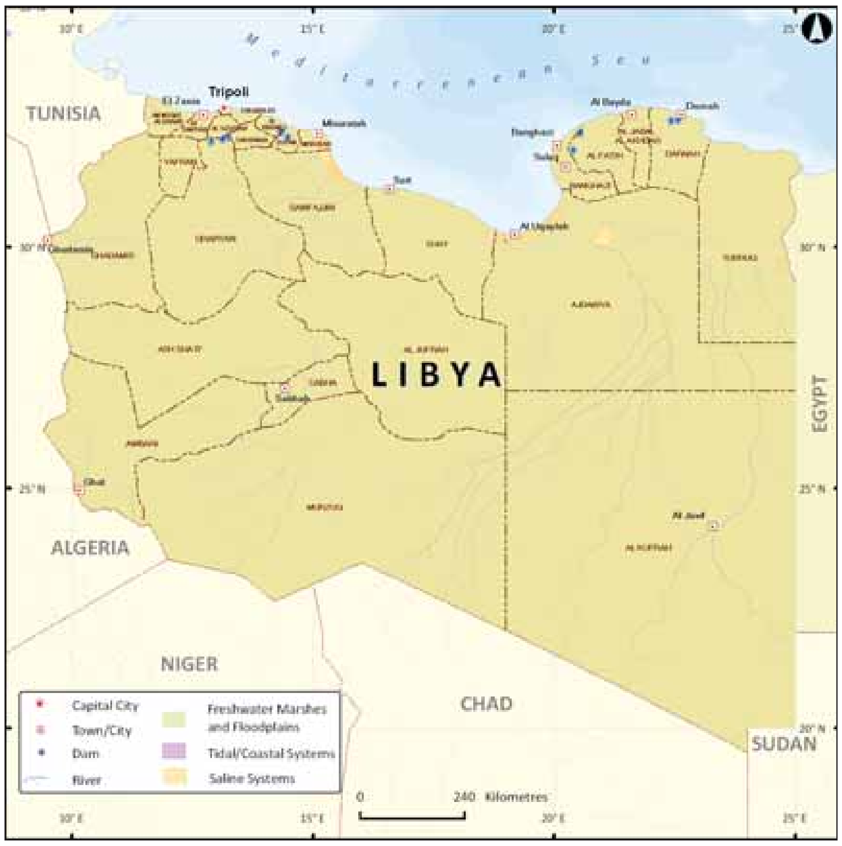




Socialist People's

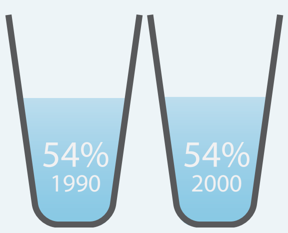
Libyan Arab Jamahiriya

Total Surface Area: 1 759 540 km²
Estimated Population in 2009: 6 420 000

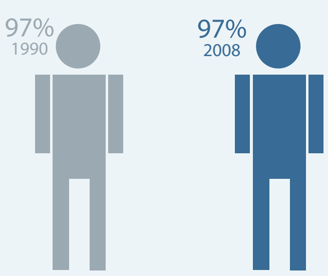


Progress Towards MDG Goal 7

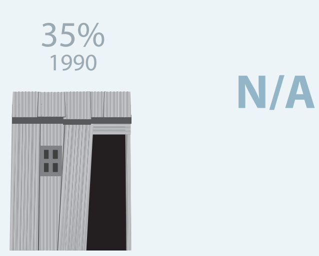
Libya is Africa's most water-scarce country, with minimal surface waters and no perennial rivers. In addition, groundwater resources near population centres on the coast have been over-drawn and contaminated by salt water. Three quarters of the population lives in the coastal regions where rainfall is highest. About 54 per cent of the population is served by improved drinking water and 96 per cent uses improved sanitation; urban and rural users have similar access to both.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	56
Total renewable water (actual) (10^9 m³/yr)	2008	0.6
Total renewable per capita (actual) (m³/inhab/yr)	2008	95.3
Surface water: total renewable (actual) (10^9 m³/yr)	2008	0.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.5
Dependency ratio (%)	2008	0

Withdrawals

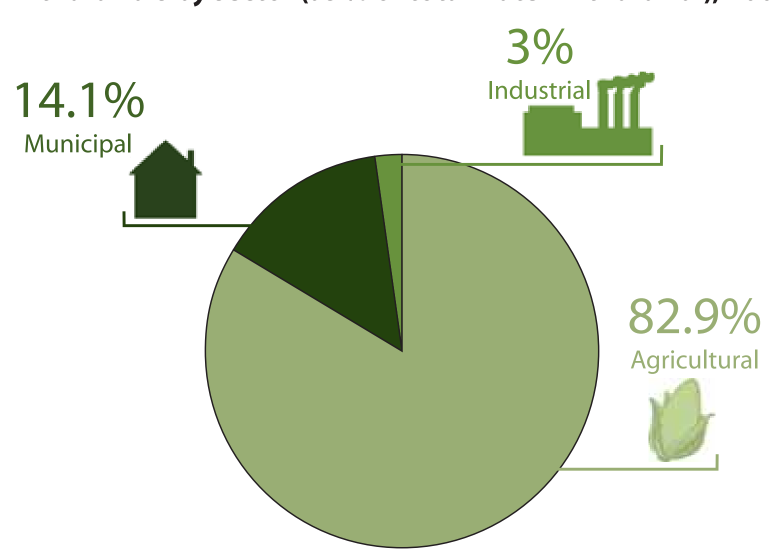
	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	4.3
Surface water withdrawal (10^9 m³/yr)	2000	0
Groundwater withdrawal (10^9 m³/yr)	2000	4.3
Total water withdrawal per capita (m³/inhab/yr)	2002	776.8
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	711.3*

** Value above 100 per cent indicate withdrawal of nonrenewable groundwater resources or use of desalinated and other supplemental water resources*

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	1998	190

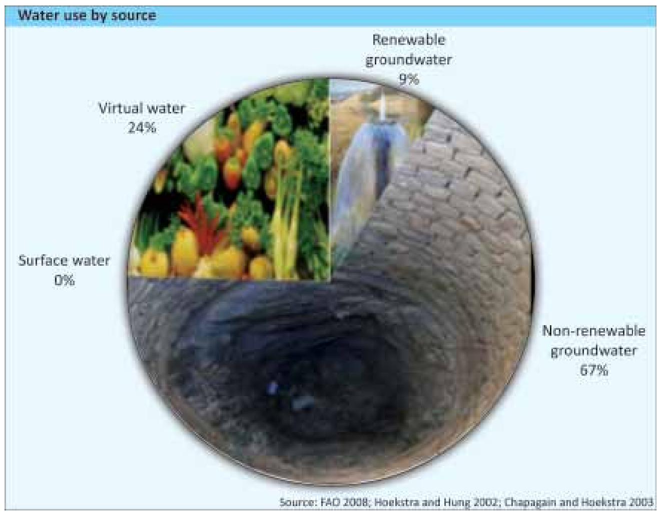
Withdrawals by sector (as % of total water withdrawal), 2000



Water Scarcity and Virtual Water

Libyan Arab Jamahiriya is a hyper-arid country and the most water scarce on the continent with only 95 m^3 of available water per person per year (FAO 2008). It faces consistently low levels of rainfall—93 per cent of the land surface receives less than 100 mm annually (FAO 2006), far below the 250-300 mm required to sustain rain-fed agriculture. For the country as a whole the average precipitation levels are only 56 mm each year (FAO 2008). The limited access to surface water resources has resulted in heavy dependence on groundwater, especially fossil aquifers. While the annual available renewable groundwater resources are only 500 million m^3 (FAO 2008) the actual withdrawal rate is over eight times this level, measured at 4 300 million m^3 in 2000 (FAO 2000).

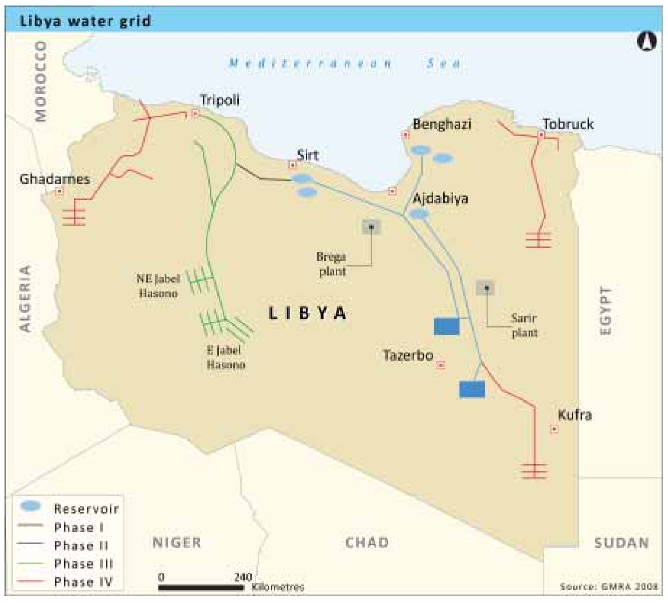
The extreme levels of water scarcity have made the import of virtual water (the embodied water used to produce a good) an important coping mechanism.



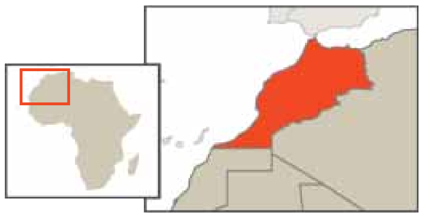
UNESCO carried out a series of studies exploring the flows of virtual water between nations both in terms of crops and livestock (Hoekstra and Hung 2002, Chapagain and Hoekstra 2003) and it was found that on average Libya imports approximately 1 400 million m^3 of virtual water each year. This represents around a quarter of the water use in the country.

Urbanization and Water Pollution

Libyan Arab Jamahiriya's water scarcity issues are further compounded by the distribution of the population relative to the available water resources. Although Libya's population density in 2010 is estimated at only four people per km^2 (United Nations 2008) the vast majority reside along the water-deficient coastal areas. Seventy-five per cent of Libya's population is concentrated over only 1.5 per cent of the total land area in the western coastal centres of Jifarah Plain and Misratha and the eastern coastal area of Al Jabalal Akhbar (FAO 2006). As a result, coastal aquifers are being exploited far beyond the replenishment rate leading to saltwater intrusion and a fall in the water table. The rapid expansion of private agriculture along the coast is further compounding the depletion. Furthermore, many of Libya's urban agglomerations have an inadequate sanitation system, which has resulted in pollution of the shallow aquifers around the cities (FAO 2006).



The country's most abundant water sources are aquifers located deep beneath the southern desert, far from the country's northern population centres. Connecting these coastal populations to this source has resulted in one of the world's most ambitious water transportation schemes, the Great Man-Made River Project (see page 113), which is expected to deliver 6.5 million cubic metres of water per day (GMRA 2008).



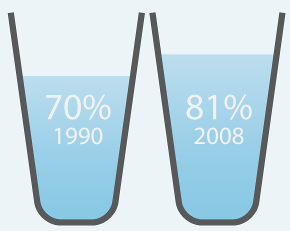
Kingdom of

Morocco

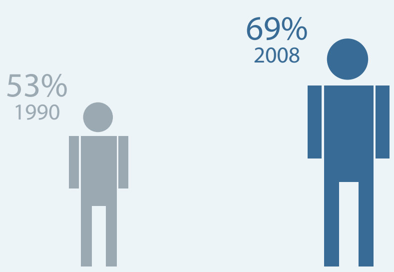
Total Surface Area: 446 550 km²
Estimated Population in 2009: 31 993 000

Progress Towards MDG Goal 7

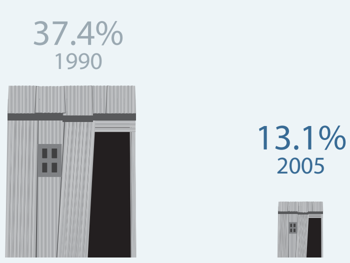
Water availability in Morocco recently dropped below the international water scarcity threshold of 1 000 m³ per person per year and it is estimated that by 2020, groundwater exploitation will exceed replenishment by 20 per cent. Between 1990 and 2008, the proportion of the population using improved drinking water sources rose from 70 to 81 per cent with both urban and rural populations experiencing increases. The proportion of the population using improved sanitation facilities rose from 53 to 69 per cent in that period.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	346
Total renewable water (actual) (10^9 m³/yr)	2008	29
Total renewable per capita (actual) (m³/inhab/yr)	2008	917.5
Surface water: total renewable (actual) (10^9 m³/yr)	2008	22
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	10
Dependency ratio (%)	2008	0

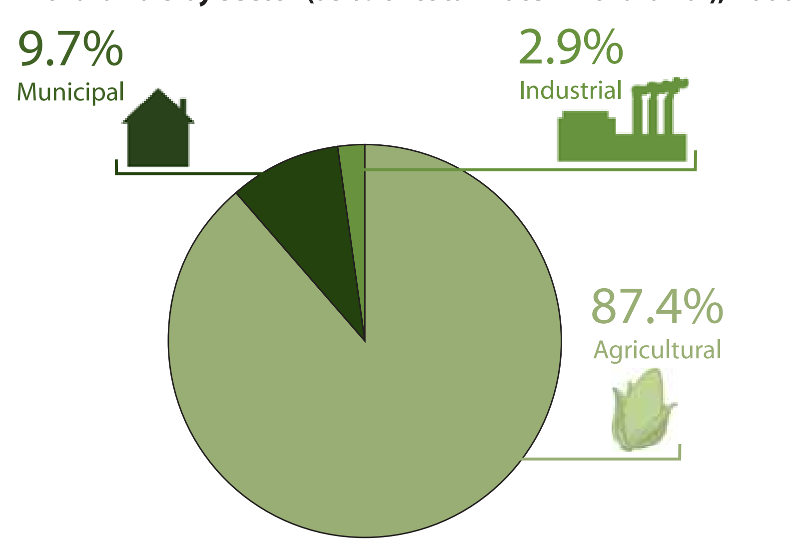
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	12.6
Surface water withdrawal (10^9 m³/yr)	2000	9.4
Groundwater withdrawal (10^9 m³/yr)	2000	3.2
Total water withdrawal per capita (m³/inhab/yr)	2002	427.2
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	43.4

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1989	15
Area salinized by irrigation (1000 ha)	2000	150

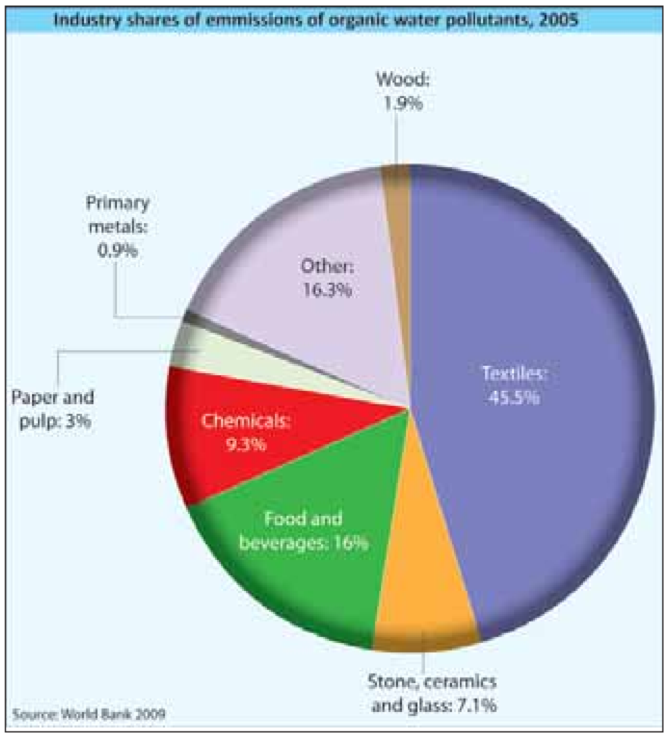
Withdrawals by sector (as % of total water withdrawal), 2000



Urban Wastewater

Fifty-six per cent of Morocco's population live in urban centres, many of which are concentrated along the country's Atlantic Ocean and Mediterranean Sea coasts (WHO/UNICEF 2010). The urbanization trend in Morocco is characterized by the establishment of newer urban centres along this coastal band, the number of which more than doubled between 1971 and 1994 (EC 2006). The emergence of such centres often brings with it a host of environmental pressures, not least in the area of water management. An estimated 500 million cubic metres of effluents are generated each year, with Morocco's coastal marine environment serving as a dumping ground for much of this urban and industrial wastewater (EC 2006).

Seventy-seven per cent of Morocco's industrial facilities are located along the Atlantic coastal zone. The majority of industrial plants discharge untreated wastewater into the sea, either directly or via urban sewage networks. Ninety-eight per cent of all industrial effluents and 52 per cent of the country's domestic effluents are released into the ocean. While 235 urban centres are equipped with a sewage network, there are only 26 wastewater treatment plants for urban effluents in operation in the entire country (EC 2006). Furthermore, the lack of sanitary treatment of municipal solid waste has lead to the contamination of groundwater tables by leachates, the liquid that drains from landfills.



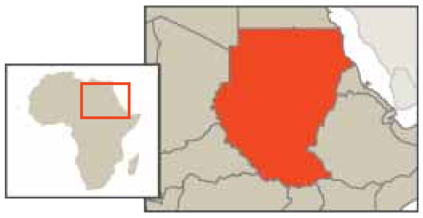
Salinity of Water Resources

Water scarcity is a growing problem in Morocco. Over the last few years, the average amount of available renewable water per capita fell below the international water scarcity threshold and was estimated to be 918 m^3 in 2008 (FAO 2008).

Agriculture is the main sector contributing to water depletion in the country, accounting for 87.4 per cent of annual freshwater withdrawals in 2007 (World Bank 2009). Much of Morocco's territory is classified as arid or semi arid, with an average rainfall of only 346 mm each year (FAO 2008). This falls to as little as 150 mm in some parts of the country (FAO 2005) making irrigation a necessity for agriculture.

The high levels of salinity evident in much of the renewable water resources, however, presents a challenge to agricultural development. Of Morocco's 29 billion cubic metres of renewable water, it is estimated that 1.1 billion have a salinity of 1-2 g/l and a further one billion cubic metres have a salinity of over 2 g/l (FAO 2005).

Much of this salinity is attributable to mismanagement of water resources, such as the over-exploitation of groundwater resources including coastal aquifers, poor soil drainage and damaging irrigation practices.

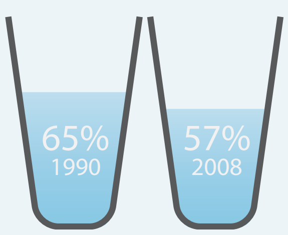


Republic of the Sudan

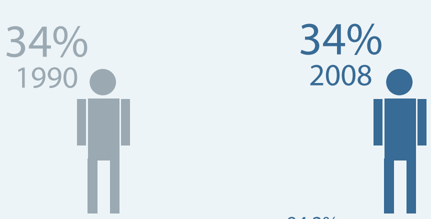
Total Surface Area: 2 505 813 km²
Estimated Population in 2009: 42 272 000

Progress Towards MDG Goal 7

Access to water and sanitation is especially low in southern Sudan due to the rapid influx of people displaced by the country's 22-year civil war. Severe water scarcity also constrains water and sanitation development. Fifty-seven per cent of the total population used improved drinking water in 2008; access declined in urban areas (from 85 to 64 per cent) and in the countryside (from 58 to 52 per cent). Improved sanitation facilities were accessible to only 34 per cent in 2008.

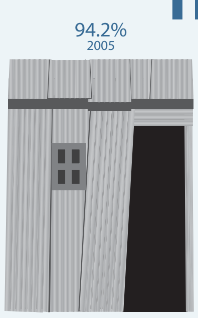


Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

N/A



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	416
Total renewable water (actual) (10^9 m³/yr)	2008	64.5
Total renewable per capita (actual) (m³/inhab/yr)	2008	1 560
Surface water: total renewable (actual) (10^9 m³/yr)	2008	62.5
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	7
Dependency ratio (%)	2008	76.9

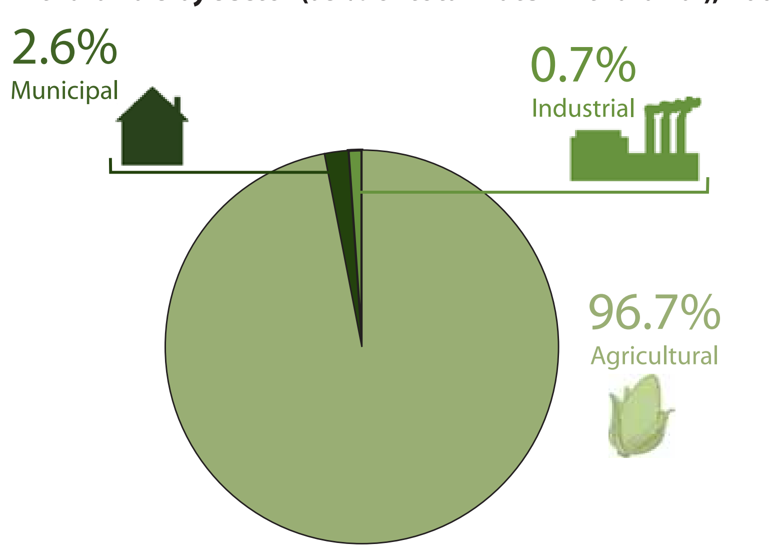
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	37.32
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	1 025
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	57.9

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1989	20
Area salinized by irrigation (1000 ha)	1999	500

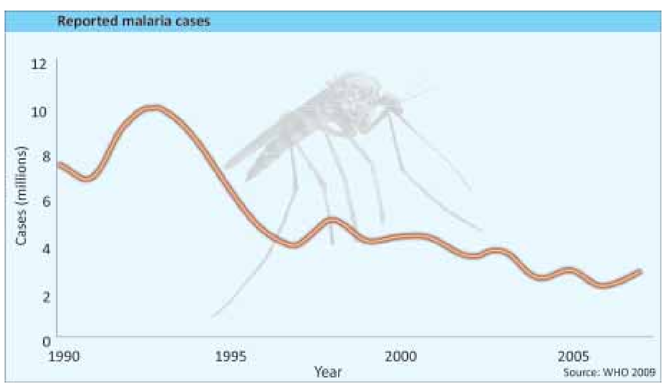
Withdrawals by sector (as % of total water withdrawal), 2000



Water-Related Disease

The prevalence of water-related communicable diseases such as malaria, diarrhoea, cholera and Guinea worm pose a significant developmental challenge for Sudan.

Malaria is endemic throughout the southern regions and along the Nile, north of Khartoum, with over 2.8 million cases reported in Sudan in 2007 (WHO 2009). The World Health Organization has found that six per cent of all hospital deaths in Sudan are attributable to malaria (WHO 2009). In addition, despite the dramatic fall in the incidences of Guinea worm in Africa and Asia over the last few decades, this water-borne parasite still remains a problem in South Sudan, which accounts for 80 per cent of worldwide cases (World Bank 2010).



The combination of population growth, urbanization and civil and environmental instability has resulted in a decline in the proportion of the population with access to improved drinking water sources. Between 1990 and 2008, this number fell from 65 per cent to 57 per cent overall and from 85 per cent to 64 per cent in urban areas (WHO/UNICEF 2010). The decades long North-South civil war, combined with environmental degradation and poverty resulted in mass displacement and rapid urbanization, especially around the capital Khartoum. While Sudan's urban population grew from 7.3 million people in 1990 to 17.8 million in 2008, the water infrastructure necessary to sustain these increased numbers failed to develop at the same rate.

Groundwater Contamination from Sewage

The quality of Sudan's freshwater resources is being degraded by pollution from domestic, agricultural and industrial activities. Groundwater contamination from inadequate sanitation practices and waste disposal pose a considerable threat to water quality.

In much of the country, especially Southern and Western Sudan, the water table lies only a few metres below the surface (UNESCO 2009). This has resulted in high levels of chemical and bacteriological contamination from sanitation systems, especially on-site disposal schemes such as septic tanks and pit latrines. According to UNESCO, almost all disposal wells and pit latrines tap the water table, often within close range of drinking water wells.

In 1990, 9.1 million people had access to improved sanitation, a figure that includes pit latrines and septic tanks. This number increased to 14.1 million in 2008 (WHO/UNICEF 2010). Sudan faces the difficult challenge of increasing access to adequate sanitation facilities without compromising the quality of groundwater resources.

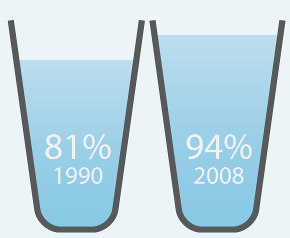
Republic of

Tunisia

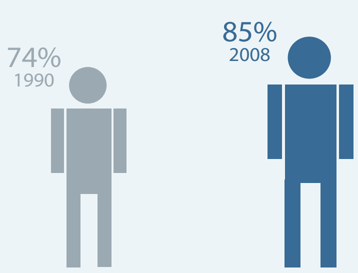
Total Surface Area: 163 610 km²
Estimated Population in 2009: 10 272 000

Progress Towards MDG Goal 7

Tunisia is one of Africa's more water-stressed countries, with high variability among regions and between years and a growing demand and shrinking supplies. Nevertheless, it serves 94 per cent of its population with improved drinking water (99 per cent in urban and 84 per cent in rural areas). Between 1990 and 2006, the proportion of people using improved sanitation increased from 95 to 96 per cent in cities and from 44 to 64 per cent in rural areas.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

N/A

Slum population as percentage of urban

9%
1990

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	207
Total renewable water (actual) (10^9 m³/yr)	2008	4.6
Total renewable per capita (actual) (m³/inhab/yr)	2008	451.9
Surface water: total renewable (actual) (10^9 m³/yr)	2008	3.4
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	1.6
Dependency ratio (%)	2008	8.7

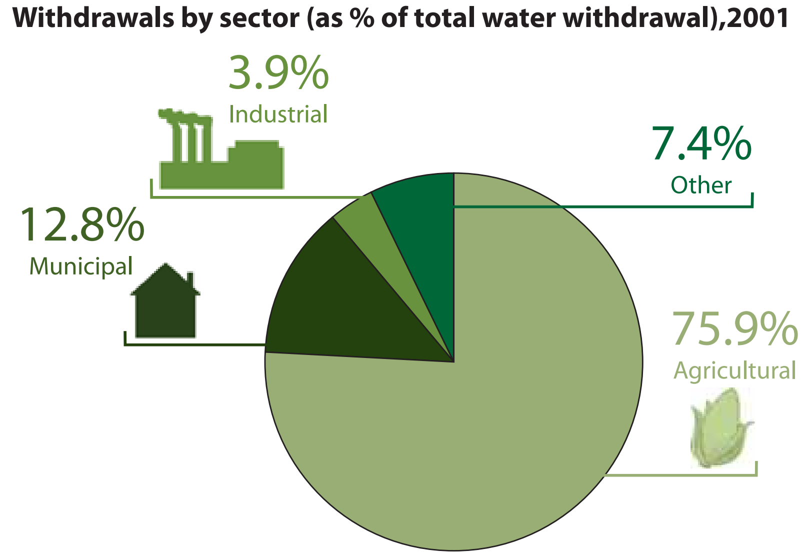
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2001	2.8
Surface water withdrawal (10^9 m³/yr)	2001	0.9
Groundwater withdrawal (10^9 m³/yr)	2001	1.9
Total water withdrawal per capita (m³/inhab/yr)	2002	296.2
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	61.3

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1991	3.5
Area salinized by irrigation (1000 ha)	2001	86

Withdrawals by sector (as % of total water withdrawal),2001



Unsustainable Exploitation of Aquifers

Aquifers are distributed unevenly throughout Tunisia, with the densely populated northeast coast providing an important source of easily accessible shallow aquifers. While the centre of the country has both shallow and deep aquifers, they are saline and of low water quality (FAO 2005). The south is characterized by a network of large and deep, often saline, aquifers with a low recharge rate, making them barely renewable (FAO 2005).

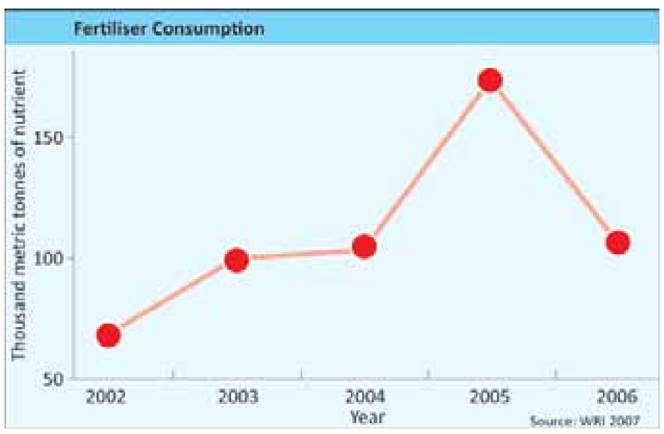
Tunisia's network of aquifers, which represent 70 per cent of the water used in the country, are currently under heavy stress from overexploitation (UNESCO 2009, FAO 2005). In 2005, the estimated exploitation rate of deep aquifers was about 80 per cent, reaching an unsustainable 108 per cent for shallow aquifers (UNESCO 2009). This is especially problematic in the populated northeast region where the shallow nature of the water table allows easier accessibility through large-diametre wells and boreholes (INECO 2009).

The agriculture sector is principally responsible for this overexploitation, using over 80 per cent of groundwater resources for irrigation. Industry accounts for four per cent and the remaining 16 per cent is used for drinking water (INECO 2009).

Coastal Water Pollution

The 1 300 km-long Tunisian coastline is characterized by its diverse countryside and rich natural resources. With a heavy industrial presence and 60 per cent of the population concentrated there, water pollution from industrial runoff and solid waste has become a serious issue (EC 2006).

Industrial activities concentrated mainly in Tunis, Sfax, Ariana, Bizerte, Sousse, Nabeul and Gabès create 250 000 tonnes of solid waste each year, polluting the marine environment and contaminating underground water resources (EC 2006). In addition, five million tonnes of phosphogypsum, a radioactive byproduct of fertilizer production, is released yearly, causing one of Tunisia's most pressing environmental concerns. In Ghannouch-Gabès, 10 000–12 000 tonnes of phosphogypsum flow into the Gulf of Gabès each year. On the Sfax coast, there are two major disposal sites of phosphogypsum. One covers an area of 57 ha and is 57 m high, the other covers 40 ha and is 30 m high (EC 2006).



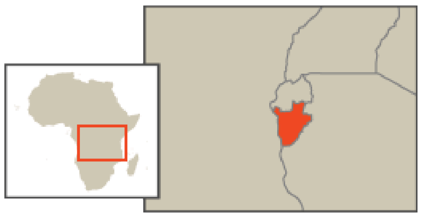
Agricultural activities also have a negative impact on coastal groundwater resources, with irrigation practices contributing heavily to the overexploitation of aquifers. Furthermore, nitrate runoff from the heavy use of fertilizers has increased vulnerability to salinazation (FAO 2005).

Climate change will potentially increase sea-level rise, leading to even greater saltwater intrusion. Studies have shown that only 53 per cent of the current coastal aquifer water reserves would remain intact as a result of climate change (IHE 2008).


Brian Jackson/Flickr.com

Eastern Africa

Burundi
Djibouti
Eritrea
Ethiopia
Kenya
Rwanda
Somalia
Uganda



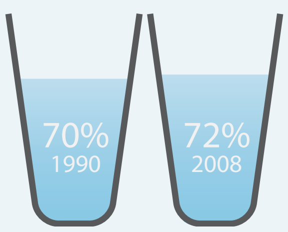
Republic of

Burundi

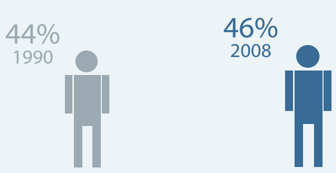
Total Surface Area: 27 834 km²
Estimated Population in 2009: 8 303 000

Progress Towards MDG Goal 7

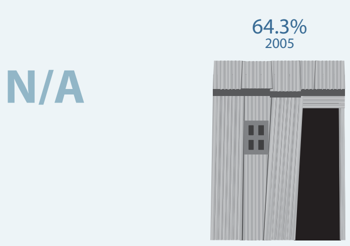
Burundi's water and sanitation services suffered during the civil war and its aftermath (1993-1999). Thus, the total proportion of the population served by improved drinking water increased only slightly, from 70 to 72 per cent for the period 1990 to 2008. To achieve the MDG target, 13 per cent of the population still needs to gain access. Less than half the population uses improved sanitation and 26 per cent still need access to it if the MDG target is to be reached.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 274
Total renewable water (actual) (10^9 m³/yr)	2008	12.6
Total renewable per capita (actual) (m³/inhab/yr)	2008	1 553
Surface water: total renewable (actual) (10^9 m³/yr)	2008	12.5
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	7.5
Dependency ratio (%)	2008	19.8

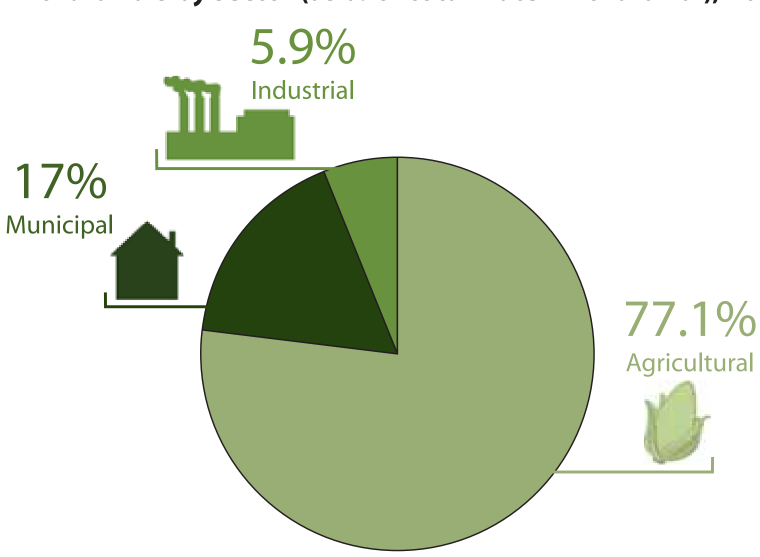
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.3
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	42.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	2.3

Irrigation

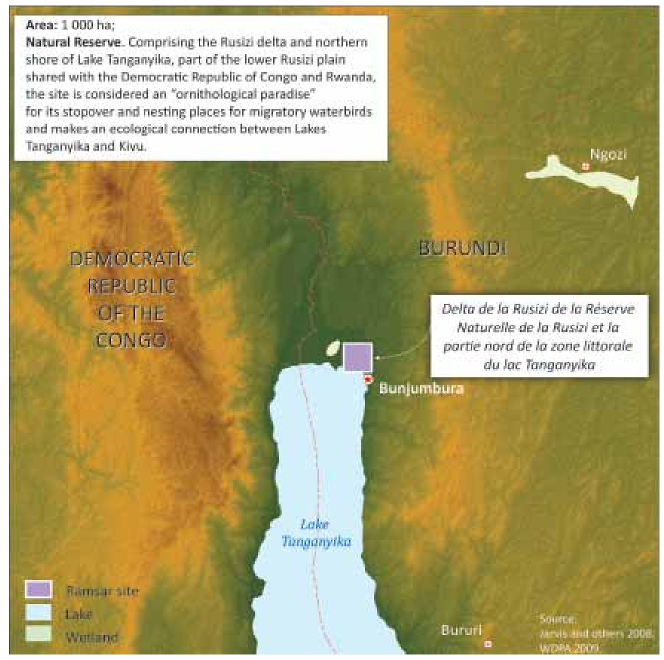
	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



Degradation of Wetland Ecosystems

Burundi's wetlands represent one of the country's most important natural resource bases. As well as providing services such as livelihoods and materials, they aid in regulating the local ecosystem and are a habitat for Burundi's abundant species biodiversity. The country's wetlands also play a role regionally as part of both the Congo and Nile watersheds, regulating effluents into the Ruvubu River, a southern source of the Nile, for example. Despite the vital role of this 120 000 ha ecosystem, only one site, with an area of 1 000 ha, has been designated for protection (WDPA 2009).



Burundi's wetlands have been degraded over the last few years fueled by a combination of drought, poverty, social conflict and high population densities. The country has a rapidly growing population and one of the highest population densities on the continent, with 792 people per km^2 of arable land in rural areas (FAO 2008). These factors, combined with the fact that 90 per cent of Burundi's people are engaged in agricultural activities (FAO 2009), have placed a high level of ecological stress on the land, leading to degradation of the arable soils and encroachment into marginal lands and wetlands.

Lake Tanganyika

Industrial Water Pollution

Burundi is endowed with plentiful surface water resources including Lake Tanganyika, which it shares with neighbouring countries. This 650-km long lake, the longest in the world, supports one million fisheries livelihoods and contains 17 per cent of the world's free freshwater (IUCN 2008). Maintaining the quality of this essential water supply in the face of industrialization and population pressures is a key challenge.

A Pollution Special Study carried out by the United Nations Office for Project Services (UNOPS 2000) found that industrial and domestic activities in Bujumbura were affecting the quality of incoming waters. The wastewaters from sectors such as textiles, breweries, battery manufacturing and abattoirs have been found to contain numerous chemicals and pollutants such as lead, mercury, blood and offal and detergents that enter the lake either directly or through inflowing rivers. The study also found that nitrogen levels in Burundi were 10 times greater than those of other neighbouring countries. In addition, eutrophication levels were highlighted as a concern in Bujumbura Bay.

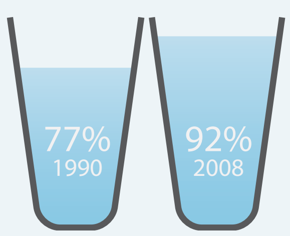
Republic of

Djibouti

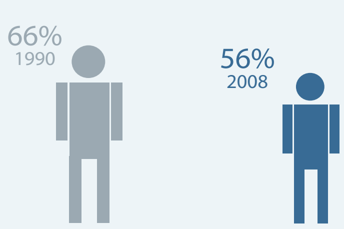
Total Surface Area: 23 200 km²
Estimated Population in 2009: 864 000

Progress Towards MDG Goal 7

From 1990 to 2008, urban access to improved drinking water rose from 80 to 98 per cent while it declined from 69 to 52 per cent among the rural population. Only 10 per cent of the rural population had access to improved sanitation in 2008 while 63 per cent of the urban population had access.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

N/A N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	220
Total renewable water (actual) (10^9 m³/yr)	2008	0.3
Total renewable per capita (actual) (m³/inhab/yr)	2008	353.4
Surface water: total renewable (actual) (10^9 m³/yr)	2008	0.3
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.02
Dependency ratio (%)	2008	0

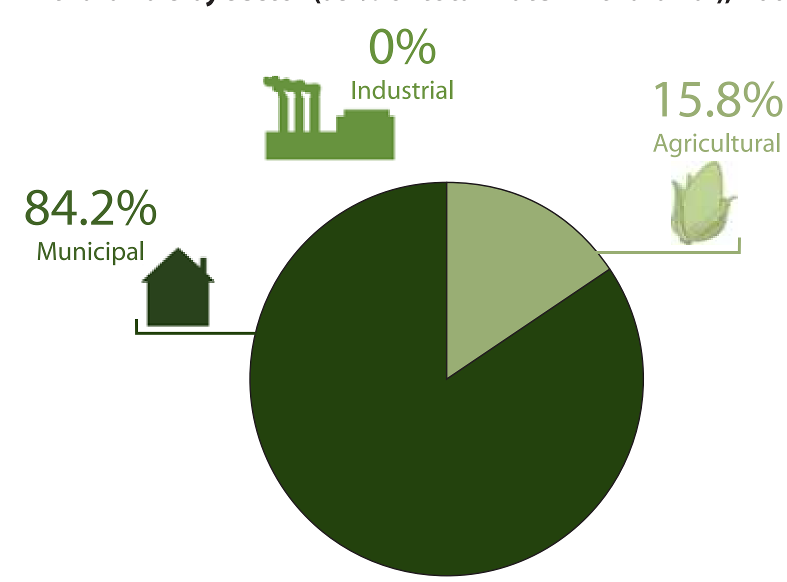
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.02
Surface water withdrawal (10^9 m³/yr)	2000	0.001
Groundwater withdrawal (10^9 m³/yr)	2000	0.02
Total water withdrawal per capita (m³/inhab/yr)	2002	24.9
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	6.3

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1989	100
Area salinized by irrigation (1000 ha)	...	...

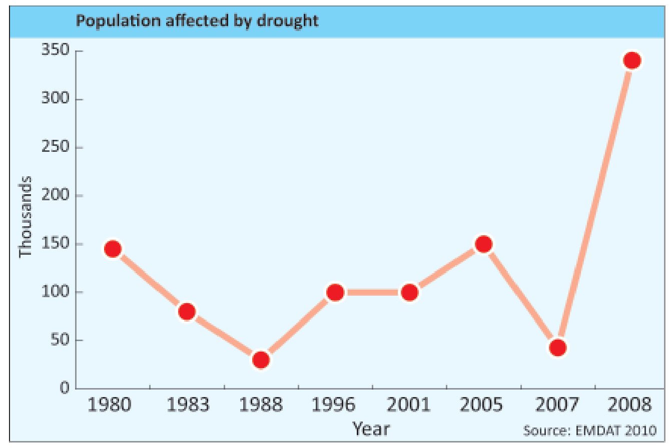
Withdrawals by sector (as % of total water withdrawal), 2000



Climate-change Impacts on Water Availability

Djibouti is an arid coastal state where freshwater availability is far below the water scarcity threshold, with only 353m^3 of freshwater available per person each year (FAO 2008). The lack of permanent surface water bodies means that Djiboutians are primarily reliant on groundwater and seasonal flows of wadis. The limited access to water resources has left Djibouti exceptionally vulnerable to any changes in climate. The threat from climatic uncertainties is further exacerbated by the fact that much of the rural population live in deserts or marginal infertile lands with limited water supplies (GEF 2008).

Climate studies predict that Djibouti faces potential temperature increases of between 1.8 and 2.1 degrees Celsius, a sea-level increase of 8 to 39 cm and decreased rainfall of between 4 and 11 per cent, as well as change in the pattern of precipitation in terms of distribution, frequency and intensity (GEF 2008). This combination of factors could have a detrimental effect on water availability in Djibouti, further aggravating an already challenging situation. Impacts include an increased severity of dry spells, erosion and flooding. Groundwater resources are particularly at risk. Precipitation declines leads to a decrease in recharge rates and sea-level rises are expected to lead to greater salt water intrusion into coastal aquifers (GEF 2008).

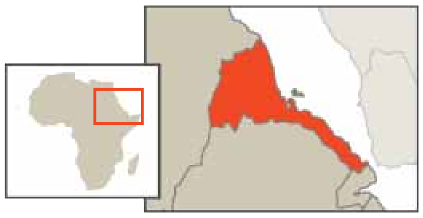


Drought and Food Security

In the last three decades, Djibouti has suffered eight serious drought events, which combined have affected an estimated 987 750 people. The last decade has been particularly dry with droughts in 2001, 2005, 2007 and 2008 (EM-DAT 2010). The most recent drought event in 2008 alone affected around 340 000 people, ranking it the most devastating natural disaster in Djibouti since 1900 in terms of the population affected (EM-DAT 2010).

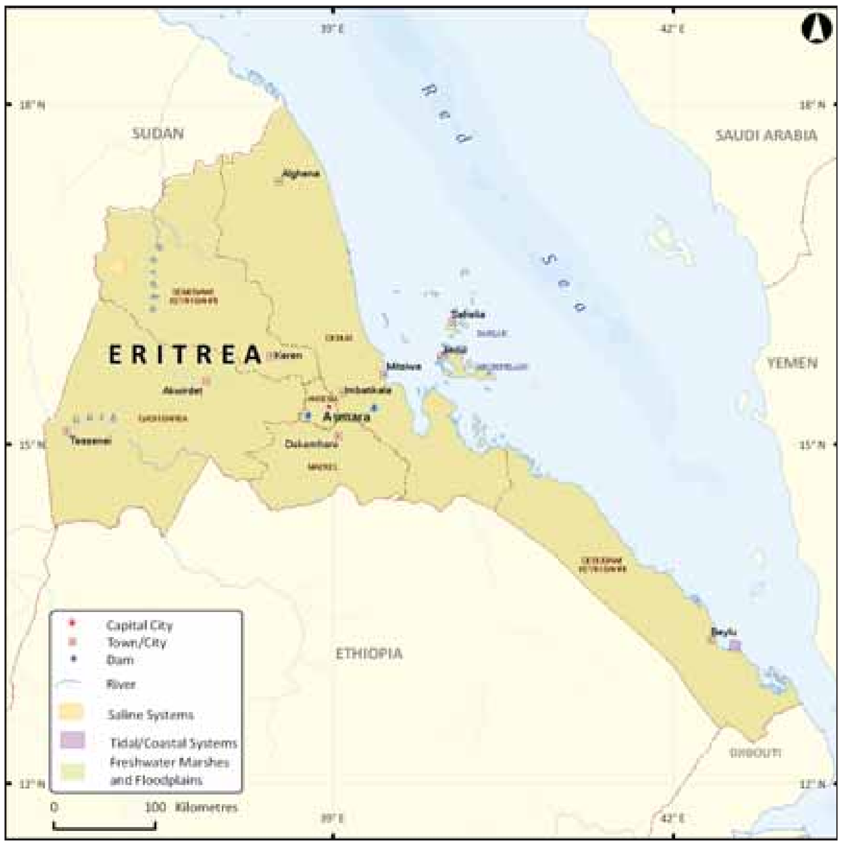
On average, Djibouti receives only 220 mm of precipitation each year making sustainable rain-fed agriculture a challenge (FAO 2008). Extended drought periods, poor successive rains and Djibouti's limited surface and groundwater resources have culminated in an ongoing threat to food security in the country. High staple food prices, insecurity, poverty and inadequate humanitarian assistance further aggravate food security concerns (FEWSNET 2010).

According to USAID's Famine Early Warning System Network (FEWSNET), around half of Djibouti's rural population will be in need of humanitarian assistance—including food aid and water supplies—until at least the end of 2010. Poor rains have left many catchments in the country's northwest dry and have contributed to high-livestock mortality rates in the southeast pastoral zones. Poor urban households are also at risk due to growing food prices. In addition, Djibouti City is expected to face severe water shortages (FEWSNET 2010).



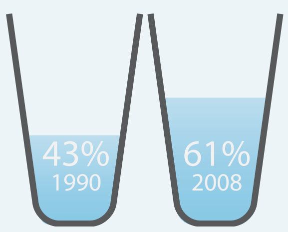
Eritrea

Total Surface Area: 117 600 km²
Estimated Population in 2009: 5 073 000



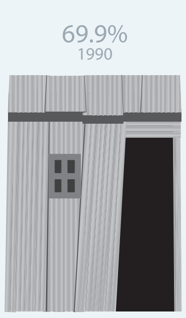
Progress Towards MDG Goal 7

With only one perennial river and no natural fresh surface water bodies, Eritrea depends on limited groundwater and demand for water is ten times greater than the national supply. The proportion of the population using improved drinking water sources increased from 43 per cent in 1990 to 61 per cent in 2008 while the proportion of the population using improved sanitation facilities rose from 9 to 14 per cent. Sanitation access is woefully inadequate.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	384
Total renewable water (actual) (10^9 m³/yr)	2008	6.3
Total renewable per capita (actual) (m³/inhab/yr)	2008	1 279
Surface water: total renewable (actual) (10^9 m³/yr)	2008	6.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.5
Dependency ratio (%)	2008	55.6

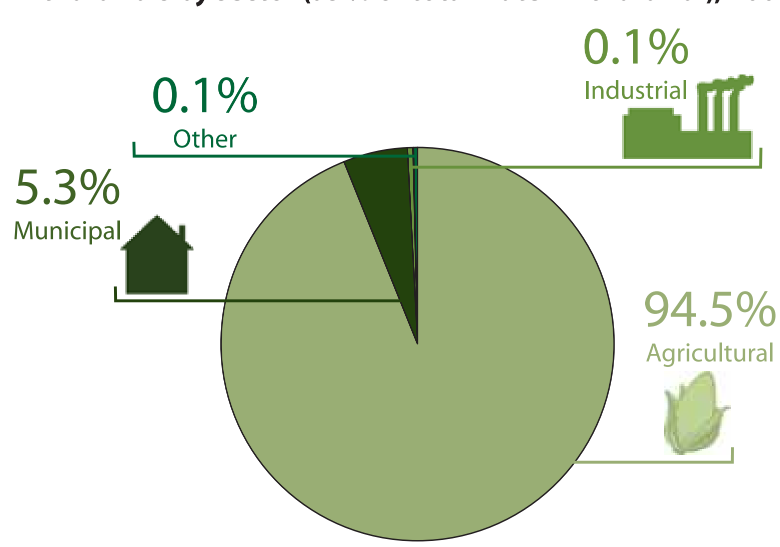
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2004	0.6
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2007	121.7
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2007	9.2

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

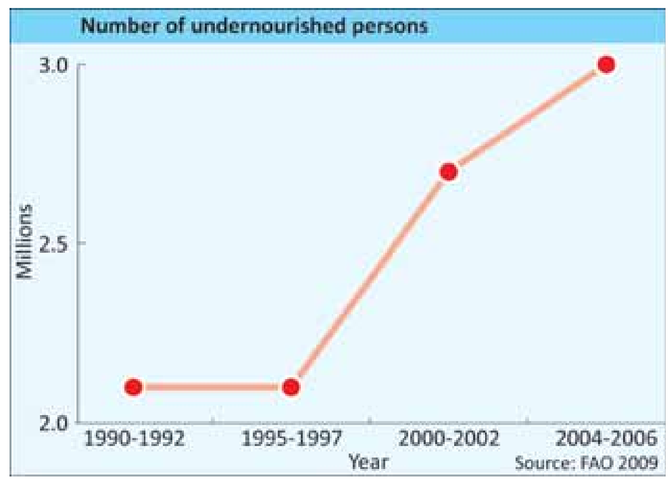
Withdrawals by sector (as % of total water withdrawal), 2004



Water Stress and Food Security

Eritrea's geographic location on the Horn of Africa makes it one of the hottest and driest places in the world. Water scarcity is projected to worsen as the impacts of climate change become more severe. A temperature rise of over four degrees Celsius by 2050 could diminish the amount of water available from runoff and boreholes and cause longer and more severe droughts.

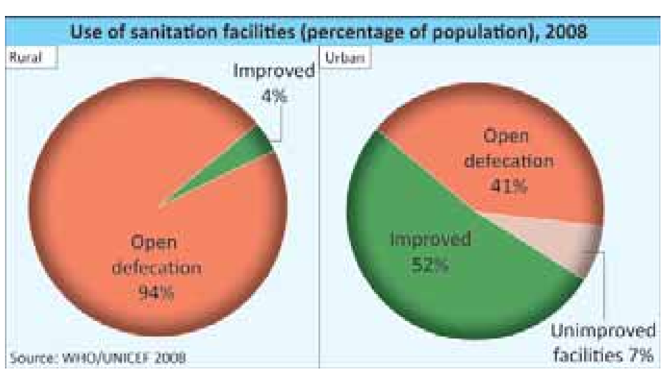
Erratic rainfall and chronic drought undermine food security in Eritrea. When the harvest is good, the country imports roughly 40 per cent of its food supply. The country's ability to feed its population has been further limited by years of drought, and insufficient food supplies have led to higher prices that few are able to afford. WHO states that 600 000 people were "at the verge of immediate risk of food insecurity and malnutrition" in 2009, and humanitarian actors noted a dramatic increase in admissions to therapeutic feeding centres.



Water shortages force Eritreans to rely on unsafe water sources and to travel long distances to reach a water supply. It takes more than 25 per cent of the population over 30 minutes to make a water collection trip making it difficult for many to adequately meet daily drinking water needs (WHO/UNICEF 2010).

Use of Improved Sanitation Facilities

Eritrea has one of the world's lowest levels of access to improved sanitation facilities, ranking 10th out of 173 countries. According to a 2010 report by WHO and UNICEF, in 2008 only four per cent of rural Eritreans used improved sanitation facilities, and 96 per cent practiced open defecation. Urban populations fared better, with 52 per cent using improved sanitation facilities and 41 per cent practicing open defecation, although city-dwellers comprise a mere 21 per cent of Eritrea's population. In addition to the urban-rural divide, socioeconomic discrepancies factor into the sanitation equation: poor people are less likely to have access to hygienic facilities (WHO/UNICEF 2010).



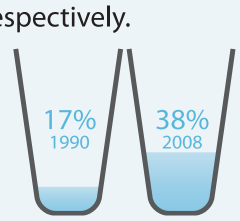
Recurrent rainfall shortages and poverty have also contributed to Eritrea's sanitation challenges. Drought and border disputes tend to take precedence over sanitation concerns, and low management and implementation capacities further restrict the country's ability to address sanitation issues.

Federal Democratic Republic of
Ethiopia

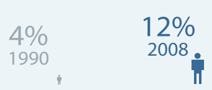
Total Surface Area: 1 104 300 km^2
Estimated Population in 2009: 82 825 000

Progress Towards MDG Goal 7

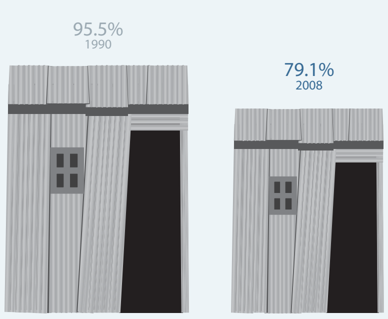
Despite its abundant water resources, access to water and sanitation in Ethiopia is among the world's lowest. More resources have been directed at improving urban water services than towards rural areas and the provision of sanitation. Overall access to improved water increased from 17 to 38 per cent from 1990 to 2008. By 2008, however, about 96 per cent of urban areas had such access although less than 20 per cent of the population resides in cities. Improved sanitation coverage grew from 4 to 12 per cent. The MDG targets for water and sanitation are 70 and 56 per cent, respectively.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	848
Total renewable water (actual) (10^9 m^3/yr)	2008	122
Total renewable per capita (actual) (m^3/inhab/yr)	2008	1 512
Surface water: total renewable (actual) (10^9 m^3/yr)	2008	120
Groundwater: total renewable (actual) (10^9 m^3/yr)	2008	20
Dependency ratio (%)	2008	0

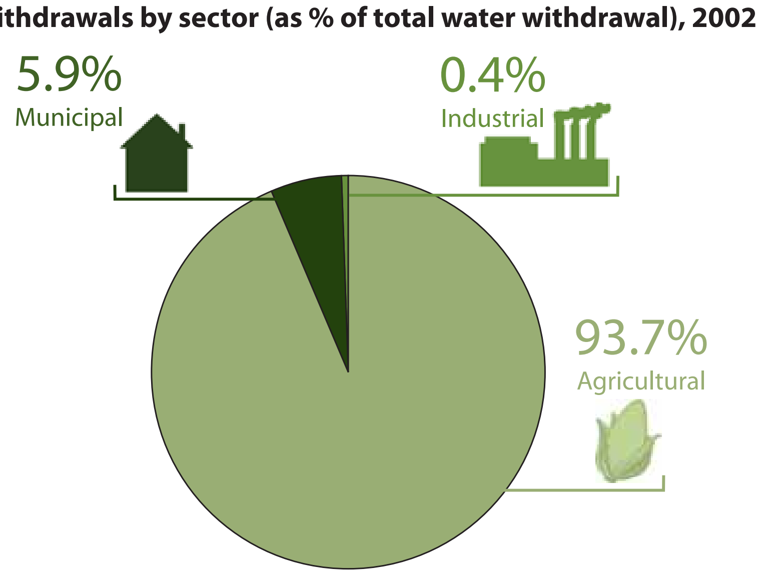
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m^3/yr)	2002	5.6
Surface water withdrawal (10^9 m^3/yr)	...	...
Groundwater withdrawal (10^9 m^3/yr)	...	...
Total water withdrawal per capita (m^3/inhab/yr)	2002	80.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	4.6

Irrigation

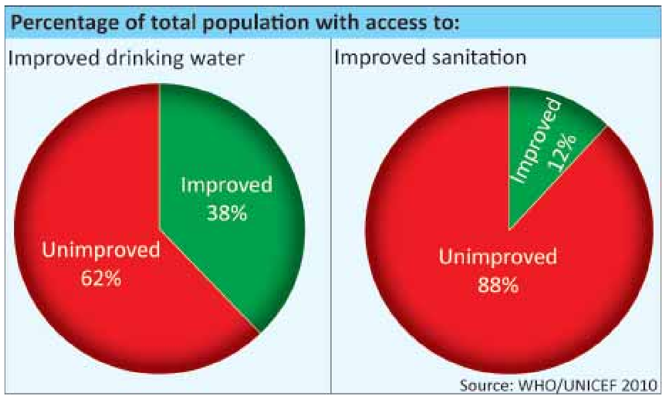
	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2002



Rural Water and Sanitation Infrastructure

In 2008, only 38 per cent of Ethiopia's population had access to an improved source of drinking water, the second-lowest rate in the world. This figure falls further to 26 per cent for rural areas. Access to improved sanitation facilities is even lower at 12 per cent nationally and eight per cent for rural locations. Ethiopia's population is overwhelmingly rural with only 17 per cent living in urban centres making the development of adequate rural water and sanitation infrastructure a key challenge facing the country (WHO/UNICEF 2010).



The Ethiopian government's Water Sector Development Programme was created in 2002 to increase rural access to potable water to 98 per cent by 2012, and rural access to latrines to 100 per cent by constructing over 13 million latrines (Aboma 2009). Despite the improvements achieved so far, the country appears set to fail in realizing these ambitious targets. According to the latest estimates, open defecation is still practiced by 71 per cent of the rural population, posing major health risks in these areas (WHO/UNICEF 2010). Meanwhile, even the quarter of the rural population with access to an improved water source often has to travel a considerable distance to acquire it—currently no rural households have access to piped water according to the WHO/UNICEF Joint Monitoring Program for Water and Sanitation.

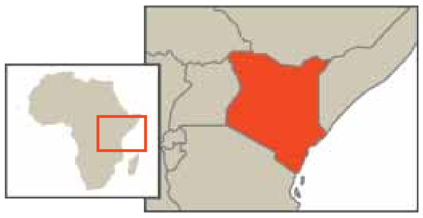
Drought and Food Security

Ethiopia faces a heightened vulnerability to extreme weather events such as droughts and floods. According to EM-DAT, the International Disasters Database, in the last 30 years there have been nine periods of drought and 43 floods. One of the most serious drought events, which occurred in 2003, affected approximately 12.6 million people. In addition to the direct impact on human lives, natural disasters have also been detrimental to Ethiopia's economy. Total economic damage costs due to the three major droughts since 1969 are estimated at US$92.6 million (EM-DAT 2010).

The changing climate is expected to increase the frequency and intensity of drought and flood events in the coming years, exposing Ethiopia to more risk. The increase in natural disasters, coupled with rapid population growth and weak infrastructure, could have dire consequences for Ethiopia's population of 82.8 million people. In 2008, two successive seasons of minimal rain events left Ethiopia in drought, and millions of people across the country hungry as crops failed and food prices soared (NASA Earth Observatory 2008). With close to half of Ethiopia's GDP attributable to the agricultural sector, managing food and economic security in the face of an uncertain climate continues to be an issue.

Top 10 natural disasters in Ethiopia 1900-2010 (Source: EM-DAT 2010)

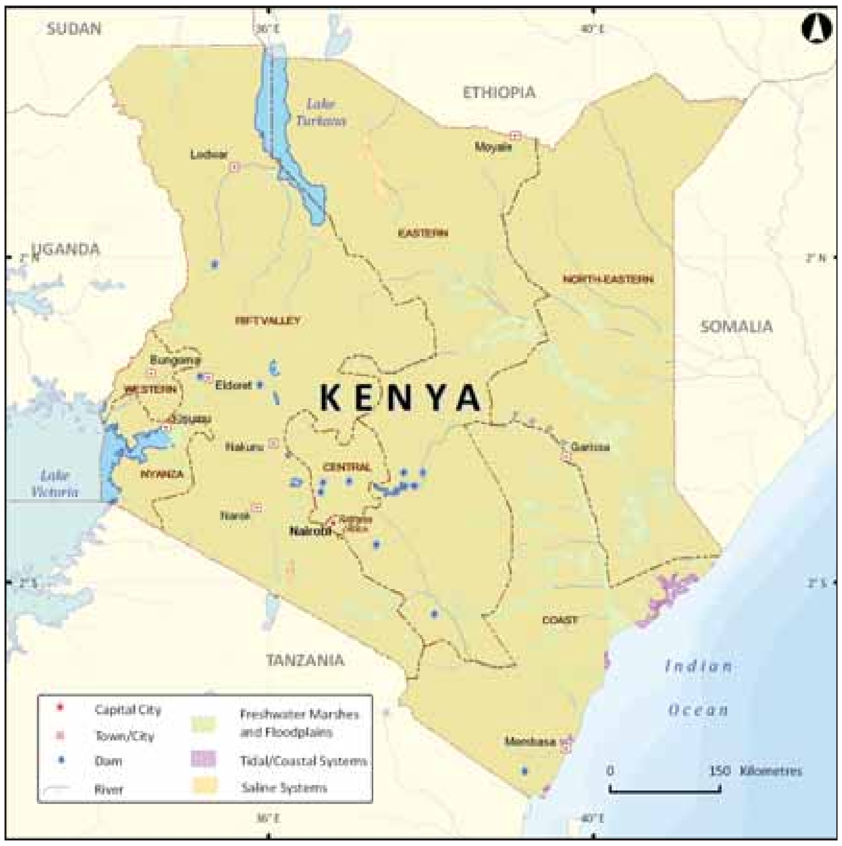
Total number of affected people:			Economic damage costs:		
Disaster	Date	Total affected (millions)	Disaster	Date	Damage (000 USD)
Drought	2003	12.6	Drought	Dec-73	76 000
Drought	May-83	7.8	Drought	Jul-98	15 600
Drought	Jun-87	7.0	Earthquake	25-Aug-06	6 750
Drought	Oct-89	6.5	Flood	23-Apr-05	5 000
Drought	May-08	6.4	Flood	15-Aug-94	3 500
Drought	Sep-99	4.9	Flood	5-Aug-94	3 200
Drought	Dec-73	3.0	Flood	23-Aug-99	2 700
Drought	Nov-05	2.6	Flood	20-May-05	1 200
Drought	Sep-69	1.7	Drought	Sep-69	1 000
Drought	Jul-65	1.5	Flood	7-May-68	920



Republic of

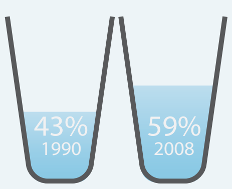
Kenya

Total Surface Area: 580 367 km²
Estimated Population in 2009: 39 802 000



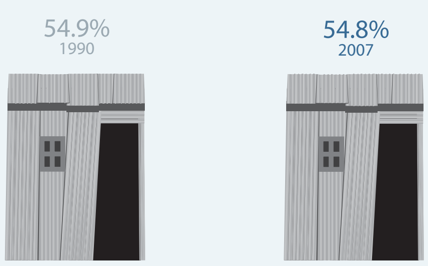
Progress Towards MDG Goal 7

In 2008, 59 per cent of Kenya's population had access to improved drinking water: 83 per cent of urban populations and 52 per cent of rural population. Urban sanitation is lacking, with only 27 per cent of urbanites using improved sources in 2008, compared to 32 per cent in rural areas. Kenya's rural areas have high water and sanitation access compared to rural areas in other sub-Saharan countries.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	630
Total renewable water (actual) (10^9 m³/yr)	2008	30.7
Total renewable per capita (actual) (m³/inhab/yr)	2008	792
Surface water: total renewable (actual) (10^9 m³/yr)	2008	30.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	3.5
Dependency ratio (%)	2008	32.6

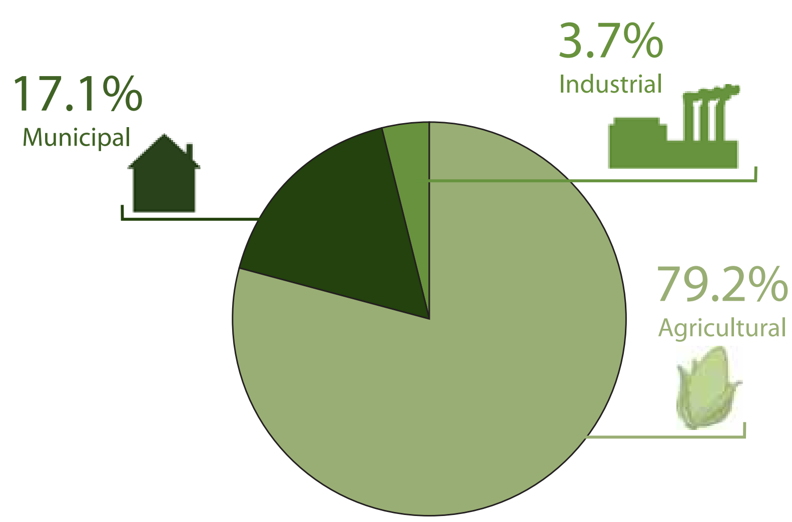
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2003	2.7
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2007	72.4
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2007	8.9

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	1990	30

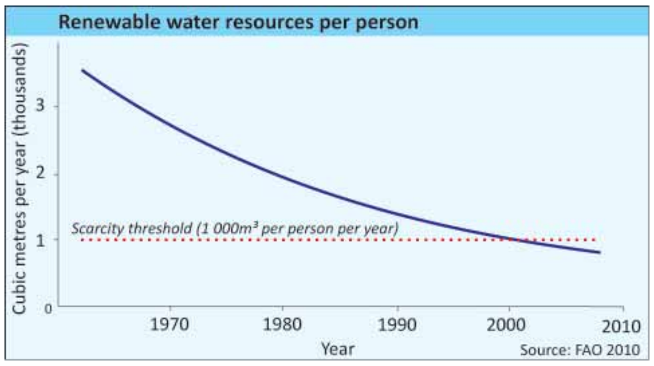
Withdrawals by sector (as % of total water withdrawal), 2003



Endemic Droughts and Water Scarcity

Despite its location along the equator, Kenya faces extreme variations in climate due to its various landforms, particularly the Rift Valley. The variable climate brings frequent droughts as well as floods. Rainfall is unevenly distributed throughout the country, with less than 200 mm/yr falling in northern Kenya (UNEP 2009) (read about Kenya's Water Towers on page 6). Surface water resources are also limited, covering only two per cent of Kenya's total surface area (UNESCO 2006).

Successfully storing and distributing already stretched water resources has proven to be a challenge, leaving the sector vulnerable to climatic variations. In addition, the erosion and sedimentation that follow Kenya's frequent flood events make improved catchment management difficult to achieve.

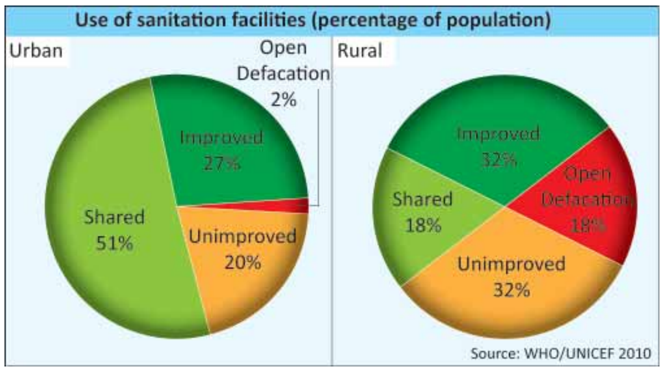


Kenya's current per capita water availability of 792 m^3 falls below the scarcity threshold (FAO 2008), and apparently the projected population growth will further aggravate the pressures on this already limited supply.

Waste Management Issues and Implications for Water Quality

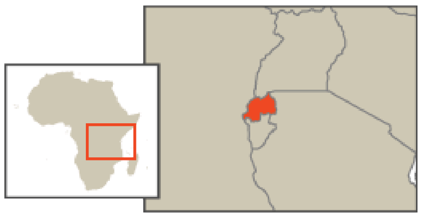
Not only will population growth strain Kenya's already limited water supply, it will also put pressures on urban and industrial sectors, which in turn will increase water pollution. The urban population is steadily increasing while access to functioning and affordable wastewater facilities in Kenya is not.

In Kibera, Nairobi's largest slum and the second-largest slum in Africa, waste management is a pressing issue. Given that these slum-settlements are illegal in Kenya, slum-dwellers are not provided any services, which would include latrines, water, maintenance and repairs, infrastructure, etc, which results in higher rates of defecation in public areas where there are no clearly defined boundaries for waste disposal. Although the proportion of urban dwellers defecating publicly has declined by 33 per cent (from three per cent in 1990 to two per cent in 2008), this has not been the case in the rural areas where the proportion has increased from 17 per cent in 1990 t0 18 per cent in 2008. In fact, more than 600 000 residents of Kibera have developed a common practice known as the "flying toilet", which refers to the practice of defecating into a plastic bag



that is then tossed away (Corcoran and others 2010). This custom poses serious environmental problems and health risks for the people in the area and greatly contributes to water pollution.

A recent invention commonly known as the "Peepoo", a biodegradable bag coated with a chemical that fertilizes human waste, is currently on trial with 50 different families throughout Kibera. Although this option has the potential to make a significant difference in the health of the Kibera population, it is only a temporary fix to the massive structural changes that need to take place in Kenya for residents to have any hope for clean water and improved sanitation.

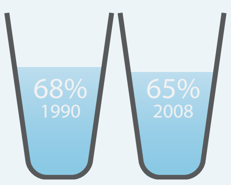


Republic of Rwanda

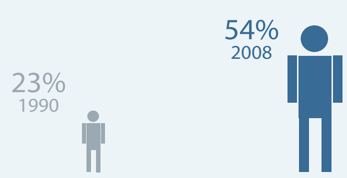
Total Surface Area: 26 338 km²
Estimated Population in 2009: 9 998 000

Progress Towards MDG Goal 7

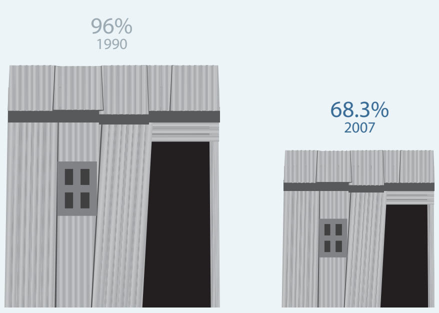
Reforms beginning in 2000 led to overall improvements in water supply and sanitation. Rwanda aims to increase improved drinking water coverage from 65 per cent in 2008 to 85 per cent in 2015, and access to improved sanitation from 54 per cent to 65 per cent. Although sanitation coverage improved from 1990 to 2008 (from 35 to 50 per cent in urban areas and from 22 to 55 per cent in rural ones), meeting the MDG target will be a challenge since there are very few wastewater systems.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 212
Total renewable water (actual) (10^9 m³/yr)	2008	9.5
Total renewable per capita (actual) (m³/inhab/yr)	2008	977.3
Surface water: total renewable (actual) (10^9 m³/yr)	2008	9.5
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	7
Dependency ratio (%)	2008	0

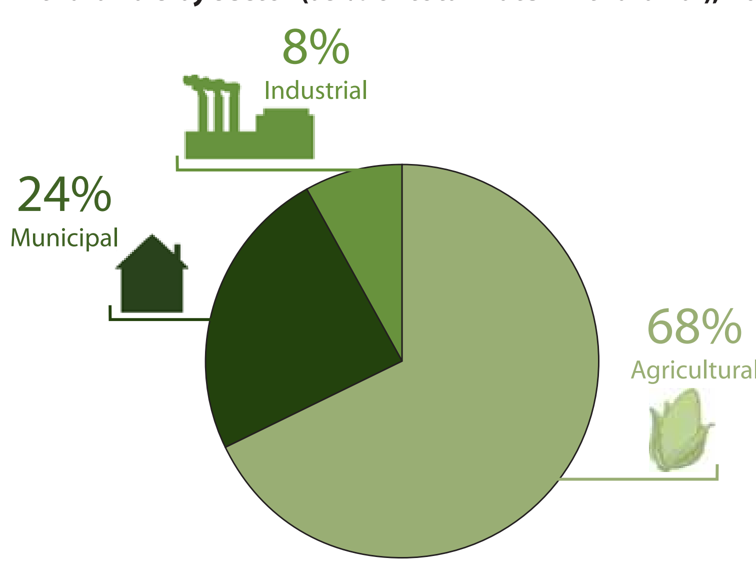
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.2
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	17.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	1.6

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



Water Pollution

Rwanda is located within the watersheds of both the Nile and Congo Rivers, with surface waters covering over eight per cent of the country's area (FAO 2005). Despite the relative abundance of water resources, access to potable water remains a challenge. An estimated 35 per cent of Rwanda's approximately 10 million people have no access to an improved drinking water source. In fact, the percentage of the population forced to use unimproved water has increased over the last two decades, from four per cent in 1990 to 23 per cent in 2008 in urban areas, and from 34 to 38 per cent in rural areas (WHO/UNICEF 2010). A high population density combined with increasing water pollution levels are contributing further to this trend.

Untreated effluents from both domestic and industrial activities are often released directly into water courses. Marshlands such as Nyabugogu, Gikondo and Nyabarongo near Kigali City, have been polluted due to a lack of wastewater treatment in most industrial plants. In many urban and peri-urban areas, sewerage pits tap the water table causing further contamination (REMA 2009). The agricultural sector, which accounts for 37 per cent of Rwanda's GDP (World Bank 2008) and employs 90 per cent of its population is contributing to the high levels of water pollution through inappropriate application of fertilizers and pesticides.

Rwanda's rich mineral resources are important for the country's economy. In 2008, the exports of metals and ores made up around 28 per cent of all merchandise exports (World Bank 2008). However, mining activities have also had an impact on water quality in the region through increased river-water contamination and sedimentation.

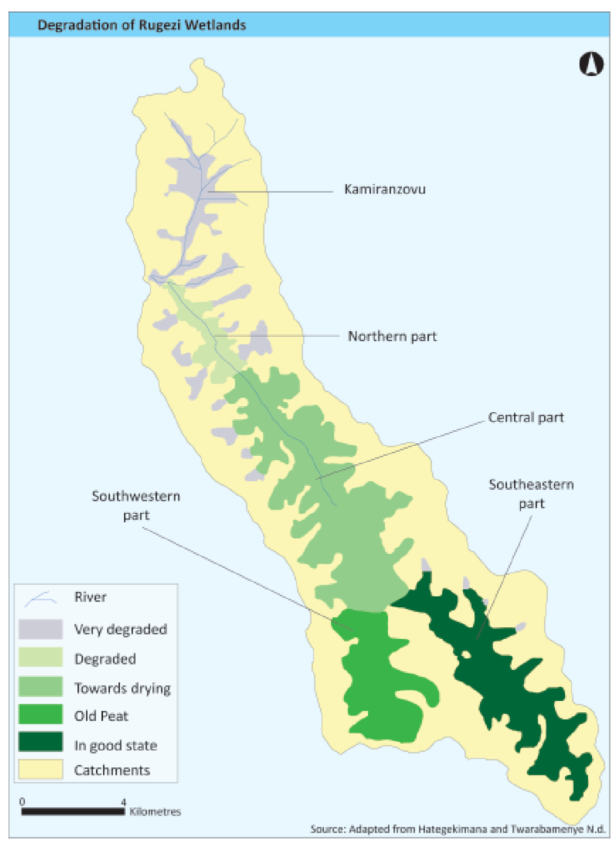
Wetland Degradation

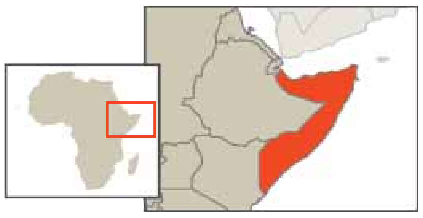
Rwanda's wetlands cover an estimated 165 000 ha, constituting seven per cent of the country's surface area (REMA 2009). The vast wetland ecosystems play a vital role in regulating and purifying water resources in the country.

Despite their important function, human activities are posing a serious threat to these key ecosystems. Approximately 56 per cent of existing wetlands are already being used for agriculture. Such practices can have far-reaching impacts on the local ecosystem, including reduction in water outflow volume, lower groundwater yields and the disappearance of permanent springs (REMA 2009).

This can prove disastrous to the services provided by wetlands. For example, the degradation of the Rugezi wetlands has led to a decrease in water levels in the lakes supplying both the Ntaruka and Mukura hydropower stations. In turn, this has led to a reduction in electrical generating capacity from these plants and an estimated daily expenditure of US$65 000 by ELECTROGAZ on diesel generation to meet the shortfall (REMA 2009).

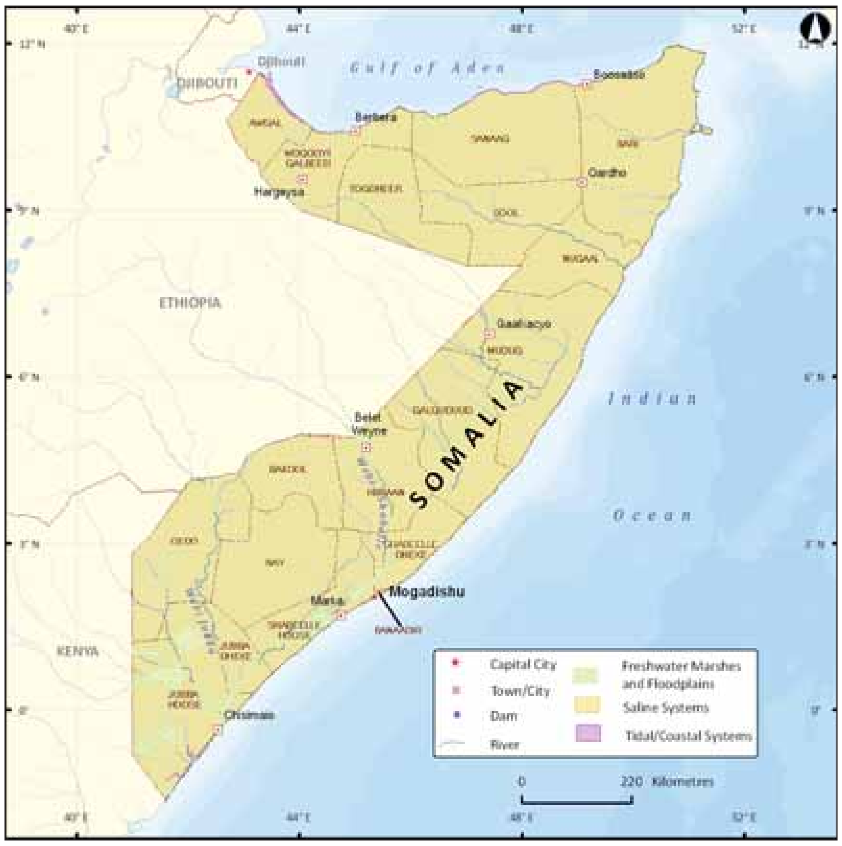
Valuing and protecting Rwanda's wetlands is essential for the sustainable provision of its valuable ecological services.





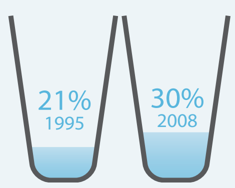
Somalia Repubic

Total Surface Area: 637 657 km²
Estimated Population in 2009: 9 133 000



Progress Towards MDG Goal 7

Water and sanitation supply in Somalia are constrained by water scarcity, severe droughts and flooding, increasing precipitation variability, local water conflicts and political instability. Many people have fled the countryside for peri-urban areas. Access to improved water sources in 2008 was extremely low at 30 per cent, with 67 per cent in urban areas and only 9 per cent in rural ones, after a decline in the latter from 20 per cent in 1995. Access to improved sanitation also declined in rural areas, from 12 to 6 per cent.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage

N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	282
Total renewable water (actual) (10^9 m^3/yr)	2008	14.7
Total renewable per capita (actual) (m^3/inhab/yr)	2008	1 647
Surface water: total renewable (actual) (10^9 m^3/yr)	2008	14.4
Groundwater: total renewable (actual) (10^9 m^3/yr)	2008	3.3
Dependency ratio (%)	2008	59.18

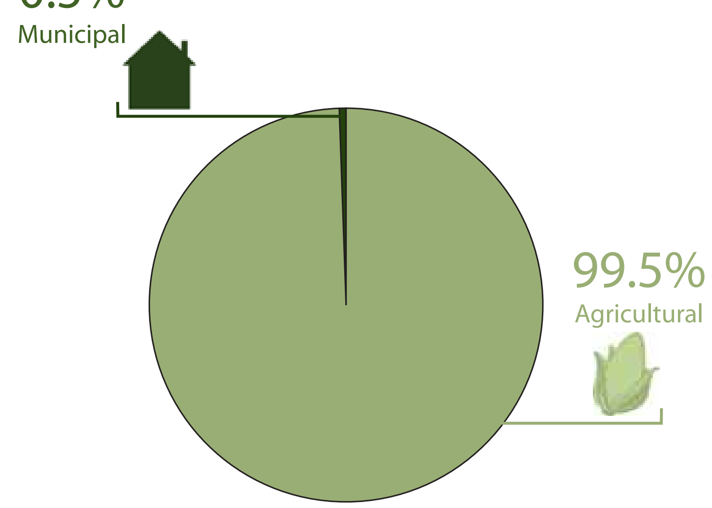
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m^3/yr)	2003	3.3
Surface water withdrawal (10^9 m^3/yr)	2003	3.3
Groundwater withdrawal (10^9 m^3/yr)	2003	0.01
Total water withdrawal per capita (m^3/inhab/yr)	2007	377.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2007	22.4

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1984	30
Area salinized by irrigation (1000 ha)	...	...

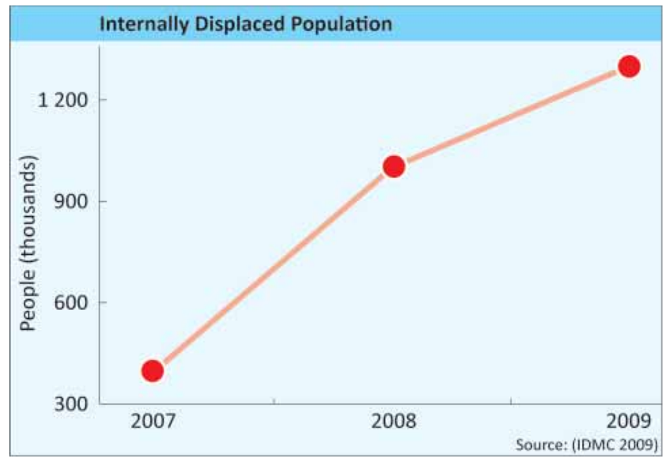
Withdrawals by sector (as % of total water withdrawal), 2003



Civil Unrest and Water Access

Two decades of civil unrest have contributed to a complete collapse of infrastructure in much of the country. Even basic resources such as food and water are severely lacking and where available sold at inflated prices, leaving many without enough water to meet their basic daily needs. Access to potable water and sanitation services is amongst the lowest in the world. Improved drinking water is available to only 30 per cent of the population whilst only 23 per cent have access to improved sanitation facilities (WHO/UNICEF 2010).

Escalated fighting has displaced an estimated 1.3 million people in the country (IDMC 2009). Rather than stabilizing, these numbers have continued to grow rapidly over the last few years, leaving much of the population in camps for the internally displaced and dependent on aid assistance for their water and food needs. According to UN agencies, an estimated 3.2 million people, or around 35 per cent of the population, are in need of emergency humanitarian assistance (UNOCHA 2010a).

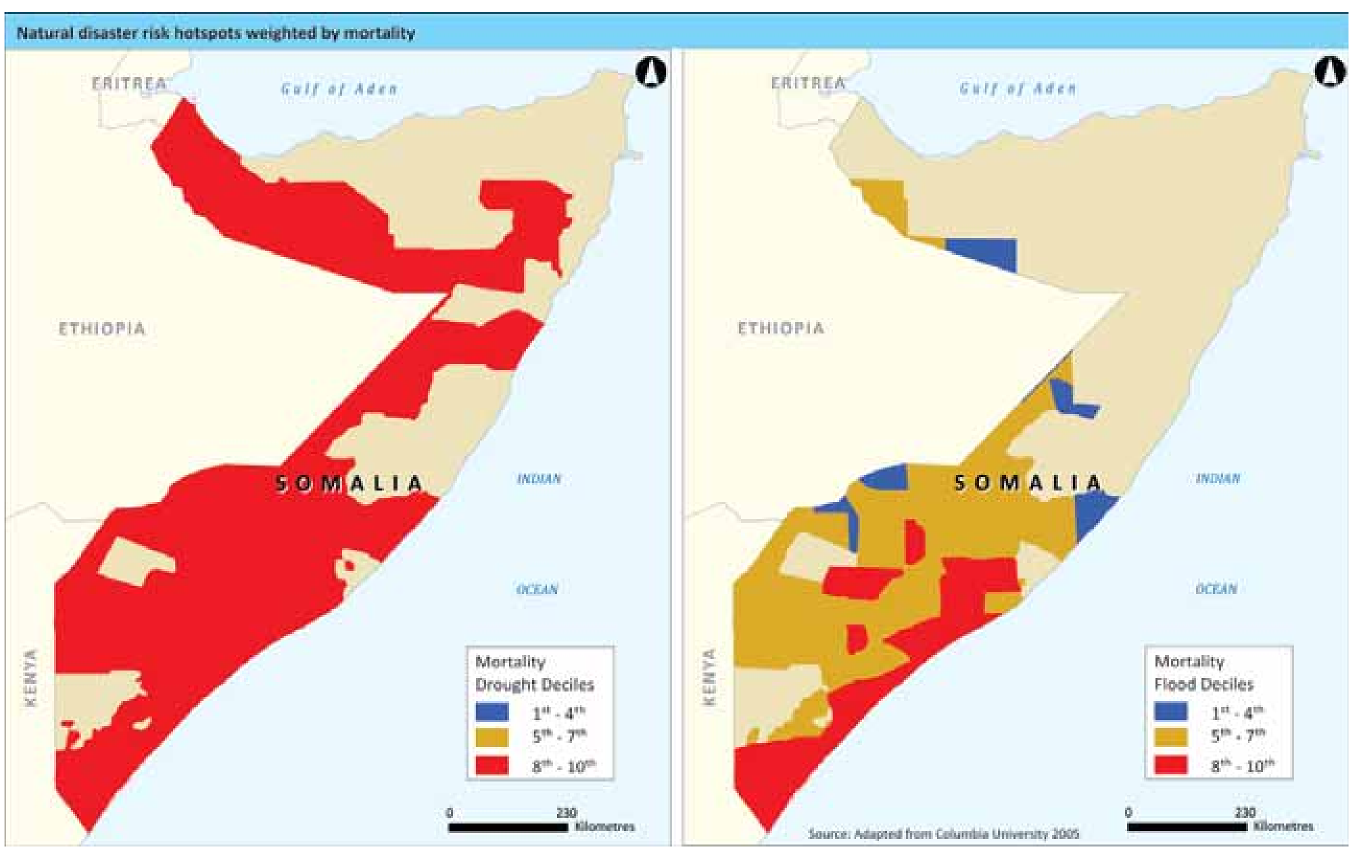


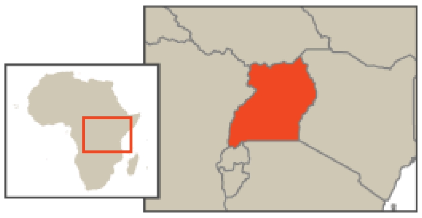
Impacts of Extreme Climate on Water Supply

Somalia's climate leaves the country vulnerable to extreme weather events with droughts and/or floods affecting much of the territory. Somalia ranks in the top risk group for natural disasters when weighted by both mortality and GDP (EM-DAT 2010). Between 2000 and 2009 alone, Somalia experienced four drought events and 18 floods affecting an estimated 5.6 million people (EM-DAT 2010).

Somalia's large cattle herding communities are particularly susceptible to the arid climate and frequent drought periods. Water shortages in 2002 culminated in the loss of up to 40 per cent of cattle and 10–12 per cent of goats and sheep (FAO 2005). Acute water shortages prompted by a prolonged drought in the central Galgadud region has seen thousands of villagers abandoning the area. Some parts of Galgadud have endured more than two years without rain and many of the local wells and water pans have completely dried up leaving many desperate for water (UNOCHA 2010b).

In addition, the country's 3 330 km-long coastline, the longest in Africa, as well as its two perennial rivers in the south (the Juba and Shabelle), are prone to frequent flood events. As recently as April 2010, hundreds of people in Somalia's Middle Shabelle region were displaced and more than 7 000 ha of newly sown crops lost following flooding when the Shabelle burst its banks (UNOCHA 2010c). In the same month, an estimated 2 500 people were displaced from their homes in the semi-autonomous Somaliland region following heavy rains and strong winds (UNOCHA 2010d).





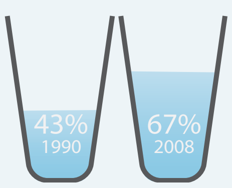
Republic of

Uganda

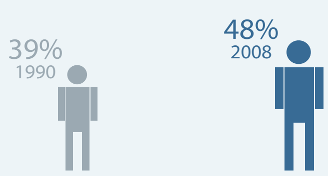
Total Surface Area: 241 038 km²
Estimated Population in 2009: 32 710 000

Progress Towards MDG Goal 7

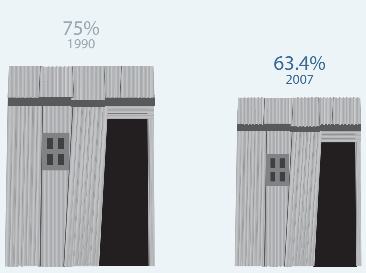
Uganda has ample water resources, but in 2008, 36 per cent of the rural population still lacked access to improved drinking water and over 60 per cent of the total rural population lacked access to improved sanitation. Successful reforms have helped to increase urban drinking water coverage from 78 to 91 per cent from 1990 to 2008. The overall sanitation target is 83 per cent, leaving 35 per cent of the country's population yet to be served before 2015.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 180
Total renewable water (actual) (10^9 m³/yr)	2008	66
Total renewable per capita (actual) (m³/inhab/yr)	2008	2 085
Surface water: total renewable (actual) (10^9 m³/yr)	2008	66
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	29
Dependency ratio (%)	2008	40.9

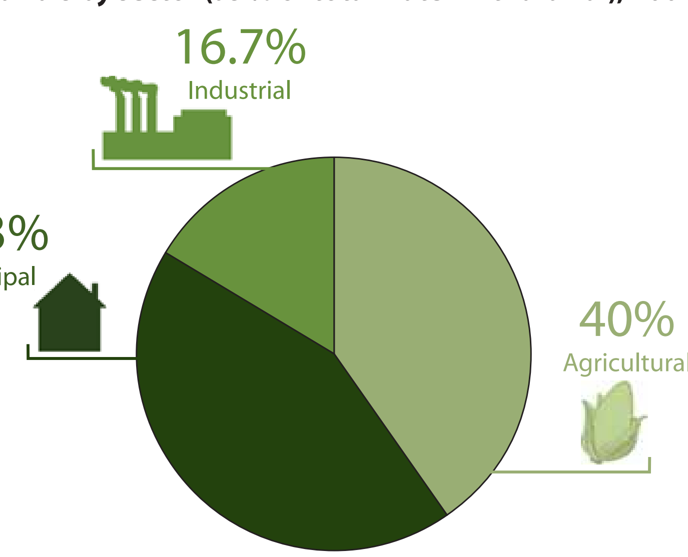
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2002	0.3
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	11.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.5

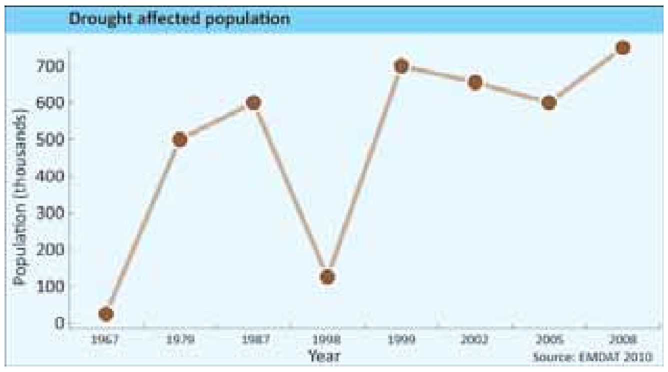
Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2002



Drought



Since 1960, Uganda has experienced eight drought periods, five of which have occurred in the years since 1998—1998, 1999, 2002, 2005 and 2008 (EM-DAT 2010). According to the country's National Adaptation Plan of Action (NAPA), drought events are increasing in frequency and severity, especially in the semi-arid areas of the cattle corridor with the rural poor most affected (UNOCHA 2009a). Food production in the country has declined as a result and some regions are perpetually dependent on food aid to meet needs (UNOCHA 2009a). Unreliable rainfall in Karamoja, Uganda's poorest region, has left most of its 1.1 million people facing starvation (UNOCHA 2009b). In addition, successive droughts have contributed to conflict amongst pastoralists over increasingly limited resources (UNOCHA 2009b).

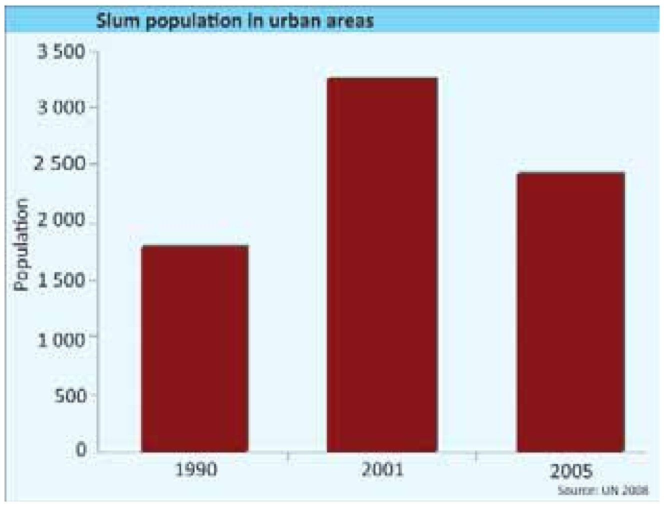
As well as leaving boreholes dry, falling water levels have affected hydroelectric power production in the country. Prolonged periods of drought in the region have also resulted in lower water levels on Lake Victoria, increasing power shortages in Uganda (UNOCHA 2005). At full capacity, Uganda's two dams produce 270 MW of electricity, however demand often exceeds availability. This shortfall is being further aggravated by droughts in upstream Rwanda and Tanzania, which in the past have led to the two power stations underperforming by up to 50 MW (UNOCHA 2005).

Sanitation Access in Kampala

More than half of Uganda's 32.7 million people do not have access to improved sanitation facilities (WHO/UNICEF 2010). This situation is especially dire in the slums of Kampala, where according to a recent survey by the Catholic Church's Justice and Peace Centre, the average toilet-to-household ratio is around 1:25 (UNOCHA 2010).

In the last three decades, Kampala's population has more than tripled, growing from 469 thousand in 1980 to approximately 1 598 thousand in 2010 (United Nations 2009). While the population has grown rapidly during this period, the city's infrastructure has not developed at the same rate. UN-HABITAT estimates that 44 per cent of Kampala's population live in unplanned, underserviced slums, with informal settlements covering up to a quarter of the city's total area (UNOCHA 2010).

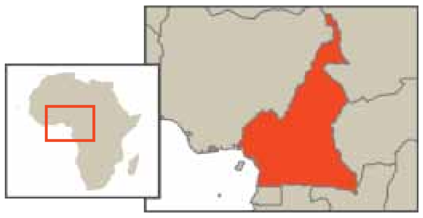
The lack of adequate sanitation infrastructure is also contributing to the pollution of local springs, with one study estimating that up to 90 per cent of the natural springs in the city have been contaminated (UNOCHA 2010). With only 19 per cent of the urban population able to access a piped water supply (WHO/UNICEF 2010), many of the city's poorest residents are reliant on springs for their water usage resulting in a high prevalence of sanitation-related diseases such as diarrhoea and worm infestations.




Brian Jackson/Flickr.com

Central Africa

Cameroon
Central African Republic
Chad
Congo
Democratic Republic of Congo
Equatorial Guinea
Gabon
Sao Tomé and Principe



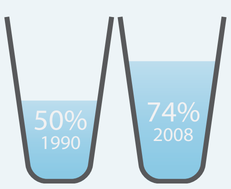
Republic of

Cameroon

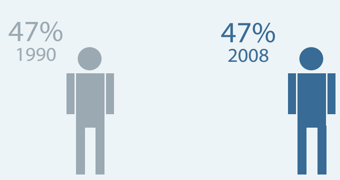
Total Surface Area: 475 442 km²
Estimated Population in 2009: 19 522 000

Progress Towards MDG Goal 7

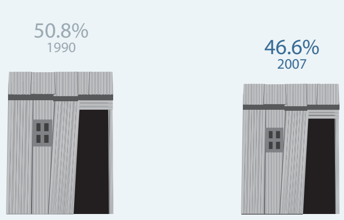
Cameroon's water sector is highly fragmented and underfunded, with an aging and poorly maintained infrastructure network that has hampered the provision of improved water sources. In addition, there has been rapid urbanization in smaller towns and peri-urban areas, overwhelming services. Cameroon increased overall access to improved water in cities from 77 to 92 per cent, and in rural areas from 31 to 47 per cent from 1990 to 2008. Overall there has not been any change in the percentage of population using improved sanitation between 1990 and 2008.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 604
Total renewable water (actual) (10^9 m³/yr)	2008	285.5
Total renewable per capita (actual) (m³/inhab/yr)	2008	14 957
Surface water: total renewable (actual) (10^9 m³/yr)	2008	280.5
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	100
Dependency ratio (%)	2008	4.4

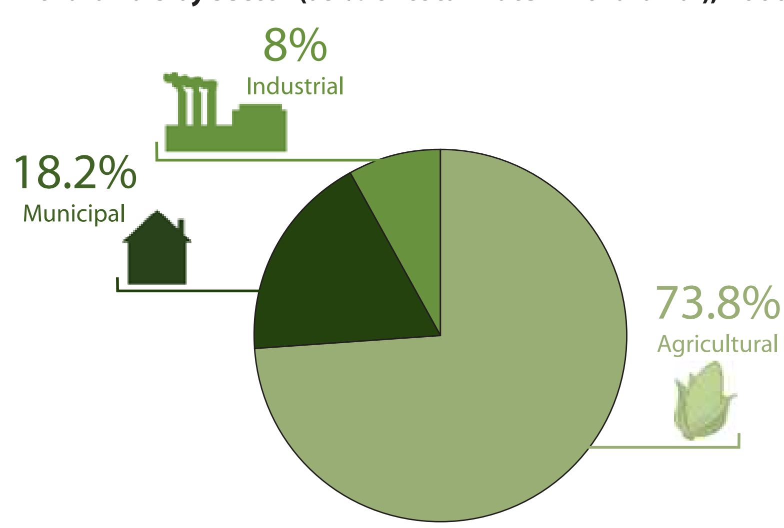
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.9
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	59.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.3

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

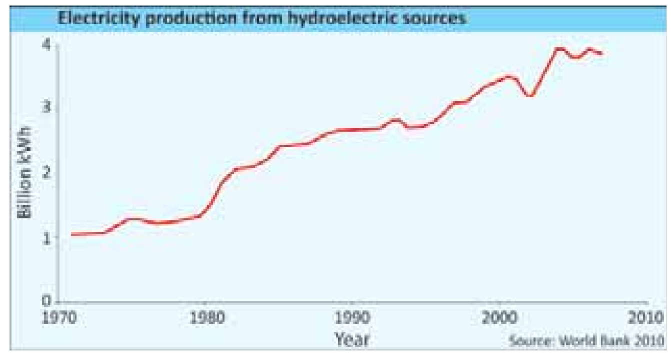
Withdrawals by sector (as % of total water withdrawal), 2000



Hydropower Capacity and Drought Vulnerability

Cameroon is endowed with abundant surface water resources, with 280.5 billion cubic metres available annually (FAO 2008) and an estimated hydropower potential of 35 GW (WWAP 2009). At present, only two per cent of this huge potential has been developed. Despite this under-utilization, hydroelectric power made up 67 per cent of all electricity generated in the country in 2007 (World Bank 2010). Total production has increased greatly in the last few decades, rising from 2.7 billion kWh in 1990 to 3.8 billion kWh in 2007 (World Bank 2010).

While capacity has increased, over half of the population still has no access to electricity. This figure falls even further in rural areas where 80 per cent of the population has no access (IEA 2006). In addition, the lack of a nationwide grid results in an inefficient system where 20 per cent of the generated power output is lost during transmission and distribution



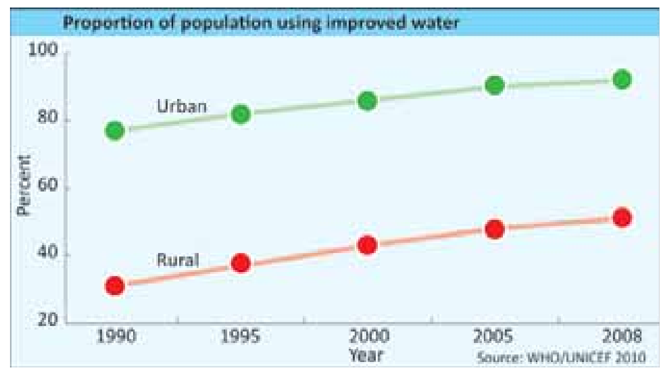
(World Bank 2009). To minimize such losses and enable greater access in rural and isolated areas, the Rural Electrification Agency (World Bank 2009) is promoting micro-hydro schemes.

Cameroon's dependence on hydropower for meeting the vast majority of its energy needs leaves the sector vulnerable to any changes in climate. Drought periods can have a serious impact on power availability, with power shortages already a problem during the dry season.

Rural Water Access

Despite plentiful renewable water, which averages at just under 15 000 m^3 per person annually, access to potable water remains a challenge. Nationally, a quarter of the population has no access to a clean drinking water source and less than half have use of improved sanitation facilities. Access is especially problematic in rural areas where 49 per cent are using unimproved water and 65 per cent have no access to sanitation (WHO/UNICEF 2010).

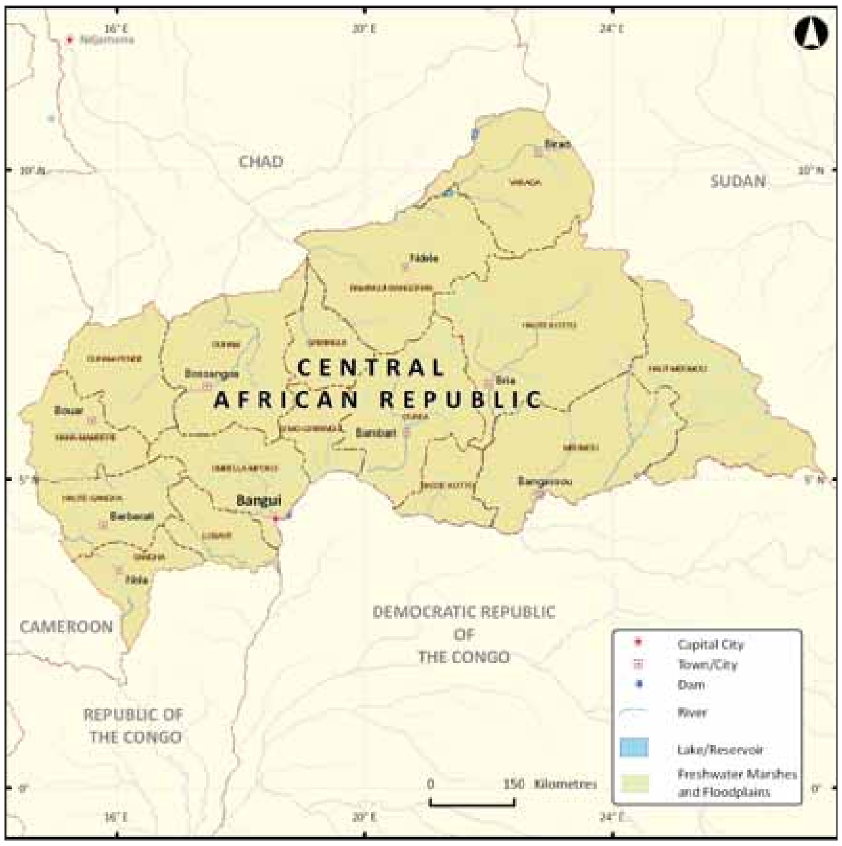
The country size (1 200 km in length), proximity to the sea, and typography give it a varied climate with wide differences in rainfall and vegetation. While the south of the country receives the maximum rainfall of up to 10 000 mm each year, this figure drops steeply further north, falling to a minimum of 500 mm in the far northern region of the country nearest the Sahara (WWAP 2009). Average rainfall has been declining since the 1950s, leading to increased



desertification in the north and a falling water table to reduced recharge. In addition, previously permanent wells are drying late in the dry season. In 2009, land degradation from farming in once-protected forest areas combined with an extended dry season culminated in an acute water scarcity crisis in the Mbouda District in western Cameroon. The local reservoir completely dried up leaving more than 100 000 residents with no access to water (UNOCHA 2009).

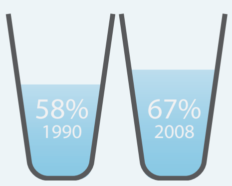
Central African Republic

Total Surface Area: 622 984 km²
Estimated Population in 2009: 4 422 000

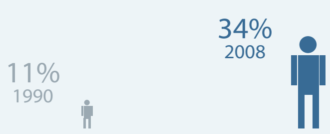


Progress Towards MDG Goal 7

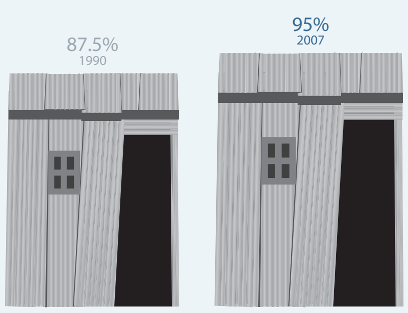
By 2008, 92 per cent of urbanites used improved drinking water, a rise from 78 per cent in 1990. More than 55 per cent of the country's population lives in rural areas, where the proportion served by improved drinking water increased from 47 to 51 per cent. Likewise, people in the countryside are less well served by improved sanitation facilities, with 28 per cent access in 2008 (up from 5 per cent in 1990) compared to 43 per cent (up from 21 per cent) in urban areas.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 343
Total renewable water (actual) (10^9 m^3/yr)	2008	144.4
Total renewable per capita (actual) (m^3/inhab/yr)	2008	33 280
Surface water: total renewable (actual) (10^9 m^3/yr)	2008	144.4
Groundwater: total renewable (actual) (10^9 m^3/yr)	2008	56
Dependency ratio (%)	2008	2.4

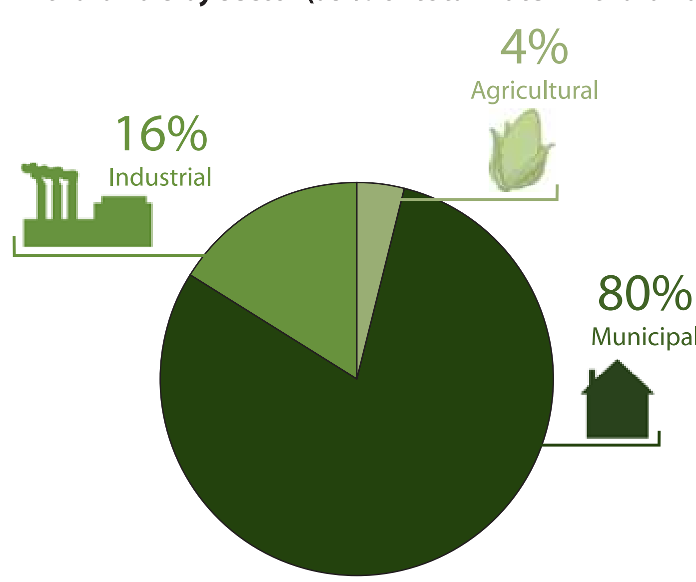
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m^3/yr)	2000	0.03
Surface water withdrawal (10^9 m^3/yr)	...	...
Groundwater withdrawal (10^9 m^3/yr)	...	...
Total water withdrawal per capita (m^3/inhab/yr)	2002	6.4
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.02

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000

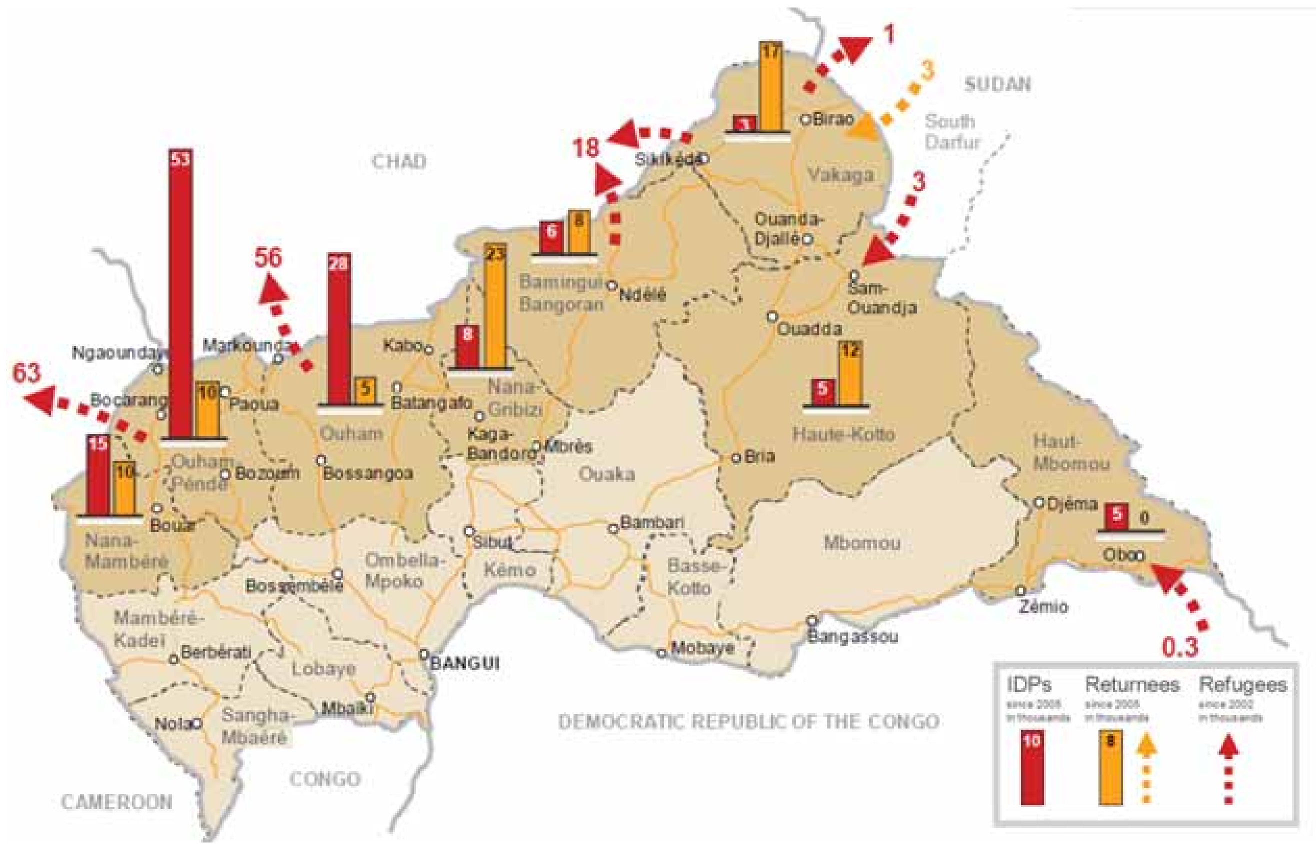


Civil Unrest Affecting Water Access

The Central African Republic is endowed with vast amounts of water resources, with two thirds of the land area lying in the Ubangi River basin and the remaining third in the basin of the Chari River. With an annual water availability of 33 280 m^3 per person there should be more than enough water to satisfy the relatively small population of 4.3 million people. Despite the abundance of water resources, however, 33 per cent of the population has no access to potable water (WHO/UNICEF 2010).

One of the key hurdles to improving water access in the region is the ongoing civil unrest and fighting between government forces and rebel groups. Relief agencies have reported that the situation is particularly problematic in the north-east of the country where thousands of people have been displaced from their villages, resulting in limited access to clean water supplies. According to the Internal Displacement Monitoring Center, there are currently over 160 000 internally displaced in the country (IDMC 2010).

The situation is further compounded by the instability in neighbouring countries such as the Democratic Republic of Congo (DRC). Despite assurances of peace, around 17 000 refugees from the DRC remain in the Central African Republic, settled temporarily in sites near the Ubangi river in the Lobaye region. Limited access to potable water amongst displaced populations is resulting in the spread of water-related diseases such as malaria, diarrhoea and typhoid (UNOCHA 2010).



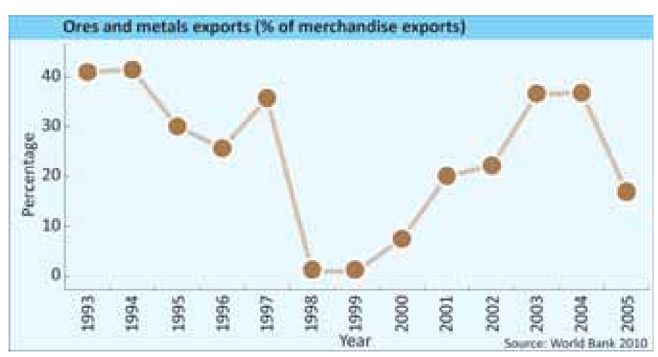
Source: IDMC 2010

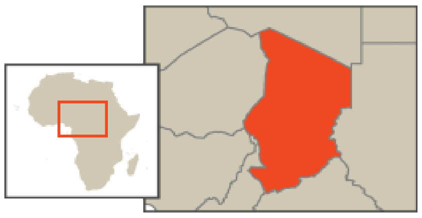
Riverine Ecosystem Degradation from Mining Activities

As well as its immense water resources, the Central African Republic is also rich in mineral deposits such as diamonds, gold and uranium. These valuable natural resources are essential for the country's economy. Ore and metal exports accounted for 17 per cent of the nation's total merchandise exports in 2005 (World Bank 2010). However, their extraction also presents a host of issues for local ecosystems.

Much of the mining is artisanal and occurs in and around streams resulting in localized damage to the riverine ecosystems. Such activities lead to further impacts, such as temporal diversion, waterway sedimentation, siltation and pollution. There are also health hazards to local communities from the stagnant water abandoned by miners, which acts as a breeding ground for mosquitoes, aggravating the spread of malaria. Further dangers include mercury runoff from gold mining.

With valuable mineral reserves in the country, balancing the economic value of mining activities with the negative impacts on the immediate environment and communities will become increasingly difficult.





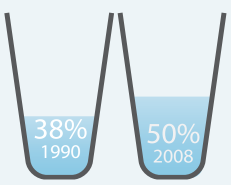
Republic of

Chad

Total Surface Area: 1 284 000 km²
Estimated Population in 2009: 11 206 000

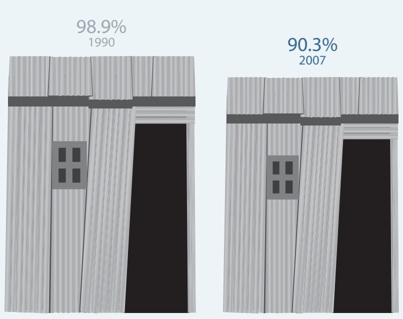
Progress Towards MDG Goal 7

Provision of water and sanitation is poor in Chad in part due to a decade of low rainfall and periodic droughts, migration to poorly served cities, the influx of Sudanese refugees and internal displacement of Chadians due to conflicts. By 2008, 67 per cent of the urban population had access to improved drinking water compared to 44 per cent in rural areas. Improved sanitation coverage grew from five to nine per cent in urban areas and from two to four per cent in rural areas from 1990 to 2008.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	322
Total renewable water (actual) (10^9 m³/yr)	2008	43
Total renewable per capita (actual) (m³/inhab/yr)	2008	3 940
Surface water: total renewable (actual) (10^9 m³/yr)	2008	41.5
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	11.5
Dependency ratio (%)	2008	65.1

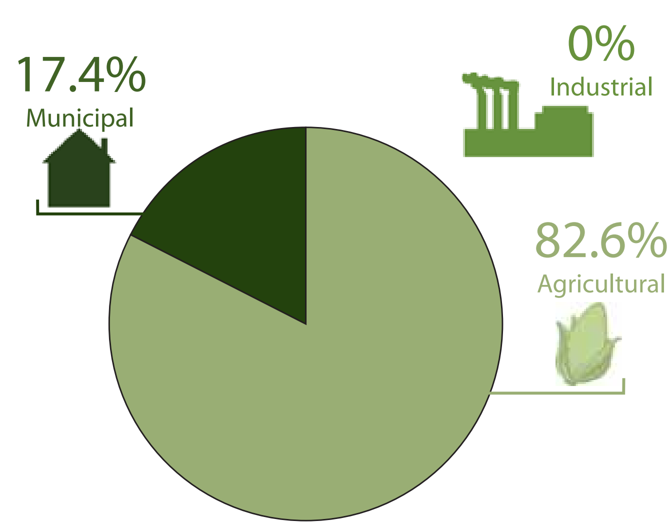
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.2
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	25.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.5

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

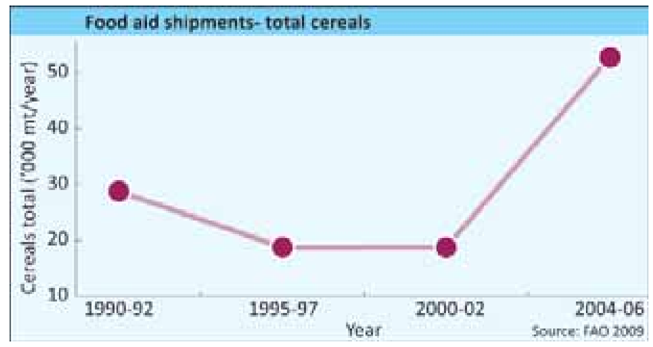
Withdrawals by sector (as % of total water withdrawal), 2000



Drought and Food Security

With 80 per cent of the population dependent on subsistence farming and herding, food security in Chad is highly vulnerable to climate variability (UNOCHA 2008). On average, Chad receives only 322 mm of rainfall each year (FAO 2008), and erratic rains and drought can have serious implications for the levels of cereal production. The World Health Organization reports that around 38 per cent of Chad's population was undernourished between 2004 and 2006 (FAO 2009). During this same period, food aid shipments of cereals averaged 52 767 Mt/yr (FAO 2009).

A drought event in 2009 affected an estimated two million people (EM-DAT 2010). According to the government, this resulted in a harvest of 30 per cent less than in recent years (UNOCHA 2010). Low crop production means that many people who would typically live off the land have difficulties in securing food. In order to cope, many households will be forced to resort to selling off their productive assets, limiting food intake and migrating to more hospitable areas (UNOCHA 2010).



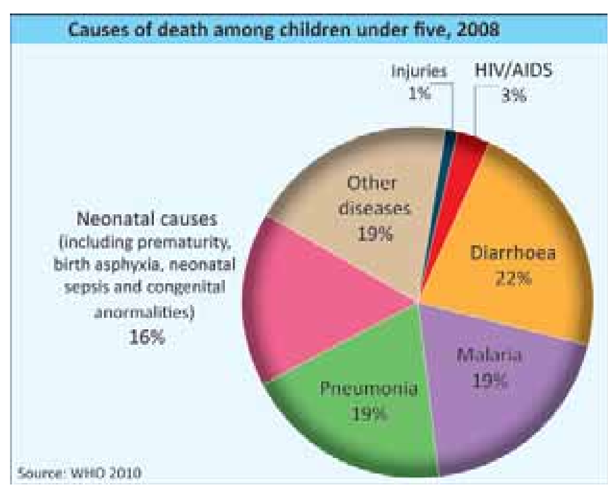
Droughts have also severely affected Chad's large pastoralist communities. The late 2009 rains caused animals in the pastoral zone, stretching from the western Kanem region to the eastern region of Biltine, to waste to death. Surviving cattle were found to have problems reproducing and producing milk (UNOCHA 2010). Dried-out pastures have already begun to alter the migration patterns of herders, also setting the stage for potential conflict between pastoralists and farmers.

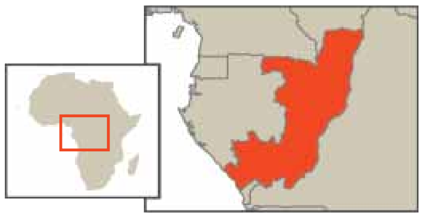
Water-related Diseases

Access to both potable water and hygienic sanitation facilities in Chad is amongst the lowest in the world. Half of the country's 11.2 million people are without access to an improved water source, and only five per cent of the population is serviced with piped water. Sanitation infrastructure is even more limited with only nine per cent of the populace able to access improved facilities. As a result, 65 per cent of inhabitants have little choice but to practice open defecation (WHO/UNICEF 2010).

In addition, instability in the region means that Chad also hosts a large refugee and internally displaced population, many of whom live in camps with little-to-no water and sanitation infrastructure. This displaced population in need of assistance was estimated at 560 460 in early 2010 (UNHCR 2010).

The absence of safe water and hygienic sanitation leaves many in Chad dependent on unprotected supplies prone to contamination from bacteria and excreta, resulting in a high prevalence of water-related diseases. In 2008, the average life expectancy at birth was just 46 years with communicable diseases accounting for the majority of years of life lost—an estimated 82 per cent in 2004 (WHO 2010). Children are particularly susceptible to water-related illnesses and Chad's child mortality rate is especially high, with more than one in five children dying before the age of five. Twenty-two per cent of these deaths are attributable to diarrhoeal disease, which is spread by an unsafe water supply and inadequate sanitation and hygiene (WHO 2010).





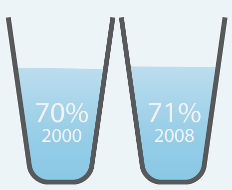
Republic of the

Congo

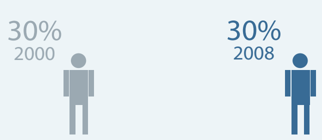
Total Surface Area: 342 000 km²
Estimated Population in 2009: 3 683 000

Progress Towards MDG Goal 7

In rural Congo, only 34 per cent of the population had access to safe drinking water in 2008. People have to walk long distances to get safe water or they live on the unsafe water that they can find nearby, which leads to diarrhoeal and other water-borne diseases. Likewise, the access to safe sanitation lagged behind among the rural population, at 29 per cent. Ninety-five per cent of the urban Congolese population had adequate access to safe water sources, but only 30 per cent had access to improved sanitation facilities.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 646
Total renewable water (actual) (10^9 m³/yr)	2008	832
Total renewable per capita (actual) (m³/inhab/yr)	2008	230 152
Surface water: total renewable (actual) (10^9 m³/yr)	2008	832
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	122
Dependency ratio (%)	2008	73.3

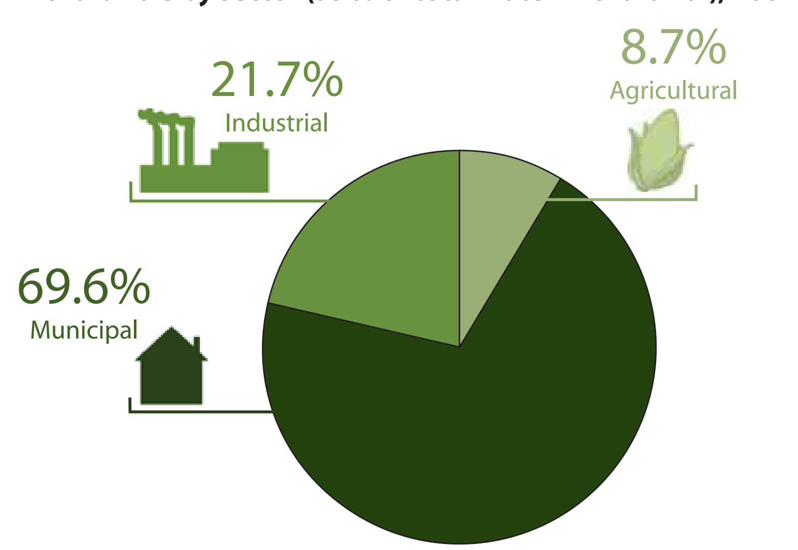
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2002	0.05
Surface water withdrawal (10^9 m³/yr)	2002	0.02
Groundwater withdrawal (10^9 m³/yr)	2002	0.02
Total water withdrawal per capita (m³/inhab/yr)	2002	14.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.01

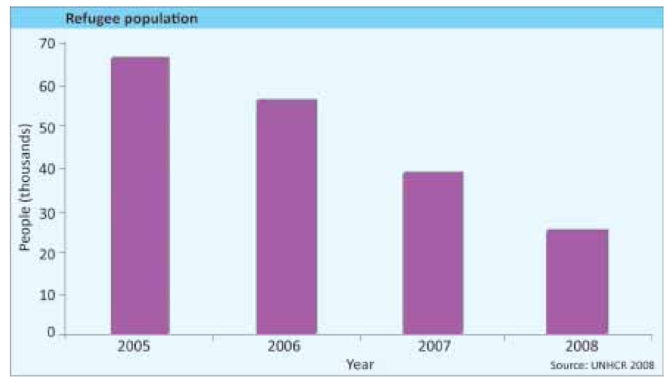
Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2002



Population and Civil Unrest Strain the Water Supply

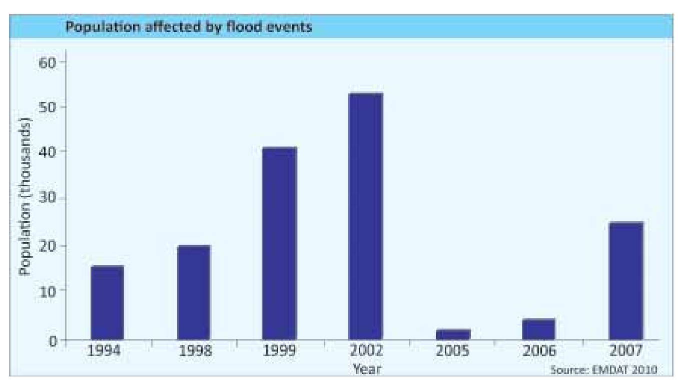


The Republic of the Congo is one of the most water-rich countries in Africa, with a per person availability of 230 152 m^3 of renewable water annually (FAO 2008). Civil unrest in the region has severely limited the ability to secure water resources, however, and the country's water supply systems and sanitation infrastructure have become damaged and degraded.

Population pressure is placing a huge strain on already inadequate infrastructure. There are an estimated 7 800 internally displaced persons in the country—mostly from the Bounenza, Niari and Brazzaville regions (IDMC 2009). In addition, the ongoing instability in some neighbouring countries has resulted in the Congo hosting a significant refugee population. According to the UNHCR, there were an estimated 28 000 persons of concern (refugees and asylum seekers) in 2008 of whom less than half were receiving assistance from the agency (UNHCR 2008). These unstable, temporary living conditions make accessing clean water extremely difficult. Even residents of Congo's capital, Brazzaville, sometimes go weeks without water, and often when water is available it tends to be at inappropriate hours—between midnight and three a.m. In many cases, people have to travel great distances to acquire water and are also required to pay for public transport.

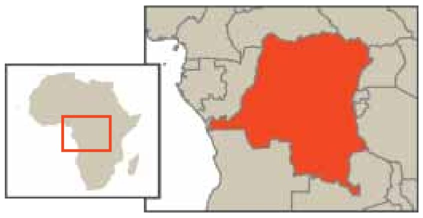
Population pressures further compound water-access issues. Since nearly 20 per cent of the population is between 15 and 24 years old, there are concerns about the nation's future growth rate (currently at three per cent per year), especially considering the high fertility level of 6.3 lifetime births per woman (UNOCHA 2008). A rapidly growing population will add additional strain to an already stressed water management system.

Impacts of Stagnant Water and Polluted Rivers on Health



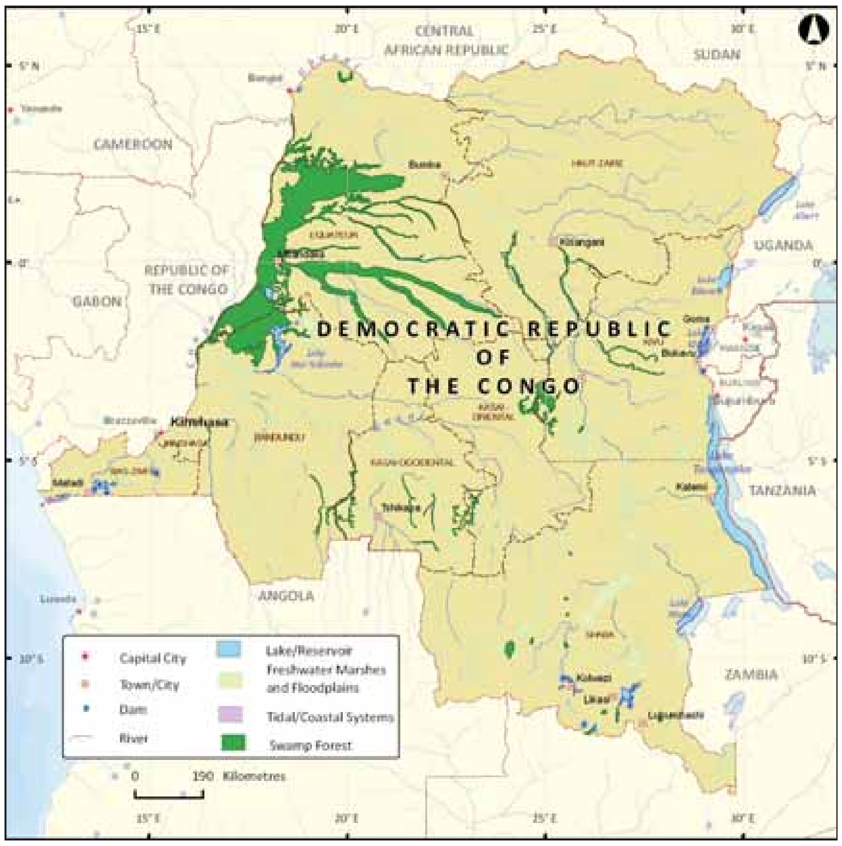
Not only are improved supply and sanitation systems lacking, but so are Congo's drainage systems. Flood events create pools of stagnant water throughout the country that remain for several days before dissipating. These pools are breeding grounds for disease vectors—including mosquitoes. In 2006, 157 757 cases of malaria were reported. The interwoven canals dug to move stagnant water away from homes have fallen into neglect—many of these canals are now buried under pools of torpid water.

Diarrhoea and dysentery are also principal causes of death in Congo, both of which are further propagated by contaminated water from floods as well as polluted river systems. Infant and under-five mortality rates in Congo are between 81 and 108 per 1 000 births (WHO 2009). Many of these deaths are attributable to water-related diseases. In 2004, diarrhoea accounted for 9.7 per cent of deaths among children under five, with malaria the single-largest cause, contributing a further 29.7 per cent (WHO 2009).



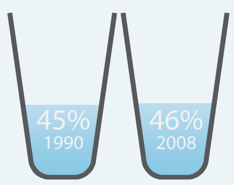
Democratic Republic of the
Congo

Total Surface Area: 2 344 858 km²
Estimated Population in 2009: 66 020 000

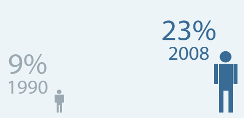


Progress Towards MDG Goal 7

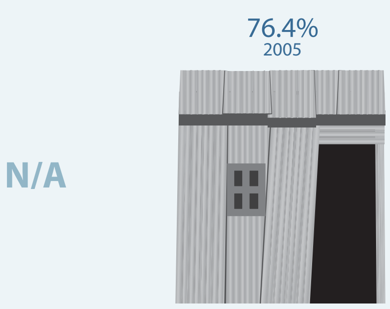
The DRC's urban population with access to improved drinking water declined from 90 to 80 per cent from 1990 to 2008, while rural areas gained better access, which increased from 27 to 28 per cent. There is a lack of services in growing peri-urban areas. Kinshasa suffers from poor and declining sanitation coverage, with undeveloped or malfunctioning services; coverage in urban areas remained the same over the period at 23 per cent while in rural areas it increased from 4 to 23 per cent.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 543
Total renewable water (actual) (10^9 m³/yr)	2008	1 283
Total renewable per capita (actual) (m³/inhab/yr)	2008	19 967
Surface water: total renewable (actual) (10^9 m³/yr)	2008	1 282
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	421
Dependency ratio (%)	2008	29.9

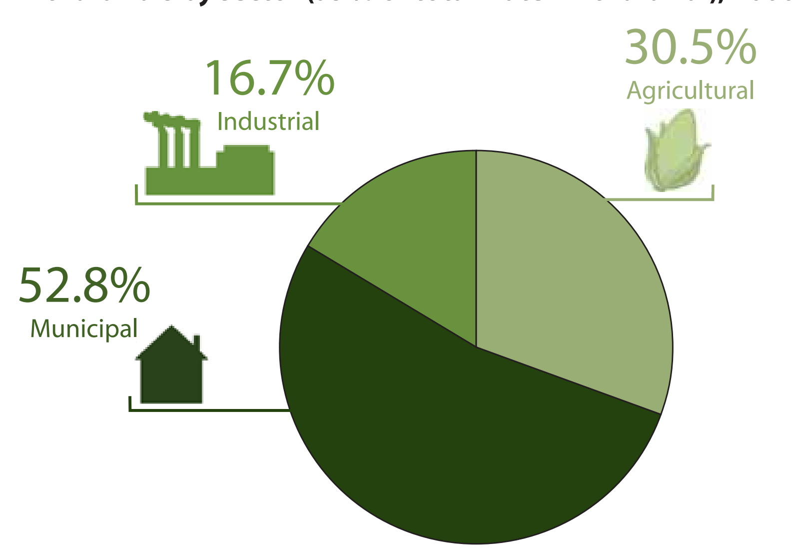
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.4
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	6.7
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.03

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



Julien Harneis/Flickr.com

Displacement and Potable Water Access in Eastern DRC

The Democratic Republic of the Congo (DRC) is one of the most water-rich countries in Africa, with an annual per capita water availability of 19 967 m^3 (FAO 2008). Despite this abundance of water resources, civil conflict, insecurity and limited infrastructure mean that less than half of the DRC's 66 million people have access to potable water (WHO/UNICEF 2010).

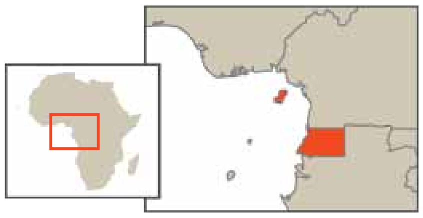
An estimated 1.9 million people are currently internally displaced (IDP) in the DRC (IDMC 2010a) and the vast majority of this IDP population lacks access to basic necessities—including clean water (IDMC 2009). In late 2009, fighting in the east of the country resulted in the displacement of around 2.1 million people in North and South Kivu and Orientale Province (IDMC 2010a) leading to an even greater decline in access to services. Many IDP's and returnees—who had previously fled to neighbouring countries—are not receiving the assistance they need either from the government or international agencies due to ongoing insecurity (UNOCHA 2010). The lack of clean water and sanitation facilities combined with the collapse of health care structures has left populations in the region particularly vulnerable to the spread of water-related infectious diseases, including cholera (IDMC 2010b).

Water Transportation

Despite its vast surface area of 2 344 858 km^2, the country's road network was only 153 497 km in 2005 (IRF 2008). The lack of road infrastructure, combined with limited working railways and expensive airlines, means that taking advantage of the DRC's extensive river network is key to meeting transportation needs in the country.

The DRC contains around 30 large rivers including the Congo River—the second-longest in Africa—as well as the Ubangi, Sangha and Kwa Rivers creating over 14 000 km of used waterways (WINNE 2002) (see map on page 42). This river network is essential for trade and travel in the country and is an economic lifeline for citizens looking to trade goods and access necessities.

However, neglect has caused much of this network to be unusable— barges often get stuck on sand banks since rivers have not been dredged in decades (UNOCHA 2006). In addition, instability throughout the region has fractured access along rivers.



Republic of

Equatorial Guinea

Total Surface Area: 28 051 km²
Estimated Population in 2009: 676 000

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	2 156
Total renewable water (actual) (10^9 m³/yr)	2008	26
Total renewable per capita (actual) (m³/inhab/yr)	2008	39 454
Surface water: total renewable (actual) (10^9 m³/yr)	2008	25
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	10
Dependency ratio (%)	2008	0

Withdrawals

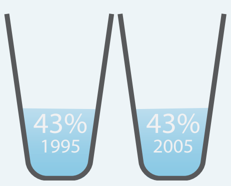
	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.1
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	192.9
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.4

Irrigation

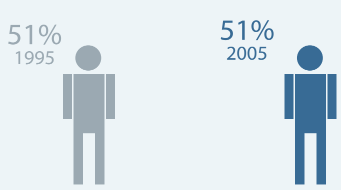
	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Progress Towards MDG Goal 7

Equatorial Guinea's climate is tropical and humid, and average annual precipitation levels are among the highest in Africa at over 2 000 mm of rain per year. The proportion of the population using both improved drinking water sources and improved sanitation facilities is low, however, and remained the same between 1995 and 2005, at 43 per cent and 51 per cent, respectively. Rural populations are less well served than urbanites.

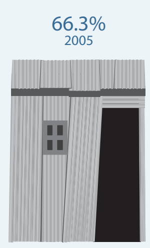


Proportion of total population using improved drinking water sources, percentage



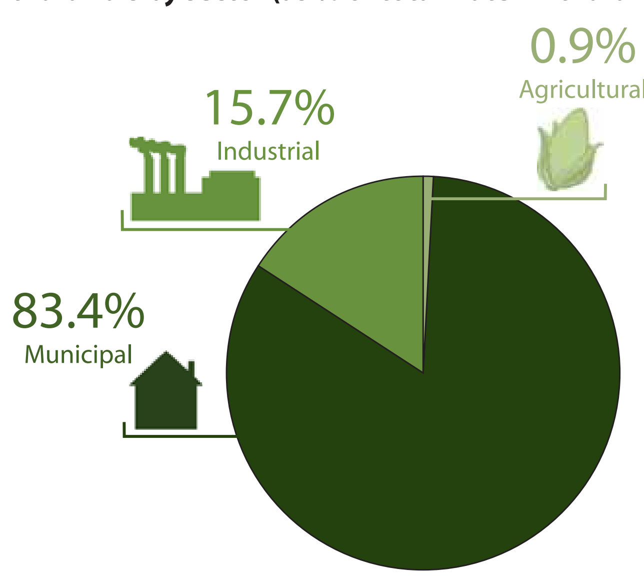
Proportion of total population using sanitation facilities, percentage

N/A



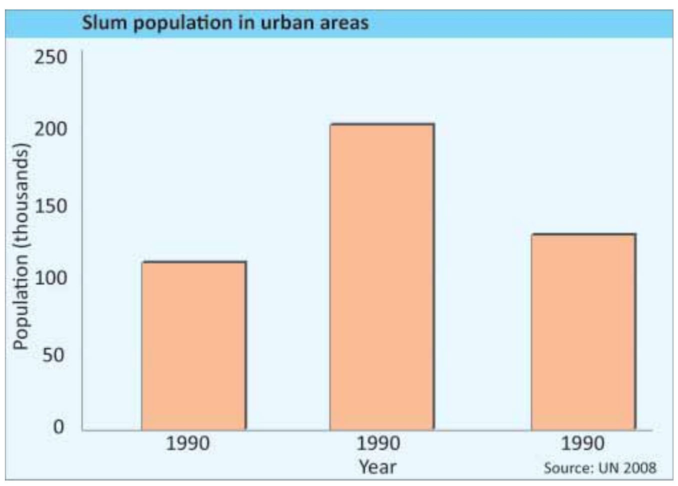
Slum population as percentage of urban

Withdrawals by sector (as % of total water withdrawal), 2000



Water Access

Despite having one of the highest levels of rainfall on the continent—2 156 mm annually (FAO 2008)—Equatorial Guinea suffers from limited access to improved water sources, especially on Bioko Island. The low figure—43 per cent of the population with access to an improved water source in 2005—stems from a combination of inadequate infrastructure and limited water storage capabilities across the islands.



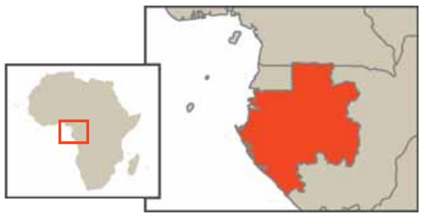
In 2005, 51 per cent of Equatorial Guinea lived in slum households (UNSD 2010); as a result, availability of any water is sometimes a struggle and potable water is beyond the reach for many. Bioko, the largest of the country's seven islands and the territory with the highest population density, is particularly at risk. The capital, Malabo, suffers from frequent water shortages, aggravated by aging infrastructure and poorly maintained infrastructure.

The lack of clean drinking water combined with the fact that nearly half the population has no access to improved sanitation facilities (UNSD 2008) has contributed to the proliferation of water-borne diseases in the country. Children are particularly susceptible to the spread of such illnesses, including diarrhoea and malaria. In 2007, Equatorial Guinea had an under-five mortality rate of over one in five, the fourth-highest rate in the world (UNICEF 2009).

Water Pollution from Oil Production

According to British Petroleum, Equatorial Guinea was Africa's seventh-largest oil producer in 2008. Production has increased rapidly since it began in the early 1990s, growing from 0.3 million tonnes in 1995 to 17.9 million in 2008 (BP 2009). The economic benefits arising from oil exports have been immense. In the three years between 2005 and 2008 alone, GDP more than doubled from US$8 217 million to over US$18 525 million (World Bank 2010). The export of goods and services—especially oil—accounts for a significant proportion of Equatorial Guinea's GDP—78.3 per cent in 2008 (World Bank 2010).

Although the economic benefits have been enormous, the environmental consequences of this expanding industry have been detrimental to local ecosystems and communities. Localized pollution from flaring and leakages can be damaging to water bodies and wetlands, threatening the services these ecosystems provide. With proven reserves of 1 700 million barrels at the end of 2008 (BP 2009), balancing oil production with the potential environmental costs will continue to be a challenge.

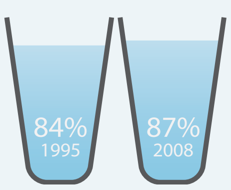


Gabonese Republic

Total Surface Area: 267 668 km²
Estimated Population in 2009: 1 475 000

Progress Towards MDG Goal 7

Gabon's freshwater availability is decreasing under severe stress from human pressures: uncontrolled pollution in urban and coastal areas makes traditional sources of freshwater unsuitable for consumption and the water-storing rain forests are threatened by an expanding logging industry. As a result, renewable water availability per capita has been declining over the last two decades—by 10 per cent from 2002 to 2007 alone. Urban dwellers suffer most, as they are forced to buy clean water from the richer suppliers. In rural areas, access to improved drinking water declined from 49 to 41 per cent of the population from 1995 to 2008.

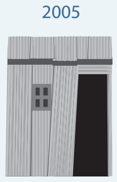


Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage

N/A

38.7%
2005



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 831
Total renewable water (actual) (10^9 m³/yr)	2008	164
Total renewable per capita (actual) (m³/inhab/yr)	2008	113 260
Surface water: total renewable (actual) (10^9 m³/yr)	2008	162
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	62
Dependency ratio (%)	2008	0

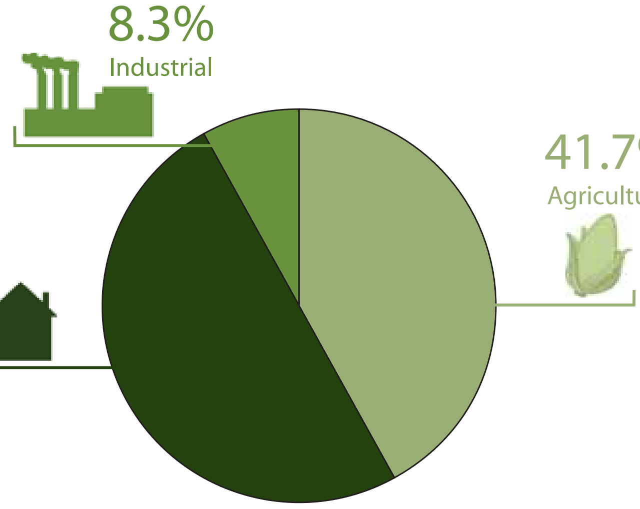
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.1
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	93.1
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.1

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000

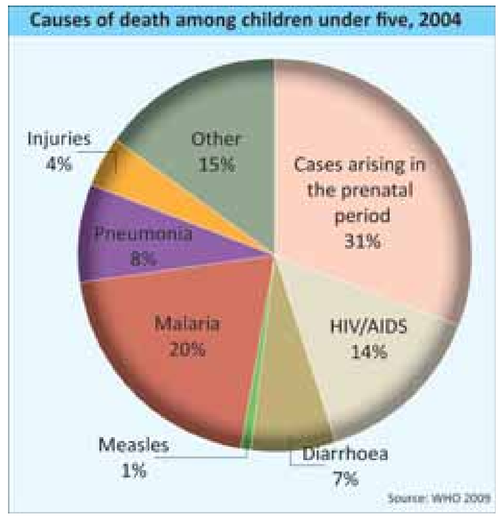


Urban Water Access and Pollution

With 85 per cent of Gabon's 1.45 million people living in urban centres, municipalities have been unable to keep up with provision of improved drinking water (WHO/UNICEF 2010). The vast majority reside in the capital Libreville, which is home to 619 000 people—approximately 43 per cent of the total population of Gabon (United Nations 2009).

Many of the city's residents live in poorer suburbs with limited water infrastructure and only half of the urban population has access to piped water (WHO/UNICEF 2010). In fact, in 2008 Gabon's urban slum population was estimated at 447 383 people, suggesting that over a third of urban residents live in sub-standard housing conditions with limited services (UNSD 2008).

The lack of adequate municipal services extends to waste disposal. A study carried out by the Ministry of Public Health and Population found that only half of households correctly dispose of garbage (IPS 2003). As a result, in flood-prone urban areas, water mixes with waste following heavy rainfalls, creating a breeding ground for disease. Children are particularly susceptible to diseases spread by contaminated and untreated water. Malaria accounted for over 20 per cent of deaths among children under the age of five in 2004, with diarrhoea responsible for a further seven per cent of mortalities (WHO 2009).



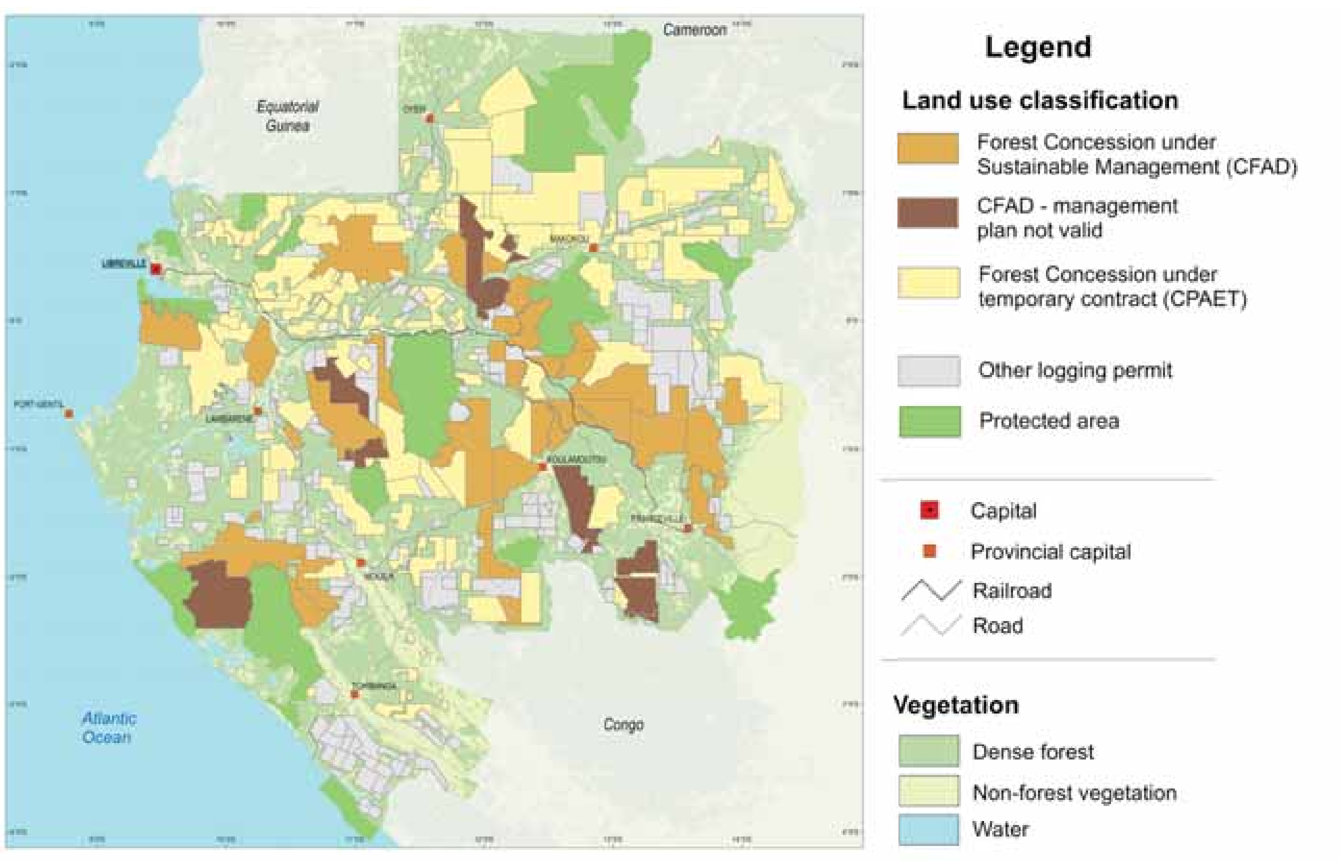

Brian Gratwicke/Flickr.com

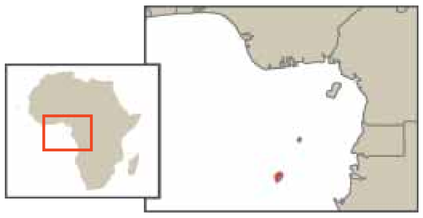
Water Contamination from Logging Activities

Gabon's expansive forests cover an estimated 217 546 km^2, making up almost 85 per cent of the total surface area (World Bank 2009). The abundant natural wealth in the country has resulted in an economy largely dependent on the extraction and export of natural resources such as oil, timber and manganese. While oil is the chief export, the logging industry is also vital to the economy and Gabon is Africa's second-largest timber exporter after Cameroon (Forest Monitor 2006).

Logging activities are having negative environmental impacts, however, not least in the area of water quality, with sediment deposits and chemical leakages often contaminating nearby water sources. The products used to treat wood regularly end up polluting the hydrological system during river transportation of logs to the ports. Many chemicals in use in Gabon have toxic properties (Forest Monitor/Rainforest Foundation 2007).

Assignment of National Forest Area (Source: WRI 2009)





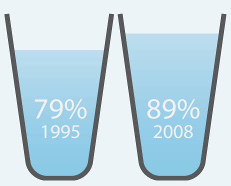
Democratic Republic of

São Tomé and Príncipe

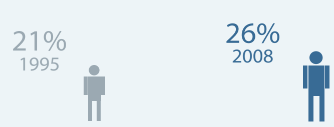
Total Surface Area: 964 km²
Estimated Population in 2009: 163 000

Progress Towards MDG Goal 7

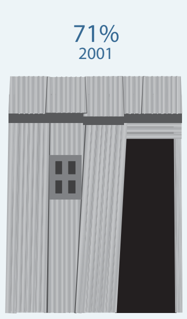
Access to an improved water source was relatively high at 89 per cent of the population in 2008. Access to improved sanitation facilities, on the other hand, is relatively low at 26 per cent, compared to the region's average of 31 per cent.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	3 200
Total renewable water (actual) (10^9 m³/yr)	2008	2.2
Total renewable per capita (actual) (m³/inhab/yr)	2008	13 625
Surface water: total renewable (actual) (10^9 m³/yr)	...	...
Groundwater: total renewable (actual) (10^9 m³/yr)	...	...
Dependency ratio (%)	2008	0

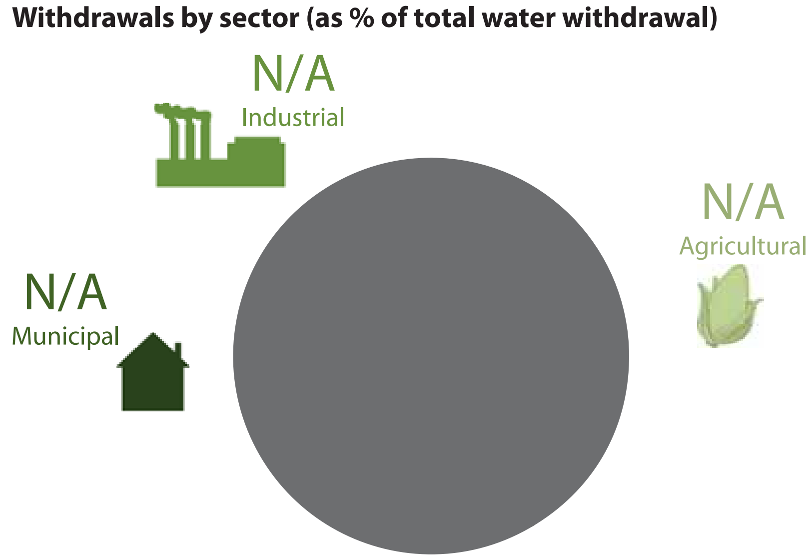
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	1993	0.01
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	1997	52.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	1997	0.3

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

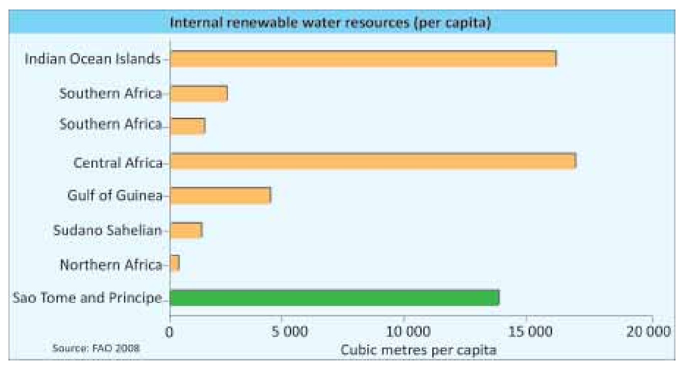
Withdrawals by sector (as % of total water withdrawal)



Water Pollution

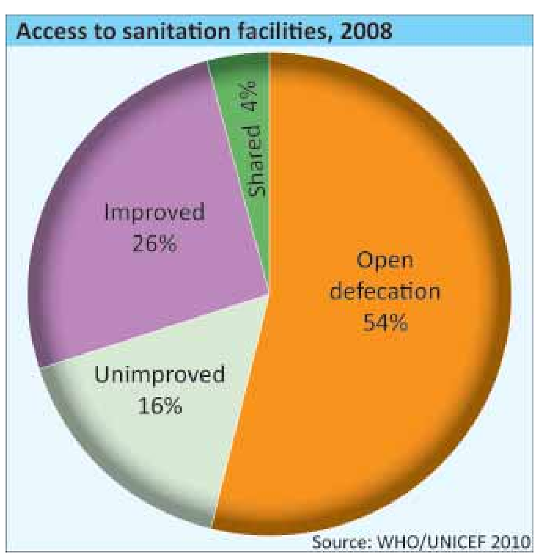
The islands of São Tomé and Príncipe have an extensive network of more than 50 rivers varying from 5 to 27 km in length (FAO 2005). Water resources are abundant, averaging at 13 625 m^3 per capita each year (FAO 2008). The quality of the island nation's freshwater supply is under threat from human activities, however, which have contaminated inland water ecosystems.

Chemical wastes from numerous sources including hospital waste, sanitary products and DDT, a synthetic pesticide used to fight mosquitoes, have polluted the waterways (FAO 2005, Republica Democratica de S. Tome e Principe 2007). The island nation has recently become an oil producer and the dumping of residues, especially on the estuary of the Água Grande River, is already damaging local ecosystems (Republica Democratica de S. Tome e Principe 2007). The agricultural sector has also contributed to the pollution of freshwater resources through the application of fertilizers.



Access to Sanitation

Access to improved sanitation facilities in São Tomé and Príncipe is among the lowest in the world—with almost three-quarters of the population reliant on either inadequate or non-existent facilities (WHO/UNICEF 2010). In rural areas, where 39 per cent of the people reside, access rates are even lower and 81 per cent of inhabitants are using unimproved facilities. The lack of sanitation infrastructure has resulted in an especially high rate of open defecation on the islands—at 55 per cent São Tomé and Príncipe has the eighth highest rate of 158 countries (WHO/UNICEF 2010).

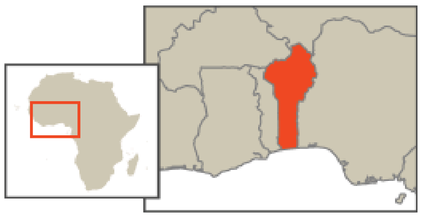


Furthermore, with only 26 per cent of the population connected to piped water, supplies are far more vulnerable to contamination (WHO/UNICEF 2010). Poor hygiene and polluted water resources have contributed to a high proliferation of water-related disease on the islands. In 2005, a cholera outbreak in São Tomé resulted in almost 2 000 reported cases (WHO 2009). Children are particularly susceptible to the spread of illnesses and the country has a high rate of child mortality with almost one in ten children dying before the age of five in 2007. Diarrhoea is among the leading causes of death in children in São Tomé and Príncipe, accounting for 18.6 per cent in 2004 (WH0 2009).

Brian Jackson/Flickr.com

Western Africa

Benin
Burkina Faso
Cape Verde
Côte d’Ivoire
Gambia
Ghana
Guinea
Guinea-Bissau
Liberia
Mali
Mauritania
Niger
Nigeria
Senegal
Sierra Leone
Togo

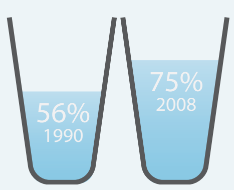


Republic of
Benin

Total Surface Area: 112 622 km²
Estimated Population in 2009: 8 935 000

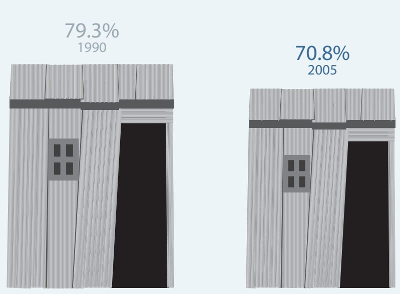
Progress Towards MDG Goal 7

Although enough water is available for current and future needs, water resources are unevenly distributed both geographically and over time. There has been some improvement in access to improved drinking water (from 56 to 75 per cent of the population from 1990 to 2008). Although access to improved sanitation increased from 5 to 12 per cent over the same period, just under 90 per cent of the rural population remains deprived of improved sanitation facilities.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 039
Total renewable water (actual) (10^9 m³/yr)	2008	26.4
Total renewable per capita (actual) (m³/inhab/yr)	2008	3 047
Surface water: total renewable (actual) (10^9 m³/yr)	2008	26.1
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	1.8
Dependency ratio (%)	2008	61

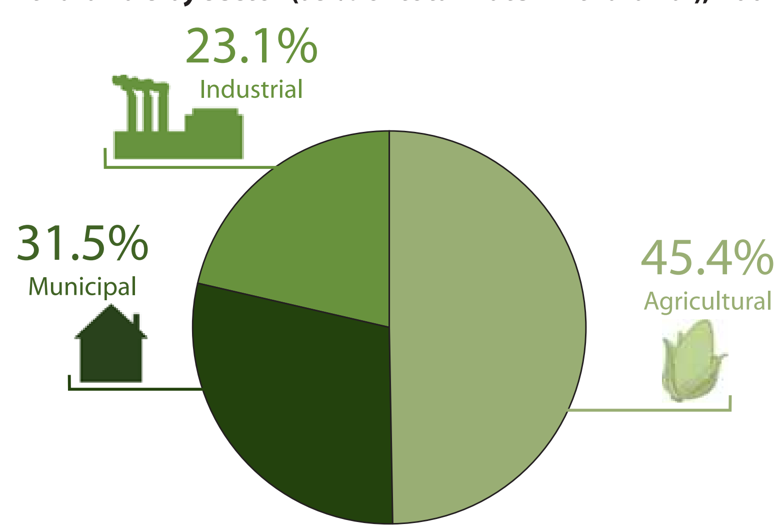
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2001	0.1
Surface water withdrawal (10^9 m³/yr)	2001	0.09
Groundwater withdrawal (10^9 m³/yr)	2001	0.04
Total water withdrawal per capita (m³/inhab/yr)	2002	18.3
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.5

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2001



Sand Mining

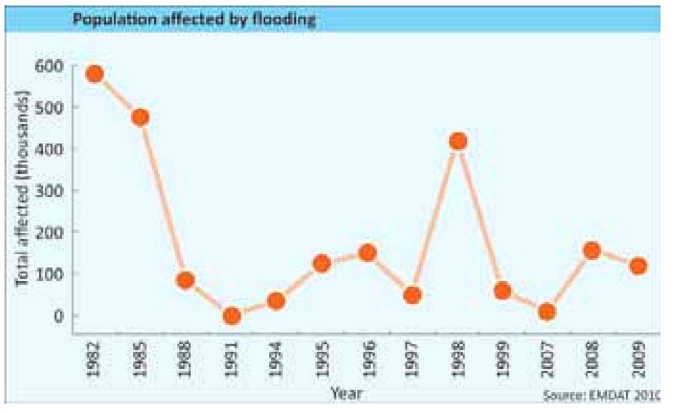
Benin's 125-km coastline on the Gulf of Guinea is at risk from flooding, fueled by a combination of sea-level rise and coastal erosion. With numerous industrial centres—including the economic capital Cotonou—sited along the shoreline as well as almost 60 per cent of the population living within 100 km of the coast in 2000 (CIESIN 2005), flooding can be devastating to local communities and economies.

One of the drivers behind the growing levels of coastal erosion is coastal sand mining where beach sand is carted away for commercial use, especially to supply a building construction boom in Cotonou. To limit the amount of sand mined from the coast, the government began promoting the use of inland sand collection in late 2008. Instead, the focus shifted to sites along rivers and lakes in Cotonou and surrounding inland cities: Abomey Calavi, SoAva, Ouidah and Seme Kpodji (UNOCHA 2008a). Local communities have denounced this shift, however, and are demanding greater compensation for the use of their land. In addition, environmental groups have warned against the threat of water pollution from the chemicals used to separate the sand from minerals (UNOCHA 2008a).

Flood Risk

According to the World Health Organization, an estimated 500 000 people are at risk of flooding in Benin (UNOCHA 2008b). Between 1980 and 2009, there have been 14 major floods affecting a total of 2.26 million people (EM-DAT 2010). The latest floods in 2008 and 2009 caused widespread damage and displacement, respectively affecting around 158 thousand and 120 thousand people (EM-DAT 2010).

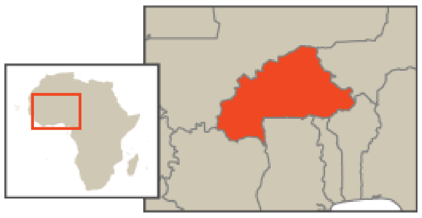
Heavy and erratic storms, the significant populations living in and near recently flooded areas and an unwillingness to relocate exacerbate the risk of flooding (UNOCHA 2008b). Recent storms have destroyed mud and straw homes, polluted rivers and washed away roads in Sagon, Tohoue, Dasso, Ouinhi and Za-Kpota. During the 2008 floods, nine out of thirteen districts in the economic capital Cotonou suffered heavy water damage. In 2009, heavy rains led to the government declaring Benin's first state of emergency in recent years (UNOCHA 2009).



As well as the physical impacts on infrastructure, heavy flooding also has implications for public health. Stagnant water can lead to the spread of water–related diseases including cholera, diarrhoea, malaria and bilharzia.

An early warning system is essential for governments and communities to prepare for severe storms. Benin's lack of reliable meteorological information, however, prevents any adequate forecasting (UNOCHA 2009).

United Nations/Flickr.com

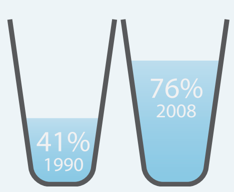


Burkina Faso

Total Surface Area: 274 000 km²
Estimated Population in 2009: 15 757 000

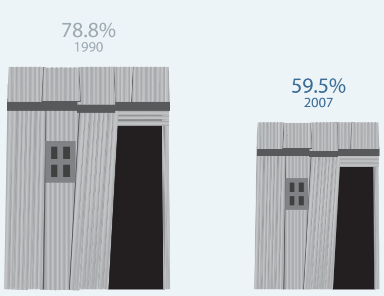
Progress Towards MDG Goal 7

Much of Burkina Faso lies within the Sahel where droughts and floods are becoming longer and more intense. People abandoning rain-fed agriculture are moving to peri-urban areas where investment in improved water and sanitation is low. It has made good progress in improved water coverage: from 73 to 95 per cent, and from 36 to 72 per cent in urban and rural areas, respectively, from 1990 to 2008. Improved sanitation coverage is much lower: 33 per cent in urban and 6 per cent in rural areas in 2008.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	748
Total renewable water (actual) (10^9 m³/yr)	2008	12.5
Total renewable per capita (actual) (m³/inhab/yr)	2008	820.5
Surface water: total renewable (actual) (10^9 m³/yr)	2008	8
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	9.5
Dependency ratio (%)	2008	0

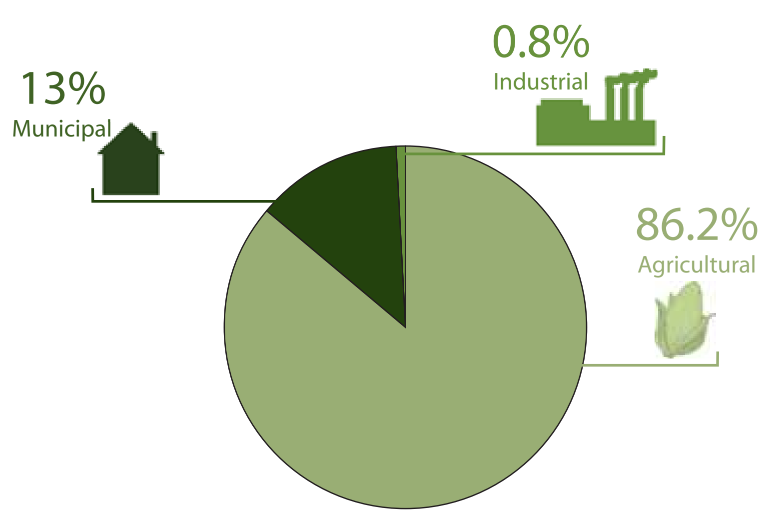
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.8
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	64.3
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	6.4

Irrigation

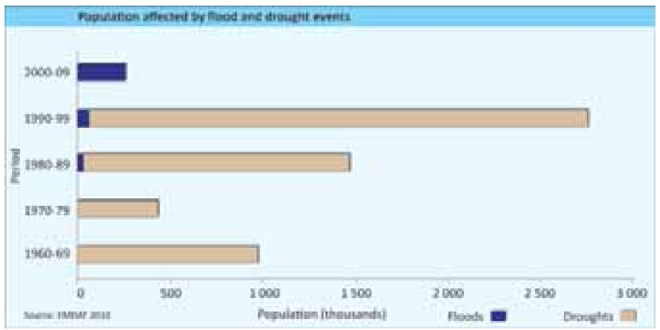
	Year	Value
Irrigated grain production as % of total grain production (%)	1992	3.2
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



Climate Variability and Water Scarcity

Water scarcity is a key challenge facing Burkina Faso due to its location in the arid savannah belt of the Sahel. Only 821 m^3 of freshwater are available per person annually, below the international scarcity threshold. This water stress situation is being further exacerbated by the country's rapidly growing population, which has almost doubled in the last two decades alone, rising from 8.8 million in 1990 to 15.2 million in 2008 (United Nations 2008).



Burkina Faso's variable climate, which manifests in highly erratic rainfall patterns and short rainy seasons, has resulted in both frequent drought periods and flood events. In the 50 years since 1960, there have been a total of 23 large-scale flood and drought events affecting an estimated six million people (EM-DAT 2010). The seasonal and annual variation in water availability has serious implications for both food security and livelihoods with around 92 per cent of the population engaged in the agricultural sector (FAO 2006).

In 2009, the country faced its most destructive rains in a decade, affecting an estimated 151 000 people (EM-DAT 2010). The heavy rainfall destroyed dams in Ouagadougou and the northern Sahel region, damaged numerous bridges and flooded infrastructure and communities, including the country's main hospital. Further flooding in both Burkina Faso and downstream Ghana resulted from the need to release water from the Volta River basin dam by opening the gates (UNOCHA 2009).

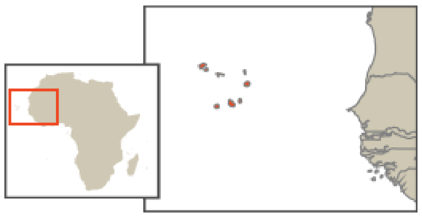
Public Health Concerns due to Extensive Dam Construction

To better regulate water supplies Burkina Faso has invested in an extensive network of approximately 2 100 dams (IEA n.d.). According to the Ministry of Water Resources, however, the current network is insufficient, with over 40 per cent of dams built in the arid north where they collect too little rain and 80 per cent holding less than one million cubic metres compared to a national annual need of 2.5 billion cubic metres (UNOCHA 2010).

The need to further expand water provisions has driven plans for multi-million dollar dam construction near wetlands in the southwest of Burkina Faso in the Samandéni and Ouessa regions. The planned series of dams is expected to cost approximately US$150 million and combined could deliver five billion cubic metres of water (UNOCHA 2010).

Despite the numerous benefits of dam construction, such developments can also have serious negative impacts on local populations, particularly in the areas of public health, and ecosystems. Stagnant water provides a habitat for organisms and vectors resulting in the proliferation of diseases such as malaria and schistosomiasis (bilharzia), both of which are prevalent in Burkina Faso. In 2007, there were an estimated 2.5 million reported cases of malaria in the country (WHO 2009) and a further 4.6 million were infected with schistosomiasis in 2008 (WHO 2010).

Jeff Attaway/Flickr.com



Republic of

Cape Verde

Total Surface Area: 4 033 km²
Estimated Population in 2009: 506 000

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	228
Total renewable water (actual) (10^9 m³/yr)	2008	0.3
Total renewable per capita (actual) (m³/inhab/yr)	2008	601.2
Surface water: total renewable (actual) (10^9 m³/yr)	2008	0.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.1
Dependency ratio (%)	2008	0

Withdrawals

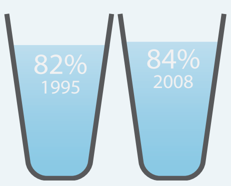
	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	...	...
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	48.4
Freshwater withdrawal as % of total renewable water resources (actual) (%)	...	...

Irrigation

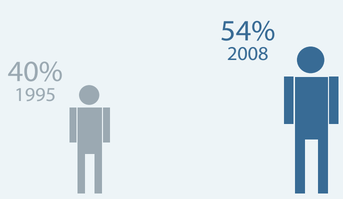
	Year	Value
Irrigated grain production as % of total grain production (%)	1998	2.5
Area salinized by irrigation (1000 ha)	...	...

Progress Towards MDG Goal 7

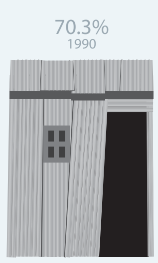
Cape Verde has low rainfall and suffers from occasional severe droughts that limit water availability. Near the coast, aquifers have been overexploited resulting in saltwater intrusion of wells. Between 1995 and 2008, the proportion of the population with access to improved drinking water increased from 82 to 84 per cent (85 per cent in urban and 82 per cent in rural areas). Fifty-four per cent of the total population has access to improved sanitation (65 per cent in cities but only 38 per cent in rural areas).



Proportion of total population using improved drinking water sources, percentage



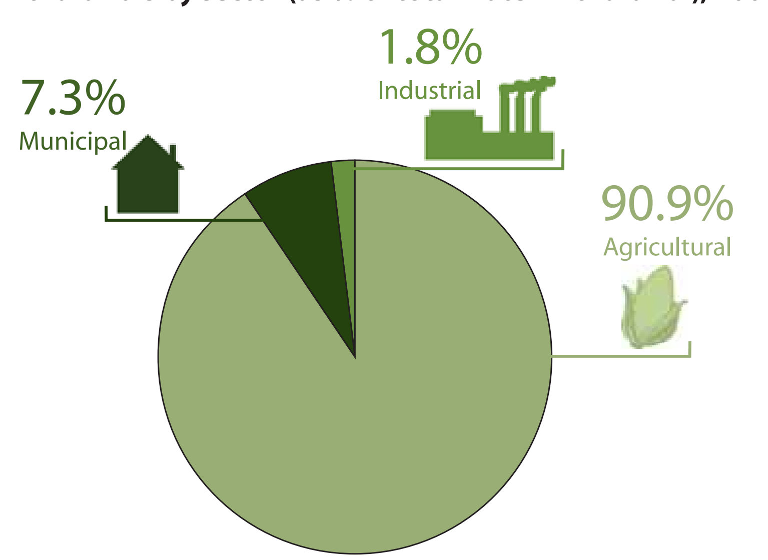
Proportion of total population using sanitation facilities, percentage



N/A

Slum population as percentage of urban

Withdrawals by sector (as % of total water withdrawal), 2001



Unsustainable Exploitation of Aquifers

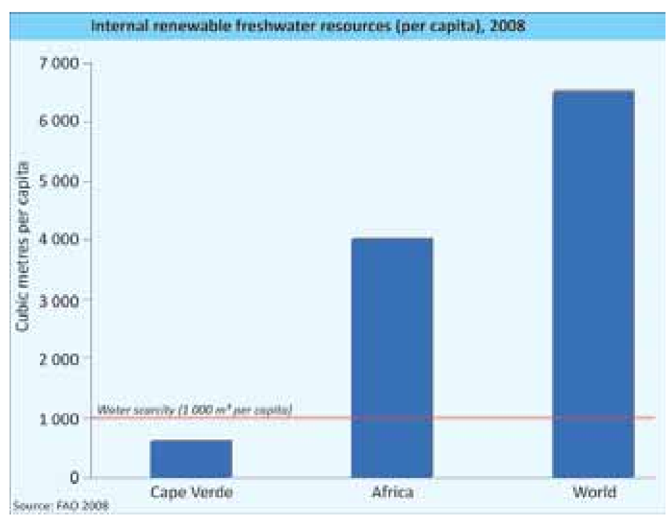
As a collection of islands and islets, Cape Verde is completely dependent on internal water resources. Annually, the total available water is estimated at 300 million cubic metres, of which 60 per cent is found on the surface with the remaining 40 per cent stored in groundwater aquifers (FAO 2008). The limited water availability has resulted in the overexploitation of available resources, primarily for agricultural purposes. In 2000, the agricultural sector was responsible for approximately 90 per cent of total water withdrawals, with the municipal and industrial sectors accounting for 7.3 per cent and 1.8 per cent of withdrawals, respectively (FAO 2008).

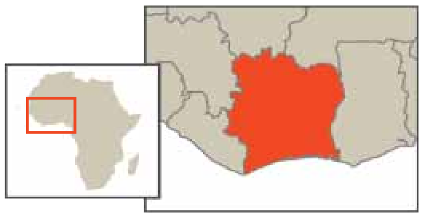
Exploitation of these resources is not felt evenly throughout this 10-island nation. On the islands of Boavista, Brava, Fogo and Maio the water resources available for irrigation exceed the amount used. On the islands of Sao Tiago and Sao Nicolau, exploitation rates are comparable to the rate of replenishment. On the islands of Sao Vicente and Santo Antão, however, overexploitation for irrigation is a major concern (FAO 2005). The over-use of water aquifers in combination with water mismanagement has led to increased salinization, one of the most pressing environmental issues in Cape Verde (FAO 2005). Saltwater intrusion contaminates underground water resources, so that they can no longer be utilized and often render agricultural land infertile.

Water Scarcity and Rainwater Harvesting

Cape Verde's dry tropical weather is characterized by two distinct seasons. Its lowest temperatures are reached between the months of January and April, with the highest temperatures from August to September. Most precipitation falls during these warmer months, with an average rainfall of roughly 228 mm a year providing 180 million cubic metres a year of renewable surface water and 120 million cubic metres a year of renewable groundwater (FAO 2008). This amounts to an availability of only 601 m^3 per person each year, well below the 1 000 m^3 international water scarcity threshold (FAO 2008).

The irregular and torrential nature of rainfall patterns has made water scarcity a major issue in Cape Verde. Only a slim proportion of water from rainfall infiltrates into underground aquifers, with the vast majority of it running off or evaporating on the surface. Surface water, in particular, is challenging to harness due to a lack of local knowledge and capacity in implementing harvesting techniques such as artificial lakes or dams (FAO 2005).





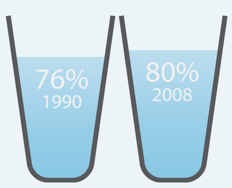
Republic of

Côte d'Ivoire

Total Surface Area: 322 463 km²
Estimated Population in 2009: 21 075 000

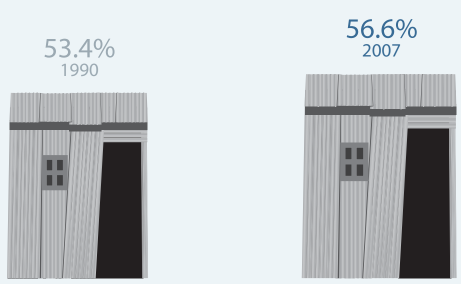
Progress Towards MDG Goal 7

Water pollution is a significant environmental problem in Côte d'Ivoire due to chemical waste from agricultural, industrial and mining sources. The proportion of the population using improved drinking water sources increased slightly in both urban and rural areas, however, with an average from 76 per cent in 1990 to 80 per cent in 2008. The overall proportion of the population using improved sanitation facilities also rose marginally, from 20 per cent in 1990 to 23 per cent in 2008, with an increase from 8 to 11 per cent in rural areas and a slight decrease in urban access, from 38 to 36 per cent.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 348
Total renewable water (actual) (10^9 m³/yr)	2008	81.1
Total renewable per capita (actual) (m³/inhab/yr)	2008	3 941
Surface water: total renewable (actual) (10^9 m³/yr)	2008	78.3
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	37.8
Dependency ratio (%)	2008	5.3

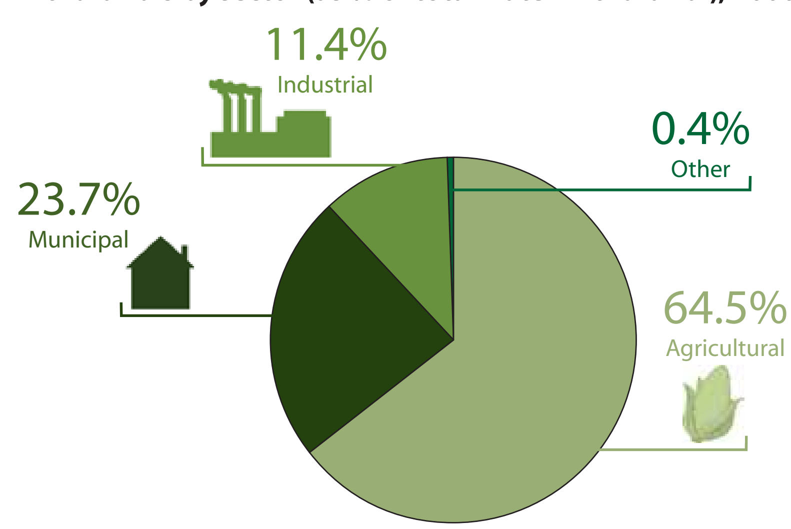
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.9
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	51.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	1.1

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000

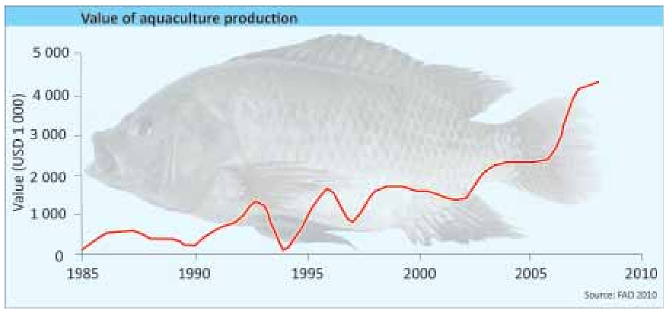


Threats to Aquaculture Production from Sea-Level Rise

Côte d'Ivoire's 515-km long coastline includes an extensive network of lagoons covering an area of approximately 1 200 km^2 (GEF 2002). Lagoons, which are inland bodies of sea or brackish water, provide important services to local communities and ecosystems, including abundant fishing. The fisheries sector in Côte d'Ivoire is both an important livelihood source and a key supply of food. The relative abundance and low-cost of fish make them a primary source of animal protein in the country, especially for lower-income households, supplying around 40 per cent of total animal protein (FAO 2008a).

Over the last three decades, aquaculture production, which takes place primarily in the lagoons, has grown steeply, rising from just 21 tonnes/yr in 1984 to 1 290 tonnes in 2008. Aquaculture is also a significant source of revenue in Côte d'Ivoire, generating US$4.36 million in 2008.

According to Côte d'Ivoire's National Communication under the Kyoto Protocol, however, the country's valuable lagoon ecosystem is vulnerable to sea-level rise (Republique de Côte d'Ivoire 2000). This in turn poses a serious threat to aquaculture production in the region.

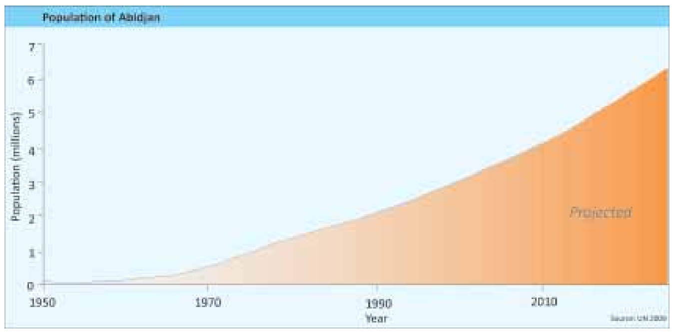


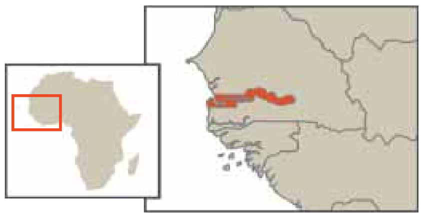
Water Shortages in Abidjan

Despite Côte d'Ivoire's relatively abundant water resources, access remains a challenge. In theory, there is an average 3 941 m^3 of water available per person each year (FAO 2008b). In practice, however, a lack of infrastructure and investment means that water shortages can be a crippling problem.

This issue is especially pronounced in Abidjan, Côte d'Ivoire's most populous city, which is home to over four million people (United Nations 2009) (read about groundwater resources on page 119). This large urban centre requires around 500 000 m^3 of water a day. Actual availability falls far below this figure, however, at 350 000 m^3, leaving many unable to use the city's central water supply (UNOCHA 2008). At one time in 2008, a third of the residents of Abidjan were left without access to drinking water leading to mass demonstrations in the city (UNOCHA 2008).

Political instability in the north of the country is an important contributing factor to water shortages both in Abidjan and Côte d'Ivoire as a whole. The unrest has caused an influx of people from the north, including an additional 1.5 million in Abidjan alone, putting additional pressure on already limited resources. Furthermore, the lack of strong administration in the north has given residents in that region little incentive to pay for utilities placing even greater strain on water infrastructure (UNOCHA 2006).

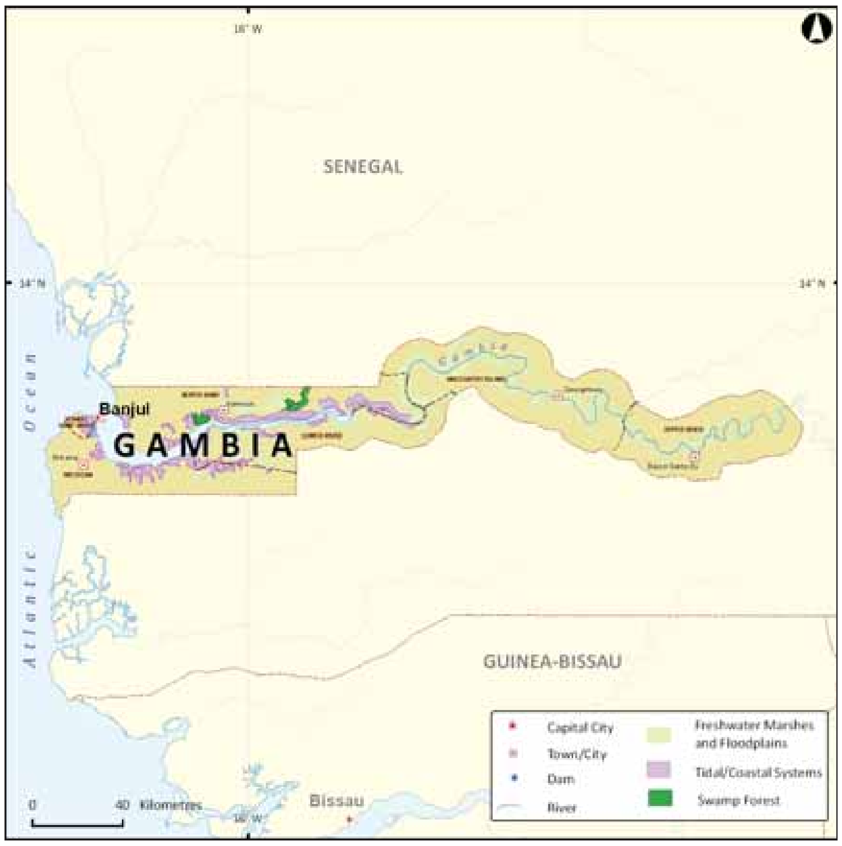




Republic of the

Gambia

Total Surface Area: 11 295 km²
Estimated Population in 2009: 1 705 000



Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	836
Total renewable water (actual) (10^9 m³/yr)	2008	8
Total renewable per capita (actual) (m³/inhab/yr)	2008	4 819
Surface water: total renewable (actual) (10^9 m³/yr)	2008	8
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.5
Dependency ratio (%)	2008	62.5

Withdrawals

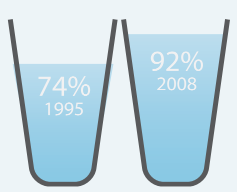
	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.03
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	22
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.4

Irrigation

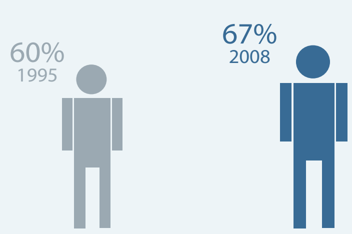
	Year	Value
Irrigated grain production as % of total grain production (%)	1991	19.6
Area salinized by irrigation (1000 ha)	...	...

Progress Towards MDG Goal 7

The entire country of Gambia lies in the drainage basin of the Gambia River, which has a highly seasonal flow. Ocean salinity affects its lowland reaches, which has an important influence on Gambia's vegetation and water use. Thus, the majority of the population uses groundwater resources for potable water. Access to safe water continues to improve in both urban and rural areas, rising on the whole from 74 per cent in 1990 to 92 per cent by 2008, while access to improved sanitation increased from 60 per cent of the total population in 1995 to 67 per cent by 2008.



Proportion of total population using improved drinking water sources, percentage

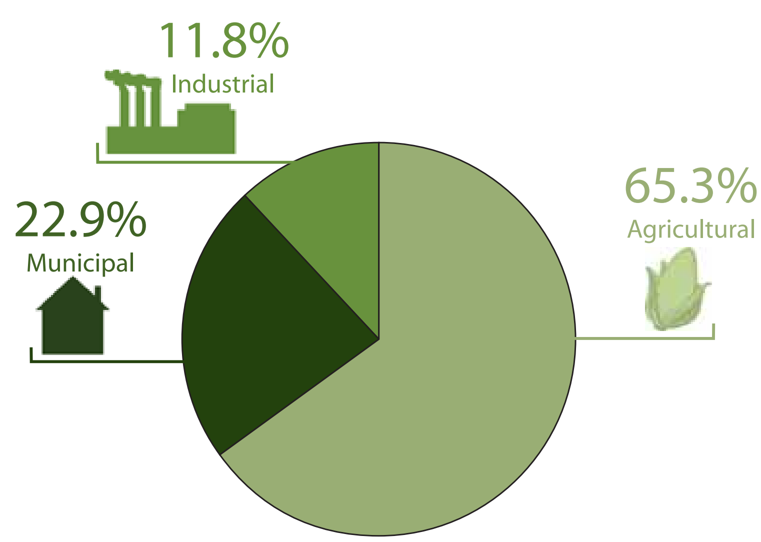


Proportion of total population using sanitation facilities, percentage

N/A

Slum population as percentage of urban

Withdrawals by sector (as % of total water withdrawal), 2000



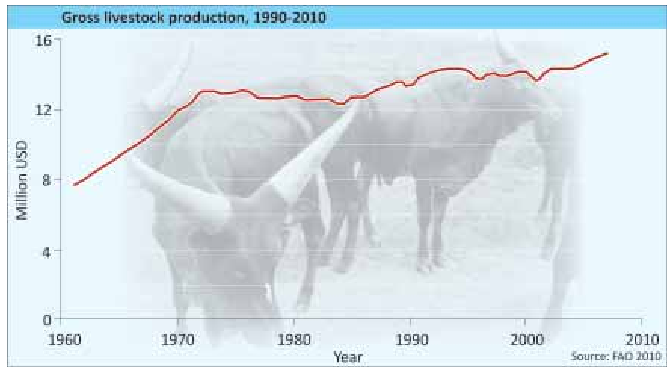
Wetland Degradation

An estimated 20 per cent of Gambia's 11 295 km^2 territory is covered by wetlands (Encyclopedia of the Earth 2010) of which 6.4 per cent is mangrove forest, and 11 per cent consists of swamps (CBD 2006). These wetlands play an increasingly important role in the lives of local communities and are used for rice cultivation, dry-season grazing for livestock and as nursery areas for commercial fish species.

The country has two globally renowned Ramsar wetland sites, the Tanbi Wetlands Complex and the Baobolon Wetlands Reserve. The Tanbi Wetlands Complex spans an area of 6 300 ha, 4 800 ha of which are mangrove forest, an ecosystem that provides Gambia with key services including coastal protection, water filtration and carbon sequestration (Access Gambia 2010). The main activities in and around the Tanbi Wetlands Complex are shrimp fisheries, small-scale vegetable farms and rice cultivation.

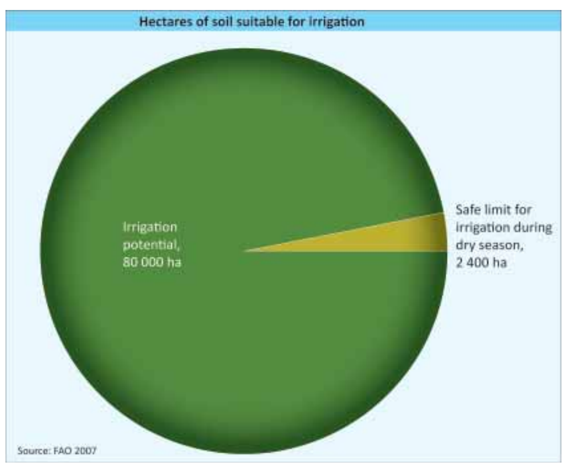
Unfortunately, Gambia has seen increasing rates of wetland degradation in recent years driven predominantly by population growth and agricultural expansion. Gambia's capital city, Banjul, has been subject to widespread urban sprawl that has now spread into neighbouring cities as the population in Banjul has more than tripled since the 1980s (UNEP 2003).

Livestock production, which also puts strains on wetland health, has been steadily increasing since the 1960's, and today accounts for 25 per cent of the annual agricultural GDP and 5 per cent of the total national GDP.

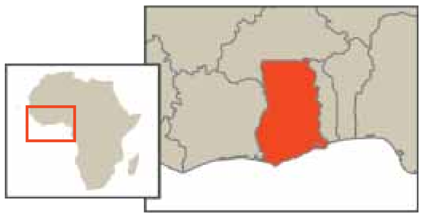


Salt Water Intrusion

Despite the relative abundance of surface water resources, estimated at eight billion cubic metres a year, the country is becoming increasingly reliant on far more limited groundwater resources. This is being primarily driven by frequent salt water intrusion into the lower reaches of the Gambia River. The Gambia River, flowing northwest for more than 1 100 km, has an extremely flat topography that makes it especially susceptible to salt water penetration (Caputo and others 2008). In the wet season, salt water can move up to 70 km upstream, and in the dry season it can reach up to 250 km (FAO 2007). Since the "salt-front" is at its peak in the late dry season, which is also when water availability is at its lowest, there can be serious ramifications for water supply, particularly for agriculture, the largest water user of any sector. In total, Gambia has 80 000 ha of suitable soil for irrigation, but because of frequent salt water intrusion upstream, the safe limit for irrigation during the dry season is estimated to be no more than 2 400 ha (FAO 2007). In practice, any water abstraction within the basin during the dry season should be studied very carefully to prevent any further salt intrusion in the region.



With an estimated annual renewable groundwater availability of only 0.5 billion cubic metres, the supply will be unable to meet the freshwater demands of a rapidly increasing population and ongoing agricultural expansion.



Republic of

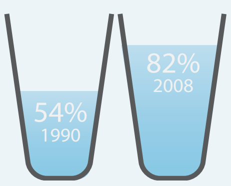
Ghana

Total Surface Area: 238 553 km²
Estimated Population in 2009: 23 837 000

Susan Bodenner/Flickr.com

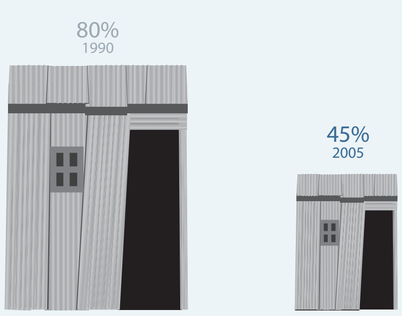
Progress Towards MDG Goal 7

Water provision reforms have achieved remarkable progress in Ghana, with an increase from 54 per cent in 1990 (84 in urban areas and 37 per cent in rural) to 80 per cent in 2008 (90 per cent in urban and 74 per cent in rural areas). The MDG target is for 85 per cent. Improved sanitation access lags far behind due to a lack of local capacity and funding. In 2008, only 13 per cent of the total population had access; the MDG target is for 80 per cent.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 187
Total renewable water (actual) (10^9 m³/yr)	2008	53.2
Total renewable per capita (actual) (m³/inhab/yr)	2008	2 278
Surface water: total renewable (actual) (10^9 m³/yr)	2008	51.9
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	26.3
Dependency ratio (%)	2008	43.1

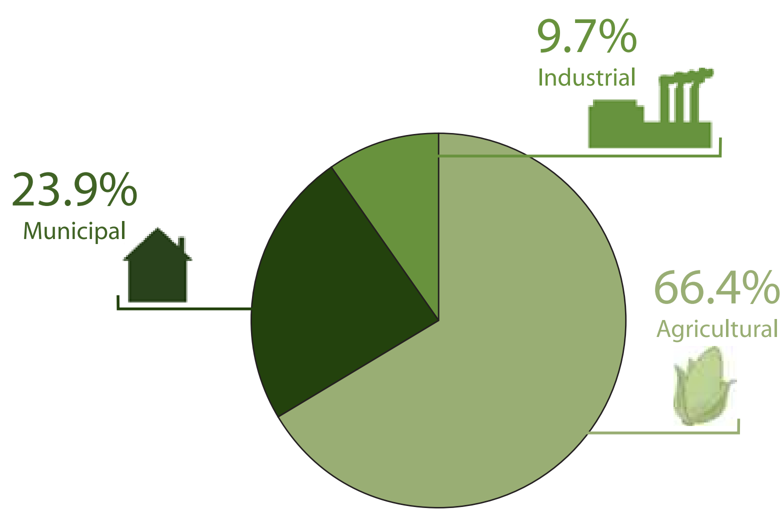
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.9
Surface water withdrawal (10^9 m³/yr)	2000	0.4
Groundwater withdrawal (10^9 m³/yr)	2000	0.1
Total water withdrawal per capita (m³/inhab/yr)	2002	48
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	1.9

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	1992	1.48

Withdrawals by sector (as % of total water withdrawal), 2000

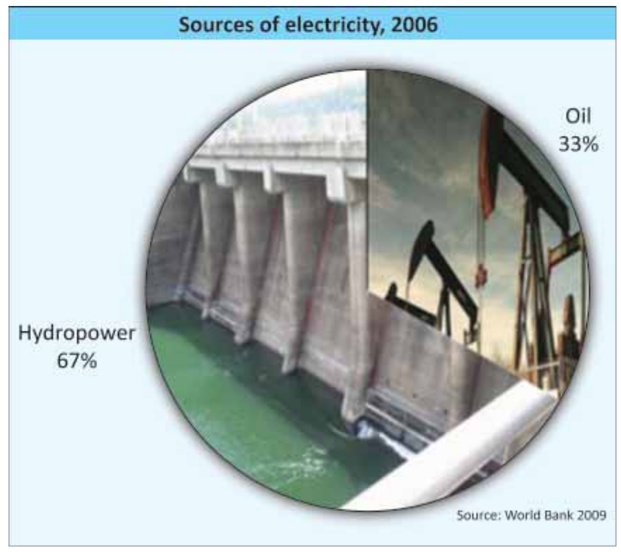


Degradation of the Lake Volta Ecosystem

Lake Volta is one of the world's largest artificial bodies of water, covering an area of approximately 8 482 km^2 (ESA 2005). The lake was created in the 1960s by the construction of the Akosombo Dam on the River Volta. It traverses much of the country and provides valuable services to both riparian communities and the country as a whole. As well as generating electricity and supporting inland transportation, its resources are vital for fishing and irrigation. However, a combination of unsustainable practices and climate variability are degrading this important ecosystem.

Lake Volta is the most productive inland fishery in Ghana, supplying both income and food to local residents. Pressure from overfishing has resulted in the stagnation of fish catch—the maximum sustainable yield has been exceeded each year since 1995 (FAO 2008).

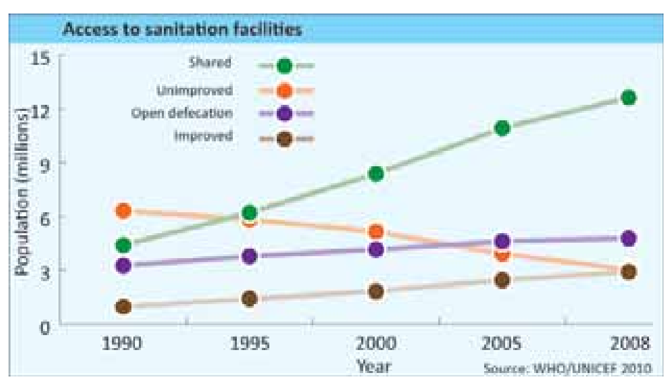
In addition, a combination of climate variability and soil erosion has led to a decrease in the lake's volume. Hydropower is a key source of electricity in Ghana, accounting for 67 per cent of the power mix in 2006 (World Bank 2009). A reduction in the lake's volume could have serious consequences for hydroelectricity generation and the country's energy security (read about the Volta River basin on page 119).



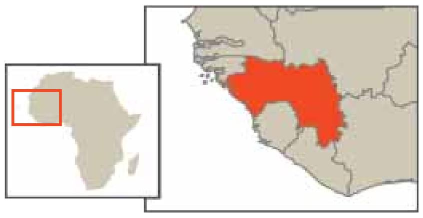
Access to Sanitation

Ghana's population has grown rapidly over the last few decades, increasing from just under 15 million in 1990 to 23.8 million in 2008 (United Nations 2008). This has had serious consequences for sanitation infrastructure in the country in both urban and rural areas. Ghana has one of the lowest levels of improved sanitation access on the continent, with only 13 per cent of the population using improved facilities. This figure is even lower in rural areas where only seven per cent have access (WHO/UNICEF 2010). While close to two million people gained access to improved sanitation between 1990 and 2008, this rate is far below that of population growth.

Open defecation is a serious issue in the country, practiced by an estimated 20 per cent of the population (WHO/UNICEF 2010). As a result it has been ranked as one of the most unsanitary places in Africa (UNOCHA 2008). Often, this waste ends up polluting Ghana's beaches and marine environment, which can have a negative effect on tourism.



The lack of sewage infrastructure has had a considerable health toll on Ghana. Sanitation-related diseases such as diarrhoea, typhoid, cholera and hepatitis have had a serious impact on the population.



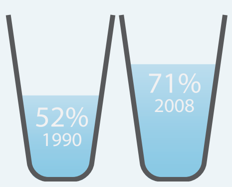
Republic of

Guinea

Total Surface Area: 245 857 km²
Estimated Population in 2009: 10 069 000

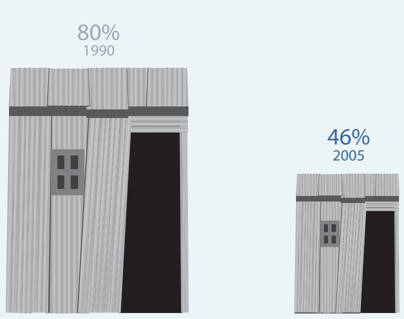
Progress Towards MDG Goal 7

Guinea is one of West Africa's wettest countries, but water treatment centres frequently break down, often leaving the country with little or no running water for weeks. Between 1990 and 2008, access to improved drinking water grew from 87 to 89 per cent in cities but from only 38 to 61 per cent in rural areas. Improved sanitation lags behind, with 19 per cent of urbanites with access in 2008 (up from nine per cent in 1990) compared to 11 per cent among rural people (up from six per cent).



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 651
Total renewable water (actual) (10^9 m^3/yr)	2008	226
Total renewable per capita (actual) (m^3/inhab/yr)	2008	22 984
Surface water: total renewable (actual) (10^9 m^3/yr)	2008	226
Groundwater: total renewable (actual) (10^9 m^3/yr)	2008	38
Dependency ratio (%)	2008	0

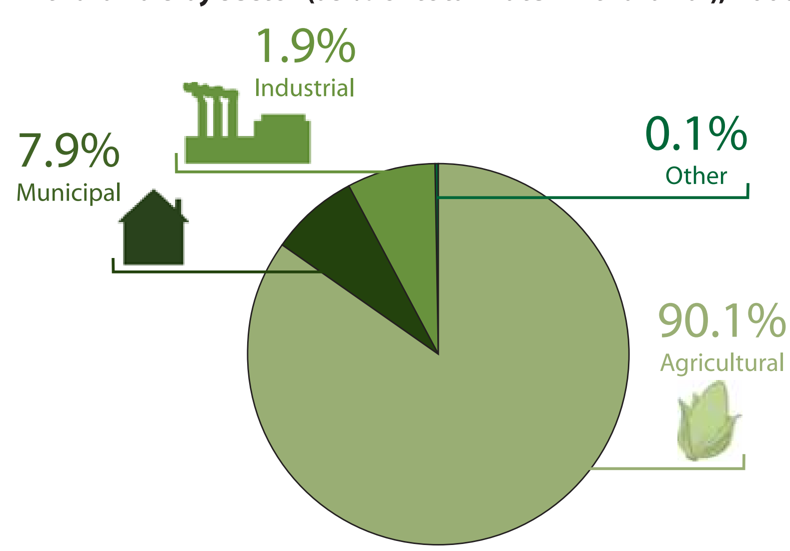
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m^3/yr)	2000	1.5
Surface water withdrawal (10^9 m^3/yr)	1987	0.7
Groundwater withdrawal (10^9 m^3/yr)	1987	0.07
Total water withdrawal per capita (m^3/inhab/yr)	2002	173.4
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.7

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



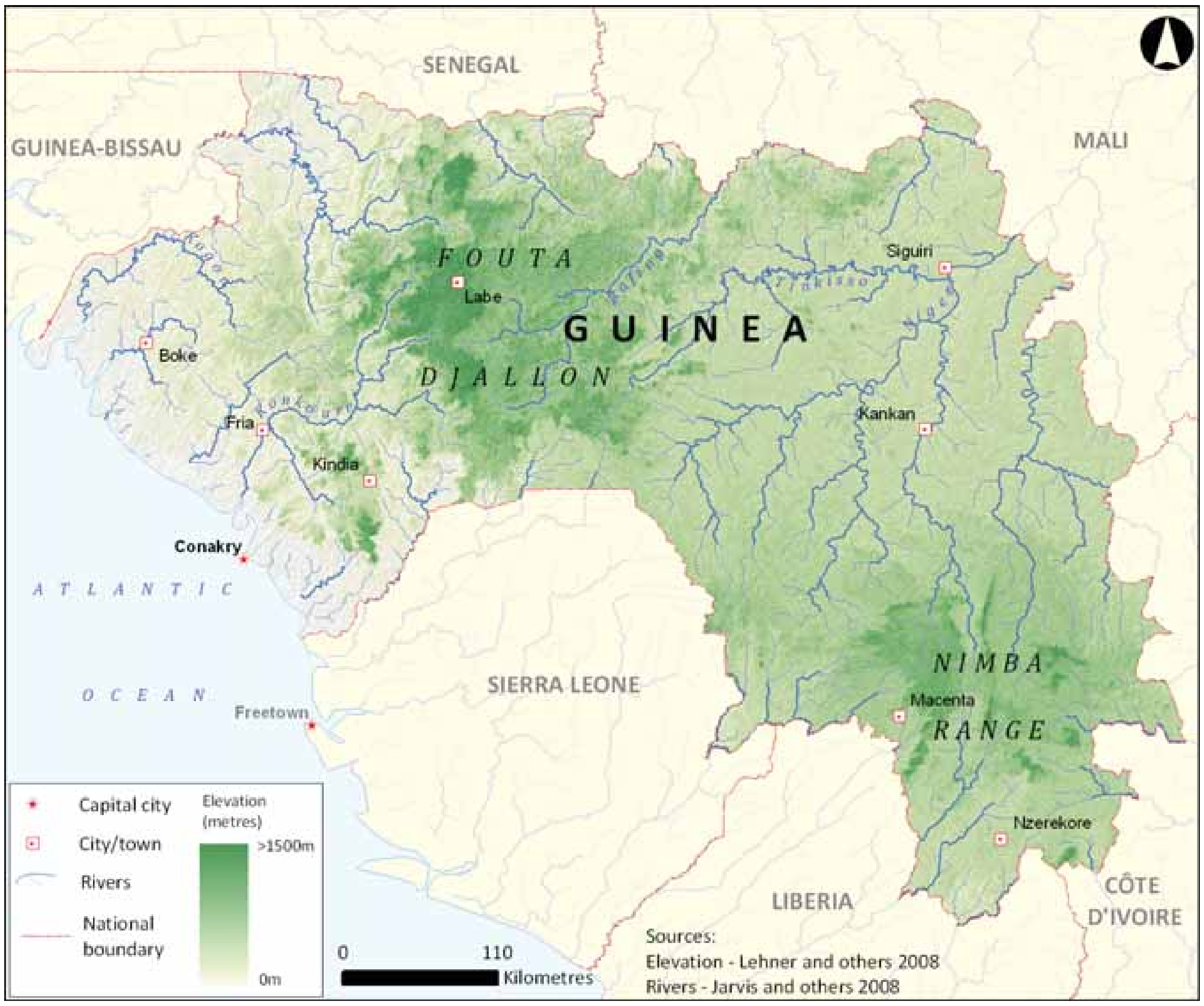
Taking Advantage of Hydropower Potential

Access to electricity is vital for promoting the socio-economic development of households and the nation as a whole. While no official figures exist for Guinea's electrification rate, a recent NOAA study that utilizes remote sensing imagery to generate electrification estimates, suggested a rate of only 21 per cent (NOAA 2009).

At the same time, Guinea is endowed with plentiful water resources and is the source for 22 major rivers including the Niger and Senegal Rivers. It has one of the highest per capita water availability rates on the continent, with annual internal renewable resources of around 22 984 m^3 per person (FAO 2008). By taking greater advantage of the vast hydro-potential in the country, there could be a dramatic increase in the proportion of the population with access to electricity.

Developing hydropower without compromising local communities and ecosystems is a significant challenge. Large-scale hydro schemes often result in the displacement of communities, decreases in fish and the spread of water-related diseases. Finding a way to balance the benefits of hydropower with the potential damage will be key to ensuring sustainable access to energy in the region.

Guinea's rivers and elevated gorges could potentialy provide hydropower generation



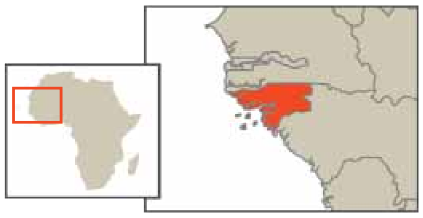
PCB Contamination in Conakry

Polychlorinated biphenyls (PCBs) are a class of human-made chemicals that are resistant to acids, bases and heat. As a result, they have had numerous applications as insulating materials in electric equipment such as capacitors (which store the electric charge) and transformers. Their use has been banned or severely restricted in many countries, however, due to the potential risks to both human health and the environment.

In Conakry, the capital of Guinea, abandoned PCB capacitors have contaminated approximately 1.21 ha of land in the city centre. Much of this PCB waste originated abroad in France, England, Germany and the United States. In addition, an electric power plant, the EDG Site de Tombo, has released an estimated 3 785 litres of PCB-contaminated transformer oil into Conakry Bay over the course of the last 50 years (Blacksmith Institute 2010).

This toxic contamination has numerous health implications for exposed people and animals. Staff at the power plant are the most directly and immediately affected. Furthermore, the PCB-saturated site is located within 135 m of a village that relies on the water from Conakry Bay for drinking, cooking and bathing.

Dealing with this pollution and implementing solutions for monitoring and combating potential drainage will be vital for ensuring the health of the local community and ecosystems.



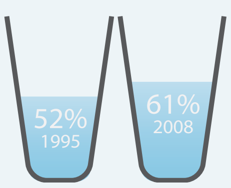
Republic of

Guinea-Bissau

Total Surface Area: 36 125 km²
Estimated Population in 2009: 1 611 000

Progress Towards MDG Goal 7

Guinea-Bissau's water and sanitation infrastructure is one of the poorest in the world. Years of conflicts have prevented the implementation of governmental and aid projects. Thus, the majority of the population is reliant on shallow wells that are often contaminated by nearby sanitation facilities. Compared to urban water and sanitation sources, access is woefully inadequate in rural areas and has not improved greatly since the 1990s. In 2008, 83 per cent of the urban population had improved water compared to 51 per cent in rural areas, while sanitation coverage was 49 per cent in cities but only 9 per cent in the countryside.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage

N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 577
Total renewable water (actual) (10^9 m³/yr)	2008	31
Total renewable per capita (actual) (m³/inhab/yr)	2008	19 683
Surface water: total renewable (actual) (10^9 m³/yr)	2008	27
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	14
Dependency ratio (%)	2008	48.4

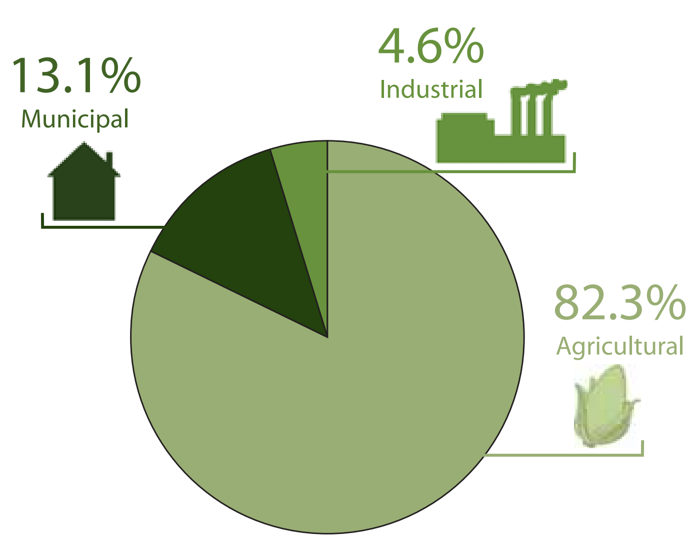
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.2
Surface water withdrawal (10^9 m³/yr)	2000	0.1
Groundwater withdrawal (10^9 m³/yr)	2000	0.03
Total water withdrawal per capita (m³/inhab/yr)	2002	127.8
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.6

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



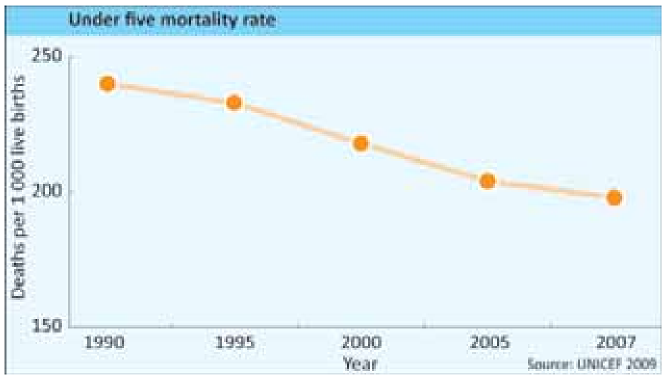
Contaminated Water Supplies in Bissau

Bissau, Guinea-Bissau's capital city, is home to 302 thousand people (Kofoed 2006)—approximately 20 per cent of the country's total population. An estimated 80 per cent of the capital's water supplies are contaminated with harmful bacteria (UNOCHA 2009).

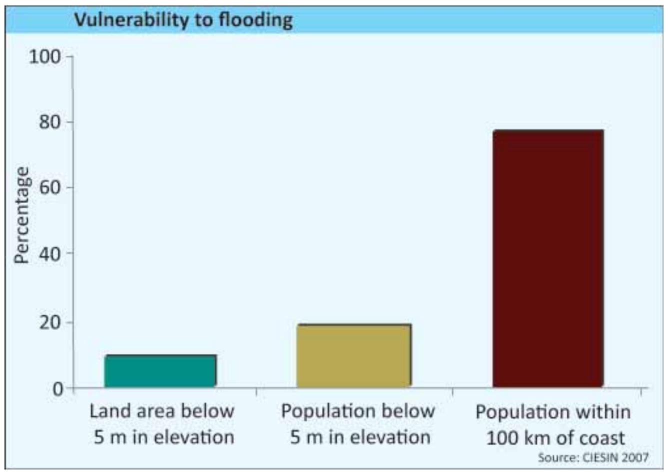
The situation is further compounded by a growing population and ongoing political instability. Between 1980 and 2005, Guinea Bissau's urban population more than tripled in size, increasing from 140 000 to 473 000 people (United Nations 2007), with the majority concentrated in the capital. Only 27 per cent of urban households have access to piped water (WHO/UNICEF 2010), as a result many draw water directly from shallow wells they construct themselves, often sited dangerously close to latrines (UNOCHA 2009).

The high levels of bacteria mean that outbreaks of waterborne diseases are regular and widespread. A cholera outbreak in February 2009 infected around 14 000 people and killed 225 (UNOCHA 2009). In 2007, Guinea Bissau ranked fifth in the world for the rate of under-five mortalities. Almost one in five children in the country die before the age of five with many of the deaths linked directly to diarrhoeal illnesses (UNICEF 2009).

Political instability and frequent coups have hampered investment in a country very much dependent on external assistance, while the lack of governmental capacity has prevented the development of adequate water infrastructure—both physically and in terms of human resources for enforcement of payment and for maintenance.

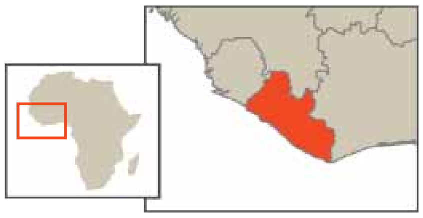


Saltwater Intrusion



Guinea-Bissau's extensive Atlantic Ocean coastline leaves it vulnerable to changes in sea level. With over 78 per cent of the population living within 100 km of the coast (CIESIN 2007), a rise in sea level—and the resultant salt water intrusions—could be devastating for local communities. The mangrove forests are essential for mitigating coastal climate change impacts since trees act as a buffer against waves, accumulate silt and create a barrier against saltwater. Wood harvesting and land conversion for agricultural purposes, however, pose a threat to this vital ecosystem.

The country has suffered from high levels of saltwater intrusion into inland and coastal freshwater systems degrading the quality of water available for domestic and agricultural use. The agricultural sector, which accounts for around 82 per cent of water withdrawals, has suffered from the flooding of rice fields following the loss of protective barriers (FAO 2005).



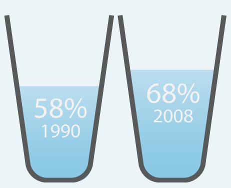
Republic of

Liberia

Total Surface Area: 111 369 km²
Estimated Population in 2009: 3 955 000

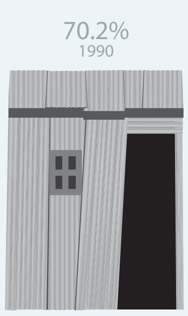
Progress Towards MDG Goal 7

The 14-year civil war from 1989 to 2003 seriously damaged water and sanitation facilities in Liberia and municipal systems collapsed as rural people took refuge in cities. All sewerage systems broke down in the countryside. There was an overall increase in access to improved drinking water from 1990 to 2008, although urban areas suffered a 13 per cent drop. Access to improved sanitation improved from 11 per cent in 1990 to 17 per cent in 2008.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	2 391
Total renewable water (actual) (10⁹ m³/yr)	2008	232
Total renewable per capita (actual) (m³/inhab/yr)	2008	61 165
Surface water: total renewable (actual) (10⁹ m³/yr)	2008	232
Groundwater: total renewable (actual) (10⁹ m³/yr)	2008	45
Dependency ratio (%)	2008	13.8

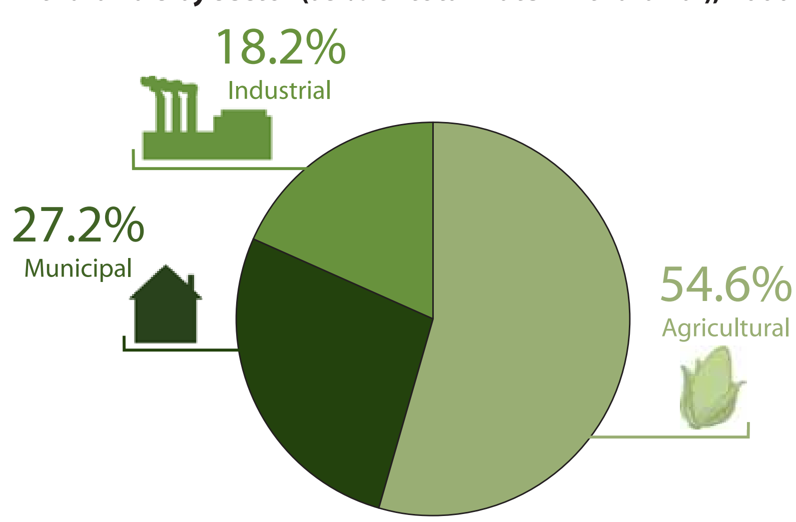
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10⁹ m³/yr)	2000	0.1
Surface water withdrawal (10⁹ m³/yr)	...	...
Groundwater withdrawal (10⁹ m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	35.9
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.05

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

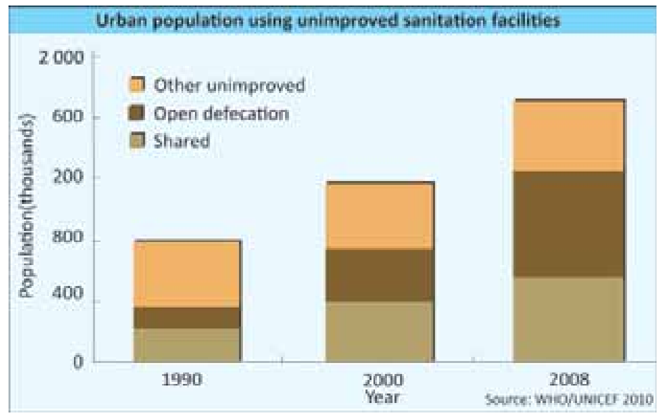
Withdrawals by sector (as % of total water withdrawal), 2000



Slums and Access to Sanitation Facilities in Monrovia

Liberia's urban population has grown rapidly over the last few decades, from just under one million people in 1990 to nearly 2.3 million in 2008 (WHO/UNICEF 2010). This has placed urban sanitation infrastructure under heavy pressure. The situation is especially dire in the capital Monrovia, home to 1.5 million residents, many of whom are living in over-crowded informal settlements.

The lack of clean water and sanitation facilities is contributing to the spread of water-related communicable diseases in the city. Twenty to thirty cases of cholera are reported weekly with 98 per cent of cases concentrated in the shanty towns such as Buzzi Quarter, West Point, Clara Town and Sawmill (UNOCHA 2009a). High malaria and diarrhoea rates are also evident and are the leading causes of child mortality in the country.

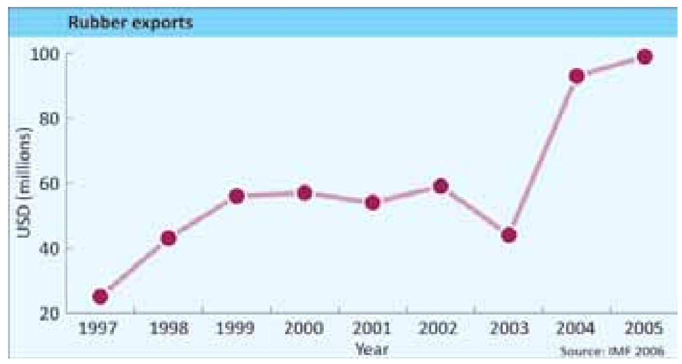


According to the UNOCHA (2009a), in the Clara Town slum, 75 000 people share 11 public toilets and 22 public taps while the 70 000 residents of West Point have access to only four public toilets. The waste from the public toilets is often discharged into rivers or beaches, further contaminating water resources. Furthermore, in many cases, residents are unable to afford pay toilets, resulting in high levels of public defecation (UNOCHA 2009a).

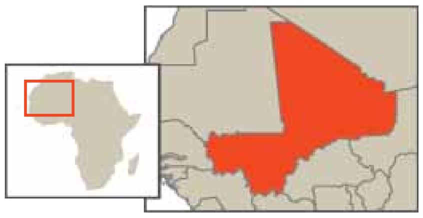
Water Pollution from Rubber Plantations

Rubber resources are a key source of wealth for Liberia, comprising one of the nation's top export commodities . The rubber concession of Firestone Natural Rubber Plantation, an American company, makes it the second-largest producer of rubber on the continent. Pollution from Firestone's plantation in Harbel Lower Margibi County, 45 km from the capital Monrovia, however, has had a serious impact on the health and livelihoods of local residents (UNOCHA 2009b). Operations have contaminated Ninpu Creek, used by the Kpayah Town Community for fishing and drinking water.

The local wetlands are an important resource for the area. Local residents have reported falling ill with diarrhoea after consuming the water and that fish populations have died. In 2009, Liberia's Environmental Protection Agency found Firestone guilty of water pollution.



Finding a way to sustainably and equitably manage Liberia's rubber resources without compromising the health of local communities and ecosystems poses a key developmental hurdle.



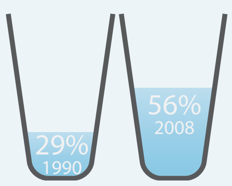
Republic of

Mali

Total Surface Area: 1 240 192 km²
Estimated Population in 2009: 13 010 000

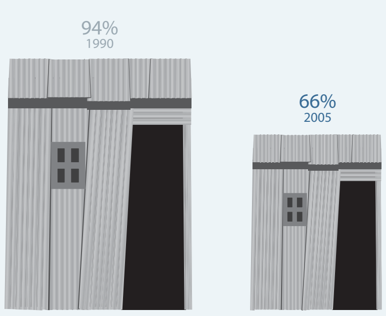
Progress Towards MDG Goal 7

From 1990 to 2008, Mali made significant progress in increasing the proportion of its population using improved drinking water (from 29 to 56 per cent), despite a decline in precipitation and rising rainfall variability. Access in rural areas grew from 22 to 44 per cent. The urban population using improved sanitation rose from 36 to 45 per cent, while in rural areas, access grew from 23 to 32 per cent.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	282
Total renewable water (actual) (10^9 m³/yr)	2008	100
Total renewable per capita (actual) (m³/inhab/yr)	2008	7 870
Surface water: total renewable (actual) (10^9 m³/yr)	2008	90
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	20
Dependency ratio (%)	2008	40

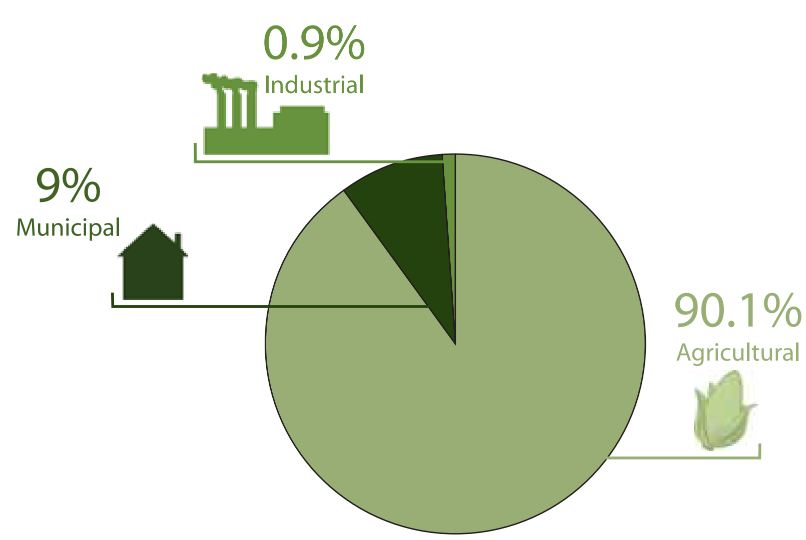
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	6.5
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	594.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	6.5

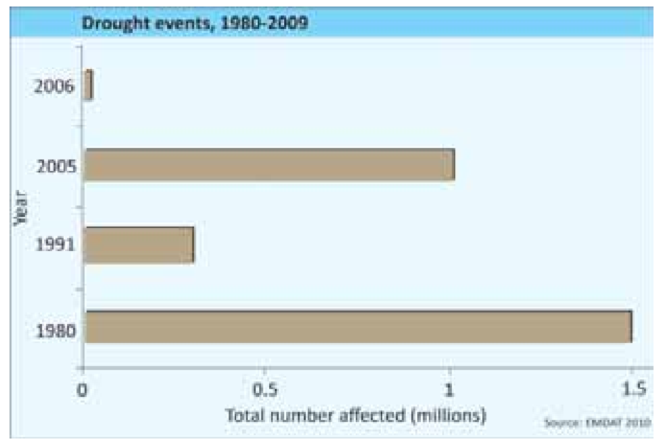
Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1994	22.4
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



Drought, Desertification and the Restoration of Lake Faguibine



Droughts and desertification are increasing threats to ecosystems and livelihoods in Mali, a landlocked country located in the heart of western Africa. While total per capita water availability is relatively high at 7 870 m^3 annually (FAO 2008), these water resources are distributed unevenly throughout the country. The Niger and Senegal Rivers provide an important lifeline in the south but much of the north is covered by desert.

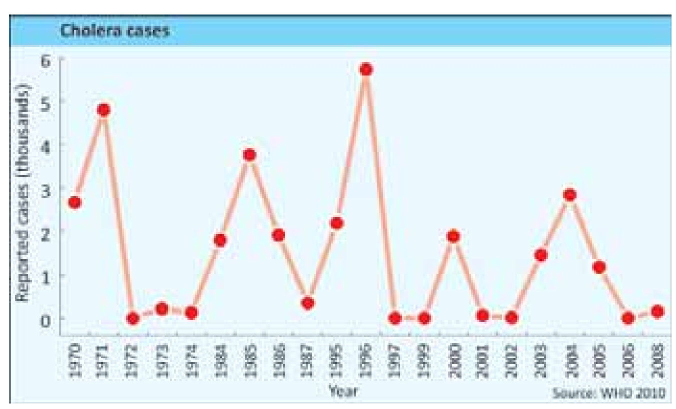
Until the 1980s, a series of four interlinked lakes, which were fed by two canals originating at the Niger River, served as an important water source in the north of Mali on the southern edge of the Sahara Desert. These lakes, of which Lake Faguibine was the largest, served as a vital ecosystem providing services such as water resources for humans and livestock, fishing and over 60 000 ha of fertile land (UNOCHA 2008). The clogging of the canals with sand and debris, combined with prolonged droughts in the mid 70s and 80s, however, caused the lakes to dry up. Today, Lake Faguibine remains mostly dry but for some pooling of water in the wet seasons of a few years since 1990. In 2006, the government set up the Lake Faguibine Authority to reopen the waterways to the lake. Limited infrastructure and increased sands from the ever-encroaching Sahara Desert, however, pose difficult obstacles to the restoration of this important ecosystem (UNOCHA 2008) (see more on Lake Faguibine on page 64).

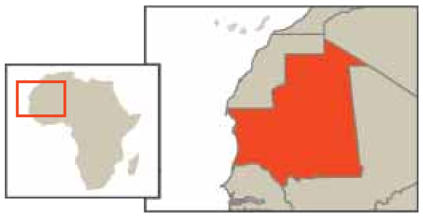
Water-related Disease

Water-related diseases such as cholera, diarrhoea and Guinea worm represent more than 80 per cent of all illnesses in Mali (WWAP 2006). The availability of clean drinking water is highly limited in the country —accessible by only 56 per cent of the population in 2008 (WHO/UNICEF 2010). As a result, many depend on unimproved water supplies to meet their daily needs. Much of Mali's rural population, which makes up just under 70 per cent of the total, rely directly on untreated water from the Niger and Senegal Rivers, which serve as a breeding ground for disease.

In recent years, there has been a resurgence of cholera in Mali, especially during the hot season of April to June with the outbreaks affecting the Mopti region in particular. *Onchoncerosis*, or river blindness, is another water-related condition that is prevalent throughout Mali. *Onchoncerosis* affects all of the river basins in Mali, spanning a total area of 350 000 km^2, placing millions of people at severe risk of exposure (AAAS 1998).

Water-quality levels are further affected by agricultural, industrial and domestic pollution. Nearly all effluents from Bamako, the capital, are released untreated into the Niger River. Additional water contamination occurs from the use of pesticides and fertilizers.





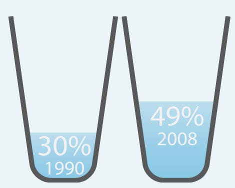
Islamic Republic of

Mauritania

Total Surface Area: 1 025 520 km²
Estimated Population in 2009: 3 291 000

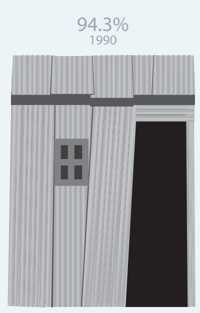
Progress Towards MDG Goal 7

Mauritania is covered by desert and subject to frequent droughts, thus water sources are naturally scarce. Both urban and rural populations suffer from poor access to improved drinking water, with the overall proportions of 30 per cent access in 1990 and 49 per cent by 2008. Access to sanitation is extremely low, with half of the urban population served in 2008 and only nine per cent of rural people with access.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	92
Total renewable water (actual) (10^9 m³/yr)	2008	11.4
Total renewable per capita (actual) (m³/inhab/yr)	2008	3 546
Surface water: total renewable (actual) (10^9 m³/yr)	2008	11.1
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.3
Dependency ratio (%)	2008	96.5

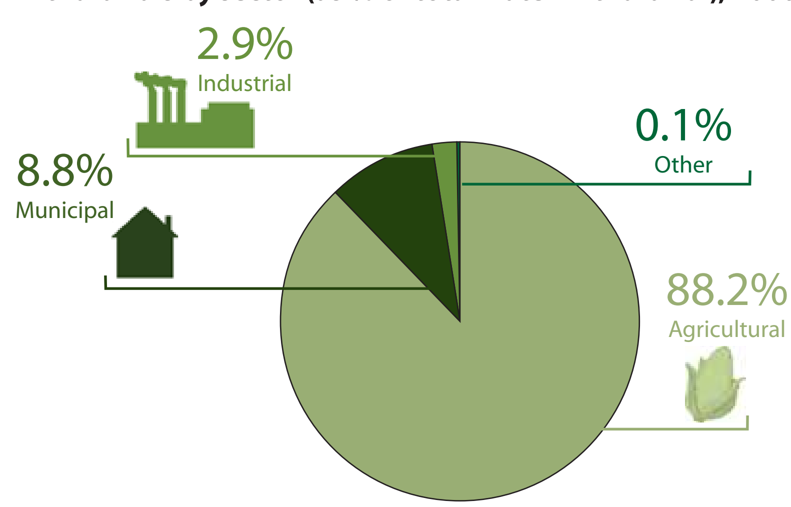
Withdrawals

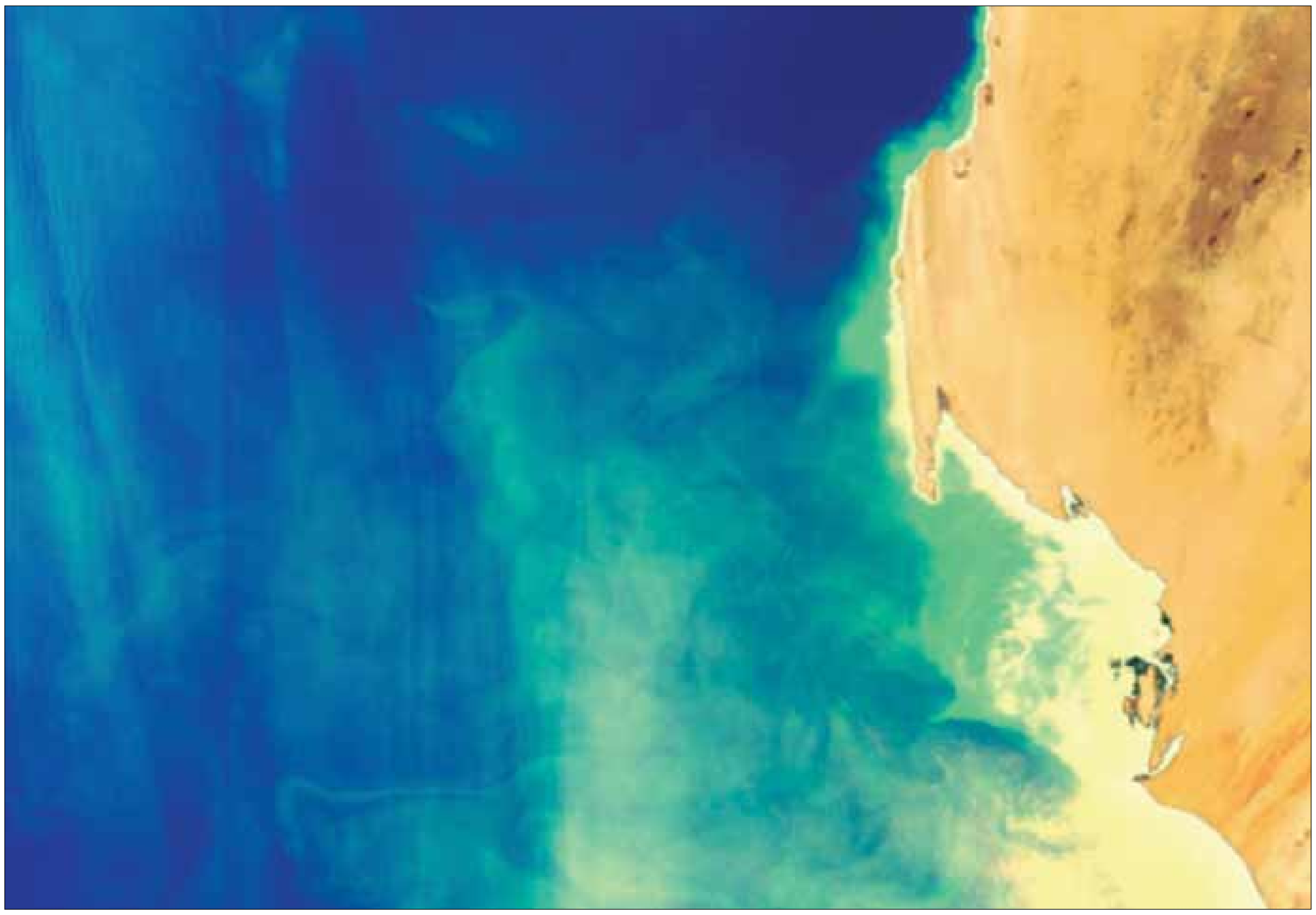
	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	1.7
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	617.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	14.9

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1993	66
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000





Phytoplankton blooms (Source: NASA Earth Observatory 2002)

Water Pollution

Thirty-three per cent of Mauritania's population live within 100 km of the 1 268-km coastline (CIESIN 2007), many of whom are dependent on the marine environment for livelihoods. This important ecosystem is vulnerable to both nutrient pollution and the expansion of irrigated agriculture. According to the IUCN, an estimated 22 fish species in Mauritanian waters are threatened (IUCN 2007).

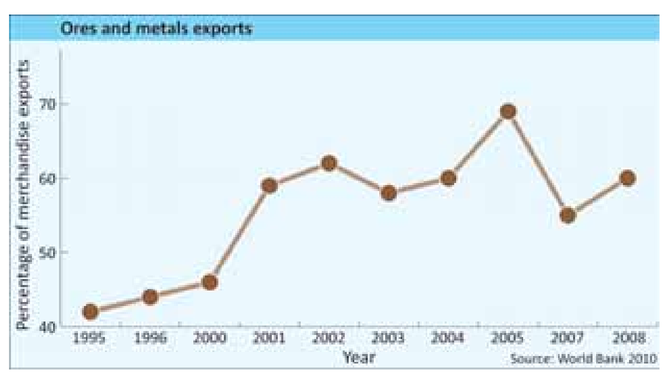
Coastal Mauritania has been suffering from episodic hypoxia-oxygen depletion since the 1990s, mostly due to dry climatic conditions (Le Loeuff 1999). Strong trade winds hit the coast from the northeast, churn up deep ocean water, bring settled nutrients to the surface and give rise to phytoplankton blooms. These blooms, shown in the image above, along with episodic hypoxic events create a cascade of problems for water quality and aquatic life.

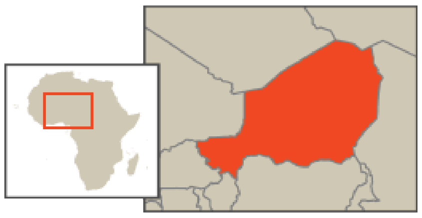
Irrigated agriculture in Mauritania is rapidly expanding, a growth primarily stimulated by the construction of two new dams on the Senegal River. Approximately 100 000 ha of land are now cultivated in the basin (WWAP 2003). However, greater agricultural capacity often comes hand in hand with increased fertilizer usage and a host of environmental problems not least in terms of water contamination. Controlling point and non-point source pollution into Mauritania's coastal waters is essential for the survival of Mauritania's aquatic life and coastal population.

Mining Impacts on the Senegal River

With an average of only 92 mm of rainfall each year, Mauritania is one of the driest countries on the continent. As a result, the 1 800 km-long Senegal River, which spans West Africa, is a vital lifeline for the region. Mauritania's 26 per cent share of the river basin covers an area of 75 500 km^2 (WWAP 2003).

Local extractive industries are having a negative environmental impact on this important water resource. Iron-ore output was 7.5 million tonnes in 2000 with iron-ore mining and processing accounting for more than 50 per cent of Mauritania's export earnings in 1999 (Encyclopedia of the Nations n.d.). In the same year, gypsum output, also in abundance in Mauritania, was measured at 100 000 tonnes. Mauritania is also rich in copper, and produces cement, clays, petroleum, refinery products, salt, sand and gravel and stone. Although mining presents economic opportunities, it threatens the health of Mauritania's water supply by physically and chemically altering nearby watersheds. In particular, the loss of wetlands due to mining activities has led to polluted water downstream, exacerbating flooding in some cases, and causing a regional loss of biological diversity and ecological productivity. Regulation of mining activities is important for ensuring wetland preservation, and in turn, clean water delivery to its people.

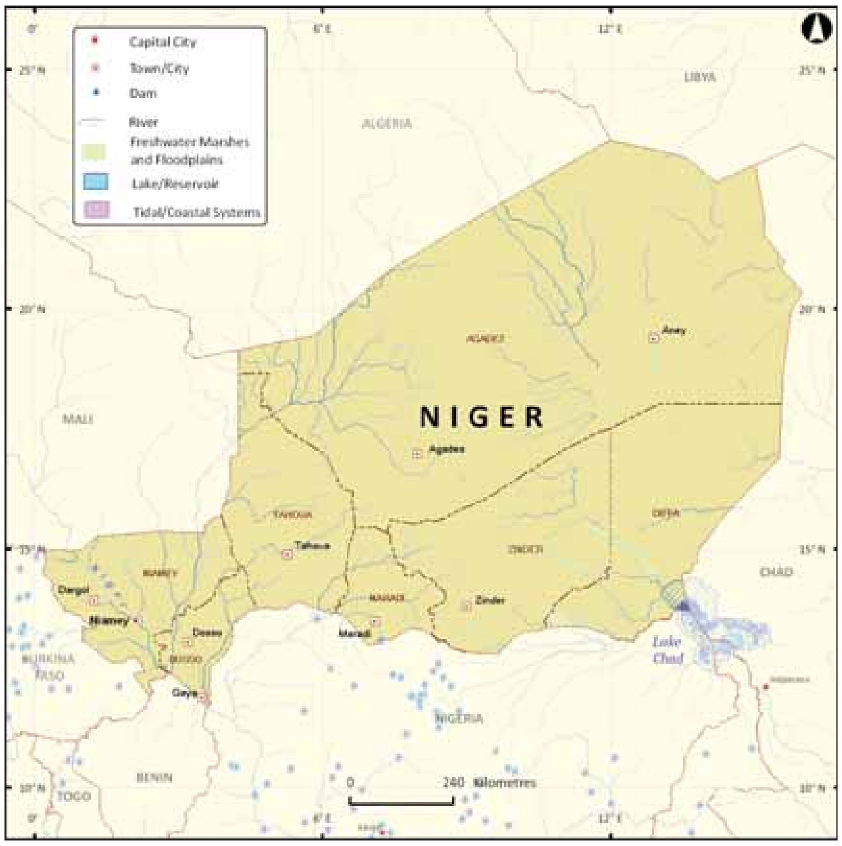




Republic of the

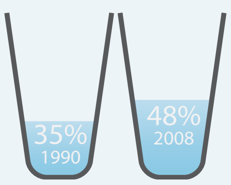
Niger

Total Surface Area: 1 267 000 km²
Estimated Population in 2009: 15 290 000



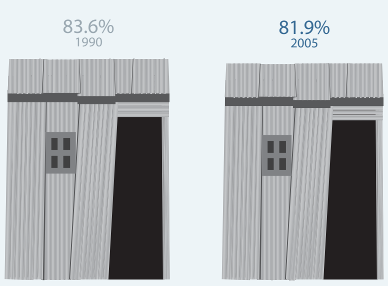
Progress Towards MDG Goal 7

Rural areas in Niger have extremely low levels of access to improved drinking water and sanitation. From 1990 to 2008, access to improved drinking water in urban areas rose from 57 to 96 per cent, and in rural areas from 31 to 39 per cent. Use of improved sanitation throughout the country is exceptionally low: 34 per cent in urban areas in 2008 (up from 19 per cent in 1990) and only four per cent in rural areas (up from two per cent).



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	151
Total renewable water (actual) (10^9 m³/yr)	2008	33.7
Total renewable per capita (actual) (m³/inhab/yr)	2008	2 288
Surface water: total renewable (actual) (10^9 m³/yr)	2008	31.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	2.5
Dependency ratio (%)	2008	89.6

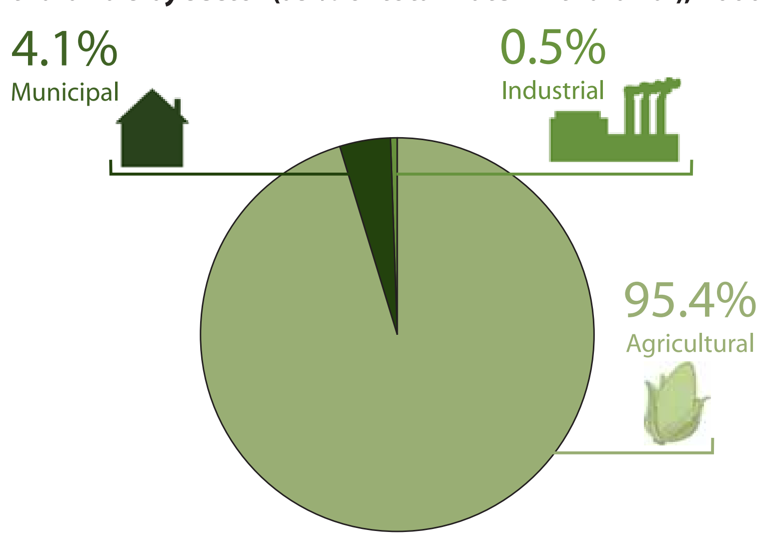
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	2.2
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	184.8
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	6.5

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	2000	0.4

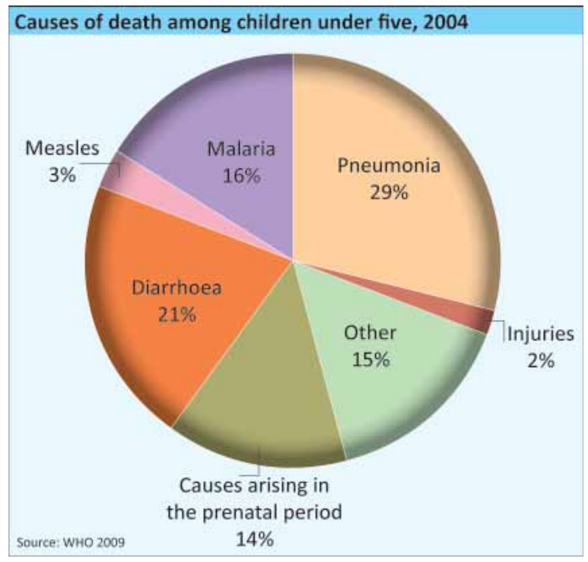
Withdrawals by sector (as % of total water withdrawal), 2000



Access to Water and Sanitation

Niger's status as one of the poorest countries in the world is reflected in its practically non-existent sanitation infrastructure and the limited access to clean water (UNDP 2009). In 2008, only nine per cent of the population had access to improved sanitation facilities. In rural areas, where 84 per cent of the population resides, this figure falls even further to four per cent. Little progress has been made in improving access levels over the last few decades and Niger is expected to miss its UN MDG sanitation target by a wide margin. Four-fifths of Niger's population have absolutely no access to sanitation facilities, instead resorting to open defecation (WHO/UNICEF 2010).

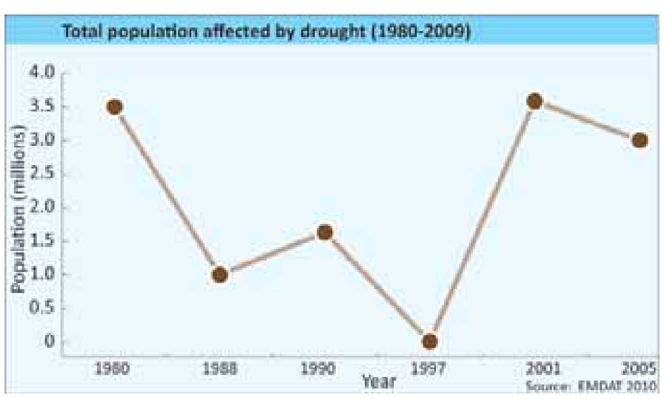
While access to an improved water source is slightly higher, just over half of the population still has no access to potable water. In many rural areas, residents have little choice but to consume pond water that is shared with livestock and contaminated with Guinea worms and high levels of chemicals such as fluorides and nitrates (UNICEF 2006).



As a result, unsafe water and poor sanitation and hygiene are a leading cause of illness and death in the country with children particularly susceptible. In 2004, diarrhoea accounted for 21.4 per cent of deaths of children under five, with malaria contributing to a further 16.4 per cent (WHO 2009). In addition, communities face regular outbreaks of cholera as well as problems with trachoma, dysentery and Guinea worm.

Water Scarcity and Food Security

With its arid climate and 65 per cent of its territory located within the Sahara Desert, only a small proportion of Niger's land is arable (FAO 2005). On average, the country receives as little as 151 mm of rainfall each year, well below the levels required to sustain rain-fed agriculture (FAO 2008). As a result, droughts are an ongoing concern, posing a serious threat to food security.



Between 1980 and 2005, there were six serious drought periods affecting a total of over 12.7 million people. Droughts in 2004/5 resulted in a serious food crisis in the country, which affected an estimated three million people (EM-DAT 2010). A prolonged drought in 2010 followed by floods spurred another food-security crisis.

Niger was ranked lowest of 182 nations in the 2009 Human Development Index (UNDP 2009). According to a government survey carried out in December 2009, an estimated 58 per cent of the population were found to be food-insecure (Reuters 2010). The high levels of poverty and insecurity add to Niger's vulnerability to climate change.

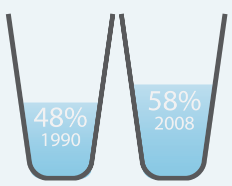
Federal Republic of

Nigeria

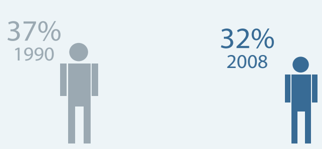
Total Surface Area: 923 768 km²
Estimated Population in 2009: 154 729 000

Progress Towards MDG Goal 7

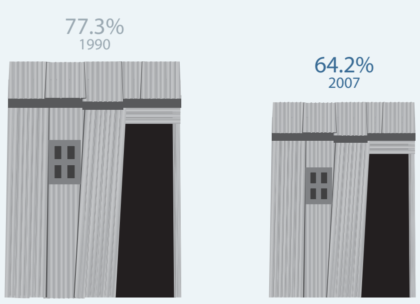
Nigeria's sanitation delivery has not kept pace with its extremely high population growth. From 1990 to 2008, there was a decline in the provision of improved water from 79 to 75 per cent and from 30 to 42 per cent in urban and rural areas, respectively. The urban decline is due to the lack of services in peri- and semi-urban areas. The proportion of the population living in urban areas is expected to rise to 60 per cent by 2015 (compared to 30 per cent in 1990).



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 150
Total renewable water (actual) (10^9 m³/yr)	2008	286.2
Total renewable per capita (actual) (m³/inhab/yr)	2008	1 893
Surface water: total renewable (actual) (10^9 m³/yr)	2008	279.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	87
Dependency ratio (%)	2008	22.8

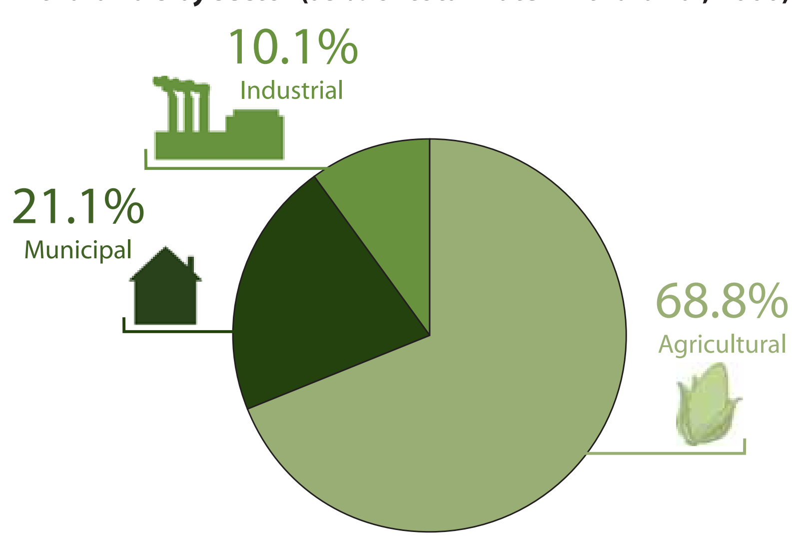
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	8.01
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	61.1
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	2.8

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1991	14.2
Area salinized by irrigation (1000 ha)	1999	100

Withdrawals by sector (as % of total water withdrawal, 2000)



Degradation of Hadejia-Nguru Wetlands

Wetlands form a key and extensive ecosystem in Nigeria. The wetlands of the Niger River Delta alone cover 75 000 km^2, making it the third-largest wetland in the world (UNDP 2006). Fadama areas, which are low-lying areas flooded during the wet season, are scattered across much of the country, including the ecological zones of Guinea Savannah, Sudan Savannah and the Sahel (FAO 2005). These wetlands provide important services for communities and biodiversity, including fishing, grazing and agriculture as well as a breeding ground for migratory birds. However, degradation is threatening the future of the country's wetlands.

The Hadejia-Ngura Wetlands, located in the northeast of Nigeria, have already suffered massive losses and degradation. This wetland ecosystem, which receives most of its water from the Hadejia and Jama'are Rivers, has lost more than half its area with much of the degradation attributable to a combination of drought and upstream dams (FAO 2005).

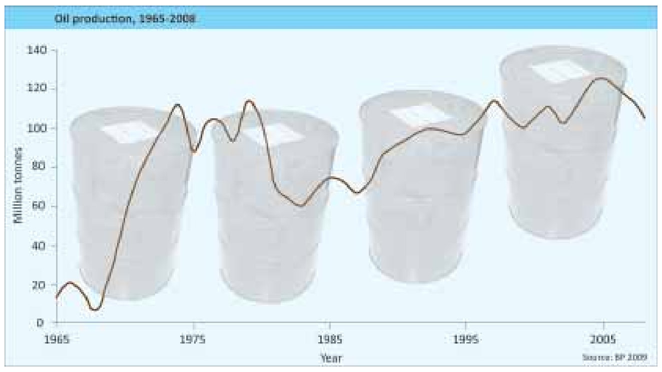
Additional upstream development projects could result in an even greater diversion of water from the wetlands. Specifically, a growth in irrigated agriculture upstream from the wetlands, as well as in the fadama areas, could have serious impacts on water availability—often leading to increased usage of groundwater aquifers. In some areas, a rise in irrigated crop production has already resulted in water-table declines (FAO 2005).

Additional threats to the wetlands have also appeared in the form of a species of wetland plant, (*Typha australis*) known as "kachalla" in Nigeria. This invasive species, which has infested river banks and farmlands in Jigawa State, disrupts both farming and fishing activities and has more than doubled in area over the last 20 years (UNOCHA 2008).

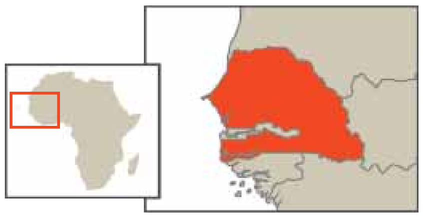
Hadejia Nguru Wetlands (Source: Joint Wetlands Livelihood Project n.d.)

Oil Pollution in the Niger Delta

In 2008, Nigeria produced 105.3 million tonnes of oil, making it Africa's largest producer and the thirteenth-largest globally (BP 2009). As a result, the petroleum industry forms the foundation of Nigeria's economy. Although the economic gains have been substantial, oil production has resulted in considerable environmental damage. In the Niger Delta, where much of the oil exploration and production occurs, oil drilling and pipe leakages have seriously polluted water resources (FAO 2005).



According to Amnesty International, more than 60 per cent of the Niger Delta's 31 million people are dependent on the natural environment for their livelihoods. However this important resource base has rapidly degraded since oil exploration began. Many in the region have to drink, cook and wash in contaminated water. In addition, oil pollution has caused long-term harm to fish stocks and fishing equipment and left the little remaining fish contaminated with toxins. Oil spills and waste dumping have also had a negative impact on soil fertility and agricultural productivity in the area (Amnesty International 2009) (see satellite image of the delta on page 68).



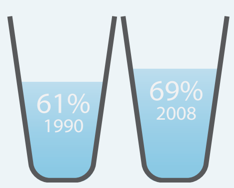
Republic of

Senegal

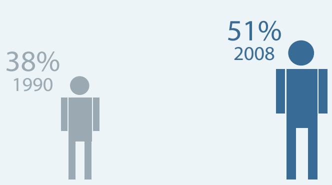
Total Surface Area: 196 722 km²
Estimated Population in 2009: 12 534 000

Progress Towards MDG Goal 7

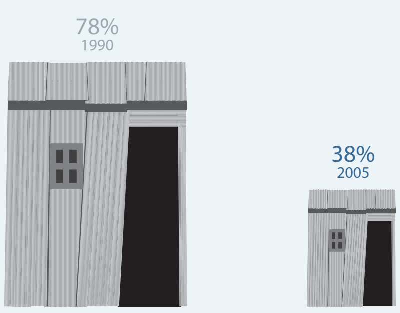
Senegal's cities are well served by improved drinking water facilities, with 92 per cent of urban populations using them (up from 88 per cent in 1990). Rural areas have yet to catch up, with 65 per cent access (up from 51 per cent in 1990). Access to improved sanitation lags far behind and there has been little change since 1990: 54 per cent of urban and only 9 per cent of rural populations use such facilities.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	686
Total renewable water (actual) (10^9 m³/yr)	2008	38.8
Total renewable per capita (actual) (m³/inhab/yr)	2008	3 177
Surface water: total renewable (actual) (10^9 m³/yr)	2008	36.8
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	3.5
Dependency ratio (%)	2008	33.5

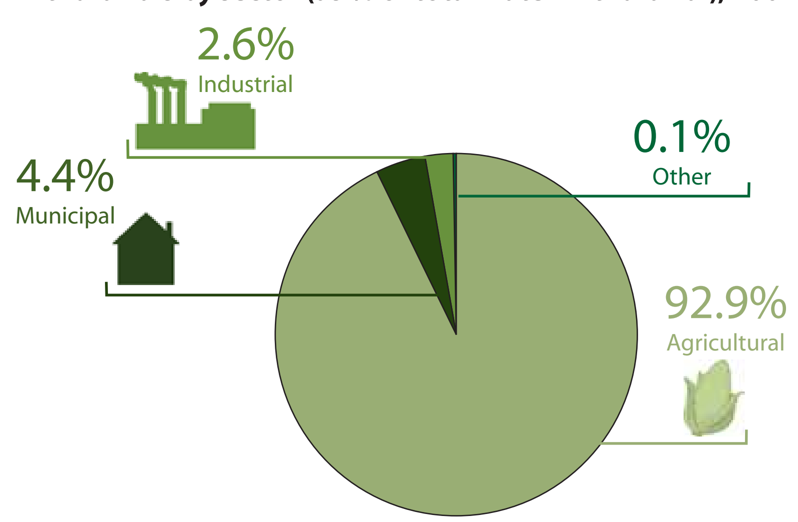
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2002	2.2
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	212.9
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	5.7

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2002

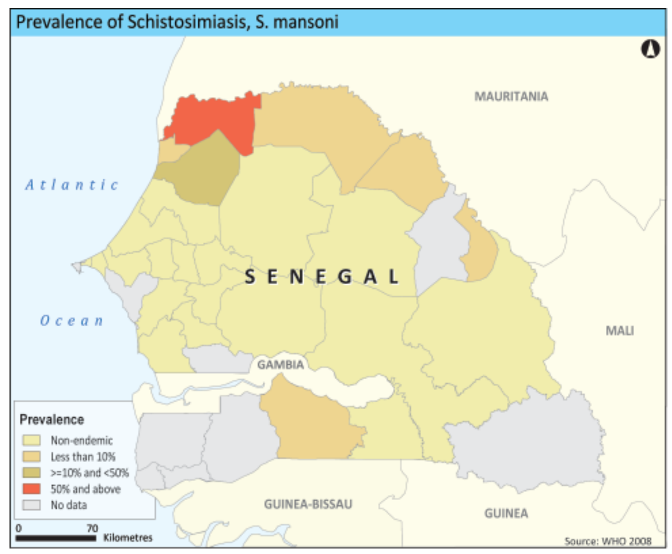


Public Health Impacts of Dams Along the Senegal River

The 1 800-km long Senegal River is an essential lifeline for its riparian countries, Guinea, Mali, Mauritania and Senegal. This important ecosystem is being threatened by dam construction, however, which has resulted in environmental degradation and negative impacts on the health of local communities.

Dam development along the river, including the Diama dam near the Senegal-Mauritania border, was initially anticipated to bring numerous socio-economic benefits by harnessing the potential of the Senegal River. While the dams have aided in providing irrigated agriculture, energy and improved flow control, they have also drastically increased incidences of water-related diseases (see more on page 94-97).

The prevalence of malaria, urinary schistosomiasis (bilharzias) and diarrhoea have all increased amongst riverine communities since the construction of the dams. Furthermore, intestinal schistosomiasis caused by *S. mansoni*, a more dangerous form of bilharzia, has also been introduced into the region. Dam development creates the ideal habitat for the snails carrying the disease, to the detriment of the local communities dependent on the water for drinking, cooking, cleaning and bathing. According to the Organization for the Development of the Senegal River, surveys found an intestinal schistosomiasis infestation rate of 44 per cent in the Walo flood plain and a 72 per cent rate around Guiers Lake where more than 90 per cent of villages are affected (WWAP 2003).

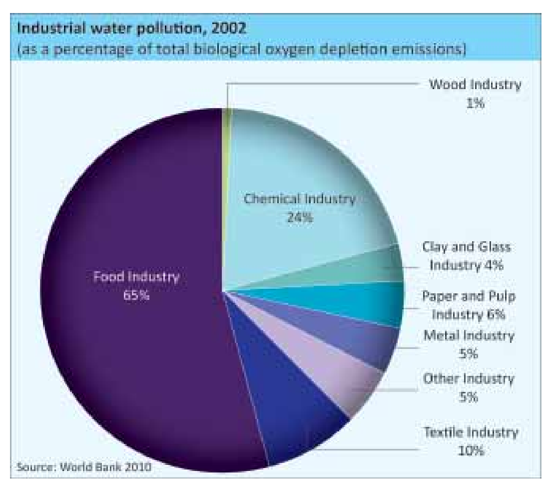


Industrial Pollution of Hann Bay

Hann Bay, which surrounds Dakar's industrial zone, is Senegal's most polluted region. Industrial water pollution as well as sewage have heavily contaminated the bay, rendering the water toxic (Blacksmith Institute 2010). As well as being an industrial centre, the area is also densely populated, with many locals relying on the bay for washing and fishing, making it an important natural resource for local residents.

There are currently at least 85 factories releasing untreated wastewater into the bay. Key industrial pollutants that have contributed to the toxicity of the water include PCBs, heavy metals, chemicals, tannery waste, sewage and solid waste (Blacksmith Institute 2010).

The largest sector contributing to industrial water pollution in Senegal is the food industry, which was responsible for 45 per cent of depletion of oxygen required by aquatic life in 2002 (World Bank 2010). The chemical and textile industries are also key emitters of untreated waste water, accounting for 24 per cent and 10 per cent, respectively. The development of industrial-waste treatment facilities is a key priority for reducing contamination levels in the bay and ensuring a more sustainable growth of the region's industry.



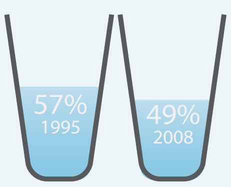
Republic of

Sierra Leone

Total Surface Area: 71 740 km²
Estimated Population in 2009: 5 696 000

Progress Towards MDG Goal 7

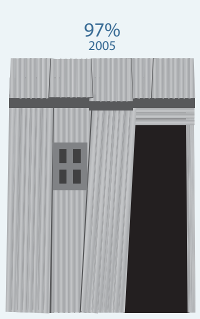
During the1991-2000 civil war, existing infrastructure was destroyed; water supply declined to 15 per cent of the population and led to increased waterborne disease and mortality. As a result of recovery strategies, water access has improved, although constrained by population growth and urbanization. Data from 1995 to 2008 show that access to improved drinking water in Sierra Leone increased in urban areas (from 72 to 86 per cent), but declined in rural ones (from 49 to 26 per cent). Throughout the country, sanitation coverage is also very poor.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage

N/A



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	2 526
Total renewable water (actual) (10⁹ m³/yr)	2008	160
Total renewable per capita (actual) (m³/inhab/yr)	2008	28 777
Surface water: total renewable (actual) (10⁹ m³/yr)	2008	150
Groundwater: total renewable (actual) (10⁹ m³/yr)	2008	25
Dependency ratio (%)	2008	0

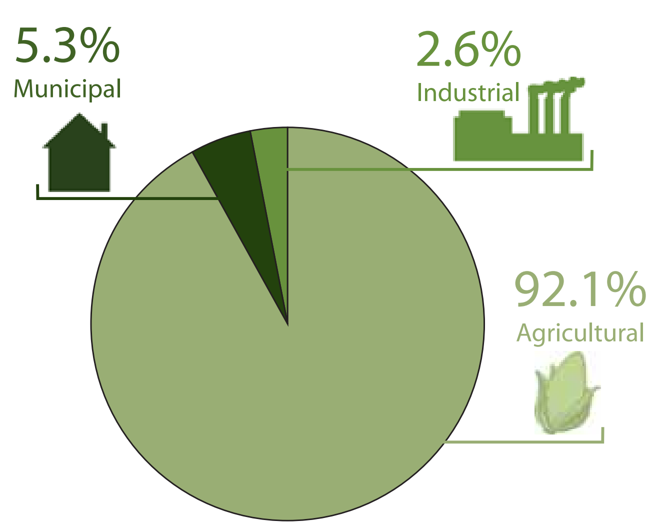
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10⁹ m³/yr)	2000	0.4
Surface water withdrawal (10⁹ m³/yr)	...	...
Groundwater withdrawal (10⁹ m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	83.7
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.2

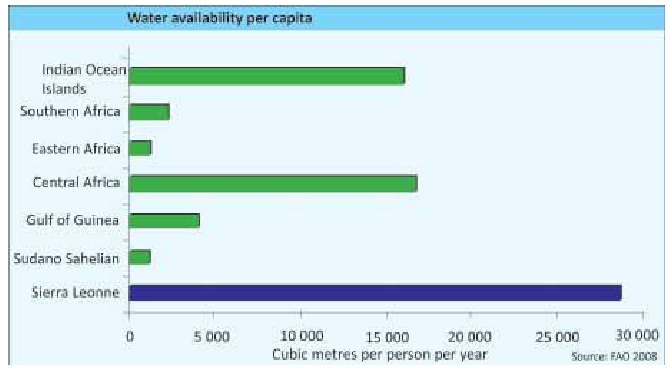
Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1991	38
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



Hydroelectric Power Potential



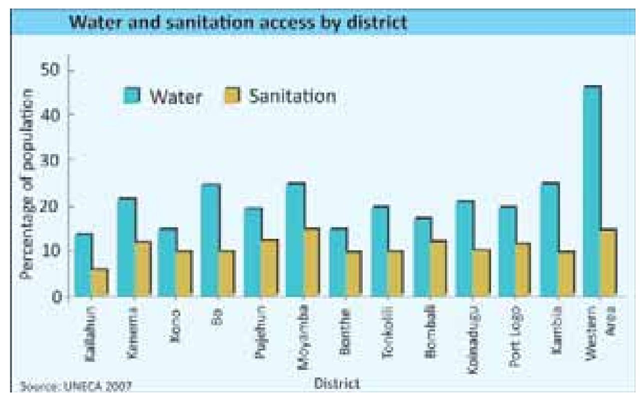
Sierra Leone's potential for hydroelectric generation is vast and underdeveloped. With its extensive river network as well as the highest average rainfall on the continent—2 526 mm each year—Sierra Leone is rich in surface water resources (FAO 2008). Sierra Leone also ranks sixth in Africa in terms of available renewable water resources per person (Elvidge and others 2010), with an annual availability of 28 777 cubic metres (FAO 2008).

Although no official figures exist for Sierra Leone's electrification rate, a recent study, which utilizes remote sensing techniques, estimated a rate of 25 per cent (Elvidge and others 2010). Most areas in the interior regions of Sierra Leone are either wholly or largely without access to electricity, and even for most electrified households access only lasts for up to a few hours a week.

Despite the socioeconomic benefits, all too often, hydropower development compromises the homes and livelihoods of riparian communities. Altered flows have many implications for native fish species that are either unable to pass through the dam or cannot adequately reproduce due to damaged spawning habitats. In addition, floodplain agriculture and dry-season livestock grazing practices are threatened because floodplains no longer inundate at the same rate.

The recent commissioning of the 50 MW Bumbuna hydroelectric plant is expected to increase the reliability and affordability of Sierra Leone's power supply (AfDB 2009). Reaching a balance between the electricity benefits of hydropower and the impacts on local communities and ecosystems is essential for the future of hydropower energy in Sierra Leone.

Rural Water and Sanitation Access



Since electricity throughout the country is often neither present nor stabilized, water pumps cannot command enough pressure to reach consumers living in high gradient or mountainous regions throughout the country. As a result, many people in remote communities are left to use untreated and unsanitary water.

Following independence in 1990, Sierra Leone made considerable progress in water supply and sanitation facilities (UNECA 2007). Despite this, in rural areas, which host 62 per cent of the population, 74 per cent of residents have no access to potable water and a further 94 per cent have no access to improved sanitation (WHO/UNICEF 2010). The low levels of clean water, sanitation facilities and hygiene translate to fatalities and health problems. Sierra Leone has the highest level of infant mortality in the world, 283 out of every 1 000 die before the age of five (DFID 2007). Waterborne and water-related diseases—such as diarrhoea and malaria— and acute respiratory disease are the most serious threats to public health in Sierra Leone.

Togolese Republic

Julius Cruickshank/Flickr.com

Total Surface Area: 56 785 km²
Estimated Population in 2009: 6 619 000

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 168
Total renewable water (actual) (10^9 m³/yr)	2008	14.7
Total renewable per capita (actual) (m³/inhab/yr)	2008	2 276
Surface water: total renewable (actual) (10^9 m³/yr)	2008	14
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	5.7
Dependency ratio (%)	2008	21.8

Withdrawals

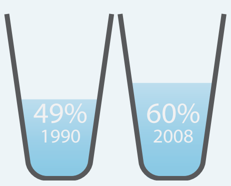
	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2002	0.2
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	30.4
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	1.2

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

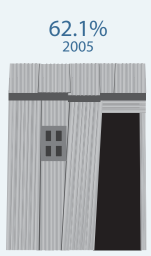
Progress Towards MDG Goal 7

Togo has a humid, tropical climate, but receives less rainfall than most of the other countries along the Gulf of Guinea. Between 1990 and 2008, the proportion of people with access to improved drinking water increased from 49 per cent to 60 per cent. Access in urban and rural populations rose from 79 to 87 per cent and 36 to 41 per cent, respectively. The percentage of people using improved sanitation facilities, however, declined from 13 to 12 per cent in the same period. Urban use dropped from 25 per cent to 24 per cent and rural use dropped from 8 per cent to 3 per cent.



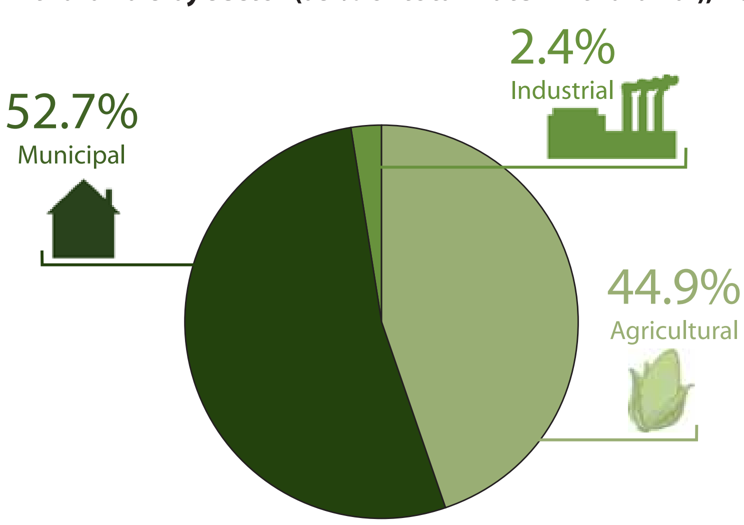
Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Withdrawals by sector (as % of total water withdrawal), 2002

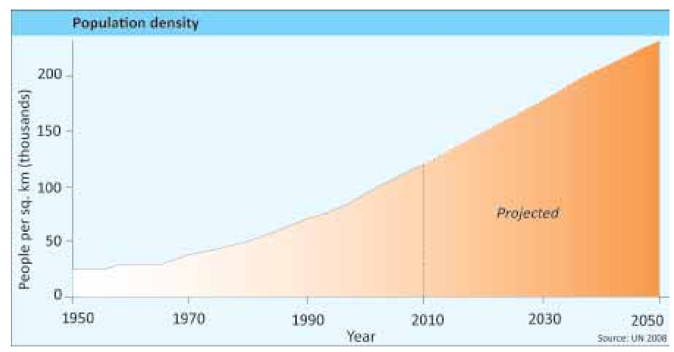


Threats from Sea-Level Rise

Togo's relatively flat topography and its extensive coastal zone with an area of 1 710 km^2 leaves it vulnerable to sea-level rises. The offshore bar (ridges and mounds of sand or gravel deposited beyond the shoreline by currents and waves) has a mean of 2-3 m above average sea level. In the barrier crossbar near lagoon and river mouths, however, it is only one metre.

The coast hosts more than 90 per cent of the nation's economic activities, and more than 42 per cent of the population (Blivi 2000). Togo's economic reliance on coastal activities further adds to the country's vulnerability to current and projected rises in sea level. Currently, the mean annual sea-level rise is 0.34 cm, but it is expected to increase with climatic changes. Other studies have shown that the extent of coastal retreat will progressively increase to 10 m/yr in the next century (Blivi 2000).

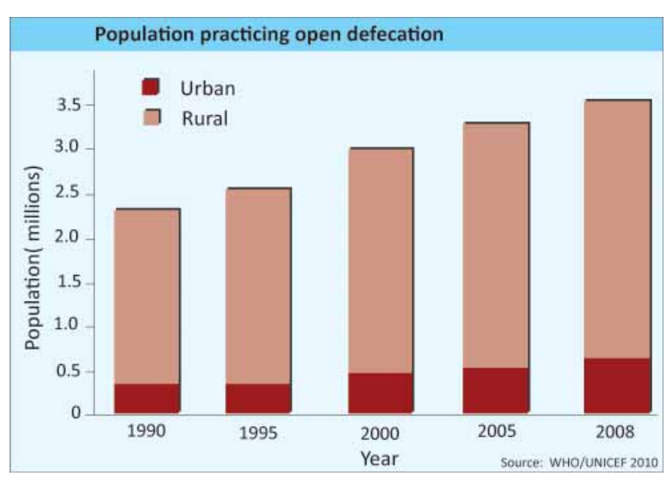
Not only will almost half of the nation's population be affected and possibly relocated if this trend continues, but saltwater intrusion from coastal waters will threaten freshwater resources (Blivi 2000). This poses threats to an already scarce water supply as Togo's per capita internal renewable water availability—2 276 m^3 annually—is approximately half of the average for sub-Saharan Africa (FAO 2008).



Low Access to Sanitation Facilities

Togo struggles to provide adequate sanitation facilities to its population. In 2008, only 12 per cent of the nation's population had access to improved sanitation facilities, with a mere three per cent in rural areas where 58 per cent of the population resides (WHO/UNICEF 2010). Open defecation is practiced by an estimated 3.55 million people in the country—over half the population. Given a current population of 6.7 million and an annual population growth rate of 2.48 per cent, the number of people living without access to essential services such as sanitation facilities is likely to grow faster than the infrastructure needed to service them (World Bank 2010).

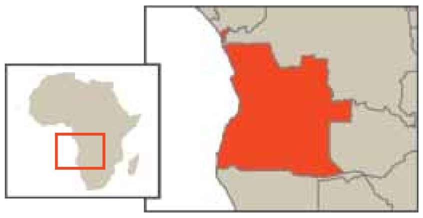
Low sanitation access brings a host of negative health impacts. Torpid wastewater is a breeding ground for many different communicable diseases. In 2008, 367 people died from cholera, and two years earlier an outbreak killed 1 159 (WHO 2010). Children are particularly vulnerable—in 2009, Togo's child mortality rate was 79 per 1 000 births. Furthermore, the percentage of years of life lost attributable to communicable diseases in 2002 was 79 per cent in Togo, compared to 59 per cent for the rest of Africa (WHO 2006). These high rates of communicable diseases are strongly linked to the nation's low access to sanitation facilities.



Brian Jackson/Flickr.com

Southern Africa

Angola
Botswana
Lesotho
Malawi
Mozambique
Namibia
South Africa
Swaziland
United Republic of Tanzania
Zambia
Zimbabwe



Republic of

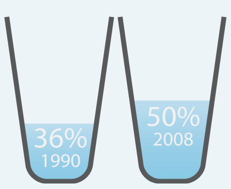
Angola

Total Surface Area: 1 246 700 km²
Estimated Population in 2009: 18 498 000

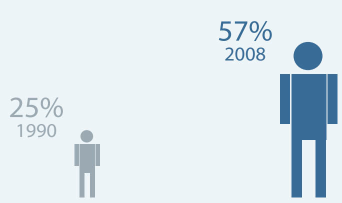
Gilson Oliveira and Rafaela Printes/Flickr.com

Progress Towards MDG Goal 7

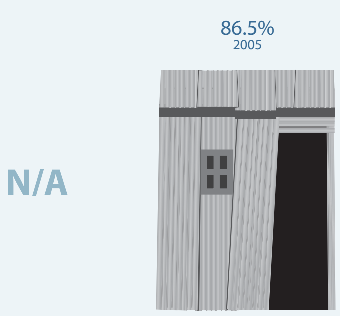
Although freshwater is relatively abundant in Angola, access to improved drinking water is low, especially in rural areas, due to aging or lack of water infrastructure, poor land and urban management and three decades of civil conflict. Access to improved drinking water increased from 36 to 50 per cent between 1990 and 2008, although rural areas did not benefit from the improvement. There was a significant increase in the proportion of the rural population with improved sanitation, however (from 6 to 18 per cent over that period).



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 010
Total renewable water (actual) (10^9 m³/yr)	2008	148
Total renewable per capita (actual) (m³/inhab/yr)	2008	8 213
Surface water: total renewable (actual) (10^9 m³/yr)	2008	145
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	58
Dependency ratio (%)	2008	0

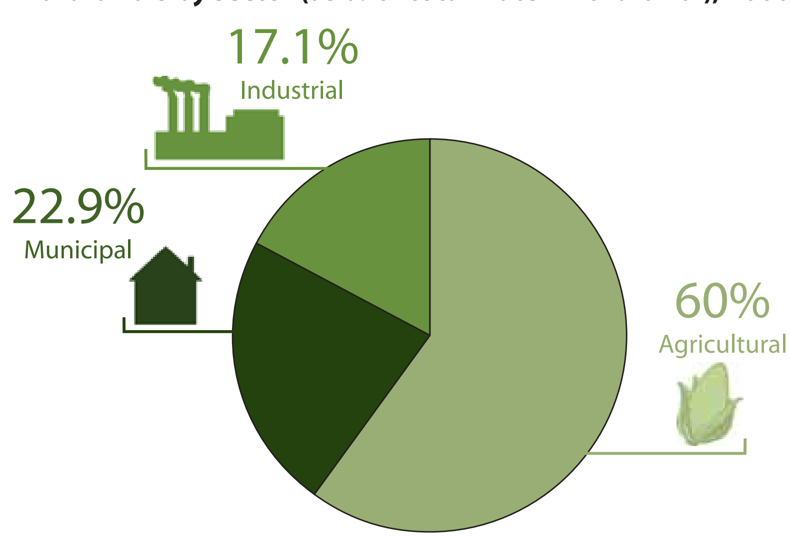
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.4
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	23.1
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.2

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



Under-developed Irrigation Potential

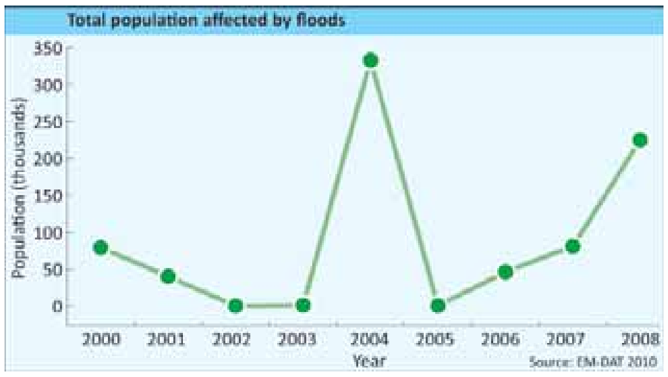
Angola shares the Okavango River's rich catchment area of approximately 15 000 km^2 with Namibia and Botswana. The Okavango Delta is a globally renowned Ramsar Wetland Site as well as the world's largest inland delta (IR 2010). Despite the high availability of water resources, only 0.2 per cent is withdrawn each year, as management and distribution capacity is practically non-existent (FAO 2005). This is mainly attributed to the 27-year long civil war that lasted from 1975 until 2002.

Under-developed irrigable land is an indication that Angola is not realizing its full water potential. The total potential irrigable area in Angola is 3.7 million ha, however, different estimates exist on how much of that land has been developed. A study by SADC in 2003 suggested a total figure of 160 000 ha, while SWECO Grøner in 2005 suggested 340 478 ha of developed area and 783 338 ha ready for development. FAO, furthermore, estimate an additional 350 000 ha of wetland under some form of agricultural water management. (UN Water 2008). Angola has become dependent on large-scale importation of food and food aid donations and suffers from a food deficit of 625 000 tonnes/yr (UN-Water 2008).

Water Pollution from Unplanned Settlements

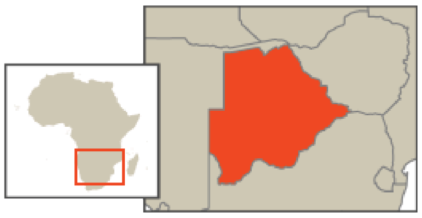
A combination of the widening gap between the rapid urbanization (at a rate of 4.9 per cent annual growth in 2000--2005), and the lower rates of housing availability are impeding planned urban growth in Angola (United Nations 2006, USAID 2006). Instead, large, informal settlements on the peripheries of cities are being built far from economic opportunities, transportation and urban services. These settlements, largely comprised of war refugees, lack waste-disposal facilities and sanitation services and are large contributors to water pollution.

Unplanned settlements are usually built in fragile, undesirable areas such as flood zones, steep slopes, and wetlands, making them more susceptible to natural disasters such as floods and landslides.



Although seasonal rains annually flood this part of sub-Saharan Africa, the rains in the first half of 2010 in Angola's Moxico Province were already far above average, affecting around 11 500 people by March 2010, according to the UN (Tearfund 2010). From 2000-2009, 21 extreme weather events, of which 18 were floods, affected an estimated 836 094 people (EM-DAT 2010).

Arsenie Coseac/Flickr.com



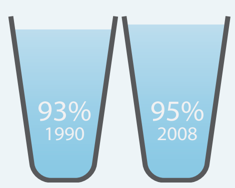
Republic of

Botswana

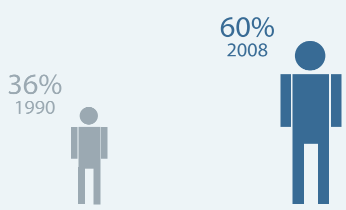
Total Surface Area: 581 730 km²
Estimated Population in 2009: 1 950 000

Progress Towards MDG Goal 7

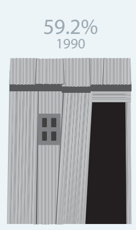
Botswana's arid climate and recurring drought are limiting factors in the provision of water. Nevertheless, in 2008, a total of 95 per cent of its population had access to improved drinking water, with full coverage in urban areas even with increasing urbanization. Rural areas had 90 per cent access. Provision of improved sanitation lags behind, with 60 per cent of the total population having access (74 per cent in cities and 39 per cent in rural areas).



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	416
Total renewable water (actual) (10^9 m^3/yr)	2008	12.2
Total renewable per capita (actual) (m^3/inhab/yr)	2008	6 372
Surface water: total renewable (actual) (10^9 m^3/yr)	2008	10.6
Groundwater: total renewable (actual) (10^9 m^3/yr)	2008	1.7
Dependency ratio (%)	2008	80.4

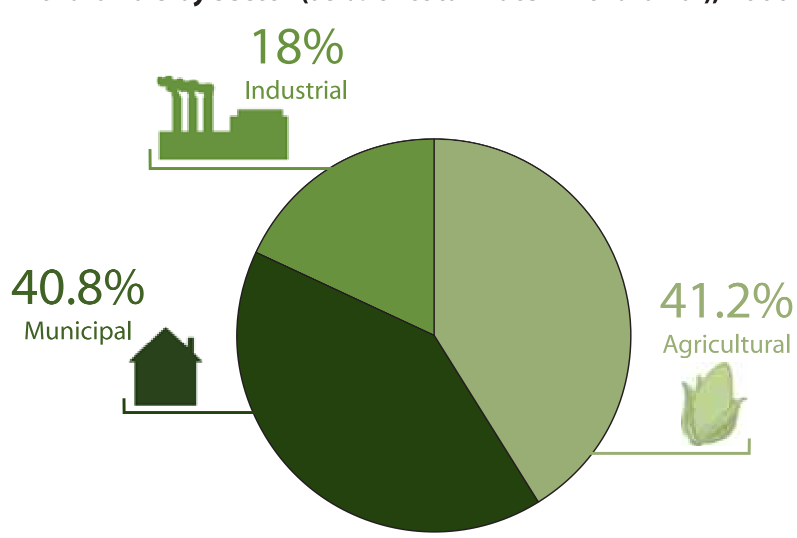
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m^3/yr)	2000	0.2
Surface water withdrawal (10^9 m^3/yr)	2000	0.1
Groundwater withdrawal (10^9 m^3/yr)	2000	0.1
Total water withdrawal per capita (m^3/inhab/yr)	2002	109.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	1.6

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1992	2.6
Area salinized by irrigation (1000 ha)	...	...

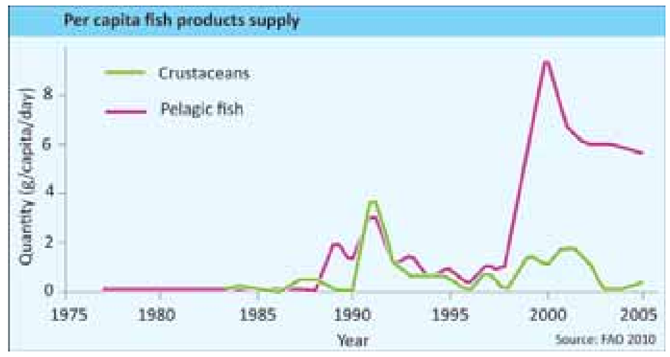
Withdrawals by sector (as % of total water withdrawal), 2000



Water Availability in the Okavango Delta

The Okavango Delta, located in northwest Botswana, is the world's largest inland delta and a globally renowned Ramsar Wetland site. This important ecosystem is a habitat for over 1 300 plant species, 440 bird species and 71 fish species (Ramberg and others 2006). As well as wildlife and the important tourism revenues they help generate, the Delta also sustains agricultural activities and rural livelihoods.

Although water demand is increasing in the three countries in the Okavango catchment, so far the total amount of water diverted from the Okavango River and its tributaries has been small relative to total flow, and no impacts from upstream diversions have been detected. Future water impoundments and diversions, however, could cause major changes to the Okavango Delta ecosystem. For example, reduced-peak inflow associated with upstream storage facilities could change the amount of water flowing into the lagoons along the panhandle, which



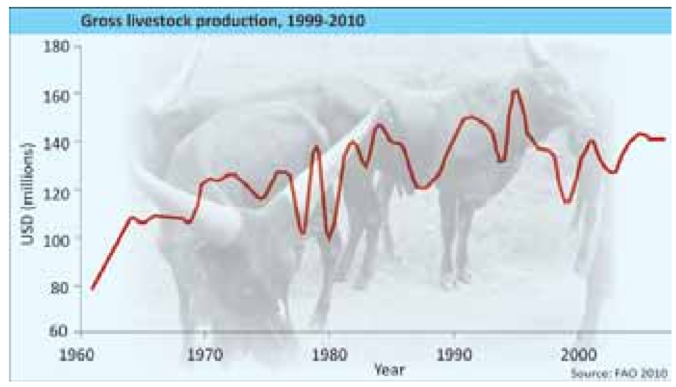
play an important role in fish production (Mosepele and others 2009).

Small-scale fisheries in Botswana depend directly on the delta's water resources for continued existence. In 2009, 55 per cent of households in Botswana were reliant on fish products for food needs (Mosepele and others 2009). Food quantitates from pelagic fish and crustaceans is now declining. With increasingly saline conditions, fish production will continue to fall in Botswana (see more on the Okavango basin on page 88).

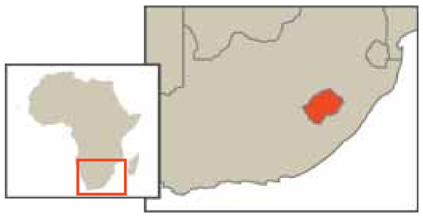
Desertification from Drought and Overgrazing

A combination of naturally arid conditions and frequent drought periods have left Botswana highly susceptible to desertification. This country-wide threat is further exacerbated by unsustainable and unevenly distributed grazing practices, which threaten already-stressed water resources and fragile land. Soil erosion is also a serious problem and various forms have been identified throughout the nation, including wind, sheet, rill and gully erosion. These soil erosion events extend grazing limits as land becomes unsuitable for cattle, as well as contribute to water-quality problems.

Although groundwater is not exceptionally abundant, with 1.7 billion cubic metres available per



year, it accounts for two-thirds of all of Botswana's water consumption (FAO 2008). Grazing practices that pollute and leach into groundwater sources, however, are increasingly threatening aquifers. Localized overgrazing concentrated around boreholes further contributes to desertification.



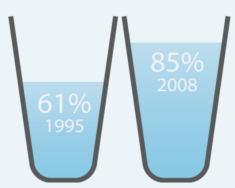
Kingdom of

Lesotho

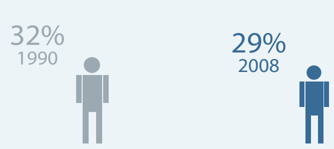
Total Surface Area: 30 355 km²
Estimated Population in 2009: 2 067 000

Progress Towards MDG Goal 7

Lesotho's climate is temperate and water resources are generally abundant, although seasonal. The proportion of the population using improved drinking water sources increased from 61 to 85 per cent between 1990 and 2008. Overall access to improved sanitation facilities decreased slightly over that period due to a decline in rural access.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	788
Total renewable water (actual) (10^9 m³/yr)	2008	3.0
Total renewable per capita (actual) (m³/inhab/yr)	2008	1 475
Surface water: total renewable (actual) (10^9 m³/yr)	2008	3.0
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.5
Dependency ratio (%)	2008	0

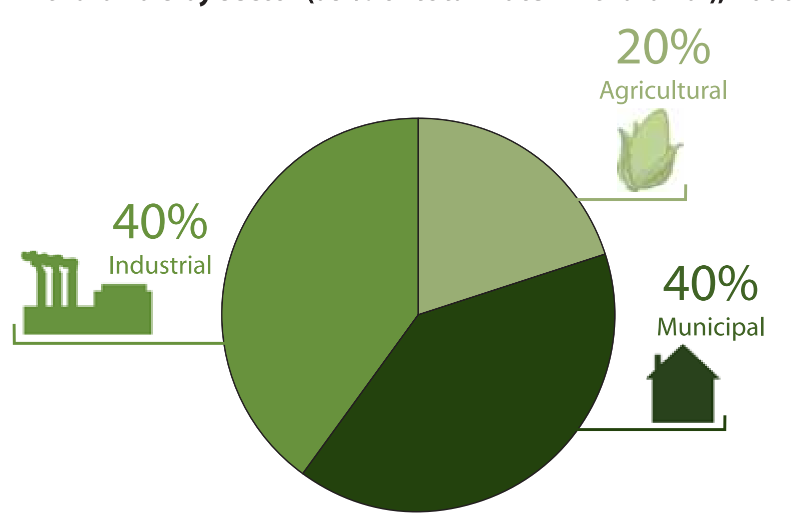
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.05
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	25.8
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	1.7

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1994	0
Area salinized by irrigation (1000 ha)	...	...

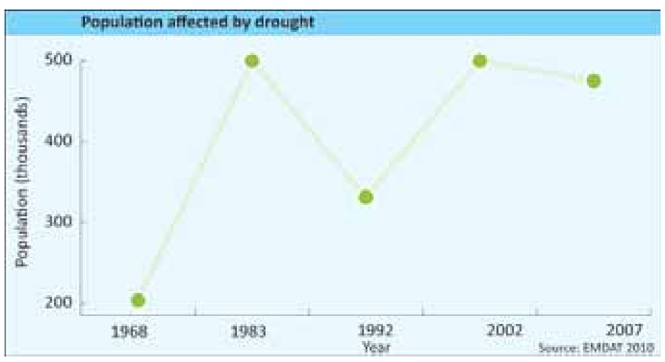
Withdrawals by sector (as % of total water withdrawal), 2000



John Pannell/Flickr.com

Water Scarcity

On average, Lesotho receives 788 mm of rainfall each year (FAO 2008), however patterns are irregular and 85 per cent occurs during October to April (FAO 2005). The last few years have been particularly dry, with 2007 considered one of the worst dry spells in three decades (UNOCHA 2008). Three consecutive parched years culminated in a dwindling national water supply with water tables receding and a number of boreholes and springs in populated rural areas drying up, leaving populations dependent on limited surface water resources. According to the Lesotho Department of Rural Water Supplies, 30 per cent of water points were found to be dry (UNOCHA 2008).

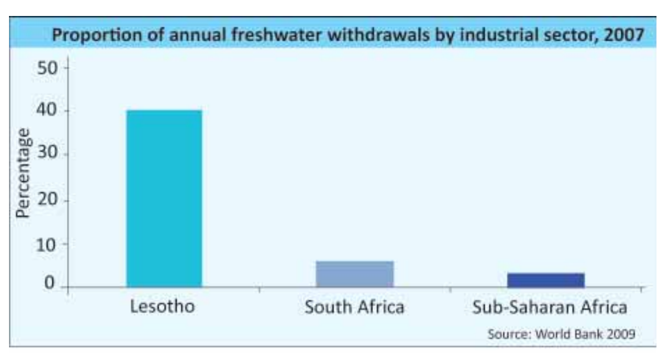


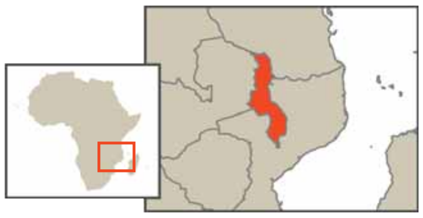
The 2007 droughts affected an estimated 475 000 people (EM-DAT 2010), almost a quarter of Lesotho's population, leaving many in need of assistance and forcing the government to declare a state of emergency. The lack of rainfall had serious impacts on food security and many rural households were unable to meet their needs. The production of maize, Lesotho's staple food, fell by more than half compared to the previous year (UNOCHA 2007). With around 75 per cent of people living in rural areas (WHO/UNICEF 2010) and 60 per cent of the population dependent on agriculture as their main income source (UNOCHA 2007), water scarcity is a serious threat to the country.

Industrial Water Pollution

Lesotho's industrial sector accounted for approximately 40 per cent of freshwater withdrawals in 2007, an especially high figure when compared to the sub-Saharan African average of only three per cent (World Bank 2009). As well as being a main user of water, the sector contributes significant amounts of water pollution. In 2005, emissions of organic water pollutants were estimated at 13.2 thousand kilograms per day (World Bank 2009). The textiles industry was responsible for 90.8 per cent of organic water pollutants, followed by food and beverages at 3.4 per cent (World Bank 2009). In addition, the slurry from diamond mining, a key economic sector in the country, also contributes to water pollution levels (FAO 2005).

According to the Kingdom of Lesotho, Ministry of National Resources (2003), industrial wastewaters are discharged untreated to Lesotho's watercourses, damaging both local ecosystems and negatively affecting downstream countries. Research carried out by the African Technology Policy Studies Network (2007) found that while the expansion of the industrial sector has had a positive effect on income and employment, the degraded water quality has been detrimental to riparian communities. More than a quarter of households surveyed reported that they stopped using waterways due to water pollution that resulted from the establishment of industries.

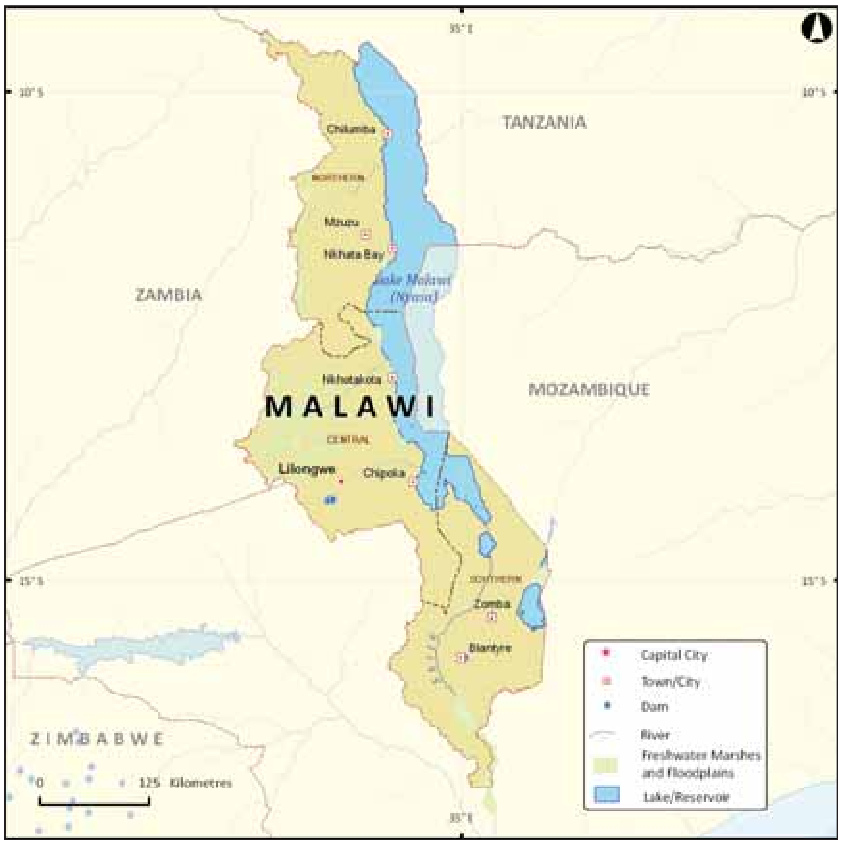




Republic of

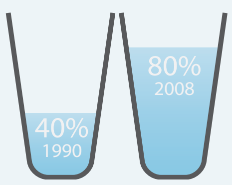
Malawi

Total Surface Area: 118 484 km²
Estimated Population in 2009: 15 263 000

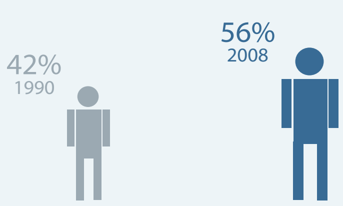


Progress Towards MDG Goal 7

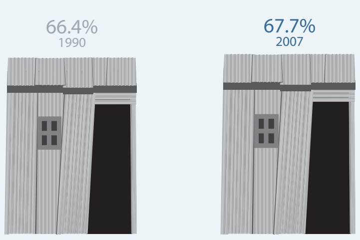
Challenges to achieving the water and sanitation MDGs include inherent water stress (less than 1 700m³/capita per year); high population growth, especially in cities and peri-urban areas; and aging water systems. Nevertheless, Malawi has reached its improved drinking water goal of providing for 75 per cent of its overall population. The sanitation target is 87 per cent, requiring that 31 per cent more of the population use improved sanitation facilities by 2015.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 181
Total renewable water (actual) (10^9 m³/yr)	2008	17.3
Total renewable per capita (actual) (m³/inhab/yr)	2008	1 164
Surface water: total renewable (actual) (10^9 m³/yr)	2008	17.3
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	2.5
Dependency ratio (%)	2008	6.6

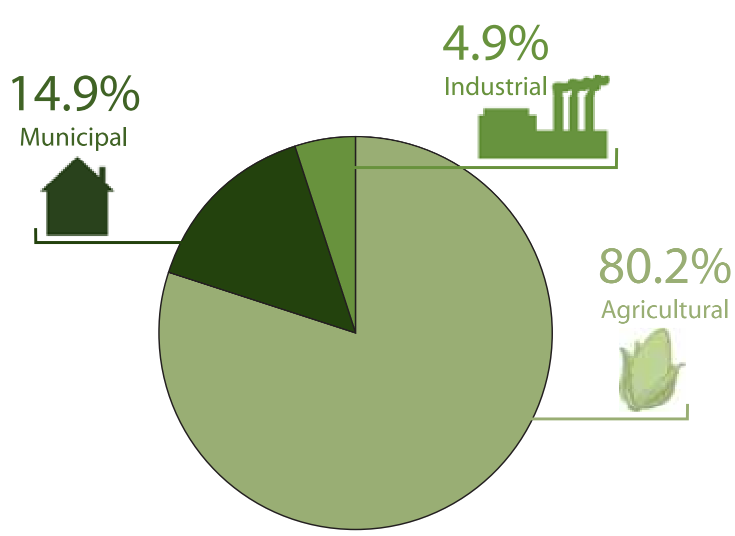
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	1.0
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	80.5
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	5.8

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1992	2
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



Water-related Constraints on Agricultural Production

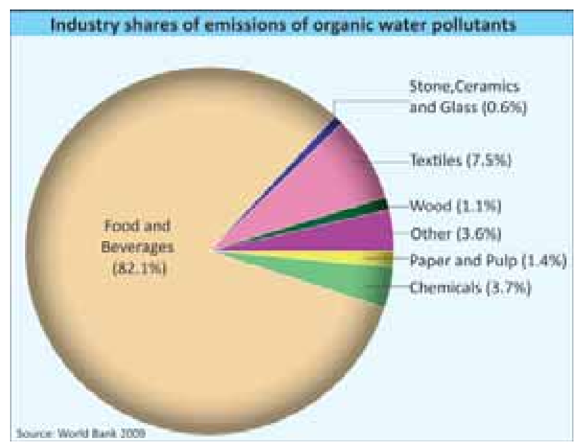
Although it accounts for just 35 per cent of the nation's economy compared to the service sector (46 per cent), Malawi's agricultural sector supports 85 per cent of the population and is thus critically important. Food insecurity remains a concern in this flood and drought-ridden country, where nearly 40 per cent of the population is classified as poor (World Bank 2009). Malawi experienced 19 disaster events between 2000 and 2009 (three droughts, 15 floods and one storm) that affected 9 672 878 people in total (EM-DAT 2010). An October 2005 drought alone affected more than five million Malawians (EM-DAT 2010). A study conducted by the International Food Policy Research Institute estimated that flooding in Malawi's southern region causes losses of about 12 per cent to maize production; they also found that drought causes on average economic losses of one per cent of Malawi's GDP every year, with agriculture

the hardest-hit sector (IFPRI 2010). Heavy reliance on maize, the crop grown on nearly 90 per cent of arable land, and a lack of new available land means that irrigation is essential for food production. However, FAO reports that increased agriculture, particularly in densely populated areas, has contributed to "considerable degradation" of water quality, raising concerns about the two-way relationship between agricultural productivity and water availability (FAO 2005).

Fisheries Management

Surface water resources cover one-fifth of Malawi's 118 484 km^2 land area (FAO 2006). Lake Malawi (Nyasa), which spans the eastern border, is Africa's third-largest lake and its rich fisheries are a key source of food and livelihoods. The lake is a habitat for significant freshwater fish biodiversity, of which 90 per cent are endemic, and contains more unique species than any other lake in the world (UNEP 2008). According to the 2005 Millennium Ecosystem Assessment, Malawi's inland fisheries supply between 70 and 75 per cent of total animal protein for both urban and rural low-income families (MA 2005).

Water pollution is seriously threatening the health of this valuable ecosystem. A combination of agricultural runoff and siltation from soil erosion, as well as urban effluents, such as sewage and industrial wastewater contaminates the country's freshwater ecosystems. In 2005, 32.7 thousand kilograms of organic water pollutants were emitted each day. The food and beverages sector alone accounted for 82.1 per cent of the industrial share of organic water pollutants (World Bank 2009).



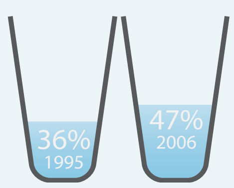
Republic of

Mozambique

Total Surface Area: 801 590 km²
Estimated Population in 2009: 22 894 000

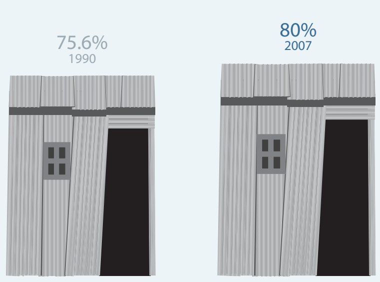
Progress Towards MDG Goal 7

Provision of improved water increased slightly in Mozambique's urban areas, from 73 to 77 per cent between 1990 to 2008. It also rose slightly in rural areas (from 26 to 29 per cent) but the proportion of rural dwellers with access is still very low. The overall MDG drinking water target is 70 per cent. Access to sanitation in 2008 was very poor, with only 53 per cent in urban areas and 4 per cent in rural areas.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 032
Total renewable water (actual) (10^9 m³/yr)	2008	217.1
Total renewable per capita (actual) (m³/inhab/yr)	2008	9 699
Surface water: total renewable (actual) (10^9 m³/yr)	2008	214.1
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	17
Dependency ratio (%)	2008	53.8

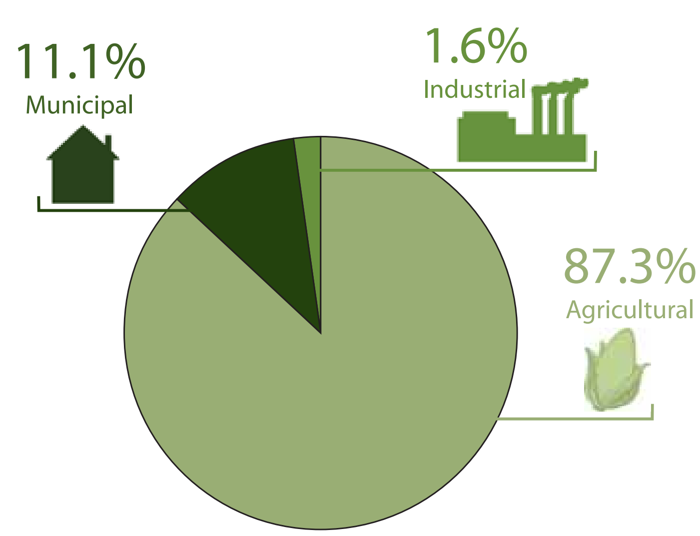
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.6
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	32.7
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.3

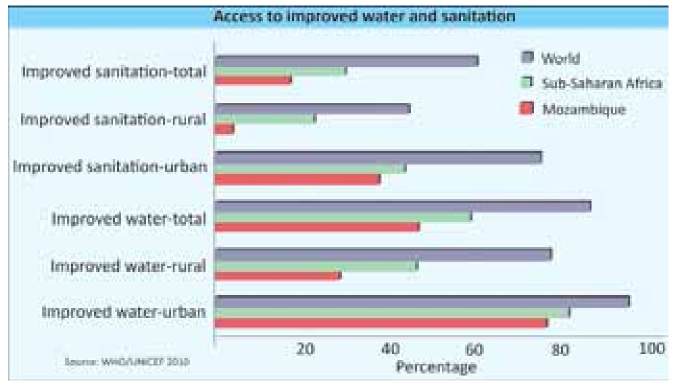
Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1993	2
Area salinized by irrigation (1000 ha)	1995	2

Withdrawals by sector (as % of total water withdrawal), 2000



Urban and Rural Water and Sanitation Challenges



Mozambique is one of the poorest countries in the world, with a per capita GNI of US$380, an under-five mortality rate of nearly 130 per 1 000 children and an average life expectancy of only 48 years (World Bank 2008). Many health challenges in the country are linked to sub-standard access to clean water sources and are further exacerbated by poor sanitation facilities.

In urban areas, where three-quarters of the population live in informal settlements or slums (UN Habitat 2008), only 38 per cent of people have access to improved sanitation facilities and 77 per cent access to improved water sources—among the lowest urban rates for improved water access in the world (WHO/UNICEF 2010).

In Maputo City—with a population density of 3 700 people per km^2 (UN Habitat 2009)—groundwater contamination from settlements not connected to existing sewage facilities is polluting the economically important Maputo Bay to the extent that swimming is inadvisable, and there is a general ban on shellfish consumption (Blacksmith Institute 2009).

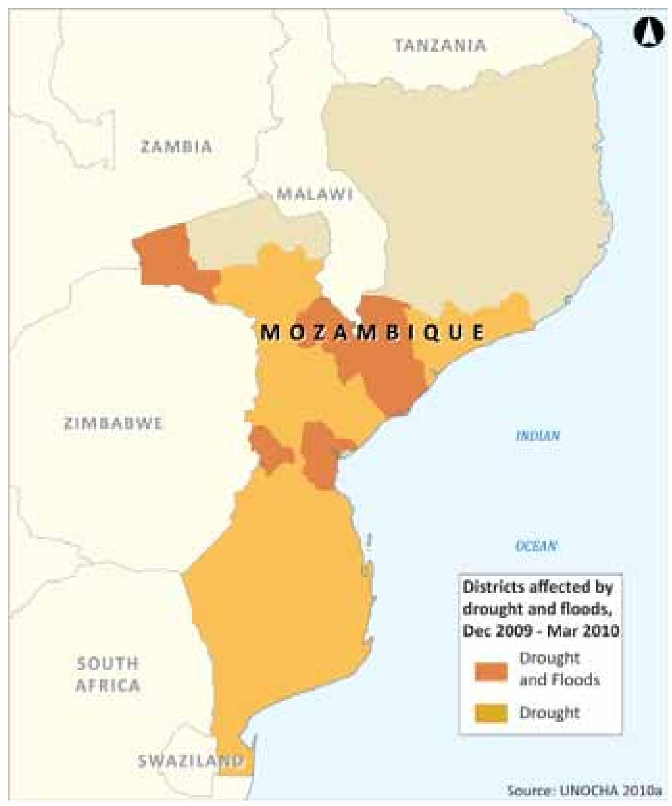
Rural access to improved water sources is even lower. Only 29 per cent of the rural population obtains their water from improved sources such as household connections or protected wells and springs. This rate is far below the average of 47 per cent rural improved water access for sub-Saharan Africa (WHO/UNICEF 2010).

Food Shortages from Drought and Flood Events

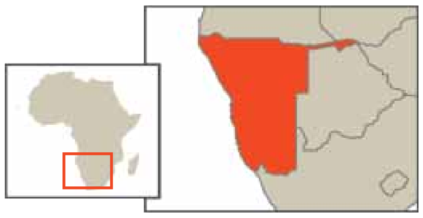
Mozambique's unpredictable climate manifests in frequent extreme weather events—between 2000 and 2009 alone, the country suffered six drought periods and 15 floods (EM-DAT 2010). These six drought events affected more than 3.2 million people in the country while the floods affected over 6 million.

In early 2010, a period of drought followed by extensive flooding left 465 000 people in need of food assistance (UNOCHA 2010a). Droughts in the centre and south of the country wiped out 30 per cent of planted land. In March, the low lying floodplains of the Zambezi, Buzi, Pungwe, Licungo and Save river basins suffered devastating flood events that displaced thousands and left many without access to food or water (UNOCHA 2010b). For the estimated 100 000 residents fleeing from the drought-affected regions to these riparian locations, the events served as a double shock—with many having lost their seeds twice (UNOCHA 2010a). As a result, food insecurity is an ongoing problem in a country that already has a 37 per cent undernourishment rate (FAO 2009).

With the government and humanitarian agencies already struggling to meet demand, continued climatic uncertainty and extreme weather events will pose a serious challenge for food and water availability in Mozambique.



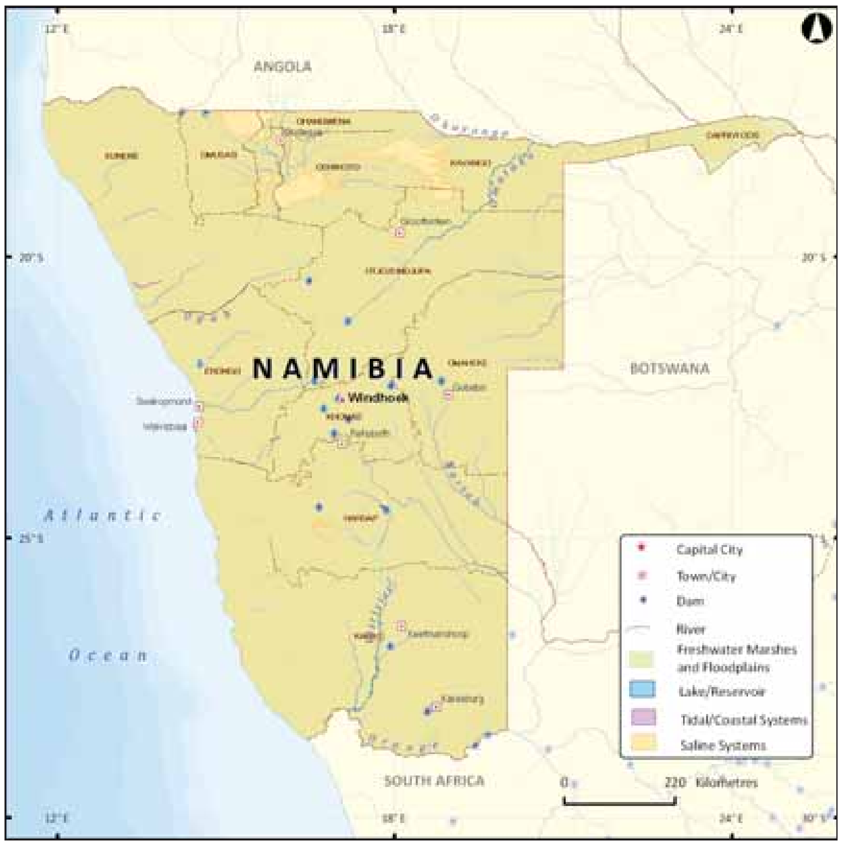
The Humanitarian Coalition/Flickr.com



Republic of

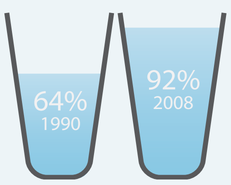
Namibia

Total Surface Area: 824 292 km²
Estimated Population in 2009: 2 171 000



Progress Towards MDG Goal 7

Access to better drinking water sources improved between 1990 and 2008 such that 99 per cent of urban and 88 per cent of rural populations are now served. The urban population with improved sanitation declined from 66 to 60 per cent, however, while rural-area access, although still highly inadequate, grew from 9 to 17 per cent.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	285
Total renewable water (actual) (10^9 m³/yr)	2008	17.7
Total renewable per capita (actual) (m³/inhab/yr)	2008	8 319
Surface water: total renewable (actual) (10^9 m³/yr)	2008	15.6
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	2.1
Dependency ratio (%)	2008	65.2

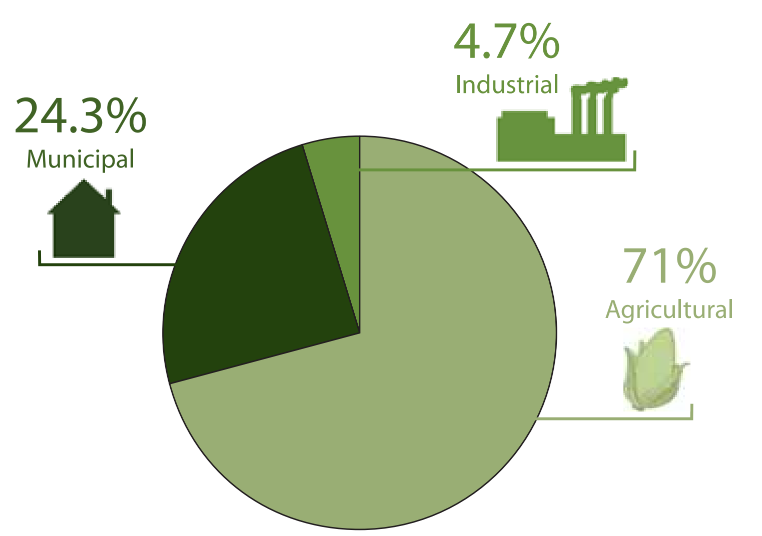
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	0.3
Surface water withdrawal (10^9 m³/yr)	1999	0.2
Groundwater withdrawal (10^9 m³/yr)	1999	0.1
Total water withdrawal per capita (m³/inhab/yr)	2002	158.1
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	1.7

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1992	43.9
Area salinized by irrigation (1000 ha)	1992	1.3

Withdrawals by sector (as % of total water withdrawal), 2000



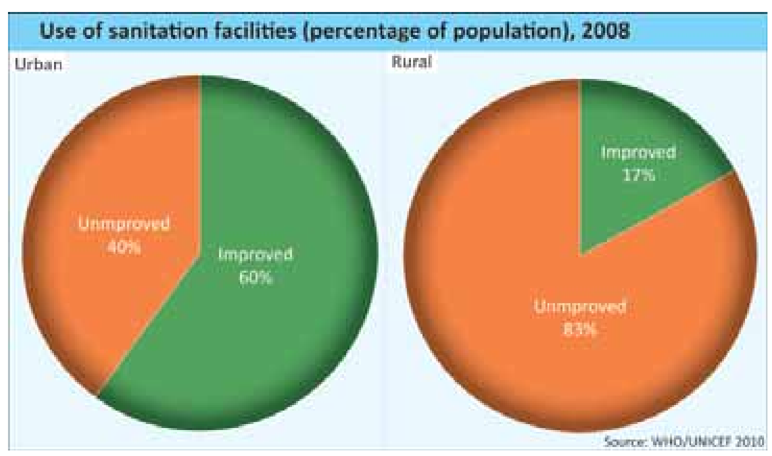
Water Scarcity

With rainfall levels averaging only 285 mm/yr, Namibia is the most arid country south of the Sahara Desert. Water resources in Namibia are distributed unevenly, both temporally and spatially (FAO 2005). The limited 17.7 billion cubic metres of renewable surface water resources available annually suffer from huge pressures (FAO 2008). Depletion of groundwater resources is also a concern, with only 2.1 billion cubic metres available each year (FAO 2008) and as little as one per cent of rainfall going towards replenishment (FAO 2005).

Namibia, with 61 per cent of its land surface classified as dry, is the driest country in sub-Saharan Africa. About ten per cent of the land area is very highly vulnerable to desertification, while nine per cent is highly vulnerable, 16 per cent is moderately vulnerable and almost three per cent is in the low risk category (Reich and others 2001).

Agricultural practices and cattle rearing are the greatest threats to already limited water availability. Almost half of Namibia's population is involved in agriculture—a sector that accounts for over 70 per cent of total water withdrawals in the country (FAO 2008). With more cattle than people in Namibia, overgrazing is also a threat to water and land resources, including declining groundwater levels, soil erosion and reduced soil fertility.

Access to Improved Sanitation

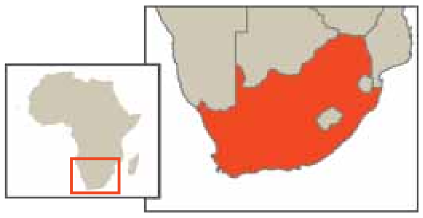


In 2008, 67 per cent of Namibians used unimproved sanitation facilities (WHO/UNICEF 2010). This marks a slight improvement from the 1990 numbers.

Like most other countries on the continent, the disparity between urban and rural access in Namibia is noticeable. Access to improved facilities in urban areas is 60 per cent, down from 66 per cent in 1990, while in rural areas, 17 per cent of the population has access, up from 9 per cent in 1990 (WHO/UNICEF 2010).

Namibia envisions full sanitation coverage by 2030 in its long term national plan, Vision 2030. Since it is estimated that by 2030, the population will be 2.8 million and 73 per cent of people will be living in urban settlements, more facilities will be needed to serve them. To attain the long-term sanitation goal, the country will need US$288 million (UNOCHA 2008).

A study conducted to help formulate the country's new Water Supply and Sanitation Policy identified insufficient budgetary allocation, lack of coordination and a general lack of knowledge of sanitation issues as major constraints in achieving the nation's sanitation goals (Italtrend 2009).



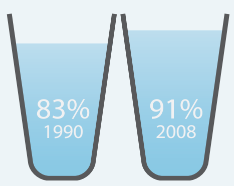
Republic of

South Africa

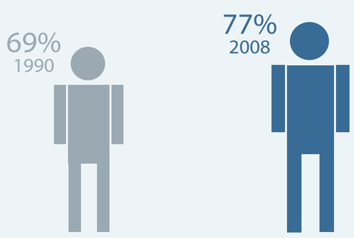
Total Surface Area: 1 221 037 km²
Estimated Population in 2009: 50 110 000

Progress Towards MDG Goal 7

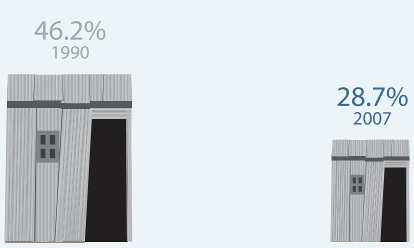
South Africa has made significant progress in supplying improved drinking water since 1994 and developing the national water and sanitation programme: 91 per cent of the population is served. Less progress has been achieved in providing improved sanitation. Between 1990 and 2008, urban provision increased from 80 to 84 per cent and it grew from 58 to 65 per cent in rural areas. South Africa is one of the few countries in the world that formally recognizes water as a human right.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	495
Total renewable water (actual) (10^9 m³/yr)	2008	50
Total renewable per capita (actual) (m³/inhab/yr)	2008	1 007
Surface water: total renewable (actual) (10^9 m³/yr)	2008	48.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	4.8
Dependency ratio (%)	2008	10.4

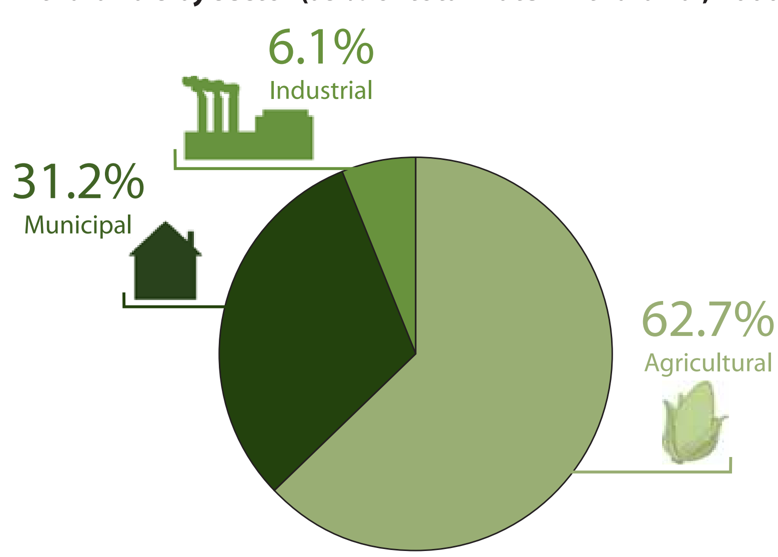
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	12.5
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	270.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	25

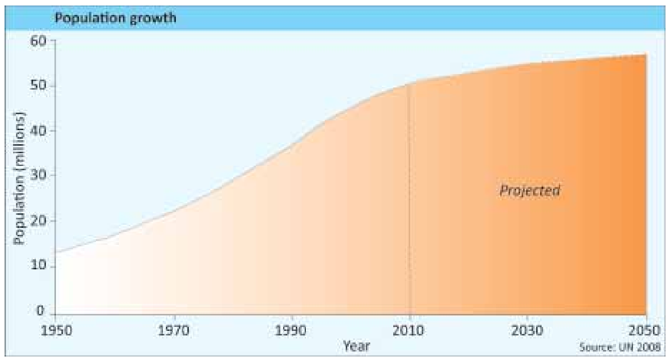
Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1988	9
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal, 2000)



Water Supply Shortage



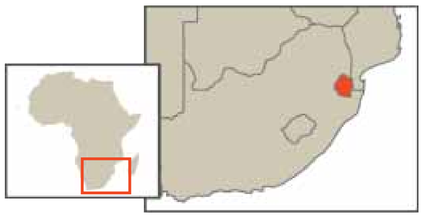
Population pressure, an expanding economy and increased evaporation driven by a changing climate are all contributing to water stress in South Africa (UNOCHA 2009a). With only 1 007 m^3 of renewable water available to each inhabitant in 2008, South Africa is already hovering dangerously close to the international water scarcity threshold (FAO 2008). The country's population has grown significantly over the last few decades. Between 1990 and 2008 alone, the population increased by almost 13 million people (WHO/UNICEF 2010). The nation's water supply is expected to become even further stretched in coming years, going from a situation of water stress to one of water scarcity.

The impending water crisis is further exacerbated by the threat to the quality of freshwater resources. In 2008, Ukhahlamba—an impoverished district in Eastern Cape Province—reported very high levels of E. Coli and other bacteria in some parts of its water supply. This necessitated an issuance of "boil alerts", with some communities requiring water delivery by tanker trucks (UNOCHA 2009b). Heavy rains can aggravate the problem by washing human and animal waste into water systems, further contaminating supplies.

Distribution of Water Rights

With an average of only 495 mm of rainfall each year, rain-fed cultivation is a challenge in South Africa (FAO 2008). Even this relatively limited level of precipitation is strictly seasonal and highly variable and 60 per cent of runoff occurs from only 20 per cent of the total land area (FAO n.d.). As a result, agricultural production in the country is extremely dependent on the ability to secure access to a water supply.

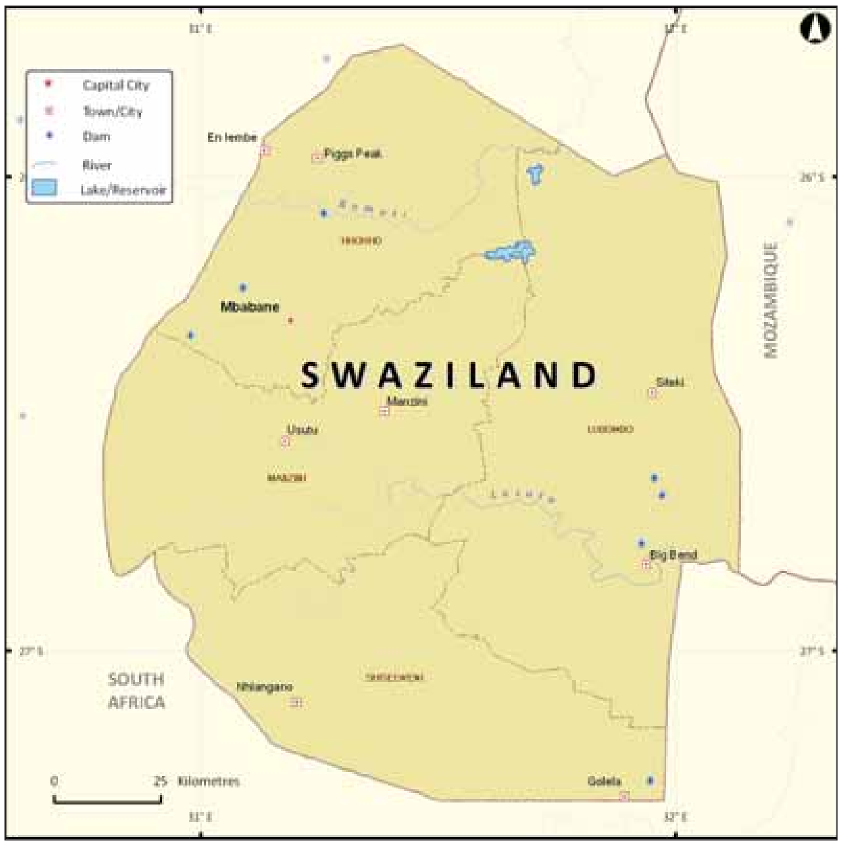
Water access is especially problematic for South Africa's small-holder farmers, many of whom attained land rights following land reform in the country. Land and water rights, however, are distributed separately causing huge inequities in access (IPS 2009). Approximately 98 per cent of water has already been allocated (UNOCHA 2010). With no legal mechanisms in place to protect the interests of small-holder farmers, many face huge obstacles in sustaining their land and production. Globally, small-holder farmers, especially women, produce an estimated 80 per cent of the food consumed in the developing world (IFAD 2010); if South Africa's farmers cannot access the water needed to sustain their crops, there is a potential for the country to suffer from food insecurity.



Kingdom of

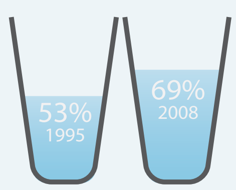
Swaziland

Total Surface Area: 17 364 km²
Estimated Population in 2009: 1 185 000

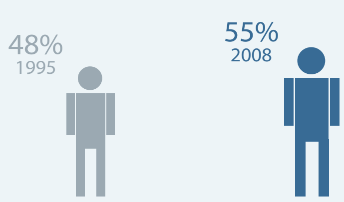


Progress Towards MDG Goal 7

Swaziland has seen little change in access to improved drinking water sources and sanitation facilities. In 1995, 53 per cent of the population used improved drinking water. By 2008, this had increased to 69 per cent. The proportion of the population using improved sanitation facilities has also increased from 48 to 55 per cent between those years. Of this, 64 per cent were urban and 46 per cent were rural.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

N/A N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	788
Total renewable water (actual) (10^9 m³/yr)	2008	4.5
Total renewable per capita (actual) (m³/inhab/yr)	2008	3 861
Surface water: total renewable (actual) (10^9 m³/yr)	2008	4.5
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.7
Dependency ratio (%)	2008	41.5

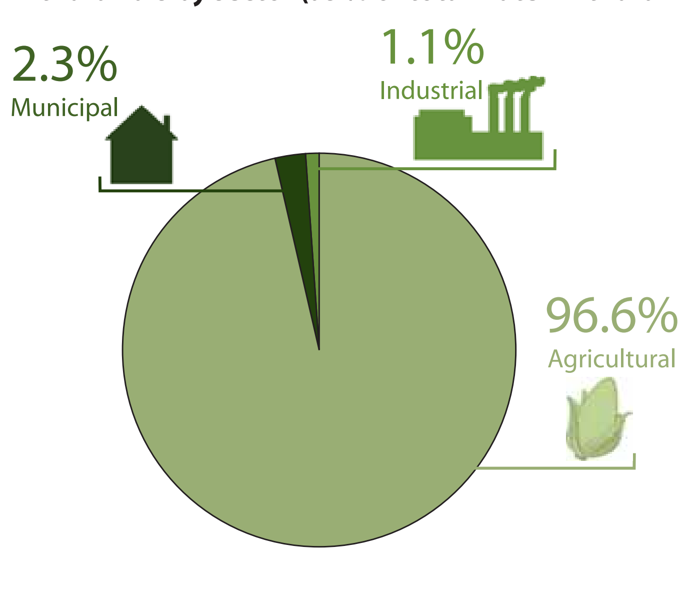
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	1.04
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	946.4
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	23.1

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal, 2000)



Responding to Natural Disasters

Over the last few decades, Swaziland has suffered an almost endless cycle of natural disasters, including droughts, floods, disease epidemics, storms and wildfires. Yet, despite the frequency with which such events occur, the response to disasters is often slow and ineffective (UNOCHA 2008).

Top 10 natural disasters in Swaziland, 1900-2009, sorted by numbers of total affected people (Source EM-DAT 2010)

Disaster	Year	Total affected
Drought	2001	970 000
Storm	1984	63 2500
Drought	2007	410 000
Flood	2000	272 000
Drought	1990	250 000
Storm	2006	6 535
Flood	2008	2 500
Wildfire	1992	2 228
Wildfire	2007	1 500
Disease	2000	1 449

Many of the most devastating disasters recorded over the last century occurred in the decades since 1980. The ten most significant events affected a combined total population of over 2.5 million people (EM-DAT 2010).

Swaziland has been particularly vulnerable to droughts: the nation experienced drought periods in 1981, 1982, 1991 to 1996, and 2001 to 2007 (UNOCHA 2008). The most recent drought event in 2007 affected an estimated 410 000 people (EM-DAT 2010), over a third of the population. The drought devastated all four regions in Swaziland, damaging up to 80 per cent of crops in certain areas and severely affecting food security. Aid agencies estimated that up to 40 per cent of the population was left in need of food assistance in the wake of the disaster (UNOCHA 2008).

A changing climate will have serious implications on the frequency of such hydro-meteorological hazards in the country. When the risks are combined with high levels of poverty and limited infrastructure and safety nets, the ramifications can be devastating for vulnerable populations and ecosystems.

Water Rationing

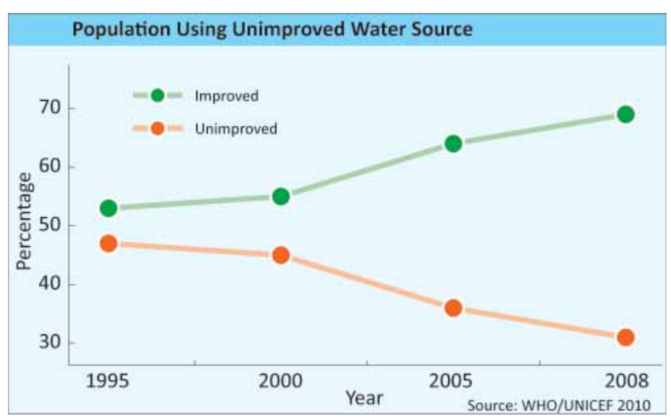
Following one of the longest drought periods in decades, water rationing was introduced as a coping mechanism in late 2007. The Swaziland Water Services Corporation, the state-run water utility, introduced water rationing following declines in water levels nationwide—beyond those in the typically dry regions of the south and east.

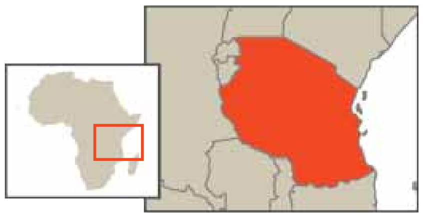
Cuts were introduced in the capital, Mbabane, the commercial centre of Manzini, the Matasapha Industrial Estate and Ezulwini, a key tourist location, leading to further economic ramifications for Swaziland (UNOCHA 2007).

River levels throughout the country decreased substantially. Water levels in the Maguga Dam, Swaziland's largest reservoir, fell to just 37 per cent of capacity, stalling the development of a joint hydropower scheme with neighbouring South Africa. Similarly, the water level in the Lupholo Dam, which supplies the commercial hub of Manzini, was down to 31 per cent of capacity (UNOCHA 2007).

With access to potable water already limited and 40 per cent of the population utilizing unimproved water sources in 2006 (WHO/UNICEF 2010), severe shortages drove many families to drinking water from streams and rivers, sharing with livestock and increasing the threat from waterborne diseases (UNOCHA 2007).

As Swaziland becomes more vulnerable to extended and widespread drought periods, water shortages and water rationing could become a frequent occurrence.





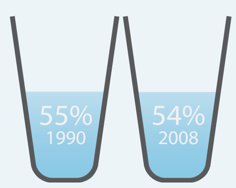
United Republic of

Tanzania

Total Surface Area: 945 087 km²
Estimated Population in 2009: 43 739 000

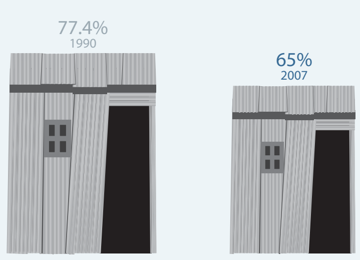
Progress Towards MDG Goal 7

Tanzania's water resources are derived from its large rivers and the Rift Valley lakes on its borders. These water-rich areas contrast with the dry savannah plains that dominate the north. Access to improved water declined from 1990 to 2008—from 94 to 80 per cent in urban areas and from 46 to 45 per cent in rural ones. Overall access to improved sanitation remained relatively unchanged at an overall rate of 24 per cent.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 071
Total renewable water (actual) (10^9 m³/yr)	2008	96.3
Total renewable per capita (actual) (m³/inhab/yr)	2008	2 266
Surface water: total renewable (actual) (10^9 m³/yr)	2008	92.3
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	30
Dependency ratio (%)	2008	12.8

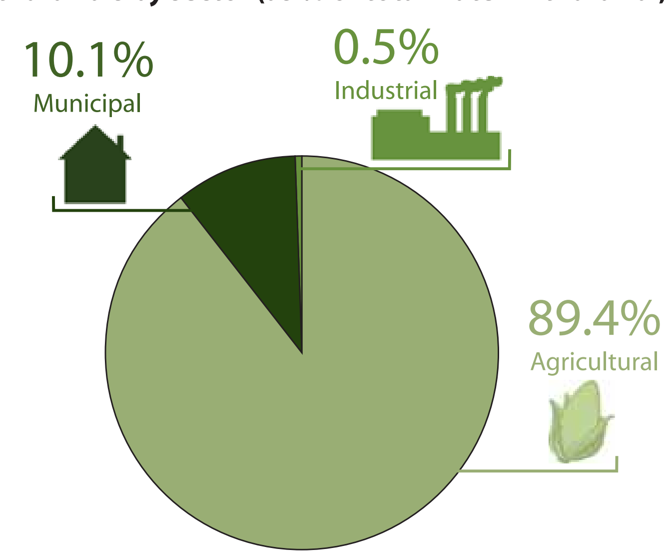
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2002	5.2
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	144.2
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	5.4

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	1999	50

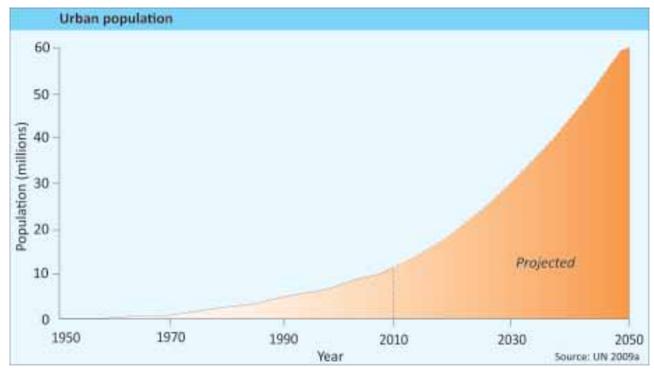
Withdrawals by sector (as % of total water withdrawal, 2002)



Lack of Water and Sanitation Infrastructure in Unplanned Settlements

Urban centres in the United Republic of Tanzania suffer from a multitude of water-quality problems stemming largely from unplanned settlements. These settlements are built on the peripheries of city borders and often lack water access, waste-disposal facilities and sanitation services. In 2007, an estimated 65 per cent of Tanzania's urban population lived in households classified as slum dwellings (United Nations 2008). In the capital, Dar es Salam, which is home to 28 per cent of Tanzania's urban population (United Nations 2009a), approximately 75 per cent of housing units are informal, unplanned settlements (PMO 2004).

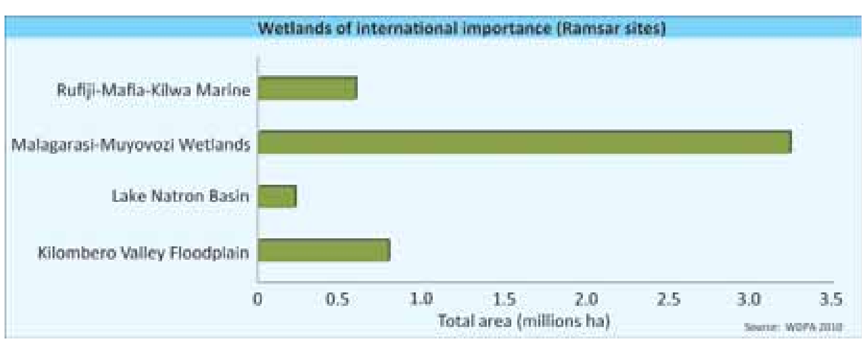
At 4.3 per cent, the growth rate of Dar es Salam's urban population far exceeds the 2.7 per cent growth rate of the nation as a whole (UNHabitat 2009). While Tanzania's urban population has increased drastically over the last few decades, from 4.8 million in 1990 to over 10.6 million in 2008, the expansion of unplanned settlements highlights the lack of capacity to provide essential services and infrastructure to urban centres.



Over two million people residing in urban areas remain unable to access a potable water source. The lack of infrastructure is further reflected in the fact that only 23 per cent of urban dwellers have access to piped water (WHO/UNICEF 2010). Similarly, in 2008, only 32 per cent of the urban population had access to improved sanitation facilities.

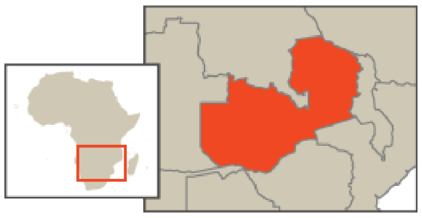
Wetland Loss

An estimated 10 per cent of Tanzania's surface is covered by wetlands, and approximately 2.7 million hectares are permanent or seasonal freshwater swamps and seasonal floodplains. The network of wetlands in Tanzania, and the Great Lakes system in general, support an extensive trading and transport system, supporting fishing, agro-pastoral activities, hydrological processes and flows for irrigation and power.



A commendable 37.7 per cent of Tanzania's total terrestrial land area has been designated as protected (United Nations 2009b), including four globally renowned Ramsar wetland sites with a combined area of 4.87 million ha (Ramsar 2010).

Despite this, the country's wetlands are threatened by mismanagement, overgrazing of domestic livestock, unsustainable use of water resources and an ever-growing agricultural sector. An estimated 42 per cent of Tanzania's total land area is cultivable, yet only 13 per cent of this area was actually under cultivation in 2002 (FAO 2005). This suggests huge potential for agricultural growth and expansion, although the challenge is to manage the development so that wetlands are not threatened, and the host of services they provide are sustained.



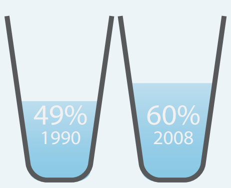
Republic of

Zambia

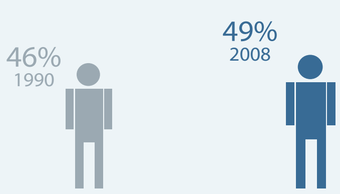
Total Surface Area: 752 618 km²
Estimated Population in 2009: 12 935 000

Progress Towards MDG Goal 7

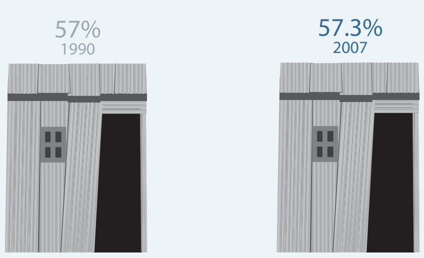
Zambia is one of sub-Saharan Africa's most highly urbanized countries with about a half of the population living in a few urban centres along major transportation routes. Eighty-seven per cent of urbanites had access to an improved drinking water source in 2008 but just 59 per cent had improved sanitation. In 2008, only 46 per cent of the rural population used improved drinking water sources (up from 23 per cent in 1990) although 59 per cent has access to improved sanitation (a decline from 62 per cent in 1990).



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 020
Total renewable water (actual) (10^9 m³/yr)	2008	105.2
Total renewable per capita (actual) (m³/inhab/yr)	2008	8 336
Surface water: total renewable (actual) (10^9 m³/yr)	2008	105.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	47
Dependency ratio (%)	2008	23.8

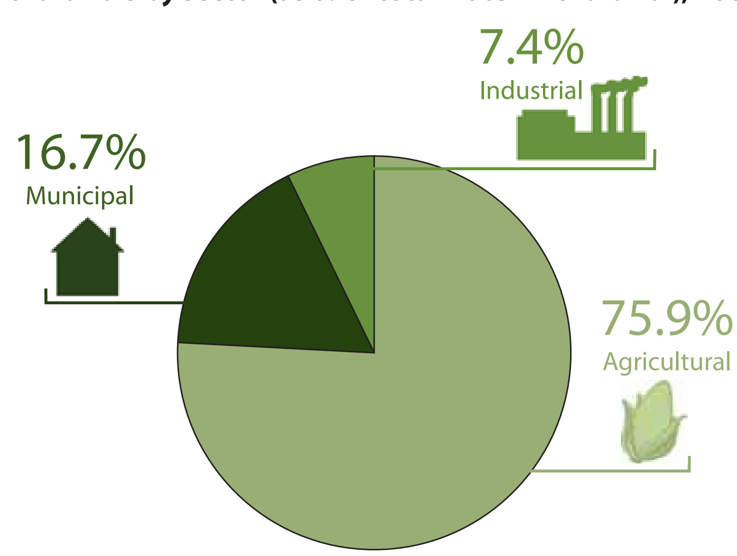
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	1.7
Surface water withdrawal (10^9 m³/yr)	1992	1.7
Groundwater withdrawal (10^9 m³/yr)	1992	0.07
Total water withdrawal per capita (m³/inhab/yr)	2002	158.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	1.7

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1991	5.4
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal), 2000



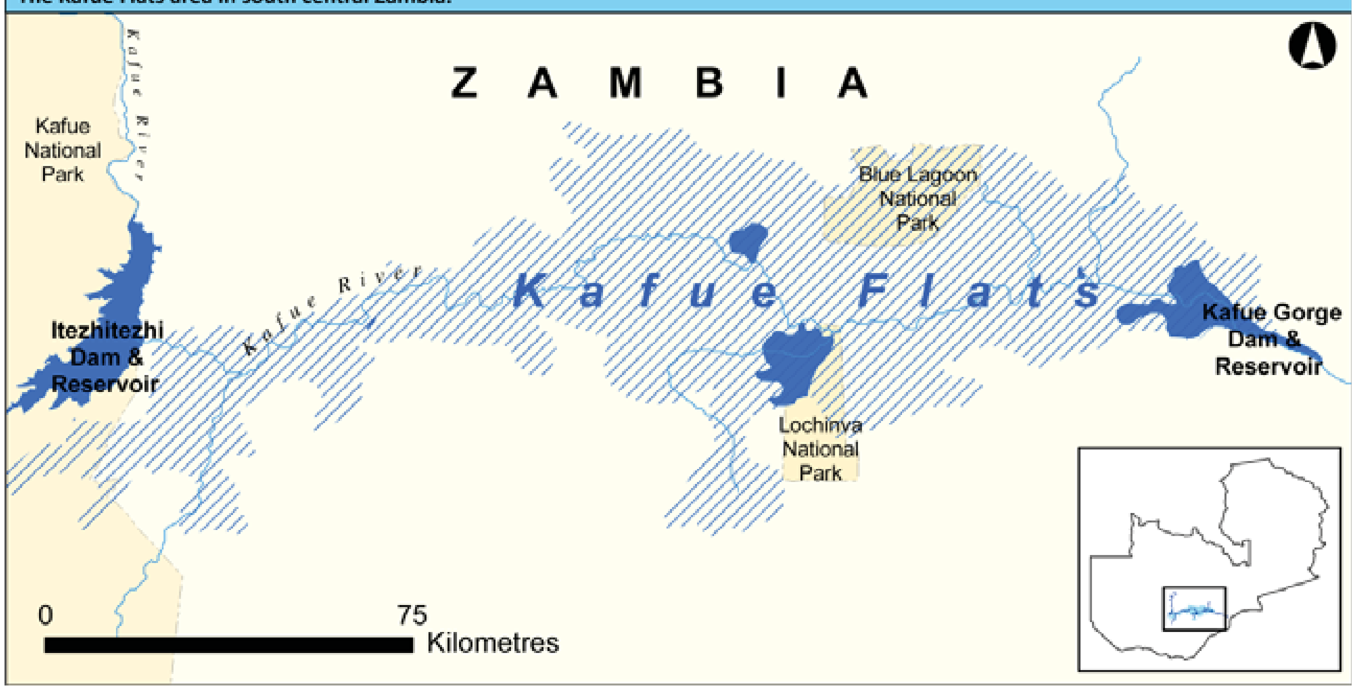
Altered Flood Regime in the Kafue River

The Kafue River flows from Zambia's Copperbelt region southward 1 576 km to join the Zambezi River along the country's southern border. In the heart of the country, it crosses the vast Kafue Flats floodplain, dropping only 10 m across a 450-km length of the river (Smardon 2009). Historically, the river flooded this vast wetland each year during the rainy season (December to March) leaving between 3 000 and 5 000 km^2 of it inundated for as long as seven months (Smardon 2009) (see satellite images of Kafue Flats on page 104). However, following construction of the Kafue Gorge Dam (1972) and the Itezhi-tezhi Dam (1978), this seasonal flooding was disrupted (Schelle and Pittock 2005).

The Kafue wetlands are important habitat for rare and endemic species including the Kafue Lechwe (*Kobus leche kafuensis*) and Wattled Crane (*Bugeranus carunculatus*) and support local livelihoods, especially cattle and fishing (Schelle and Pittock 2005). The limited flooding following the construction of Itezhi-tezhi Dam has been linked to a significant decline in fish production (AAAS 1998) and the decline of the Kafue Lechwe population from around 90 000 before the dam to around 37 000 in 1998 (CEH 2001).

In May of 2004, a partnership between WWF, the Zambian Ministry of Energy and Water Development and the Zambian Electricity Supply Company put new rules in place for releases of water to mimic the natural flooding patterns of the Kafue Flats (Schelle and Pittock 2005). The use of Integrated Water Resources Management principles provides hope that a multiple-use strategy will prevail, maximizing benefits to all stakeholders and the ecosystem.

The Kafue Flats area in south central Zambia.

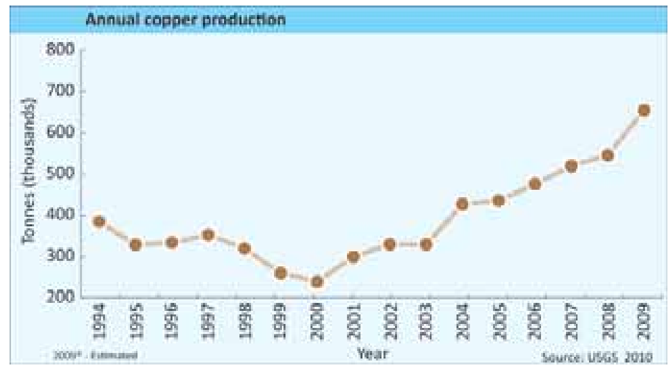


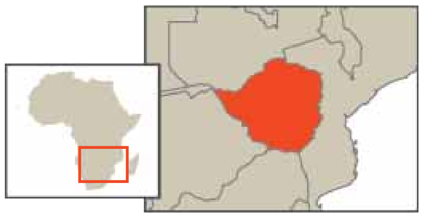
Water Quality Implications of Copper Mining

For decades, copper mines, metallurgical plants, textile plants, fertilizer factories, sugar processing plants and cement factories have polluted Zambia's water sources. In the past decade, Zambia's "copperbelt"—powered entirely by the Kafue Gorge Dam and generating three-quarters of the country's foreign exchange—has made the country a world leader in copper production (Gondwe 2010). On the other hand, the industry is simultaneously devastating water resources for local communities located downstream of the copper mines. Each tonne of ore produced creates approximately two tonnes of waste, which the mining companies often manage (Dymond 2007).

The increased sedimentation from copper mining activities has resulted in crop losses for downstream farmers from the sediment and silt particles that have flooded their fields. In 2005 alone, these lost incomes amounted to US$20 181 (Dymond 2007). Agriculture's contribution to GDP and the fact that 65 per cent of the labour force is employed in agriculture (FAO 2008) has made agricultural growth a government priority. With estimated copper reserves of 19 million tonnes (USGS 2010), balancing the copper-mining industry with agricultural productivity and water quality will be a key challenge for Zambia.

Annual copper production





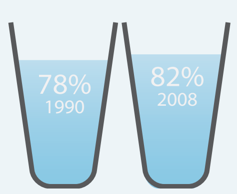
Republic of

Zimbabwe

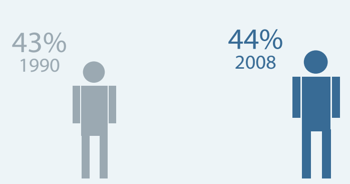
Total Surface Area: 390 757 km²
Estimated Population in 2009: 12 523 000

Progress Towards MDG Goal 7

Between 1990 and 2008, the percentage of people in Zimbabwe with improved drinking water sources increased from 78 to 82 per cent. The percentage of the population using improved sanitation facilities increased from 43 per cent to 44 per cent. Urban use dropped from 58 per cent to 56 per cent and rural population use remained the same at 37 percent over the period.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2005	657
Total renewable water (actual) (10^9 m³/yr)	2008	20
Total renewable per capita (actual) (m³/inhab/yr)	2008	2 558
Surface water: total renewable (actual) (10^9 m³/yr)	2008	19
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	6
Dependency ratio (%)	2008	38.7

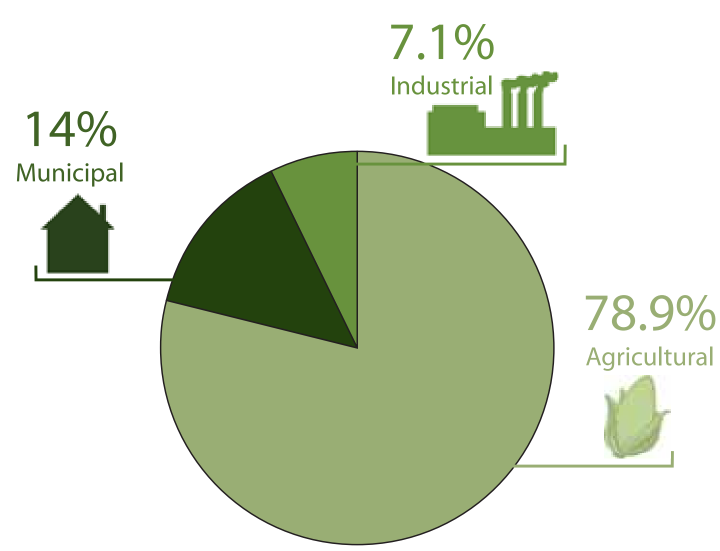
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2002	4.2
Surface water withdrawal (10^9 m³/yr)	2002	3.8
Groundwater withdrawal (10^9 m³/yr)	2002	0.4
Total water withdrawal per capita (m³/inhab/yr)	2002	513.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	21

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

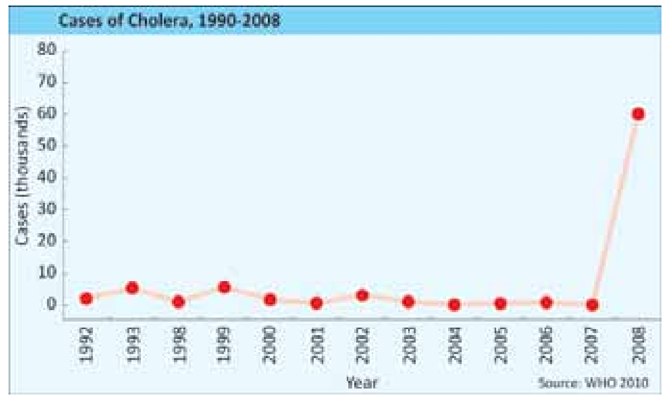
Withdrawals by sector (as % of total water withdrawal), 2002



Water-related Diseases

Zimbabwe's unreliable sanitation infrastructure, highly frequent sewage-system collapse and shallowly dug wells contribute to the high incidence of communicable diseases in the country. This is further amplified by a frail economy that often prevents the purchase of materials and chemicals for water purification.

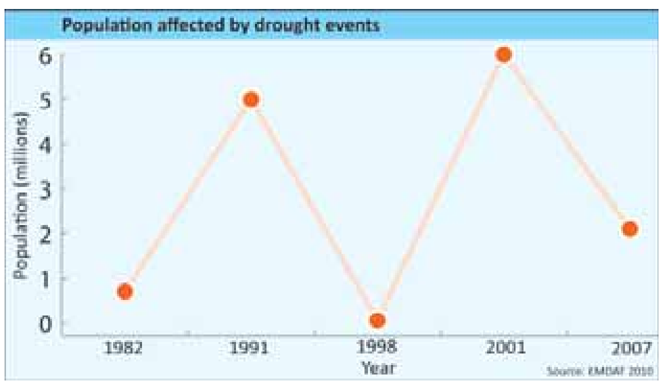
The nation is also threatened by the prevalence of water-related diseases including malaria, schistosomiasis (*bilharzia*), enteric diseases like diarrhoea, agrochemical poisoning, skin and eye diseases and cholera. Recently, Zimbabwe suffered one of sub-Saharan Africa's most severe cholera outbreaks, causing the death of more than 4 000 people and infecting 60 055 others (UNOCHA 2009, WHO 2010). In 2009, a further 1 912 people died from the disease and 37 000 cases were reported (WHO 2010). Although the fatality rate has dropped from 5.1 per cent to 3.4 per cent, it still remains above the average expected fatality rate for cholera.



Both rural and urban areas are susceptible to the proliferation of water-related diseases. Eighty-two per cent of cholera cases were reported in rural areas, where 63 per cent of the population reside. Urban areas in Zimbabwe are also threatened by cholera. Harare, Zimbabwe's capital, was the epicentre of the 2008-2009 epidemic where 30 strains of cholera were detected in the city and every water source in the area was contaminated (UNOCHA 2009).

Water Scarcity Affects Agricultural Water Use

The agricultural sector accounts for almost 79 per cent of total water withdrawal in Zimbabwe (FAO 2005). Approximately 60 per cent of Zimbabwe's economically active population is directly dependent on agriculture for food and livelihoods and the sector contributes 17 per cent of the nation's GDP (FAO 2005). Major irrigated crop products include cotton, sugar cane, tobacco, soybeans, fruit, vegetables and maize.



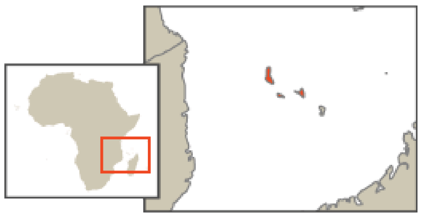
Drought events are a major constraint on agricultural productivity as 80 per cent of the nation's land lies in areas where rainfall is erratic and inadequate (FAO 2005). The total estimated exploitable yield from all river basins is estimated at 8.5 km^3/yr. Roughly 56 per cent of this, or 4.8 km^3/yr, is already committed. This leaves only 3.7 km^3/yr available for irrigation and other sectors (FAO 2005).

The issue of naturally limited water availability is further compounded by changes made to Zimbabwe's agricultural system in the last decade. Following the expropriation of farms in 2000, many new farm owners were unable to maintain the water systems and irrigation dams that had previously powered the sector (IPS News 2008), which introduced additional barriers to agricultural productivity and food security.


Brian Jackson/Flickr.com

Western Indian Ocean Islands

Comoros
Madagascar
Mauritius
Seychelles



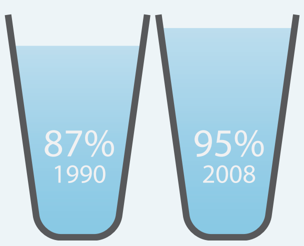
Union of the

Comoros

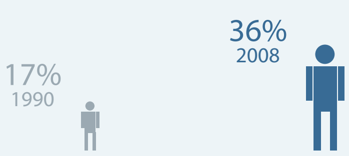
Total Surface Area: 2 235 km²
Estimated Population in 2009: 676 000

Progress Towards MDG Goal 7

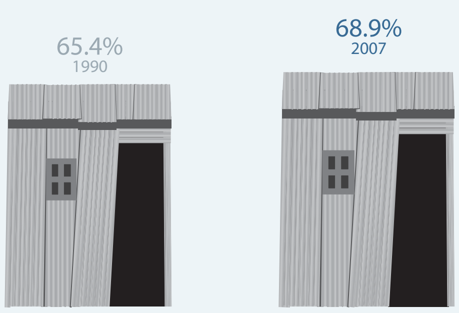
A history of political violence in Comoros has contributed to its poverty and lack of development. In addition, eruptions from Mount Karthala have contaminated Grande Comore's fragile water sources. From 1990 to 2008, while the proportion of people using improved water declined from 98 to 91 per cent in urban areas, it increased from 83 to 97 per cent in rural ones. Access to improved sanitation increased from 34 to 50 per cent and from 11 to 30 per cent in urban and rural areas, respectively during the same period.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	900
Total renewable water (actual) (10^9 m³/yr)	2008	1.2
Total renewable per capita (actual) (m³/inhab/yr)	2008	1 412
Surface water: total renewable (actual) (10^9 m³/yr)	2008	0.2
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	1
Dependency ratio (%)	2008	0

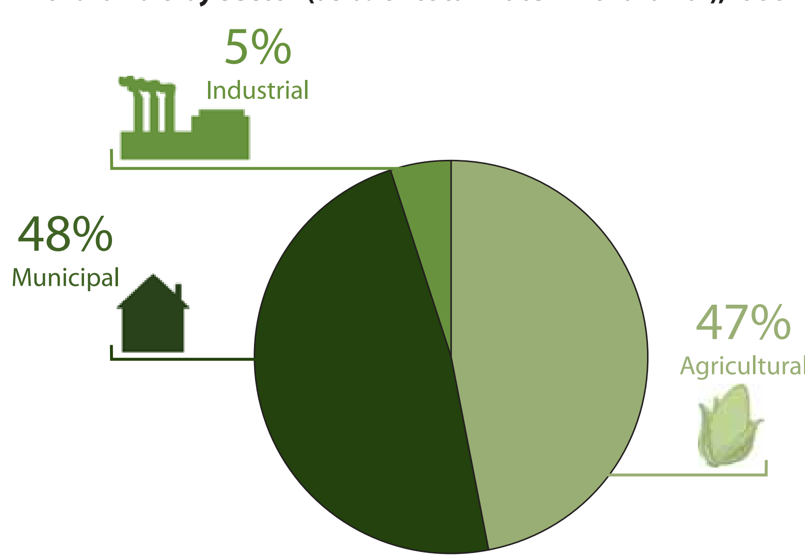
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	1999	0.01
Surface water withdrawal (10^9 m³/yr)	...	...
Groundwater withdrawal (10^9 m³/yr)	...	...
Total water withdrawal per capita (m³/inhab/yr)	2002	13.6
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	0.8

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal),1999



Water Contamination from Volcanic Eruptions

The islands of the Comoros archipelago were formed through volcanic activity, and a 2 360 m active volcanic system covers nearly two-thirds of Ngazidja, the largest and most developed island. Mount Karthala is one of the most active volcanoes in the world, erupting as recently as 1977, 1999 and 2005, with a minor eruption in 2006. The 2005 eruptions, which spewed ash up to five metres deep across the island, affected an estimated 284 000 people (EM-DAT 2010). The eruption polluted Ngazidja's fragile water supply and left much of the island covered in debris (UNICEF 2006).

The island has limited rivers and streams, with only 200 million cubic metres of surface water available each year across the entire archipelago (FAO 2008). In addition, only 30 per cent of the population has access to a piped water source (WHO/UNICEF 2010). As a result, many of Ngazidja's residents are dependent on rainwater gathered in large cisterns or tanks, which became clogged with ash following the volcano eruption, leaving many without access to a clean water supply (UNICEF 2006). There are fears that volcanic activity is becoming more frequent and yet the country has an inadequate early-warning system—the scale of the 2005 eruption was realized only two hours before the event (UNOCHA 2008). Protecting its water supplies from potential future contamination is a key challenge for Comoros.

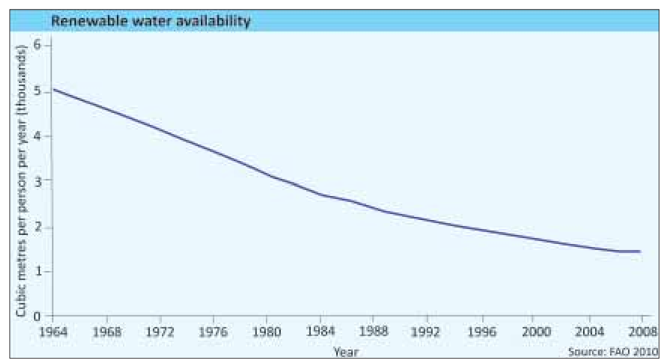
Top 10 natural disasters in Comoros for the period of 1900-2010, sorted by number of total affected people (Sources: EM-DAT 2010)

Disaster	Year	Total affected
Volcano	24/11/2005	245 000
Storm	03/01/1987	50 000
Volcano	16/04/2005	39 000
Storm	14/02/1985	35 000
Storm	10/01/1983	30 052
Volcano	05/04/1977	25 000
Epidemic	16/02/1988	3 200
Flood	20/04/2009	2 500
Epidemic	Mar-07	1 490
Epidemic	12/03/2005	1 358

Climate-Change Impacts on Water Resources

Water resources on the island state are vulnerable to changes in climate. The water supply is already insufficient to meet the needs of a growing population, a situation that will be further exacerbated under various climate-change scenarios. The country's essential groundwater resources are especially at risk (UNFCCC 2002).

Groundwater accounts for 83 per cent of the total renewable water resources in Comoros (FAO 2008), but this supply is already threatened by the balance between salt and freshwater, overexploitation, contamination by septic tanks, insufficient pumps in Ngazidja and sub-standard equipment . Any rise in sea level will further disrupt this already fragile equilibrium. In addition, increasing air temperatures could also lead to a rise in the levels of evapotranspiration, negatively affecting underground water supplies (UNFCCC 2002).



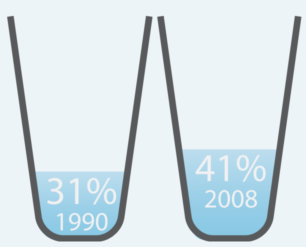
Republic of

Madagascar

Total Surface Area: 587 041 km²
Estimated Population in 2009: 19 625 000

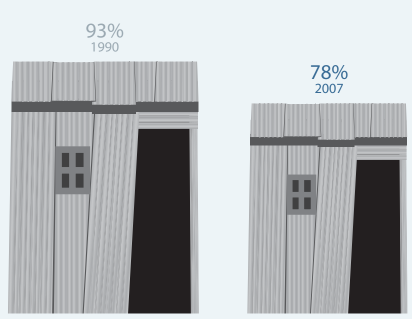
Progress Towards MDG Goal 7

Access to improved water sources in Madagascar's urban areas declined from 78 to 71 per cent from 1990 to 2008, while rural access increased from 16 to 29 per cent. Sanitation provision lags far behind. It rose from 6 to 10 per cent in rural areas and from 14 to 15 per cent in urban areas. The MDG sanitation target is 54 per cent, requiring an increase of 43 per cent from the overall average of 11 per cent in 2006.



Proportion of total population using improved drinking water sources, percentage

Proportion of total population using sanitation facilities, percentage



Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	1 513
Total renewable water (actual) (10^9 m³/yr)	2008	337
Total renewable per capita (actual) (m³/inhab/yr)	2008	17 634
Surface water: total renewable (actual) (10^9 m³/yr)	2008	332
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	55
Dependency ratio (%)	2008	0

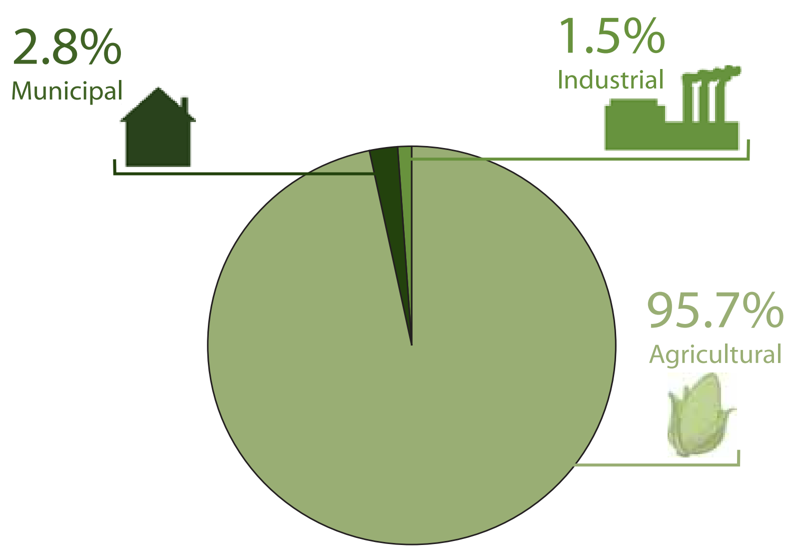
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2000	15
Surface water withdrawal (10^9 m³/yr)	2000	15
Groundwater withdrawal (10^9 m³/yr)	2001	0.02
Total water withdrawal per capita (m³/inhab/yr)	2002	924
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2002	4.4

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	1992	67
Area salinized by irrigation (1000 ha)	...	...

Withdrawals by sector (as % of total water withdrawal in 2000)

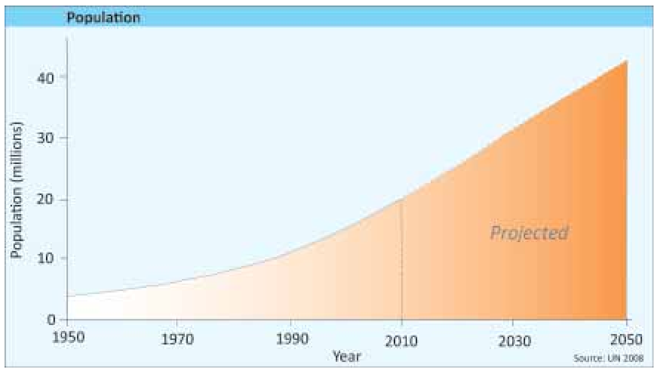


Drought in Southern Madagascar

Despite receiving an average 1 513 mm of rainfall each year (FAO 2008), regional variations mean that some parts of the island suffer chronic water shortages. The Toliary region in the south receives less than 400 mm of rainfall annually and experiences around eight dry months a year. Madagascar has had five drought periods since 1980, occurring in 1981, 1988, 2000, 2002 and 2005; combined they have affected a total of 2 795 290 people (EM-DAT 2010).

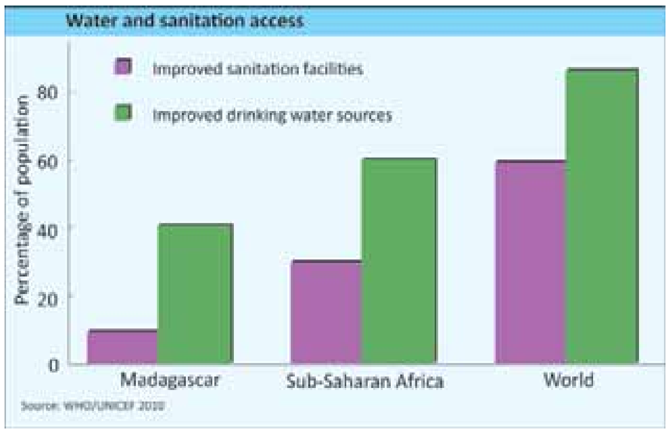
The arid conditions in southern Madagascar have left populations in the region particularly susceptible to shocks. Climate change has increased the frequency of droughts that used to occur every decade, but now occur annually (UNOCHA 2009). The intensity of drought events in the south has also increased. A report compiled in May 2009 noted that 250 000 people were affected by food insecurity in 2009, compared to 100 000 in the same period in 2008 (UNOCHA 2009).

The food security situation is further exacerbated by land degradation, political instability and a rapidly growing population. Madagascar's population almost doubled between 1990 and 2008, increasing from 11.2 million to 19.1 million (WHO/UNICEF 2010).



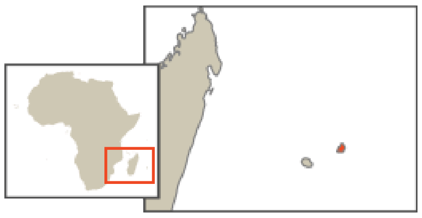
Water and Sanitation Access

Access to improved water and sanitation facilities in Madagascar is among the lowest in the world, falling well below the average for sub-Saharan Africa. Only 41 per cent of the population uses an improved drinking water source adequately protected from outside contamination. This figure falls to 29 per cent in rural areas, where 71 per cent of the total population resides (WHO/UNICEF 2010). Access to improved sanitation facilities is even lower, with only 11 per cent of the population using facilities that hygienically separate human excreta from human contact (WHO/UNICEF 2010). As a result of this slow progress, Madagascar is not on track to meet the Millennium Development Goal's water and sanitation targets. One of the main factors behind the limited progress is the country's rapid population growth, which has placed additional pressures on infrastructure to serve the rising needs.



Water-related diseases are a serious issue in the country. The lack of adequate sanitation and the fact that 32 per cent of the population practice open defecation (WHO/UNICEF 2010) have resulted in considerable surface water pollution from sewage contamination. Outbreaks of water-borne illness such as diarrhoea are becoming increasingly frequent and stagnant canals are contributing to the spread of malaria and bilharzia, especially in coastal areas (FAO 2005).

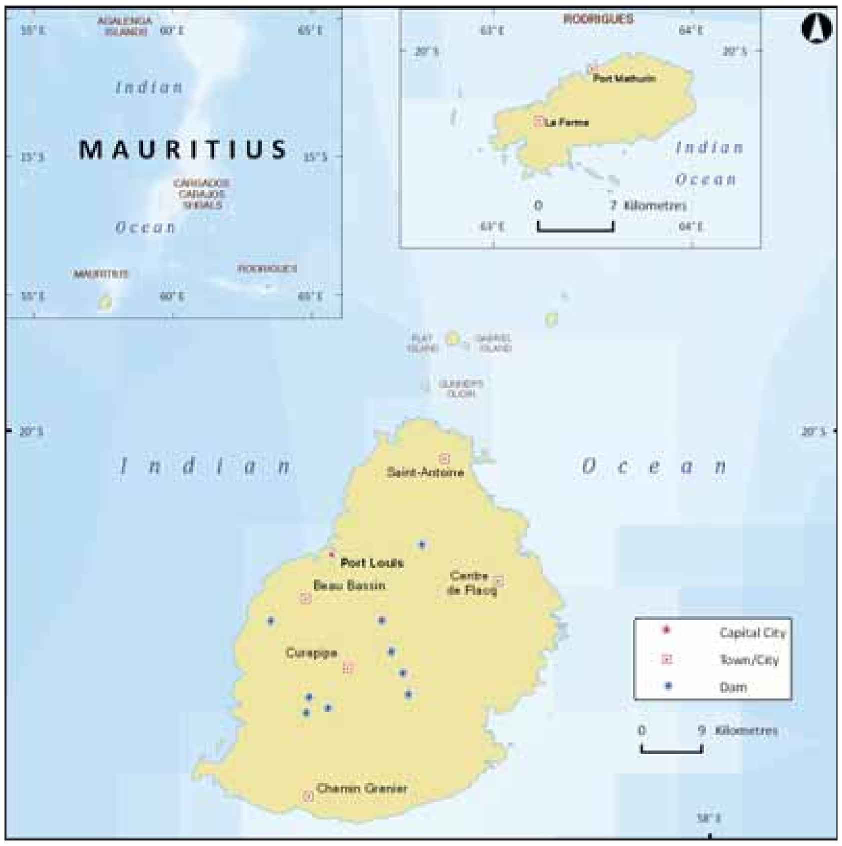
Silvio/Flickr.com



Republic of

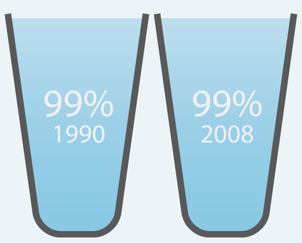
Mauritius

Total Surface Area: 2 040 km²
Estimated Population in 2009: 1 288 000

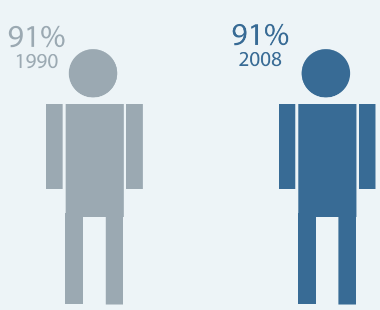


Progress Towards MDG Goal 7

Mauritius's water supply is equally sourced from groundwater and surface water. Dams are used to augment dry periods assuring sufficient freshwater supply to the island population. Ninety-nine per cent of households have access to safe drinking water, most of which is piped to the premises. The population is also well served by improved sanitation facilities such that 91 per cent of people enjoy such access.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

N/A N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	2 041
Total renewable water (actual) (10^9 m³/yr)	2008	2.8
Total renewable per capita (actual) (m³/inhab/yr)	2008	2 149
Surface water: total renewable (actual) (10^9 m³/yr)	2008	2.4
Groundwater: total renewable (actual) (10^9 m³/yr)	2008	0.9
Dependency ratio (%)	2008	0

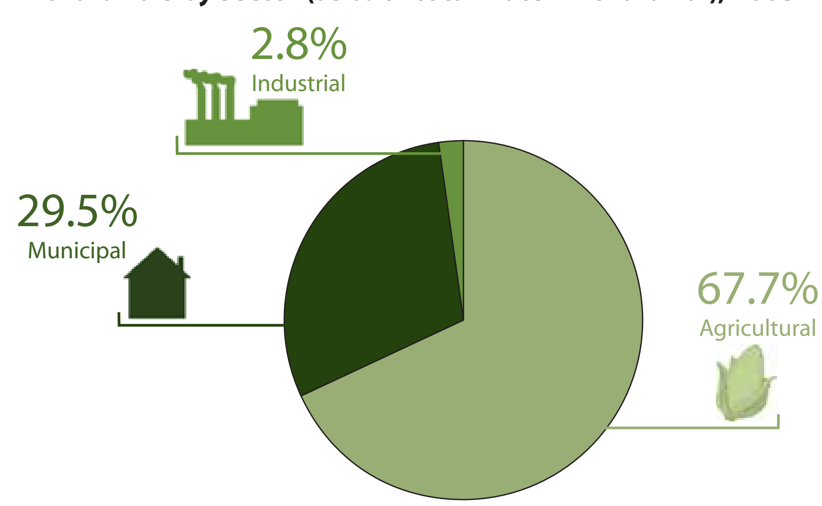
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2003	0.7
Surface water withdrawal (10^9 m³/yr)	2003	0.6
Groundwater withdrawal (10^9 m³/yr)	2003	0.1
Total water withdrawal per capita (m³/inhab/yr)	2007	570.4
Freshwater withdrawal as % of total renewable water resources (actual) (%)	2007	26.4

Irrigation

	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	2002	0

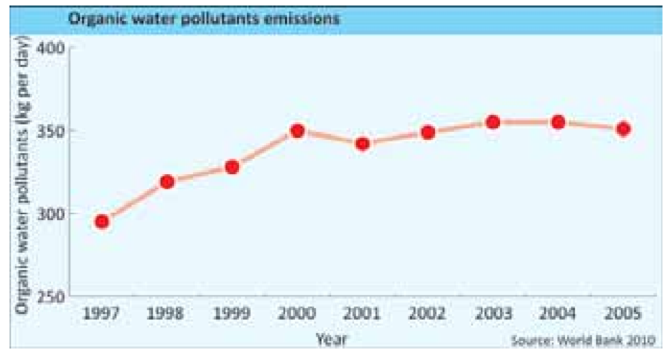
Withdrawals by sector (as % of total water withdrawal), 2003



With 101 000 ha of land cultivated, or almost half of the total land area, the agricultural sector also plays a key role in both the usage and quality of water resources in the country (FAO 2009). Sugar-cane exports contribute significantly to Mauritius's economy, with 4 533 000 tonnes produced in 2008 alone (FAO 2009). In order to maintain these high yields, farmers in the country use fertilizers, herbicides and pesticides, further deteriorating water quality in the country.

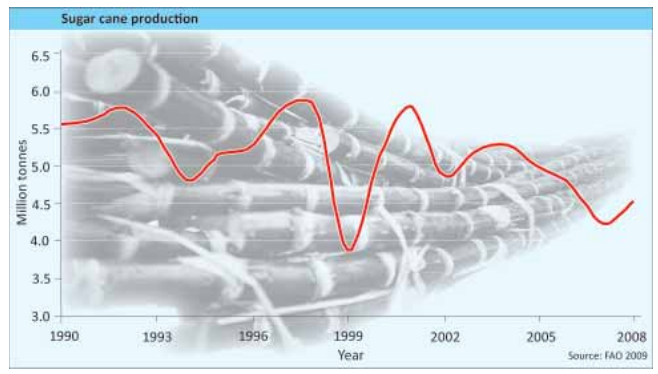
Water Pollution

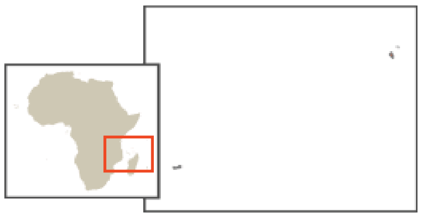
The release of effluents, primarily from the industrial and agricultural sectors, is degrading the quality of Mauritius' water resources. In 2005, approximately 351 kg of organic pollutants were emitted daily to the country's water resources (World Bank 2010). Wastewater discharge from the manufacturing industries includes substantial amounts of dyestuff, heavy metals and complex chemical compounds that contaminate both freshwater and coastal ecosystems.



Drought

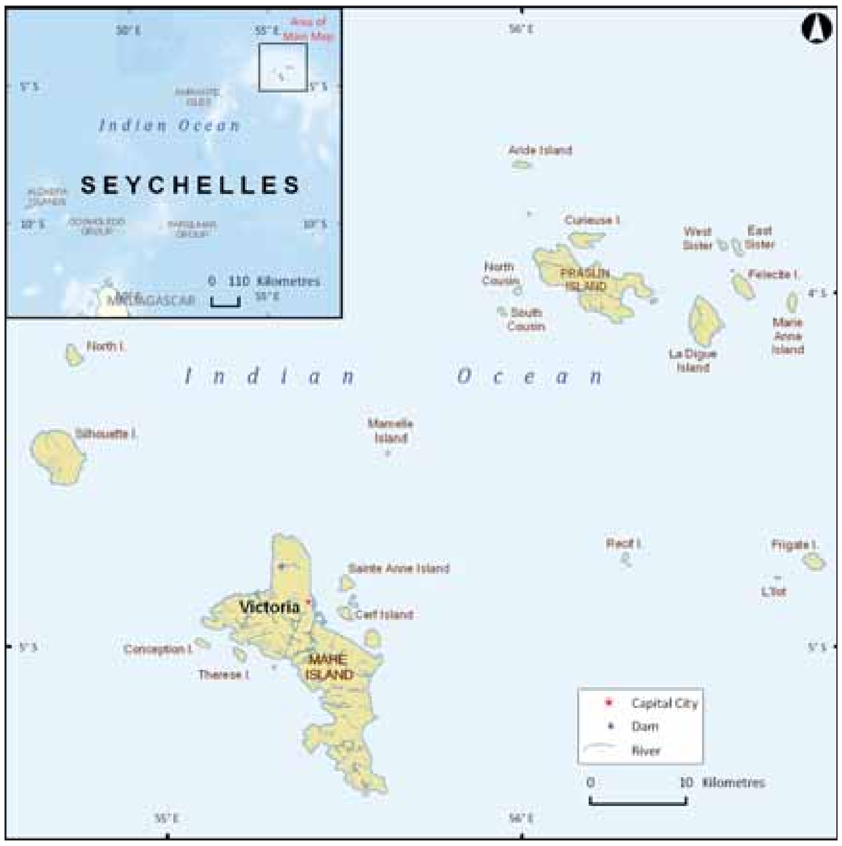
Reduced rainfall and drought pose serious threats to water availability in Mauritius. Between 1960 and 2006, OND (October-November-December) rainfall in the country declined at an average rate of 8.7 per cent per decade (ALM 2009). In 1999, Mauritius experienced one of its most severe drought periods in almost a century. The dry spell caused water reserves on the central plateau, the island's wettest region, to fall to an estimated 56 per cent of normal levels. As a result, tough restrictions were placed on water supply. In the capital, Port Louis, water usage was limited to six hours a day while the rest of the island only had access for one hour each day (UNOCHA 1999). Agricultural yields also suffered as sugar-cane production decreased by almost 1.9 million tonnes compared to 1998 levels—a drop of almost a third (FAO 2009). This shortfall of vital sugar exports resulted in an estimated loss of US$160 million in revenues for Mauritius (UNOCHA 1999). In addition, the drought affected hydroelectric power generation, leading to a 70 per cent fall in the annual production of electricity (UNECA 2008). Severe drought periods can further affect the quality of water resources by depressing water levels in aquifers, facilitating seawater intrusion.





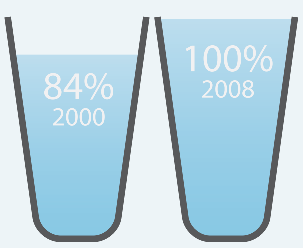
Republic of Seychelles

Total Surface Area: 455 km²
Estimated Population in 2009: 84 000

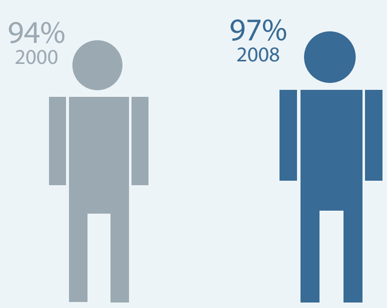


Progress Towards MDG Goal 7

Water resources are limited due to the size, geology and terrain of this group of islands. Dams capture ephemeral river flows supplying the populated coastal areas with freshwater. Eighty-seven per cent of the population has piped water on the premises and 88 per cent has flushing toilets. The proportion of the population using improved drinking water sources increased from 84 per cent in 2000 to 100 per cent in 2008. The proportion of the population with access to improved sanitation facilities also increased, from 94 to 97 per cent in the same time period.



Proportion of total population using improved drinking water sources, percentage



Proportion of total population using sanitation facilities, percentage

N/A N/A

Slum population as percentage of urban

Water Profile

Water Availability

	Year	Value
Average precipitation in depth (mm/yr)	2008	2 330
Total renewable water (actual) (10^9 m³/yr)	...	...
Total renewable per capita (actual) (m³/inhab/yr)	...	...
Surface water: total renewable (actual) (10^9 m³/yr)	...	...
Groundwater: total renewable (actual) (10^9 m³/yr)	...	...
Dependency ratio (%)	2008	0

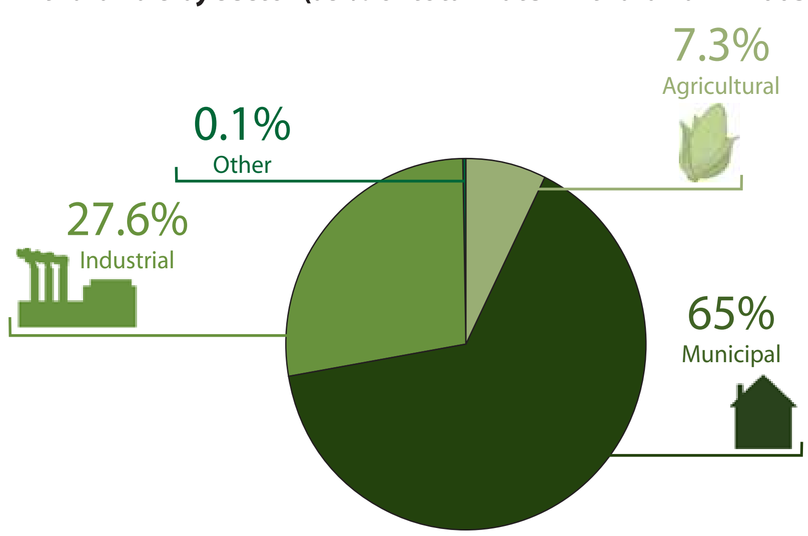
Withdrawals

	Year	Value
Total freshwater withdrawal (surface water + groundwater) (10^9 m³/yr)	2003	0.01
Surface water withdrawal (10^9 m³/yr)	2003	0.01
Groundwater withdrawal (10^9 m³/yr)	2003	0.00
Total water withdrawal per capita (m³/inhab/yr)	2007	148.2
Freshwater withdrawal as % of total renewable water resources (actual) (%)	...	...

Irrigation

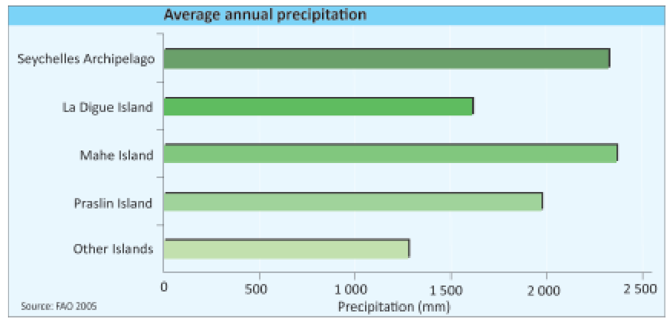
	Year	Value
Irrigated grain production as % of total grain production (%)	...	...
Area salinized by irrigation (1000 ha)	2003	0

Withdrawals by sector (as % of total water withdrawal in 2003)



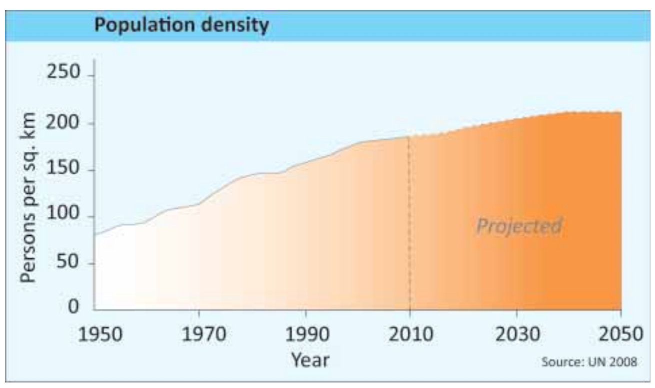
Water Availability and Storage

The Seychelles Archipelago receives abundant rainfall, averaging 2 330 mm annually. Precipitation levels vary on the different islands and range from 1 290 mm up to 3 500 mm/yr on the central plateau of Mahe Island (FAO 2005). Although rainfall levels are substantial, the inability to harvest and store water is a challenge to freshwater availability. An estimated 98 per cent of rainfall is lost either through runoff or evaporation, leaving only two per cent to infiltrate streams and groundwater aquifers (Government of Seychelles 2000). Dams are key for harnessing water resources since many of the water courses are ephemeral (flowing only immediately after precipitation), and groundwater resources are limited and often saline. The total dam capacity in the Seychelles is around 0.970 million cubic metres and is split between two main dams, La Gogue and Rochon, which respectively store 0.920 and 0.050 million cubic metres (FAO 2005). During the dry season, however, this limited supply cannot meet demands and there is a need for water rationing (Government of Seychelles 2000).



Climate-Change Impacts

Small island states such as Seychelles are especially vulnerable to the impacts of climate change. The almost exclusive dependency on surface water resources leaves the archipelago susceptible to any changes in the volume and distribution of rainfall. Relatively small variations in temperature and precipitation can result in a significant change in runoff and consequently in water availability (Government of Seychelles 2000).



In addition, Seychelles is also at risk of flooding due to a combination of sea-level rise and storm surges. An estimated 43.9 per cent of the total land area is below five metres in elevation and more than 40 per cent of the population lives in these low lying areas (CIESIN 2007). As well as the direct impacts on coastal populations, any rise in sea level will also affect the quality of water resources by increasing the intrusion of salt water.

Seychelles extensive network of wetlands acts as an important buffer to changes in water levels by storing floodwater and storm runoff. This reduces the impacts of floods and storms and also minimizes the scouring and erosion of stream banks, which can occur after such events. The increase in development and reclamation pressures has lead to the degradation of this vital ecosystem (Government of Seychelles 2005). Both water shortages and the strain on wetlands will be further exacerbated by the Seychelles' growing population, which puts pressure on both water resources and land.

References

WHO/UNICEF. (2008). Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/resources/documents.html (Last accessed on January 11, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Northern Africa

Algeria

EC. (2006). Support to DG Environment for development of the Mediterranean De-pollution Initiative "Horizon 2020". European Commission. http://ec.europa.eu/environment/enlarg/med/pdf/algeria_en.pdf (Last accessed on March 17, 2010).

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Algeria. Food and Agriculture Organization of the United Nations http://www.fao.org/nr/water/aquastat/countries/algeria/indexfra.stm (Last accessed on March 17, 2010).

FAO. (2008). AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations- Land and Water Development Division. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

Egypt

AFED. (2009). Arab Environment: Climate Change Impact of Climate Change on Arab Countries. Arab Forum for Environment and Development.http://www.afedonline.org/afedreport09/Full%20English%20Report.pdf (Last accessed on March 11, 2010).

EEAA. (2008). Egypt State of Environment Report 2008. Arab Republic of Egypt Ministry of State for Environmental Affairs Agency. http://www.eeaa.gov.eg/English/reports/SoE2009en/Egypt%20State%20of%20Environment%20Report.PDF (Last Accessed on September 11, 2010).

United Nations. (2008). United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. World Population Prospect, The 2008 Revision.

World Bank. (2006). Project Appraisal Document for a Proposed Loan to the Arab Republic of Egypt for a Second Pollution abatement Project. http://www.wds.worldbank.org/external/default/DSContentServer/WDSP/IB/2006/03/16/000012009_20060316094617/Rendered/INDEX/ R20060002902.txt (Last Accessed On September 11, 2010).

Libyan Arab Jamahiriya

Chapagain, A. and Hoekstra, A. (2003). 'Virtual water flows between nations in relation to trade in livestock and livestock products', Value of Water Research Report Series No. 13, UNESCO-IHE.

FAO. (2006). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Libyan Arab Jamahiriya. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/libya/index.stm (Last Accessed on March 13, 2010).

FAO. (2008). AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations- Land and Water Development Division. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last Accessed on January 11, 2010).

GMRA. (2008). The Great Man-Made River Authority.http://www.gmmra.org/en/index.php?option=com_content&view=article&id=76&Itemid=50 (Last accessed on March 13, 2010).

Hoekstra A. and Hung P. (2002). Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade, Value of Water Research Series No. 11, UNESCO-IHE.

United Nations. (2008). United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. World Population Prospect, The 2008 Revision.

Morocco

EC. (2006). Support to DG Environment for development of the Mediterranean De-pollution Initiative "Horizon 2020". European Commission. http://ec.europa.eu/environment/enlarg/med/pdf/algeria_en.pdf (Last accessed on March 17, 2010).

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Morocco. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/morocco/indexfra.stm (Last accessed on March 17, 2010).

FAO. (2008). AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations- Land and Water Development Division. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

World Bank. (2009). World Development Indicators. Online database. World Bank. Washington, D.C. http://databank.worldbank.org/ddp/home.do?Step=12&id=4&CNO=1147 (Last accessed on January 11, 2010).

Sudan

UNESCO. (2009). World Water Assessment Programme - 2009. The United Nations World Water Development Report 3, Case Study Volume: Facing The Challenges. United Nations Educational, Scientific and Cultural Organization. http://www.unesco.org/water/wwap/wwdr/wwdr3/case_studies/pdf/WWDR3_Case_Study_Volume.pdf (Last accessed on September 11, 2010).

WHO. (2009). Global Health Atlas. Geneva: WHO. World Health Organization. http://www.who.int/globalatlas/ (Last accessed on January 11, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

World Bank. (2010). Sudan: Water Supply and Sanitation Project – Project Information Document (PID) Concept Stage. http://www.reliefweb.int/rw/rwb.nsf/db900sid/VVOS-82AUAQ?OpenDocument&RSS20&RSS20=FS (Last accessed on September 11, 2010).

Tunisia

EC. (2006). Support to DG Environment for development of the Mediterranean De-pollution Initiative "Horizon 2020". European Commission. http://ec.europa.eu/environment/enlarg/med/pdf/algeria_en.pdf (Last accessed on March 17, 2010).

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Tunisia. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/tunisia/indexfra.stm (Last accessed on March 17, 2010).

IHE. (2008). Rapport de synthèse - Seconde Communication Nationale – EANM : Vulnérabilité et adaptation. Ingénierie de l'Hydraulique, de l'Equipement et de l'Environnement (IHE) - Ministre de l'Environnement et du Developpement Durable de la Tunisie. http://www.tn.undp.org/pdf/synthese_seconde_comm.pdf (Last accessed on September 11, 2010).

INECO. (2009). Proposition Paper Aquifer Depletion in Tunisia. Institutional and Economic Instruments for Sustainable Water Management in the Mediterranean Region.http://environ.chemeng.ntua.gr/ineco/Default.aspx?t=413 (Last accessed on March 17, 2010).

WRI. (2007). Agricultural Inputs: Fertilizer consumption. World Resources Institute. http://earthtrends.wri.org/searchable_db/index.php?step=countries&cID%5B%5D=183&theme=8&variable_ID=196&action=select_years. (Last accessed on September 11, 2010).

Eastern Africa

Burundi

FAO. (2008). UN Food and Agriculture Organization- Statistics Division. FAOSTAT: Online Database. Arable land data- ResourceSTAT module; Rural population data- PopSTAT module; Calculation by World Resources Institute for 2008 http://faostat.fao.org/site/348/default.aspx (Last accessed on March 20, 2010).

FAO. (2009). FAOSTAT: Online Database. PopSTAT Module. Food and Agriculture Organization of the United Nations. http://faostat.fao.org/site/550/default.aspx#ancor (Last accessed on March 20, 2010).

IUCN. (2008). Projects: Lake Tanganyika Basin. International Union for Conservation of Nature. http://www.iucn.org/about/work/programmes/water/wp_where_we_work/wp_our_work_projects/wp_our_work_ltb/ (Last accessed on March 20, 2010).

Jarvis A., Reuter, H., Nelson, A., Guevara, E. (2008). Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT). http://srtm.csi.cgiar.org. (Last accessed on August 23, 2010).

UNOPS. (2000). Special Study on Pollution and Its Effects on Biodiversity (PSS)- Summary of Findings for the Strategic Action Programme. United Nations Office for Project Services. http://www.ltbp.org/FTP/SPSS.PDF (Last accessed on September 28, 2010).

WDPA. (2009). World Database on Protected Areas- Burundi: Wetlands of International Importance (Ramsar) Delta de la Rusizi de la Réserve Naturelle de la Rusizi et la partie nord de la zone littorale du lac Tanganyika http://www.wdpa.org/siteSheet.aspx?sitecode=900788 (Last accessed on September 28, 2010).

Djibouti

EM-DAT. (2010). EM-DAT: The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on September 16, 2010)

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

FEWSNET. (2010). DJIBOUTI Food Security Outlook. Famine Early Warning Systems Network. http://www.fews.net/docs/Publications/Djibouti_2010_04_final.pdf (Last accessed on September 17, 2010).

GEF. (2008). Implementing NAPA Priority Interventions to Build Resilience in the most Vulnerable Coastal Zones. Global Environment Facility. http://www.thegef.org/gef/node/2904 (Last accessed on September 17, 2010).

Eritrea

FAO. (2009). Food Security Statistics. Food and Agriculture Organization of the United Nations. http://www.fao.org/economic/ess/food-security-statistics/en/ (Last accessed September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. http://www.unwater.org/downloads/JMP_report_2010.pdf (Last accessed on September 16, 2010).

Ethiopia

Aboma, G. (2009). Ethiopia: Effective financing of local governments to provide water and sanitation services. WaterAid Report. http://www.wateraid.org/documents/plugin_documents/local_financing__ethiopia.pdf (Last accessed on September 16, 2010).

EM-DAT: The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 9, 2010).

NASA Earth Observatory. (2008). Drought in Ethiopia. http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19764 (Last accessed on April 13, 2010).

<u>Kenya</u>

Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D., Savelli, H. (eds). (2010). Sick Water? The central role of wastewater management in sustainable development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no.

FAO. (2010). AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations- Land and Water Development Division. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

UNEP. (2009). Kenya Atlas of our Changing Environment. United Nations Environment Programme. Division of Early Warning and Assessment. Nairobi.

UNESCO. (2006). The 2nd UN World Water Development Report: 'Water, a shared responsibility'. Section 5- Sharing responsibilities, Case Study-Kenya. United Nations Educational, Scientific and Cultural Organization. http://www.unesco.org/water/wwap/wwdr/wwdr2/table_contents.shtml (Last accessed on October 5, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. http://www.unwater.org/downloads/JMP_report_2010.pdf (Last accessed on September 16, 2010).

Rwanda

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Rwanda. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/rwanda/indexfra.stm (Last accessed on April 17, 2010).

REMA. (2009). Rwanda State of Environment and Outlook Report". Rwanda Environment Management Authority. P.O. Box 7436 Kigali, Rwanda.

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

World Bank. (2008). World dataBank-Online Database. http://databank.worldbank.org/ (Last accessed on April 19, 2010).

Somalia

Columbia University. (2005). Somalia Natural Disaster Profile. Center for Hazards & Risk Research at Columbia University. http://www.ldeo.columbia.edu/chrr/research/profiles/somalia.html (Last accessed on September 16. 2010).

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2005). Irrigation in Africa in figures- AQUASTAT Survey 2005. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/somalia/somalia_cp.pdf (Last accessed on September 16, 2010)

IDMC. (2009). Internal Displacement: Global Overview of Trends and Developments. Internal Displacement Monitoring Centre, Norwegian Refugee Council. http://www.internal-displacement.org/ (Last accessed on September 16, 2010).

UNOCHA. (2010a). SOMALIA: Minister urges WFP to release food from Mogadishu stores. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=88849 (Last accessed on September 16, 2010).

UNOCHA. (2010b). SOMALIA: Galgadud villages abandoned as water shortage bites. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=88454 ((Last accessed on September 16, 2010).

UNOCHA. (2010c). SOMALIA: Floods near Jowhar displace hundreds, destroy crops. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=88791 (Last accessed on September 16, 2010).

UNOCHA. (2010d). UN Office for the Coordination of Humanitarian Affairs SOMALIA: Rains displace hundreds in Somaliland. IRIN online news service http://www.irinnews.org/Report.aspx?ReportId=88944 (Last accessed on September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. http://www.unwater.org/downloads/JMP_report_2010.pdf (Last accessed on September 16, 2010).

Uganda

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

United Nations. (2009). United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. World Urbnanization Prospects, The 2009 Revision.

UNOCHA. (2005). UGANDA: Prolonged drought affecting hydroelectric power production. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/report.aspx?reportid=52793 (Last accessed on September 16, 2010).

UNOCHA. (2009a). UGANDA: Rising temperatures threatening livelihoods. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=83267 (Last accessed on September 16, 2010).

UNOCHA. (2009b). UGANDA: Water scheme proposed for parched Karamoja. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=82789 (Last accessed on September 16, 2010).

UNOCHA. (2010). UGANDA: "Flying toilets" still not grounded. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=87677 (Last accessed on September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Central Africa

Cameroon

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en Last acccessed on January 11, 2010).

IEA. (2006). World Energy Outlook 2006. International Energy Agency. http://www.iea.org/textbase/nppdf/free/2006/weo2006.pdf (Last accessed on September 16, 2010).

UNOCHA. (2009). CAMEROON: Epidemic looms as town's water dries up. IRIN online news service . UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=83781 (Last accessed on September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. http://www.unwater.org/downloads/JMP_report_2010.pdf (Last accessed on September 16, 2010).

World Bank. (2010). World dataBank-Online Database. http://databank.worldbank.org/ (Last accessed on April 19, 2010).

WWAP. (2009). The United Nations World Water Development Report 3, Case Study Volume: Facing The Challenges. World Water Assessment Programme.

Central African Republic

IDMC. (2010). Internal Displacement Monitoring Center- Global Statistics. http://www.internal-displacement.org/8025708F004CE90B/(httpPages)/22FB1D4E2B196DAA802570BB005E787C?OpenDocument&count=1000 (Last accessed on April 9, 2010).

UNOCHA. (2010). DRC-CENTRAL AFRICAN REPUBLIC: Refugees not ready to return. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=87743 (Last accessed on April 9, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Chad

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2008). AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/chad/indexfra.stm (Last accessed on September 16, 2010).

FAO. (2009). Food Security Statistics. Food and Agriculture Organization of the United Nations. http://www.fao.org/economic/ess/food-security-statistics/en/ (Last accessed on September 16, 2010).

UNHCR. (2010). 2010 UNHCR country operations profile – Chad. United Nations High Commissioner for Refugees. http://www.unhcr.org/pages/49e45c226.html (Last accessed on September 16, 2010).

UNOCHA. (2008). Chad-Humanitarian Country Profile. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/country.aspx?CountryCode=TD&RegionCode=WA (Last accessed on September 16, 2010).

UNOCHA. (2010). CHAD: Hungry season sets in early. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=88370 (Last accessed on September 16, 2010).

WHO. (2010). World Health Statistics 2010. World Health Organization. http://www.who.int/whosis/whostat/2010/en/index.html (Last accessed on September 16, 2010).

Congo

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations.http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

IDMC. (2010). Internal Displacement Monitoring Center- Statistical Summary. http://www.internal-displacement.org/ (Last accessed on April 9, 2010).

UNHCR. (2008). Field Information and Coordination Support Section, Division of Operational Services, United Nations High Commissioner for Refugees (UNHCR). Global Refugee Trends: Statistical overview of populations of refugees, asylum-seekers, internally displaced persons, stateless persons, and other persons of concern to UNHCR. Geneva: UNHCR. http://www.acnur.org/biblioteca/pdf/7096.pdf (Last accessed on September 16, 2010).

UNOCHA (2008). Republic of Congo- Humanitarian Country Profile. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/country.aspx?CountryCode=CG&RegionCode=GL (Last accessed on September 16, 2010).

WHO. (2009). Global Health Atlas. World Health Organization.Geneva: WHO.

Democratic Republic of Congo

FAO. (2008). AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/congo_dem_r/ (Last accessed on January 11, 2010).

IDMC. (2009). DEMOCRATIC REPUBLIC OF THE CONGO: Massive displacement and deteriorating humanitarian conditions. Internal Displacement Monitoring Center. http://www.internal-displacement.org/8025708F004BE3B1/(httpInfoFiles)/28ADEA4D511D15F3C125762700390BC0/$file/Democratic+Republic+of+the+Congo+-+August+2009.pdf (Last accessed on September 16, 2010).

IDMC. (2010a). Internal Displacement Monitoring Center- Global Statistics. http://www.internaldisplacement.org/8025708F004CE90B/(httpPages)/22FB1D4E2B196DAA802570BB005E787C?OpenDocument&count=1000 (Last accessed on September 16, 2010).

IDMC. (2010b). DEMOCRATIC REPUBLIC OF THE CONGO: Over 2.1 million IDPs in the context of deteriorating humanitarian conditions. Internal Displacement Monitoring Center. http://www.internaldisplacement.org/8025708F004BE3B1/(httpInfoFiles)/F4D1EB858711A38AC12576D4005079A5/$file/DRC_Overview_Feb10.pdf (Last accessed on September 16, 2010).

IRF. (2008). World Road Statistics. Geneva: International Road Federation http://www.irfnet.org/statistics.php (Last accessed on September 16, 2010).

UNOCHA. (2006). DRC: Country without roads. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=59568 (Last accessed on September 16, 2010).

UNOCHA. (2010). Insecurity hampers relief, prevents return of refugees. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=88467 (Last accessed on September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

WINNE. (2002). DRC: Paving the reconstruction. World Investment News. http://www.winne.com/congo/bf02.html (Last accessed on September 16, 2010).

Equatorial Guinea

BP. (2009). Statistical Review of World Energy 2009. British Petroleum. http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622 (Last accessed on January 11, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

UNICEF. (2009). The State of the World's Children 2009. The United Nations Children's Fund. http://www.unicef.org/sowc09/index.php (Last accessed on September 16, 2010).

United Nations. (2008). Millenium Development Goals Databse. UN Statistics Division. http://data.un.org/Data.aspx?d=MDG&f=seriesRowID%3A711 (last accessed on October 5, 2010).

UNSD. (2010). Millennium Development Goal Indicators. United Nations Statistics Division. http://unstats.un.org/unsd/mdg/Default.aspx (Last accessed on September 16, 2010).

World Bank. (2010). World dataBank-Online Database. http://databank.worldbank.org/ (Last accessed on April 19, 2010).

Gabon

Forest Monitor. (2006). Country Profile- Gabon. http://new.forestsmonitor.org/fr/reports/540539/549944 (Last accessed on September 16, 2010).

Forest Monitor/ Rainforest Foundation. (2007). Concessions to Poverty-The environmental, social and economic impacts of industrial logging. http://www.forestsmonitor.org/uploads/2e90368e95c9fb4f82d3d562fea6ed8d/Concessions_to_Poverty.pdf (Last accessed on September 16, 2010).

IPS. (2003). GABON: Access to Clean Water Still a Big Problem. Inter Press Service News Agency. http://ipsnews.net/africa/interna.asp?idnews=17577 (Last accessed on September 16, 2010).

UNSD. (2010). Millennium Development Goal Indicators. United Nations Statistics Division. http://unstats.un.org/unsd/mdg/Default.aspx (Last accessed on September 16, 2010).

United Nations. (2009). United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. World Urbanization Prospects, The 2009 Revision http://esa.un.org/unpd/wup/index.htm (Last accessed on September 16, 2010).

WHO. (2009). Global Health Observatory Database. World Health Organization. http://apps.who.int/ghodata/ (Last accessed on September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

World Bank (2009). Gabon: Strengthening Capacity for Managing National Parks and Biodiversity. http://web.worldbank.org/external/projects/main?Projectid=P070232&theSitePK=40941&piPK=73230&pagePK=64283627&menuPK=228424 (Last accessed on September 16, 2010).

WRI. (2009). Interactive Forestry Atlas for Gabon. World Resources Institute. http://www.wri.org/publication/interactive-forestry-atlas-gabon (Last accessed on September 16, 2010).

Sao Tomé and Principe

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Sao Tome and Principe. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/sao_tome_prn/indexfra.stm (Last accessed on January 11, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

Republica Democratica de S. Tome e Principe. (2007). MINISTRY FOR NATURAL RESOURCES AND THE ENVIRONMENT DIRECTORATE GENERAL FOR ENVIRONMENT. NATIONAL REPORT ON THE STATUS OF BIODIVERSITY IN S.TOMÉ AND PRÍNCIPE http://69.90.183.227/doc/world/st/st-nr-03-en.pdf (Last accessed on September 16, 2010).

WHO. (2009). Global Health Atlas. World Health Organization.Geneva: WHO.

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Western Africa

Benin

CIESEN. (2005). Center for International Earth Science Information Network (CIESIN), Columbia University; and Centro Internacional de Agricultura Tropical (CIAT). 2005. Gridded Population of the World Version 3 (GPWv3). Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. http://sedac.ciesin.columbia.edu/gpw. (Last accessed on September 16, 2010).

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

UNOCHA. (2008a). BENIN: Erosion-inducing coastal sand mining to be outlawed. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=80746 (Last accessed on September 16, 2010).

UNOCHA. (2008b). BENIN: Half million potential flood victims : WHO. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=80153 (Last accessed on September 16, 2010).

UNOCHA. (2009). Affairs BENIN: Flooding prompts state of emergency. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=85192 (Last accessed on September 16, 2010).

Burkina Faso

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2006). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Burkina Faso. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/burkina_faso/indexfra.stm (Last accessed on March 17, 2010).

IEA. (n.d.) Country Brief, Burkina Faso. In: International Small-Hydro Atlas – Small-Scale Hydro Annex of IEA Implementing Agreement for Hydropower Technologies and Programmes. http://www.small-hydro.com/index.cfm?Fuseaction=countries.country&Country_ID=120 (Last accessed on October 4, 2010).

United Nations. (2008). World Population Prospect, The 2008 Revision. United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section.

UNOCHA. (2009). BURKINA FASO-GHANA: One country's dam, another's flood. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=86015 (Last accessed on March 29, 2010).

UNOCHA. (2010). BURKINA FASO: Dwindling rains spur dam construction. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=88519 (Last accessed on March 29, 2010).

WHO. (2009). Global Health Atlas. World Health Organization.Geneva: WHO.

WHO. (2010). World Health Organization- PCT Databank. http://www.who.int/neglected_diseases/preventive_chemotherapy/sch/en/index.html (Last accessed April 3, 2010).

Cape Verde

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Cape Verde. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/capeverde/indexfra.stm (Last accessed on March 17, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

Côte d'Ivoire

GEF (2002). Cote D'ivoire Coastal Zone, Phase 1: Integrated Environmental Problem Analysis. Global Environment Facility, UNEP. http://www.oceandocs.net/bitstream/1834/630/1/Cote%20d'Ivoire%20National%20Report%20040302.pdf (Last accessed on September 16, 2010).

FAO. (2008a). Food Security Statistics. Food and Agriculture Organization of the United Nations. http://www.fao.org/economic/ess/food-security-statistics/en/ (Last accessed on September 16, 2010).

FAO. (2008b). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

FAO. (2010). Fisheries and Aquaculture Department. FishStat: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/fishery/topic/2017/en (Last accessed on April 25, 2010).

Republique de Cote d'Ivoire. (2000). "Communication Nationale Initiale de la Cote d'Ivoire". http://www.adaptationlearning.net/sites/default/files/Cote%20D'Ivoire%20-%20National%20Communication%20-%202%20February%202001%20French.pdf (Last accessed on September 16, 2010).

United Nations. (2009). World Urbanization Prospects, The 2009 Revision. United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. http://esa.un.org/unpd/wup/index.htm (Last accessed on September 16, 2010).

UNOCHA. (2006). In-Depth: Running Dry: the humanitarian impact of the global water crisis IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/InDepthMain.aspx?InDepthId=13&ReportId=62408&Country=Yes (Last accessed on September 16, 2010).

UNOCHA. (2008). COTE D'IVOIRE: Protests and mounting anger over lack of water in Abidjan. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=77032 (Last accessed on September 16, 2010).

Gambia

AcessGambia. (2010). Tanbi Wetland Complex. Gambia Guide – Gambia Information Site. http://www.accessgambia.com/information/tanbi.html (Last accessed on September 16, 2010).

Caputo, B., Nwakanma, D., Jawara, M.; Adiamoh, M., Dia, I,; Konate, L., Petrarca, V., Conway, D.J., della Torre, A. (2008). Anopheles gambiae complex along The Gambia river, with particular reference to the molecular forms of An. Gambiae s.s. Malaria Journal 7: 182.

CBD. (2006). The Gambia- Third national report. Convention on Biological Diversity. www.cbd.int/doc/world/gm/gm-nr-03-en.doc (Last accessed on September 16, 2010).

Encyclopedia of the Earth. (2010). Water profile for Gambia. The Encyclopedia of the Earth. http://www.eoearth.org/article/Water_profile_of_Gambia (Last accessed on September 16, 2010).

FAO. (2007). Irrigation potential in Africa: A basin approach. Food and Agriculture Organization of the United Nations. www.fao.org/docrep/w4347e/w4347e00.htm (Last accessed on September 16, 2010).

FAO. (2010). the Gambia- Agriculture sector. Food and Agriculture Organization of the United Nations. http://www.fao.org/countryprofiles/index.asp?lang=en&iso3=GMB&subj=4 (Last accessed on September 16, 2010).

UNEP. (2003). Africa at a glance. United Nations Environment Programme. http://na.unep.net/publications/selected/Africa.pdf (Last accessed on September 16, 2010).

Ghana

ESA. (2005). "Lake Volta, Ghana". European Space Agency. http://www.esa.int/esaEO/SEMN6MXEM4E_index_0.html (Last accessed on September 16, 2010).

FAO. (2008). FAO Fisheries and Aquaculture Information and Statistics Service. FISHSTAT Plus - Universal software for fishery statistical time series. Food and Agriculture Organization of the United Nations. http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp (Last accessed on September 16, 2010).

United Nations. (2008). World Population Prospects, The 2008 Revision. United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section.

UNOCHA. (2008). GHANA: Dodging faeces on the beaches. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs http://www.irinnews.org/Report.aspx?ReportId=80395 (Last accessed on September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

World Bank. (2009). World Development Indicators 2009. World Bank: Washington D.C..

Republic of Guinea

Blacksmith Institute. (2010). PCB Cleanup and removal in Guinea http://www.blacksmithinstitute.org/projects/display/9 (Last accessed on September 16, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

Jarvis A., Reuter, H., Nelson, A., Guevara, E. (2008). Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT). http://srtm.csi.cgiar.org. (Last accessed on August 23, 2010).

Lehner, B., Verdin, K., Jarvis, A. (2008). New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89(10): 93-94. http://hydrosheds.cr.usgs.gov (Last accessed on August 23, 2010).

NOAA. (2009). WHO'S IN THE DARK – SATELITE BASED ESTIMATES OF ELECTRIFICATION RATES. National Oceanic and Atmospheric Administration. http://www.ngdc.noaa.gov/dmsp/pubs/Whosinthedark_20091022.pdf (Last accessed on September 16, 2010).

Guinea-Bissau

CIESIN. (2007). National Aggregates of Geospatial Data: Population, Landscape and Climate Estimates, v.2 (PLACE II), Palisades. Center for International Earth Science Information Network (CIESIN), Columbia University, 2007.http://sedac.ciesin.columbia.edu/place/ (Last accessed on September 16, 2010).

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Guinea-Bissau. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/guineabissau/indexfra.stm (Last accessed on September 16, 2010).

Kofoed, P. (2006). Treatment of uncomplicated Malaria in Guines-Bissau. Karolinska Institute, Stockholm. http://diss.kib.ki.se/2006/91-7140-698-0/thesis.pdf (Last accessed on September 16, 2010).

UNICEF. (2009). The State of the World's Children 2009: Maternal and Newborn Health. United Nations Children's Fund. http://www.unicef.org/sowc09/index.php. (Last accessed on September 16, 2010).

United Nations. (2007). World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2007 Revision. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat http://esa.un.org/unup (Last accessed on October 5, 2010).

UNOCHA. (2009). GUINEA-BISSAU: Instability Deprives People of Clean Water. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs http://www.irinnews.org/report.aspx?ReportID=83723 (Last accessed on September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Liberia

IMF. (2006). Liberia - Statistical Appendix. International monetary Fund. http://www.imf.org/external/country/lbr/index.htm?type=9998 (Last accessed on September 20, 2010).

UNOCHA. (2009). LIBERIA: Community demands action on rubber pollution. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.alertnet.org/thenews/newsdesk/IRIN/0bba24f7b2afd57fb0847d97e2f11e5c.htm (Last accessed on March 11, 2010)

UNOCHA. (2009). LIBERIA: Disease rife as more people squeeze into fewer toilets. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=87110 (Last accessed on March 11, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Mali

AAAS. (1998). Water and Population Dynamics: Local Approaches to a Global Challenge. The American Association for the Advancement of Science. http://www.aaas.org/international/ehn/waterpop/contents.htm (Last accessed on October 5, 2010).

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

UNOCHA. (2008). MALI: All it takes to save the lakes from climate change is money. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=78604 (Last accessed on September 20, 2010).

WHO. (2010). Global Health Atlas. World Health Organization. Geneva: WHO.

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

WWAP. (2006). The United Nations World Water Development Report 2, Water a Shared Responsibility. Case Study: Mali. World Water Assessment Programme. http://www.unesco.org/water/wwap/wwdr/wwdr2/case_studies/pdf/mali.pdf (Last accessed on September 16, 2010).

Mauritania

CIESIN. (2007). National Aggregates of Geospatial Data: Population, Landscape and Climate Estimates, v.2 (PLACE II), Palisades, NY: CIESIN, Columbia University. Center for International Earth Science Information Network (CIESIN), Columbia University, 2007. http://sedac.ciesin.columbia.edu/place/. (Last accessed on September 20, 2010).

Encyclopedia of the Nations. (n.d). "Mauritania-Mining". http://www.nationsencyclopedia.com/Africa/Mauritania-MINING.html (Last accessed on April 30, 2010).

IUCN. (2007). 2007 IUCN Red List of Threatened Species. Gland, Switzerland: IUCN. International Union for Conservation of Nature and Natural Resources. http://www.redlist.org/info/tables/table5; http://www.iucnredlist.org/info/2007RL_Stats_Table%201.pdf. (Last accessed on September 20, 2010).

Le Loeuff, P. (1999). The benthic macrofauna of the variable salinity waters ecosystems along the Atlantic coast of tropical Africa; biodiversity variations with the current climatic conditions (rainfall) and the regional climatic history. Zoosystema 21:557-571.

NASA Earth Observatory. (2002). Phytoplankton off the West Coast of Africa. http://earthobservatory.nasa.gov/IOTD/view.php?id=2362 (Last accessed on April 30, 2010).

World Bank. (2010). World dataBank-Online Database. http://databank.worldbank.org/ (Last accessed on April 19, 2010).

WWAP. (2003). Senegal River Basin (Guinea, Mail, Mauritania, Senegal). World Water Assessment Programme. http://www.unesco.org/water/wwap/wwdr/wwdr1/ (Last accessed on September 20, 2010).

Niger

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2005). FAOSTAT on-line statistical service. Rome: FAO. Food and Agriculture Organization of the United Nations. http://apps.fao.org (Last accessed on January 11, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

UNDP. (2009). Human Development Report 2009 - HDI rankings. United Nations Development Programme. http://hdr.undp.org/en/statistics/ (Last accessed on September 20, 2010).

UNICEF. (2006). 'WASH' strategy improves access to safe water and sanitation in Niger. United Nations Children's Fund. http://www.unicef.org/infobycountry/niger_35633.html (Last accessed on September 20, 2010).

WHO. (2009). Global Health Observatory. World Health Organization.http://apps.who.int/ghodata/# (Last accessed on April 23, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Nigeria

Amnesty International. (2009). Nigeria: Petroleum, Pollution and Poverty in the Niger Delta. http://www.amnesty.org/en/library/asset/AFR44/017/2009/en/e2415061-da5c-44f8-a73c-a7a4766ee21d/afr440172009en.pdf (Last accessed on September 20, 2010).

BP. (2009). Statistical Review of World Energy 2009. British Petroleum. http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622 (Last accessed on September 20, 2010).

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Nigeria. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/nigeria/index.stm

Joint Wetlands Livelihood Project. (n.d.). The Hadejia-Nguru Wetlands. http://www.jwlnigeria.org/mapwetlands.htm (Last accessed on September 20, 2010).

UNDP. (2006). Niger Delta Human Development Report. United Nations Development Programme. http://hdr.undp.org/en/reports/nationalreports/africa/nigeria/name,3368,en.html (Last accessed on September 20, 2010).

UNOCHA. (2008). NIGERIA: Cattails smother livelihoods of farmers and fishermen in Jigawa State. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=77143 (Last accessed on September 20, 2010).

Senegal

BlackSmith Institute. (2010). "Baia de Hanne, Senegal". http://www.blacksmithinstitute.org/projects/display/10 (Last accessed on September 20, 2010).

WHO. (2008). Preventive Chemotherapy and Transmission Control. Department of Control of Neglected Tropical Diseases. World Health Organization. http://www.who.int/neglected_diseases/preventive_chemotherapy/databank/CP_2008_Senegal.pdf (Last accessed on September 20, 2010).

World Bank. (2010). World dataBank-Online Database. http://databank.worldbank.org/ (Last accessed on April 19, 2010).

WWAP. (2003). Senegal River Basin (Guinea, Mail, Mauritania, Senegal). World Water Assessment Programme. http://www.unesco.org/water/wwap/wwdr/wwdr1/ (Last accessed on September 20, 2010).

Sierra Leone

AfDB. (2009). Bumbuna Hydoelectric Plant Will Bring Down the Cost of Doing Business in Sierra Leone. African Development Bank Group. http://www.afdb.org/en/news-events/article/bumbuna-hydoelectric-plant-will-bring-down-the-cost-of-doing-business-in-sierra-leone-5500/ (Last accessed on October 5, 2010).

DFID. (2007). Building better water supplies in Freetown, Sierra Leone. 2007. Department for International Development . http://webarchive.nationalarchives.gov.uk/+/http://www.dfid.gov.uk/casestudies/files/africa/sierra-leone-water.asp (Last accessed on April 22, 2010).

Elvidge, C., Baugh, K., Sutton, P., Bhaduri, B., Tuttle, B., Ghosh, T., Ziskin, D., Erwin, E. (2010).` Who's In The Dark: Satellite Based Estimates Of Electrification Rates, Urban Remote Sensing: Monitoring, Synthesis and Modeling in the Urban Environment, Ed. Xiaojun Yang, Wiley-Blackwell, Chichester, UK, In Press.

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

UNECA. (2007). Water Supply and Sanitation Policy for Sierra Leone. United Nations Economic Commission for Africa. http://www.uneca.org/awich/Reports/Sierra%20Leone%20%20Water%20and%20Sanitation%20Policy-Final.pdf (Last accessed on September 20, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Togo

Blivi, A. (2000). Implications of Accelerated Sea-Level Rise for Togo. http://www.nodc-togo.org/documents/implicationsofseatogo.html (Last accessed on May 5, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

United Nations. (2008). World Population Prospects: The 2008 Revision. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, http://esa.un.org/unpp. (Last accessed on September 20, 2010).

WHO. (2006). Country Health System Fact Sheet 2006-Togo. World Health Organization. www.afro.who.int/index.php?option=com_docman&task=doc (Last accessed on September 28, 2010)

WHO. (2010). Global Health Atlas. World Health Organization. Geneva: WHO.

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

World Bank. (2010). World dataBank-Online Database. http://databank.worldbank.org/ (Last accessed on April 19, 2010).

Southern Africa

Angola

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

IR. (2010). "The Okavango Delta". International Rivers. http://www.internationalrivers.org/en/node/2431 (Last accessed on April 13, 2010).

Ramberg, L., Hancock, P., Lindholm, M., Meyer, T., Ringrose, S. Sliva, J., Van As, J., VanderPost, C. (2006). Species diversity of the Okavango Delta, Botswana. Aquatic Sciences 68:310-337.

Tearfund. (2010). "Partner responds to Angolan flood chaos". Tearfund. http://www.tearfund.org/News/World+news/Angola+floods.htm (Last accessed on September 21, 2010).

UN-Water. (2008). National Investment Brief- Angola. Water for Agriculture and Energy in Africa- the Challenges of Climate Change. Sirte, Libyan Arab Jamahiriya - 15 - 17 December 2008. http://www.sirtewaterandenergy.org/docs/reports/Angola-Draft2.pdf (Last accessed on September 21, 2010).

United Nations. (2006).World Urbanization Prospects The 2005 Revision. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. http://www.un.org/esa/population/publications/WUP2005/2005WUPHighlights_Final_Report.pdf (Last accessed on September 28, 2010).

USAID. (2006). Youth Assessment in Angola. US Agency for International Development. http://www.usaid.gov/ao/youthassessment.pdf (Last accessed on September 28, 2010).

Botswana

FAO. (2005). Consumption of Fish and Fishery Products: Food Balance Sheets. http://www.fao.org/fishery/statistics/global-consumption/en (Last accessed on May 4, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

FAO. (2010). Livestock and Fish primary Equivalent- FAOSTAT. Food and Agriculture Organization of the United Nations. http://faostat.fao.org/site/610/DesktopDefault.aspx?PageID=610#ancor (Last accessed on September 21, 2010).

Mosepele, K.; Moyle, P.; Merron, G.; Purkey, D.; Mosepele, B. (2009). Fish, Floods, and Ecosystem Engineers: Aquatic Conservation in the Okavango Delta, Botswana. Bioscience 59(1).

Lesotho

ATPSN. (2007). African Technology Policy Studies Network. POLICY IMPLICATIONS FOR INDUSTRIAL WATER POLLUTION IN LESOTHO. http://www.atpsnet.org/pubs/brief/Technopolicy%20Brief%2016.pdf?pno=870 (Last accessed on September 21, 2010).

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2005). AQUASTAT Information System on Water and Agriculture- Lesotho. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/lesotho/index.stm (Last accessed on September 21, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

Kingdom of Lesotho Ministry of Natural Resources. (2003). Industrial Wastewater Management Policy. http://www.lwsims.gov.ls/Documents/Industrial%20Waste%20Water%20Management%20Policy.pdf (Last accessed on September 21, 2010).

UNOCHA. (2007). LESOTHO: One of the worst droughts in 30 years prompts US$18.9 million appeal. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs http://www.irinnews.org/Report.aspx?ReportId=73492 (Last accessed on September 19, 2010).

UNOCHA. (2008). LESOTHO: Water running on empty. IRIN online news service . UN Office for the Coordination of Humanitarian Affairs http://www.irinnews.org/Report.aspx?ReportId=79102 (Last accessed on September 21, 2010).

World Bank. (2009). World Development Indicators. Online database. World Bank. Washington, D.C. http://databank.worldbank.org/ddp/home.do?Step=12&id=4&CNO=1147 (Last accessed on January 11, 2010).

Malawi

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

IFPRI. (2010). Karl, P. and Thurlow, J.- Economic Losses and Poverty Effects of Droughts and Floods in Malawi. International Food Policy Research Institute. www.oerafrica.org/ResourceDownload.aspx?id=38030&userid=-1 (Last accessed on September 21, 2010).

FAO. (2005). Irrigation in Africa in figures AQUASTAT Survey – 2005. FAO Land and Water Development Division. Food and Agriculture Organization of the United Nations. ftp://ftp.fao.org/agl/aglw/docs/wr29_eng_including_countries.pdf (Last accessed on October 5, 2010).

FAO. (2006). AQUASTAT Information System on Water and Agriculture- Lesotho. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/malawi/index.stm (Last accessed on September 21, 2010).

FAO. (2010). FAOSTAT, Production. Food and Agriculture Organization of the United Nations. http://faostat.fao.org/site/567/default.aspx#ancor (Last accessed on September 21, 2010).

MA. (2005). Ecosystems and Human Well-being: Synthesis. Island Press: Washington, DC. Millenium Ecosystem Assessment.

UNEP. (2008). Africa Atlas of our Changing Environment. Division of Early Warning and Assessment (DEWA). United Nations Environment Programme (UNEP). P.O. Box 30552 Nairobi 00100, Kenya.

UN-Water. (2008). National Investment Brief- Angola. Water for Agriculture and Energy in Africa- the Challenges of Climate Change. Sirte, Libyan Arab Jamahiriya - 15 - 17 December 2008. http://www.sirtewaterandenergy.org/docs/reports/Angola-Draft2.pdf (Last accessed on September 21, 2010).

Mozambique

Blacksmith Institute. (2009). Online Database- Mozambique. http://www.blacksmithinstitute.org/projects/regions/africa (Last accessed on April 19, 2010).

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2009). UN Food and Agriculture Organization- Food Security Statistics. Food and Agriculture Organization of the United Nations. http://www.fao.org/economic/ess/food-security-statistics/en/ (Last accessed on September 21, 2010).

UNHabitat. (2008). Mozambique Urban Sector Profile. http://www.unhabitat.org/pmss/getElectronicVersion.asp?nr=2786&alt=1 (Last accessed on September 21, 2010).

UNHabitat. (2009). Cities and Climate Change Overview. Maputo, Mozambique. http://www.unhabitat.org/downloads/docs/6007_12369_Maputo%20flyer%20oct%2009.pdf (Last accessed on October 4, 2010).

UNOCHA. (2010a). MOZAMBIQUE: Drought and floods bring food shortages. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=88612 (Last accessed on September 21, 2010).

UNOCHA. (2010b). MOZAMBIQUE: After the floods. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=88549 (Last accessed on September 21, 2010)

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

World Bank. (2008). World dataBank-Online Database. http://databank.worldbank.org/ (Last accessed on April 19, 2010).

Namibia

Bank of Namibia. (2010). Economic Outlook, February 2010. https://www.bon.com.na/docs/pub/Economic%20Outlook%20Feb%202010.pdf (Last accessed on September 21, 2010).

FAO. (2005, 2007, 2008). AQUASTAT Information System on Water and Agriculture-Lesotho. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/lesotho/index.stm (Last accessed on September 21, 2010).

LAC and Stanford Law School (2009). Not coming up dry: Regulating the use of Namibia's scarce water resources by mining operations. Legal Assistance Centre (LAC) and Mills International Human Rights Clinic, Stanford Law School, Windhoek, Namibia and Palo Alto California, USA http://www.lac.org.na/projects/lead/Pdf/not-coming-up-dry.pdf (Last accessed on October 6, 2010).

Namibia Ministry of Environment and Tourism. (2002). Directorate of Environmental Affairs: Key Environmental Issues in Namibia. Namibia Ministry of Environment and Tourism. http://www.met.gov.na/dea/env_issues/env_issues.htm (Last accessed on May 5, 2010).

Reich, P., Numbem, S., Almaraz, R., Eswaran, H. (2001). Land resource stresses and desertification in Africa. In:Bridges, E., Hannam, I., Oldeman, L., Pening de Vries, F., Scherr, S., Sompatpanit, S. (eds.). Responses to Land Degradation. Proc. 2nd. International Conference on Land Degradation and Desertification, Khon Kaen, Thailand. Oxford Press, New Delhi, India. http://soils.usda.gov/use/worldsoils/papers/desertification-africa.html (Last accessed on October 6, 2010).

Schneider, G. (2008). A strategic environmental assessment for the Namibian uranium province, EGG-01 General contributions to environmental geology - Part 1. International Geological Congress, Oslo, August 6-14. http://www.cprm.gov.br/33IGC/1352507.html (Last accessed on September 21, 2010).

USGS. (2009). Mineral Commodity Summaries 2009. U.S. Geological Survery, U.S. Department of the Interior. http://minerals.usgs.gov/minerals/pubs/mcs/2009/mcs2009.pdf (Last accessed on May 5, 2010).

South Africa

FAO. (n.d.). Case Study: South Africa. Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/003/x9419E/x9419e08.htm (Last accessed on September 21, 2010).

FAO. (2008, 2009). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

IFAD (2010). Proceedings of the Governing Council High-Level Panel and Side Events: From summit resolutions to farmers' fields: Climate change, food security and smallholder agriculture in Conjunction with the Thirty-third Session of IFAD's Governing Council, February 2010. International Fund for Agricultural Development. http://www.ifad.org/events/gc/33/panels/proceedings_web.pdf (Last accessed on October 6, 2010).

IPS. (2009). We Have Land Rights but No Water Rights – Farmers. Inter Press Service News Agency http://ipsnews.net/africa/nota.asp?idnews=48726 (Last accessed on September 21, 2010).

United Nations. (2008). United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. World Population Prospect, The 2008 Revision.

UNOCHA. (2009a). SOUTH AFRICA: Clock ticks towards water scarcity. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/report.aspx?ReportID=84517 (Last accessed on September 21, 2010).

UNOCHA. (2009b). UN Office for the Coordination of Humanitarian Affairs SOUTH AFRICA: The quiet water crisis. IRIN online news service http://www.irinnews.org/Report.aspx?ReportId=82750 (Last accessed on September 21, 2010).

UNOCHA. (2010). SOUTH AFRICA: Drinking the fog. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://irinnews.org/Report.aspx?ReportId=88804 (Last accessed on September 21, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Swaziland

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

UNOCHA. (2007). SWAZILAND: Water rationing arrives. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=74231 (Last accessed on September 21, 2010).

UNOCHA. (2008). SWAZILAND: Preparing for disaster. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=76782 (Last accessed on September 21, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Tanzania

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- United Republic of Tanzania. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/tanzania/index.stm (Last accessed on September 16, 2010).

PMO. (2004). Disaster Vulnerability Assessment Phase II DMD & UCLAS Dar es Salaam. Unpublished Report. (Last accessed on September 16, 2010).

Ramsar. (2010). Ramsar Sites Information Service. Tanzania, United Republic Of. http://ramsar.wetlands.org/Database/Searchforsites/tabid/765/language/en-US/Default.aspx (Last accessed on April 22, 2010).

United Nations. (2007). World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2007 Revision. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat http://esa.un.org/unup (Last accessed on October 5, 2010).

United Nations. (2009a). United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. World Urbanization Prospects, The 2009 Revision.

United Nations. (2008, 2009b). UN Millennium Development Goals Indicators-Online Database. http://mdgs.un.org/unsd/mdg/Default.aspx (Last accessed on September 16, 2010).

UNHabitat. (2009). Tanzania: Dar Es Salaam City Profile. www.unhabitat.org/pmss/getElectronicVersion.aspx?nr=2726 (Last accessed on September 16, 2010).

WDPA. (2010). 2010 World Database on Protected Areas Annual Release. http://www.wdpa.org/AnnualRelease.aspx (Last accessed on September 16, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Zambia

AAAS. (1998). Case Study: Zambia – Integrating Water Conservation and Population Strategies on the Kafue Flats, Harry N. Weza Chabwela, University of Zambia & Wanga Mumba, Environment and Population Centre. http://www.aaas.org/international/ehn/waterpop/zambia.htm (last accessed on Accessed June 7, 2007)

CEH. (2001). Managed Flood Releases: A working conference on guidelines for managed flood releases and lessons learned from Itezhi-tezhi. Lusaka 13-14 March 2001. Workshop Report. Centre for Ecology and Hydrology

Dymond, A. (2007). Undermining Developoment? Copper Mining in Zambia. ACTSA. http://www.actsa.org/Pictures/UpImages/pdf/Undermining%20development%20report.pdf (Last accessed on September 16, 2010).

FAO. (2006-2010). National Aquaculture Sector Overview. Zambia. National Aquaculture Sector Overview Fact Sheets. Text by Maguswi, C. T. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 1 January 2003. http://www.fao.org/fishery/countrysector/naso_zambia/en (Last accessed on September 22, 2010).

FAO. (2008). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: online Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on January 11, 2010).

Gondwe, K. (2010). China Reaps Reward of Zambia Copper Investment. BBC News. 5 April 2010. http://news.bbc.co.uk/2/hi/business/8523967.stm (Last accessed on September 21, 2010).

Schelle, P. and Pittock, J. (2005). Restoring the Kafue Flats, A partnership approach to environmental flows in Zambia. Presented at 10th International Riversymposium & Environmental Flows Conference, Brisbane, Australia, September 3, 2005.

Smardon, R. (2009). Sustaining the world's wetlands: setting policy and resolving conflicts – Chapter 4 The Kafue Flats in Zambia, Africa: A Lost Floodplain?. Springer Science.

USGS. (2010). Mineral Copper Statistics and Information- Commodity Summaries 1996-2010. U.S. Geological Survey. http://minerals.usgs.gov/minerals/pubs/commodity/copper/ (Last accessed on September 21, 2010).

Zimbabwe

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Zimbabwe. Food and Agriculture Organization of the United Nations. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/zimbabwe/index.stm (Last accessed on September 21, 2010).

IPS News. (2008). Water Wars Hit Rural Zimbabwe. Inter Press Service News Agency. http://ipsnews.net/africa/nota.asp?idnews=44294 (Last accessed on September 21, 2010).

UNOCHA. (2009). Zimbabwe: Cholera keeps a low profile. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=87828 (Last accessed on September 21, 2010).

WHO. (2010). Global Health Atlas. Geneva: WHO. World Health Organization. http://www.who.int/globalatlas/ (Last accessed on January 11, 2010).

Western Indian Ocean Islands

Comoros

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010).

FAO. (2008, 2010). UN Food and Agriculture Organization- Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Accessed on January 11, 2010).

UNFCCC. (2002).Union Dea Comores. Initial National Communication on Climate Change. United Nations Framework Convention on Climate Change. http://unfccc.int/resource/docs/natc/comnc1e.pdf (Last accessed on September 21, 2010).

UNICEF. (2006). Protecting the water supply of Grand Comore from future volcanic eruptions. United Nations Children's Fund. http://www.unicef.org/infobycountry/comoros_36118.html (Last accessed on September 21, 2010).

UNOCHA. (2008). COMOROS: Between the devil and the deep blue sea. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs http://www.irinnews.org/Report.aspx?ReportId=81854 (Last accessed on September 21, 2010).

Madagascar

EM-DAT. (2010). The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be (Last accessed on April 23, 2010). (Last accessed on September 21, 2010).

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Madagascar. http://www.fao.org/nr/water/aquastat/countries/madagascar/indexfra.stm (Last accessed on September 21, 2010).

FAO. (2008). UN Food and Agriculture Organization- Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Online Database. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (Last accessed on September 21, 2010).

United Nations. (2008). United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. World Population Prospect, The 2008 Revision.

UNOCHA. (2009). MADAGASCAR: Just add water, better seeds and new knowledge. IRIN online news. UN Office for the Coordination of Humanitarian Affairs service. http://www.irinnews.org/Report.aspx?ReportId=84503 (Last accessed on September 21, 2010).

WHO/UNICEF. (2010). Progress on Sanitation and Drinking-Water: 2010 Update. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. World Health Organization, United Nations Children's Fund. http://www.wssinfo.org/datamining/tables.html (Last accessed on January 11, 2010).

Mauritius

ALM. (2009). Mauritius - Country-level Climate Data Summary. Adaptation Learning Mechanism http://www.adaptationlearning.net/climate-data/mauritius-country-level-climate-data-summary (Last accessed on January 11, 2010).

FAO. (2009). FAOSTAT on-line statistical service. Rome: FAO. Food and Agriculture Organization of the United Nations. http://apps.fao.org (Last accessed on January 11, 2010).

UNECA. (2008). Africa Review Report on Drought and Desertification. United Nations Economic Comission for Africa http://www.uneca.org/eca_resources/Publications/books/drought/ (Last accessed on September 21, 2010).

UNOCHA. (1999). MAURITIUS: Water restrictions introduced. IRIN online news service. UN Office for the Coordination of Humanitarian Affairs. http://www.irinnews.org/Report.aspx?ReportId=10166 (Last accessed on September 21, 2010).

World Bank. (2008). World dataBank-Online Database. http://databank.worldbank.org/ (Last accessed on April 19, 2010).

Seychelles

CIESEN. (2007). Center for International Earth Science Information Network (CIESIN), Columbia University. 2007. National Aggregates of Geospatial Data: Population, Landscape and Climate Estimates, v.2 (PLACE II). http://sedac.ciesin.columbia.edu/place/ (Last accessed on September 21, 2010).

FAO. (2005). Land and Water Development Division. AQUASTAT Information System on Water and Agriculture: Country Profile- Seychelles. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/countries/seychelles/index.stm (Last accessed on September 21, 2010).

Government of Seychelles. (2000). Initial National Communications under the United Nations Framework Convention on Climate Change; Ministry of Environment and Transport, Republic of Seychelles. http://www.adaptationlearning.net/sites/default/files/seync1.pdf (Last accessed on September 21, 2010).

Government of Seychelles. (2005). Seychelles National Wetland Conservation and Management Policy; Policy, Planning and Services Division, Ministry of Environment. http://www.env.gov.sc/Seychelles_National_Wetland_Policy.pdf (Last accessed on September 21, 2010).

United Nations. (2008). United Nations, Department of Economic and Social Affairs (DESA). Population Division, Population Estimates and Projections Section. World Population Prospect, The 2008 Revision.

Acronyms

AfDB	African Development Bank
AFED	Arab Forum for Environment and Development
AICD	Africa Infrastructure Country Diagnostic
APF	African Partnership Forum
ARTS	Arctic Slope Regional Corporation Research and Technology Solutions
ARWG	Africa Resources Working Group
BFCA	boron-fluorine-chrome-arsenic
BP	British Petroleum
CAADP	Comprehensive Africa Agriculture Development Programme
CAPP	Central African Power Pool
CAR	Central African Republic
CBD	Center for Biological Diversity
CCA	Chromated Copper Arsenate
CEDARE	The Center for Environment and Development for the Arab Region and Europe
CGIAR	Consultative Group on International Agricultural Research
CIESEN	Center for International Earth Science Information Network
CIOS	The Commission Internationale du Bassin Congo-Oubangui-Sangha
CNEARC	Centre National d'Etudes Agronomiques des Régions Chaudes
CREPA	Regional Center for Low-cost Water and Sanitation
DDT	Dichlorodiphenyltrichloroethane
DFID	Department of Foreign and International Development
DRC	Democratic Republic of the Congo
EAPP	East African Power Pool
EAWAG	Eigenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz (Swiss Federal Institute for Environmental Science and Technology / ETH)
EC	European Commission
ECA	Economic Commission of Africa
EEAA	Egyptian Environmental Affairs Agency
EESIA	
EM-DAT	International Disasters Database
ENSO	El Niño/La Niña-Southern Oscillation
ESRI	Environmental Systems Research Institute, Incorporated
FAO	Food and Agriculture Organisation
FAO AGL	The Land and Water Development Division of Food and Agriculture Organisation
FEWSNET	Famine Early Warning System Network
GAR	Global Assessment Report
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIWA	Global International Waters Assessment
GMO	Genetically Modified Organisms
GMR	Great Man-made River
GMRA	Great Man-made River Authority
GNI	Gross National Income
GRDC	Global Runoff Data Centre
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IAS	The Iullemeden sedimentary groundwater basin
IC	The Intercalary Continental
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICRSE	International Center for Remote Sensing of Environment
IDMC	Internal Displacement Monitoring Center
IDP	Internally Displaced Persons
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
ILEC	International Lake Environment Committee
ILO	International Labour Organisation
IMF	International Monetary Fund
INECO	Institutional and Economic Instruments for Sustainable Water Management in the Mediterranean Basin
INPIM	International Network on Participatory Irrigation Management.
IPCC	Intergovernmental Panel on Climate Change
IPS	Inter Press Service News Agency
IRIN	Integrated Regional Information Networks (sub-Saharan Africa)
IRRI	Internal Renewable Resources
ITDG	Intermediate Technology Development Group
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
LCBC	Lower Chad Basin Commission
MDG	Millennium Development Goals
MA	Millennium Ecosystem Assessment
MoE	Kenyan Ministry of Energy
Mt	Mountain
MToe	Million tonnes of oil equivalent
NAPA	National Academy of Public Administration
NASA	National Aeronautics and Space Administration
NEMC	National Environmental Management Commission
NBI	Nile Basin Initiative
NGO	Non-Governmental Organisation
NNPC	Nigerian National Petroleum Corporation
NSAS	The Nubian Sandstone Aquifer System
NWSAS	The North-Western Sahara Aquifer System
OECD	Organization for Economic Co-operation and Development
OMVS	Senegal River Development Organisation
ORNL	Oak Ridge National Laboratory
OSU	Oregon State University
PACN	Pan Africa Chemistry Network
PCB	Polychlorinated biphenyl
REMA	Rwanda Environment Management Authority
ROR	Run Off River
SADC	Southern African Development Community
SAPP	Southern African Power pool
SARDCN	Southern African Research and Documentation Centre
SGT, Inc	Stinger Ghaffarian Technologies, Incorporated
TBT	Tetrabutyl Titanate
TC	The Terminal Complex
TPA	Tanzania Ports Authority
UN	United Nations
UNHCR	United Nations High Commissioner for Refugees
UN WPP	United Nations World Population Prospectus
UNCCD	United Nations Combat to Convention Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFPA	United Nations Population Fund
UNECA	United Nations Economic Commissions of Africa
UNECE	United Nations Economic Commission for Europe
UN-ESA	United Nations European Space Agency
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children Fund
UN HABITAT	United Nations Human Settlements Programme
UNPD	United Nations Procurement Division
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNOPS	United Nations Office for Project Services
UNU	United Nations University
USAID	United States Agency for International Development
USGS	Unites States Geological Survey
USh	Uganda Shilling
UVA	Ultraviolet Radiation
WAPP	West African Power Pool
WDPA	World Database on Protected Areas
WCMC	World Conservation Monitoring Centre
WHO	World Health Organisation
WINNE	World Investment News
WRC	Water Research Commission
WRI	World Resources Institute
WWAP	World Water Assessment Programme
WWF	World Wildlife Fund
WMO	World Meteorological Organization
WTO	The World Toilet Organisation

Units

BTU	British Thermal Unit
cm	Centimetres
GWh	Giga Watt Hour
K	Kwacha
km	Kilometres
KM2	Square kilometer
KM3	Cubic kilometer
kWh	Kilo watt hour
mm	Millimetres
M3	Cubic meter
m3/inhab/yr	cubic metre per inhabitant per year
m3/yr	cubic metre per year
MW	Mega Watts
%	per cent
ha	hectare
US$	United States Dollar

Glossary

Agro-pastoral System based on agriculture and the rearing of livestock.

Anthropogenic Caused by humans.

Aquaculture The cultivation of aquatic animals or plants under marine or freshwater conditions, especially for food.

Aqueduct An artificial channel or pipe designed to convey water from a distant source, usually by gravity.

Aquifer Water-bearing geological formations such as permeable rock, soil or sediment that are capable of yielding enough water to cater for human use.

Archipelago An expanse of water with many scattered islands.

Artisanal fishing Generally refers to fishing that is small-scale; local (usually in-shore), relatively poor, non-industrial, and based on low technology.

Biodegradable Capable of being broken down especially into harmless products by the action of living things, such as microorganisms.

Biodiversity The level of diversity in an environment as indicated by numbers of different species of plants and animals.

Carbon sequestration The process of removing carbon from the atmosphere and depositing it in a reservoir for long-term storage.

Communicable disease An infectious disease that can be passed from person to person by direct contact with an affected person's fluids or discharges, or indirectly through a vector.

Crustaceans Class of mostly aquatic arthropods such as lobsters or crabs whose bodies are covered by a firm crust like shell.

Delta A generally flat plain of alluvial deposit between diverging branches of a river at its mouth.

Dependency ratio The proportion of total renewable water resources originating from outside of a country, given as a percentage and usually used to compare how different countries depend on external water resources.

Desertification Broadly refers to the processes by which an area becomes a desert, through the loss of plants and topsoil due to natural processes or human actions, or a combination of both.

Ecological units Delimited areas of different biological and physical potentials.

Economic water scarcity Generally refers condition in which water resources are abundant relative to water use, but it takes time and resources to get the water. This is in contrast to physical water scarcity, where there is a natural shortage of the water.

Ecosystem The complex of a community of organisms and its environment functioning as an ecological unit.

Effluent Liquid waste that is discharged into a body of water, such as sewage or industrial discharge.

Epidemic Affecting or tending to affect a disproportionately large number of individuals within a population, community, or region at the same time.

Estuary A water passage where the sea tide meets a river current; especially the inlet of the sea at the lower end of a river.

Eutrophication The process by which a body of water becomes enriched in dissolved nutrients such as nitrates and phosphates that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen.

Evaporation The loss of a volume of fluid such as water when it converts from liquid to vapour.

Evapotranspiration The movement of moisture from the earth to the atmosphere through evaporation of water and transpiration from vegetation.

Exploitation Use or utilization of water or other natural resources.

Fertiliser A substance containing nutrients essential for plant growth such as manure or a mixture of chemicals, that is used to increase soil fertility.

Fertility level Average number of lifetime births per woman.

Floodplain Level land that may be submerged by floodwaters or a plain built up by stream deposition.

Food security The availability of adequate and nutritious food and its accessibility to people.

Groundwater The area below the water table where all of the pores, cracks, and spaces between rock or soil particles are saturated with water.

Hard water Water that contains magnesium, calcium or iron salts, making it difficult to form a soap lather.

Herbicide Chemical prepared for the purpose of killing plants, especially weeds.

Hypoxia	A deficiency of oxygen. A situation where there is no oxygen at all would be anoxia.
Improved drinking-water source	One that is protected from outside contamination.
Improved sanitation facility	One that hygienically separates human excreta from human contact.
Infiltration	The movement of water into soil or rock through seepage.
Internal renewable water	The volume of average annual flow of surface water and resources; groundwater generated from precipitation within the country.
International dollar	A hypothetical unit of currency based on the concept of purchasing power parities that shows how much a local currency unit is worth within a country's borders. It is considered more valid than exchange rates when comparing measures such as standard of living across different countries.
Lagoon	An inland shallow body of sea or brackish water separated from the sea by sand dunes.
Leachate	The liquid that drains from landfill.
Mortality rate	The proportion of deaths to population.
Non-point source pollution	Water pollution from diffuse sources, such as agricultural fields. In contrast, point source pollution comes from a single source such as a pipe from a chemical factory.
Open defection	The discharge of human waste into an open area or unimproved sanitation source.
Pelagic	Refers to organisms living or growing at or near the surface of the ocean, far from land.
Per capita	Per person.
Peri-urban	Characterises areas near city limits, or urban fringes.
Permeability	The capacity of porous geological material to allow water flow through pore spaces.
Pesticide	A chemical prepared to destroy or kill pests.
Phytoplankton	A collection of plants and plantlike microscopic organisms that float or drift in fresh or salt water, especially at or near the surface, that serve as food for fish and other larger organisms.
Plateau	An area raised above adjoining land on at least one side, and with a relatively level surface.
Potable water	Water that is suitable for drinking.
Rainwater harvesting	Systematically collecting runoff from a roof for household use, or collecting runoff in the field for supplemental irrigation.
Refugees	People who flees to a foreign country or power to escape danger or persecution.
Riparian	Relating to or living or located on the bank of a natural watercourse such as a river, or sometimes of a lake or a tidewater.
Salinity	The saltiness or dissolved salt content of a body of water.
Saltwater intrusion	The movement of saline water into freshwater aquifers.
Savannah	A grassland ecosystem characterized by the trees being sufficiently small or widely spaced so that the canopy does not close.
Schistosomiasis	Also known as bilharzia, bilharziosis or snail fever - A parasitic disease caused by several species of fluke of the genus Schistosoma.
Sedimentation	The deposition of sediment.
Seismic activity	Related to the vibration of the earth vibration of the earth, due to natural or artificial causes.
Shanty town	One that is characterized by shanties or crudely constructed houses.
Shared sanitation facility	A public facility, free for all, or one that is shared between two or more households, but distinguished by male and female.
Slum	A densely populated usually urban area marked by crowding, dirty run-down housing, poverty, and social disorganization.
Total volume of the earth's freshwater resources	Includes ice and permanent snow cover in mountainous regions and in the Antarctic and Arctic regions; that stored underground (in the form of groundwater in shallow and deep groundwater basins, soil moisture, swamp water and permafrost); and freshwater lakes and rivers.
Torpid water	Inactive or slow water.
Transpiration	The passage of water vapor from a living part of a plant through membranes or pores.
Vector	An insect or organism that transmits pathogen.
Virtual water	The embodied water used to produce a good.
Water mining	When the rate of water abstraction exceeds the rate of recharge.
Water scarcity	Less than 1000 m3/person/year.
Water stress	Less than 1000 to 1700 m3/person per year.
Waterlogging	Saturating with water.

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