"However it is viewed, the hotspots concept can be used to identify situations that, if left unattended, could prove harmful, both to the environment and to those dependent on it"

-FAO 2003

Chapter 4: Environmental Hotspots

This chapter is the heart of the Atlas. It is a visually stunning series of satellite photos that in a glance shows readers the extent to which human activities have wrought changes on Kenya's landscapes. It relies heavily on the interpretation of environmental change by comparing two satellite photos of the same place at different times, sometimes as much as thirty years apart. The images are displayed side-by-side, allowing viewers to engage in the well-known "spot the difference" puzzle. Readers are aided by short descriptions of each site and pointers that note specific salient changes.

The focus is on "environmental hotspots," a generic term used here to describe those lands and waters that are experiencing the most evident and dramatic change. This is the first publication that systematically uses satellite imagery to identify environmental change in Kenya and a number of caveats are in order. First, it was beyond the scope and resources of the researchers to scan images of Kenya's entire area over a 30-year period to identify change; second, some important environmental change is too subtle to be evident on such images; and third, the nature, cause, and consequences of some apparent change remains unknown until research is conducted on the ground.

Thus, this chapter is not a comprehensive rendering of all kinds of alterations actually taking place in Kenya's ecosystems. Rather, it shows the results of a survey of images to illustrate the major changes already noted in the scientific literature. The paired images have been organized into the following series of case studies, each of which includes an introduction to the issue: Land use and land use change; Water; Forests; Land degradation; and Biodiversity.

An arid ecosystem is home to a variety of flora and fauna

Christian Lambrechts/UNEP

A Cheetah in the Scenic Landscape of the Maasai Mara Game Reserve

Cheetahs have disappeared from many areas in their African range because of habitat loss, lack of prey, disease, and high cub mortality. Based on past estimates of cheetah numbers in Kenya's protected areas, it is thought that less than 1 000 remain in the country, although it is likely that most cheetahs live outside such areas.

Land Use and Land Use Change

This section depicts the extent and distribution of various land uses in Kenya and describes how they have been changing over the past several decades. It provides context for the following pairs of satellite images that show some environmental changes taking place in specific areas of the country. This introduction portrays change in agricultural and pastoral land areas in particular; environmental change in forested regions is described in another section further on and has been discussed in the part of Chapter 1 that looks at Kenya's five "water towers". Urban land use change is discussed elsewhere in this Atlas. Although urban areas occupy only 0.1 per cent of the land, their impacts can be far-reaching, as noted in Chapter 5.

Land Use and Land Use Change

Kenya's land area is about 582 646 km², of which 2.2 per cent is surface water. Generally, Kenya's land use is largely pastoral in semi-humid and semi-arid zones and agricultural in the moist and humid zones. A huge proportion of Kenya's land area is mainly arid or semi-arid lands, called ASALs, accounting for over 80 per cent of the total area (GoK 2004). About 17 to 20 per cent of the land has medium to high potential for agriculture; these lands are termed High to Medium Potential Lands (HMPLs). Together, forests, woodlands, national reserves, and game parks cover ten per cent of the land (Survey of Kenya 2003, NLPS 2007, WRI and others 2007). Figure 1 shows the proportions devoted to various land uses and land covers, which correspond to those shown on the map (Figure 2).
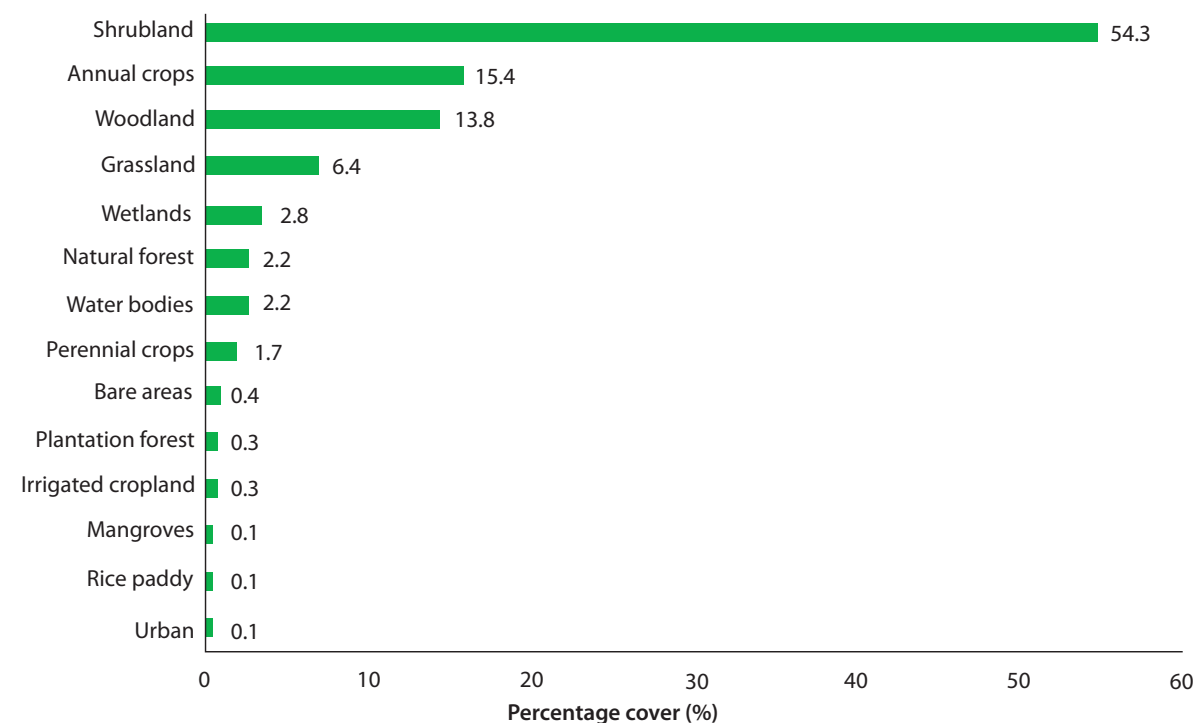
Croplands

Agricultural activity supports about 80 per cent of Kenyans and contributes, directly and indirectly, about 53 per cent of the nation's Gross Domestic Product. Agroecosystems cover about 19 per cent of the land, and HMPLs support about 75 per cent of the country's population (WRI and others 2007). Only about eight per cent of the total land area is arable, however, and Kenya has a lower average population-to-cropland ratio than sub-Saharan Africa in general, with an estimated 160 ha of land for every thousand people compared to 280 ha, respectively (IFPRI 2007).
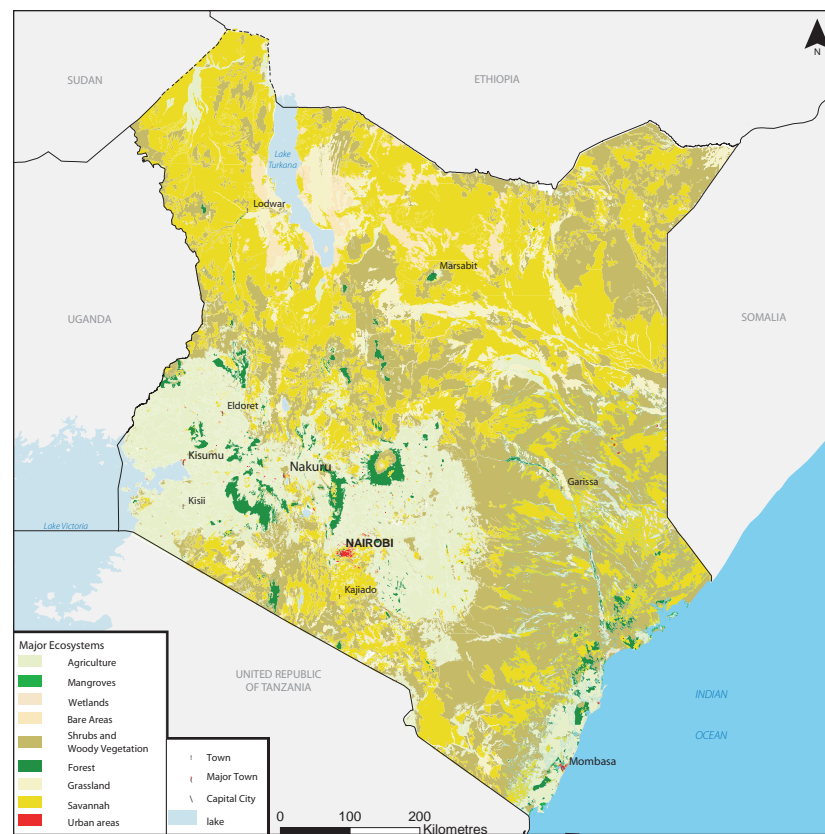
Most Kenyan farming is exclusively rainfed, so occurs where annual and seasonal rainfall patterns are reliable. About 90 per cent of croplands are in areas with high agricultural potential in central and western Kenya where they are dominated by a mix of dairy cattle, food, and cash crops, including wheat, tea, sugarcane, irrigated rice, and maize. Agropastoral activities involving some cropping mixed with livestock

Land cover type	Percentage cover (%)
Shrubland	54.3
Annual crops	15.4
Woodland	13.8
Grassland	6.4
Wetlands	2.8
Natural forest	2.2
Water bodies	2.2
Perennial crops	1.7
Bare areas	0.4
Plantation forest	0.3
Irrigated cropland	0.3
Mangroves	0.1
Rice paddy	0.1
Urban	0.1

**Figure 1: Land use and land cover types
(Source: FAO 2000)**

**Figure 2: Map of land uses and land cover types
(Source: FAO 2000)**

raising take places where rainfall is scant or erratic (WRI and others 2007).

The total average area under cultivation at a national level continues to increase, as crops are introduced in degazetted forest lands, some humid rangelands are converted to farmland, and land under fruits and vegetables increases. Crops are grown on a significant proportion of marginal land with low or variable rainfall and it is likely that more such lands are being converted to crops even though there is high risk of failure (WRI and others 2007).

Amounts of land in the agriculturally productive highlands and the productivity of these lands are declining due to growing populations; an increase in competing land uses including forestry, wildlife conservation, and urban development; poorly planned settlements; new cultivation methods and cropping systems; the sub-division of land; and the introduction of irrigation schemes and sedentary farming and livestock management (Figure 2).

Land division is an ongoing problem in the HMPLs, where they often suffer from continuous fragmentation into sizes too small to be profitable. Social impacts include the exclusion of women in land ownership and decision-making (NLPS 2007). As a result of these changes, all areas are experiencing land degradation, which is examined in another section of this chapter.

Pastoral lands

Kenya's arid and semi-arid lands (ASALs) cover as much as 80 per cent or more of its total area and are comprised of savanna and grassland ecosystems, and bushland and woodland ecosystems (WRI and others 2007). They are characterized by a patchwork of grasses, trees, and shrubs and support about 70 per cent of the national livestock herd and are home to about 10 million people (or about 34 per cent of the population) (GoK 2004).
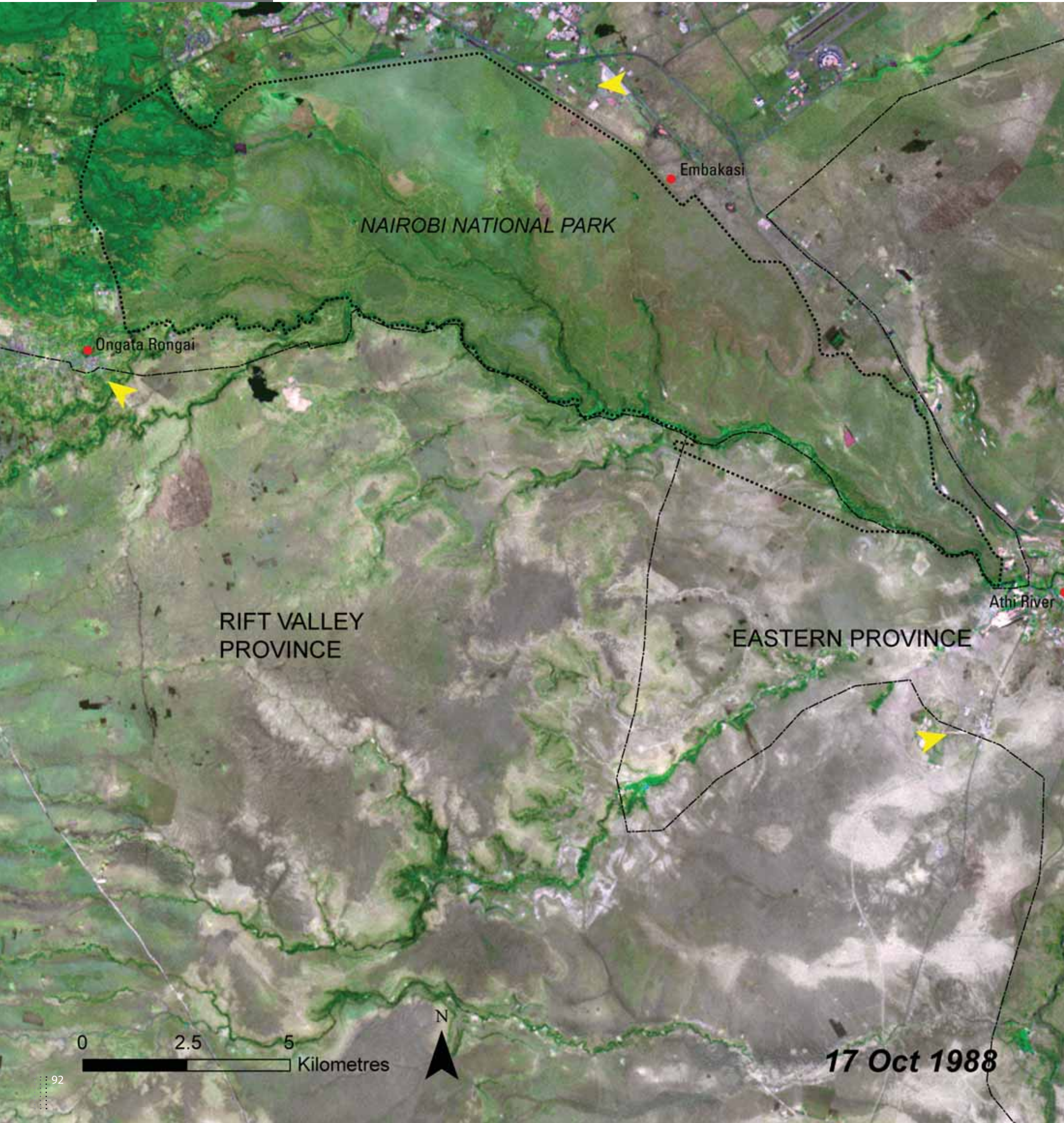
Pastoralists and agropastoralists own about half the country's cattle and small ruminant herd and all of its camel population. Kenya's pastoralist systems hold a significant amount and variety of the country's human and natural capital, including languages, indigenous knowledge, cultures, and uniquely adapted breeds (GoK 2004). They also contain most of Kenya's national parks and game reserves and so are key contributors to the tourism industry.

Land use has been changing in the ASALs as traditional land rights are increasingly ignored and growing human and livestock populations degrade pasture and water resources. Access to grazing land has diminished as more lands are appropriated for crops, the development of new water sources, conservation areas, and uses by the state (GoK 2004, WRI and others 2007). In addition, ASALs are subject to recurring drought, which exacerbates land degradation and threatens the lives and livelihoods of over 3.5 million pastoralists (UNEP 2008).

Nairobi National Park
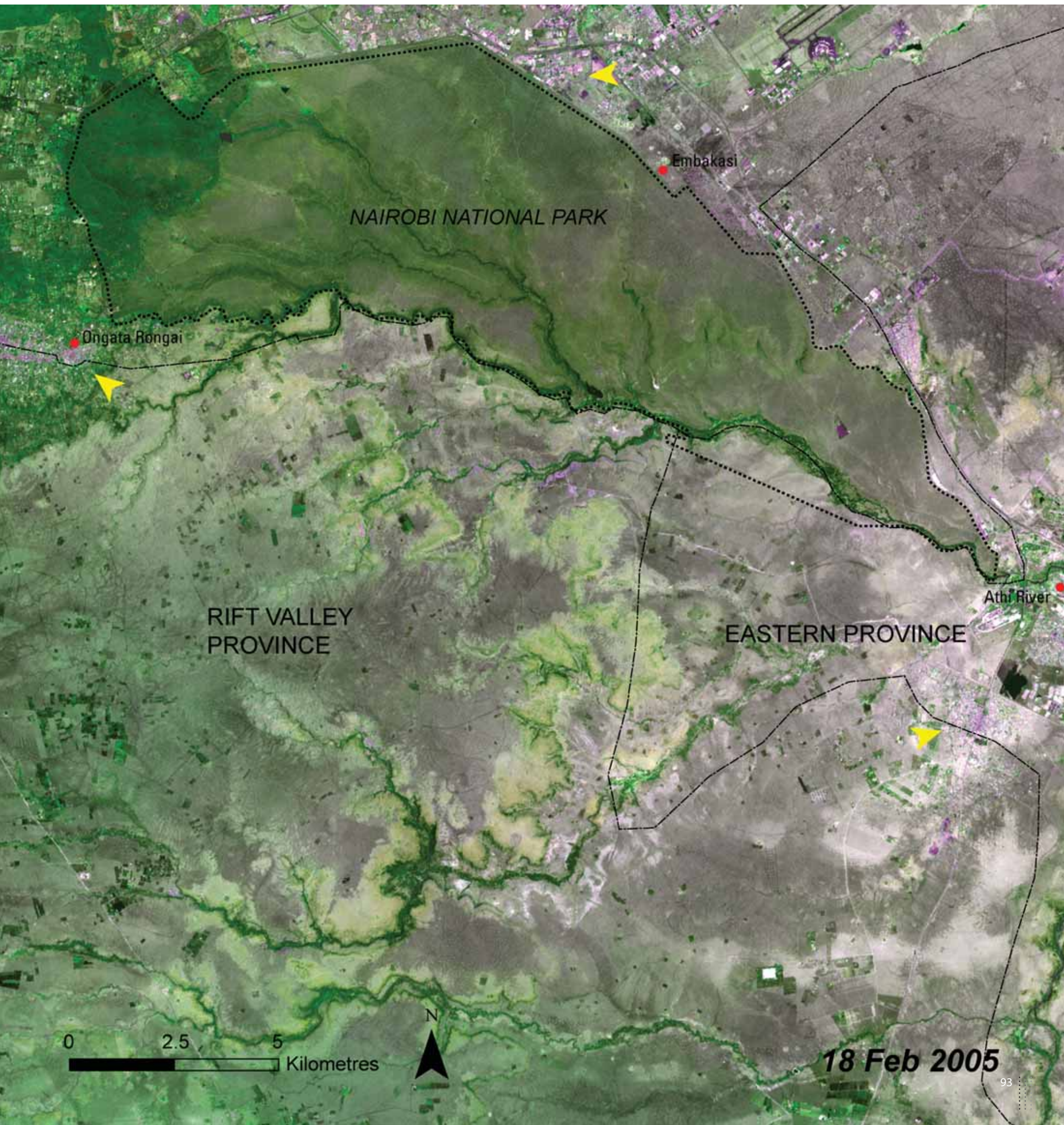**Barriers to Wildlife**

Founded in 1946, Nairobi National Park covers 117 km^2 and is the world's only Game Park located within a major city. The park's highland dry forest and savannah grasslands host a diverse range of wildlife species. About 100 species of mammals, including four of the "big five" (lion, leopard, buffalo, rhino) reside in the park. Other animals commonly observed include cheetah, Serval cats, hyenas, crocodiles, wildebeest, zebra, baboons, and snakes. With over 400 bird species, the park is classified as an Important Bird Area (IBA). For hundreds of years, Nairobi National Park was the terminus of migratory wildlife moving in search of water and breeding grounds. Animals dispersed to the Park from Kilimambogo/Oldonyo sabuk in the north, Amboseli in the south, Narok in the south west, and Machakos in the east. Between the 1950s and 1960s,

Embakasi

NAIROBI NATIONAL PARK

Ongata Rongai

RIFT VALLEY
PROVINCE

EASTERN PROVINCE

Athi River

0   2.5   5
Kilometres

N

17 Oct 1988

however, farmers and settlers gradually took over the land at the base of the Ngong Hills in the west. South of the Park, group ranches sprung up by the 1970s and private land ownership was adopted in the 1980s and 90s, thus blocking migratory corridors for wildlife.

Among Kenya's Parks, Nairobi National Park ranks fifth in visitor numbers and income generation. It receives more than 100 000 visitors a year, which generates about Ksh. 45 million. The Park's main challenges include a burgeoning human population, which grew from 80 000 to 410 000 from 1969 to 1999, and increasing settlements south of the park. This has led to human-wildlife conflict, pollution of streams, poaching for game meat, livestock invasion by wild animals, and the introduction of invasive species.
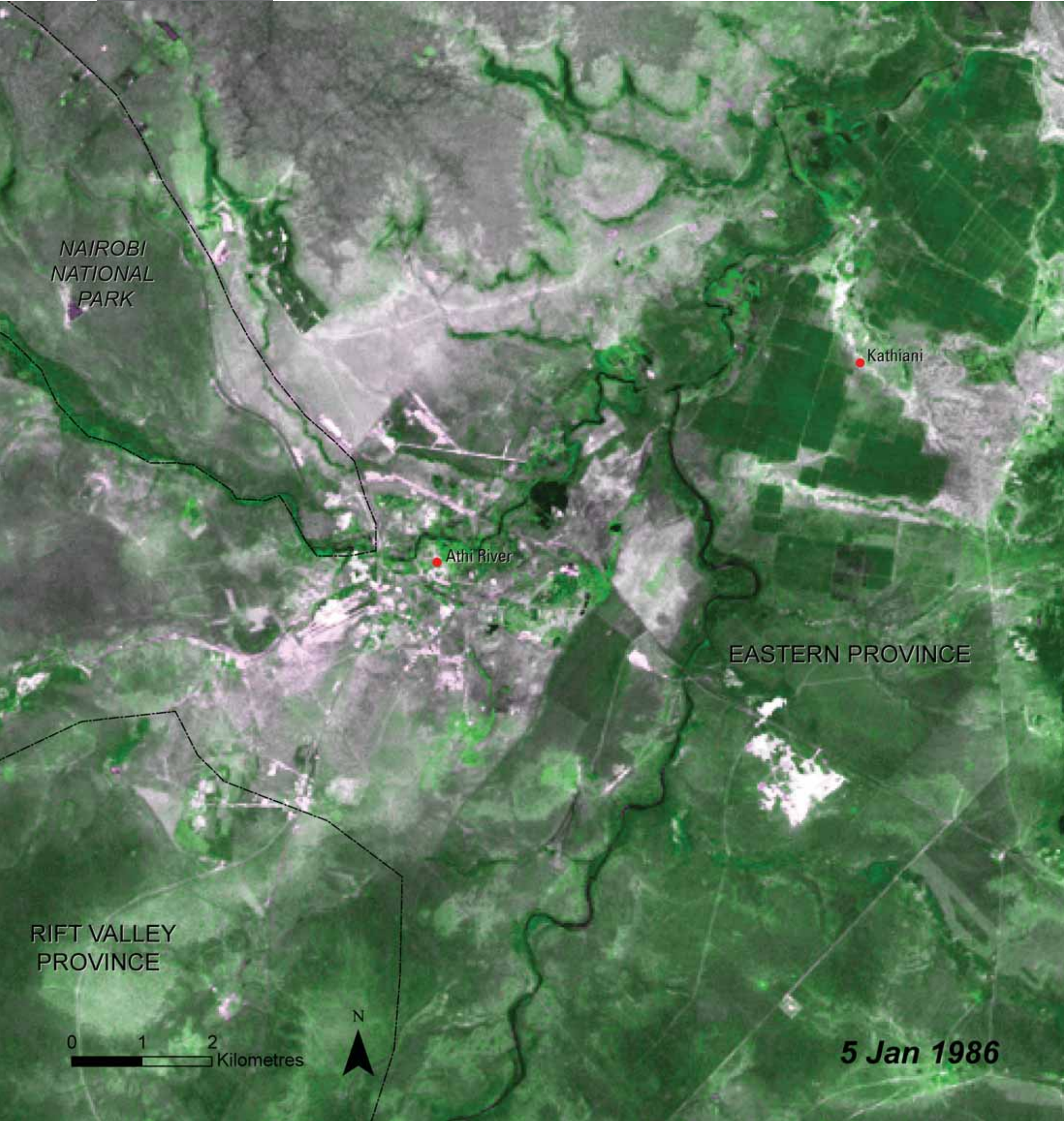
NAIROBI NATIONAL PARK

Embakasi

Ongata Rongai

RIFT VALLEY
PROVINCE

EASTERN PROVINCE

Athi River

0   2.5   5
Kilometres

N

18 Feb 2005

Mlolongo Township
Urban Sprawl

Mlolongo Township is situated along the Nairobi-Mombasa highway about 15 km southeast of Nairobi (1°23'38"S, 36°56'28"E). It is strategically positioned, with Nairobi's industrial area eight kilometres to the north, the Kitengala urban sprawl six kilometres to the south, and the densely populated Athi river mining area five kilometres to the southeast.
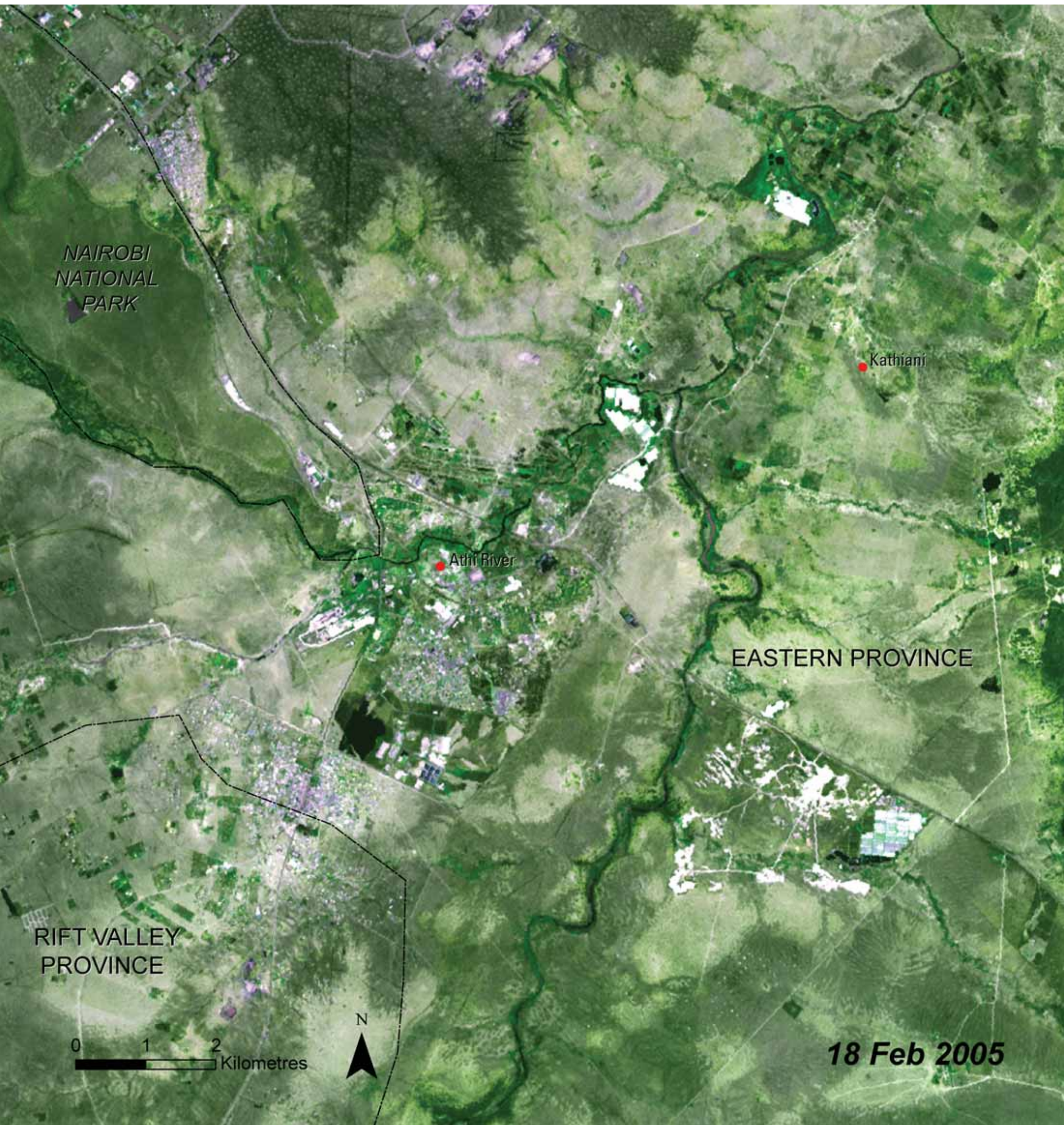
Mlolongo is the Swahili word for "queuing". It earned this name because trucks form long queues for the weighbridge here while they rest and wait for goods to be inspected. By the mid 1980s, sand traders from Machakos district some 30

NAIROBI
NATIONAL
PARK

• Kathiani

• Athi River

EASTERN PROVINCE

RIFT VALLEY
PROVINCE

0   1   2
Kilometres

N

5 Jan 1986

km further east had found Mlolongo a suitable place for trading. By the 1990s, Mlolongo was booming and the town's trade was fast expanding.

From a small long-distance truck stopover, Mlolongo grew rapidly until its present population of over 12 000 people. The township has recently been included in Nairobi's metropolitan plan, which will improve its infrastructure development and the provision of urban services that are currently lacking.

NAIROBI NATIONAL PARK

Kathiani

Athi River

EASTERN PROVINCE

RIFT VALLEY PROVINCE

0   1   2
Kilometres

N

18 Feb 2005

Lake Naivasha
Greenhouse Footprints

Unlike other lakes in Kenya's Eastern Rift Valley, Lake Naivasha is a freshwater lake, receiving most of its inflow from the Aberdare Mountains to its east. Naivasha has a history of fluctuating depths and surface area due to its shallow depth and rainfall variability in its catchment. It is a valuable freshwater resource for human uses and for a diverse population of waterbirds and large mammals, including hippopotamuses. The lake supports a range of economic activities including commercial flower growing, fishing, and a geothermal power plant.

In recent years, pressure on the Lake has increased as population and human activities have intensified throughout its catchment. Several of these changes can be seen in the differences between the 1973 and 2008 satellite images. The

Eburru
Forest
Reserve

R I F T   V A L L E Y
P R O V I N C E

Naivasha

Lake
Naivasha

Crescent
Lake

Crater
Lake

Karagita

Oloiden
Lake

0   3   6
Kilometres

N

3 Jan 1973

Mt. Longonot

footprints of Naivasha town and Karagita have grown considerably, reflecting the increased population throughout the catchment, now well above 600 000. Many commercial greenhouse flower farms have been built since the early 1980s. These are visible surrounding the lake as bright white and light blue squares of greenhouse roofs. The boundary of the Eburru Forest also retreats noticeably between the two images.

Designated a Ramsar Wetland of International Importance, efforts are being made to sustainably manage the lake. Nevertheless, water abstraction for agriculture; watershed deforestation; diversion of inflow from Malewa and Gilgil Rivers; nutrient, sediment, and chemical runoff into the lake; and invasive species are just some of the many concerns bearing on Naivasha's future.

Eburru
Forest
Reserve

R I F T   V A L L E Y
P R O V I N C E

Commerical
Flower
Greenhouses

Naivasha

Lake
Naivasha

Crescent
Lake

Crater
Lake

Karagita

Oloiden
Lake

Commerical
Flower
Greenhouses

Commerical
Flower
Greenhouses

Ol Karia
Geo-thermal
Project

0   3   6
Kilometres

N

20 Mar 2008

Mt Longonot

Loita Plains
Grasslands Lost to Farms

The Loita Plains, northeast of world famous Maasai Mara National Reserve, are an important part of the larger Serengeti-Mara Ecosystem. They are core breeding and calving grounds and wet-season grazing land for the wildebeest, whose annual migration is the primary tourism feature of the Maasai Mara Reserve. The natural landscape here is tall grass savanna with some scattered acacia and dwarf shrubs. The primary human inhabitants of the Loita Plains are the Maasai, who have traditionally been nomadic pastoralists. Responding to the limited, unpredictable, and seasonal rains on these grasslands, the Maasai, like the wildebeest, traditionally migrated through the year to where the grasses provided adequate food for their cattle. Over the past several decades, changes in land use in the Narok District have caused
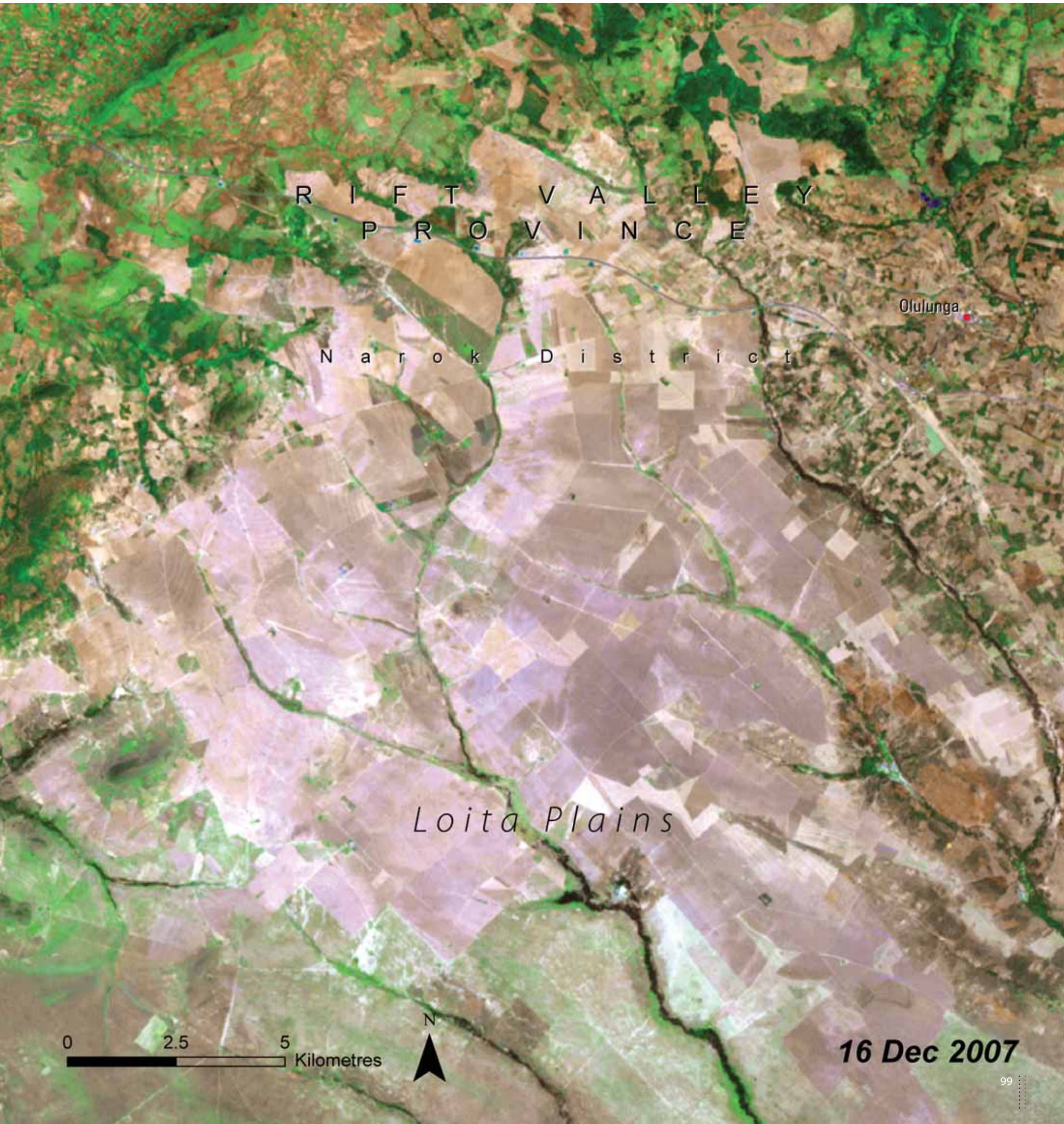
RIFT VALLEY PROVINCE

Olulunga

Narok District

H.Gyde Lund/UNEP

Loita Plains

0   2.5   5 Kilometres

N
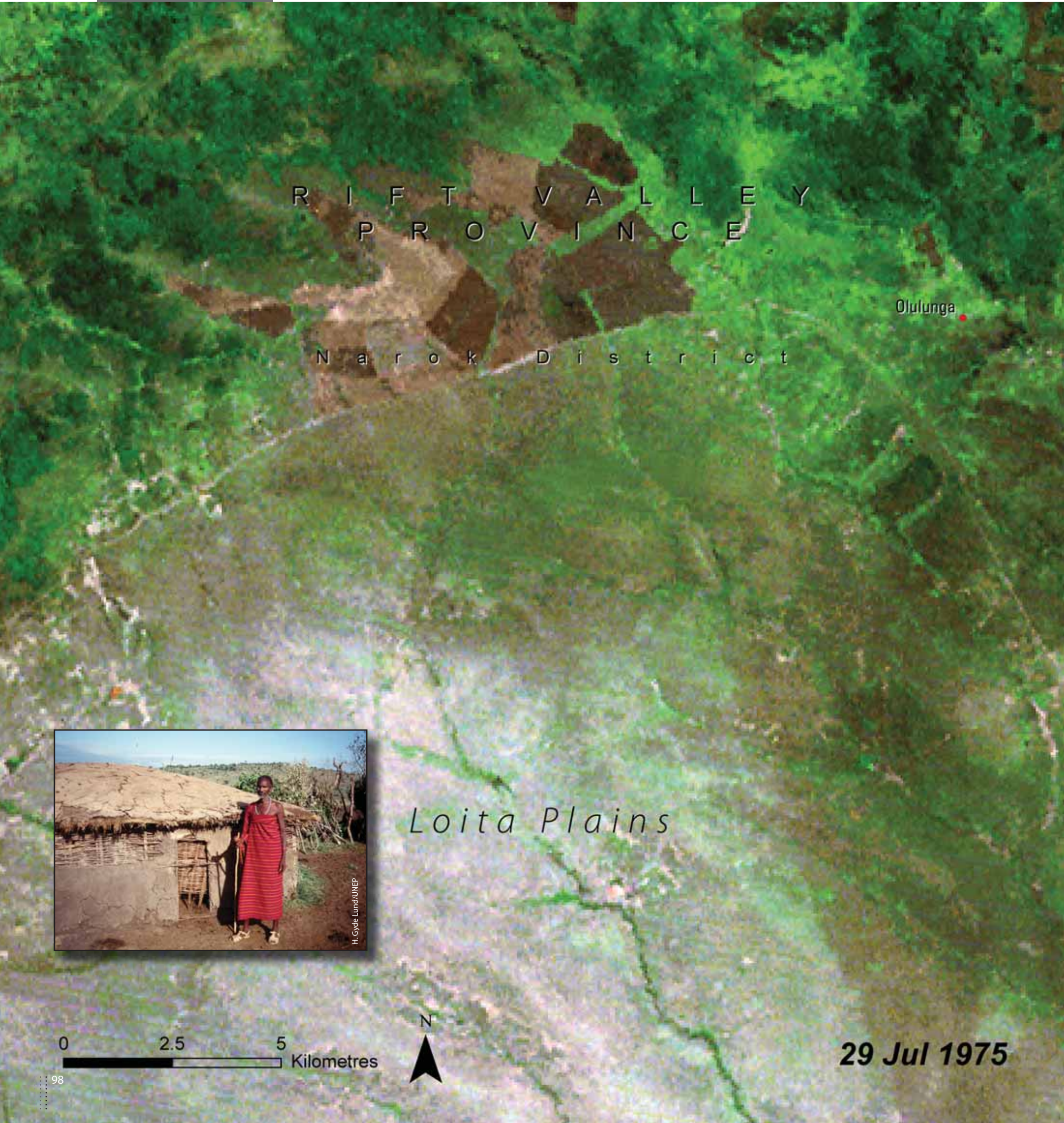
29 Jul 1975

changes in ways of life for both the Maasai and the wildebeest. While most Maasai in both Tanzania and in Kenya have taken up cultivation in recent decades, land tenure restrictions in Tanzania have tended to prevent widespread development of mechanized cultivation. In Kenya, however, large mechanized wheat farms in the area surrounding Maasai Mara expanded roughly 1 000 per cent between 1975 and 1995, most of them on the Loita Plains. This has reduced the available natural grasslands in this important wildebeest habitat. The Maasai Mara is perhaps the most famous of Kenya's tourist attractions and the annual migration of the wildebeest and other large mammals is one of the Mara's most compelling features. Management of competing land uses for this vast grassland will require a careful balance if its value is to be preserved for future generations.
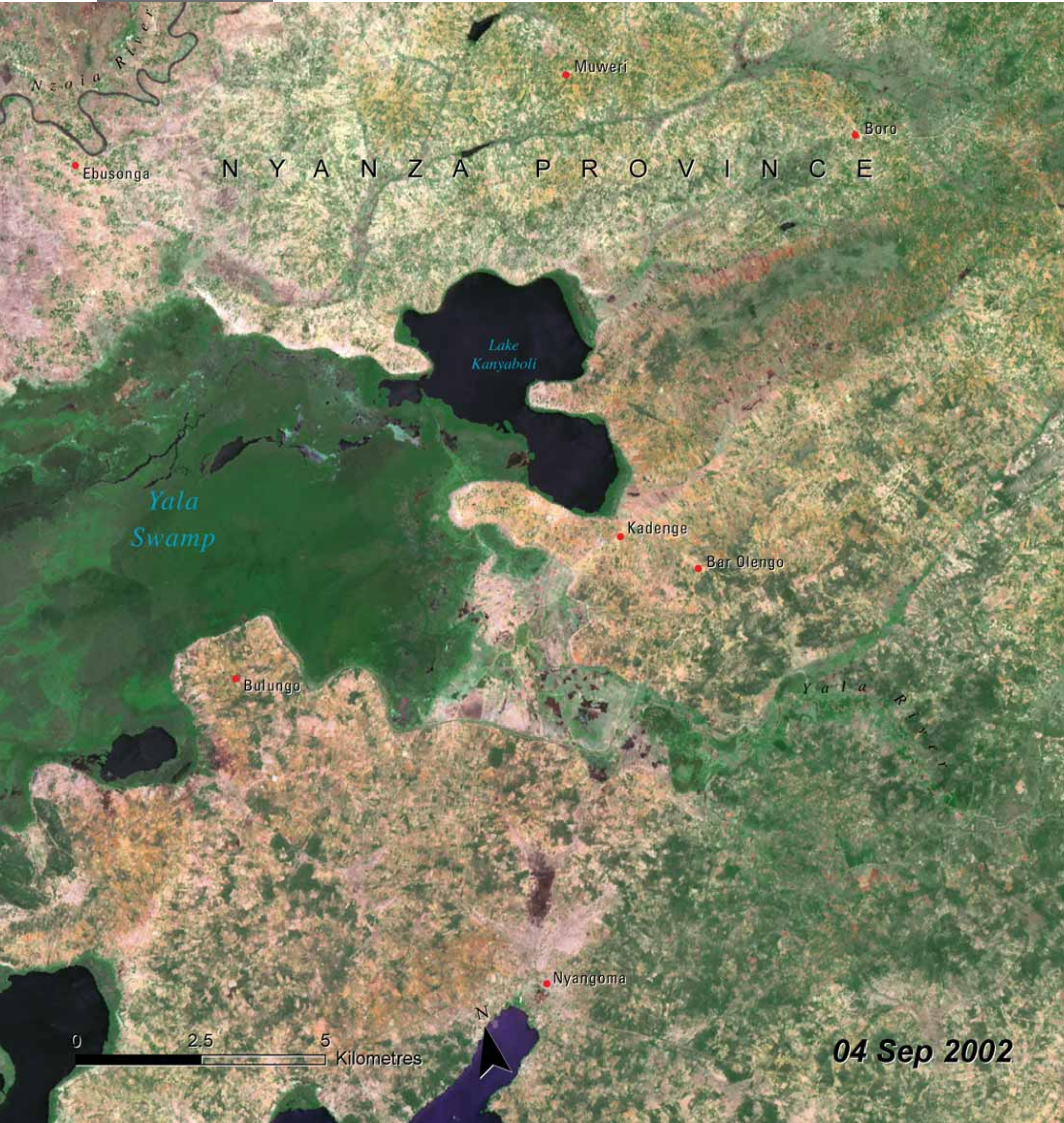
R I F T   V A L L E Y
P R O V I N C E

Olulunga

N a r o k   D i s t r i c t

Loita Plains

0   2.5   5
Kilometres

N

16 Dec 2007

Yala Swamp
Irrigation Drains a Wetland

Yala Swamp, Kenya's third largest wetland, is formed on the deltaic sediments of the Nzoia and Yala Rivers where they enter the northeastern corner of Lake Victoria. The majority of the swamp's surface area is covered with emergent wetland vegetation, including papyrus, phragmites, and typha. The wetland is vital habitat for many bird and fish species including several fish species that have disappeared from the main body of Lake Victoria, displaced by the introduction of the Nile Perch. The swamp also serves as a filter to the waters entering Lake Victoria, limiting sediments, nutrients, and pollutants from the Nzoia and Yala River catchments.

Nzoia River

Muweri

Boro

Ebusonga

N Y A N Z A   P R O V I N C E

Lake Kanyaboli

Yala Swamp

Kadenge

Bar Olengo

Bulungo

Yala River

Nyangoma

N

0   2.5   5
Kilometres

04 Sep 2002

Drainage of the swamp has been ongoing since the mid-1960s, with a significant portion of the swamp's original 17 500 ha now converted to agriculture. In 2002, 10 000 ha were leased to a foreign company for a large-scale irrigated rice project. The project built a dam on the Yala River, drained a large area of swamp, and flooded public land, disrupting the lives of many and displacing some from their homes. The company has proposed a further expansion of its activities, which would require the draining and development of an additional 9 200 ha of Yala Swamp extending from its current location to the north boundary of Yala Swamp. Development of this area has pitted the Kenyan government and private investors against conservationists and local citizens. The large commercial rice project development can be seen at the centre of the two satellite images.

25 Feb 2008
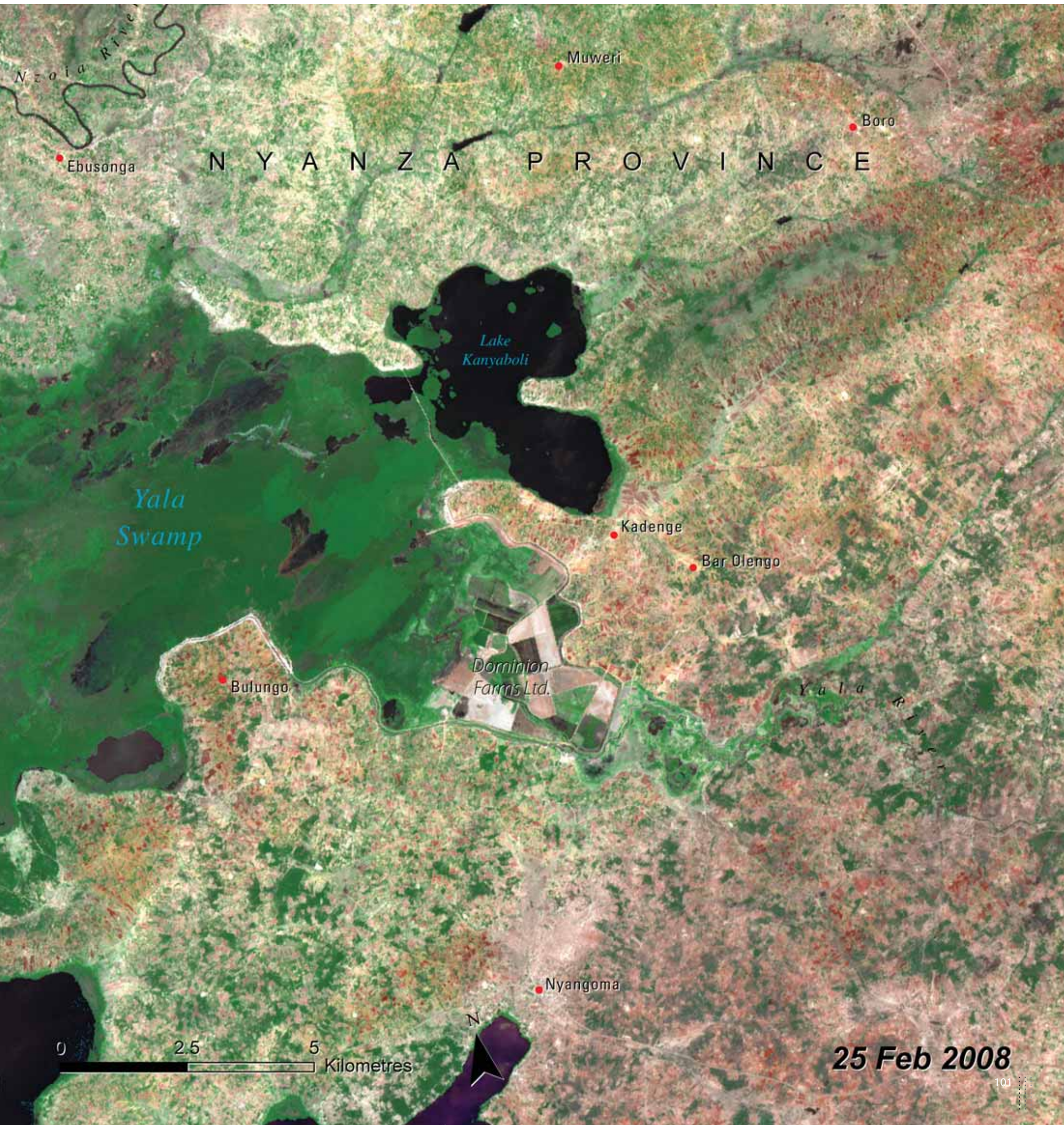
Lake Nakuru
Degrading Watershed

Lake Nakuru, in Kenya's Eastern Rift Valley, falls entirely within Lake Nakuru National Park, the second most visited protected area in Kenya. Its primary water source, the River Njoro, originates on the eastern escarpment of the Mau Forest Complex. With no outlet, Lake Nakuru has highly saline and alkaline water.

It hosts the world's largest concentration of flamingoes, as well as many of the animal species that make Kenya a highly-valued tourism destination, including lions, leopards, rhinoceros, and water buffaloes. In its total area of 188 km^2, there are over 450 bird species and 56 mammal species. Recognized as a Wetland of International Importance, Lake Nakuru was declared a Ramsar Site in 1990.

Menengai FR

Bahati FR

Nakuru FR

Nakuru

Lake Nakuru Water Catchment

Lake Nakuru

K e n y a

Excised Forest (2001)

Nakuru National Park

Eastern Mau FR

Mau Narok FR

Eburru FR

12 Kilometres

N

31 Jan 1973

Loss of natural vegetation, particularly forests, in Nakuru's watershed threatens the Lake's water quality and water balance. Between 1986 and 2003 alone, roughly one-fifth of the forested area in the upper reaches of the River Njoro catchment was lost. Another analysis found that just less than half of the dense vegetation cover in the Lake Nakuru basin was lost between 1973 and 2003. These images show the land-cover degradation in the Lake's catchment between 1973 and 2006. In 2001, the Government of Kenya announced its intention to excise 353 km² of forest in the eastern Mau Forest Reserve (the white boundary in the 2006 image). As a result, most of the forest cover in the upper catchment of River Njoro will disappear.

27 Jan 2006
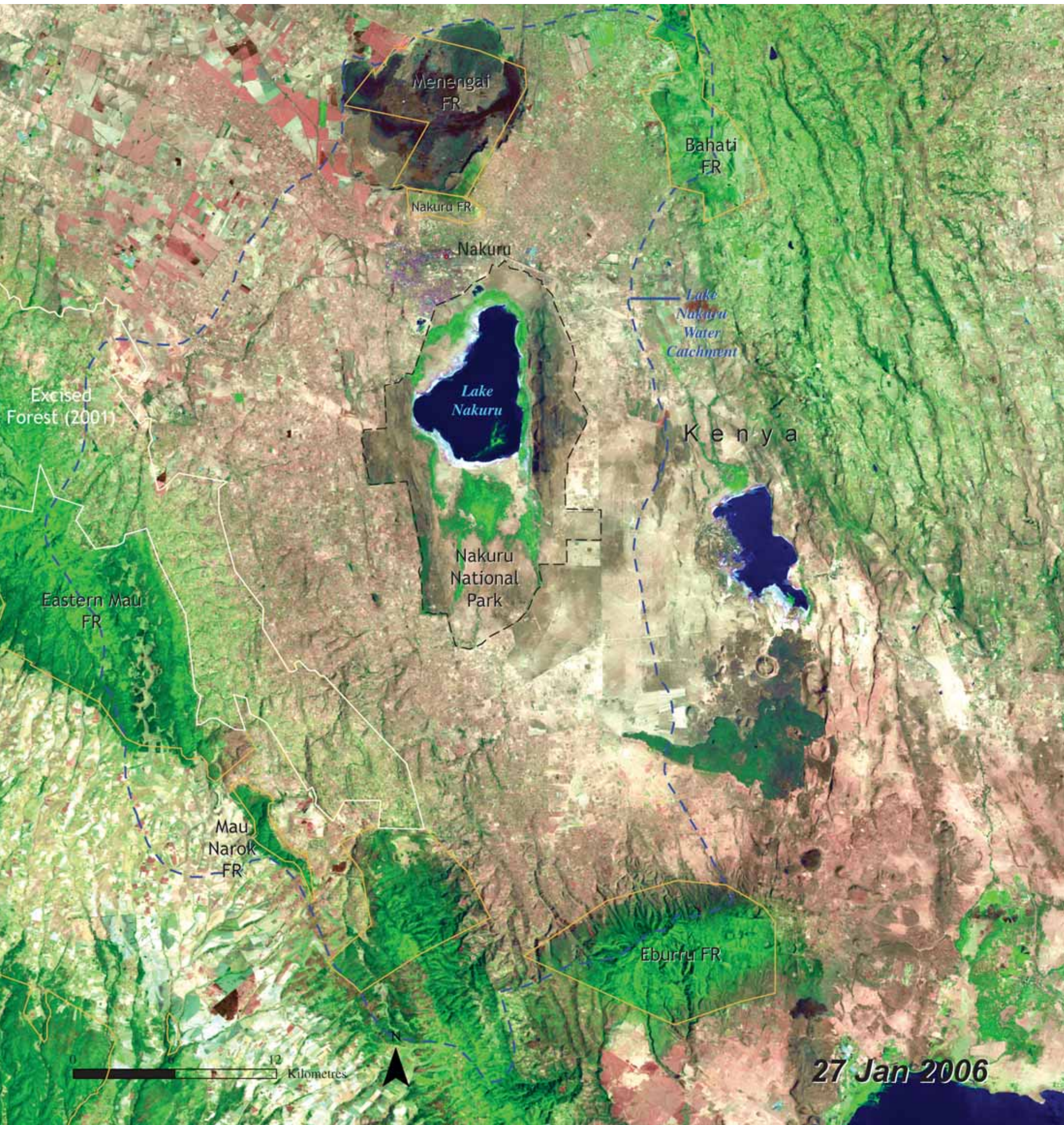
Lake Baringo
Introduced Species

Prosopis, a perennial deciduous thorny shrub or small tree native to the Americas, was introduced in the Baringo District in central Kenya in the 1980s by the Kenyan government, with financial backing from the Food and Agricultural Organization of the United Nations (FAO). It was intended to ensure self-sufficiency in wood products, make the environment habitable, and safeguard existing natural vegetation from over exploitation by rising human populations.

Some parts of the world where it has been introduced have benefitted from the new shrub but it has become invasive in the Lake Baringo area and has been of little use. Prosopis distribution in Baringo District is generally limited to Mairigat Division but has spread rapidly causing problems to traditional pastoral livelihoods by blocking pathways, altering river

Sobilo

Loruk

Lake Baringo

Nosoguro

RIFT VALLEY
PROVINCE

Salabani

Loiminange

Marigat

N

0 2 4 Kilometres

31 Jan 1973

Logumukum

courses, taking over farmlands, and suppressing other fodder species. In addition, when goats eat the pods from the bushes the high sugar content damages their teeth. The worst hit locations include Salabani, Ngambo, and Lobo.

There has been an effort to manage Prosopis in Baringo with assistance from FAO. The project, which has adopted a participatory approach, is testing for viable methods of utilizing and controlling the species. Initial results from this small-scale project have shown that with the appropriate support, local communities can manage large infestations, although strict follow-up programmes are needed to check any future re-invasion.

Sobilo

Loruk

Lake Baringo

RIFT VALLEY
PROVINCE

Nosoguro

Salabani

Loiminange

Marigat

N

0   2   4
Kilometres

6 Aug 2008

Logumukum

Water

This section and the paired images that follow illustrate the changes and threats to Kenya's fragile water sources. Kenya's natural endowment of freshwater is already highly limited; the annual renewable fresh water supplies represent 647 m^3 per capita, which is significantly below the 1 000 m^3 per capita the United Nations classifies as chronically water-scarce (UNEP 2008). Population growth alone will continue to reduce per capita water availability in the future so that by 2020, it is expected to be only 359 m^3 per capita (UNESCO 2006, WRI and others 2007).

Rainfall

Kenya's water supplies are fed by rainfall, which is highly spatially variable, ranging from less than 200 mm a year in the northern arid and semi-arid lands to 1 800 mm in the western region (Figure 1). It exceeds 1 250 mm a year in only three per cent of the country's area, but these regions feed Kenya's major rivers. Rainfall is also erratic and varies greatly throughout the year. There are two distinct rainy seasons east of the Rift Valley: the "long rains" come from March to May and the "short rains" from October to December. Major droughts and floods occur regularly. Since 98 per cent of Kenya's crops are rainfed, high rainfall variability is a significant risk factor for most farmers. Rainfall variability will likely increase with climate change, further straining the natural resource base of Kenya's economy and its citizens' livelihoods (Survey of Kenya 2003, WRI and others 2007).
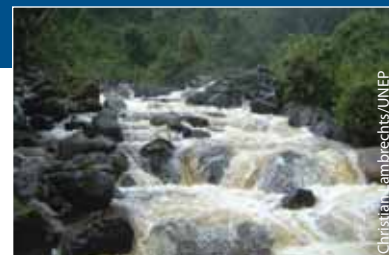
Water resources

Surface waters cover about two percent of Kenya and supply 20.2 billion m^3 of the country's estimated 30.7 billion m^3 of renewable water per year. The rest, about 14 per cent of total water resources, comes from groundwater and transboundary rivers (NEMA 2004).

Figure 1: Average annual rainfall distribution

The majority of Kenya's lakes are in the Great East African Rift Valley and include closed and open-basin systems. Most of the lakes are saline with the exception of Victoria, Naivasha, and Baringo. As shown in Chapter 1 and Figure 2, surface waters are fed by five "water towers" representing the country's major drainage areas in the highland's forested catchments (WRI and others 2007).
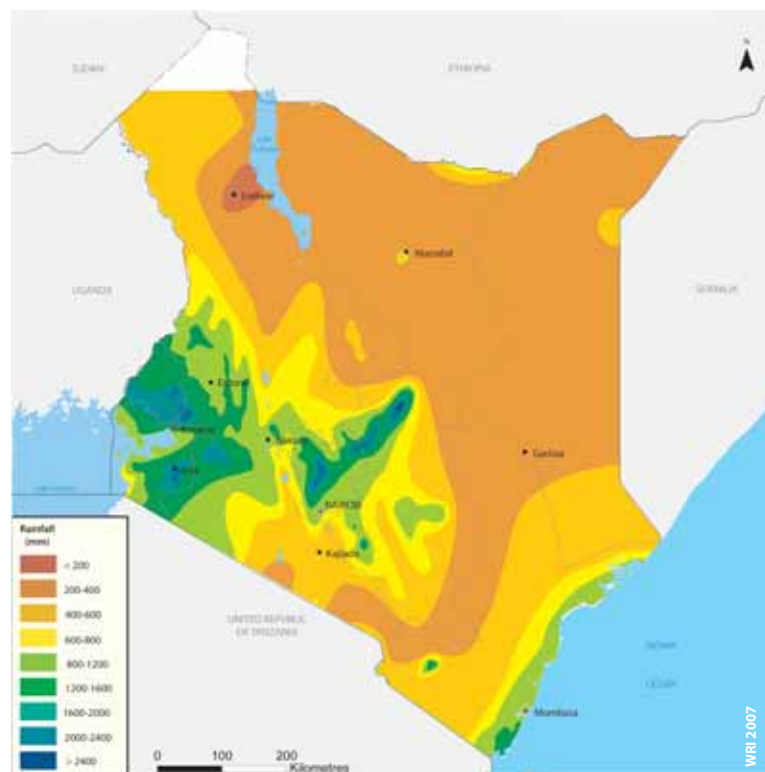

Figure 2: Kenya's surface drainage systems

Kenya's water resources include its important wetlands, which cover about 3 to 4 per cent of the land and include coral reefs, marine inshore waters, mangroves, deltas, creeks, lake shores, rivers, marshes, ponds, dams, and mountain bogs. Many communities rely on wetlands for food, medicinal plants, firewood, and many other materials. Wetlands also provide ecosystem services such as filtering and storing water, protecting coastlines from erosion, and as wildlife habitats (Ramsar 2001, FAO 2006).

Water demand and use

Agriculture uses just over three-quarters of the surface water withdrawn for human uses while
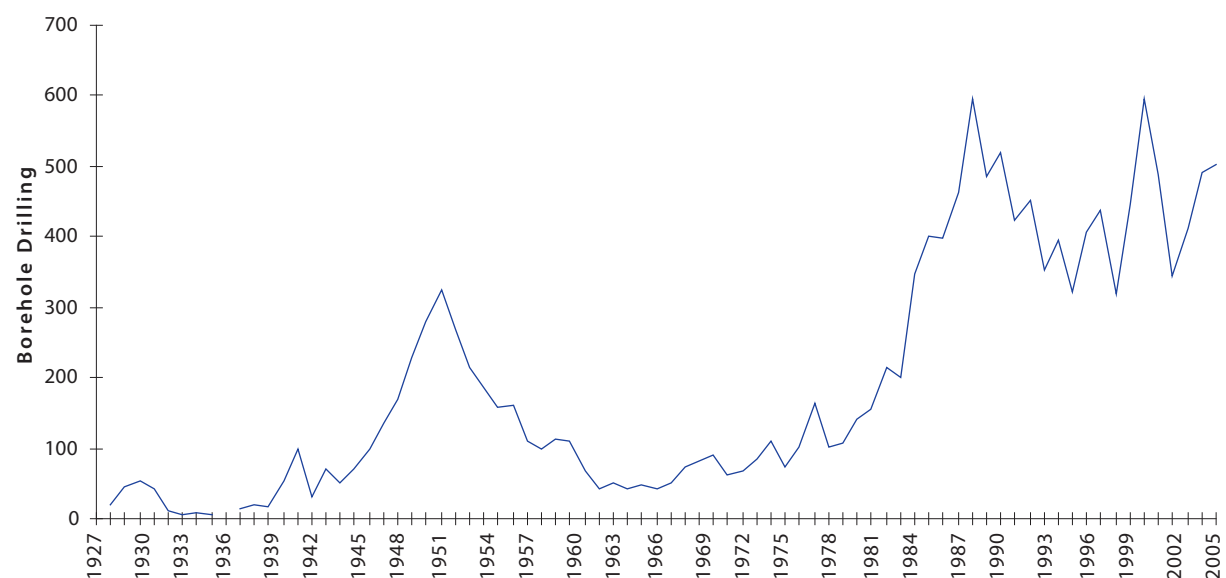
Figure 3: Borehole drilling 1927-2005
(Source: GoK 2008)

domestic and industrial withdrawals account for 17.2 and 3.7 per cent, respectively (FAO 2006). At the same time as water availability has been decreasing and rainfall variability rises with climate change, demand for water has also been growing. Total water withdrawal is estimated to be over 2.7 km^3 but water demand is projected to increase withdrawals to 5.8 km^3 by the year 2010 (FAO 2006).

Only two per cent of Kenya's croplands are irrigated, compared to the sub-Saharan average of 2.7 per cent, and only 19 per cent of land with irrigation potential is presently equipped with irrigation systems (WRI and others 2007). There are some 9 000 boreholes throughout the country to withdraw groundwater. Figure 3 shows the increased rate at which they were sunk, especially since the 1980s. Given the age of many of them, most require rehabilitation (FAO 2006).

Environmental challenges

Kenya's 1992 National Development Plan noted that 33 sub-basins without perennial river flow had an apparent water shortage and predicted that of 164 sub-basins with perennial river flows, 90 will suffer from surface water deficit by 2010 (FAO 2006). Population pressures and the increased pace and scale of human activities in watersheds are straining water supplies. As shown in Chapter 1, encroachment into the forested areas that make up Kenya's five "water towers" is seriously degrading the catchment areas as trees are felled for fuel, new farming areas, settlements, and pastures. In addition sediment loads are increasing due largely to poor land use practices in the catchments. Every year, the Rivers Tana and Sabaki deposit several million tonnes of sediment. Sedimentation seriously degrades various coastal resources and reduces the life of reservoirs (Twong'o and Sikoyo 2002).

Both surface and groundwaters receive urban pollution from wastewaters and sewage and chemicals from agricultural runoff. As well, declining and degraded water supplies have led to conflicts among different users, such as between pastoralists and farmers, upstream and downstream users, humans and wildlife, among others. Invasive species are another environmental problem associated with human impacts on water resources in Kenya. Some lakes, especially Victoria and Naivasha, have been subject to the invasive water hyacinth, which has choked off large parts of their surfaces, while the introduction of the Nile Perch in Lake Victoria has affected species composition.

Population pressures and increased human activity in and around wetlands are transforming them for commercial uses including agriculture, salt-panning, and fish farming, among others, and they are being compromised by pollution from agricultural runoff, industries, and municipal effluents that renders their waters unhealthy for humans and livestock (Macharia 2004, Ramsar 2001). The following satellite images provide examples of how some of the environmental changes described above are affecting the country's water sources.

Seven Forks Dams
Silting of Reservoirs

The River Tana, Kenya's longest river, originates in the elevated forest regions of Mount Kenya and the Aberdare Mountains. Masinga Dam built in 1980-1981, and the four reservoirs below it are known as the Seven Forks Dams. Masinga was designed to control the Tana's flow to maximize the hydroelectric output of the other dams. The Seven Forks Dams provide the bulk of Kenya's hydroelectric power.

The Project's design estimated that three million metric tonnes of sediment would accumulate behind the dams per year. Thus, their life span was expected to be roughly 500 years. By 1988, however, the siltation rate was 10 million metric tonnes per year—a rate that will drastically reduce the dam's life.

Embu

Kutus

Siakago

EASTERN PROVINCE

Gitaru Dam

Kamburu Dam

Kindaruma Dam

Masinga Dam

Ithanga

Kithyoko

Kangonde

Matuu

N

0   6   12   Kilometres

25 Feb 1987

Increased agricultural activity and deforestation, particularly in the upper elevations where rainfall is much heavier, have been blamed for this increase in sediment. Deforestation has increased the erosive capacity of rainwater throughout the catchment, especially in the Thiba and Tana catchment basins.

The satellite images from 1987 and 2005 both show suspended sediments in the waters of some of the Seven Fork's reservoirs. In the 2005 images, the light-colourerd areas in the eastern half of Masinga indicate light reflected by suspended sediments in the water. In spite of issues with the Project's long term viability, the Project has continued to expand. The recently built Kiambere Dam can be seen at the right edge of the 2005 image.
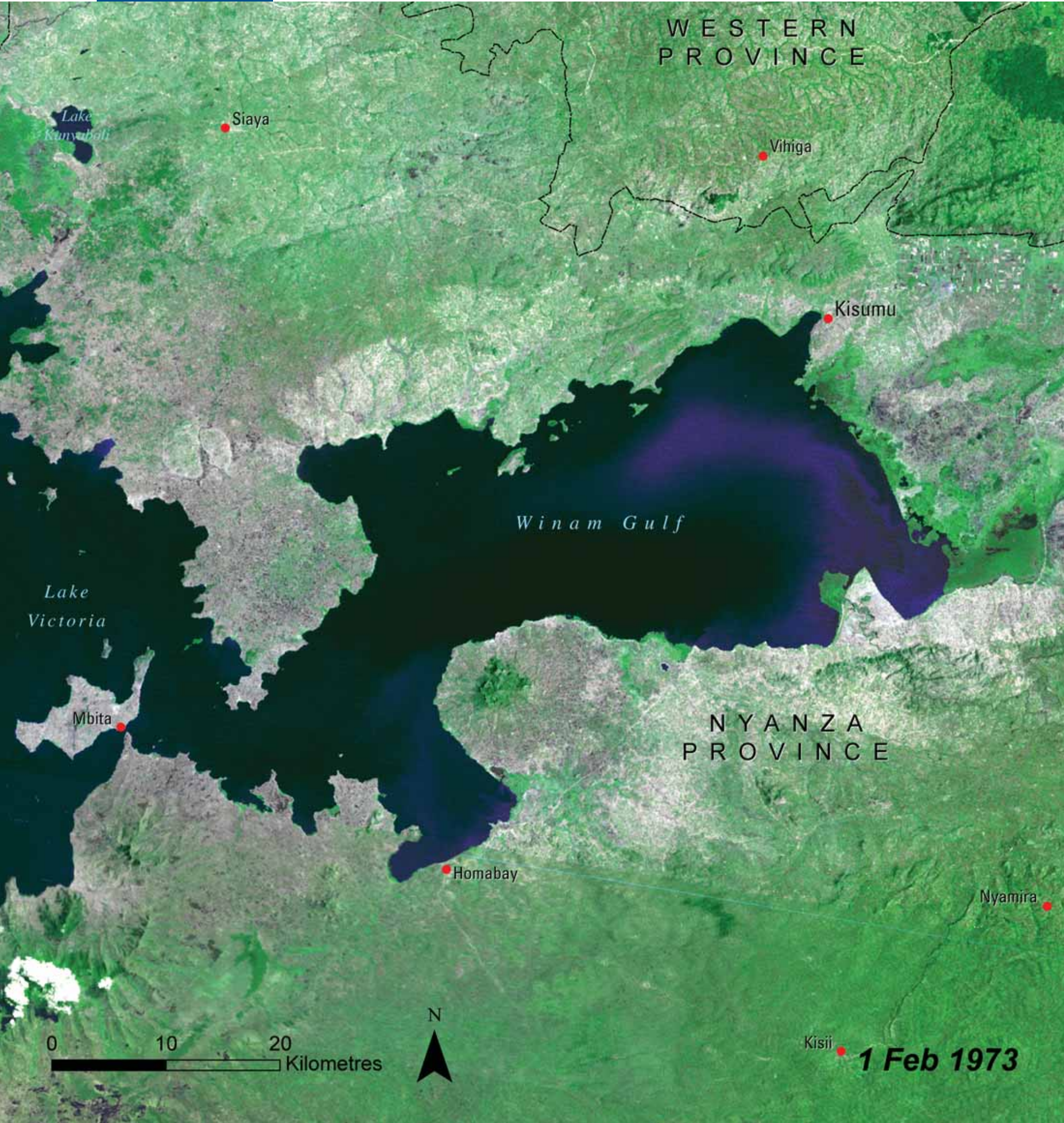

18 Feb 2005
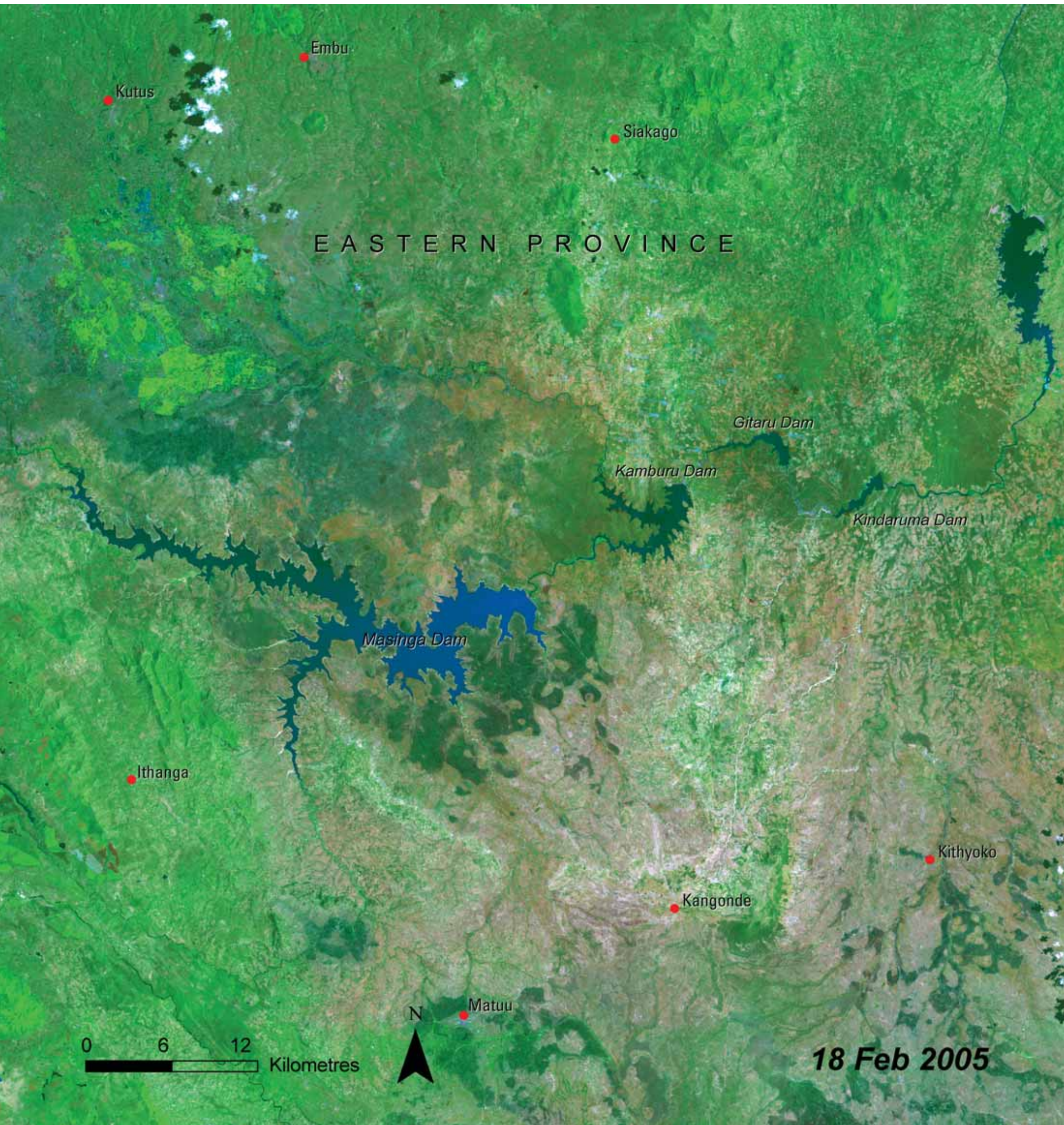
Winam Gulf
Silt and Sewage

With a surface area of 68 870 km^2, Lake Victoria is Africa's largest lake and the world's second-largest freshwater lake. Its waters are shared by three East African countries — Kenya, Tanzania, and Uganda. The lake has experienced myriad environmental problems including invasive species, declining water quality, fluctuating water levels, and direct discharge of wastes into the water system.

The Winam Gulf is the protruding arm of Lake Victoria into Kenya. The gulf is about 100 km west to east and 50 km north to south with an average water depth of about six metres. Among the environmental challenges Winam Gulf faces are sedimentation, waste contamination, and agricultural runoff. Poor land-management practices, including

WESTERN PROVINCE

Lake Kanyaboli

Siaya

Vihiga

Kisumu

Winam Gulf

Lake Victoria

Mbita

NYANZA PROVINCE

Homabay

Nyamira

N

0 10 20 Kilometres

Kisii

1 Feb 1973

deforestation in the Nandi Hills, have resulted in excessive sediment flowing into the lake. A comparison of Landsat images from 1973 and 2001 shows a significant increase in suspended sediment in the gulf. The lighter cyan color in the 2001 image is light reflected from siltation and sedimentation.

A massive increase in human population has led to increased solid waste and sewage. Lacking proper waste-management systems, much of this finds its way into the Gulf. Also, because of increased agriculture, agro-chemicals are transported through streams into the Gulf. These pollutants cause algal blooms that deplete the dissolved oxygen in the Gulf, threatening the fish population.

WESTERN PROVINCE

Lake Kanyaboli

Siaya

Vihiga

Kisumu

Winam Gulf

Lake Victoria

Mbita

NYANZA PROVINCE

Homabay

Nyamira

0   10   20
Kilometres

N

Kisii

5 Feb 2001
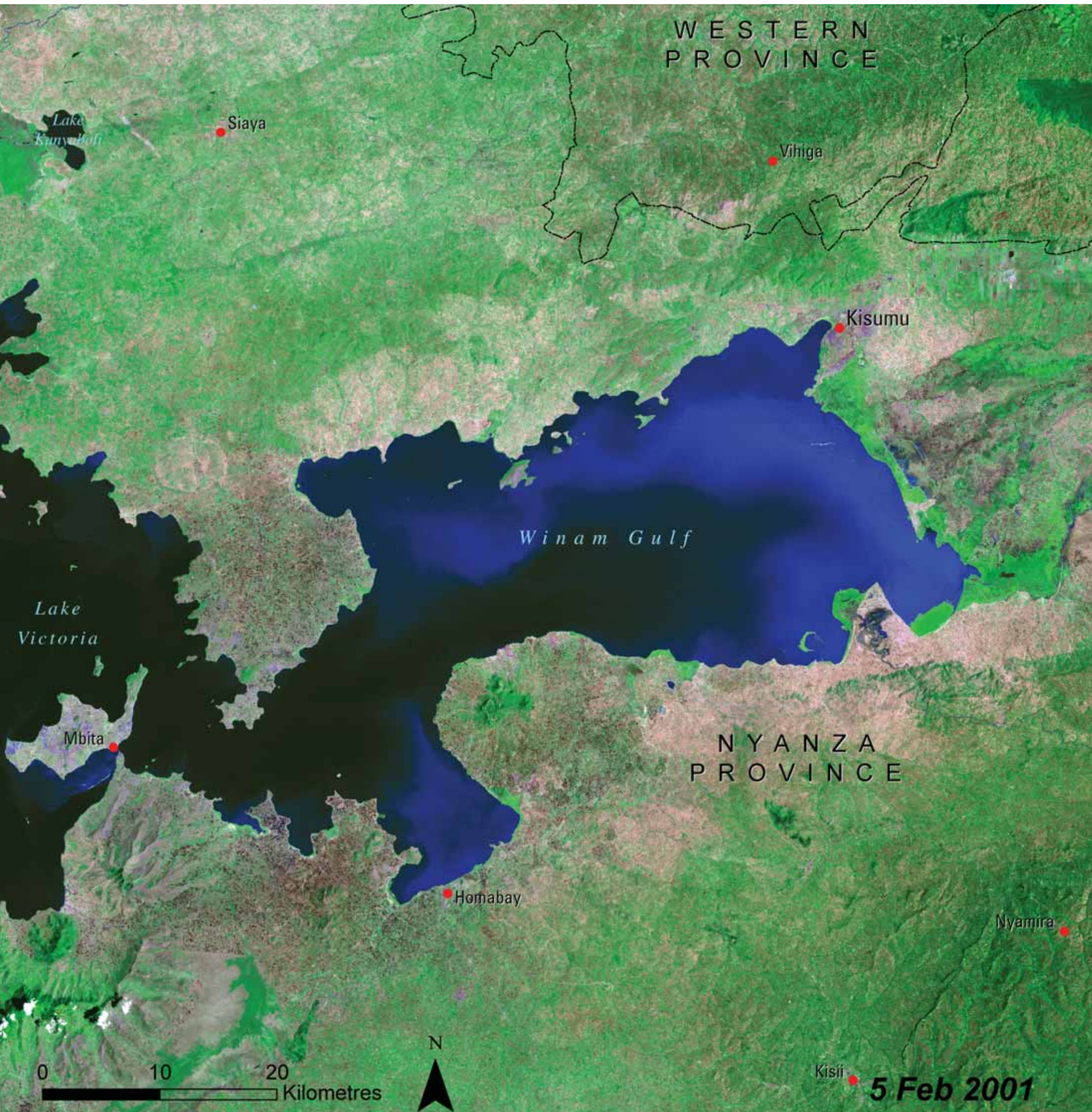
Lake Olbollosat
Disappearing Lake

Lake Olbollosat, the only lake in Kenya's Central Province, lies in Great Rift Valley to the northwest of the Aberdare Mountains. The Lake covers over 40 km², of which only a small part is open water. Its catchment is the Ewaso Nyiro North Basin, which covers over 200 000 km² and is the country's largest drainage basin. It is also an internal basin, which along with a high evaporation rate, gives the Lake its elevated salinity level.

The lake and its catchment area provide a variety of important habitats including open water, floating marshes and swamps, open grasslands and riverine forests along the rivers, and springs that feed the lake. The lake is earmarked for

31 Jan 1973

designation as a Ramsar Wetland of International Importance because of the wealth of biodiversity it supports, particularly its migratory bird species.

A rapidly growing population threatens this valuable habitat. Impacts include catchment degradation, siltation, overgrazing, encroachment on riparian land, agricultural pollution, and excessive water abstraction. Lake Olbollasat's water volume has fluctuated over the years. While Lake Olbollasat has periodically dried up and then come back to life in the past, environmentalists are concerned that the increasing number of pressures may mean that if it dries up again, it could be the end of Lake Olbollasat.

RIFT VALLEY
PROVINCE

Nyahururu

Ndaragwa

RIFT
VALLEY
PROVINCE

Ol Joro Orok

Lake Olbollosat

CENTRAL
PROVINCE

Rurie

0   2.5   5
Kilometres

N

Ol Kalou

2 Feb 2008

Forests

Although forests cover only about three per cent of Kenya's land area, they are essential ecosystems, providing fuel, timber, food, medicinal plants and other forest products, wildlife habitat, tourist attractions, water catchments, carbon storage, and a myriad of additional goods and services as well as cultural and spiritual values. As underscored in Chapter 1, about 10 per cent of the population lives within five km of Kenya's indigenous closed-canopy forests and derive direct benefits from them, and in some areas, as much as 70 per cent of the income in households adjacent to forests comes from forest activities (KFWG 2008). Kenya's coastal forests are important for their role in protecting shores from degradation, especially erosion, and its mangroves are particularly significant for the role they play in trapping sediment, filtering water, recycling nutrients, and as habitat for valuable fish species. The closed canopy forests are habitat for a disproportionately large percentage of the country's wildlife and other biodiversity. It is estimated that they harbour 40 per cent of large mammals, 30 per cent of birds, and 35 per cent of the nation's butterflies. About half of Kenya's threatened mammals and birds are found in its forests (Survey of Kenya 2003).

Kenya's forests are so important that Chapter 1 devoted a large section to the country's five "water towers", whose forests capture and store water that flows into rivers delivering this precious resource to people and ecosystems as far away as the coast and all its borders with neighbouring countries. These catchments produce crucial waters that generate hydro electricity, feed irrigation schemes for small landholders and large plantations, and sustain wildlife in the country's famous wilderness parks (Survey of Kenya 2003). This section gives an additional brief overview of Kenya's forest resources to provide context for the following paired images depicting environmental change in the nation's forested "hotspots".

Kenya's forest stocks

Kenya's different forest types are classified according to climatic conditions: coastal forests, dry-zone forests, montane forests, and the western rain forests. According to the Kenya Indigenous Forests Conservation Programme (KIFCON), Kenya has about 1.24 million ha of closed-canopy indigenous forests. The Kenya Forest Service manages most of these as gazetted forest reserves while the Kenya Wildlife Service (KWS) manages other closed-canopy forests gazetted as National Parks and National Reserves (KFWG 2008). In total, gazetted reserves cover about 1.64 ha or two per cent of the land area (Figure 1) (Wass, 1995, World Bank/GoK 2000, UNEP 2006).

The Forestry Department's inventory states that 165 000 ha are under plantations but this figure does not account for them all. The Ministry of Local Government holds some 100 000 ha of forest as Trust Land on behalf of local people; these forests are generally poorly managed (KFWG 2008). Kenya's total forest area also includes woodlands, bushlands, and wooded grasslands, which in fact contain most of the country's woody biomass (WRI and others 2007). The densest forests occur in the moist highlands where the human population and agricultural production are also concentrated. In the extensive semi-arid region, forests are mainly found on isolated hills and in discontinuous narrow bands along riverbeds. Coastal forests exist in
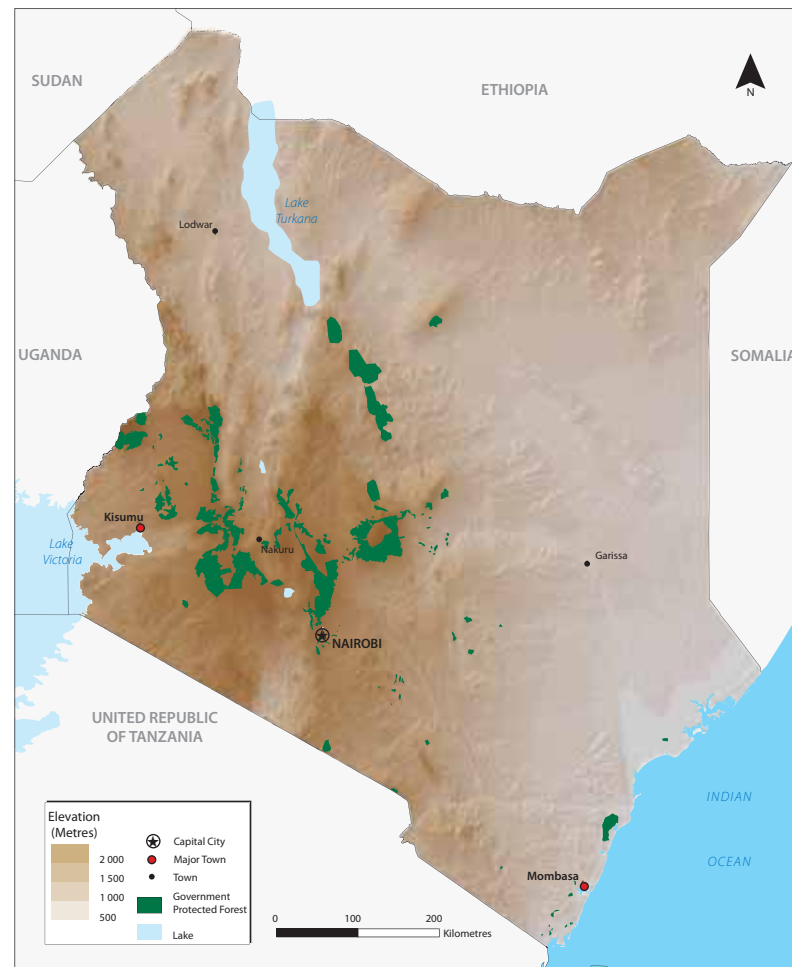
Uneven forest canopy

isolated blocks comprising about 83 800 ha and mangroves along the coast cover about 53 000 ha (Twong'o and Sikoyo 2002).

Human use of the forests

Kenya's forests and woodlands have been subject to intense human activity and with its growing population and economic expansion, they continue to be threatened by encroachment for agriculture, pastures, woodfuel, and timber. As shown in Chapter 1, firewood and charcoal from forests and woodlands account for about 70 per cent of national energy, while plantations provide wood for timber and poles; these needs continue to grow (KFWG 2008, WRI and others 2007). Forests have also been lost to land conversion by burning, which emits large amounts of greenhouse gases (Ogola n.d.) and parts of protected areas have been degazetted or excised, as

**Figure 1: Gazetted forests
(Source: KFS 2007)**

mentioned in Chapter 1. Coastal forests have been subject to overharvesting for timber and other products, large-scale conversion to ports, settlements, tourist infrastructure, aquaculture, rice farms, and salt pans. Untreated wastes, agricultural chemicals, and industrial pollution from upstream waters also threaten them as does siltation as a result of upstream dams (Twong'o and Sikoyo 2002, WWF 2006). Among Kenya's most endangered forests are the Kakamega Forest, the Mau Forest Complex, and Karura Forest (UNEP and DRSRS 2004).
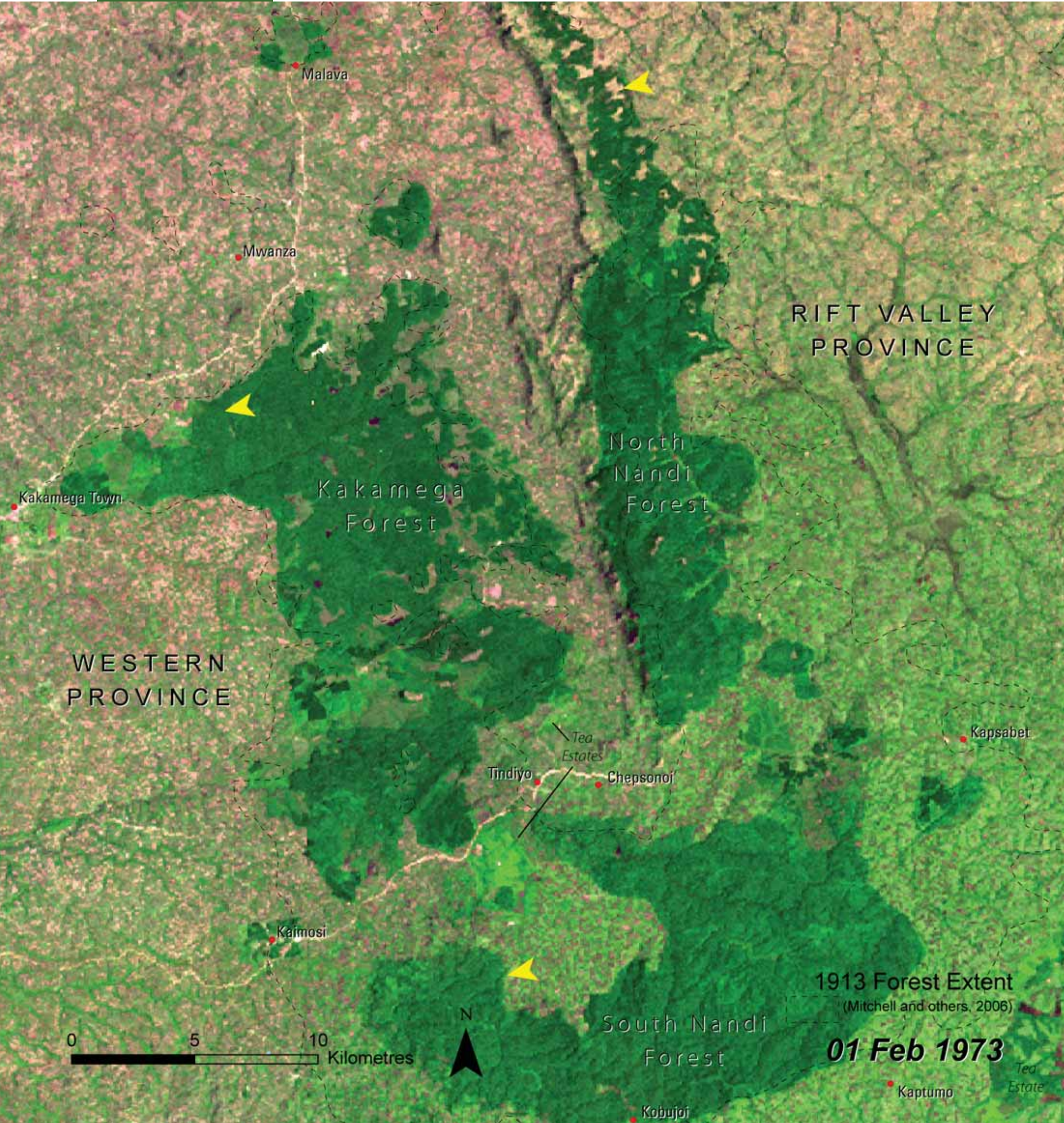
During the 1990s, forests suffered severe losses, with as much as 93 000 ha cut during the decade (FAO 2001). In total, between 1990 and 2005, Kenya lost five per cent of its remaining forest cover, or around 186 000 ha of which 38 000 ha were indigenous forests (UNEP 2006). It is thought that since pre-agricultural times, about 70 per cent of Kenya's mangroves have been lost (Twong'o and Sikoyo 2002). The result of forest loss has been fragmentation, land degradation and the loss of precious topsoil, the loss of wildlife habitat and consequent declines in biodiversity (Peltorinne 2004). This severe deforestation and degradation led to serious plantation activity beginning in 2003, and in 2004, felling of valuable natural hardwood was banned. Deforestation rates of indigenous forest since 2005 decreased by 5.1 per cent (UNEP 2006).

C.Lambrecht/UNEP

Kakamega Forest
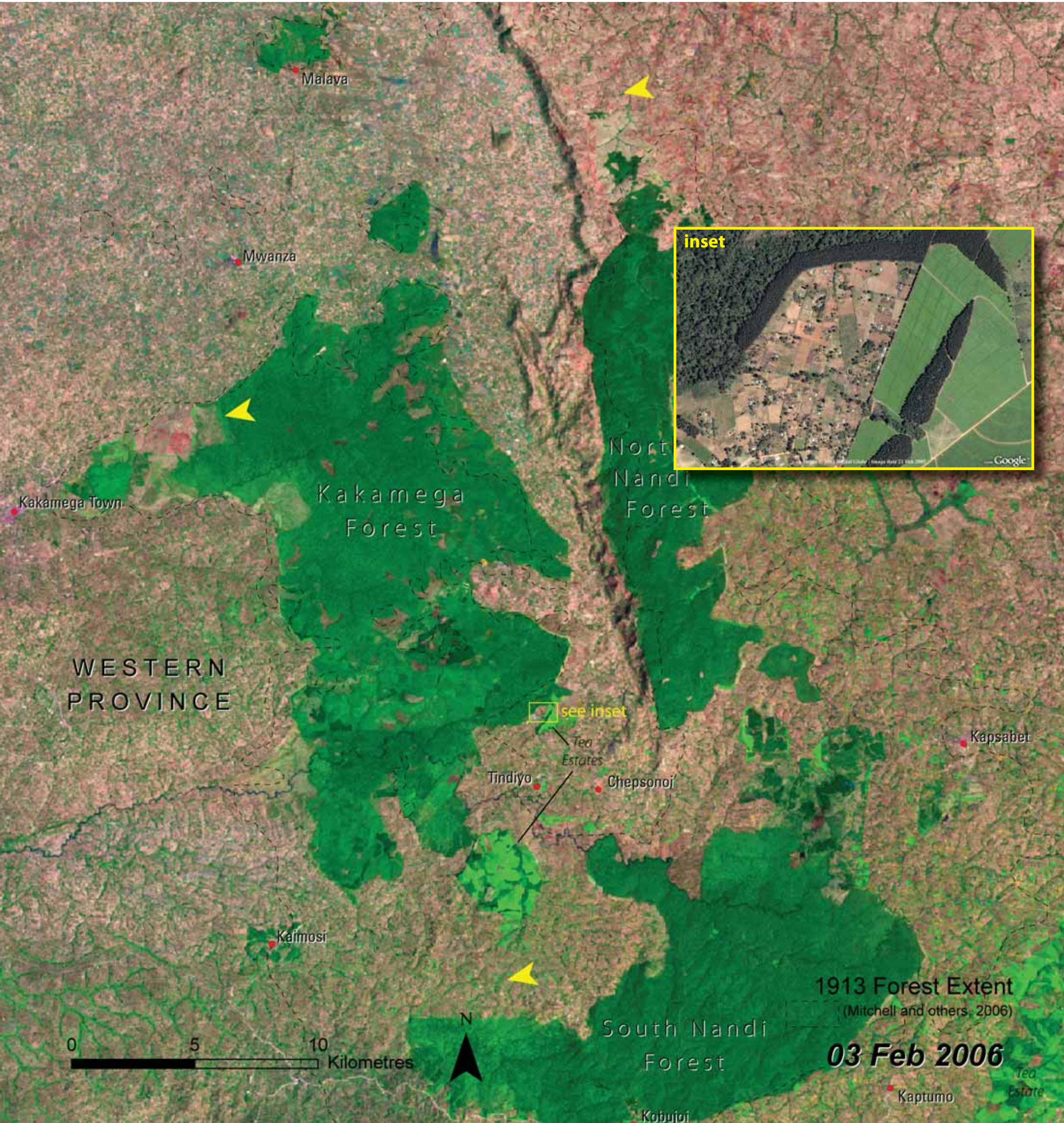## Kenya's Only Tropical Rain Forest

Kakamega Forest is Kenya's only area of tropical rain forest and the eastern-most remnant of the Guineo-Congolian tropical rain forests. It receives among the highest average precipitation of any area in Kenya, ranging from 1 500 mm to 2 300 mm. It was contiguous with the North and South Nandi Forests as recently as 1913; both these forests are slightly more elevated and have more montane forest species than does Kakamega. Kakamega Forest contains a wealth of biodiversity including several globally and regionally threatened bird species. Kakamega, North Nandi, and South Nandi are all designated Important Bird Areas. The Kakamega area is also home to among the densest rural populations in the world, with between 400 and 1 300 people per km². This population has put heavy pressure on the forest (yellow

Malava

Mwanza

Kakamega Town

Kakamega Forest

WESTERN PROVINCE

RIFT VALLEY PROVINCE

North Nandi Forest

Kapsabet

Tea Estates

Tindiyo   Chepsonoi

Kaimosi

1913 Forest Extent
(Mitchell and others, 2006)

01 Feb 1973

South Nandi Forest

0   5   10 Kilometres

N

Kaptumo

Tea Estate

Kobujoi

arrows), converting land for tree plantations, tea estates, selective logging, charcoal production, cattle, and shamba agriculture. It is estimated that the forested area of the Kakamega, North Nandi, and South Nandi blocks has been reduced to roughly 34 per cent of its 1913 extent (not counting forest plantations). A core of "near natural and old secondary forest" remains but is surrounded by secondary forests, plantation forests, grassland, bushland, and tea plantations.

Kenya's natural endowments, including Kakamega and the Nandi Forests, are central attractions for tourism and crucial to the livelihoods of its people. Intense pressure through continued encroachment poses a very real threat to the future of Kakamega Forest.

inset

Malava

Mwanza

Kakamega Town

Kakamega Forest

North Nandi Forest

WESTERN PROVINCE

see inset

Tea Estates

Tindiyo   Chepsonoi

Kapsabet

Kaimosi

N

South Nandi Forest

1913 Forest Extent
(Mitchell and others, 2006)

03 Feb 2006

0   5   10   Kilometres

Kaptumo

Tea Estate

Kobujoi

Ngomeni
Disappearing Mangroves

Mangroves are salt-tolerant species of trees and shrubs found in the inter-tidal environments of the tropics and sub-tropics. There are approximately 54 000 ha of mangroves along Kenya's 450 km-long coastline, primarily in protected bays, river estuaries, and on the lee side of islands. The majority of Kenya's mangroves are concentrated in the Lamu (June 2008 image) and Tana River districts, with concentrations also at Mombasa, Kilifi, Gazi Bay (October 2002 image), and Funzi Bay. Kenya's mangroves are nursery areas for many marine species, including edible crabs and small pelagic fish. In addition, they provide habitat for a variety of bird, vertebrate, and invertebrate species. Mangroves also provide timber products such as firewood, building poles, and charcoal, and non-timber products like honey, crabs, fish, and medicinal plants.

COAST PROVINCE

Gazi

Gazi Bay

0   0.75   1.5 Kilometres

01 Oct 2002

COAST PROVINCE

Mokowe

Matondoni

Lamu

Shela

INDIAN OCEAN

N

0   2   4 Kilometres

04 Jun 2008

RHIZOPHORA MUCRONATA =200M =2.5OM

Kenya's mangroves are threatened by overexploitation of wood products and conversion to salt-panning, agriculture, and other land uses. Some estimates suggest that about half of the mangroves in Kenya have been lost over the past 50 years. The images from June 1975 and January 2000 show the loss of roughly 10 000 ha of mangroves to salt-panning operations between Ngomeni and Karawa (yellow arrows). Many of Kenya's remaining mangroves have been seriously degraded by over exploitation of wood products, particularly in the area around Lamu. Researchers have been studying reforestation of mangroves in the Gazi Bay area with the hope of being able to restore some of Kenya's lost mangroves.

COAST PROVINCE

Fundisa

Ngomeni

Gongoni

02 Jun 1975

INDIAN OCEAN

0   2   4
Kilometres

N

COAST PROVINCE

Kuraw Salt Works

Krystalline Salt Works

Malindi Salt Works

Fundisa

Kensalt Salt Works

Ngomeni

Fundisa Salt Works

Ngomeni Salt Works

Gongoni

22 Jan 2000

INDIAN OCEAN

0   2   4
Kilometres

N