**Fires Near Lake Malawi, Africa**

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

## 3.2 Images of Change: Africa's Lakes

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

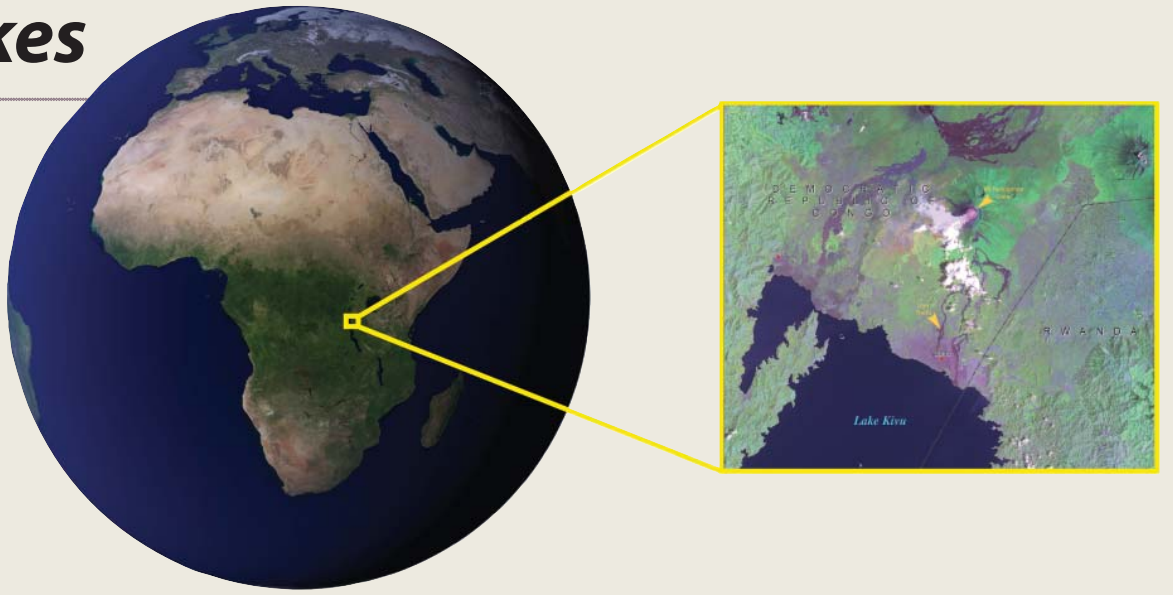
By comparing two images of the same area taken 10, 20 or even 30 years apart, it is often easy to see human and naturally-induced changes in a specific location. There are very few places remaining on the planet that do not show at least some impact from people's activities. Freshwater lakes are often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

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

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

*Julie Brazier/UNEP/MorgueFile*

# Africa's Killer Lakes




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

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

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

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

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

## Degassing Lake Nyos

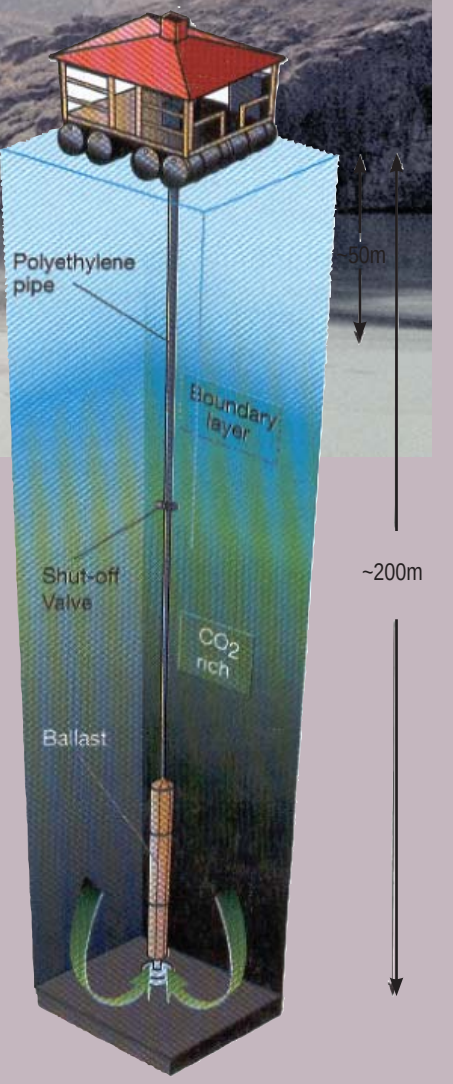
Lake Nyos is situated in the crater formed from the collapse of the pipe feeding a now extinct volcano. The lake is compositionally stratified, with fresh water in the upper 50 m (164 ft) and heavier sodium- and carbon dioxide-rich water below that. The water below 180 m (591 ft) is particularly rich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

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

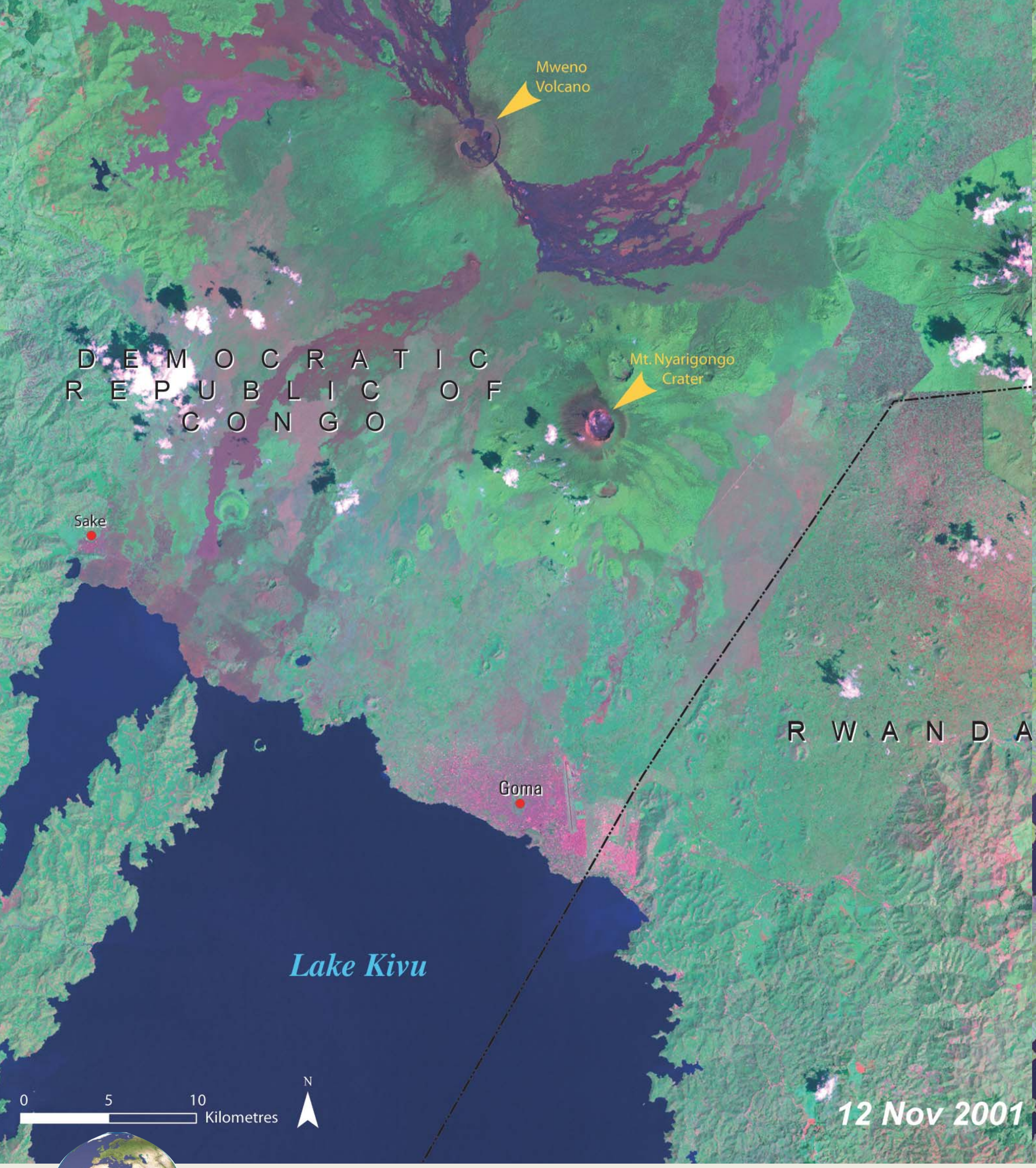
In 1995 an international team of scientists and engineers tested a procedure to degas the lower parts of Lakes Nyos and Monoun in a controlled way, and a team is now in the region to begin the project in earnest. The procedure involves lowering a strong polyethylene pipe to the lake bottom. Some water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

French scientists degassing Lake Nyos.

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




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

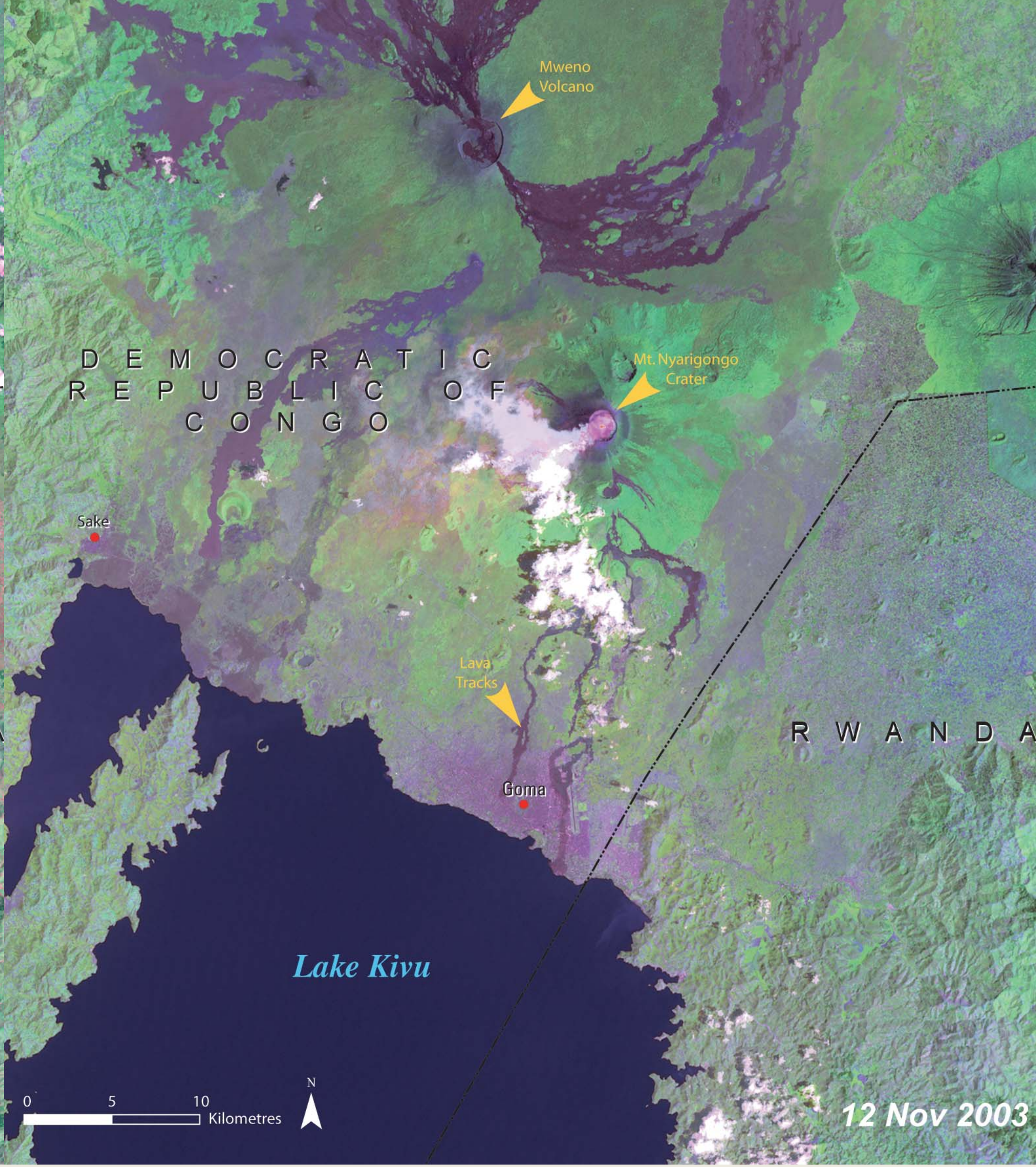




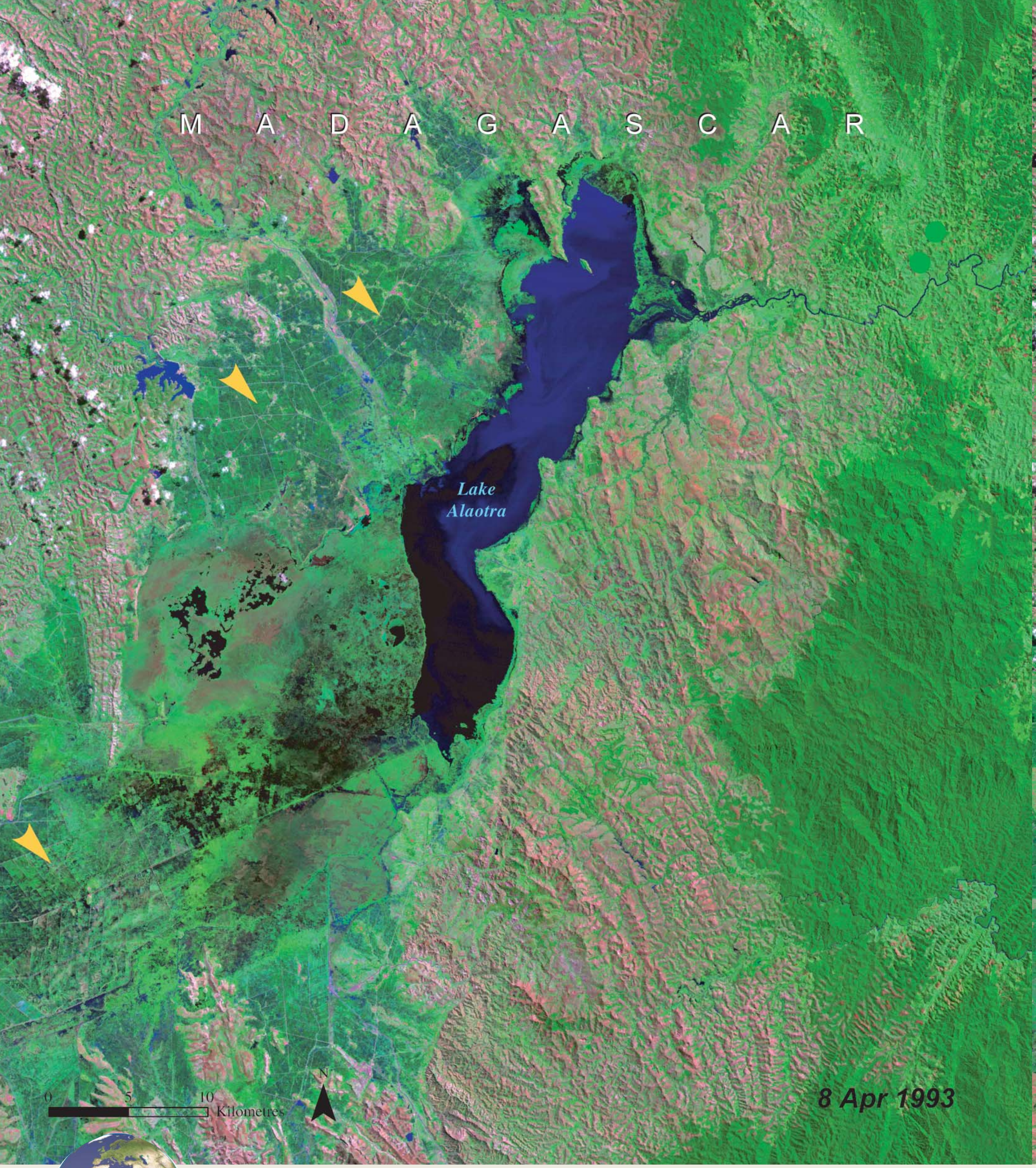
# Africa's Killer Lake

## Lake Kivu

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



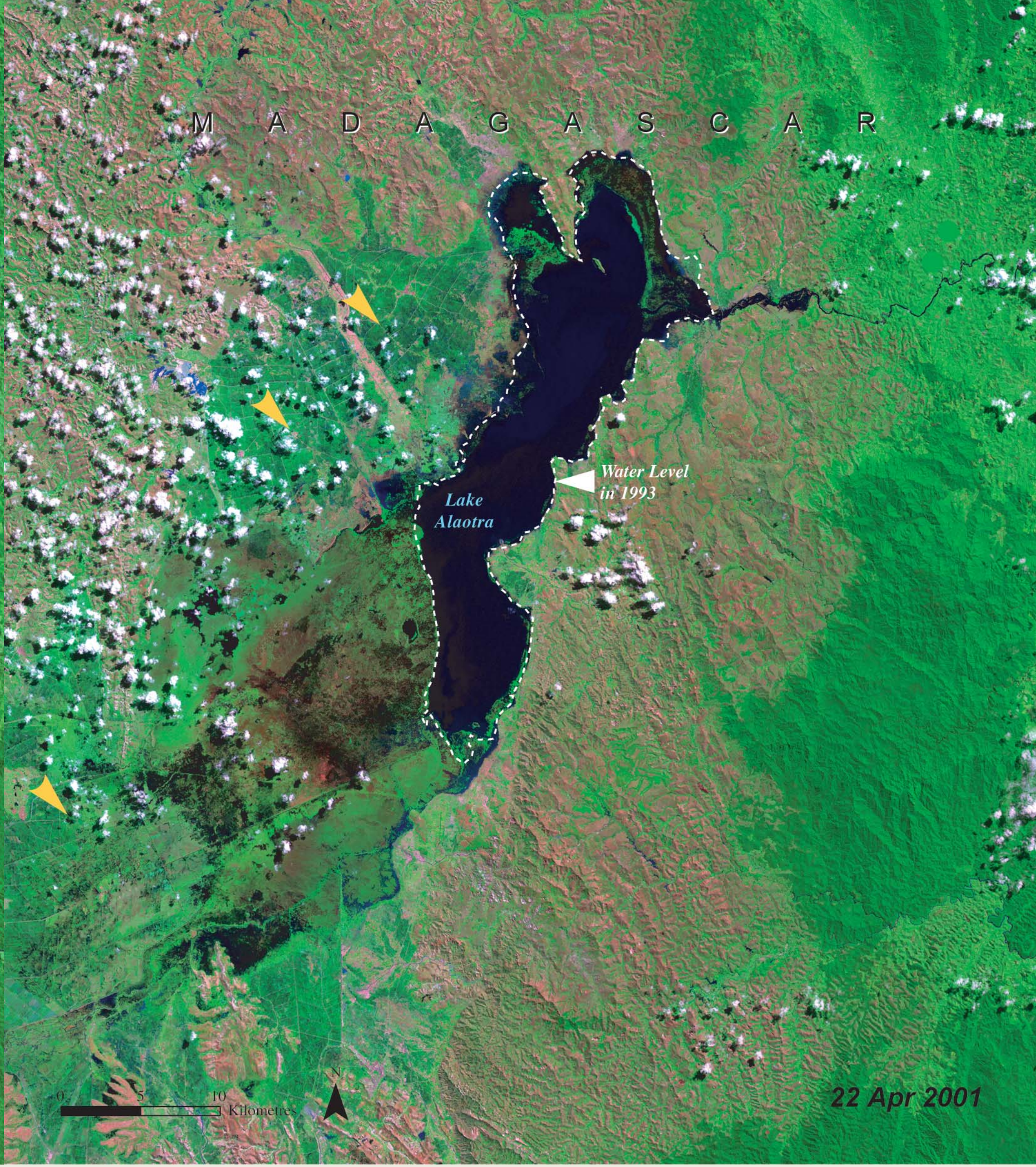

is also an important tourist center. These satellite images of Lake Kivu show dramatic changes before and after the eruption of Mt. Nyiragongo in January 2002. The 2003 image clearly shows the track of the lava flow, which traveled through Goma town and into the northeastern part of the lake, contaminating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





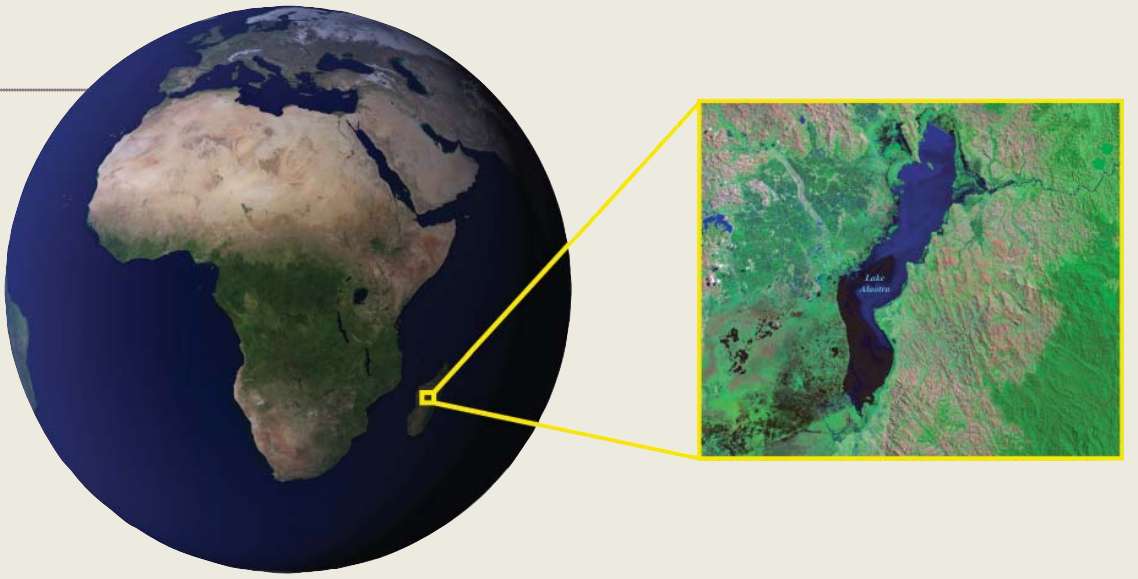
# Lake Alaotra
## Madagascar

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




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

# Lake Alaotra




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

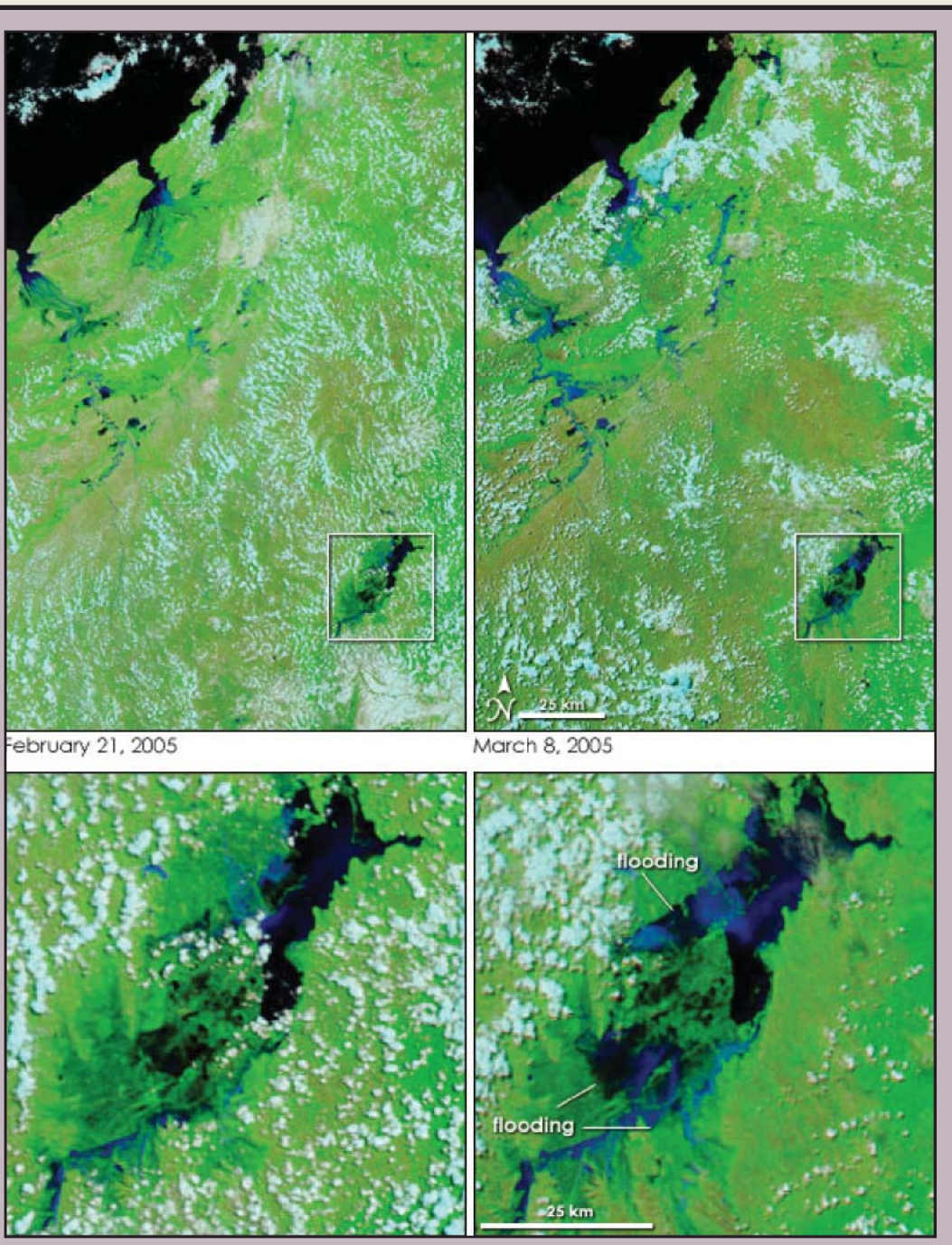
Although the hills surrounding Lake Alaotra were once completely forested, most have been cleared for farmland in the last few decades. Severe erosion on these vulnerable slopes has caused considerable sedimentation of the lake, which is fast disappearing; the lake is now only 60 cm (24 inches) deep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

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

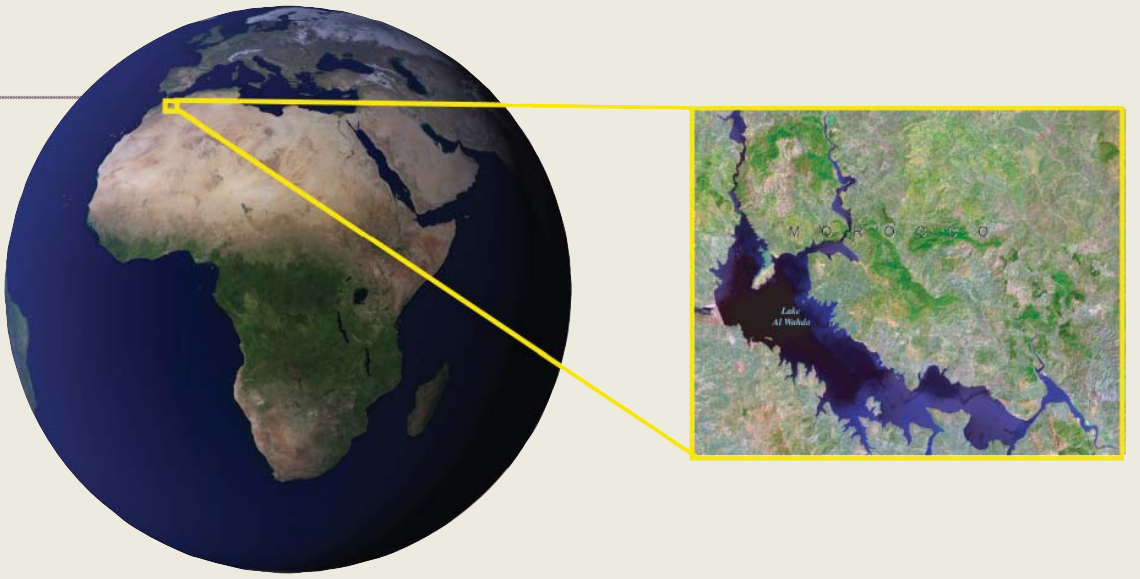
## Floods in Central Madagascar

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

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



# Lake Al Wahda




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

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

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

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

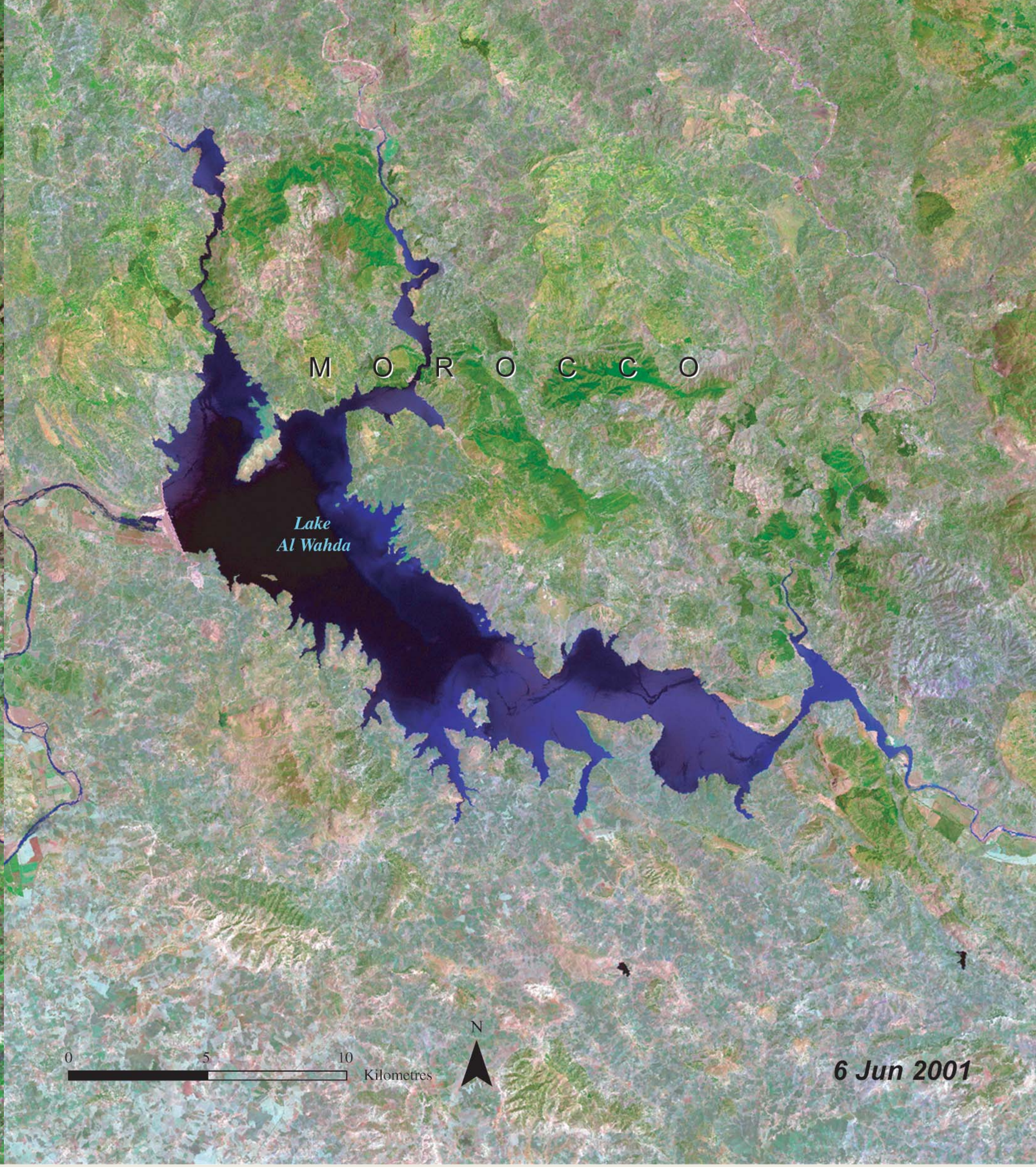
Riverbed in Atlas mountains, Morocco.

*Jason Webber/UNEP/MorgueFile*



# Lake Al Wahda
## Morocco

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




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

Chipera

MOZAMBIQUE

Zambezi River

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21 Nov 1972


# Lake Cahora Basa

## Mozambique

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


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