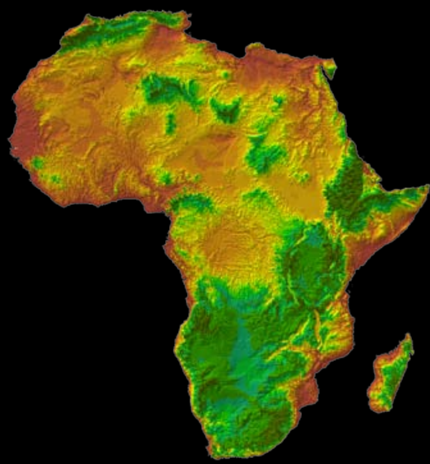
UNEP



AFRICA
Mountains Atlas

AMCEN UNEP




AFRICA

Mountains Atlas

AMCEN

NORWEGIAN MINISTRY OF FOREIGN AFFAIRS

UNIVERSITÄT BERN
CDE CENTRE FOR DEVELOPMENT AND ENVIRONMENT

UNEP

NEMA National Environment Management Authority — Ensuring Sustainable Development

Austrian Development Cooperation

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

BOKU

Swiss Agency for Development and Cooperation SDC

ARCOS NETWORK

ISBN: 978-92-807-3406-5

Job Number: DEP/1829/NA

United Nations Environment Programme
PO Box 30552, Nairobi 00100, Kenya
Tel: +254 20 7621234
Fax: +254 20 7623943/44
http://www.unep.org

For bibliographic and reference purposes this publication should be referred to as:

UNEP (2014), *Africa Mountains Atlas*. United Nations Environment Programme (UNEP), Nairobi.

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

Printed by Progress Press Ltd, Malta

Distribution by Earthprint, Ltd, UK

Figures

Tables

Boxes

Foreword

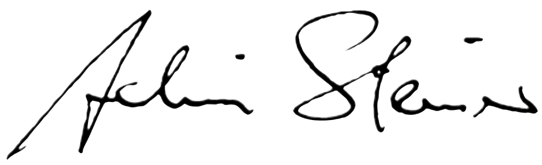
This Atlas impresses upon us the critical importance of Africa's mountainous areas on a continent known better for its vast plains. Millions of people live in highland areas where it is cooler, wetter and often more fertile, and millions more depend on the water that flows from these "water towers" to places that otherwise would be too dry to support a large diversity of life forms. This message alone alerts us to the crucial need to protect Africa's mountains for its people, its wildlife and its economies.

This publication is another in UNEP's series of Atlases of Our Changing Environment, in which vivid satellite images of landscapes past and present reveal the state of our planet. It follows and complements the Africa Atlas, the Africa Water Atlas and the Africa Lakes Atlas. It is in keeping with UNEP's commitment to disseminate and share evidence-based environmental information and raise public awareness on critical and emerging environmental issues, a goal that was strengthened, at the United Nations Conference on Sustainable Development (RIO +20) and as reflected in its outcome document "The Future We Want".

Rio + 20 specifically recognized the importance of mountains, especially their role in providing water and as centres of biodiversity. This Atlas reveals facts about Africa's mountains that can only be ignored at our peril. For example, it shows clearly how water, which is critical to people in the region, is collected, stored and released in its mountainous regions. Montane forests need further protection and replenishing to continue to provide this vital ecosystem service as well as act as a habitat for rich but increasingly threatened biodiversity. The immense amounts of water stored by Africa's mountains also need to be protected and wisely used, including as future sources of clean energy on a continent with limited electricity supply.

We know that agriculture represents a significant proportion of most African economies and the Atlas stresses that much of it takes place in highland areas where rainfall is abundant and soils fertile. As well, in many African countries, mountain tourism brings in significant revenues from hiking and wildlife viewing. It is also worth noting that the average population density in land that rises above 1 500 m is more than triple that in Africa's lowlands and highland populations are growing. Collectively countries should strengthen relevant national policies and legislation, bolster transboundary agreements and build local capacity to protect and restore Africa's mountain habitats. This is one of the key ingredients in a recipe to sustain African economies and provide opportunities for poverty eradication.

Finally let me draw the attention of decision makers to Chapter 5 of this Atlas, which provides a wealth of information on actions required to achieve important goals that carry the promise to put the region on the path to sustainable development.



Achim Steiner

UNEP Executive Director and

Under-Secretary-General of the United Nations

Africa's environmental assets are the primary drivers of its economic development, and life, livelihoods and national security depend on the continued availability and integrity of the continent's natural resources. The African Ministerial Conference on the Environment (AMCEN) is dedicated to ensuring environmental protection in Africa so that basic human needs are met, social and economic development is realized at all levels, and the region's food security requirements are fulfilled.

AMCEN continually guides Africa's progress towards achieving previously agreed goals, including the Millennium Development Goals and implementing the conventions established further to the United Nations Conference on Environment and Development (Earth Summit) in 1992, as well as agreements reached during the United Nations Conference on Sustainable Development (Rio+ 20). In particular, AMCEN leads the implementation of the environmental action plan for the New Partnership for Africa's Development (NEPAD). To inform these and other initiatives, the Ministerial Conference is committed to monitoring and reporting on the state of Africa's environment and has adopted UNEP's *Africa Environment Outlook* (AEO) as its key instrument.

In keeping with this commitment, AMCEN is pleased to contribute to reporting on the state of Africa's mountains through the publication of this important Atlas. It recognizes the immense contribution that Africa's mountains make to economic and human development and the need to value the ecosystem goods and services that mountain provide, which are essential to achieving the development agenda that the region has set for itself. Key among these is the role they play as water towers and agricultural areas. This is indeed echoed in the Gaborone Declaration of AMCEN which calls for strengthening capacity in research and evidence-based knowledge, creation of awareness, formulation of adequate laws, policies and institutions on mountains, including adopting transboundary and regional frameworks on sustainable management of African mountains ecosystems,

I would like to underscore the Atlas's concluding message, which calls for a framework to set and guide an African mountains agenda that creates a firm basis to buttress their management in an efficient, integrated, harmonized and sustainable manner.

Armed with the invaluable information contained in this Atlas, AMCEN's members, who are ministers responsible for the environment in the region, are well placed to be part of a process that creates this enabling framework. They will need to collaborate with colleagues in all other sectors, since mountain resources and peoples are represented in a wide spectrum of economic and social arenas. The excellent examples of available opportunities to overcome challenges related to poverty, food and energy insecurity, fragile mountain ecosystems, growing populations, lack of land availability, erosion of landscapes, climate change and rapid global development, among others, are especially relevant and should be utilized.

The main messages in the Atlas are well aligned with AMCEN's goal to enhance regional cooperation in environmental policies, strengthen technical and scientific activities to address environmental degradation and to protect natural resources.

I highly recommend this Atlas to all AMCEN's members, its partners and all decision makers who share the aspiration to promote further progress towards sustainable development in Africa.

I wish you all an informative and pleasant reading.

Dr. Binilith Satano Mahenge

Minister of State for Environment, Office of the Vice-President, United Republic of Tanzania and President of AMCEN

Sunrise on Mount Kilimanjaro, United Republic of Tanzania

Mountains are among Africa's most dramatic landscapes. They rise above and stand in stark contrast to its vast plains teaming with wildlife. Admired and protected for their beauty, mountains are also vital to Africa's 1.1 billion people because of their ecosystem goods and services. Africa's mountains are water towers, providing water for domestic, industrial, irrigation and hydropower uses. They are also the breadbaskets for highland and lowland communities. They are sites of food production, forest products, minerals, tourism, sacred places, wildlife habitat and biodiversity conservation, among many other important assets.

They are thus critical in the transition to a green economy, supporting sustainable development and poverty alleviation as the region strives to move towards a low carbon, resource-efficient and more equitable future. Although extremely important to the whole continent, they are increasingly vulnerable to environmental change. With uncertainties created by climate change, high population growth and land use change, urgent political action is needed to foster the enabling conditions to increase funding and investment in sustainable mountain development in Africa.

International agenda for mountain protection

In the international agenda, the concept of mountain protection was first introduced in Agenda 21, a 40-chapter programme of action that was the outcome of the 1992 United Nations Conference on Environment and Development (UNCED). Chapter 13 of Agenda 21 specifically recognizes the important ecological, economic and social functions of, and services provided by, mountainous regions. As a follow up by its resolution 53/24, the UN General Assembly proclaimed 2002 as the **International Year of Mountains**, with the objective of raising international awareness about mountains, their global importance, the fragility of their resources and the necessity for sustainable approaches to mountain development. In 2002, during the "UN International Year of Mountains," the UN General Assembly designated 11 December, from 2003 onwards, as "**International Mountain Day**." Furthermore, the Mountain Partnership was founded by the Governments of Italy and Switzerland, FAO and UNEP and launched at the World Summit for Sustainable Development in Johannesburg, South Africa, in 2002.

Twenty years after the Rio conference, mountains and their communities gained renewed global political attention at the UN Conference on Sustainable Development, popularly known as **Rio+20,** which was held in Rio de Janeiro from 20 to 22 June 2012. Its outcome document, "The future we want", contains three paragraphs (210-212) dedicated to mountains.

In Africa, a step towards cooperative action and the creation of collaborative platforms for sustainable mountain development was taken at a regional meeting for African mountain regions held in November 2011 in Mbale, Uganda. By stimulating dialogue and experience-sharing, the meeting laid the foundations for an African process of consultative and planning meetings aimed at advancing an agenda for action on sustainable mountain development and a constituency to support it. The meeting called for the identification of options to establish an "African mountain hub" in the form of a specialized centre for knowledge and capacity building, information-sharing, networking, awareness creation, communication and advocacy.

Chapter summaries

The Atlas is organized into five chapters. Throughout, the narrative comes alive through the dramatic use of satellite imagery and photos. They are used to great effect by depicting environmental change through image sequences of the same place from the past to the present. Graphs, maps, diagrams and tables also help to visually illustrate the key messages.

nyctosf / Foter / CC BY-NC

Chapter 1: Africa's Mountains

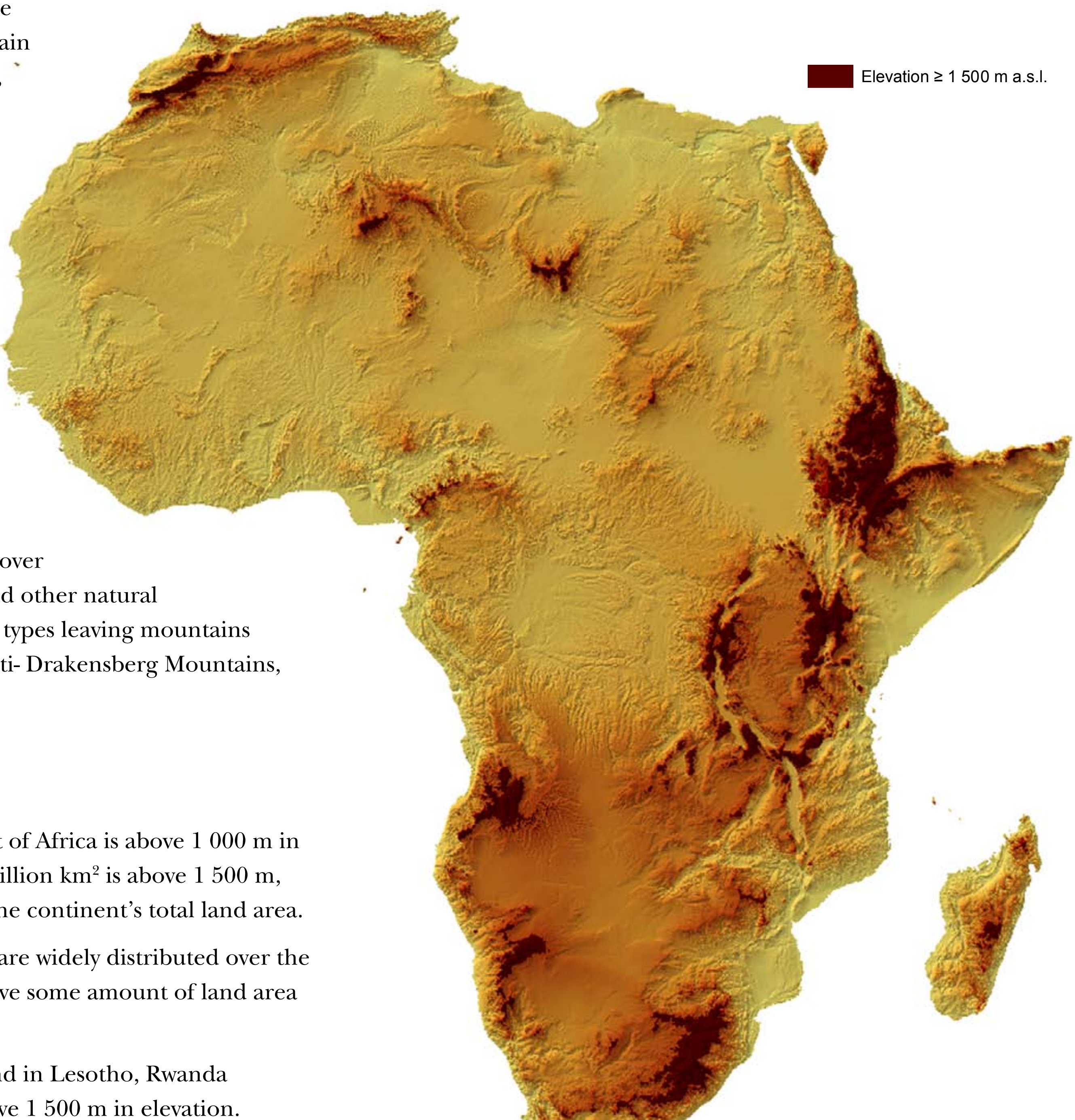
The first chapter familiarizes the reader with Africa's mountainous landscapes. It provides context through maps of their distribution, definitions of mountain and rock types and a simplified geologic time scale. These reference tools allow readers to situate the region's mountains and their formation in time and space and understand the processes that account for the geology and soils of which they are composed.

The chapter describes several of Africa's key mountainous areas, providing information about their location, extent, formation, geology, major peaks, altitude, climate, minerals, vegetation, other important features as well as ecosystem goods and services.

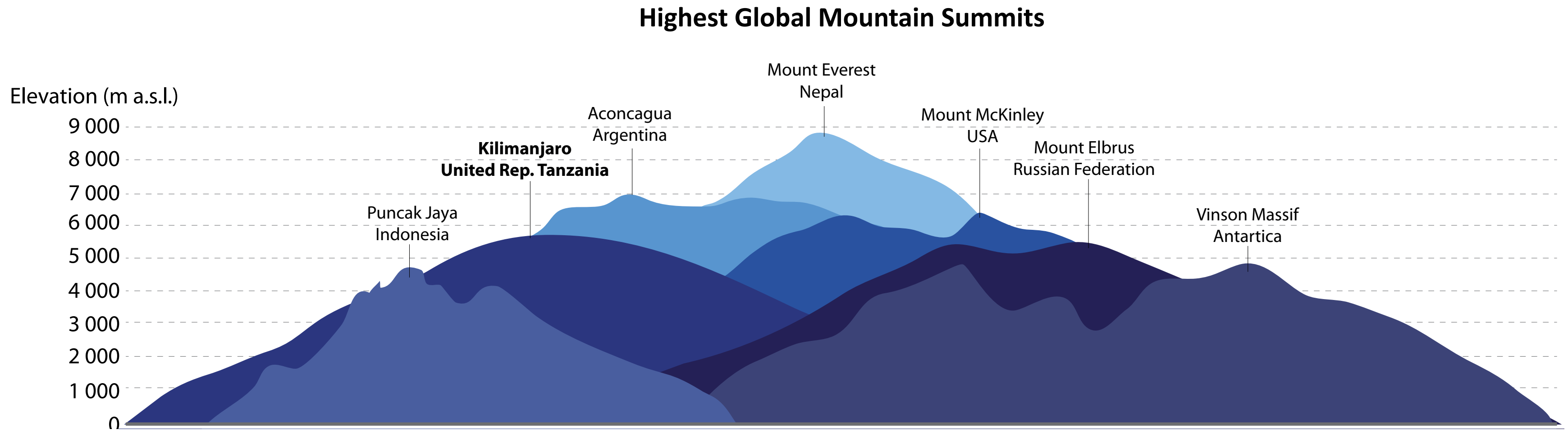
The supercontinent Pangaea began to break up approximately 225 – 200 million years ago (Ma), resulting in two land masses: Laurasia and Gondwanaland. The ensuing break-up of Gondwanaland that began about 165 Ma, and continues today, accounts for the formation of some of Africa's main mountain systems. For example, the collision of the African and European plates during the Cenozoic era crumpled their edges into the high folds of northern Africa's Atlas Mountain range. Other African mountains, such as the Rwenzori range, are younger, formed between 5 and 2 Ma from uplift, while volcanic activity formed other mountains, including its largest and tallest—Mounts Kilimanjaro and Kenya. Finally, over millions of years, rivers, wind and other natural processes eroded different rock types leaving mountains such as the transboundary Maloti- Drakensberg Mountains, standing between valleys.

Key Facts

- Approximately 20 per cent of Africa is above 1 000 m in elevation and nearly 1.5 million km^2 is above 1 500 m, comprising 5 per cent of the continent's total land area.
- Mountains and highlands are widely distributed over the continent: 37 countries have some amount of land area above 1 500 m.
- All, or nearly all, of the land in Lesotho, Rwanda and Burundi lies at or above 1 500 m in elevation. Mountainous areas in these countries include the Maloti Mountains in Lesotho (Mount Thabana Ntlenyana at 3 582 m), Rwanda's Mount Karisimbi (4 507 m) in the Virunga chain and Mount Heha in Burundi (2 670 m).
- Mountains that rise above 4 500 m are concentrated in the northwestern, central and eastern regions.
- Africa's three highest peaks are found on Mount Kilimanjaro (5 895 m), Mount Kenya (5 199 m) and in the Rwenzori Mountains (5 109 m).
- The major mountain ranges, which can extend over hundreds of kilometres, are the Atlas, Rif, Drakensberg, Cape and the Eastern Arc Mountains.
- Africa's main block mountains, horsts or massifs, which are large, coherent units displaced along fault lines, include the Tibesti massif in the Sahara Desert (Emi Koussi at 3 394 m), the Aïr massif in Niger (Idoukal-n-Taghès at 2 022 m), the Tsaratanana massif in Madagascar (2 876 m) and Ras Dashen in Ethiopia (4 620 m).



USGS Digital Elevation Model



Peaklist. (2008). Prominence Lists and Maps Index. Retrieved March 6, 2014, from Peaklist: http://peaklist.org/lists.html

Chapter 2: The Dynamics of Africa's Mountain Ecosystems

This chapter describes the dynamics of ecological goods and services in Africa's mountainous landforms. They are fundamental in providing water; supporting forests, agroforestry, non-timber forest products and agriculture; harbouring biological diversity; providing tourism opportunities; and respected as sacred places, among other services. It also looks at opportunities to generate income from Payment for Ecological Services (PES) such as carbon sequestration. The material is organized by region—Northern; Western; Central; Eastern; and Southern Africa and the Western Indian Ocean Islands.

Key Facts

- Generally, mountainous areas in Africa receive more rain than adjacent lowlands. They act as water towers, supplying crucial water resources to places that would otherwise be too dry to support life. They capture water, store it in glaciers, snow and groundwater, purify it and release it to lowland areas. For example, mountain waters feed some of Africa's major transboundary rivers, including the Nile, Senegal and Orange, which flow from high rainfall areas to dry lowlands. Africa's major water towers include the Middle Atlas range, the Fouta Djallon Highlands, the Jos Plateau, the Ethiopian Highlands, the Kenyan highlands, the Angolan Plateau, the Lufilian Arc and the Lesotho Highlands. Such water towers supply vital water resources to some of Africa's major cities, including Nairobi, Dar es Salaam, Johannesburg and Marrakech.
- Africa's mountain areas harbour rich biodiversity of high conservation value. Because of their vertical rise and rapid changes in vegetation, mountains host a rich diversity of ecosystems. From the lowest to the highest levels, vegetation cover can include montane forests, a belt of bamboo, low canopy montane forest, and high montane heath followed by moorland, with changes occurring within short distances along their slopes. Rich species diversity also exists within these habitats, including many species that thrive nowhere else. For example, the Albertine Rift is home to more than 7 500 plant and animal species, of which 1 175 are endemic. Africa's tropical mountain areas contain higher levels of species richness and biodiversity than other areas in sub-Saharan Africa.
- Africa's mountainous areas are extremely important for agricultural production. Abundant rainfall, as well as suitable location, altitude and soils generally make many highland areas throughout the region the primary places to practice agriculture. Agriculture includes subsistence crops and livestock as well as important cash crops that thrive in cool mountain climates, such as tea and coffee.
- Africa's montane forests are significant sources of important goods that support local economies. Montane forests, agroforestry practices and afforestation initiatives provide wood for fuel, construction and other timber products, and help to conserve or regrow mountain woodlands and prevent erosion. In addition, non-timber forest products, such as wild food, fodder, medicinal plants, fibres, gums, sap, cane, resins, etc. harvested from mountain forests are important to local livelihoods.
- Tourism ranks as one of the main industries in many African nations, and mountains are favoured destinations. Examples include tourism on Mount Kilimanjaro in the United Republic of Tanzania, which generates US$50 million a year; the potential for future tourism revenues to reach US$235 million per year from direct access to Virunga National Park; and primate viewing in the Mgahinga Gorilla National Park (MGNP) in Uganda, which brought in over US$300 000 in 2010.

Chapter 3: Impacts on Africa's Mountains

Chapter 3 describes the natural forces and human activities that affect Africa's mountain environments and influence their ability to perform ecological functions and supply essential goods and services. It highlights hotspots of environmental change using satellite-image sequences to show marked landscape alteration over time.

Natural impacts

The first section looks at the impacts of earthquakes, volcanoes and landslides that occur in mountainous areas and dust storms that take place because of conditions related to mountains. Landslides happen in areas of high rainfall, significant rock weathering and high rates of deforestation. Mount Elgon, which straddles the boundary between Kenya and Uganda, is a hotspot for landslides, which are increasing due to heavy rainfall, growing populations and forest clearing.

Key Facts

- About 27 per cent of Africa's mountainous areas are susceptible to destructive earthquakes.
- Seismic activity occurs mainly in northern Africa at the border of the African and Eurasian plates, mostly along the Atlas Mountain range and in southeastern Africa in the East African Rift Valley.
- Volcanoes are primarily concentrated along the East African Rift, stretching from Djibouti in the north through Ethiopia and Kenya to the United Republic of Tanzania in the south.
- Landslides occur in mountainous areas, including those of Cameroon, Kenya, Uganda and Malawi, causing damage to property, affecting livelihoods and eroding large volumes of soil.
- Few glaciers remain on Mount Kenya, Mount Kilimanjaro and the Rwenzori Mountains.

Human impacts

The second part of Chapter 3 describes human impacts on fragile mountain ecosystems. Increasing population numbers and densities are a major driving force of environmental change. Pressures from increasing human activities in these regions include deforestation for agriculture, fuelwood and timber; settlements; dam construction; mining activities; fire; tourism; and illegal encroachment and poaching. Secondary impacts from these activities include biodiversity loss, erosion, siltation of water courses, land degradation, fires and conflict over resources.

Africa's montane forests continue to be lost to agriculture and other uses at significant rates across Africa's mountain areas. Deforestation in mountains can cause more damage than in gentler topography because logging roads, infrastructure and vehicles disturb the unstable soils on steep slopes, causing erosion.

Key Facts

- The average population density for areas with an elevation of 1 500 m or above is more than triple that in the lowlands (105 persons/km^2 compared to 31 persons/ km^2), while some mountains have even higher densities and others have no inhabitants at all. High and increasing population density is a major driving force of environmental change in Africa's mountainous areas.

The Katse Dam, part of the Lesotho Highlands Water Project

- Dams are necessary for harnessing water and power resources in Africa, but can be socially and environmentally detrimental. The Lesotho Highlands Water Project, for example, is an extremely important source of water that serves industries and settlements in Lesotho and South Africa. However, the project is reported to have raised numerous environmental and social concerns. In other areas, such as the agricultural communities of northern Africa, dams capture water from the Atlas Mountains to supply the dry lowland areas with adequate water for agriculture and consumption.

Chapter 4: Protecting Africa's Mountains

This chapter provides a broad overview of the existing policy and legal frameworks for managing mountains at global, continental, national and community scales. The chapter also uses satellite-image change pairs to highlight positive or negative changes demonstrating that such measures must be enforced and respected to be effective.

Several national and regional policies and laws exist, but there continues to be an urgent need for regional collaboration to develop and enforce protection measures for Africa's mountainous areas to ensure the continued viability of their functions for the benefit of the entire continent and its inhabitants.

Areas protected by international designations include World Heritage Sites. Of these, some protected areas such as the Aïr and Ténéré Natural Reserves and the transboundary Mount Nimba Strict Reserve, are now on the List of World Heritage in Danger, prompting the need for increased awareness and protection.

At regional levels, there are also some efforts to protect mountain forests. Numerous mountain ecosystems stretch across borders between African nations, motivating the countries that share the mountain resources to enter into cooperative management agreements. For example, a set of contiguous transboundary protected areas covers the Central Albertine Rift, requiring collaboration to manage this network of parks, guided by the 10-year strategic plan under the Albertine Rift Transboundary Agreement (ARTA). This chapter also highlights transboundary efforts to resolve unsustainable land use in adjacent areas, which threatens shared mountain ecosystems in many transboundary protected areas. Transboundary protection of the Central Albertine Rift also extends to protecting the mountain gorilla. The last remaining wild populations of mountain gorilla (*Gorilla beringei beringei*) reside in the Virunga Mountains of the DRC, Rwanda and Uganda and in the Bwindi Impenetrable National Park in Uganda. They are critically endangered by human activities. Joint management of the protected areas, however, is helping to increase their populations.

One of the most important national-level mechanisms is the designation of parks, reserves and other wilderness areas that are governed by rules limiting human activities. Several of Africa's UNESCO World Heritage Sites, named for their outstanding universal value as natural or cultural sites, encompass mountain ecosystems. The chapter highlights the Mau Forest Complex in Kenya as an essential water tower and the Simien Mountains National Park in Ethiopia. In the latter, designation as a National Park has helped to reduce some agricultural pressures on the land, although it remains on the List of World Heritage in Danger.

Mountain forests are often protected at the community level through sustainable and participatory forest management approaches, using traditional indigenous knowledge. This chapter highlights some of these exemplary efforts through case studies, including *Agdal* forest management in the High Atlas Mountains of Morocco and community forest management in Kilum-Ijim Forest in the mountains of Cameroon.

Key Facts

- Many sectoral policies related to forestry, water, agriculture, etc. incorporate mountain issues, but they are rarely tailored to the unique conditions or needs of mountain areas.
- Of Africa's 468 National Parks, 125, or about 27 per cent are found in the mountainous areas of 26 different countries.
- Social groups and mountain communities are often successful in protecting forest resources using traditional and participatory approaches.

Chapter 5: Challenges and Opportunities

This chapter examines the growing challenges Africa faces in ensuring the sustainable development of mountain areas. These include poverty, ecosystem fragility, a fast-growing population, climate change and rapid global development. Amid these challenges, there are clear opportunities for African nations individually, regionally and internationally to improve human and environmental conditions in their highland regions.

Key Challenges

- Poverty can lead to overexploitation of resources that mountain communities depend upon to support their livelihoods.
- Agricultural productivity and food production in Africa's mountains is constrained in various ways that affect food security.

- The numerous pressures facing mountain ecosystems means that both financial and human resources are required to manage these assets, but mobilizing and prioritizing financial resources to invest in developing mountain areas is still a major challenge in Africa.
- The region has limited electricity supply leading to low levels of access to energy. Only 4 to 8 per cent of Africa's hydro capacity is developed and it has the lowest per-capita energy consumption of any continent. There is insufficient capacity to harness the considerable volume of available water resources to develop the energy required in the region.
- There is high pressure on water and land resources and a notable lack of legislation to guide mountain development and sustainable use of these resources.
- The full participation of both men and women in development activities in mountain areas needs to be ensured to achieve gender equality.
- Mountainous regions will be affected by the impacts of a changing climate and will need to learn to adapt to changing conditions. African nations will need to develop and support policies, investments and activities that build the adaptive capacities of human and wildlife mountain populations.

Key Opportunities

- Tackle mountain poverty by addressing its multidimensional nature, distributing mountain resources equitably and supporting indigenous knowledge and investments in greening the economy.
- Prioritize financing environmental management in mountain areas; use a multi-sectoral approach, corresponding to the multitude of ecosystem services that mountains provide in various interlinked sectors such as energy, water and food security.
- Introduce sustainable land management approaches, including soil conservation, retention, agroforestry and other techniques, and foster awareness of their importance among local people.
- The immense amounts of water stored by Africa's mountains are a potential source of clean energy. Rivers with headwaters in these mountains and highlands have untapped potential as sources of hydroelectricity. It is imperative to develop hydropower in Africa's mountains, which would significantly contribute to energy security, poverty alleviation, improved health, increased productivity, enhanced competitiveness and economic growth.
- Invest in agriculture and improve land tenure in rural mountain areas where the majority of the population lives. Support agricultural research and development, including climate-smart agriculture, to increase agricultural productivity.
- Increase investments in highland tourism, taking advantage of the clean air and attractive scenery, and take the opportunity to invest in sports tourism by developing high-altitude training centers for athletes.
- Develop gender-equitable laws, policies and programs that facilitate the participation of mountain women in development initiatives.
- Take advantage of mountains as sensitive indicators of global climate change and support research on its impacts; provide early warning and improve existing data and environmental monitoring networks.
- Support policies, investments and activities that build capacity among mountainous human and wildlife populations to adapt to the impacts of a changing climate.

Conclusion

While Africa's mountain populations face many challenges, there are also countless opportunities to accommodate growing populations and address environmental issues to ensure future sustainable development. A framework is needed to set and guide the mountain agenda for Africa. There is an evident lack of enabling institutional, policy and legal frameworks to guide mountain development, which is a major hurdle to achieving sustainable development in mountain areas at national, sub-regional and regional levels. A constituency of all sectors of society is also needed to buttress such an agenda in an efficient, integrated and harmonized manner.


Flight paths over Africa's mountains at night

NASA / Anton Balazh / Shutterstock

Africa's Mountains

1

Africa is endowed with dramatic landscapes. Most vivid in our minds, no doubt, are its vast plains teeming with wildlife. Rising above them in stark contrast are its no less impressive mountains. Its most iconic mountains include the ice and snow-capped Mount Kilimanjaro, while massive blocks of highlands define the vast East African Rift Valley, including some of its highest mountains on the edges of the western branch. Thus, mountains are significant geographical features in Africa, representing unique landscapes from rolling hills to high mountain peaks. More than 20 per cent of Africa has an elevation above 1 000 m (Messerli, et al., 1988) and about 5 per cent rises above 1 500 m; these mountainous regions account for almost 1.5 million km^2 of land across 37 countries (GIS analysis UNEP/GRID). Admired and protected for their wild character and beautiful scenery, mountains are also vital to many of Africa's 1.1 billion people because of the ecosystem goods and services they provide. These include water and food, rich biodiversity, recreational areas and important centres of cultural integrity and heritage (UNEP, 2006; UNDESA, 2013; FAO, 2000). Mountainous streams and rivers, for example, are a source of hydropower, indirectly benefiting over 40 per cent of the population (Kollmair, Gurung, Hurni, & Maselli, 2005; Macchi & ICIMOD, 2010). In many parts of Africa, mountains are sacred, providing both spiritual values and protection. The Atlas Mountains, Ethiopian Highlands, Fouta Djallon Highlands, Eastern Arc Mountains and the Drakensberg are some of Africa's major mountain areas, while Mounts Kilimanjaro and Kenya are its most charismatic peaks. Notably, some of Africa's smallest countries have the highest coverage of mountainous areas, including Lesotho, Rwanda and Burundi, have all, or nearly all, of their land area at or above 1 500 m in elevation.

This first chapter provides context for the Atlas by including maps of the distribution of Africa's mountainous areas, tables with definitions of mountain and rock types and a simplified geologic time scale. These reference tools allow readers to situate Africa's mountains and their formation in time and space and understand the descriptions of the rocks and soils of which they are composed. The narrative describes the physical characteristics of Africa's mountains, leaving future chapters to show how these important ecosystems provide life-supporting goods and services for millions of people on the African continent.


Tizouyags, Ahaggar Mountains, Algeria

Chapter Highlights

- Geologic processes such as plate tectonics, volcanic activity and erosion have formed and shaped the many mountain ranges, highland regions and escarpments that can be found in 37 of Africa's countries.
- More than 20 per cent of Africa has an elevation above 1 000 m, with nearly 5 per cent above 1 500 m, accounting for about 1.5 million km^2 of land.
- Lesotho, Rwanda and Burundi have all, or nearly all, of their land area 1 500 m or above in elevation.
- The United Republic of Tanzania, Kenya and Uganda are home to Africa's three tallest mountains—and its only mountains with glaciers—Mount Kilimanjaro, Mount Kenya and the Rwenzori Mountains.

What is a Mountain?

A mountain can be most simply defined as an elevated area of land that rises above its surrounding lowlands. Furthermore, thresholds of elevation (altitude), slope, area, prominence and even importance to the imagination, can also be used when refining the definition of a mountain (Byers, Price, & Price, 2013).

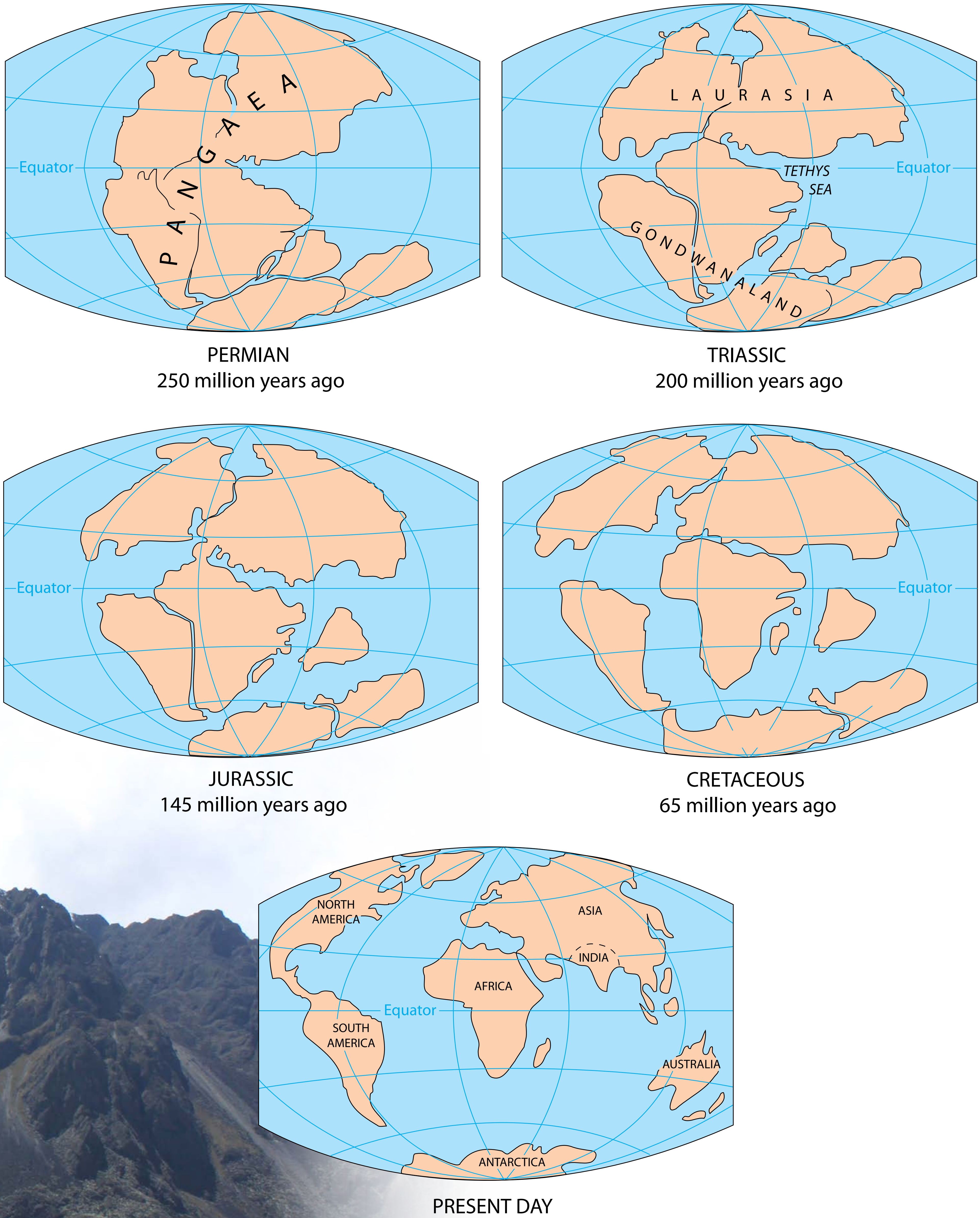
The elevation of mountains in Africa can range anywhere from about 300 m, such as Demuni Mountain in Ghana (345 m), to nearly 6 000 m, like Mount Kilimanjaro in the United Republic of Tanzania (5 895 m). For the purposes of this Atlas, any area of land that rises 1 500 metres above sea level (m a.s.l.) will be discussed as a mountainous area.

The Creation Story: Plate Tectonics and Mountain Formation

According to Alfred Wegner's continental drift theory, the world's present-day continents used to be one large super continent called Pangaea. About 225 - 200 million years ago (Ma), Pangaea began to break up and split into two main land masses: Laurasia in the northern hemisphere and Gondwanaland in the southern hemisphere. These two landmasses continued to break into smaller continents and move apart, eventually becoming what we know today (Kious & Tilling, 1996; Figure 1.1). Gondwanaland was made up of present-day Africa, South America, India, Madagascar, Australia and New Zealand (TPWS, 2010).

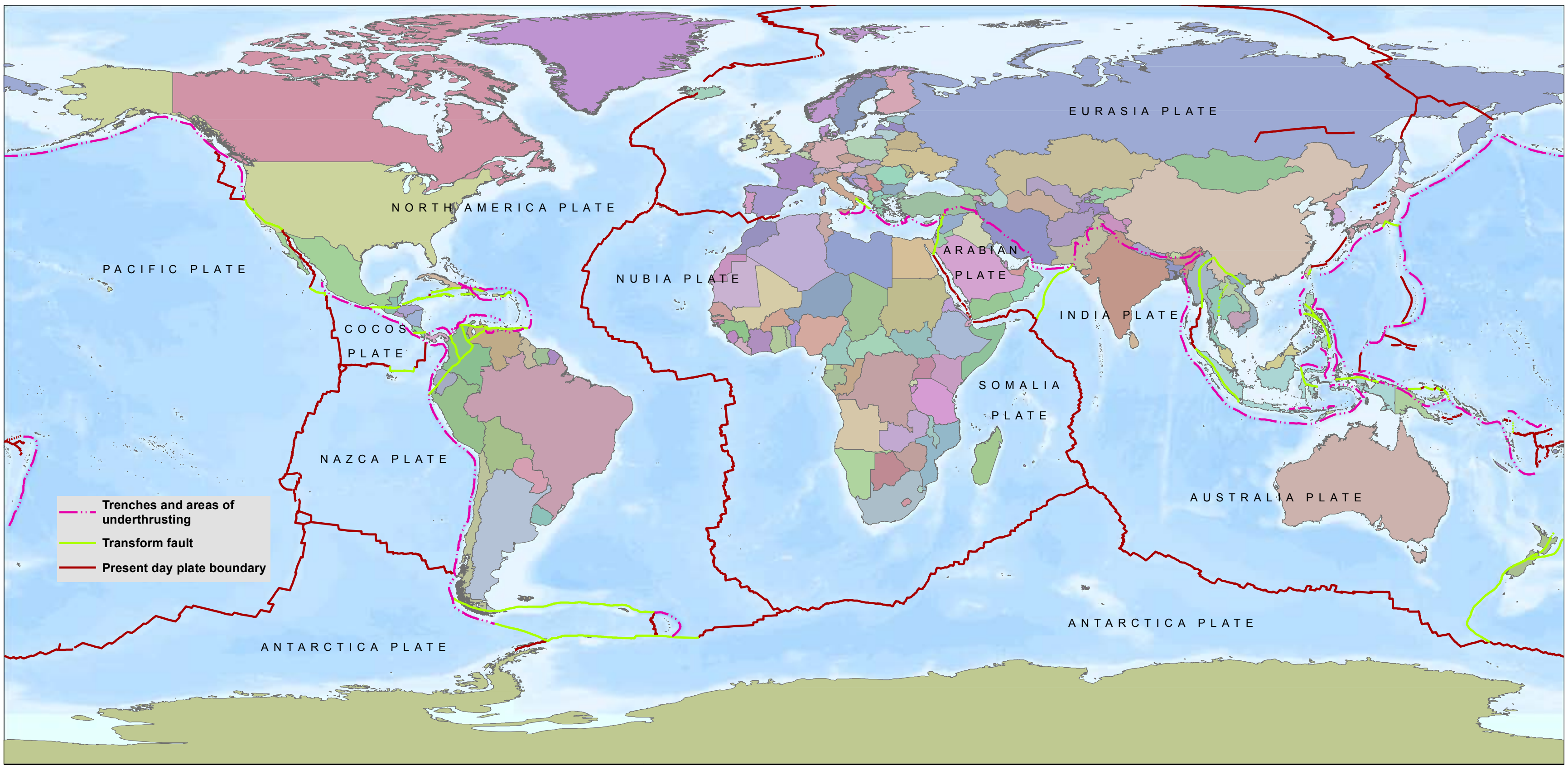
Rwenzori massif

Figure 1.1: Break-up of Pangaea over time



Source: Kious & Tilling, 1996

Figure 1.2: Present day plate boundaries



Source: data from Coffin, Gahagan, & Lawver, 1998; labels from Simkin, et al., 2006 ; UNEP/DEWA

Top Photo: Granite cliffs in Madagascar (IamNotUnique / Flickr / CC BY-NC-SA)

Middle Photo: Folded quartzite in the Cape Fold Belt, South Africa (Brian Roman / Flickr / CC BY-NC-SA)

Bottom Photo: Sandstone outcrop in Golden Gate Highlands National Park, South Africa (Andrew Ashton / Flickr / CC BY-NC-ND)

Box 1.1: Definition of rock types

Igneous rock – Rock formed when magma cools and solidifies and has not been changed much by weathering; major varieties include plutonic (such as intrusive) and volcanic (such as extrusive) rocks. Examples: andesite, basalt, granite.

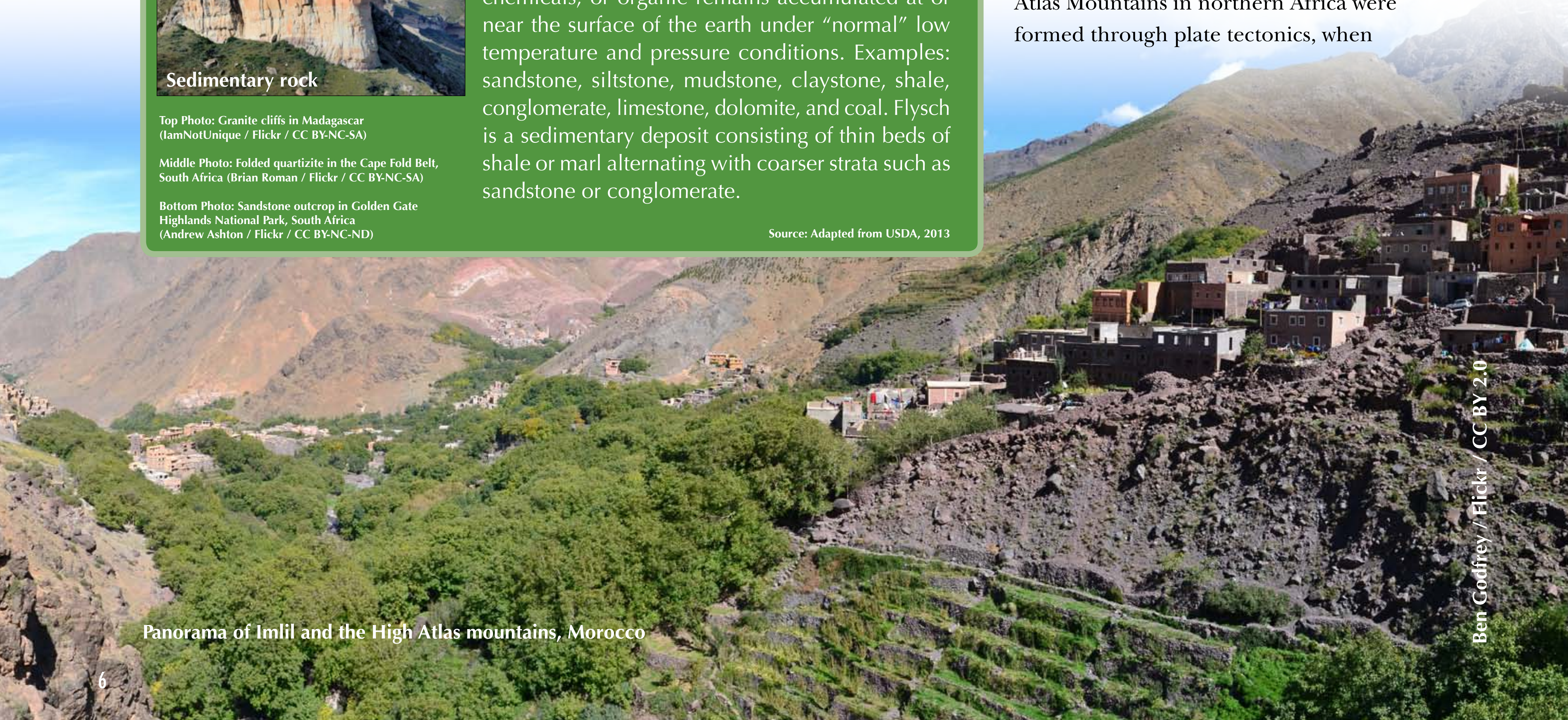
Metamorphic rock – Rock of any origin whose mineral or chemical composition or structure has been altered by heat, pressure and movement deep in the earth's crust. Nearly all such rocks are crystalline. Examples: schist, gneiss, quartzite, slate, marble.

Sedimentary rock – A consolidated deposit of clastic particles (rock or sediment composed mainly of fragments derived from pre-existing rocks or minerals and moved from their place of origin), chemicals, or organic remains accumulated at or near the surface of the earth under "normal" low temperature and pressure conditions. Examples: sandstone, siltstone, mudstone, claystone, shale, conglomerate, limestone, dolomite, and coal. Flysch is a sedimentary deposit consisting of thin beds of shale or marl alternating with coarser strata such as sandstone or conglomerate.

Source: Adapted from USDA, 2013

Approximately 165 Ma, Gondwanaland began to break up, causing volcanic activity and tensions in the earth's crust. The drifting and collision of the continental or tectonic plates produced present-day topographical features. They account for the rock geology in some parts of Africa, such as rifts in the earth's surface, the presence of igneous rock types (Box 1.1) in the southern regions and the underlying geology of mountain formations (TPWS, 2010).

Mountains are formed through processes such as tectonic activity, volcanic action, and erosion. For example, the Atlas Mountains in northern Africa were formed through plate tectonics, when



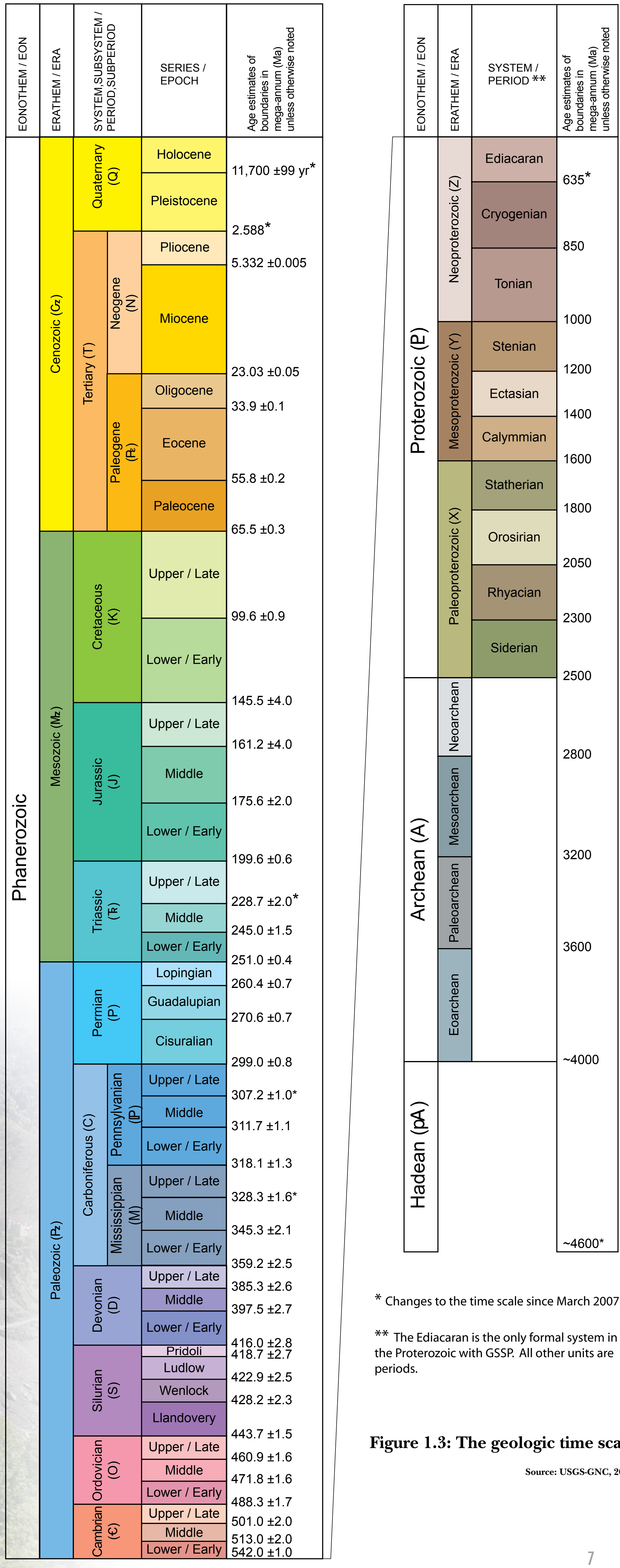
Panorama of Imlil and the High Atlas mountains, Morocco

Ben Godfrey / Flickr / CC BY 2.0

the African and European plates converged during the Cenozoic era (Ellero, Ottria, & Ouanaimi, 2012). The enormous impacts of colliding plates caused the earth to crumple and fold like an accordion, causing high mountains, such as the Atlas Mountains, to form (Cain, 2009). Figure 1.3 shows the present-day position of plate boundaries. Mountains form along fault lines when two plates meet and move alongside one another causing blocks of the earth's crust to lift up and tilt over. One side is pushed upward and forms a mountain block, while the other slides downward and tends to fill with eroded material. The Rwenzori (Ruwenzori) Mountains in central and eastern Africa are an example of this faulting and uplifting. They are considered young in geological time, formed during the late Pliocene, less than 5 Ma (Eggermont, Van Damme, & Russell, 2009; Figure 1.2) and lifted to alpine heights approximately 2 Ma (Bussman, 2006). Some of the oldest of Africa's mountains are the Cape Ranges on the Cape Fold Belt, which formed on the Gondwanaland supercontinent before it broke up (Johnston, 2000). Figure 1.3 explains the geologic timeline.

Two of Africa's tallest mountains, Mount Kilimanjaro and Mount Kenya, are examples of those formed by volcanic activity. Magma and molten material erupted from under the earth's surface creating these volcanic mountains. It is believed that this occurred when the African and Eurasian plates rebounded after they collided, causing a weakness in the crust.

Finally, erosion, which occurs at varying rates depending on the hardness of the rock material, caused mountainous formations in other parts of Africa (USDA, 2013). Flowing water can erode or strip away sediment and transport it while disaggregating bedrock, forming mountains between river valleys. South Africa's Drakensberg Mountains, for example, were formed this way over millions of years as rivers, wind and other natural factors eroded high plateaus.



* Changes to the time scale since March 2007.

** The Ediacaran is the only formal system in the Proterozoic with GSSP. All other units are periods.

Figure 1.3: The geologic time scale

Source: USGS-GNC, 2010

Figure 1.4: Elevation map of Africa

Source: USGS 7.5 arc second maximum Digital Elevation Model (DEM); UNEP/DEWA

Types of Africa's Mountains

Three main types of mountainous areas are found in Africa: (1) mountain ranges and massifs, (2) deeply-incised gorges or escarpments and (3) highlands and plateaus (Messerli, et al., 1988). Examples of mountain ranges include the Atlas and the Rif in northern Africa, the Aberdare in eastern Africa and the Drakensberg and Cape in South Africa, while the Rwenzori and the Tibesti are classified as massifs. Volcanoes, such as Mount Kilimanjaro, Mount Kenya and Mount Cameroon, can also be a part of mountain ranges and massifs. Deeply incised escarpments that can accompany highland areas include the Nile Valley gorge in Ethiopia and the Rift Valley in the United Republic of Tanzania (Messerli, et al., 1988). Figure 1.4 is a map of Africa, showing elevation and mountainous areas. The mountains and highlands are widely distributed over the continent: those higher than 2 000 m are found in more than half of Africa's countries and those above 4 500 m are concentrated in the northwestern, central and eastern regions (Bagoora, 2012). Africa's highest peaks are mostly found in eastern and southern Africa on Mount Kenya, Kilimanjaro and the Rwenzori massif.

A mountain range (Box 1.2) is part of a mountain system in a geographic area; ranges are generally geologically young, some made up of mainly Cretaceous and Tertiary sediments of sandstones, limestone and clay, while others are made up of old Precambrian material (National Geographic, 2013). Typically, they can extend hundreds of kilometres and plate tectonics and

Box 1.2: Key terminology

Craton – A part of the earth's crust that has attained stability and has been minimally deformed for a prolonged period.

Block mountain or fault-block mountains – Mountains formed primarily by block faulting, when large, coherent block units hinged along fault lines were rotated asymmetrically and displaced vertically from a horizontal plane.

Escarpment – A relatively continuous and steep slope or cliff produced by erosion or faulting. It breaks the general continuity of more gently sloping land surfaces.

Fold – A fold is formed when there is a high amount of confining pressure on malleable rock strata, which causes it to bend in three primary ways: upward, downward or dipping in one direction.

Highland - flat area of land with varying elevations, climatological limitations and ecological-agricultural gradients.

Horst – An elongated block bounded on both sides by normal faults that dip away from the interior.

Massif – A compact portion of a mountain range, containing one or more summits, also known as block mountains or mountain horsts.

Mountain – An elevated land area above surrounding lowlands, usually with a summit area and with steep sides.

Mountain range – A single, large mass consisting of a succession of mountains or narrowly spaced mountain ridges, with or without peaks, closely related in position, direction, orientation, formation and age; a component part of a mountain system.

Mountain system – A group of mountain ranges with certain unifying features, such as similarity in form, structure and alignment, and presumably originating from the same general causes.

Plateau – A comparatively flat area of great extent and elevation; specifically an extensive land region considerably elevated (more than 100 m) above adjacent lower-lying terrain. An abrupt descent usually occurs on one side of a plateau, which has a flat or nearly level surface. A large part of a plateau surface is near summit level.

Ridge – A long, narrow elevation of land, usually with a sharp crest with steep sides forming an extended upland between valleys. The term is used in areas of both hill and mountain relief.

Summit – The highest point of a mountain.

Volcano – A vent in the surface of the earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material. A shield volcano has a very broad, gently sloping dome, built by flows of very fluid lava or ash. A stratovolcano is constructed of alternating layers of deposits of lava and rock particles ejected from the volcanic vent.

Sources: Compiled from NOAA, 2009; USDA, 2013; Haywick, 2008; Messerli, et al., 1988

volcanic activity can influence the appearance of each mountain within the mountain range. The highest peak, or point, in a range is called the summit. Inevitably, mountain ranges can become hills when subjected to erosion processes. A few of the major mountain ranges in Africa are the Atlas, Rif, Drakensberg, Cape and the Eastern Arc Mountains.

A mountain massif is a topographically high part of the earth's crust bounded by faults and can be shifted by tectonic movements. Also known as block mountains or mountain horsts (Box 1.2), mountain massifs are the result of earth movements that occurred during the Tertiary period, resulting in fracture and up-thrust of the central block between two opposing forces (Bagoora, 2012). The Tibesti massif is an example of a prominent African massif (Ghuma & Rogers 1978). The majority of block mountains in the region are of low-to-moderate height, and include the Usambara in the United Republic of Tanzania, the Danakil Alps in Ethiopia and the Karas region in Namibia.

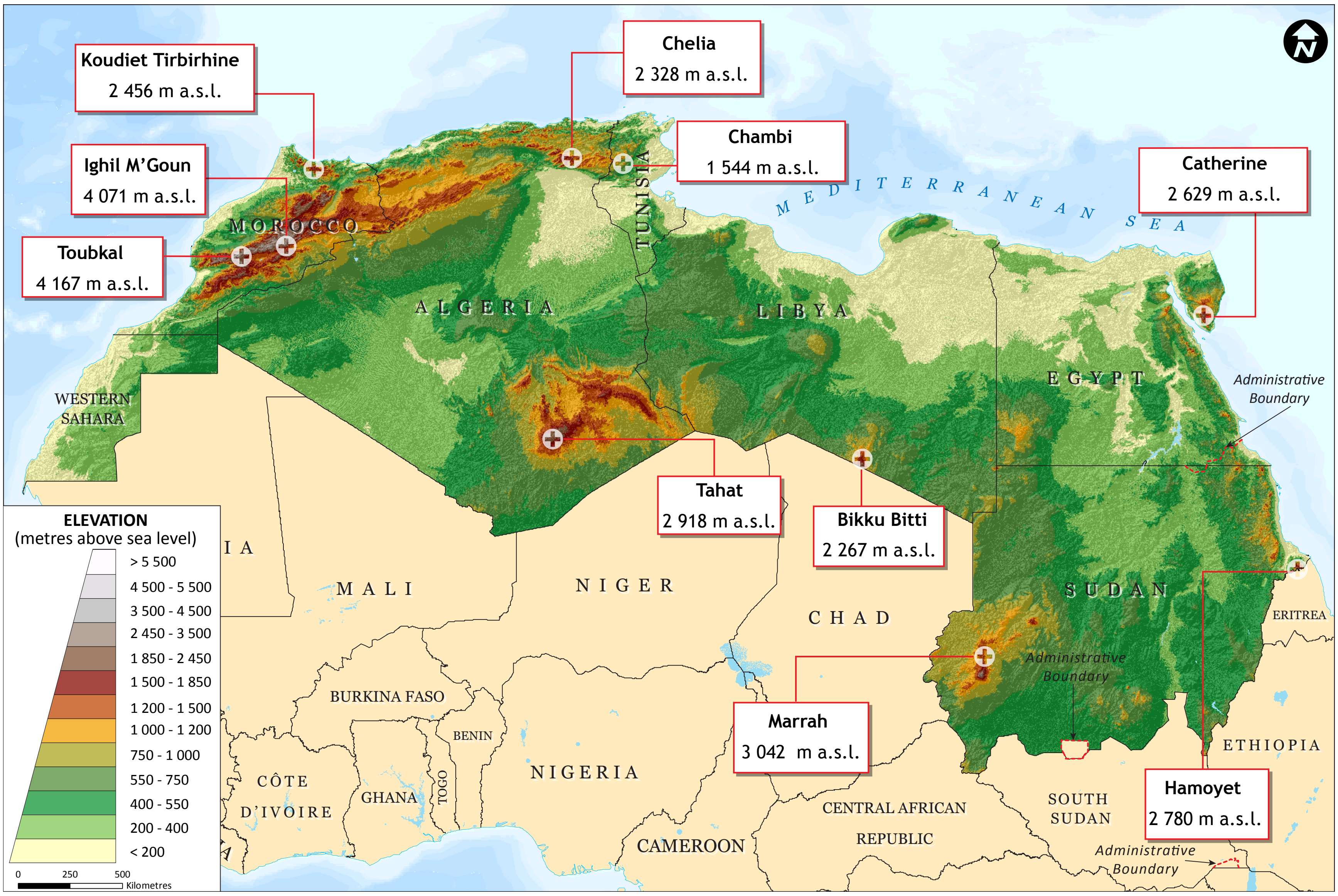
Highland and plateau areas refer to those that raise above surrounding land with a relatively flat top with varying elevations and climatological limitations. Distinct ecological-agricultural gradients can also be characteristic of highland areas in Africa (Messerli, et al., 1988). One of the most well-known highland areas in Africa is the Ethiopian Highlands.

Divided by UNEP region (Figure 1.5), the tables and maps on the following pages show the diverse topography of Africa and highlight some of the continent's highest peaks.

Figure 1.5: Regional divisions

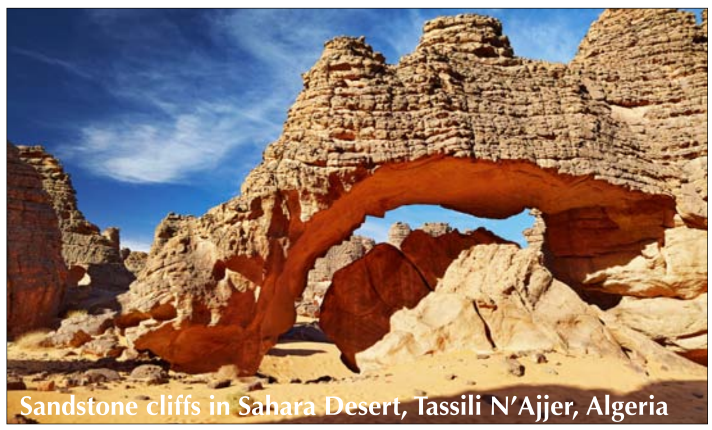
Source: UNEP; UNEP/DEWA
Note: UNEP Regional divisions are according to Economic Commission association

Figure 1.6: Elevation map of northern Africa




Woman carrying grass in Atlas Mountain area


Ait Barka, Atlas Mountains

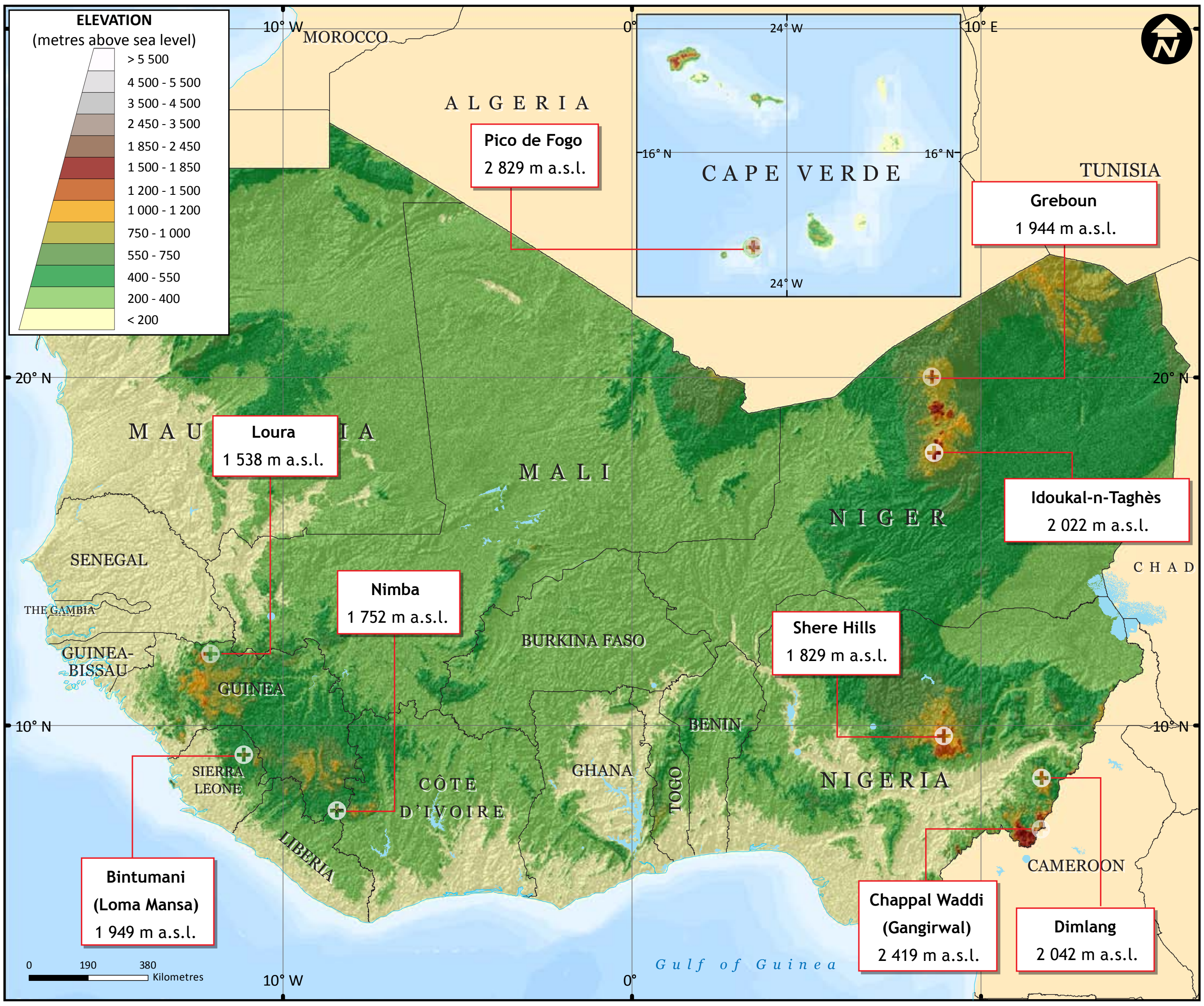

Sandstone cliffs in Sahara Desert, Tassili N'Ajjer, Algeria


Steep cliffs in Imlil, Morocco

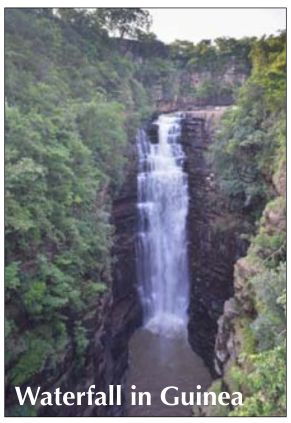
Table 1.1: Elevation and location of selected mountains in northern Africa

Name	General Location (lat/long)	Summit Elevation (m a.s.l.)	Country (-ies)
Toubkal	31.06°N, 7.92°W	4 167	Morocco
Ighil M'Goun	31.51°N, 6.44°W	4 071	Morocco
Marrah	12.93°N, 24.24°E	3 042	Sudan
Tahat	23.17°N, 5.83°E	2 918	Algeria
Hamoyet	17.55°N, 38.03°E	2 780	Sudan, Eritrea
Catherine	28.50°N, 33.96°E	2 629	Egypt
Koudiet Tirbirhine	34.85°N, 4.51°W	2 456	Morocco
Chelia	35.33°N, 6.67°E	2 328	Algeria
Bikku Bitti	21.98°N, 19.15°E	2 267	Libya
Chambi	35.21°N, 8.68°E	1 544	Tunisia

Figure 1.7: Elevation map of western Africa




Cape Verde mountain village


Waterfall in Guinea


The Gashaka Gumti National Park, which surrounds Chappal Waddi, Nigeria


Pico de Fogo, Cape Verde

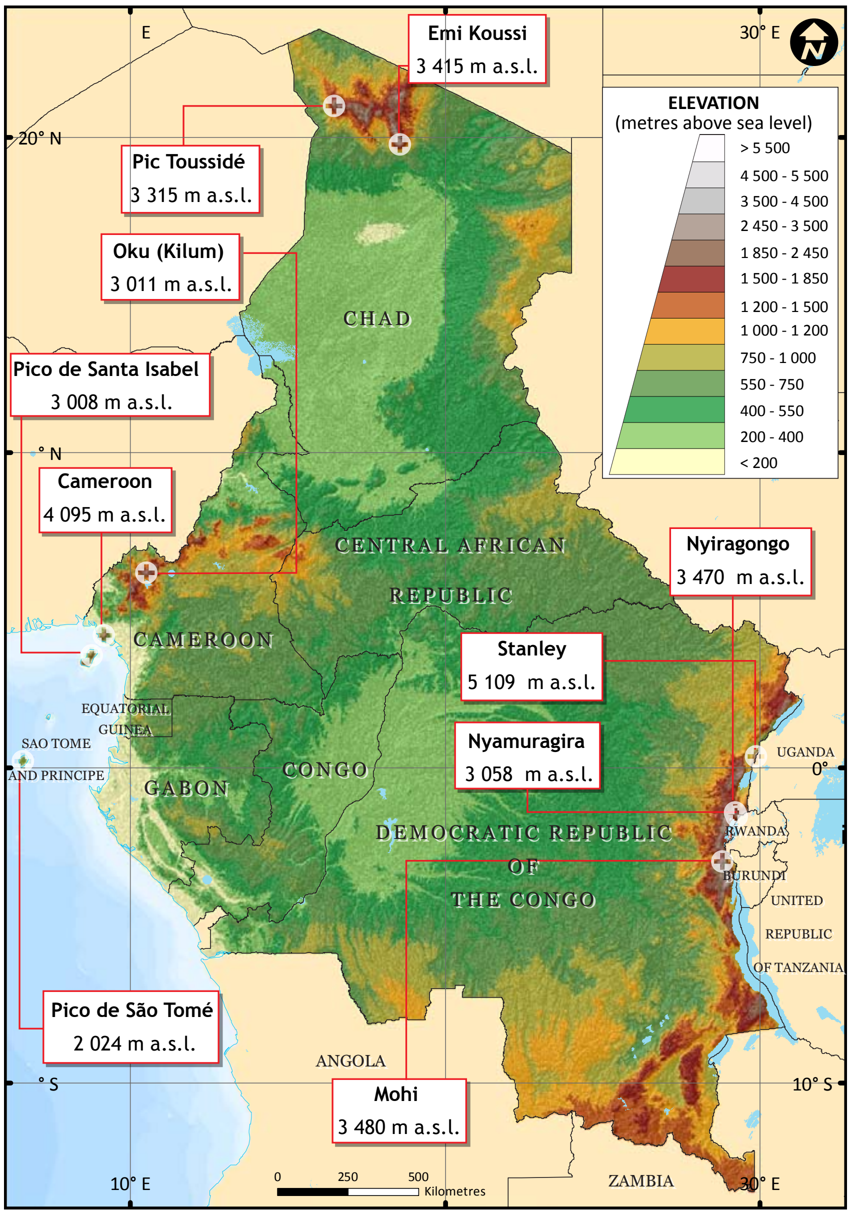
Table 1.2: Elevation and location of selected mountains in western Africa

Name	General Location (lat/long)	Summit Elevation (m a.s.l.)	Country (-ies)
Pico de Fogo	14.95°N, 24.34°W	2 829	Cape Verde
Chappal Waddi (Gangirwal)	7.04°N, 11.72°E	2 419	Nigeria, Cameroon
Idoukal-n-Taghès	17.85°N, 8.70°E	2 022	Niger
Dimlang	8.50°N, 11.75°E	2 042	Nigeria
Bintumani (Loma Mansa)	9.17° N, 11.12° W	1 949	Sierra Leone
Greboun	20.02°N, 8.60°E	1 944	Niger
Shere Hills	9.94°N, 9.04°E	1 829	Nigeria
Nimba	7.56°N, 8.46°W	1 752	Cote d'Ivoire, Guinea, Liberia
Loura	12.07°N, 12.09°W	1 538	Guinea

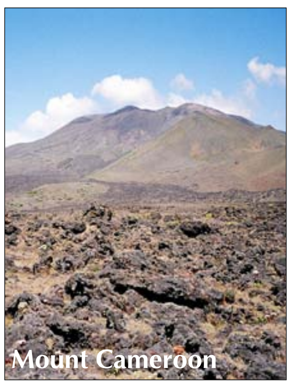
Photos (left to right): Pierre-Jean Durieu / Shutterstock; jbdodane / Flickr / CC BY-NC; Rosemary Lodge / Flickr / CC BY-NC-SA; (2) Sundebo / Shutterstock

Central Africa

Figure 1.8: Elevation map of central Africa




Tuareg and sand dunes in the desert in Chad


Mount Cameroon


Pico de Sao Tomé


Mikeno Volcano in the Virunga Mountains, DRC

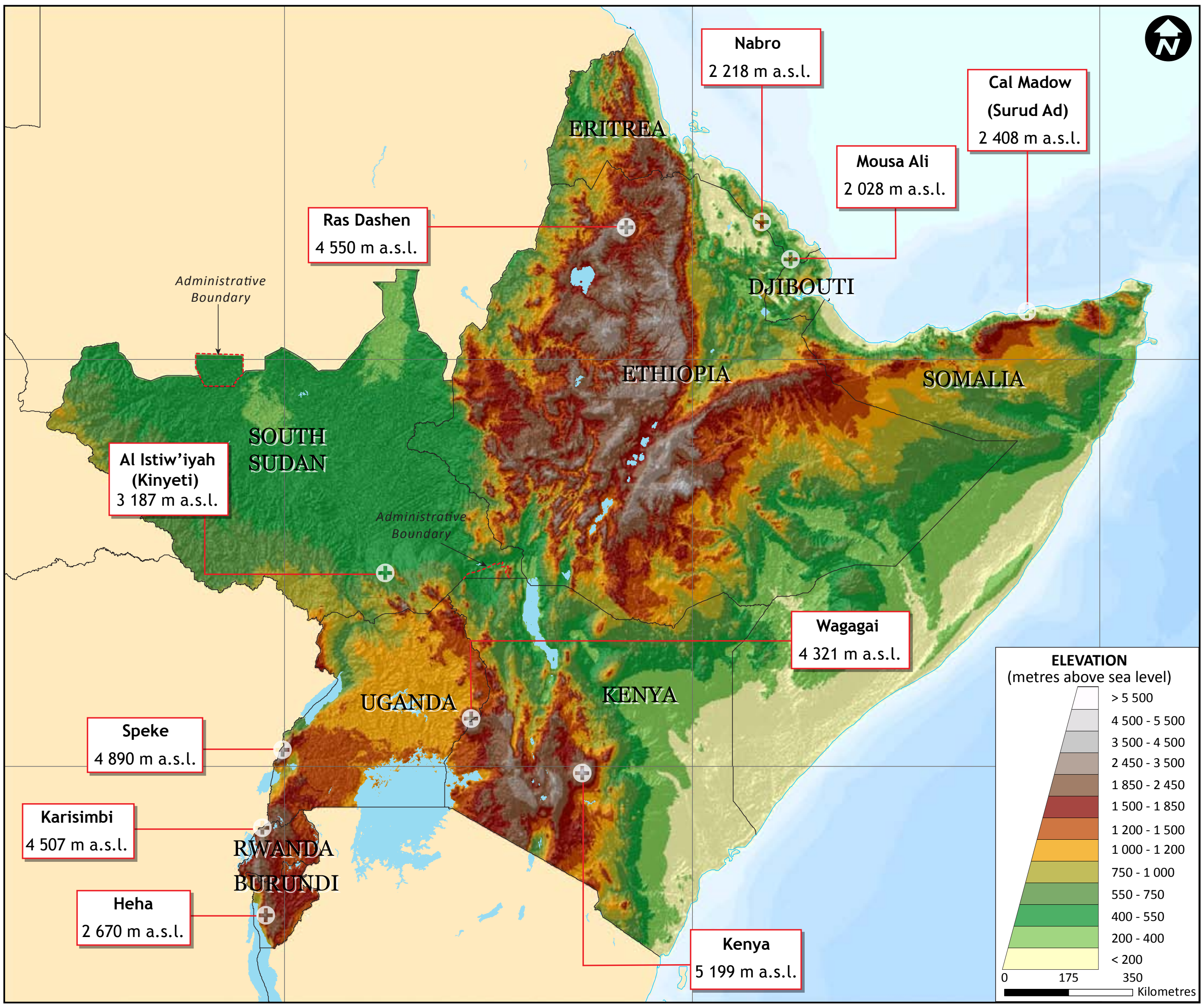
Table 1.3: Elevation and location of selected mountains in central Africa

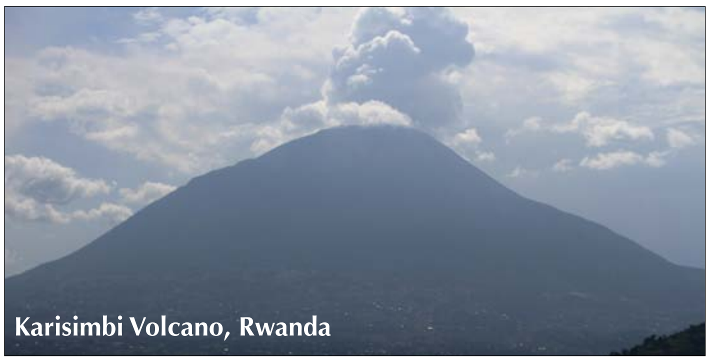
Name	General Location (lat/long)	Summit Elevation (m a.s.l.)	Country (-ies)
Stanley	0.39°N, 29.87°E	5 109	DRC, Uganda
Cameroon	4.22°N, 9.17°E	4 095	Cameroon
Mohi	2.95°S, 28.78°E	3 480	DRC
Nyiragongo	1.52°S, 29.25°E	3 470	DRC
Emi Koussi	19.79°N, 18.55°E	3 415	Chad
Pic Toussidé	21.04°N, 16.47°E	3 315	Chad
Nyamuragira	1.41°S, 29.20°E	3 058	DRC
Oku (Kilum)	6.20°N, 10.52°E	3 011	Cameroon
Pico de Santa Isabel	3.58°N, 8.77°E	3 008	Equatorial Guinea
Pico de São Tomé	0.23°N, 6.60° E	2 024	São Tomé and Príncipe

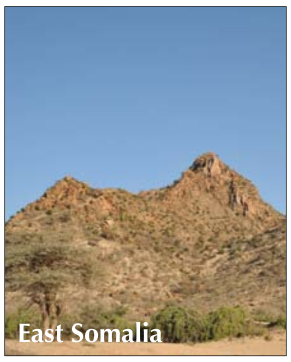
Note: Mount Stanley, part of the Rwenzori massif, summits in the DRC, but its entire mountain area also crosses into Uganda, which is in eastern Africa, as do Mounts Speke and Baker, also part of the Rwenzori massif.

Photos (left to right): sunsinger / Shutterstock; Genky / strollerdos / Flickr / CC BY-NC; mp3ief / Flickr / CC BY-NC-SA; (2) Monika Hrdinova / Shutterstock

Figure 1.9: Elevation map of eastern Africa




Karisimbi Volcano, Rwanda


East Somalia


Mount Kenya


Mountainous agricultural land in Banga, Burundi

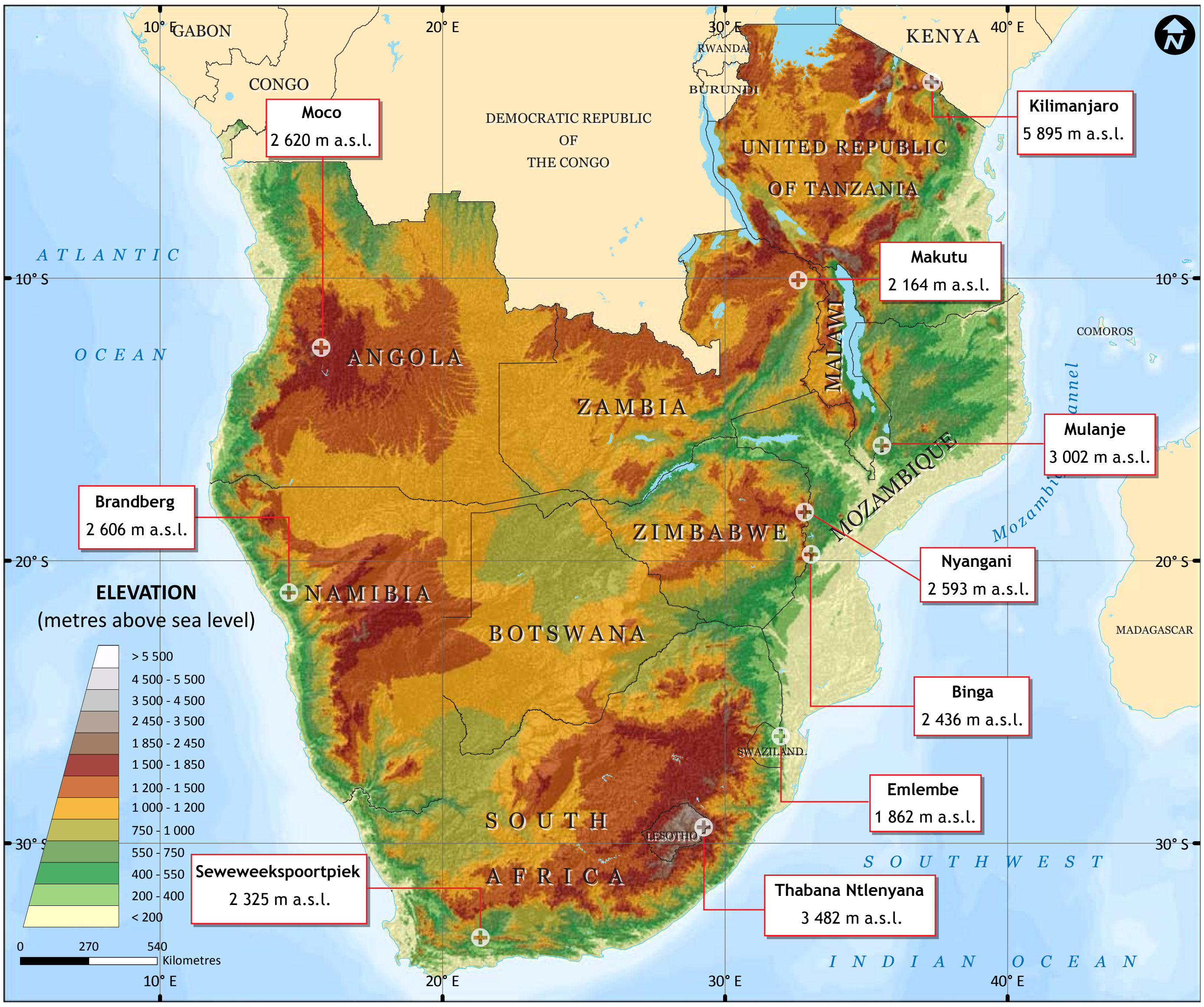
Table 1.4: Elevation and location of selected mountains in eastern Africa

Name	General Location (lat/long)	Summit Elevation (m a.s.l.)	Country (-ies)
Kenya	0.15°S, 37.31°E	5 199	Kenya
Speke	0.40°N, 29.89°E	4 890	Uganda
Ras Dashen	13.25°N, 38.38°E	4 550	Ethiopia
Karisimbi	1.51°S, 29.45° E	4 507	Rwanda, DRC
Wagagai	1.12°N, 34.53°E	4 321	Uganda
Al Istiw'iyah (Kinyeti)	3.95°N, 32.91°E	3 187	South Sudan
Heha	3.60°S, 29.50° E	2 670	Burundi
Cal Madow (Surud Ad)	11.18°N, 48.22°E	2 408	Somalia
Nabro	13.37°N, 41.70°E	2 218	Eritrea
Mousa Ali	12.47°N, 42.40°E	2 028	Djibouti, Eritrea, Ethiopia

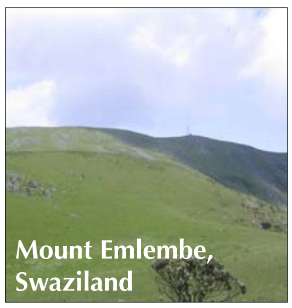
Note: Mount Elgon is a transboundary mountain, spanning the border of Kenya and Uganda. However, its highest peak, Wagagai, is located in Uganda.

Southern Africa

Figure 1.10: Elevation map of southern Africa




Semonkong, Lesotho


Mount Emlembe, Swaziland

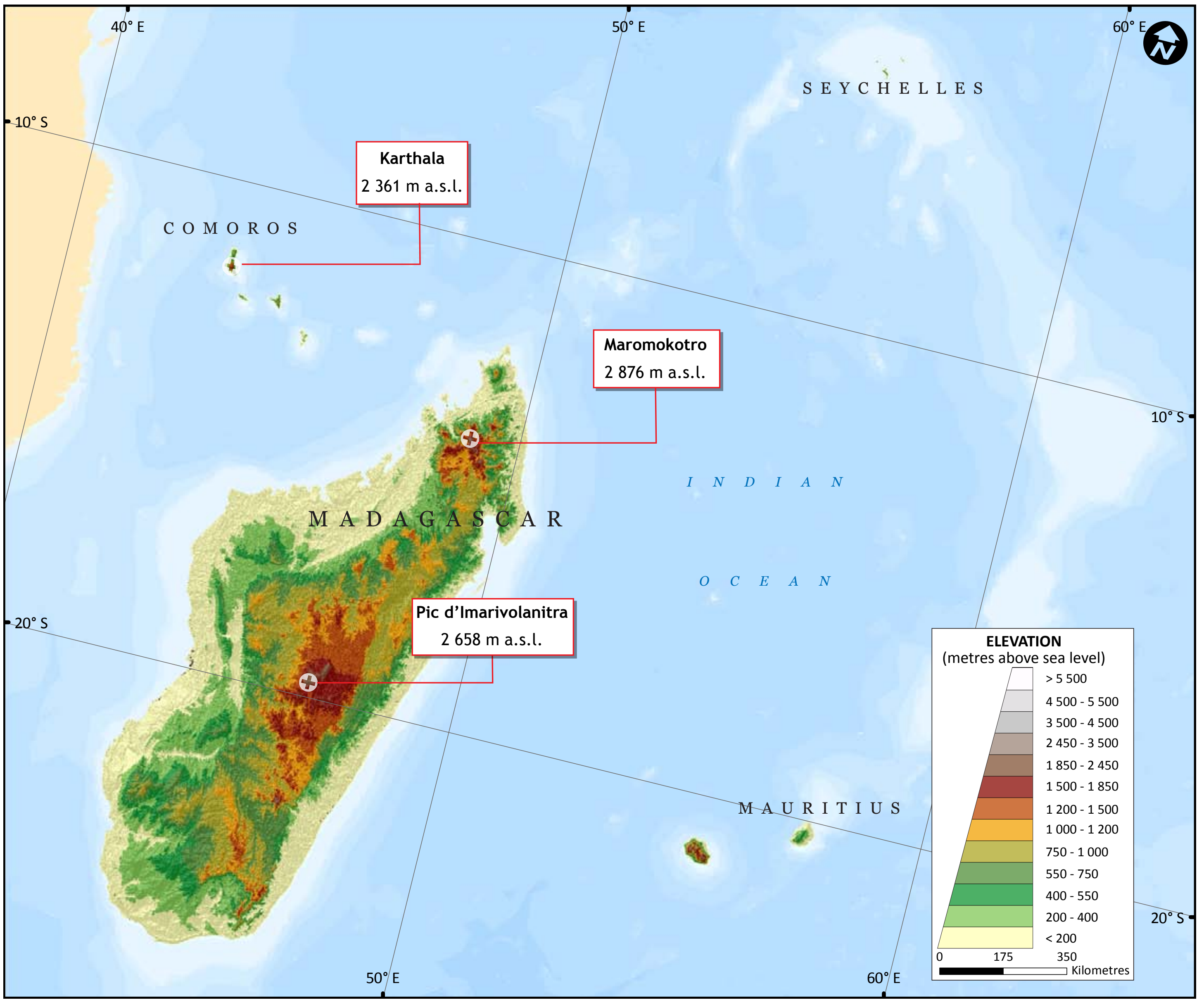

Brandberg Mountain, Namibia


View of Mount Binga, Mozambieque and Zimbabwe

Table 1.5: Elevation and location of selected mountains in southern Africa

Name	General Location (lat/long)	Summit Elevation (m a.s.l.)	Country (-ies)
Kilimanjaro	3.08° S, 37.35° E	5 895	United Rep. of Tanzania
Thabana Ntlenyana	29.47° S, 29.27° E	3 482	Lesotho
Mulanje	15.93° S, 35.62° E	3 002	Malawi
Moco	12.46° S, 15.17° E	2 620	Angola
Brandberg	21.15° S, 14.58° E	2 606	Namibia
Nyangani	18.30° S, 32.84° E	2 593	Zimbabwe
Binga	19.78°S, 33.06°E	2 436	Mozambique, Zimbabwe
Seweweekspoort-piek	33.38°S, 21.36°E	2 325	South Africa
Makutu	10.40°S, 33.25°E	2 164	Zambia
Emlembe	25.92°S, 31.12°E	1 862	Swaziland

Figure 1.11: Elevation map of the western Indian Ocean Islands




Madagascar landscape


Comoros waterfall


Karthala Crater, Comoros


The rugged terrain of Madagascar with Maromokotro in the distance

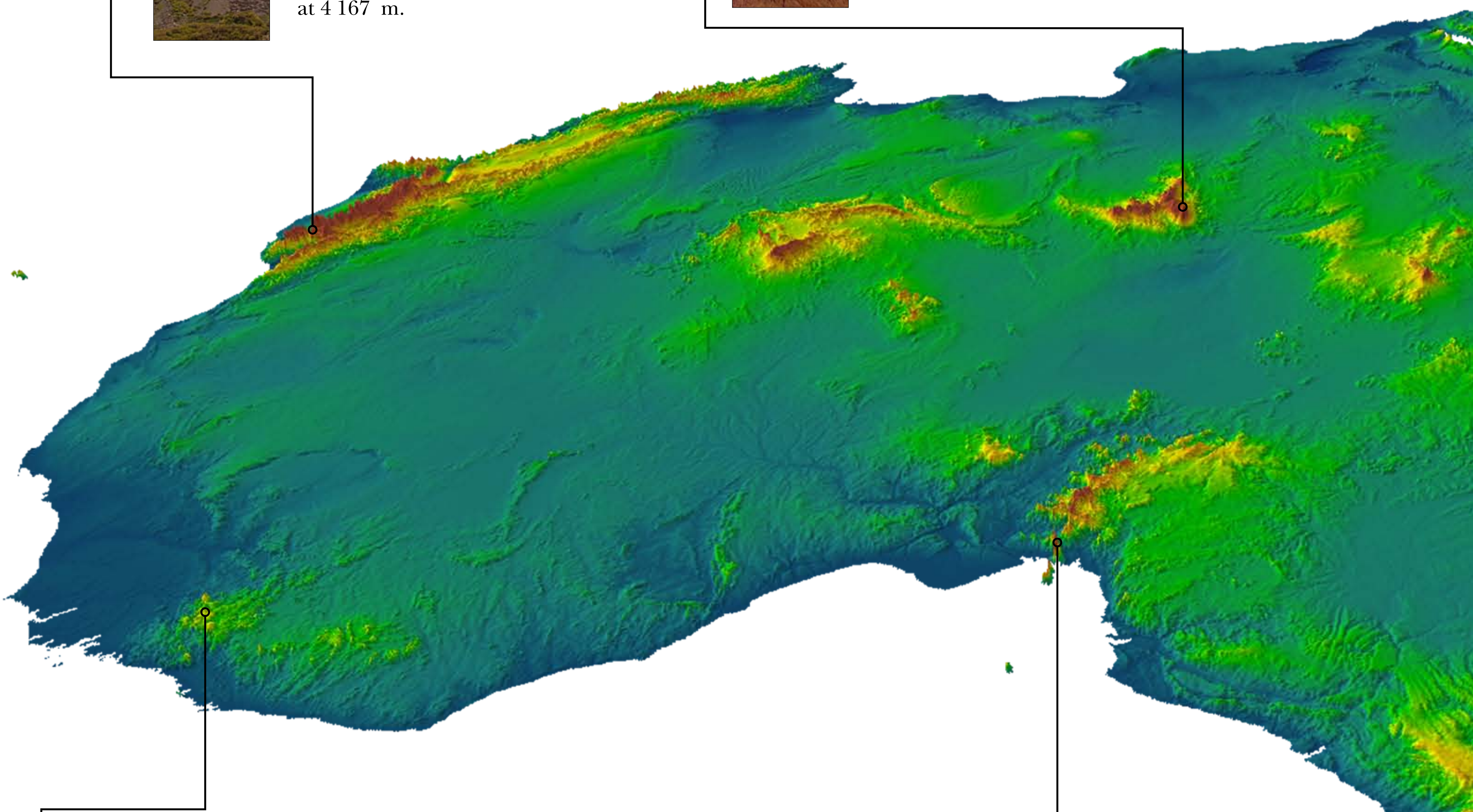
Table 1.6: Elevation and location of selected mountains in the Western Indian Ocean Islands

Name	General Location (lat/long)	Summit Elevation (m a.s.l.)	Country (-ies)
Maromokotro	14.02°S, 48.96°E	2 876	Madagascar
Pic d'Imarivolanitra	22.20°S, 46.88°E	2 658	Madagascar
Karthala	11.76°S, 43.35°E	2 361	Comoros

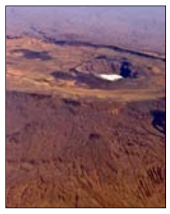
Sources: Table 1.1 - Table 1.6 sources compiled from: Bjørstad, 2007; PGWC, 2007; EECRG, 2002; Peter, 2009; Peaklist, 2007; RAMSAR, 2006; St-Katherine, 2006; Timberlake, et al., 2009; NASA, 2013; SI, 2013 ; Bradt, 2011

Figure 1.6 - Figure 1.11 sources: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Photos (left to right): almondd / Shutterstock; Leksele / Shutterstock; Daryl Wallace/ Flickr / CC BY-SA 2.0; (2) David Darricau / Flickr /CC BY-NC-SA



Jebel Toubkal
Jebel Toubkal is the highest peak in Morocco, and of all northern Africa, at 4 167 m.



Emi Koussi
Emi Koussi, the peak of the Tibesti massif, is the tallest mountain in the Sahara Desert at an elevation of 3 394 m.

Mount Loura
Mount Loura is the highest peak on the Fouta Djallon plateau at an elevation of 1 538 m.

Mount Cameroon
Mount Cameroon is an active volcano and the highest peak west of the Cameroon border at 4 095 m.

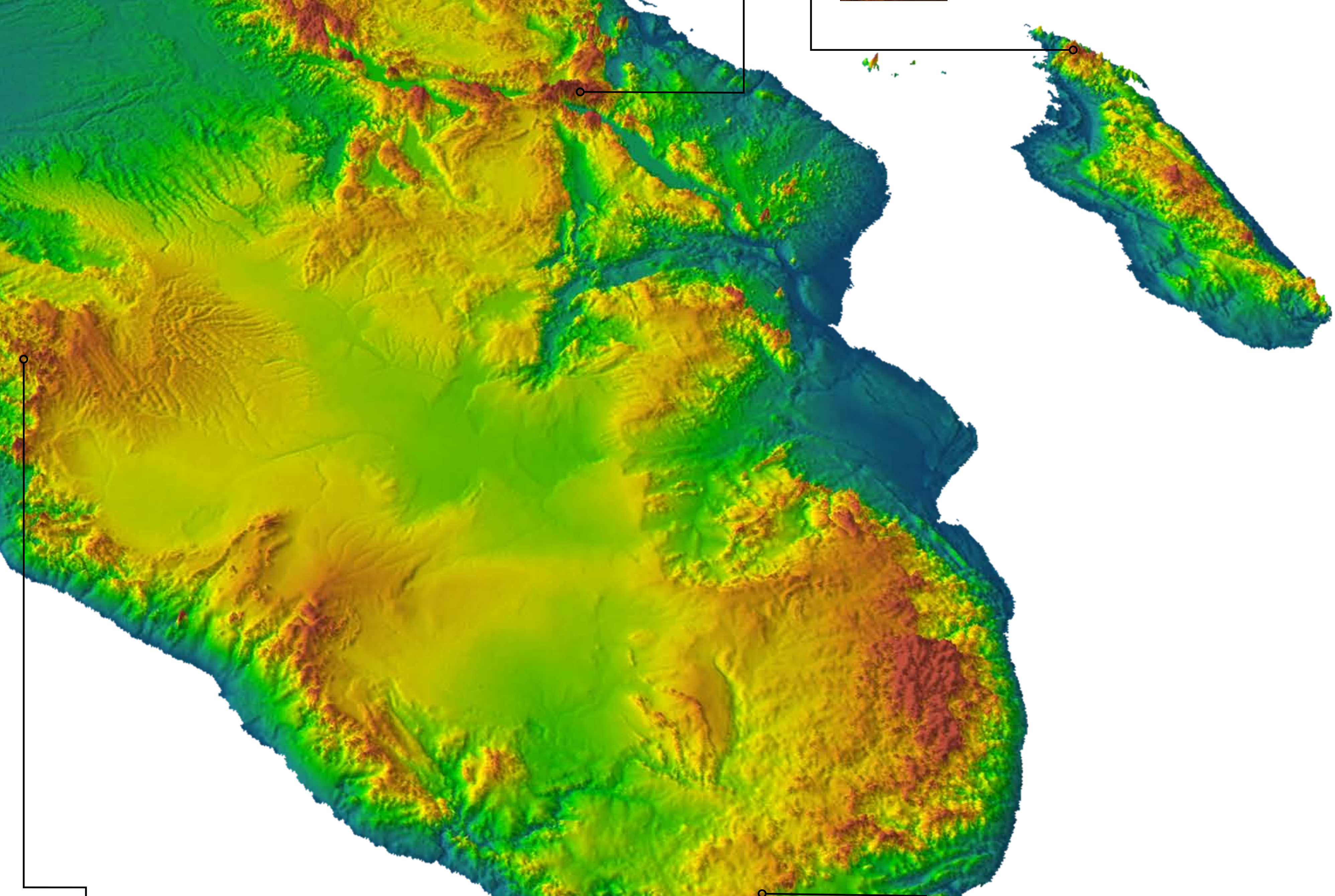
Characteristics of Africa's Mountainous Areas

Mount Stanley
Margherita Peak on Mount Stanley is the highest peak of the Rwenzori Mountains and 4th highest in Africa, with an elevation of 5 109 m.

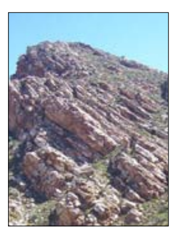
Ras Dashen
At 4 620 m, Ras Dashen is the highest peak of the Simien Mountains and Ethiopia; it is the 10th highest peak in Africa.

Kibo
Kibo, the highest peak of Kilimanjaro, is also the highest peak in Africa and the highest volcano with a grand elevation of 5 895 m.

Maromokotro
Located on the Tsaratanana massif, Maromokotro is the highest peak on the island of Madagascar, rising to 2 876 m.



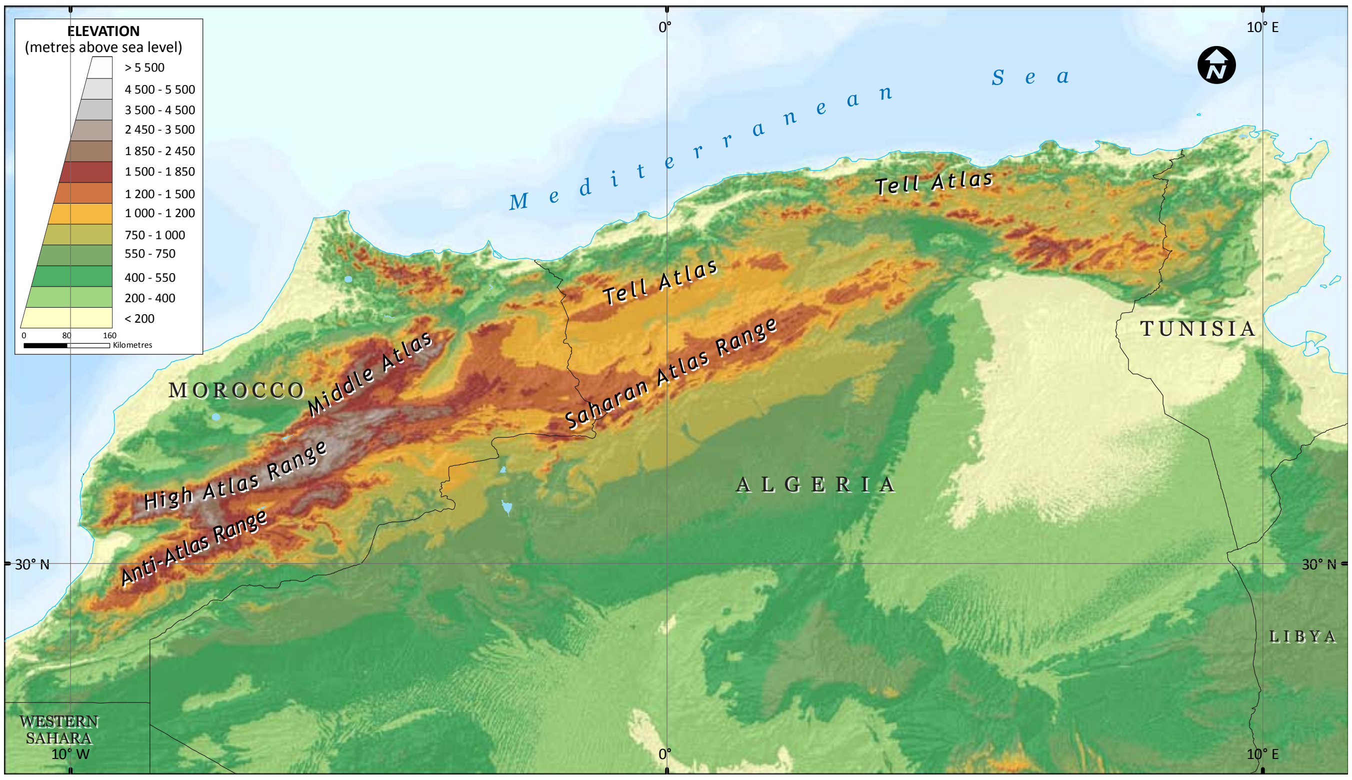
Mount Moco
The highest peak of Angola, Mount Moco rises to an elevation of 2 620 m.



Seweweekspoortpiek
Found along the Cape Fold Belt, Seweweekspoortpiek is the highest highest peak of the Cape Fold Belt with an elevation of 2 325 m.

Atlas Mountains

Figure 1.12: Elevation map of the Atlas Mountains



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

The Atlas Mountains form the main topographic feature of Morocco, Algeria and Tunisia. The mountain range extends for about 1 610 km (UNEP, 2008) from the Moroccan port of Agadir in the southwest to the Tunisian capital of Tunis in the northeast. The mountain range separates the Mediterranean basin in the north from the Sahara Desert in the south (Figure 1.12). The highest peak in the Atlas Mountain range is Jebel Toubkal with an elevation of 4 167 m (Table 1.1; Figure 1.6). Sub-ranges of the Atlas system include the Anti-Atlas that runs parallel to the High Atlas; the Saharan Atlas in Eastern Morocco and Algeria; and the Tell or Maritime Atlas along the Mediterranean coast (Figure 1.12). The highest peaks are covered by snow for most of the year, yet they lack the presence of glaciers (Peakware, 2013). The Atlas Mountains are dominated by the dry, sandy soils of the Sahara, which are characteristically low in levels of organic matter and water-retention capacity. These are dissected by ephemeral river systems, which have poorly developed soils that are vulnerable to degradation by human activities such as overgrazing of livestock (Jones, et al., 2013).

High Atlas Mountains above Marrakech in Morocco

John Copland / Shutterstock

The Atlas Mountain range, situated at the boundary of the African and Eurasian plates, is a result of uplifting and deformation during the Cenozoic geological era (Figure 1.3). The mountain chain's peaks are largely formed of Palaeozoic basement granites and extrusions of lavas of rhyolite and andesite. The Tell Atlas are made up of carbonates, flysch and crystalline basement rocks (Piqué, 2001; Box 1.1). A variety of important mineral deposits, phosphates and metal ores are found in the Atlas Mountain range, including lead, zinc, iron, manganese, antimony, phosphates, coal, gold, silver and oil (UNEP, 2008; Paradise, 2010; CEE, 2012).

Vegetation in the Atlas Mountain range is unique. It is home to the argan tree (*Sapotacea*) in the west (UNESCO, 2002), plants similar to Mediterranean Europe in the moist ocean climate of the north and scrubby vegetation on the semi-desert southern slopes (Bussman, 2006). These semi-desert areas, such as the Hammada on the southern side of the High Atlas, are characterized by sparse vegetation, with the exception of dwarf shrubs (Lindstadte & Baumann, 2013), and the sandy desert has very little vegetation (Rankou, Culham, Jury, & Christenhusz, 2013). Figure 1.13 highlights a few general zones of vegetation that can be found in different elevations of the High Atlas Mountains.

Berber village in the Atlas Mountains

danm12 / Shutterstock

Snowcapped Atlas Mountains, Morocco

Govert Nieuwland / Shutterstock

Argan trees (*Argania spinosa*) in the Atlas Mountains

Jan Mastnik / Shutterstock

Figure 1.13: Vegetation zonation of the High Atlas Mountains

Sources: Barrow & Hicham, 2000; Hammi et. al, 2010

Photos (top to bottom): Rol1000 / Flickr / CC BY-NC-ND 2.0; ihorga / Shutterstock; Galyna Andrushko / Shutterstock

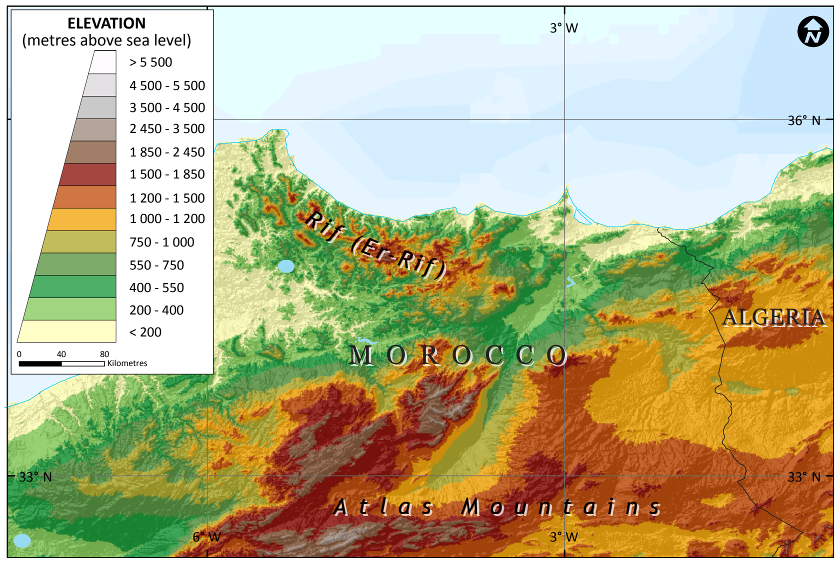
Rif Mountains

Separated from the main Atlas Mountain chain, the Rif Mountain range in Morocco extends for 290 km (Figure 1.14). The range reaches from the Strait of Gibraltar in the west to the Moulouya River valley near the Moroccan-Algerian border in the east, hugging the Mediterranean Sea and peaking multiple times at snow-capped mountains, including Mount Koudiet Tirbirhine, which stands at 2 456 m (Valdés, Rejdali, Achhal El Kadmiri, & Jury, 2002; Table 1.1; Figure 1.6).

The Rif belt was formed at about the same time as the Mediterranean Sea, when the African and European tectonic plates converged (Fernandez, et al., 1998; Michard, Chalouan, Feinberg, Goffe, & Montigny, 2002). The Rif belt is divided into three segments: the Internal Zone, Intermediate Flysch and External Zone (Wildi, 1983). The Internal zone consists of metamorphic rocks and Mesozoic marine sediments (Wildi, 1983; Calvert, et al., 2000); the Intermediate Flysch Zone consists of deep marine deposits of pieces of older rocks from the early Cretaceous to early Miocene, and the External Zone is made up of sedimentary rock from the Mesozoic era and Tertiary period (Wildi, 1983).

The Rif Mountains are home to a diversity of plants owing to the various types of soil making up the region (Draper, Mazimpaka, Albertos, Gariletti, & Lara, 2005). At higher elevations, Mediterranean conifer and mixed forests dominate with the Atlas cedar extending over 150 km² (Benabid & Fennane, 1994). Endemic plants such as the *Abies marocana*, a Mediterranean fir, and endangered relic and pine forests grow in isolated areas but can stretch over hundreds to thousands of hectares (WWF, 2013).

Figure 1.14: Elevation map of the Rif Mountains



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Rif Mountains, Morocco

Lukasz Janyst / Shutterstock

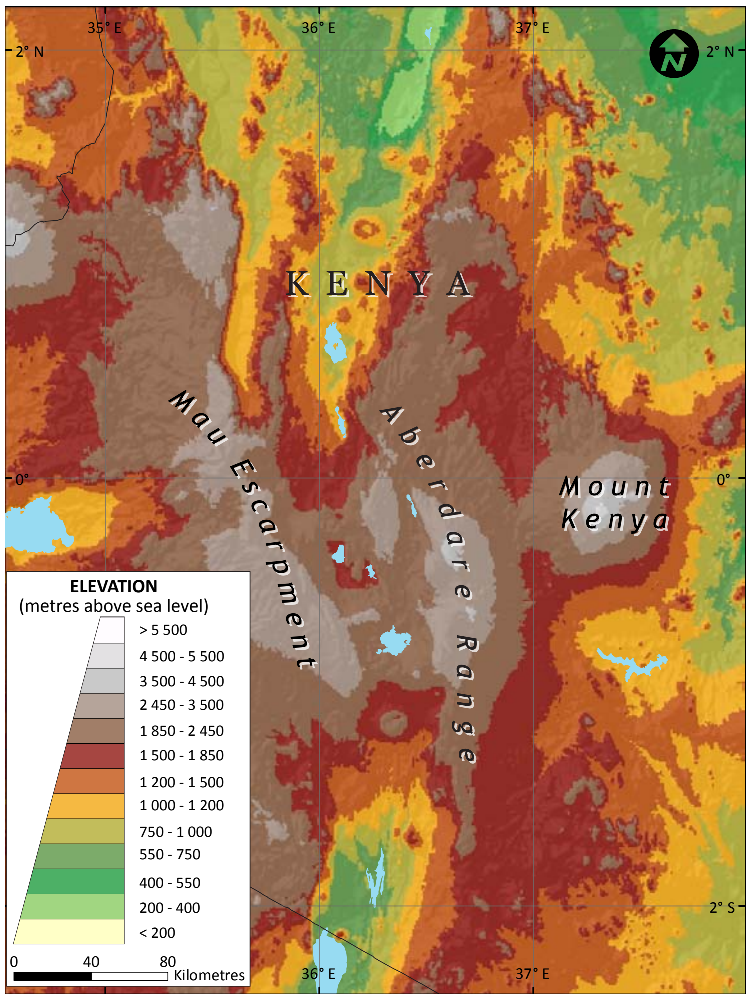
Aberdare Mountains

The Aberdare Mountains are an isolated volcanic range in central Kenya (Figure 1.15) that extends for a length of about 100 km from north to south, rising at two main peaks: Ol Donyo Lesatima (3 999 m) to the north and Kinangop (3 906 m) to the south (UNESCO, 2010a).

The Aberdare range formed during the early Tertiary to the Pleistocene epoch by uplifting, warping and tectonic movement, followed by volcanism and faulting of the African basement (Peltorinne, 2004). Following this, volcanic rock and lava rose up through the fractures in the crust, creating the mountain (van Hinsbergen, Buiter, Torsvik, Gaina, & Webb, 2011). As a product of fissure volcanic eruptions, the Aberdare ranges are mainly made up of alkaline rock types including basalts, rhyolites and other rocks ejected during the volcanic eruption (Kenya Forest Service, 2010).

The Aberdare Forest Reserve comprises approximately 103 300 ha of forest cover on the range's lower slopes and is home to 52 of Kenya's 67 Afrotropical highland species and numerous types of plants, making it a rich area for wildlife and biodiversity (UNESCO, 2010a). The variation of vegetation types with elevation in the Aberdare range is quite similar to that of Mount Kenya. Diverse forests grow above 2 500 m including cedar and riverine forests. From about 2 700 m to 2 900 m there is a belt of bamboo and above 2 900 m cloud forests with species such as *Hagenia abyssinica* grow. Above 3 100 m, the upper limit of the montane forests, with species such as *Erica excelsa* can be found (Bussman, 2006).

Figure 1.15: Elevation map of the Aberdare Mountains



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

An elephant in the Aberdare forest, Kenya

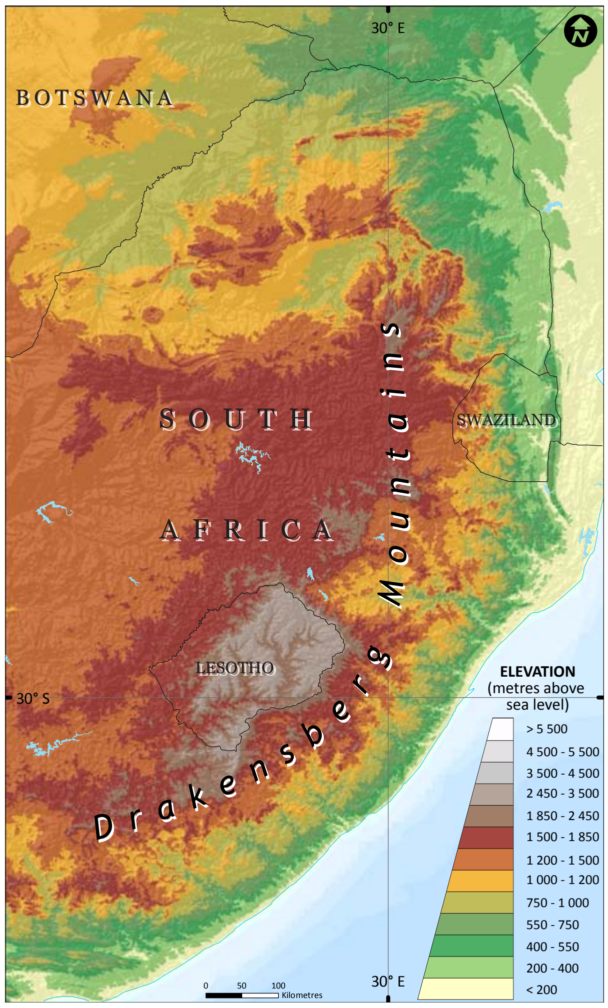
Eric Hui / Shutterstock

Drakensberg Mountains


Cathedral Peak in the Drakensberg Mountains

Santi Martin / Flickr / CC BY NC SA

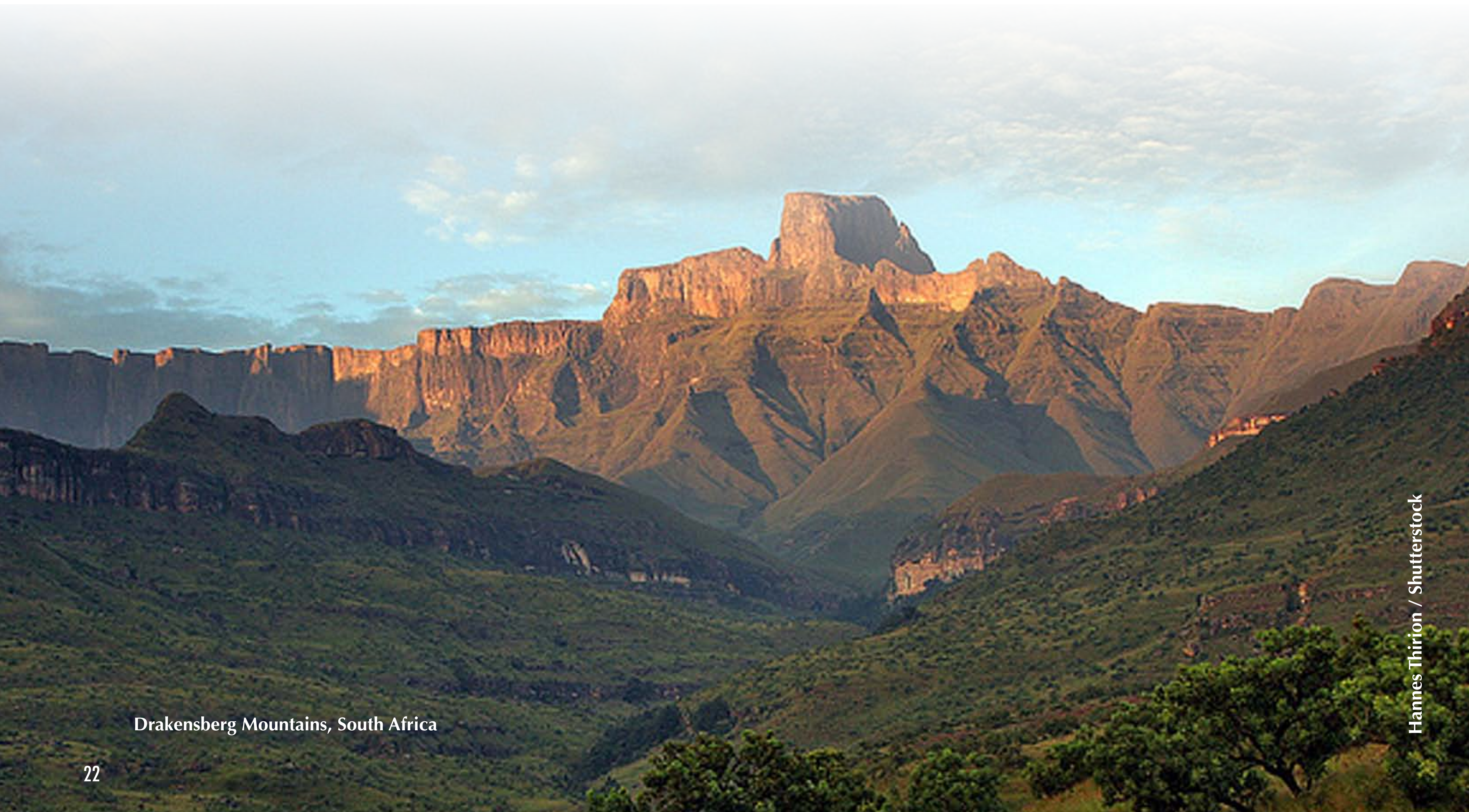
Figure 1.16: Elevation map of the Drakensberg Mountains



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Located along the 300-km eastern border of Lesotho and South Africa, the Drakensberg Mountains extend for about 1 125 km, covering 40 000 km^2 and rising to altitudes of between 1 800 m and 3 482 m (Figure 1.16). At its highest peak, the Drakensberg Mountain range rises to 3 482 m at Thabana Ntlenyana in Lesotho (Figure 1.10; Table 1.5). The mountain range forms the headwaters of the Vaal and Orange-Senqu Rivers (Compton & Maake, 2007).

The Drakensberg Mountain range formed when sand and mud carried by runoff settled into sedimentary layers and


Drakensberg Mountains, South Africa

Hannes Thirion / Shutterstock

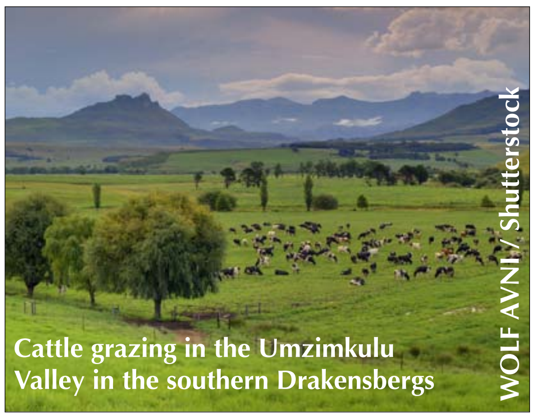
hardened under the compacting weight. Later, as pressure built, the tectonic plates split apart allowing lava to pour out through the fracture, creating layers of basalt of up to 1 400 m in thickness underlain by sandstone (EECRG, 2002). Due to their jagged appearance, the Drakensberg Mountains are also known as uKhahlamba, a local term that means "barrier of spears".

The formation of the mountains has also resulted in numerous waterfalls. The Tugela Falls, which drops for 948 m and is the second-highest waterfall in the world, is one of the Drakensberg Mountain range's most prominent features (World Waterfall Database, 2013).

Grasslands dominate the vegetation, which occur in patches in the northern regions, but there are also tall conifers in some of Africa's largest coniferous forests. Much of the flora and fauna is endemic, including mostly reptile and angiosperm species (WWF, 2008). Figure 1.17 shows the changes in vegetation with elevation in the Drakensbergs.

Tugela Falls

deysale / Flickr / CC BY NC SA



Cattle grazing in the Umzimkulu Valley in the southern Drakensbergs

WOLF AVNI / Shutterstock

Natal bottlebrush in the Drakensbergs

Peter Mooi / Shutterstock

Figure 1.17: Vegetation zonation of the Drakensberg Mountains

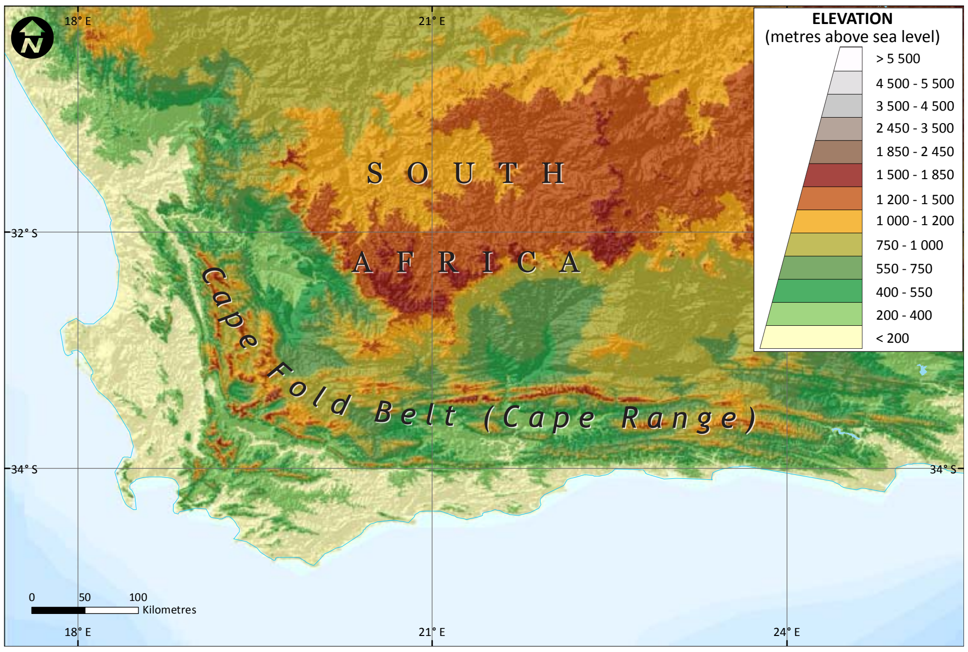
Source: Scott-Shaw & Escott, 2011
Photos (top to bottom):unknown / Wikipedia / CC BY-SA 3.0; Renier Maritz / Wikipedia / CC BY-SA 3.0; Cwawebber/ Wikipedia / CC BY-SA 3.0

Cape Ranges

The mountain ranges of the Cape Fold Belt system, the Cape Ranges, extend for more than 600 km from the Cederberg Mountains in the northwest to Port Elizabeth in the east, and their base is mainly at or near sea level (Johnston, 2000; Figure 1.18). Seweweekspoortpiek, which summits at an elevation of 2 325 m, is the highest point of the Cape Fold Belt (Figure 1.10; Table 1.5).

The Cape Fold Belt is deformed Precambrian basement rock, early Paleozoic Cape Granites and Ordovician to Carboniferous sedimentary rocks (Johnston, 2000). The formation and existence of the Cape Fold Belt plays a role in the continental drift and plate tectonics theories. One element of these theories stems from the fact that the now separated fold and thrust belts found in southern Africa, such as the Cape Fold Belt, South America and Antarctica were once one continuous belt referred to as the Gondwanide orogenic belt. Still a mystery, however, is how the Cape Fold Belt formed so distant from the active margin of the Gondwana supercontinents (Johnston, 2000). The formation processes of the Cape Fold Belt have created unusual features in the Cape Ranges. For example, there are pyroclastic rocks and igneous debris that make up the sediments formed after the folding and faulting in the earth's crust (Newton, 1973). Additionally, the sedimentary strata of the Karoo geology system also underlie the Fold Belt. The Karoo formed about 345 - 190 Ma and extends from the Equator to the Cape of Good Hope at the southeastern tip of South Africa (EB, 2011).

Figure 1.18: Elevation map of the Cape Ranges



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

The Cape area has diverse soil types and as the soil changes, so does the flora. Forest vegetation is found in deeper soils, shrubby and herbaceous plants are found where precipitation is not as frequent (Goldblatt & Manning, 2002) and sandy soils give way to highly endemic flora with species-rich sclerophyllous fynbos and succulent shrubland (McDonald & Cowling, 1995). Fynbos, a type of natural shrubland, is the major type of vegetation in the small Cape Floral Kingdom botanical region, which is high in biodiversity (Maneveldt, n.d.). Other shrubs, such as *Asteraceae* species, thrive in the clay-like soils (Goldblatt & Manning, 2002).

Cederberg Mountains, South Africa

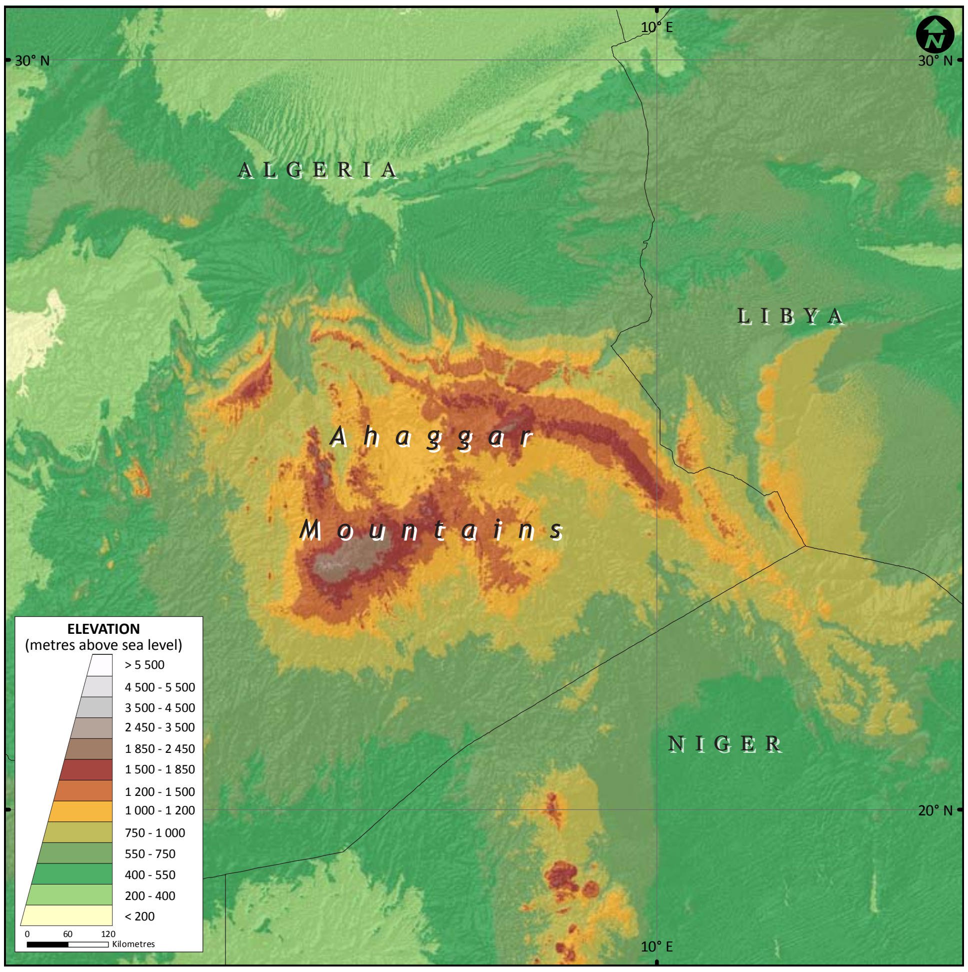
dr322 / Shutterstock

Ahaggar Mountains

Covering nearly 544 000 km^2, the Ahaggar Mountains, also named the Hoggar, are a block-mountain system covering southeastern Algeria and crossing into Niger and Libya. The range is found along the Tropic of Cancer in the Sahara desert (Figure 1.19).

Some 300 million years ago, volcanic activity underneath the Ahaggar plateau pushed it upwards, raising its granite base high above the Sahara. The following volcanic eruptions resulted in the formation of basaltic lava beds and pumice, which make up much of the geology of the Ahaggar Mountains (Waskey, 2005). The Ahaggar plateau, which is covered in lava fields, provides a base for the Ahaggar Mountains, whose highest peak reaches 2 918 m at Mount Tahat (Waskey, 2005; Figure 1.6; Table 1.1). It also consists of Precambrian crystalline slate, conglomerate and gneiss. The Ahaggar massif is built of rock some 300 million years old and is part of the old bearing rock of the African continent. Some of the peaks are volcanic plugs, or solidified lava. Over millions of years, the outer layers of these volcanoes have been subjected to water and wind erosion, leaving only the plugs or "necks" protruding above the pink granite plateau. Two waterfalls can be found in the Ahaggar Mountains, the Tamekrest and the Imeleoulaouene (Waskey, 2005).

Figure 1.19: Elevation map of the Ahaggar Mountains



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Much of the Ahaggar plateau is sparsely vegetated, although there are significant stands of trees and perennial vegetation that often align with the drainage patterns because of water availability in this region of sharp topography. Dominant shrubs include *Zilla spinosa*, *Artenisia* species and *Fagonia* species (Wacher, et al., 2005). The main tree species is *Olea laperrinei* (olive), which can be found at elevations between 1 400 and 2 800 m in fragmented patches (Baali-Cherif & Besnard, 2005).

Ahaggar Mountains, Algeria

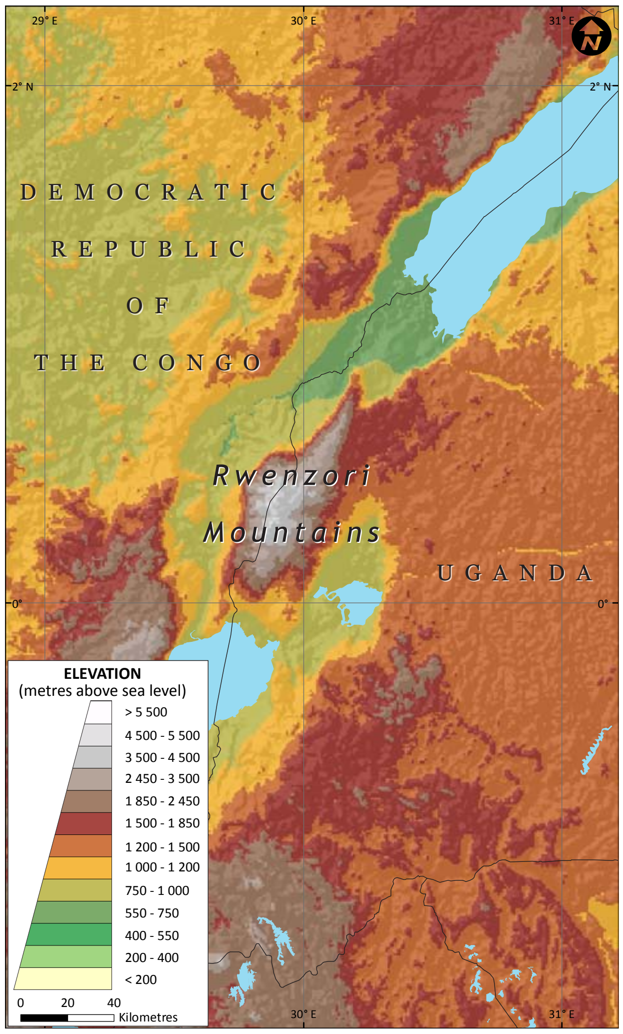
Rwenzori Mountains

The Rwenzori Mountains, known as the "Mountains of the Moon" (Russell, Eggermont, Taylor, & Verschuren, 2009), are comprised of six massifs that cross the border of Uganda and the DRC (Young & Hastenrath, 1991; Figure 1.20). They cover a total of 3 000 km² and extend for 120 km (Russell, Eggermont, Taylor, & Verschuren, 2009). The highest peak is Margherita peak on Mount Stanley, reaching 5 109 m (Table 1.3; Figure 1.8). Although the Rwenzoris are located just north of the equator, glaciers can be found on Mount Stanley, Mount Baker (4 873 m) and Mount Speke (4 891 m) (Table 1.4; Figure 1.9), but are quickly disappearing (see Chapter 3).

The Rwenzori Mountains were formed by faulting activities that also formed the Albertine Rift, which is part of the Great Rift Valley. They are largely composed of metamorphic rock, believed to have been tilted and squeezed upwards during plate tectonic activity and continental drifting (Peter, 2009).

The unique alpine landscape has unusual vegetation, including giant lobelias, ericas, groundsels and heathers. Five major zones of vegetation occur at different altitudes, including a base of montane forests leading up to forests of bamboo at 3 000 m, the botanically large flora of heathers

Figure 1.20: Elevation map of the Rwenzori Mountains



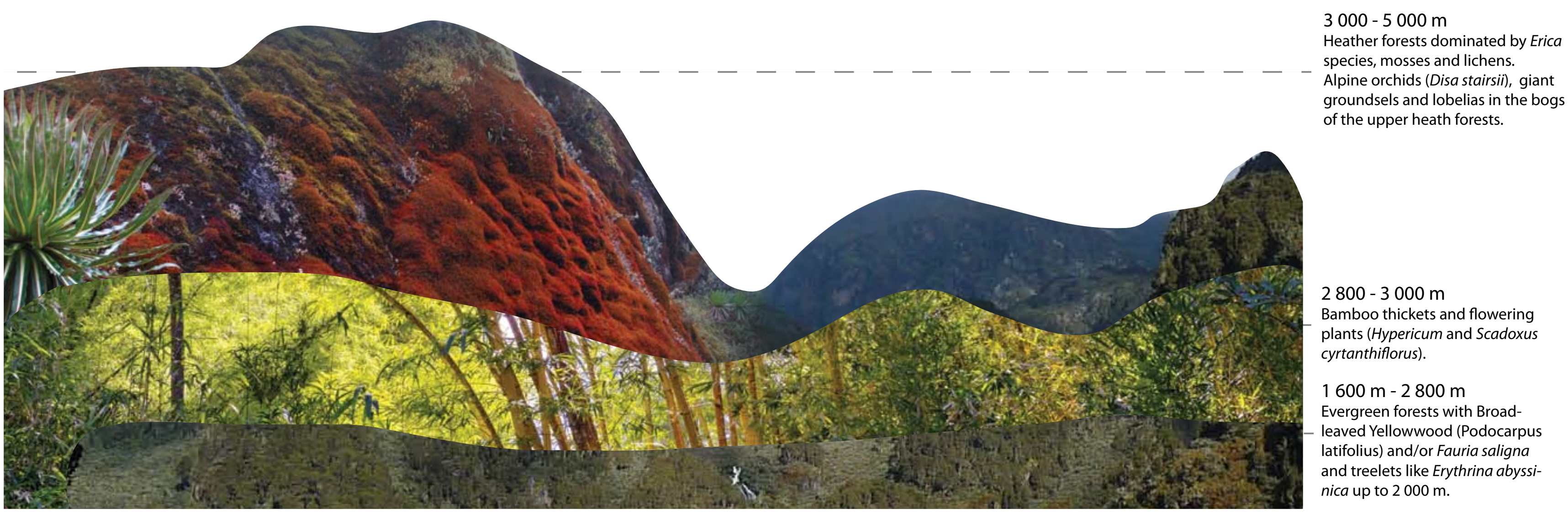
Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Giant Lobelias in the Rwenzori Mountains

Jorn Eriksson / Flickr / CC BY

and heath vegetation at 3 800 m and finally small trees and undergrowth leading upwards to an Afroalpine moorland above 4 400 m (Figure 1.21). The vegetation contributes to its significance as a vital catchment area. The mountains receive heavy rainfall, and together with ice and snow melt from its peaks, the region is the most permanent water source for the Nile River (Eggermont, Van Damme, & Russell, 2009; Taylor, Mileham, Tindimugaya, & Mwebembezi, 2009; UNESCO, 2013).

Figure 1.21: Vegetation zonation of the Rwenzori Mountains



Source: Linder & Gehrke, 2006
Photos (top to bottom): Monika Hrdinov / Shutterstock; Oleg Znamenskiy / Shutterstock; Clément Girardot / Flickr / CC BY-NC-SA 2.0

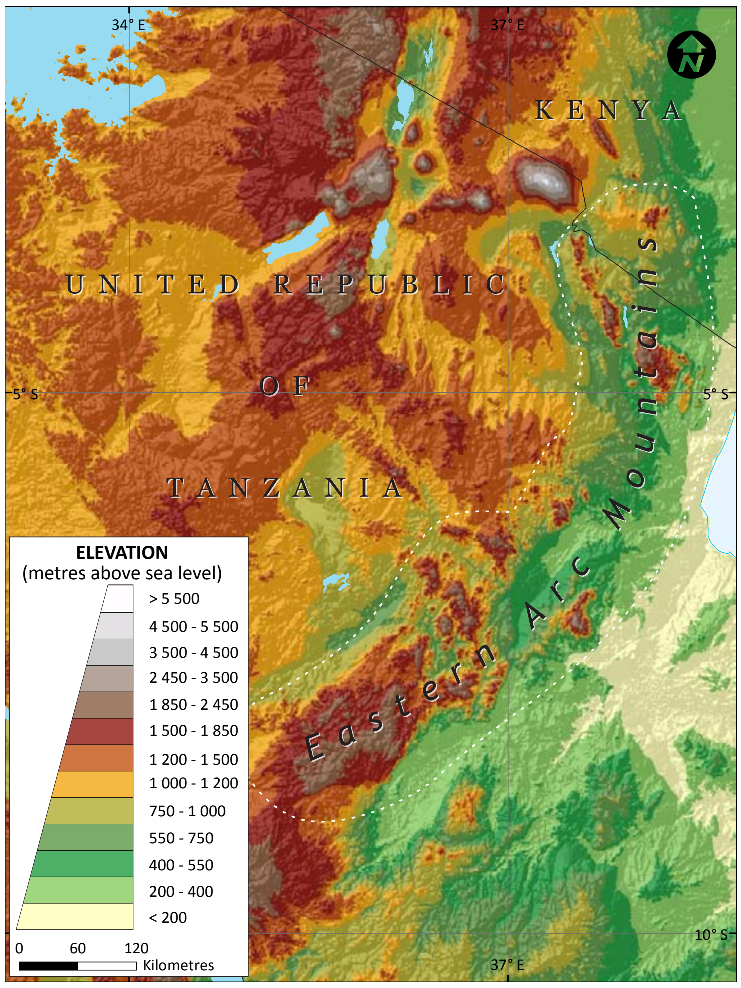
Eastern Arc Mountains

Extending for about 600 km, covering an area of approximately 23 000 km² and comprising 13 mountain blocks, the Eastern Arc Mountain system extends from the Taita Hills in southern Kenya to the Makambako Gap in the southern United Republic of Tanzania (Lovett & Wasser, 1993; GEF, 2002; MNRT, 2010; Figure 1.22). The summit elevations of these mountain groups ranges from 1 000 m to 2 800 m (Newmark, 2002). Twelve of the mountain blocks are found in the United Republic of Tanzania and one in Kenya. The highest peak in the Eastern Arc Mountains is Kimhandu with an elevation of 2 653 m, which is found in the Uluguru Mountains (GEF, 2002).

The Eastern Arc Mountains were formed by block faulting and are made up of Precambrian crystalline rocks that have been dated back to 3 235 to 290 Ma. Sedimentary rocks from the Cretaceous and Jurassic periods and volcanic rocks from the Tertiary period to recent times are also found within the mountains. Uplifting began to occur before the break-up of Gondwanaland, approximately 290 to 180 Ma during the Karoo period, (Newmark, 2002). Cycles of uplift and erosion continued, with the most recent uplift occurring during the creation of the East African Rift, which began about 7 Ma (Griffiths, 1998).

Woodlands, grasslands and shrubs and some forest cover the lowland areas. Submontane forests begin around 800 m and extend upward to the dry montane forests, which receive less than 1 200 mm of annual rainfall, and the montane forests which receive more than 1 200 mm. Montane grasslands and the upper montane forests can be found at elevations above 1 800 m. Overall, there is slightly less than 5 000 km² of natural forest remaining in the Eastern Arc Mountain region (Harper, et al., 2010).

Figure 1.22: Elevation map of the Eastern Arc Mountains



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Usambara Mountains, United Republic of Tanzania

Stephan Scherhag / Shutterstock

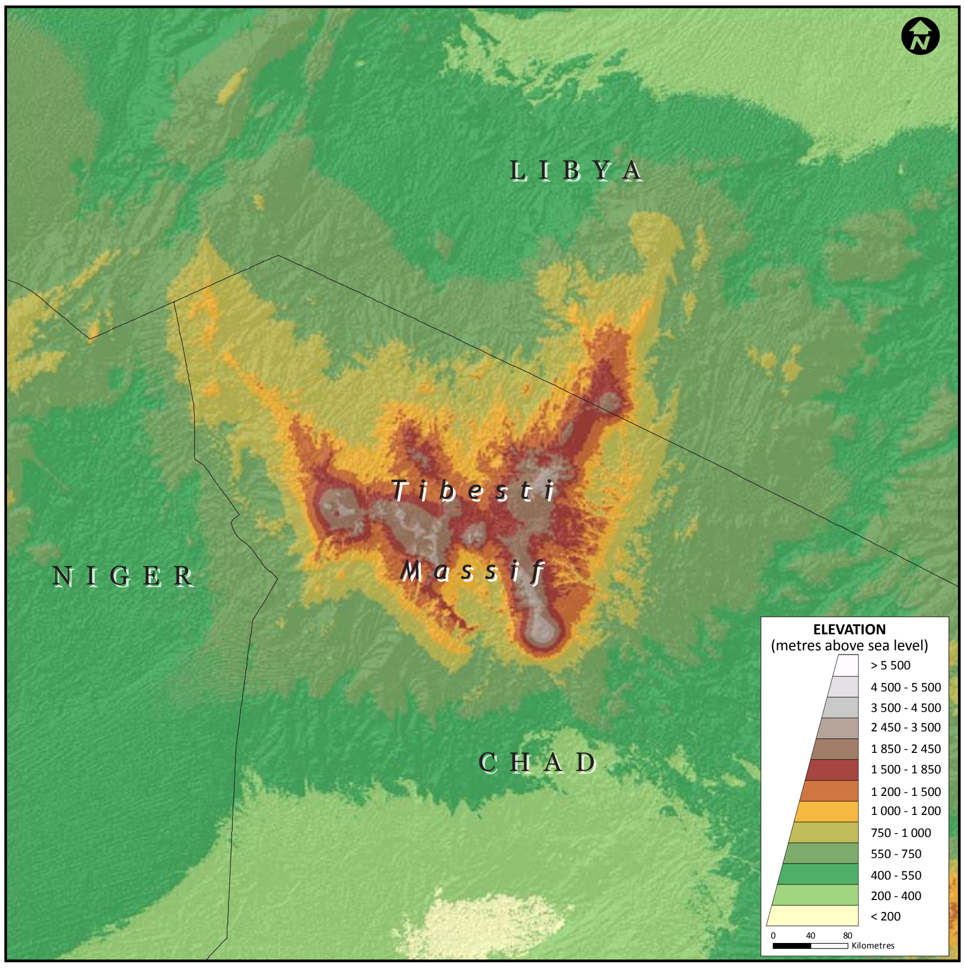
Tibesti Massif

The Tibesti massif, which covers about 100 000 km^2, is a distinctive feature in the Sahara Desert that spans southern Libya and northern Chad (Permenter & Oppenheimer, 2007; Figure 1.23). The tallest peaks of the massif are Cenozoic volcanoes (Schlüter & Trauth, 2008), summiting at Emi Koussi with an elevation of 3 415 m, located in Chad (SI, 2013; Table 1.3; Figure 1.8).

The massif is a result of faulting and volcanic activity (Guiraud, Doumnang Mbaigane, Carretier, & Dominguez, 2000). The massif is one of only six areas in Africa that expose Precambrian crystalline rocks. The core of the exposure is metamorphic and intrusive rocks and they are surrounded by Palaeozoic rocks and partially topped by Tertiary volcanic rocks (Ghuma & Rogers, 1978).

Although the Tibesti massif is located in the desert, water is collected in gorges and wadis (intermittent steams), enabling tropical palms and other plants to grow in certain areas (White, 1983). For example, the northern part of the massif supports a permanent lake, the Mare de Zoui, in which wetland vegetation such as *Phragmites* and *Typha* can be found. Varieties of woody vegetation can be found the deep gorges that cut into the massif (Hughes & Hughes, 1992).

Figure 1.23: Elevation map of the Tibesti massif



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Aerial view of the Emi Koussi volcano on the Tibesti massif, Chad

Volcanic Mountains

Volcanic mountains are usually cone-shaped, having been formed by acculations of lava, ash and hot gases ejected from below the earth's surface. Typically, volcanoes have a depression on top where the crater is or was, although erosion may have caused ancient volcanic mountains to change shape. Volcanoes can be classified into three general states of activity: active, dormant and extinct (Box 1.3).

Box 1.3: Volcano terminology

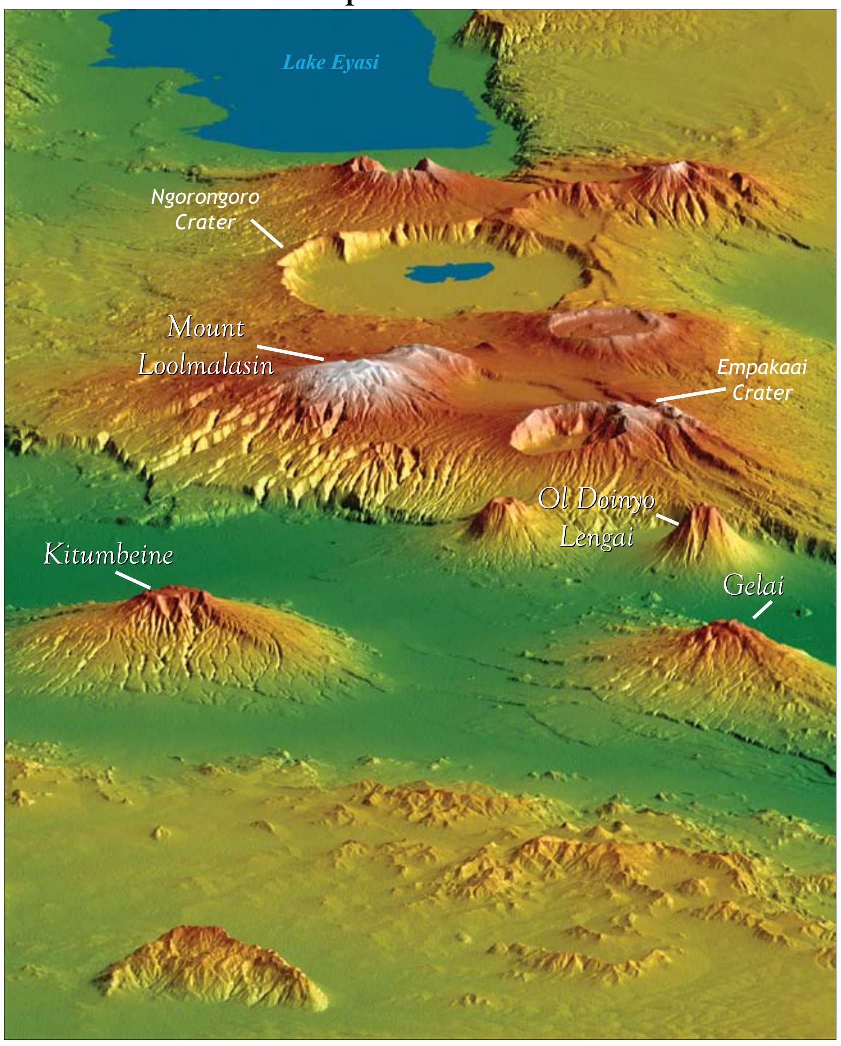
An **active volcano** is one that has in historic time, or is currently erupting or showing signs of unrest, such as earthquake activity or discharge of significant amounts of gas.

A **dormant volcano** is not currently active, but could show activity or erupt again.

An **extinct volcano** is one that has erupted thousands, or tens of thousands, years ago and is unlikely to do so again.

Source: USGS-VHP, 2009

Figure 1.24: Crater highlands, part of the East Africa Rift Zone in the United Republic of Tanzania



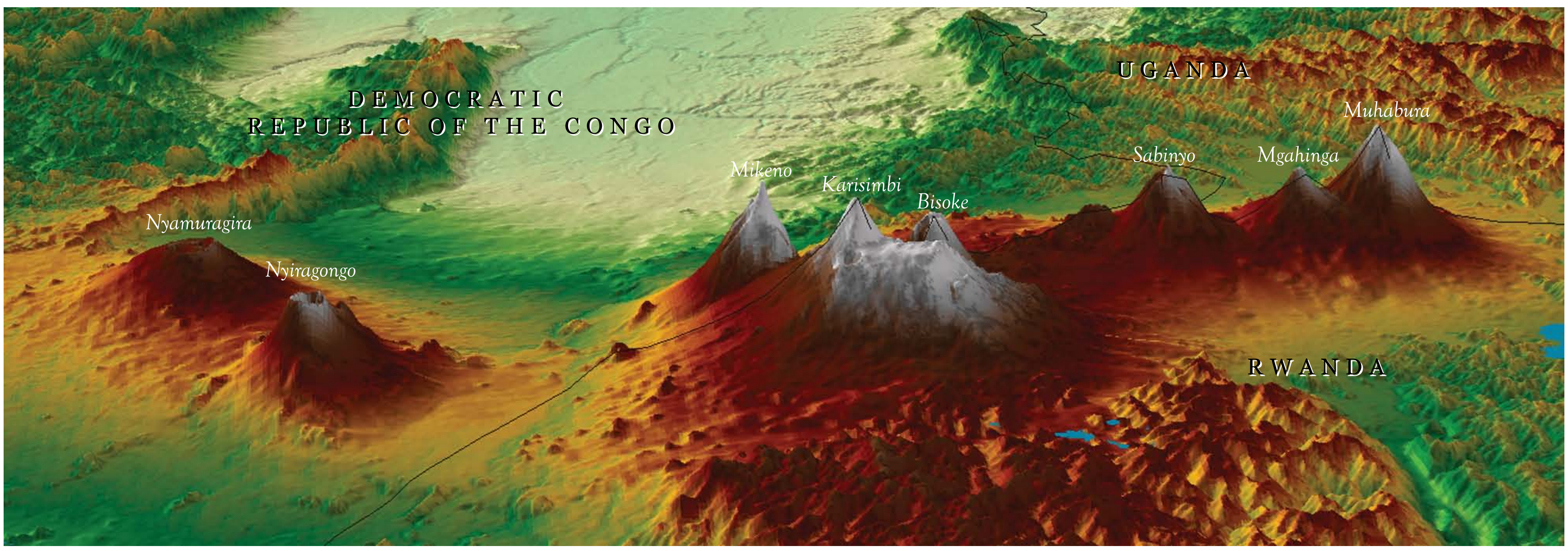
Source: NASA, 2013

Fracturing of the earth's crust and the spreading of the African plate on the west and the Somalian plate on the east formed the East African Rift, one of the world's most dramatic geological structures and the site of many volcanoes and prevalent volcanic activity (NASA, 2013). This region is also home to Africa's highest and lowest volcanoes, Mount Kilimanjaro in the United Republic of Tanzania and Ethiopia's Danakil Depression, respectively (Omenda, 2010).

The two branches of the rift converge at the crater highland area of the United Republic of Tanzania (Figure 1.24). The Rift area also includes the many volcanoes of the Virunga region, which encompasses northern Rwanda, the Democratic Republic of the Congo and Uganda. It is situated between Lake Edward and Lake Kivu and runs in an east-west direction 50 km north of Lake Kivu (Demant, Lestrade, Lubala, Kampunzu, & Durieux, 1994).

The Virunga volcanic region has eight major volcanoes, and these are divided into three groups: eastern (Muhabura, Mgahinga and Sabyinyo), central (Visoke (Bisoke), Karisimbi and Mikeno) and western (Nyiragongo and Nyamuragira) (Figure 1.25). The eastern and central volcanic groups are dormant, while the volcanoes in the western group are active (Wafula, et al., 2007).

Figure 1.25: Volcanoes of the Virunga region



Source: SRTM 1 arc-second DEM; UNEP/DEWA

Extinct Volcanic Mountains

Mount Kenya

Mount Kenya is relatively isolated, lying 180 km to the north of Nairobi, the capital of Kenya, and just south of the equator (Bussman, 2006; Figure 1.9). It is an extinct volcano and the second highest mountain in Africa, rising to Batian, its highest peak at 5 199 m (Baker, 1967).

Mount Kenya was formed as a result of intense tectonic activity on East Africa's central plateau (Baker, 1987; Table 1.4; Figure 1.9). The rift system, created by fracturing, underwent more major faulting events that caused some of the structures to drop lower than sea level. Mount Kenya arose out of this system when lava flows and a succession of volcanic rock from the Pleistocene and Pliocene came up through crust fractures (van Hinsbergen, Buiter, Torsvik, Gaina, & Webb, 2011).

The mountain's main peaks at Batian and Nelion have coarse-grained, intrusive igneous rock, while the lower slopes have different lavas and agglomerates (Wielochowski, 2013). Glacial activity eroded the mountain summit's original cone shape, resulting in jagged topography of knife-edge ridges, pyramidal peaks, U-shaped valleys and rock basins.

Mount Kenya's vegetation includes savanna grasslands at the base; forests of tall and broad-leafed trees on the lower mountain slopes; podocarpus and cedar trees in the middle slopes; a belt of bamboo from about 2 200 m to 3 100 m, surrounded by thin forests of *Hagenia* and *Hypericum* trees above and below the belt; and the alpine zone above 4 000 m. Above 5 000 m, the landscape is bare rock and glaciers (MKT, 2009; Young & Hastenrath, 1991).

Mount Elgon

On the border between Kenya and Uganda, this impressive extinct volcano has numerous peaks including the highest, Wagagai, standing at 4 321 m on the Uganda side (Table 1.4; Figure 1.9). The caldera of Mount Elgon, along with hot springs, is located at an elevation of approximately 4 000 m (UNESCO, 2010b). The caldera measures 40 km^2 in area (UWA, 2012) and is one of the largest intact calderas in the world (UNESCO, 2010b).

This solitary volcano is one of the oldest in eastern Africa, created during the early Miocene epoch (20 - 12 Ma) when lava debris erupted from an enlarged volcanic vent (Mugagga, Buyinza, & Kakembo, 2010). The main rock types are basaltic parent materials, weathered granites (Claessens, Knapen, Kitutu, Poesen, & Deckers, 2007), carbonate intrusions in lower areas (Knapen, et al., 2006; Claessens, Knapen, Kitutu, Poesen, & Deckers, 2007), and inorganic clay soils of high plasticity, which make it extremely vulnerable to landslides (Mugagga, Kakembo, & Buyinza, 2012a; see Chapter 3).

Above 3 500 m, swamps and moorland vegetation dominates, leading downward to bamboo and low-canopy montane forest from 2 400 m to 3 000 m; below 2 500 m, a mixed montane forest overlooks the base of the mountain (Mugagga, Kakembo, & Buyinza, 2012b).

Dormant Volcanic Mountains

Mount Kilimanjaro

Soaring to 5 895 m at Kibo peak (Table 1.5; Figure 1.10), Mount Kilimanjaro is the highest mountain and volcano on the African continent and the highest free-standing mountain in the world. It lies in the northeastern region of the United Republic of Tanzania, along the East African Rift, close to the Kenyan border (Nonnotte, et al., 2008).

Mount Kilimanjaro has three volcanic centres: Shira, Kibo and Mazenzi (from west to east) (Nonnotte, et al., 2008). Kibo is the tallest and youngest centre and the only of the three peaks where glaciers remain (Cullen, et al., 2006). Shield and volcanic eruptions created the mountain, forming mostly igneous rock types in the process (UNDP, 2010; Hayes, 2004). Volcanic activity at the Shira vent began approximately 2.5 Ma and stopped about 1.9 Ma. Activity at Mawenzi and Kibo began about 1 Ma (Nonnotte, et al., 2008). The youngest volcanic rocks found in the Mawenzi eruptive centre are from approximately 448 thousand years ago (ka) and the last volcanic eruption on Kibo occurred around 200 - 150 ka (Nonnotte, et al., 2008). Shira and Mawenzi are considered extinct (Young & Hastenrath, 1991), however Kibo may not be completely extinct (Nonnotte, et al., 2008)

Historic evidence of a more extensive cover of glacier ice on Kilimanjaro has left behind distinct physical features typical of glaciated landscapes, such as moraines, boulder trains, U-shaped valleys, glaciated pavements, rock basins and kettle lakes (Young & Hastenrath, 1991).

There are five main altitudinal vegetation zones on the mountain: colline (below 900 m), submontane (900 - 1 600 m), montane forest (1 600 m to about 2 800 m), subalpine moorland (about 2 800 m to 3 900 m) and alpine vegetation beginning around 3 900 m (Hemp, 2002; Young & Hastenrath, 1991). Parts of the montane forest belt are comprised of Erica excelsa forests from 2 700 m to 3 100 m on the southern slopes and 2 800 m to 3 400 m on the northern slopes (Bussman, 2006). A true alpine desert exists on Kilimanjaro. At the highest elevations on the mountain, annual precipitation is very low (< 200 mm) (Hemp, 2002), thus creating desert-like conditions (Bussman, 2006).

Mount Muhabura

Mount Muhabura is located on the border between Rwanda and Uganda. A dormant stratovolcano in the eastern region of the Virunga volcanic complex, it is the third highest of the eight major mountains in the area, reaching 4 127 m (Table 1.4; Figure 1.9). A 40 m-wide lake is found at the summit (SI, 2013).

Mount Muhabura and two other nearby volcanoes, Mount Sabyinyo and Mgahinga were formed in the early to mid-Pleistocene era of layers of ash and cinder deposits from the lava flow (Kingston, 1967). Mount Muhabura is the youngest volcano of the three (Rogers, James, Kelley, & De Mulder, 1998).

Vegetation ranges from submontane forest at low altitudes (1 300 – 2 000 m) to supra-tropical mountain forests at mid-range altitudes (2 000 – 2 300 m) (Bussman, 2006).

Active Volcanic Mountains

Mount Nyiragongo and Mount Nyamuragira

Mount Nyiragongo and Mount Nyamuragira, which are part of the Virunga volcanic complex (Figure 1.25), are among the most active volcanoes on Earth. The stratovolcano Mount Nyiragongo rises to 3 470 m (Table 1.3; Figure 1.8) and is situated 18 km north of Goma city in eastern DRC. It lies just west of the border between the DRC and Rwanda and approximately 15 km away from neighbouring Mount Nyamuragira, Africa's most active volcano. Rising to 3 058 m (Table 1.3; Figure 1.8), Mount Nyamuragira is a high-potassium basaltic shield volcano located 25 km north of Lake Kivu in the DRC (Volcano Discovery, 2013). The volcanoes are located in the Virunga National Park, Africa's oldest national park, established in 1925 (UNESCO, 2014).

The formation of volcanoes in the Virunga complex could be a result of the Western Rift system spreading horizontally into the Congo craton (Ashwal & Burke, 1989). Nyiragongo and Nyamuragira emerged through regular volcanic processes (hardening of lava and volcanic ash from earlier eruptions), although the divergent movement of two African plates account for the high volcanic activity on mount Nyiragongo (UNOPS, 2009). Nyiragongo and Nyamuragira are relatively young, having formed not more than 2 Ma (Briggs & Booth, 2009). Lava on Mount Nyiragongo flows into the world's largest lava lake at its summit and has chemical compositions similar to ancient asteroids, suggesting the lava comes from deep inside the earth where the source of molten rock is in its pristine condition (Science 20, 2009; Chakrabarti, Basu, Santo, Tedesco, & Vaselli, 2009). Volcanic eruptions from Nyamuragira have low silica content and the lava is alkaline. The lava is very fluid with flow rates of as high as 20 km/hr (Head, Shaw, Wallace, Sims, & Carn, 2011). Nyiragongo has a unique semi-permament lava lake that fills its crater. Prior to 1977 the lake was permanent (Demant, Lestrade, Lubala, Kampunzu, & Durieux, 1994), but now it empties every so often, posing a threat to nearby communities when it does (UNESCO, 2014).

The vegetation on Nyiragongo and Nyamuragira varies from bright-green forested areas to cleared areas to old lava flows with sparse vegetation and some agricultural fields. Nyiragongo and Nyamuragira both primarily have meadows on their east-facing slopes and mixed forest on their west-facing slopes. Some heather and *Mimulopsis* may be found at some of highest elevations on Nyiragongo (Steklis, Madry, Steklis, & Faust, 2005).

View of Nyiragongo from Goma, DRC

Grassy slopes of Mount Cameroon

Mount Cameroon

Mount Cameroon is in southwestern Cameroon and rises to a summit elevation of 4 095 m (Table 1.3; Figure 1.8). The mountain belongs to the Cameroon Volcanic Line (Figure 1.26), a major structural feature that extends from the island of Príncipe through Equatorial Guinea to the highlands of Adamoua in Cameroon and Obudu in Nigeria (Laird, Awung, Lysinge, & Ndi, 2011). On average, eruptions on Mount Cameroon occur every 10 to 20 years, making it the most active volcano on the Cameroon Volcanic Line (SI, 2013) and one of the most active in all of Africa (Suh, et al., 2011).

Mount Cameroon is a stratovolcano formed by three types of volcanic activity (Bardintzeff & McBirney, 2000): effusive eruptions (formed of easily-flowing hot lava), explosive eruptions (due to cooler magma building up pressure) and hydro-magmatic activity (from the interaction of magma and water). It is largely comprised of alkaline rocks (Tsafack, Wandji, Bardintzeff, Bellon, & Guillou, 2009).

Due to the wide altitudinal range, climate and regular volcanic eruptions, Mount Cameroon has diverse vegetation types and high levels of species endemism and richness, including 2 500 plant species. Major forest types on Mount Cameroon include lowland montane rain forest, subalpine rain forest and subalpine grasslands (Cable & Cheek, 1998).

Figure 1.26: Mount Cameroon Volcanic Line (age of formation)

Source: USGS 7.5 arc second maximum DEM; Suh, et al., 2011; Tsafack, Wandji, Bardintzeff, Bellon, & Guillou, 2009; UNEP/DEWA

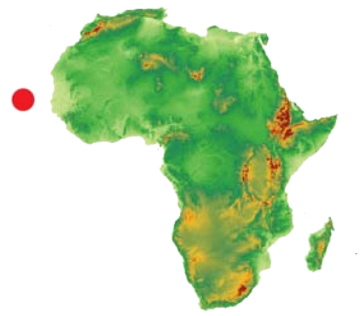
Island volcanoes

Comoros

The Comoros Islands are an archipelago of four tropical volcanic islands, located south of the equator in the northern part of the Mozambique Channel of the Indian Ocean, between Madagascar and the African continent. Together, the islands of Ngazidja (Grande Comore), Mwali (Mohéli) and Ndzuani (Anjouan) form the Union of the Comoros (Granek & Brown, 2005; Sang, et al., 2005) and the archipelago is completed by Mayotte Island, a French overseas département (France.fr, n.d.). Coral patches and fringing coral reefs surround the volcanic islands and a handful of smaller uninhabited islets (Granek & Brown, 2005).

Karthala, an active volcano located on Ngazidja Island, is the highest point of Comoros with an elevation of 2 361 m (Table 1.6; Figure 1.11). La Grille (1 087 m) is an extinct volcanic massif that is also located on Ngazidja, dominating the northern part of the island. Only Karthala has been active historically, with more than twenty eruptions during the past 150 years. The Karthala eruptive style is mostly effusive, however highly magmatic explosions have occurred (Savin, Ritz, Join, & Bachelery, 2001; Bachèlery, et al., 1995; Poppe, et al., 2012).

The original vegetation is mostly evergreen forest, but above approximately 1 500 m, the trees on Karthala give way to stands of a giant heath. In drier parts of northern Grand Comoros and southern and eastern Mayotte, trees are replaced by scrub, with such typical plants as Baobab trees (Louette, 2000; Louette, Meirte, & Jocque, 2004).



Cape Verde

The Republic of Cape Verde is an island archipelago of ten volcanic oceanic islands and minor islets spread over 58 000 km^2 in a horseshoe-shaped cluster of active and inactive volcanoes. Cape Verde is located approximately 500 km offshore of Senegal and 2 000 km east of the Mid-Atlantic Ridge (Pim, Peirce, Watts, Grevemeyer, & Krabbenhoeft, 2008). With about 1 050 km of coastline, the Cape Verde Islands are typically classified into three groups: northern, eastern and southern.

Despite the islands' varied appearances, all are volcanic in origin, since they sit over a hotspot where magma pushes up through the earth's crust and erupts on the sea floor. The relatively low, flat islands of Sal, Boa Vista and Maio are sandy and dry with coastal zones that are predominantly bordered by extensive sandy beaches and low near-shore islets. In contrast, high mountains, prominent sea cliffs, extraordinarily steep

Sao Vicente in Cape Verde

slopes and a wide range of vegetated habitats in relatively small areas characterize the northern and southern island groups (Mayoral, et al., 2013).

Fogo Island contains Cape Verde's tallest mountain, Pico do Fogo, which rises to 2 829 m and represents the only island with recent volcanic activity (Table 1.2; Figure 1.7). The roughly circular 25-km wide island is truncated by a large 9-km wide caldera that is breached to the east and has a headwall that is 1 km high.

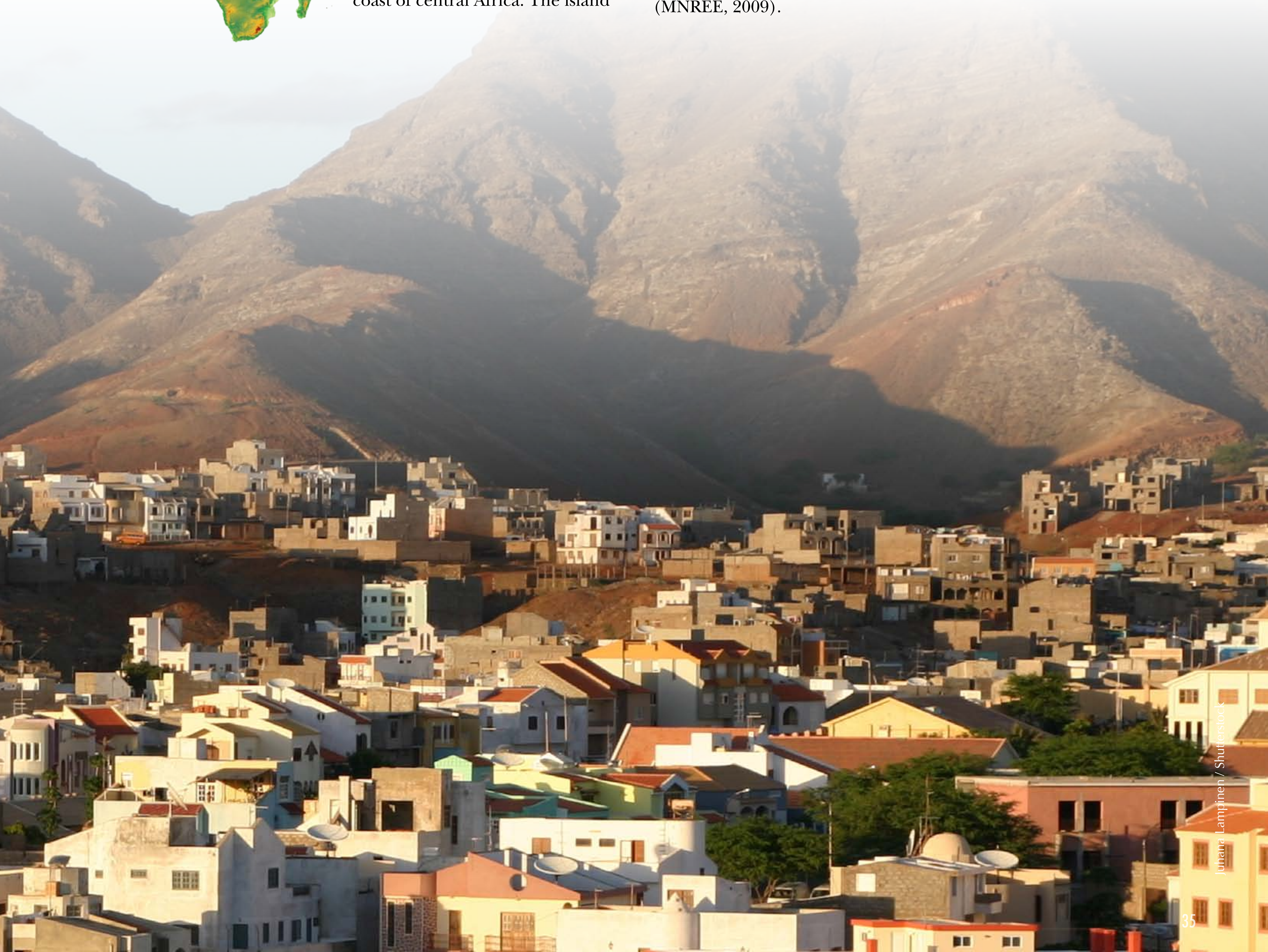
Echium vulcanorum, a woody fuel, is endemic to Fogo and grows at elevations of 1 800 m and above. On Fogo's ancient lava flows, medicinal species such as *Artemisia gorgonum* and *Erysimum caboverdeanum* can be found (Duarte & Romerias, 2009).

São Tomé and Príncipe

The Democratic Republic of São Tomé and Príncipe is a small island nation in the Gulf of Guinea, off the western equatorial coast of central Africa. The island state consists of the main volcanic island of São Tomé (860 km^2) on the equator and Príncipe (104 km^2), which lies 136 km to the north. It also includes some small, mainly unpopulated, rocky offshore islands.

The São Tomé and Príncipe islands are a part of the Cameroon Volcanic Line, having been formed through volcanic processes (Burke, 2001; Figure 1.26). Rocks on the island are primarily basalt, traquite, phenol and andesite; soils are composed of residue from magmatic rocks and other volcanic material (MNREE, 2009). São Tomé is the more mountainous of the two islands, whose highest points are Pico de São Tomé at 2 024 m (Table 1.3; Figure 1.8) and Pico do Príncipe at 948 m, respectively.

Vegetation on the mountains of São Tomé and Príncipe is primarily endemic. At elevations above 1 800 m, flora such as *Psychotria guerkeana* and *Erica thomensis* can be found. Foggy forests exist near peaks and in the highest elevations. In these forests there are *Lobelia barnsii*, trees such as *Homalium henriquensii* and other endemics such as *Peddiea thomensis* (MNREE, 2009).



Juhana Lampinen / Shutterstock

Simien Mountains, Ethiopia

Highlands

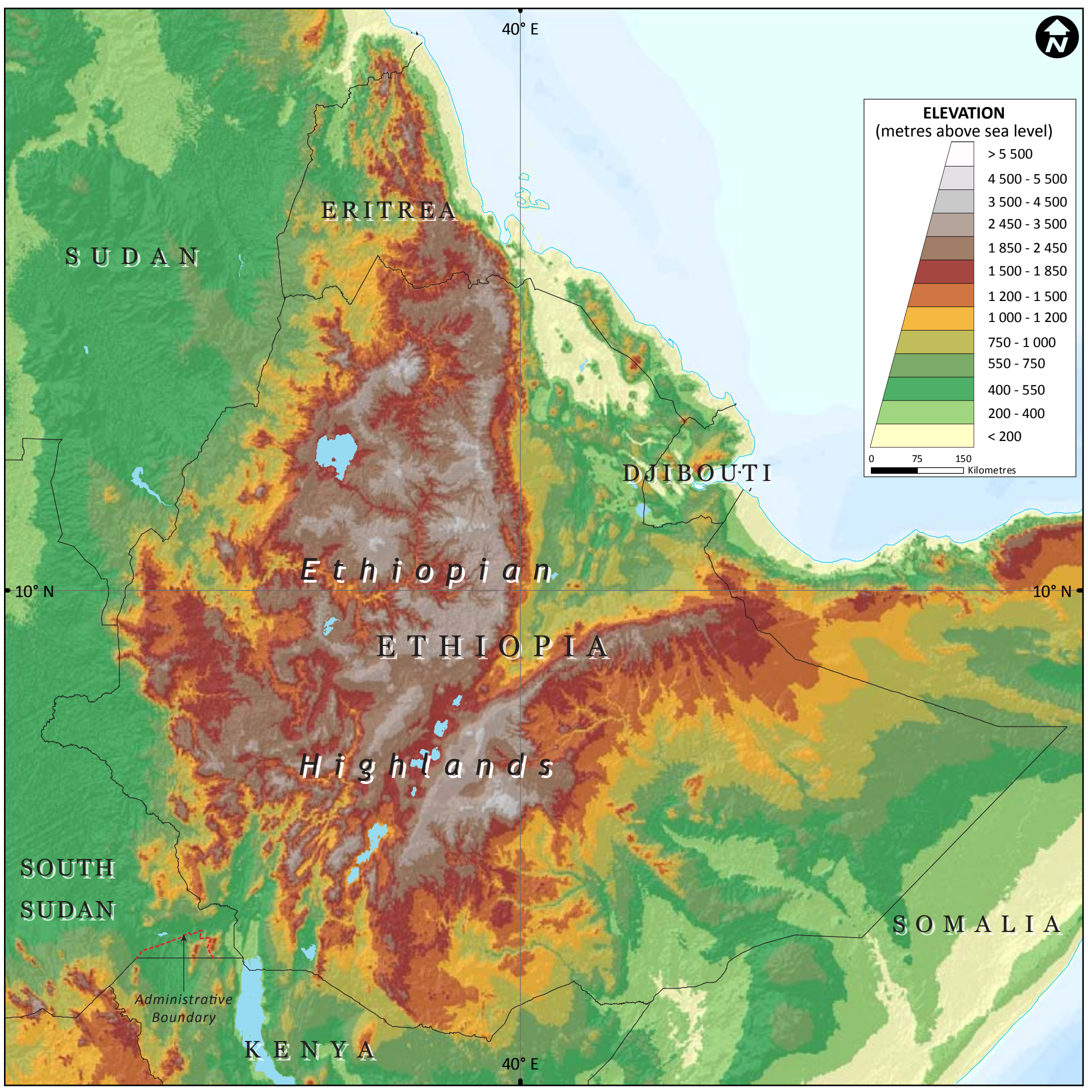
Ethiopian Highlands

The Ethiopian Highlands (above 1 500 m) cover an area of 537 000 km^2, or 43 per cent, of Ethiopia and account for more than half of all the highland areas in Africa (Hurni, 1988). The western Ethiopian Highlands extend from central Eritrea through Ethiopia to the Lake Rudolf basin in the south. The eastern portion of the Highlands extend from south of the Djibouti border to southern Ethiopia (EB, 2013; Figure 1.27). The Highlands contain two main mountain ranges: the Simien and the Bale. Ethiopia's highest peak, Ras Dashen (4 550 m) (Table 1.4; Figure 1.9), is in the Simien range and its second highest, Mount Tullu Demtu (4 377 m), is in the Bale (Sepulchre, et al., 2006).

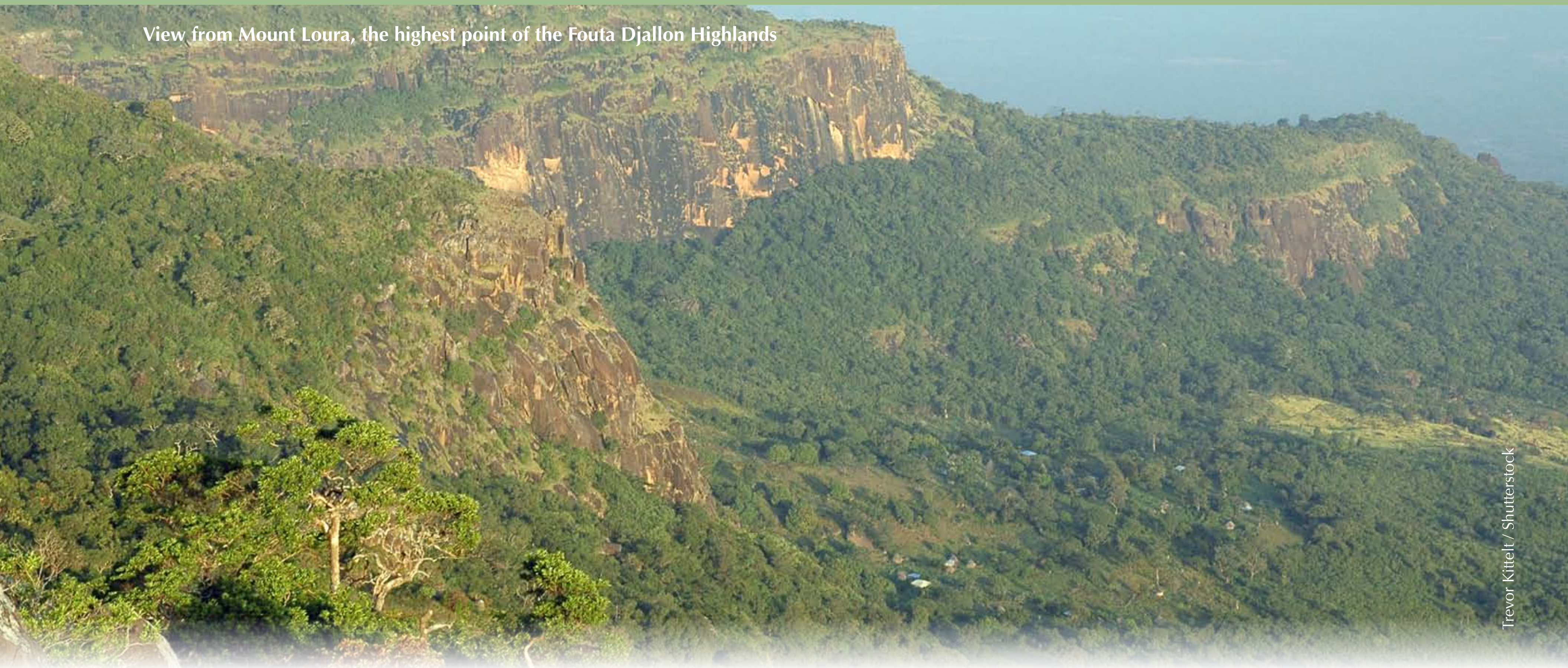
The Ethiopian Highlands were formed 75 million years ago when volcanic forces under the earth pushed upward. The northern and southern highlands were formed along with the Great Rift Valley, cutting the main dome in half. Tertiary lava flows cap Precambrian basement, which form the layer underlying the area's montane forests. The southern highlands and remainder of the massifs are made up of Mesozoic rocks and Tertiary basalts, respectively. Rich volcanic soils are abundant, supporting the region's great biodiversity (EB, 2013).

In the south, a variety of Yellowwood (*Podocarpus falcatus*) and the African juniper (*Juniperus procera*) are found on the drier hillsides and a cloud-forest belt dominates the area between 2 000 and 2 500 m. A broadleaf evergreen montane forest is found in the north while the eastern and western areas are covered in montane forests at lower levels and by Afroalpine ecoregions at higher elevations (EB, 2013).

Figure 1.27: Elevation map of the Ethiopian Highlands



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA



View from Mount Loura, the highest point of the Fouta Djallon Highlands

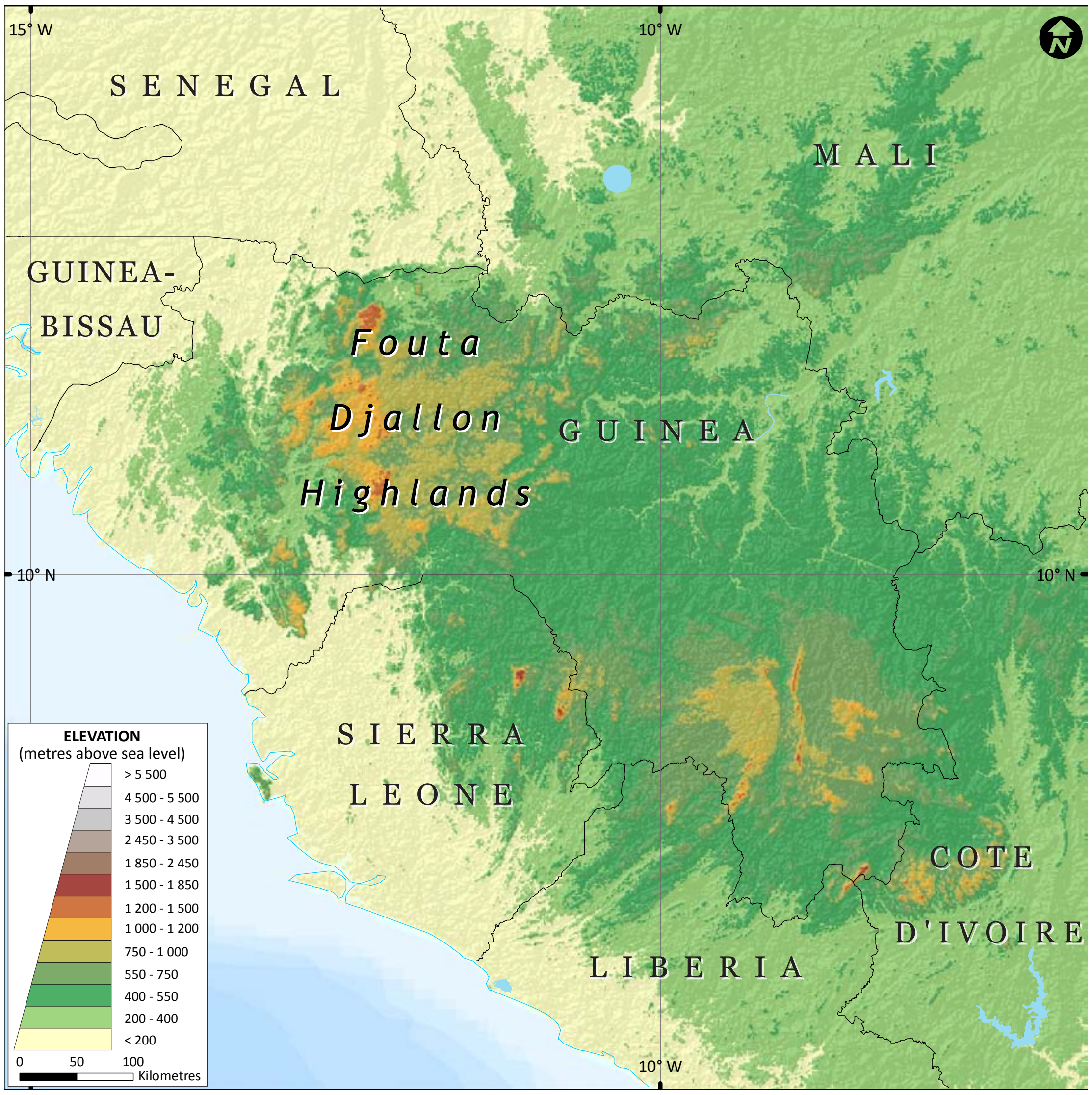
Fouta Djallon Highlands

The Fouta Djallon Highlands (FDH) in west-central Guinea in West Africa cover about 384 300 km^2 of land among parts of five countries: Guinea, Guinea-Bissau, Mali, Senegal and Sierra Leone (Verschoren, 2012; Figure 1.28). The FDH are characterised by blocky elevated sandstone plateau and deep gorges with rivers that feed western Africa's greatest rivers, such as the Niger and the Senegal (Daget, 1962; Capo, Sottolichio, Brenon, Castaing, & Ferry, 2006; EB, 2012). The highest point of the FDH is Mount Loura with an elevation of 1 538 m (Table 1.2; Figure 1.7).

The FDH may be the result of the West African swell after uplifting that occurred about 30 million years ago. Residual relief rose with the uplifted African surface creating stairwells on the uplifted flanks. The elevated surface made of sandstone was eroded further to create the Fouta Djallon plateau highland region (Burke & Gunnell, 2008). The highly weathered soils left behind are rather infertile and the ecological conditions dictate the type of land use (FAO, 1985).

Submontane vegetation, such as the Guinea plum (*Parinari excelsa*) and the locust bean tree (*Parkia biglobosa*), are prevalent in the upland areas (Sayer & Harcourt, 1992), which are bordered by forest and savanna transition zones.

Figure 1.28: Elevation Map of the Fouta Djallon Highlands



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Conclusion

This chapter has identified and described some of Africa's mountainous and highland regions, providing the basic knowledge upon which to further examine these ecosystems.

Now that a foundation of knowledge has been built, the Atlas turns to looking at what are called "ecosystem goods and services". These are the functions we take for granted, such as storing and filtering water, as well as the goods derived from mountains, such as forest products, water for domestic use, irrigation and hydroelectricity, and fertile soils for crops, among many others. The next chapter reveals why mountains are so vital to Africa's 1.1 billion people.

References

Ashwal, L., & Burke, K. (1989). African lithospheric structure, volcanism, and topography. Earth and Planetary Science Letters, 96, 8-14.

Baali-Cherif, D., & Besnard, G. (2005). High Genetic Diversity and Clonal Growth in Relict Populations of Olea europaea subsp. laperrinei (Oleaceae) from Hoggar, Algeria. Annals of Botany, 96, 823-830.

Bachèlery, P., Ben Ali, D., Desgrolard, F., Toutin, J., Coudray, J., Cheminée, J., . . . Klein, J. (1995). L'eruption phréatique du Karthala (Grande Comore) en Juillet 1991. . C. R. Acad. Sci. Paris, Ser. IIa, 320, 691-698.

Bagoora, F. (2012). Potential and climate change vulnerability, impacts and adaptation options in African mountains. International Conference of Mountain Countries Climate Change in Kathmandu, Nepal, (p. 94 slides).

Baker, B. (1967). Geology of the Mount Kenya Area. Nairobi: Republic of Kenya Ministry of Natural Resources Geological Survey of Kenya.

Baker, B. (1987). Outline of the Petrology of the Kenya Rift Alkaline Province. Geol. Soc. Lond. Spec. Publ., 30, 293-311.

Bardintzeff, J., & McBirney, A. (2000). Volcanology, 288.

Barrow, C., & Hicham, H. (2000). Two complimentary and integrated land uses of the western High Atlas Mountains, Morocco: the potential for sustainable rural livelihoods. Applied Geography, 20, 369-379.

Benabid, A., & Fennane, N. (1994). Connaissance sur la vegetation du Maroc: phytogégraphie, phytosociologie et sèrie de végétation. Lazaroa, 14, 21-97.

Bjørstad, P. (2007). The Africa 50 Finest Mountains ranked by primary factor. Retrieved from http://www.ii.uib.no/~petter/mountains/africa_finest.html

Bradt, H. (2011). Madagascar: Bradt Travel Guides. Guilford: The Globe Pequot Press Inc.

Briggs, P., & Booth, J. (2009). Rwanda (4th ed.). Connecticut, USA: The Globe Pequot Press Inc.

Burke, K. (2001). Origin of the Cameroon Line of Volcano-Capped Swells. The Journal of Geology, 109, 349-362.

Burke, K., & Gunnell, Y. (2008). The African Erosion Surface:A Continental-scale Synthesis of Geomorphology, Tectonics, and Environmental Change Over the Past 180 Million Years (Vol. 201). Geological Society of America Memoirs. doi:10.1130/2008.1201

Bussman, R. (2006). Vegetation zonation and nomenclature of African Mountains - An overview. Lyonia: A journal of ecology and application, 41-66.

Byers, A., Price, L., & Price, M. (2013). Introduction to Mountains. In M. Price, A. Byers, D. Friend, T. Kohler, & L. Price (Eds.), Mountain Geography: Physical and Human Dimensions (pp. 1-10). Berkeley and Los Angeles: University of California Press.

Cable, S., & Cheek, M. (1998). The Plants of Mt Cameroun: A conservation checklist. London: The Royal Botanic Gardens.

Cain, F. (2009). How Mountains Are Formed. Retrieved December 12, 2013, from http://www.universetoday.com/29833/how-mountains-are-formed/

Calvert, A., Sanvol, E., Seber, D., Barazangi, M., Roecker, S., Mourabit, T., . . . Jabour, N. (2000). Geodynamic Evolution of the Lithosphere and Upper Mantle Beneath the Alboran Region of the Western Mediterranean: Constraints from Travel Time Tomography. Journal of Geophysical Research, 105, 10871-10898.

Capo, S., Sottolichio, A., Brenon, I., Castaing, P., & Ferry, L. (2006). Morphology, hydrography and sediment dynamics in a mangrove estuary: The Konkoure Estuary, Guinea. Marine Geology, 230:99–215.

CEE. (2012). Atlas Mountains. Retrieved August 21, 2013, from The Columbia Electronic Encyclopedia 6th Ed: http://www.infoplease.com/encyclopedia/world/atlas-mountains.html#ixzz2bH18pwsK

Chakrabarti, R., Basu, A., Santo, A., Tedesco, D., & Vaselli, O. (2009). Isotopic and geochemical evidence for a heterogeneous mantle plume origin of the Virunga volcanics, Western rift, East African Rift system. Chemical Geology, 259, 273-289.

Claessens, L., Knapen, A., Kitutu, M., Poesen, J., & Deckers, J. (2007). Modelling landslide hazard, soil redistribution and sediment yield of landslides on the Ugandan foot-slopes of Mount Elgon. Geomorphology, 90, 23-35.

Coffin, M.F., Gahagan, L.M., Lawver, L.A. (1998). Present-day Plate Boundary Digital Data Compilation. University of Texas Institute for Geophysics Technical Report No. 174. Retrieved June 13, 2014, from The University of Texas Institute for Geophysics: http://www.ig.utexas.edu/research/projects/plates/data.htm

Compton, J., & Maake, L. (2007). Source of the suspended load of the upper Orange River, South Africa. South African Journal of Geology, 110, 339-348.

Cullen, N., Mõlg, T., Kaser, G., Hussein, K., Steffen, K., & Hardy, D. (2006). Kilimanjaro Glaciers: Recent areal extent from satellite data and new interpretation of observed 20th century retreat rates. Geophysical Research Letters, 33(L16502). doi:10.1029/2006GL027084

Daget, J. (1962). Les poissons de du Fouta Djalon et de la basse Guinee. Memoire de l'institut francais d'Afrique Noir, 65, 1-210.

Demant, A., Lestrade, P., Lubala, R., Kampunzu, A., & Durieux, J. (1994). Volcanological and Petrological Evolution of Nyiragongo Volcano, Virunga Volcanic Fields, Zaire. Bulletin of Volcanology, 56, 47-61.

Draper, V., Mazimpaka, B., Albertos, R., Gariletti, R., & Lara, F. (2005). A survey of the spiphytic bryophyte flora of the Rif and Tazzeka Mountains (northern Morocco). Journal of Biology, 27, 23-34.

Duarte, M., & Romeiras, M. (2009). Cape Verde Islands. In R. Gillespie, & D. Clague (Eds.), Encyclopedia of Islands (pp. 143-147). Berkeley, Los Angeles, London: University of California Press.

EB. (2011). Veld. Retrieved January 10, 2014 from Encyclopedia Britannica: http://www.britannica.com/EBchecked/topic/624804/veld/37025/Plant-life

EB. (2012). Fouta Djallon. Retrieved January 10, 2014 from Encyclopedia Brittanica: http://www.britannica.com/EBchecked/topic/215288/Fouta-Djallon.

EB. (2013). Ethiopia: Soils. Retrieved January 10th, 2014, from Encyclopedia Brittanica: http://www.britannica.com/EBchecked/topic/194084/Ethiopia/37681/Soils

EECRG. (2002). The Drakensberg Mountains of South Africa and Lesotho. Retrieved from Ecological and Environmental Change Research Group: http://www.eecrg.uib.no/projects/AGS_BotanyExp/Drakensberg/Drakensberg.htm

Eggermont, H., Van Damme, K., & Russell, J. (2009). Rwenzori Mountains (Mountains of the Moon); Headwaters of the White Nile. (D. H., Ed.) The Nile: Origin, Environments, Limnology and Human Use.

Ellero, A., Ottria, G. M., & Ouanaimi, H. (2012). Chapter 9: Structural Geological Analysis of the High Atlas (Morocco): Evidences of a Transpressional Fold-Thrust Belt. In E. Sharkov, Tectonics - Recent Advances (pp. 229-258). Intech, Open Access Book.

FAO. (1985). Integrating crops and livestock in West Africa. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2000). International Year of Mountains. Rome, Italy: Food and Agriculture Organization of the United Nations.

Fernandez, M., Berastegui, X., Puig, C., Garcia-Castellanos, D., Jurado, M., Torne, M., & Banks, C. (1998). Geophysical and geological constraints on the evolution of the Guadalquivir foreland basin. In A. Mascle, H. Puigdefabregas, H. Luterbacher, & M. Fernandez, Cenozoic foreland basins of western Europe (pp. 29-48). Geol. Soc. Spec. Publ.

France.fr. (n.d.). Mayotte: a preserved archipelago. Retrieved April 9, 2014, from france.fr: The Official Website of France: http://www.france.fr/en/regions-and-cities/mayotte-preserved-archipelago.html

GEF. (2002). Project Brief: Conservation and Management of the Eastern Arc Mountain Forests, Tanzania. Arusha, Tanzania: GEF.

Ghuma, M., & Rogers, J. (1978). Geology, Geochemistry, and tectonic setting of the Ben Ghnema batholith, Tibesti massif, Southern Libya. Geol Soc Am Bull, 89, 1351-1358.

Goldblatt, P., & Manning, J. (2002). Plant Diversity of the Cape Region of South Africa. Ann. Missouri Botanical Gardens, 89, 281–302.

Granek, E., & Brown, M. (2005). Co-Management Approach to Marine Conservation in Moh'eli, Comoros Islands. Conservation Biology, 19(6), 1724-1732.

Griffiths, C. (1993). The geological evolution of East Africa. (C. Lovett, & S. Wasser, Eds.) Biogeography and ecology of the rain forests of eastern Africa, 9-21.

Guiraud, R., Doumnang Mbaigane, J., Carretier, S., & Dominguez. (2000). Evidence for a 6000 km length NW-SE striking lineament in northern Africa: The Tibesti Lineament. J Geol Soc, 157, 897-900.

Hammi, S., Simonneaux, V., Cordier, J., Genin, D., Alifriqui, M. M., & Auclair, L. (2010). Can traditional forest management buffer forest depletion? Dynamics of Moroccan High Atlas Mountain forests using remote sensing and vegetation analysis. Forest Ecology and Management, 260, 1861-1872.

Harper, E.B., Measey, G.J., Patrick, D.A., Menegon, M., Vonesh, J.R., Swilla, I. (2010). Field Guide to the Amphibians of the Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya. Nairobi: Camerapix Publishers International.

Hayes, S. (2004). Magmatic evolution of the Shira Volcanocs, Mt Kilimanjaro, Tanzania. Queensland University of Technology, Australia.

Haywick, D. (2008). Geological Maps 2: Folded Strata. University of Southern Alabama. Retrieved March 12, 2014, from http://www.usouthal.edu/geology/haywick/GY111/folds.pdf

Head, E., Shaw, A., Wallace, P., Sims, K., & Carn, S. (2011). Insight into volatile behaviour at Nyamuragira volcano (D.R. Congo, Africa) through olivine-hosted melt inclusions. Geochemistry, Geophysics, Geosystems, 12(10). doi:10.1029/2011GC003699

Hemp, A. (2002). Ecology of the pteridophytes on the southern slopes of Mt. Kilimanjaro. Plant Ecology, 159, 211 - 239.

Hughes, R.H., & Hughes, J.S. (1992). A Directory of African Wetlands. Gland, Cambridge, Nairobi: IUCN, UNEP, WCMC.

Hurni, H. (1988). Degradation and Conservation of the Resources in the Ethiopian Highlands. Mountain Research and Development. 8(2/3), 123 - 130.

Johnston, S. (2000). The Cape Fold Belt and Syntaxis and the rotated Falkland Islands: dextral transpressional tectonics along the southwest margin of Gondwana. Journal of African Earth Sciences, 31(1).

Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., . . . R., Z. (2013). Soil Atlas of Africa. Luxembourg: European Commission Joint Research Centre.

Kenya Forest Service. (2010). Aberdare Forest Reserve Management Plan - 2010-2019. Nairobi: Kenya Forest Service.

Kingston, B. (1967). Working Plan for Mgahinga Central Forest Reserve, Forest Department. Kampala: Unpubl. Report.

Kious, W., & Tilling, R. (1996). This Dynamic Earth: The Story of Plate Tectonics. U.S. Geologic Survey.

Knapen, A., Kitutu, M., Poesen, J., Breugelmans, W., Deckers, J., & Muwanga, A. (2006). Landslides in a densely populated county at the foot-slopes of Mount Elgon (Uganda): Characteristics and causal factors. Geomorphology, 73, 149-165.

Kollmair, M., Gurung, G., Hurni, K., & Maselli, D. (2005). Mountains: Special places to be protected? An analysis. International Journal of Biodiversity Science and Management, 181-189.

Laird, S., Awung, G., Lysinge, R., & Ndi, L. (2011). The interweave of people and place: biocultural diversity in migrant and indigenous livelihoods around Mount Cameroon. Special Issue: Forests, Biodiversity and Food Security. International Forestry Review, 13(3), 275-293.

Linder, P., & Gehrke, B. (2006). Common plants of the Rwenzori, particularly the upper zones. Zurich: Institute for Systematic Botany University of Zurich.

Lindstadte, A., & Baumann, G. (2013). Abiotic and biotic recovery pathways of arid rangelands: Lessons from the High Atlas Mountains, Morocco. Catena, 103, 3–15.

Lock, B. (1980). Flat-plate subduction and the Cape Fold Belt of South Africa. Geology, 8, 35-39.

Louette, M. (2000). Bird communities on the Comoro Islands. Bonn Zool Monogr, 46, 325–336.

Louette, M., Meirte, D., & Jocque, R. (2004). La faune terrestre de l'archipeldes Comores (MRAC, Tervuren). Stud Afrotrop Zool, 293.

Lovett, J. (1998). Continuous Changes in Tanzania moist forest tree communities with elevation. Journal of Tropical Ecology, 14, 719-722.

Lovett, J., & Wasser, S. (1993). Biogeography and Ecology of the Rain Forests of Eastern Africa. Cambridge: Cambridge University Press.

Macchi, M., & ICIMOD. (2010). Mountains of the World: Ecosystem services in a time of global and climate change. Kathmandu: ICIMOD.

Maneveldt, G. (n.d.). UWC's Enviro-Facts Guide to Fynbos. Retrieved January 18, 2014, from The University of the Western Cape, Department of Biodiversity & Conservation Biology: http://www.botany.uwc.ac.za/envfacts/fynbos/

Mayoral, E., J., L.-V., Baarli, B., Santos, A., R., R., Cachão, M., . . . Johnson, M. (2013). Ichnology in oceanic islands; case studies from the Cape Verde Archipelago. Palaeogeography, Palaeoclimatology, Palaeoecology, 381-382, 47-66. doi:http://dx.doi.org/10.1016/j.palaeo.2013.04.014

McDonald, D., & Cowling, R. (1995). Towards a profile of an endemic Mountain Fynbos flora: Implications for conservation. Biol. Conserv., 72, 1-12.

Messerli, B., Hurni, H., Wolde-Semaya, B., Tedla, S., Ives, J., & Wolde-Mariam, M. (1988). African Mountain and Highlands: Introduction and Resolution. Mountain Research and Development, 8(2/3), 93-100.

Michard, A., Chalouan, A., Feinberg, H., Goffe, B., & Montigny, R. (2002). How does the Alpine belt end between Spain and Morocco? Bull. Soc. géol. Fr., 73(1) 3-15.

MKT. (2009). Mount Kenya Ecology and Environment: Booklet for Schools and Education Centers. Mount Kenya Trust (MKT). Nairobi: Kenya.

MNREE. (2009). Fourth National Report on the Biodiversity. Democratic Republic of Sao Tomé and Principe: Ministry of Natural Resources, Energy and Environment (MNREE).

MNRT. (2010). Nomination of Properties for Inclusion on the World Heritage List Serial Nomination: Eastern Arc Mountain Forests of Tanzania. United Republic of Tanzania: Ministry of Natural Resources and Tourism (MNRT).

Mugagga, F., Buyinza, M., Kakembo, V. (2010). Livelihood Diversification Strategies and Soil Erosion on Mount Elgon, Eastern Uganda: A Socio-Economic Perspective. Environmental Research Journal, 4(4), 272 - 280.

Mugagga, F., Kakembo, V., & Buyinza, M. (2012a). A characterisation of the physical properties of soil and the implications for landslide occurence on the slopes of Mount Elgon, Eastern Uganda. Natural Hazards, 60(3), 1113-1131.

Mugagga, F., Kakembo, V., & Buyinza, M. (2012b). Land use changes on the slopes of Mount Elgon and the implications for the occurrence of landslides. Catena, 90, 39-46. doi:10.1007/s11069-011-9896-3.

NASA. (2013). Crater Highlands, Tanzania. Retrieved February 18, 2014, from National Aeronautics and Space Administration: http://www.nasa.gov/topics/earth/earthmonth/earthmonth_2013_02.html

National Geographic. (2013). Mountains. Retrieved January 31, 2014, from http://science.nationalgeographic.com/science/earth/surface-of-the-earth/mountains-article/

Nelson, M. (2010). Ten interesting facts about Mount Kilimanjaro. WWF. Retrieved August 9, 2013, from http://worldwildlife.org/blogs/wwf-travel-blog/posts/ten-interesting-facts-about-mt-kilimanjaro

Newmark, W.D. (2002). Conserving Biodiversity in East African Forests: A Study of the Eastern Arc Mountains. Heidelberg and New York: Springer-Verlag.

Newton, A. (1973). A gravity-folding model for the Cape fold-belt. Geological Society of South Africa Transitions, 5(76), 145-152.

NOAA. (2009). Glossary - M. Retrieved January 16, 2014, from National Oceanic and Atmospheric Administartion's National Weather Service: http://w1.weather.gov/glossary/

Nonnotte, P., Guillou, H., Le Gall, B., Benoit, M., Cotton, J., & Scaillet, S. (2008). New Ar-K age determination of Kilimanjaro volcano in the North Tanzania diverging rift, East Africa. Journal of Volcanology and Geothermal Research, 173(1-2), 99-112.

Omenda, P. (2010). The Geology and Geothermal Activity of the East African Rift. Short Course V on Exploration for Geothermal Resources (pp. 1-18). Kenya: UNU-GTP, GDC and KenGen.

Paradise, T. (2010). Atlas Mountains. Retrieved from Encyclopedia of World Geography: http://world-geography.org/mountain/53-atlas-mountains.html

Peaklist. (2007). The World Ultras Homepage. Retrieved February 18, 2014, from Peaklist: http://www.peaklist.org/ultras.html

Peakware. (2013). Atlas Mountains. Retrieved from Peakware World Mountain Encyclopedia: http://www.peakware.com/areas.html?a=309

Peltorinne, P. (2004). The forest types of Kenya. University of Helsinki, Department of Geography. Helsinki: Pellikka, P., J. Ylhaisi & B. Clarke (Eds.) Taita Hills and Kenya, 2004 - seminar, reports and journal of a field excursions to Kenya.

Permenter, J., & Oppenheimer, C. (2007). Volcanoes of the Tibesti Massif (Chad, northern Africa). Bull Volcanol, 69, 609-626.

Peter, M. (2009). The Ruwenzori (Rwenzori) Mountains, Africa. Retrieved June 13, 2013, from http://www.eoearth.org/view/article/156551

PGWC. (2007). Socio-Economic Profile: Central Karoo District 2007. Cape Town: Provincial Government of Western Cape.

Pim, J., Peirce, C., Watts, A., Grevemeyer, I., & Krabbenhoeft, A. (2008). Crustal structure and origin of the Cape Verde Rise. Earth and Planetary Science Letters, 272, 422-428.

Piqué, A. (2001). Geology of Northwest Africa (Beiträge zur Regionalen Geologie der Erde). Gebrüder Borntraeger, 29.

Poppe, S., Kervyn, M., Soulé, H., Cnudde, V., De Kock, T., & Jacobs, P. (2012). Volcano-tectonic architecture of a Caldera Complex, Karthala volcano, Grande Comore: new field observations . Geophysical Research Abstracts 14. EGU General Assembly, held 22-27 Apr (p. 5334). Vienna: EGU General Assembly.

RAMSAR. (2006). Ethiopia. Retrieved February 18, 2014, from The Ramsar Convention on Wetlands: http://ramsar.wetlands.org/Portals/15/ETHIOPIA.pdf

Rankou, H., Culham, A., Jury, S., & Christenhusz, M. (2013). The endemic flora of Morocco. Phytotaxa, 78(1),1–69.

Rogers, N., James, D., Kelley, S., & De Mulder, D. (1998). The generation of potassic lavas from the eastern Virunga province, Rwanda. Journal of Petrology, 39(6), 1223-1247.

Russell, J., Eggermont, H., Taylor, R., & Verschuren, D. (2009). Paleolimnological records of recent glacier recession in the Rwenzori Moutains, Uganda-D.R. Congo. Journal of Paleolimnology, 41(2), 253-271.

Savin, C., Ritz, M., Join, J.-L., & Bachelery, P. (2001). Hydrothermal system mapped by CSAMT on Karthala volcano, Grande Comore Island, Indian Ocean. Journal of Applied Geophysics, 48, 143-152.

Sayer, J., & Harcourt, C. (1992). The conservation atlas of tropical forests: Africa. London, UK: IUCN.

Science 20. (2009). Why is the Nyiragongo volcano lava different from others? Retrieved February 18, 2014 from Science 20: http://www.science20.com/news_releases/why_nyiragongo_volcano_lava_different_others

Schlüter, T., Trauth, M.H. (2008). Geological Atlas of Africa: With Notes on Stratigraphy, Tectonics, Economic Geology, Geohazards, Geosites and Geoscientific Education of Each Country. Springer.

Scott-Shaw, C., & Escott, B. (2011). KwaZulu-Natal Provincial Pre-Transformation Vegetation Type Map 2011: Unpublished GIS Coverage [kznveg05v2_1_11wll.zip]. Pietermaritzburg: Biodiversity Conservation Planning Division, Ezemelo KZN Wildlife.

Sepulchre, P., Ramstein, G., Fluteau, F., Schuster, M., Tiercelin, J., & Brunet, M. (2006). Tectonic Uplift and Eastern Africa Aridification. Science, 313(5792), 1419-1423. doi:10.1126/science.1129158

Shuler, A., & Ekstrom, G. (2009). Anomalous earthquakes associated with Nyiragongo volcano: Observations and potential mechanisms. Journal of Volcanology and Geothermal Research, 181, 219-230.

SI. (2013). Global Volcanism Program: National Museum of Natural History. Retrieved from Smithsonian Institute: http://www.volcano.si.edu/

Simkin, T., Tilling, R.I., Vogt, P.R., Kirby, S.H., Kimberly, P., Stewart, D.B. (2006). This Dynamic Planet: World Map of Volcanoes, Earthquakes, Impact Craters, and Plate Tectonics. Retrieved June 13, 2014 from, USGS: http://pubs.usgs.gov/imap/2800/TDPfront.pdf

Steklis, D., Madry, S., Steklis, N.G., &Faust, N. (2005). GIS Applications for Gorilla Behavior and Habitat Analysis. Retrieved June 18, 2014 from, ESRI: http://www.esri.com/news/arcnews/summer05articles/gis-applications.html

St-Katherine. (2006). The Sinai High Mountian Region. Retrieved February 18, 2014, from St. Katherine and the Sinai High Mountian Region: http://www.st-katherine.net/english/mountains.php

Suh, C., Stansfield, S., Sparks, R., Njome, M., Wantim, M., & Ernst, G. (2011). Morphology and structure of the 1999 lava flows at Mount Cameroon Volcano (West Africa) and their bearing on the emplacement dynamics of volume-limited flows. Geol. Mag., 148(1), 22-34.

Taylor, R., Mileham, L., Tindimugaya, C., & Mwebembezi, L. (2009). Recent glacial recession and its impact on alpine riverflow in the Rwenzori Mountain of Uganda. Journal of African Earth Sciences, 55, 205-213.

Timberlake, J., Dowsett-Lemaire, F., Bayliss, J., Alves, T., Baena, S., Bento, C., . . . de Sousa, C. (2009). Mt. Namuli, Mozambique: Biodiversity and Conservation; Report produced under the Darwin Initiative Award 15/036. London: Royal Botanical Gardens, Kew.

TPWS. (2010). Gondwana the Great Supercontinent. Tasmania: Tasmania Parks & Wildlife Service. Retrieved from Tasmania Parks and Wildlife Service.

Tsafack, J., Wandji, P., Bardintzeff, J., Bellon, H., & Guillou, H. (2009). The Mount Cameroon stratovolcano (Cameroon Volcanic Line, Central Africa): Petrology, geochemistry, isotope and age data. Geochemistry, Mineralogy and Petrology, 47, 65-78.

UNDESA. (2013). World Population: The 2012 Review. UN Department of Economic and Social Affairs, New York.

UNDP. (2010). Proposed Project: Reducing Land Degradation on the Highlands of Kilimanjaro Region. Tanzania: United Nations Development Programme.

UNEP. (2006). Africa Environmental Outlook 2: Our Environment, Our Wealth. Nairobi: United Nations Environment Programme.

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

UNESCO. (2002). Biosphere reserves: Special Places for people and Nature. Paris: UNESCO.

UNESCO. (2010a). Aberdare Mountains. Retrieved August 8, 2013, from United Nations Educational, Scientific and Cultural Organization World Heritage List: http://whc.unesco.org/en/tentativelists/5506/

UNESCO. (2010b). Biosphere Reserve Information: Uganda, Mount Elgon. Retrieved June 18, 2014, from United Nations Educational, Scientific and Cultural Organization - MAB Biosphere Reserves Directory: http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?code=UGA+02&mode=all

UNESCO. (2013). Kilimanjaro National Park. Retrieved August 14, 2013, from United Nations Educational, Scientific and Cultural Organization World Heritage List: http://whc.unesco.org/en/list/403

UNESCO. (2014). Virunga National Park. Retrieved April 14, 2014, from United Nations Educational, Scientific and Cultural Organization World Heritage List: http://whc.unesco.org/en/list/63

UNOPS. (2009). Mount Nyiragongo Risk Management Unit: Monitoring volcanic risk and raising awareness. Copenhagen: UNOPS.

USDA. (2013). National Soil Survey Handbook Part 629: Glossary. Retrieved January 16, 2014, from United States Department of Agriculture, Natural Resources Conservation Service: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/16/nrcs143_020629.pdf

USGS-GNC. (2010). Divisions of geologic time - major chronostratigraphic and geochronologic units. Reston: United States Geological Survey Geologic Names Committee.

USGS-VHP. (2009). VHP Photo Glossary: Volcano. Retrieved June 12, 2014 from, United States Geological Survey (USGS) Volcanic Hazards Program (VHP): http://volcanoes.usgs.gov/images/pglossary/volcano.php

UWA. (2012). Mount Elgon National Park. Retrieved June 18, 2014 from, Uganda Wildlife Authority (UWA): http://www.ugandawildlife.org/explore-our-parks/parks-by-name-a-z/mount-elgon-national-park

Valdés, B., Rejdali, M., Achhal El Kadmiri, A., & Jury, J. (2002). Catalogue des plantes vasculares du Nord du Maroc, incluant des clés d'identification. Madrid: Consejo Superior d'Investigaciones Cientıficas.

van Hinsbergen, D., Buiter, S., Torsvik, T., Gaina, C., & Webb, S. (2011). The Formation and Evolution of Africa: A Synopsis of 3.8 Ga of Earth History. London: Geological Society of London.

Verschoren, V. (2012). Trends in the hydrology of small watersheds in the Fouta Djallon Highlands. Rome: Food and Agriculture Organization of the United Nations.

Virunga National Park. (2011). Nyamuragira Volcano Erupts in Virunga National Park. Press Release.

Volcano Discovery. (2013). Nyamuragira Volcano. Retrieved October 31, 2013, from http://www.volcanodiscovery.com/volcanoes/africa/nyamuragira.html

Wacher, T., De Smet, K., Belbachir, F., Belbachir-Bazi, A., Belghoul, M., & Marker, L. (2005). Sahelo-Saharan Interest Group Wildlife Surveys: Part 4 – Ahaggar Mountains, Algeria. Algeria: Sahelo-Saharan Interest Group.

Wafula, M., Kasereka, M., Rusangiza, K., Kavuke, K., Mukambilwa, K., Mavonga, T., . . . Ciraba, M. (2007). Some considerations on the Nyamulagira eruption of November 27th, 2006. In A. Muwanga, M. Owor, A. Schumann, & W. Kawule, Abstracts Volume of the international conference on the East African Rift System, EARS 07 (pp. 68-71). Kampala, Uganda.

Waskey, A. (2005). Ahaggar Mountains. In Encyclopedia of World Geography (p. 11). New York.

White, F. (1983). The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO Vegetation Map of Africa (3 Plates, Northwestern Africa, Northeastern Africa, and Southern Africa, 1:5,000,000). Paris: United Nations Educational, Scientific and Cultural Organization.

Wielochowski, A. (2013). Mount Kenya: Geology and Glaciology. Retrieved August 14, 2013, from Mount Kenya Map and Guide: http://www.kilimanjaro.cc/mkgeolog.htm

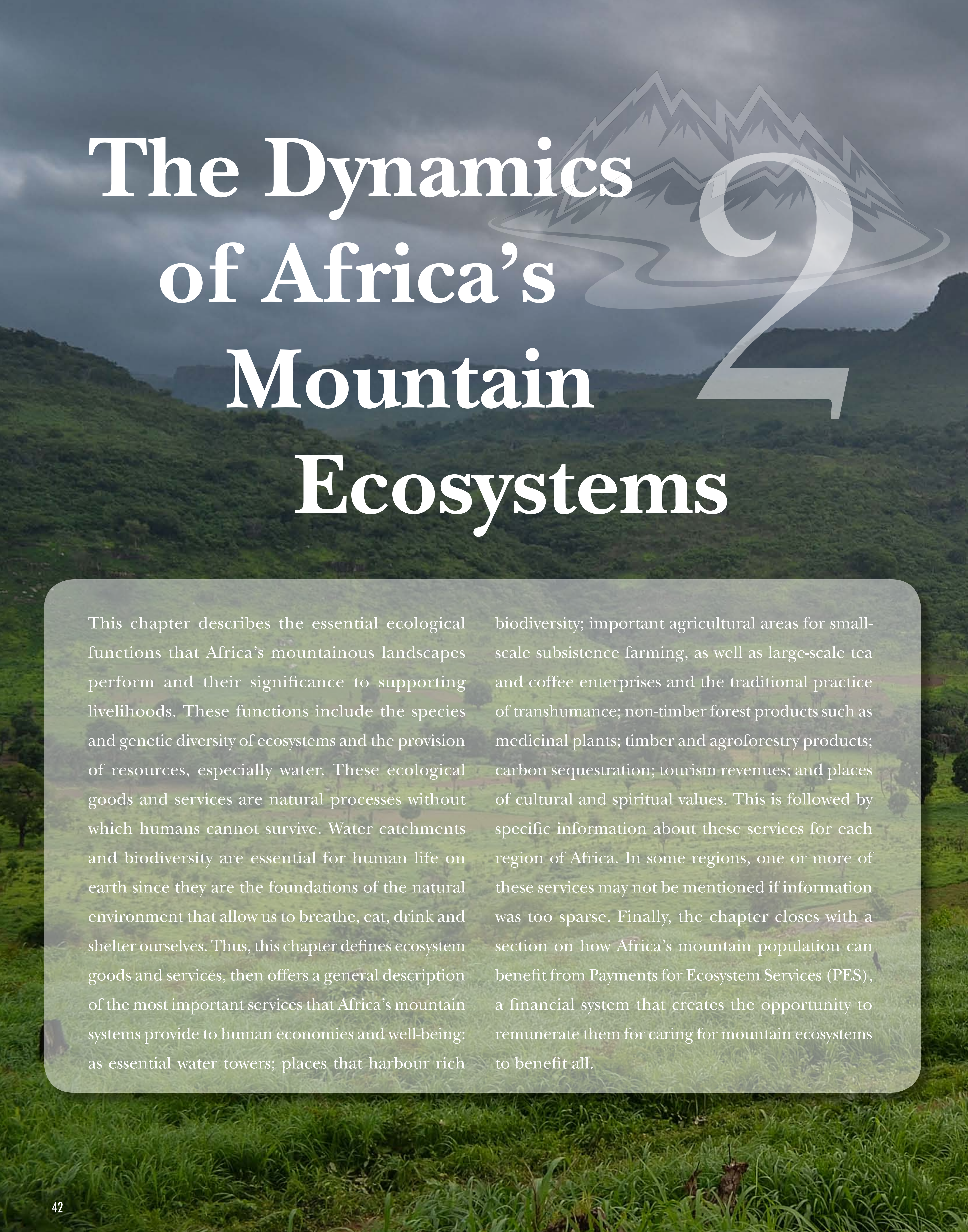
Wildi, W. (1983). La chaîne tello-rifaine (Algérie, Maroc, Tunisie): structure, stratigraphie et évolution du Trias au Miocène. Rev. Géol. dyn. Géogr. phys., 24, 201-297.

World Waterfall Database. (2013). World's Tallest Waterfall. Retrieved from http://www.worldwaterfalldatabase.com/tallest-waterfalls/total-height/

WWF. (2008). Drakensberg Montane Shrublands & Woodlands. Retrieved from WWF Global: http://wwf.panda.org/about_our_earth/ecoregions/drakensberg_shrublands_woodlands.cfm

WWF. (2013). Northern Africa: Algeria and Morocco and Tunisia. Retrieved December 12, 2013, from http://worldwildlife.org/ecoregions/pa0513

Young, J., & Hastenrath, S. (1991). Glaciers of the Middle East and Africa - Glaciers of Africa. In R. J. Williams, & J. Ferrigno, Satellite Image Atlas of Glaciers of the World (pp. 1389-G-3). Reston:U.S. Geologic Survey.



The Dynamics of Africa's Mountain Ecosystems

2

This chapter describes the essential ecological functions that Africa's mountainous landscapes perform and their significance to supporting livelihoods. These functions include the species and genetic diversity of ecosystems and the provision of resources, especially water. These ecological goods and services are natural processes without which humans cannot survive. Water catchments and biodiversity are essential for human life on earth since they are the foundations of the natural environment that allow us to breathe, eat, drink and shelter ourselves. Thus, this chapter defines ecosystem goods and services, then offers a general description of the most important services that Africa's mountain systems provide to human economies and well-being: as essential water towers; places that harbour rich biodiversity; important agricultural areas for small-scale subsistence farming, as well as large-scale tea and coffee enterprises and the traditional practice of transhumance; non-timber forest products such as medicinal plants; timber and agroforestry products; carbon sequestration; tourism revenues; and places of cultural and spiritual values. This is followed by specific information about these services for each region of Africa. In some regions, one or more of these services may not be mentioned if information was too sparse. Finally, the chapter closes with a section on how Africa's mountain population can benefit from Payments for Ecosystem Services (PES), a financial system that creates the opportunity to remunerate them for caring for mountain ecosystems to benefit all.

Fouta Djallon Highlands, Guinea

Chapter Highlights

- ▲ The Fouta Djallon Highlands in Guinea and the Kenyan Highlands are 2 of the 11 prominent highland or mountain areas that serve as water towers for Africa. These areas supply crucial water resources to places that would otherwise be too dry to support life.
- ▲ Many of Africa's mountain areas harbour rich biodiversity, including the Albertine Rift region, which is home to more than 1 175 endemic plant and animal species.
- ▲ Coffee and tea are important mountain cash crops for Africa, with Ethiopia alone producing 400 000 tonnes of coffee per year from its highlands and Africa holding 12 per cent of the global stake in the coffee market. Kenya is the world's third largest tea producer.
- ▲ Afromontane forests account for approximately 6 per cent of the continent's forests, supplying not only firewood and shelter, but also products such as honey, medicines from plants such as *Prunus africana* and tree-derived chemicals and dyes.
- ▲ A successful carbon sequestration project is ongoing in the Huambo Province of the Ethiopian Highlands. Reforestation has resulted in the issuance of at least 73 000 carbon credits (2012) and an estimated 880 000 tonnes of CO_2 is expected to be sequestered over the 30 year life of the project.
- ▲ There is also a tremendous cultural value harboured in Africa's mountains, much of which is preserved through the observance of sacred places. More than 100 sacred sites can be found in the Rwenzori Mountains alone.

Ecosystem Goods and Services

A variety of ecosystems exist in Africa's mountain areas, including forests, shrublands, grasslands and desert (Figure 2.1). These ecosystems provide a wide range of goods and services to people living in highland regions as well as the surrounding lowland regions. Box 2.1 defines the services that mountain ecosystems can provide to these regions. They include freshwater from water stored in glaciers, snow and rivers; medicines and food, both wild and cultivated; cultural values, such as those derived from sacred mountains; tourism and recreational values through activities such as wildlife viewing, mountain climbing and hiking; economically valuable minerals; and hydropower generation (Grêt-Regamey, Brunner, & Kienast, 2012). Land to cultivate food and cash crops and forests that play a major role in the global carbon cycle, including carbon storage, are other important assets. Thus, mountain areas are extremely important to Africa's economy and to the well-being of both highland and lowland populations.

Box 2.1: Mountain ecosystem goods and services

Provisioning services supply the goods themselves. Examples include:

- Extractive resources that primarily benefit lowland populations (water for drinking and irrigation, timber, and so on)
- Ecosystem production (agricultural production for local subsistence and for export; pharmaceuticals and medicinal plants; and non-timber forest products)

Regulating services control climate, as well as events such as flooding and the spread of disease. Examples include:

- Biodiversity
- Watershed and hazard prevention
- Climate modulation
- Migration (transport barriers/routes)
- Carbon storage

Cultural services address the beauty and inspiration of nature. Examples include:

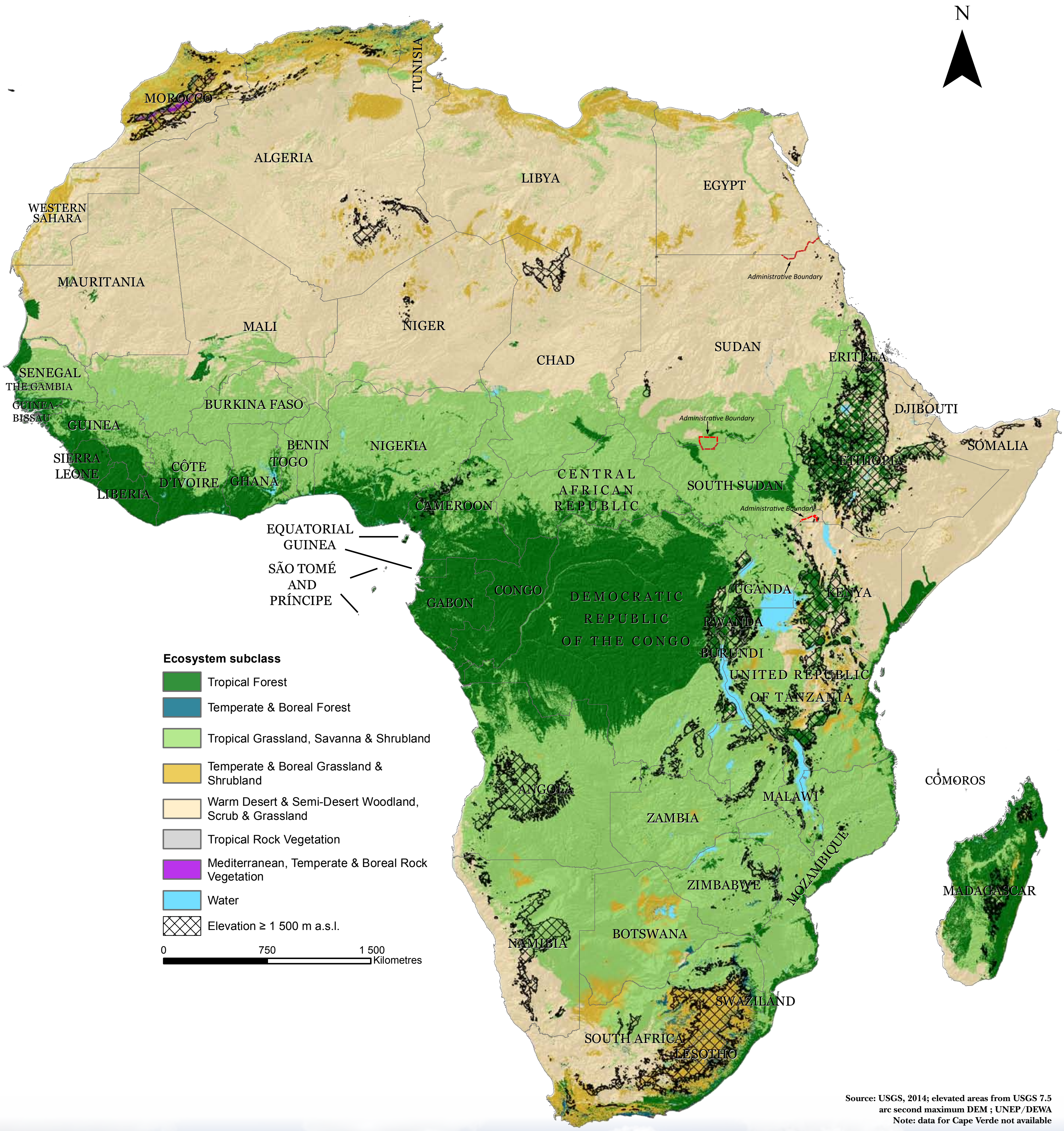
- Spiritual role of mountains
- Biodiversity
- Recreation
- Cultural and ethnological diversity

Supporting services provide for vegetation growth and production. Examples include:

- Soil formation
- Photosynthesis
- Nutrient cycling

Sources: Compiled from Korner & Ohsawa, 2005; EC, 2009

Figure 2.1: Ecosystem subclasses



Source: USGS, 2014; elevated areas from USGS 7.5 arc second maximum DEM ; UNEP/DEWA
Note: data for Cape Verde not available

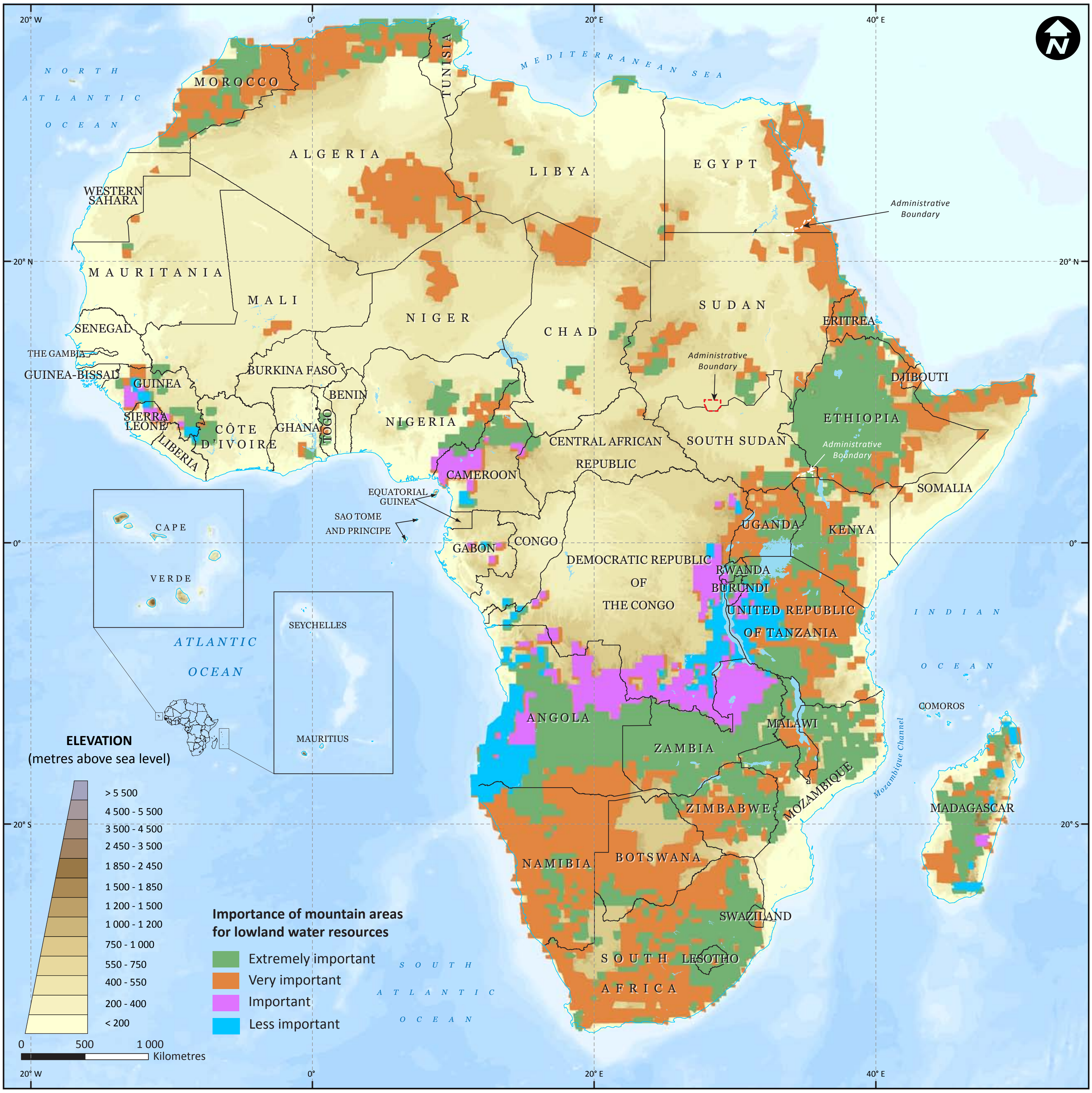
Maloti Mountains near Clarens, South Africa

Water Towers

Mountains capture, store and purify water (Grêt-Regamey, Brunner, & Kienast, 2012) and release it to lowland areas (Figure 2.2). Rainwater collects on the surface of mountains and contributes runoff to streams and rivers that carry water downstream. Additionally, water is captured and stored as groundwater, released through springs, and also stored in vegetation (FAO, 2002).

The term "water towers" refers to elevated areas of land (generally at least 200 m above the surrounding area) that receive at least 750 mm of rainfall and 250 mm of runoff per year and are significant water sources for populations beyond their immediate delineated boundaries (UNEP, 2010). There are at least 11 prominent water towers in Africa including the Middle Atlas range, the Fouta Djallon

Figure 2.2: Importance of mountain areas for lowland water resources



Adapted from Viviroli, et al., 2007 in Ariza, Maselli, & Kohler, 2013; UNEP/DEWA region, the Jos Plateau, Ethiopian Highlands, Kenyan Highlands, Angolan Plateau and Lesotho Highlands (Figure 2.3). Some of Africa's major rivers, including the Nile, Senegal and Orange-Senqu, flow from these water towers, carrying water to places that would otherwise be too dry to support life (Ariza, Maselli, & Kohler, 2013; UNEP, 2010; Table 2.1).

The water towers support highland and lowland livelihoods by supplying water for domestic needs, agriculture, wildlife, tourism, industries and hydropower generation. Water towers can also be transboundary, meaning they cross national borders (Table 2.1), which calls for international cooperation for resource use and protection (see Chapter 4).

Table 2.1: Associated major rivers of the water towers

Water Tower	Major Rivers
Middle Atlas Range	Sebou Oum Errabiaa
Fouta Djallon	Senegal Niger Volta Gambia
Jos Plateau	Jama'are Bénoué Komadugu-Yola Niger
Angolan Plateau	Cuanza Cunene Okavango Kwa-Kasai
Lesotho Highlands	Vaal Senqu Orange Limpopo
Lufilian Arc	Kafue Zambezi
Southern Highlands	Great Ruaha
Albertine Rift	White Nile Congo
Kenyan Highlands	Tana Ewaso Ng'iro
Ethiopian Highlands	Blue Nile Juba Shabelle Omo Atbara
Central High Plateau	Mangoky Tsiribihina Betsiboka

Sources: UNEP, 2010; UNEP, 2011

Figure 2.3: The water towers

Source: Adapted from UNEP, 2010; UNEP/DEWA

Biodiversity

Biodiversity is usually high in mountain areas, supporting a significant range in vegetation and wildlife types. Figure 2.4 shows the various zones of vascular plant species density throughout Africa. Notable highland areas with high density of vascular species include the Albertine Rift region with 2 000 to 3 000 species and the eastern coast of Madagascar with 4 000 to 5 000 per 10 000 km², one of the densest zones.

A high degree of endemism is integral to the biodiversity of Africa's mountains. The term "endemism" refers to species that can only be found in one particular region and cannot be found anywhere else in the world, thus making them prime areas for conservation interests (WCS, 2014; Myers, Mittermeier, Mittermeier, da Fonseca & Kent, 2000). Indeed, mountains are often referred to as "islands" of biodiversity rising above "seas" of lowland vegetation (Bagoora, 2012a). Africa's tropical mountain areas contain higher levels of species richness and biodiversity than other areas in sub-Saharan Africa (Burgess, et al., 2007a). There are eight main biodiversity regions in Africa that

Figure 2.4: Vascular plant species diversity

Source: Adapted from Krauer, CDE, University of Bern, 2011 in Ariza, Maselli, & Kohler, 2013 based on data from Barthlott, et al., 2005; UNEP/DEWA

An aloe plant on top Table Mountain

contain highland or mountainous regions. These areas have been identified, first by Norman Myers and then expanded upon by Conservation International, because of their large concentrations of endemic species and their significant loss of habitat (Myers, Mittermeier, Mittermeier, da Fonseca & Kent, 2000; CI, 2014). A brief synopsis of each biodiversity region is given in Box 2.2. Some regions, such as the Cape Floristic and Succulent Karoo areas of biodiversity, occur within one country (South Africa), and others, such as the West African Forests, cross many country boundaries (Table 2.2).

Table 2.2: Mountains in different biodiversity regions

Biodiversity region	Mountains	Country
Mediterranean Basin	Rif	Morocco
	Atlas	Morocco Algeria Tunisia
West African Forests	Cameroon Volcanic Line	Cameroon
	Chappal Waddi	Nigeria
	Loma Mountains	Sierra Leone
	Pico de São Tomé	São Tomé and Príncipe
	Fouta Djallon Highlands	Guinea
	Mount Nimba	Côte d'Ivoire Liberia Sierra Leone
Succulent Karoo (Southern Karoo sub-region)	Cape Ranges	South Africa
Cape Floristic	Cape Ranges Table Mountain	South Africa
Madagascar and the Indian Ocean Islands	Maromokotro	Madagascar
	Karthala	Comoros
Eastern Afromontane	Virunga Rwenzori Mitumba	DRC Rwanda Uganda
	Aberdare	Kenya
	Kilimanjaro Eastern Arc	United Republic of Tanzania
	Ethiopian Highlands	Ethiopia
	Nyangani	Zimbabwe
Maputaland-Pondoland-Albany	Lebombo Amatola	South Africa
Coastal Forests of Eastern Africa	-	-
Horn of Africa	Cal Madow	Somalia

Source: CI, 2014; Myers, Mittermeier, Mittermeier, da Fonseca & Kent, 2000

Box 2.2: Biodiversity regions in areas with elevation ≥ 1 500 m a.s.l.

Mediterranean Basin: Typically associated with Europe, this region also covers parts of northern Africa. Previously dominated by forests, this region is now mostly hard-leafed or matorral shrublands. There are 11 700 endemic plant species.

West African Forests: These forests are home to more than 25 per cent of Africa's mammals and has approximately 1 800 endemic plant species.

Succulent Karoo (Southern Karoo sub-region): About 69 per cent, or 2 439, of the plant species found in this region are endemic. There are approximately 1 700 species of leaf succulents.

Cape Floristic: Dominated by evergreen fire-dependent shrubs, this region has the greatest concentration of non-tropical higher plant species in the world. There are more than 6 000 endemic plant species.

Madagascar and the Indian Ocean Islands: The island of Madagascar has more than 50 species of lemur and approximately 11 600 endemic plant species. However, 15 lemur species have gone extinct since humans arrived on the island.

Eastern Afromontane: This region, which transcends parts of both eastern and central Africa, supports many freshwater lakes that are home to more than 600 endemic fish species. There are also more than 2 300 endemic plant species in this region.

Maputaland-Pondoland-Albany: This region has the most number of tree species (nearly 600) of any temperate forest in the world and is also home to about 80 per cent of South Africa's remaining forests.

Horn of Africa: The region is entirely arid, yet supports 2 750 endemic plant species and at least three threatened antelope: the beira, the dibatag and the Speke's gazelle.

Source: CI, 2014

A lemur in Madagascar

Agriculture

Africa's mountainous areas are extremely important for agricultural production and agriculture is essential to livelihoods and food security in these regions (see Chapter 5). Most of these elevated areas are endowed with plentiful rainfall and cooler temperatures. Mountain agriculture includes cropping, animal husbandry, horticulture and agroforestry. Common food crops grown in mountain areas include maize, barley, wheat, rice and cassava, and most is grown by subsistence farmers (FAO, 2002). Small-scale mountain agriculture helps to shape mountain landscapes and can provide ecosystem services such as freshwater, disaster risk-reduction, agro-biodiversity, recreation and tourism (FAO, 2013b). Since agriculture makes a significant contribution to the economies of most African nations, these regions are also crucial to the continent's development. The data on agricultural outputs in mountains is not easily available, however, making it difficult to determine the actual proportion they contribute to Africa's total agricultural industry (Bagoora, 2012b).

Many mountainous areas in Africa are some of the continent's most productive agricultural regions because of favourable conditions related to location and altitude. For example, in many places, rainfall is more plentiful than in the surrounding lowlands due to the proximity and orientation to rain-bearing winds and the air-cooling property of mountains that fosters rain formation. Fertile volcanic soils also attract farming in some mountain areas. Volcanoes such as Mount Kenya, Mount Elgon and Mount Kilimanjaro have very fertile and productive soils, are densely populated and support highly intense agricultural practices based both on cash crops such as coffee and tea (see page 65) and subsistence farming of food crops mainly for domestic consumption (Bagoora, 2012b).

Conservation practices such as agroforestry and zero grazing are increasingly being used in Africa's mountains to make crop growing and livestock rearing more sustainable by preventing serious soil erosion and the conversion of forests to crops, among other negative impacts of mountain farming (Bagoora, 2012b). Family farming can also contribute to sound food security and could be the backbone for sustainable mountain development if proper practices are implemented (FAO, 2013b).

Two important cash crops, coffee and tea, are described in the following pages. In the regional profiles, other crops specific to small- and large-scale farmers of different mountainous African countries are identified.

A small village in the middle of rice fields in the mountains of Madagascar

Picking coffee in Rwanda

Coffee

The *Coffea* plant is endemic to Africa with two main species commercially grown: Arabica (*Coffea arabica*) and Robusta (*Coffea robusta*). *C. arabica* originated in the highlands formerly known as Kaffa in southern Ethiopia (Hindorf & Omondi, 2011). The global "Coffee Belt" extends across mountainous regions from 30ºN to 30ºS where rainfall, temperature and sun exposure are ideal for growing coffee (Hitimana, Mugiraneza, & Murasira, 2012). Africa's eastern highlands are one of the few places in the world with conditions conducive to producing premium coffee. At these altitudes, rainfall is adequate (1 500 mm to 1 600 mm) and temperatures remain relatively cool, ranging from 18°C to 22°C (Illy & Viani, 1995). Crop seasons, which vary from country to country (Table 2.3), are defined by these conditions. Africa accounts for about 12 per cent of world coffee production (ITC, 2011).

Coffee trees produce bright red cherries that are harvested and dried to extract the aromatic beans (IFAD, 2005). After harvesting and refining, the beans are tested for quality and sold on the global market. *C. arabica* makes up 70 per cent of commercial coffee production and is grown at elevations ranging from 550 m in Zimbabwe to 1 800 m in Kenya, Ethiopia and Rwanda (Illy & Viani, 1995; Senbeta & Denich, 2006). Figure 2.5 shows all the coffee-growing countries in Africa. Some of the last remaining Afromontane rain forests in Ethiopia support wild coffee plants, some of which still grow in the Bale Mountains National Park (Senbeta & Denich, 2006). *C. robusta* is grown at much lower elevations, from sea level to almost 1 000 m (Illy & Viani, 1995) and is tolerant of warmer conditions (Mitchell, 1988).

Ethiopia is the fifth top producer of coffee in the world (USDA-FAS, 2013) and is Africa's largest coffee producer, growing only Arabica and producing

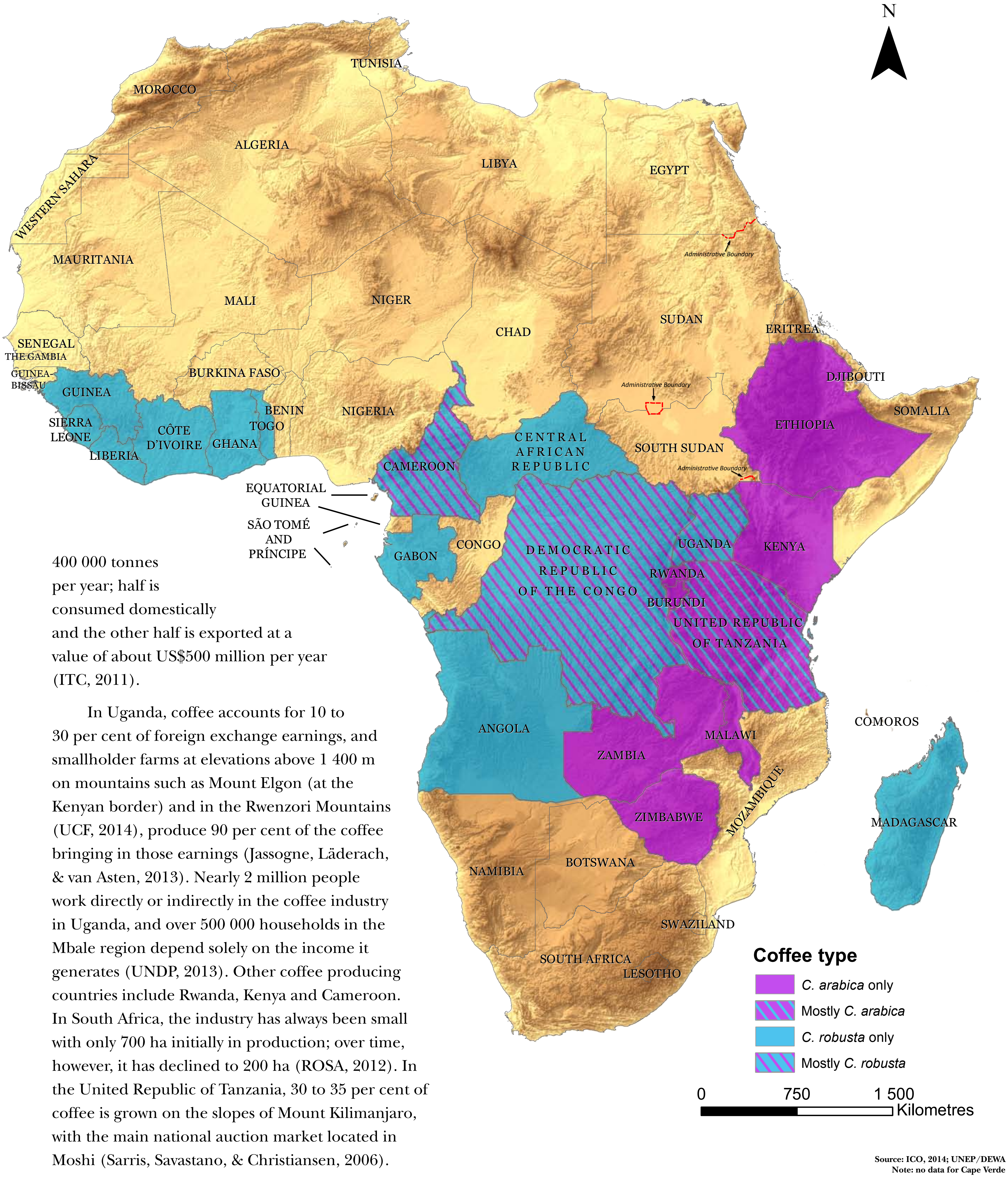
Table 2.3: Coffee crop seasons

Country	Coffee Type	Crop Season
Angola	R	Apr/Mar
Burundi	A	Apr/Mar
Cameroon	R/A	Oct/Sep
Central African Republic	R	Oct/Sep
Côte d'Ivoire	R	Oct/Sep
DRC	R/A	Oct/Sep
Ethiopia	A	Oct/Sep
Gabon	R	Oct/Sep
Ghana	R	Oct/Sep
Guinea	R	Oct/Sep
Kenya	A	Oct/Sep
Liberia	R	Oct/Sep
Madagascar	R	Apr/Mar
Malawi	A	Apr/Mar
Rwanda	A	Apr/Mar
Sierra Leone	R	Oct/Sep
United Rep. of Tanzania	A/R	Jul/Jun
Togo	R	Oct/Sep
Uganda	R/A	Oct/Sep
Zambia	A	Jul/Jun
Zimbabwe	A	Apr/Mar

Source: ICO, 2014

Key:
R = *C. robusta*
A = *C. arabica*
R/A = Mostly *C. robusta*, some *C. arabica*
A/R = Mostly *C. arabica*, some *C. robusta*

Figure 2.5: Coffee producing countries



400 000 tonnes per year; half is consumed domestically and the other half is exported at a value of about US$500 million per year (ITC, 2011).

In Uganda, coffee accounts for 10 to 30 per cent of foreign exchange earnings, and smallholder farms at elevations above 1 400 m on mountains such as Mount Elgon (at the Kenyan border) and in the Rwenzori Mountains (UCF, 2014), produce 90 per cent of the coffee bringing in those earnings (Jassogne, Läderach, & van Asten, 2013). Nearly 2 million people work directly or indirectly in the coffee industry in Uganda, and over 500 000 households in the Mbale region depend solely on the income it generates (UNDP, 2013). Other coffee producing countries include Rwanda, Kenya and Cameroon. In South Africa, the industry has always been small with only 700 ha initially in production; over time, however, it has declined to 200 ha (ROSA, 2012). In the United Republic of Tanzania, 30 to 35 per cent of coffee is grown on the slopes of Mount Kilimanjaro, with the main national auction market located in Moshi (Sarris, Savastano, & Christiansen, 2006).

Coffee grown in eastern Africa is primarily small scale. For example, approximately 70 per cent of coffee farmers in the Kilimanjaro region are smallholder farmers (Sarris, Savastano, & Christiansen, 2006) and 90 per cent of coffee grown in Uganda is done so on farms ranging from 0.5 to 2.5 ha in size (UCDA, 2012). In other places, such as the Ethiopian Highlands, coffee grows wild among the montane rain forests and local communities manage the forests for coffee production (Senbeta & Denich, 2006). Although most is small scale, some commercial coffee plantations do exist (Newmark, 2002), as do public and private plantations (Sarris, Savastano, & Christiansen, 2006).

Box 2.3: Using Geographic Information Systems (GIS) to find the best-tasting coffee in Rwanda

With over 500 000 farmers growing coffee in Rwanda, and an average family size of seven, growing good quality and tasty coffee is essential for them to make a living. By increasing their coffee's quality, farmers can charge a higher price. To help Rwandan coffee farmers increase their incomes and better their livelihoods, agronomist Tim Schilling and GIS professional and geographer Dr. Michelle Adesir-Schilling combined their talents with those of local farmers, statisticians and other scientists to discover the best-tasting coffee in Rwanda.

The opening of a central coffee-washing station in 2002 in Maraba sector was the first step to unveiling high-quality coffee because it is washed, revealing the best coffee cherries. By selling these best beans, Rwanda was introduced into the worldwide market for speciality coffee, enabling their beans to reach as far away as England and the United States and farmers to charge twice the normal price for coffee. At this time, GIS was an emerging technology in Rwanda and with the aid of a team of agronomists, technicians and farmers, more locations for coffee-washing stations could be identified. Factors such as proximity to roads, water, national parks and large coffee growing areas were considered. As more coffee stations were being built, the Rwandan coffee market expanded to Japan. As of 2011, 200 coffee-washing stations had been built with 50 per cent of the country's coffee production processed through those stations.

Construction of coffee-washing stations led to increased collaboration between international coffee experts and the Rwandan coffee farmers to enhance the coffee's taste and increase its sale price. The GIS technologies were used again to define the best places in which to grow coffee. The researchers considered variables such as temperature, precipitation, altitude, soil pH and the service area of existing coffee-washing stations. The GIS analysis also included coffee-specific variables, such as taste, flavour, aroma and finish. As the data were amassed, recorded and analyzed, specific flavours and tastes associated with different growing regions became more apparent; the team was able to literally map the taste of Rwandan coffee.

Over the past 10 years or so, this project has led to improved farmer incomes and livelihoods: the average annual household income of a farming family rose from US$500 in 2000 to US$3 000 by 2010. Another outcome was the establishment of the Global Coffee Quality Research Initiative in the United States. Its aim to improve the quality of coffees worldwide and increase sustainable yields is ultimately bringing Rwanda's practices to other coffee-producing countries.

Sources: Compiled from ESRI, 2011a; ESRI, 2011b; Akinyemi, 2008

Coffee farm in Maraba, Rwanda

Box 2.3 is an example of how small-scale farmers in Rwanda worked with geographers to bring better-tasting coffee to the international market and were able to increase family incomes.

Historically, traditional growers planted coffee in the shade of other existing trees. By keeping the forest intact, this method improves soil fertility, promotes biodiversity and can decrease erosion and deforestation compared to large-scale coffee plantations (Takahasi & Todo, 2013). Additionally, the forest-like plots can increase bird habitat, sequester carbon, control pests and improve pollination (Rice, 2010).

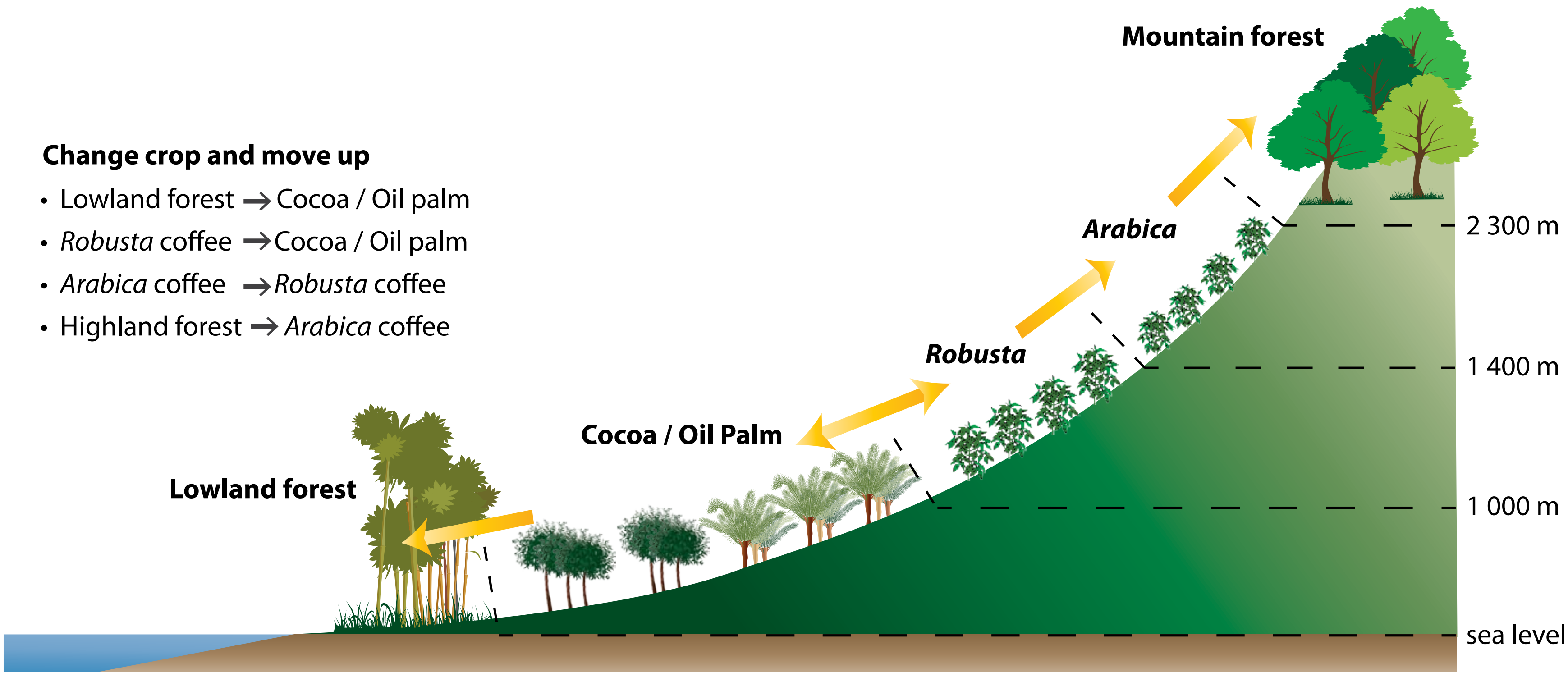
Before the 1990s, harvesting and selling coffee was a good source of revenue for smallholder farmers, but between 1999 and 2004, the International Coffee Organization (ICo) reported that coffee's international market value dropped dramatically from US$2.65/kg to between US$0.99 and 1.65/kg (Bacon, 2005) due to oversupply (Rice, 2003). The price began to increase again to a 34-year high in early 2011, reaching more than US$6/kg (ICO, 2012; Global Post, 2011). This increase prompted farmers to switch from traditional shade-grown coffee to more productive "sun coffee" practices to compete in the demanding market. Sun-coffee estates can have major environmental impacts on the surrounding ecosystem, such as erosion and chemical runoff (Perfecto, Rice, Greenberg, & Van der Voort, 1996). Some studies have shown that the transition from shade-grown to sun-grown drives deforestation rates higher in mountain regions (Getahun, Van Rompaey, Van Turnhout, & Poesen, 2013).

More recently, coffee has also been grown in mixed farming systems such as agroforestry where individual trees are used to shade patches of coffee plants within a field of crops such as corn, and intercropping where coffee is grown along with bananas or beans (UCDA, 2012). These farming approaches, however, still convert primary forests to create the mixed systems (Gove, Hylander, Nemomisa, & Shimelis, 2008), but they can help ensure food security as well as provide a cash crop (UCDA, 2012).

Though shade-grown coffee certification is an effective way to ensure farmers will focus on sustainable coffee growing rather than industrial processes, scientists still debate whether such certification can motivate farmers to convert existing primary forests into shade-coffee forests (Rappole, King, & Rivera, 2003). Although shade-forest ecosystems are important for maintaining forest cover and help promote biodiversity, creating them is not the same as leaving the native forest untouched (Tejeda-Cruz, Silva-Rivera, Barton, & Sutherland, 2010; Tscharntke, et al., 2011); forest cover can still be lost to plant coffee and can impact floristic composition, species diversity and wild coffee populations (Senbeta & Denich, 2006). Nonetheless, shade-grown coffee incentives can reduce the amount of forest that would otherwise be cleared to establish industrial plantations or facilitate extractive timber practices (Takahasi & Todo, 2013). In areas like Mount Cameroon, where cash crops make up a large part of the economy and forest dwellers are completely dependent on forest resources, these incentives can be very important in promoting environmental conservation while also supporting the economic livelihoods of local people (CREE, 2014).

Climate change has had an effect on Africa's coffee growing regions and is an especially important factor in Uganda's coffee producing mountains. Kok, Mount Elgon's major production zone, has seen changes in temperatures and rainfall, which can affect the bean quality, and prices have decreased in recent years (UNDP, 2013). Rising temperatures could cause coffee growing zones to migrate to higher elevations (Figure 2.6), creating competition with other crop growing areas or natural forest reserves and possibly pushing farmers to switch to other crops entirely (Jassogne, Läderach, & van Asten, 2013).

Figure 2.6: Climate change effects on coffee growing



Source: Adapted from Jassogne, Läderach, & van Asten, 2013; UNEP/DEWA

Tea farmer in the Mount Kenya region

Tea

Tea, the second-most consumed beverage in the world next to water, is also grown on African mountains because of ideal conditions (Tea USA, 2013). As with coffee, tea growth is optimal in favourable mountain conditions with high annual rainfall, a mild climate and high soil fertility (UNEP, 2012a). Higher elevations are also preferable and elevation ranges vary depending on the growing country (Table 2.4). Tea is most efficiently grown on large plantations, but in Africa, smallholder farmers are also common (Fernando, 2011). For example, Kenya has more than 500 000 registered smallholder tea farmers with the Kenya Tea Development Agency (KTDA) (TBK, 2012). The larger tea plantations extend across vast areas of land, which have generally been converted from forest (Newmark, 2002). Tea is also often grown along with other crops, as in the Nyungwe Forest National Park in Rwanda where tea plantations are integrated with eucalyptus and pinewood, creating a buffer zone protecting subsistence agriculture and wetlands (UNEP, 2012a).

Tea production and processing are highly energy intensive, causing pollution and emitting greenhouse gases (UNEP, 2012a). A FAO "cradle-to-grave" life-cycle assessment (FAO, 2012b) showed that the carbon footprint (the amount of carbon emitted from an activity or organization) of tea production in Kenya amounted to 12 kilograms of CO_2 equivalent for every kilogram (kg CO_2 eq/kg) of dry tea. Tea production accounts for 20 per cent of the total carbon footprint of the entire chain from tea production to consumption (FAO, 2012b). In terms of energy use, it is instructive to compare tea to another industry. For example, it takes 6.3 kilowatt-hours (kWh) to produce 1 kg of steel while the energy to produce tea from drying to packing can range from 4 to 18 kWh/kg of finished tea (AIT, 2002). The amount of energy used depends on the type of fuel: thermal energy, firewood, natural gas, electricity or diesel. In some regions like Kenya, deforestation has occurred because firewood logged from natural forests is burned to dry the tea leaves, the most energy-intensive phase of the supply chain (AIT, 2002; Clay, 2004).

The world market price for black tea is low, yet the difference between producer prices and consumer prices is high, creating an inequality for farmers working in the tea industry in African mountains (ROSA, 2011). A few elite international companies have a monopoly over tea trade and distribution so the consumer price of their teas is relatively stable (van der Wal, 2008). Kenya is the world's third largest tea producer, having produced nearly 370 000 tonnes in 2012 (Table 2.5), but because most of it is grown in relatively remote areas, there are limited market channels. The KTDA manages all the smallholder farmers and owns almost all the tea factories in those regions. As a result, such farmers lack other options than to sell their picked tea leaves to that one company for processing, which limits their bargaining power (van der Wal, 2008).

Table 2.4: Elevation ranges of tea plantations

Country	Elevation range (m a.s.l.)
Kenya	1 500 - 2 700
Rwanda	1 900 - 2 200
Malawi	600 - 1 300
Zimbabwe	600 - 1 100

Sources: Compiled from TBK, 2014; IFAD, 2005; TRFCA, 2013

Table 2.5: Top ten tea producers in 2012

Country	Tea Production (tonnes)
China	1 714 902
India	1 000 000
Kenya	369 400
Sri Lanka	330 000
Turkey	225 000
Viet Nam	216 900
Islamic Republic of Iran	158 000
Indonesia	150 100
Argentina	100 000
Japan	85 900

Source: FAOSTAT, 2014

Transhumance

Although traditional nomadic pastoralism is changing, it remains an extremely important way of life for many African people. Nomadic pastoral communities refer to those that move long distances to herd domesticated livestock in response to scarce pasturage, setting up tents or temporary homes as they move. Typically, they herd cattle, sheep or goat and their lives revolve around the needs of the herd (Oba & Lusigi, 1987). Data from the mid-2000s show that in the Sahel and western African regions, pastoralism accounts for 70 per cent of the milk supply and provides 60 per cent of cattle meat and 40 per cent of goat meat to the local population (SWAC-OECD/ECOWAS, 2008).

Pastoralism in Africa's mountainous areas usually takes the form of seasonal transhumance, a practice in which settled herders respond to wet and dry periods by temporarily moving their livestock to more favourable areas (McPeak & Turner, 2012). It is difficult to determine what percentage of Africa's total pastoral practices occur in its mountainous areas and few generalizations can be made about the status and trends in transhumance, so this section illustrates this type of mountain economy by providing some examples.

In Africa's mountains, transhumance herders and pastoralists can be found in the Ethiopian Highlands and the Atlas Mountains (Price, Byers, Friend, Kohler, & Price, 2013), but this practice also occurs in western Africa (SOS Sahel, 2008), Lesotho and across the DRC, Burundi and Rwanda (AU-DREA, 2010).

The pastoral lands of the Atlas Mountains of Morocco and Algeria are arid, with most rainfall recorded in winter (100 mm to 400 mm), and summers are hot. Sheep and goat production are the common pastoral activities in these high altitude lands (AU-DREA, 2010).

In the Congo Nile crest, which includes the DRC, Rwanda and Burundi, pastoralism can be found in its high altitude humid forests. Rainfall is plentiful, with an annual average of 1 600 mm. The pastoral population of the DRC is comprised of people from Sudan, Burundi, Rwanda and Uganda (AU-DREA, 2010).

In Niger, the Tuareg people, who have a feudal society, have a variable extent of transhumance. Some travel long ranges, up to 1 000 km, while others remain in villages or camps that are close to fields and gardens (FAO, 2006). The pastoral range near the Aïr massif generally extends from its southwestern and southeastern edges south to Gouré (FEWS NET, 2011; FAO, 2006).

As is generally the case of pastoralism in Africa, it appears that a number of changes are challenging the mobility of herders who traditionally moved their livestock up and down mountains, from dry to wet highland areas according to seasonal access to resources. For example, seasonal transhumance between lowland and highland pastures was common in the Middle and High Atlas mountains until the mid-1950s, but this practice has nearly ceased due to the combination of a number of factors, including the introduction of fixed tribal boundaries and the conversion of tribal areas into administrative districts that led to sedentarization; the expansion of lowland farms that deprived pastoral herders of access; and the creation of state lands that denied them their traditional tribal ownership rights and forbade goat-grazing and tree-cutting (Barrow & Hicham, 2000).

Likewise, in the grasslands of the eastern mountain catchments of Lesotho, Basotho people historically kept their sheep, horses, donkeys and goats in the villages during the winter, but when the crops were planted in surrounding lands, they moved the livestock to grassland grazing areas higher up

Goat herd near Lake Tamda in the High Atlas Mountains

A sheep herder in Semonkong Lesotho

the mountain. They kept their herd below the alpine region that occurs above 2 900 m. However, this area is an IUCN Managed Resource Area, designed to protect the mountain catchment and is out of bounds for livestock. With population growth and increased areas devoted to crops, the availability of grazing area around villages declined. As a result of the reduced winter forage, winter grazing lands were established in subalpine valleys between about 2 600 and 2 700 m and these areas began to be used more intensively than the summer grazing areas. A report from 1994 noted that because of these changes in transhumance practices, there was a greater potential for degradation of the subtropical vegetation in the subalpine belt (Quintan & Morris, 1994). In 2004, another report confirmed the decline in ground cover and pasture productivity throughout much of Lesotho's rangeland in recent decades (Turner, 2004). Box 2.4 is another example of transhumance, taken from Ethiopia.

Box 2.4: Challenges to Godantu in Bale Mountains National Park (BMNP)

The term *godantu* refers to traditional transhumance practiced by local residents of BMNP in which livestock, usually cattle, is herded across lands and altitudes in a wet and dry season rotational pattern. Throughout Ethiopia, livestock are key to the livelihoods of many local people. In the Bale Mountains region, the household earnings from the sale of livestock is estimated at US$228 a year, not counting milk and other associated products and services.

Typically, herders move their livestock to graze on higher grounds when the lower areas are devoted to the growing season and to take advantage of forests higher up the mountain for shade and water during the dry season. In general, resources to support livestock are plentiful in the BMNP, but may become more difficult to obtain in the future as competition for them increases. This is due to more restrictions on land use, such as limitations imposed by protected areas as more land is set aside for conservation, and competition with agricultural land as communal grazing areas are converted to farming plots for crops and land registration systems move towards individual land ownership and rights. Thus, herder mobility is being challenged since they increasingly have to walk longer distances between grazing areas, or experience a general absence of suitable grazing resources as the amount of available land declines. In addition, it has been reported that there has been a decrease in the availability of adequate water supplies from high altitude mineral springs, known as hora, which mountain herders rely on for water supplies.

Adopting integrated landscape planning and management at the regional level, with the full participation of the rural communities and backed up by extension services, would help to improve the situation for these herders.

Sources: Compiled from BMNP, 2014; BERSMP, 2009

Bale Mountains, Ethiopia

Non-timber Forest Products

Forests provide many types of goods and products other than timber. Non-timber forest products include numerous wild food-stuffs and medicines that can be harvested from trees and the undergrowth, such as fruit, vegetables, nuts, native spices, medicinal plants and fodder for livestock (Bagoora, 2012b; FAO, 2011b). For example, *Prunus africana* is one of the most important medicinal plants found in Africa's montane forests as its bark is used internationally to treat prostate diseases (see also Chapter 5) (FAO, 2011a). Raw materials for constructing housing and for household articles or to sell for cash, such as roots, sap, cane, resins, gums, fibres, charcoal, ornamental plants, chemicals and dyes, are also valuable non-timber forest products (Bagoora, 2012b; Ndangalasi, Bitariho, & Dovie, 2007). Raw materials can be turned into profitable goods, such as fruits processed into juice and marketed (FAO, 2011b). During times of famine, the wild plants and nuts that grow in forests can replace scarce food and contribute to survival (Ndangalasi, Bitariho, & Dovie, 2007). Furthermore, on a per-hectare basis, these products can often support a regular household income, and through sales, even contribute more to the national or international economy than timber (Bagoora, 2012b). These resources need to be properly managed, however, to ensure they are used sustainably. This will require laws to protect or limit the amount of material that can be taken and ways to protect both the wild resources and local livelihoods, such as the local organization of management practices (Ndangalasi, Bitariho, & Dovie, 2007).

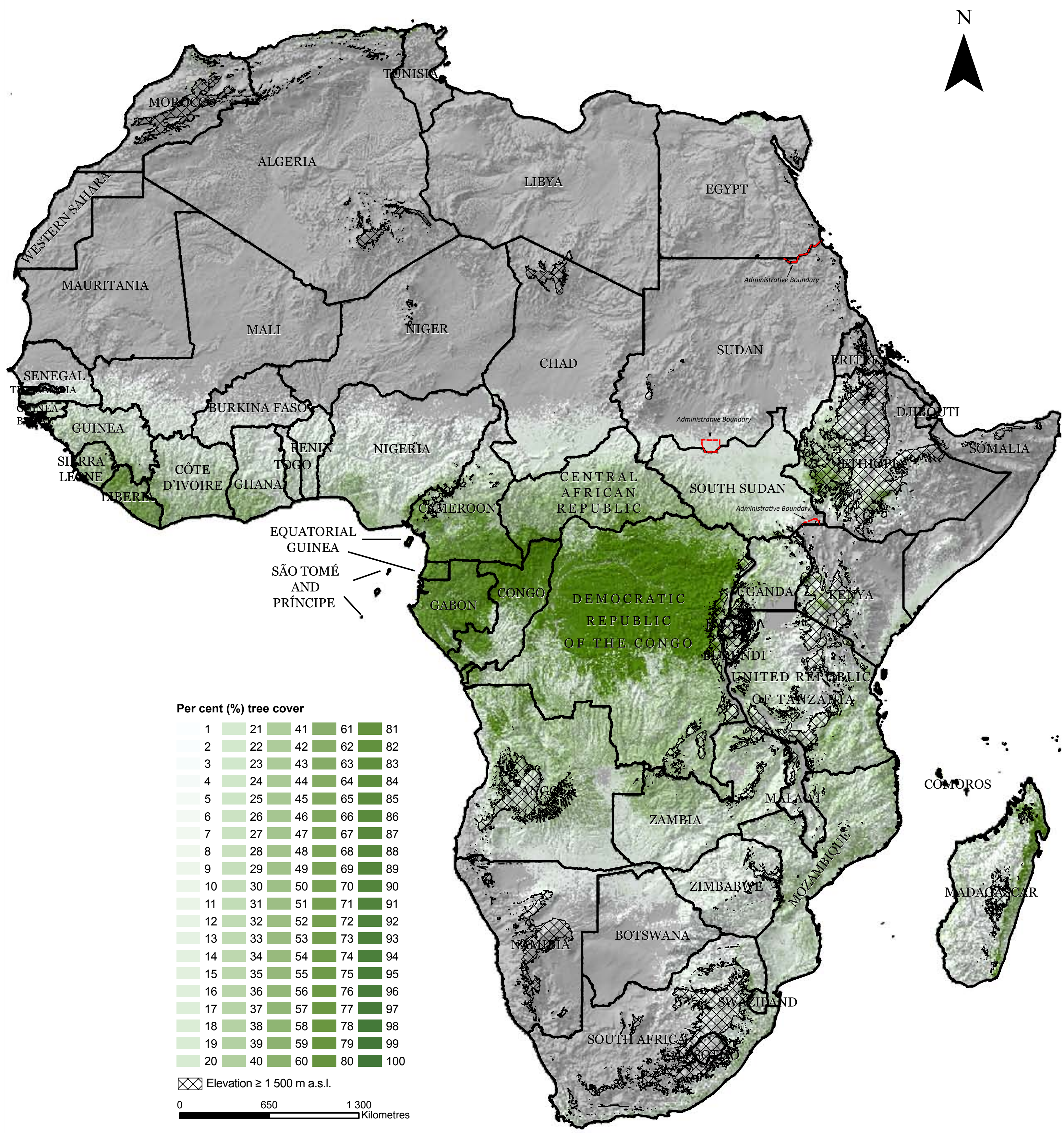
Basella alba L. a common non-timber forest product in the highlands of the United Republic of Tanzania

Forests and Agroforestry

Forest cover on the African continent is centrally concentrated (Figure 2.7), with dense forest covering most of Cameroon, Gabon, the Congo and the Democratic Republic of the Congo (DRC). Africa's mountains are home to some of the most biodiverse tropical montane forests in the world. Africa's forests provide a multitude of environmental services including protecting biodiversity and watersheds, controlling erosion and stabilizing the global climate (FAO, 2003). Forests offer shelter from sun, wind and rain, protect rivers and their watersheds (Laaksom & Tyynelä, 2006) and naturally purify water. In central Africa, mountain forests provide countries with most of their high-quality timber, and as already noted, African montane forests contain important medicinal plants, including the globally significant *Prunus africana* (FAO, 2011a).

Deforestation is a threat to many of Africa's montane forests (see Chapter 3), but improved forest management that results in increased canopy cover can decrease forest flammability and improve the biodiversity of plants and animals that require

Figure 2.7: Percentage of tree cover derived from 2010 Landsat satellite imagery



Source: Data provided by USGS/UMD; UNEP/DEWA shade (Putz, Zuidema, Pinard, & Sayer, 2008), in addition to protecting all the other ecosystem services inherent in forested mountains. Community forest projects, such as those in the Ethiopian Highlands highlighted in the eastern Africa regional section below, have helped to establish community woodlots for these reasons (Bishaw & Abdelkadir, 2003). Farmers are also increasingly complementing these schemes by planting trees on their land for both conservation and livelihood purposes (Bagoora, 2012b).

Trees within mountain areas but outside of dense forests, such as those in human settlements, on farms or in agroforestry areas, also provide many environmental goods and services. Agroforestry refers to the combined activities of cultivating trees along with crops or livestock to make use of the benefits of trees. These include services such as nutrient transfer, microclimate moderation and soil stabilization (FAO, 2011a; FAO, 2010). Forests and plantations also complement the benefits communities derive from farming by providing fuelwood, construction timber, fodder, shade, fruit and many other timber and non-timber forest products. In many highland areas and middle-altitude mountains, governments have instituted afforestation (establishing forests on lands previously unforested) and reforestation (establishing forests on lands previously forested) and agroforestry schemes to protect watersheds and water towers, stem forest loss and provide the ecosystem services already mentioned. The regional profiles included in this chapter highlight distinct aspects of forests and agroforestry practices in Africa's mountainous areas.

Carbon Sequestration

The world's mountains host 28 per cent of global forest cover. They store or sequester carbon (FAO, 2011b), an ecosystem service that is increasingly recognized as of crucial importance for mitigating climate change. Based on estimations by Thompson, et al., 2012, Africa's mountain forests (tropical and subtropical) account for approximately 6 per cent of all its forests, but provide a significant proportion of its above-ground biomass carbon and total biomass carbon. Tropical mountain forests in Africa have the second-highest total biomass carbon density per hectare of all types of African forests with only tropical rain forests exceeding them (Table 2.6). When logging, submerging or burning removes trees, however, carbon is released, contributing to the build-up of greenhouse gases in the atmosphere and to global climate change. Deforestation in tropical areas emits approximately 1.5 gigatons (Gt) of carbon to the atmosphere each year; improved forest management, however, could reduce those emissions by 10 per cent (0.16 GtC/yr) (Putz, Zuidema, Pinard, & Sayer, 2008).

Trees and other long-term vegetation cover and land use practices such as tree-planting and zero-tillage farming absorb carbon dioxide (CO_2) from the atmosphere (Jindal, Swallow, & Kerr, 2008). The Clean Development Mechanism (CDM) under the Kyoto Protocol allows industrialized countries to support tree-planting projects that sequester CO_2 in developing nations as a recognized way to offset a small part of their own CO_2 emissions. Afforestation and reforestation are eligible activities under the CDM. The CDM has the potential to help improve livelihoods in Africa's forested mountain areas (Jindal, Swallow, & Kerr, 2008). Challenges in obtaining accurate forest-carbon stock estimates are common in Africa, however, due to the lack of quality data and standard data collection methods. Costs for monitoring the amount of carbon that is released or retained can be shared among governments, stakeholders and REDD credit programmes (Putz, Zuidema, Pinard, & Sayer, 2008).


Taking measurements to quantify the amount of carbon storage in the Uluguru Mountains

Primary school children planting trees

Table 2.6: Carbon biomass values of Africa's forests

Forest Type	Forest Area (Mha)	Above-ground biomass carbon density (Mg C ha^{-1})		Total biomass carbon density (Mg C ha^{-1})	
		Mean ± SD	SE (±)	Mean ± SD	SE (±)
Tropical rainforest	252.9	107 ±51	37	135 ±64	
Tropical moist deciduous forest	110.6	38 ±18	13	50 ±23	17
Tropical shrubland	1.6	41 ±25	14	53 ±32	17
Tropical dry forest	36.1	38 ±15	13	49 ±23	16
Tropical mountain system	22.7	64 ±39	22	82 ±49	28
Sub-tropical humid forest	1.5	38 ±15	13	49 ±19	17
Sub-tropical dry forest	0.7	31 ±16	11	41 ±21	14
Sub-tropical mountain system	1.1	34 ±11	11	45 ±14	15
Africa total	**427.2**	**80 ±78**	**27**	**102 ±98**	**35**

Source: Thompson, et al., 2012
Note: SD = Standard Deviation; SE = Standard Error

Table 2.7: REDD countries

Country receiving support for National Programme	Other partner countries
DRC	Benin
Nigeria	Cameroon
Congo	Central African Republic
United Rep. of Tanzania	Côte d'Ivoire
Zambia	Ethiopia
	Gabon
	Ghana
	Guinea Bissau
	Kenya
	Madagascar
	Malawi
	South Sudan
	Sudan
	Tunisia
	Uganda
	Zimbabwe

Source: UN-REDD, 2009

The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD), is an ongoing initiative to help combat carbon emissions from deforestation and degradation. Since 2008, the initiative's aim is to support capacity building in developing countries to reduce emissions, aid in conservation and sustainable forest management and enhance forest-carbon stocks (UN-REDD, 2011). Many African countries are REDD partner countries, with five countries having benefitted from full National Programmes, which include initial readiness support and targeted support for identified work areas (Table 2.7). Three of the partner countries selected to be part of the UN-REDD "Quick Start" pilot project were in Africa: DRC, United Republic of Tanzania and Zambia (UN-REDD, 2011). Additional REDD activities are underway in Ethiopia (Watson, Mourato, & Milner-Gulland, 2013) and Uganda is preparing to participate (GoU, 2011). The regional profiles in this chapter discuss individual projects that are ongoing in some of Africa's mountains.

Tourism

Tourism is ranked as one of the main industries in many African nations, and mountains are one of the favoured destinations. Mountain tourism can bring revenues and employment to locals through the selling of handmade goods, guiding tours, providing portering services and working in hotels and lodges. These include places of great beauty that attract admirers and recreational visitors; challenging rugged terrain that appeals to mountain climbers, trekkers, adventurers and sports enthusiasts; and rich biodiversity and cultures (Box 2.5) appreciated by eco-tourists (Bagoora, 2012b). Many countries are promoting ecotourism or sustainable tourism in recognition of the negative impacts of high use in fragile mountain environments, the importance of maintaining the attractive wildlife, natural landscapes and host communities for the long-term and to channel revenues toward conservation and benefit-sharing (Bagoora, 2012b).

Box 2.5: Cultural Tourism in the United Republic of Tanzania

Cultural tourism in the United Republic of Tanzania is a product of community involvement and development. Having been initiated in a northern Tanzanian community by a young Maasai group of dancers in 1996, cultural tourism has continued to develop and become more precisely defined. For the United Republic of Tanzania, cultural tourism takes a community-based, sustainable pro-poor approach and refers to the use of tours to demonstrate to tourists the natural and cultural aspects and values of local lives. Locals are also able to sell their goods and services directly to tourists, an additional economic benefit of cultural tourism.

Activities can include touring the mountainous agriculture fields, discovering the traditions of pastoral tribes, listening to drums and watching tribal dancers. In Mulala, a village on the rural slopes of Mount Meru, tourists are able to learn how to make cheese, tour coffee and banana farms, hike in the Mount Meru forest reserve and visit the Agape Women's Group to learn about traditional activities that women do in the mountains. Other mountain activities in other regions include climbing Rungwe Mountain (2 960 m), exploring the East African Rift Valley and visiting the Pare people and hiking Mount Kindoroko.

Source: TCTP, n.d.

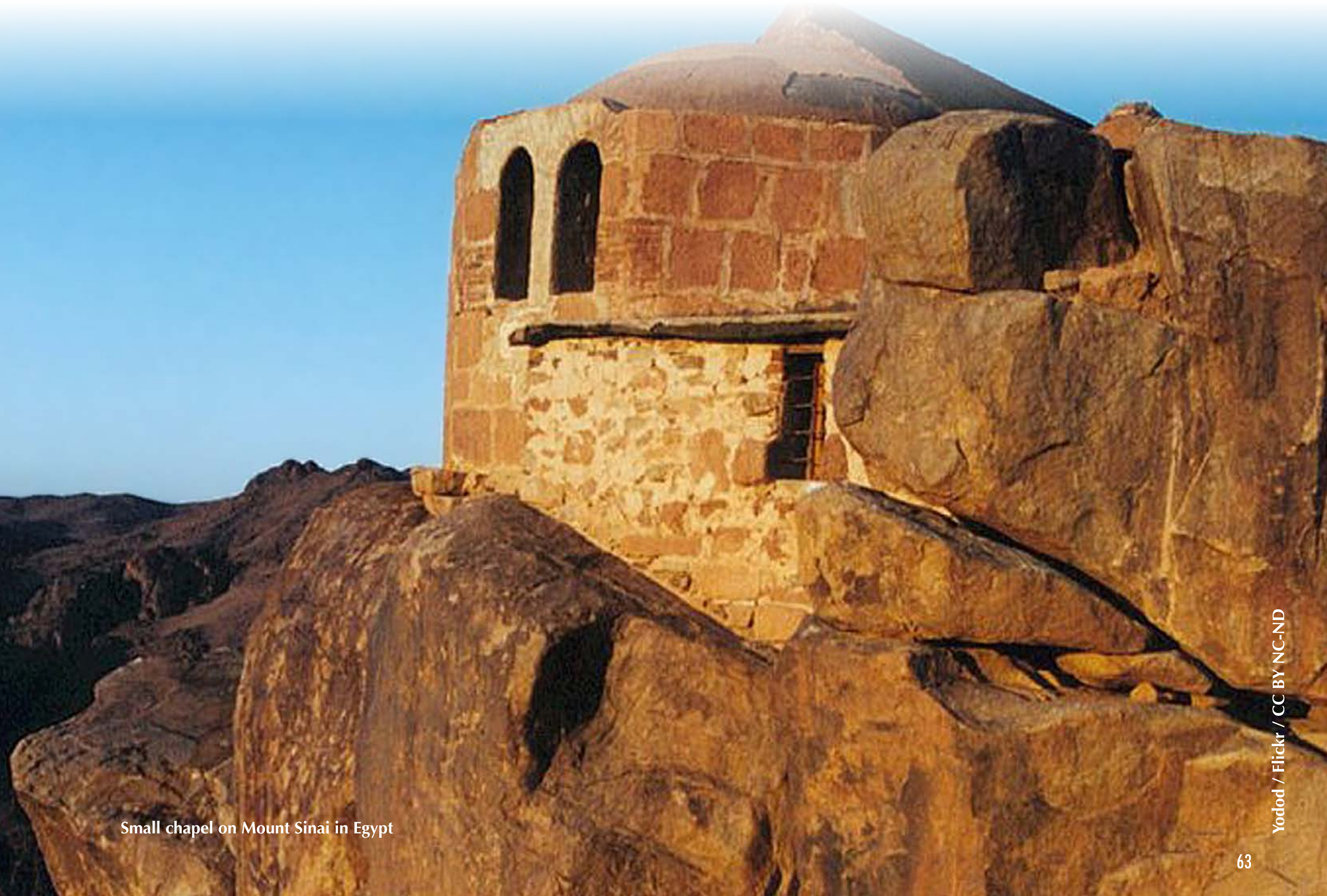
Many tents at the Barafu camp on the Machame route, Mount Kilimanjaro, United Republic of Tanzania

lexan / Shutterstock

Sacred Places

A sacred natural site can be defined as "a critical place within an ecosystem, such as a forest, mountain, river and sources of water, which is of ecological, cultural and spiritual importance, and exists as a network embedded in a territory" (Adam, 2012). Mountains evoke awe and inspiration, and local people imbue them with evocative power and significance (Bagoora, 2012b). As a result, there are some mountains or hills, or the forests that grow on them, that hold traditional, cultural or spiritual values amongst the communities in which they are located. This reverence allows people to connect or communicate with their environments. Historically, mountain communities have revered particular mountains in their environments as areas with special sacred qualities and powers. As noted by Bagoora (2012b), "these 'sacred mountains' are associated with myths, beliefs, and religious practices such as pilgrimage, meditation, and sacrifice. The longest form of tourism in the African mountains is reported to be religious pilgrimage". Several sacred sites, such as the Saint Catherine Monastery near Mount Sinai in Egypt and the monolithic churches of Lalibela, Ethiopia are recognized as cultural UNESCO World Heritage sites.

Although many mountain areas and forest groves deemed sacred by local communities have been spared from destructive human uses because of the special spiritual and cultural practices and rules regulating activities, each place has its own specific history and no general statement can be made about environmental protection in Africa's sacred mountains. A study of Africa's sacred groves (natural areas, usually forest groves, set aside by local communities for ritual use and thought to be protected by spiritual forces) notes that they are created and constantly modified by humans, since in addition to serving ritual purposes, the rules governing them often allow various other human activities such as herding, hunting, gathering firewood and building materials, collecting non-timber forest products such as medicinal plants and even growing crops (Maddox, 2009). The examples provided in the regional profiles below stress the important cultural services of these areas for local peoples.

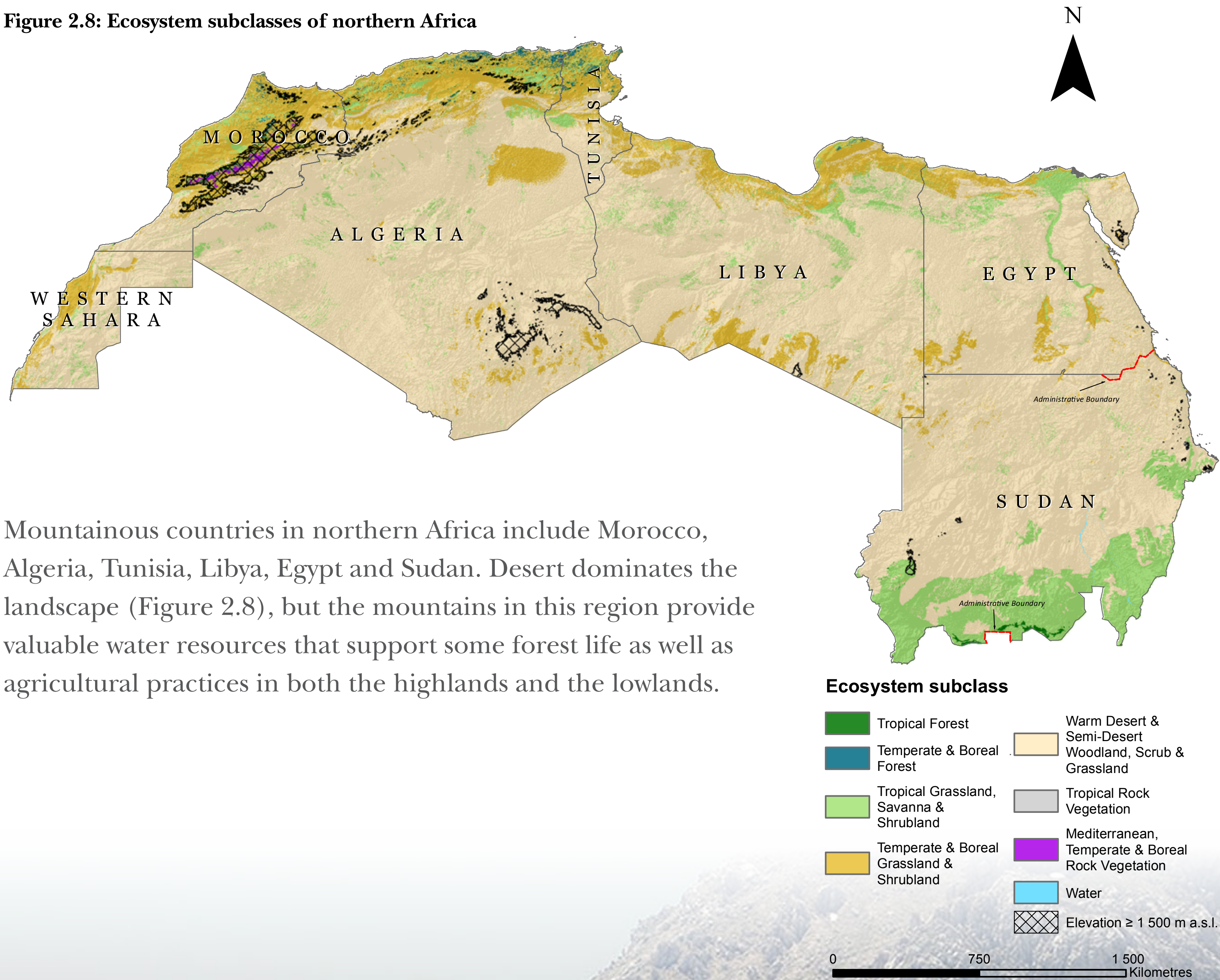


Small chapel on Mount Sinai in Egypt

Yodod / Flickr / CC BY NC-ND

Northern Africa

Figure 2.8: Ecosystem subclasses of northern Africa



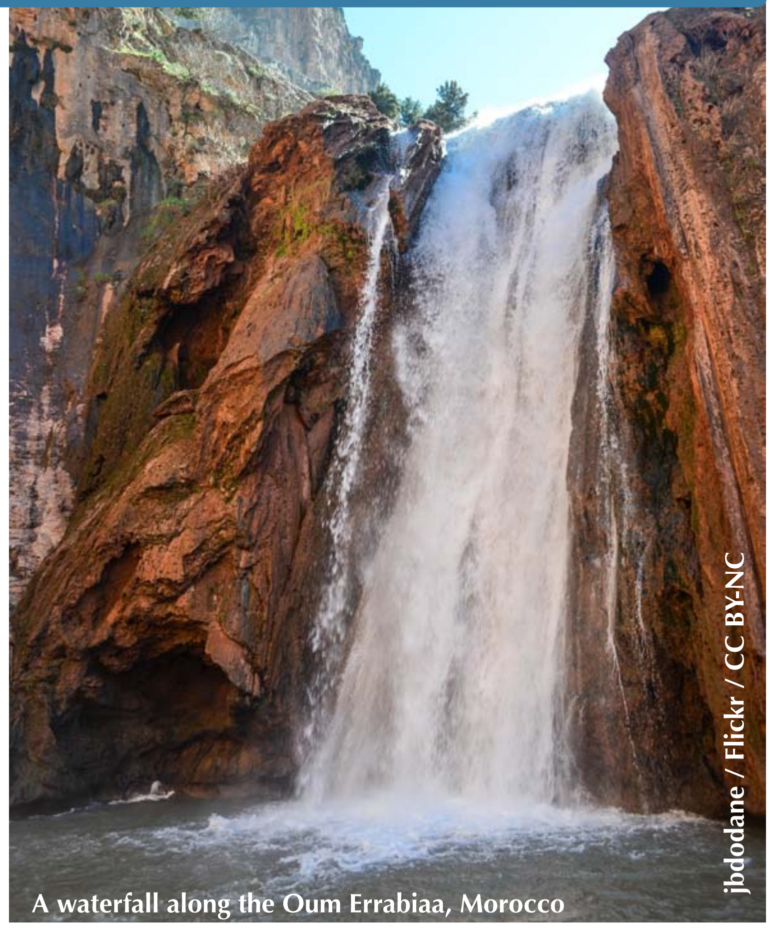
Source: USGS, 2014; elevated areas from USGS 7.5 arc second maximum DEM; UNEP/DEWA

Mountainous countries in northern Africa include Morocco, Algeria, Tunisia, Libya, Egypt and Sudan. Desert dominates the landscape (Figure 2.8), but the mountains in this region provide valuable water resources that support some forest life as well as agricultural practices in both the highlands and the lowlands.

Vegetation around Lac Goulmine in the Djurdjura Mountains, Algeria

Water Towers

The High Atlas Mountains are water towers for the arid plains to the north and southwest and the valleys to the southeast (Boudhar, et al., 2010). The tallest peaks hold snow for weeks to months at a time and meltwater from this snow contributes to water flow that benefits agriculture from late winter to early summer. Modelling studies show that snowmelt from the northern faces of the High Atlas Mountains contributes approximately 25 per cent of streamflow in its catchments (Boudhar, et al., 2009). The headwaters of the Sebou River and the Oum Errabiaa are in the Atlas Mountains (Table 2.1). Water from the Sebou River and its tributaries, including the Oued Fez, is used for irrigation of vegetables and other crops in the surrounding areas. However, wastewater pollution generated by growing urban areas along the river are compromising this irrigation source (Perrin, Raïs, Chahinian, Moulin & Ijjaali, 2014; see Chapter 3).


A waterfall along the Oum Errabiaa, Morocco


An adult Striped Hyena

Biodiversity

Mediterranean conifer and mixed forests grow in high elevations of the major mountain massifs in northern Africa. Small, isolated relict stands of these fir and pine forests are endemic (Olson, et al., 2001). One variation of the pine, the black pine (*Pinus nigra*), can be found in Algeria's Djurdjura Mountains and has been studied for its potential to naturally regenerate (UNESCO, 2002). The Rif, Middle Atlas and High Atlas mountains have a high level of endemic species and are home to some rare taxa in the region (Draper, Albertos, Garilleti, Lara, & Mazimpaka, 2007). The Tell Atlas Mountains harbour 91 endemic plant species; the Rif Mountains has at least 190 and the Middle Atlas Mountain range contains 237 species that grow only in that place (Berrahmouni & Regato, 2014). About ten rare epiphytic bryophytes can be found in the Rif and five occur in the Middle Atlas (Draper, Albertos, Garilleti, Lara, & Mazimpaka, 2007). The forests of northern Africa's mountains are also precious habitat for some species. For example, the M'Zaris Forest in the Djurdjura Mountains is one of the few known habitats remaining of the striped hyena (*Hyaena hyaena*) (UNESCO, 2002; Arumugam, Wagner, & Mills, 2008).

Agriculture

Mountain agriculture in northern Africa mostly takes place on small farms, usually less than 10 ha in size (Jacobs & van't Klooster, 2012; Sahli, 2010). In Morocco, approximately two-thirds of the country's arable land is located in mountainous areas and agriculture is a significant part of Morocco's economy (Jacobs & van't Klooster, 2012). It is so important that in 2008, the government began implementing the *Plan Maroc Vert* (Green Morocco Plan) as a new strategy to increase production and further develop small-scale farms with local involvement (Ait Kadi & Benoit, 2012).

Saffron and other spices for sale at a market in Essaouira

Typically, agriculture can take place on the Mediterranean-facing land at the foot of the Atlas Mountains and the majority of crops are rain-fed while others are irrigated from water captured by the many dams in the area (Jacobs & van't Klooster, 2012). Small-scale farms use locally-developed irrigation schemes combined with modern agricultural technologies that use land and water efficiently to grow fruits and vegetables that are sold to cities in the lowlands or exported to Europe (Bagoora, 2012b). The mountain communities also rear livestock. In the western High Atlas, two complementary land uses are integrated: (1) private land is cultivated intensively by hand, mainly using irrigated valley terraces, and (2) sedentary herders rear sheep and goats, grazing them during the summer on common lands at high altitudes, often above 2 500 m and within travelling distance of one or two days, and at other times, they graze them in their valley meadows or on crop stubble. The latter is a form of transhumance, described earlier on. In some areas, socio-economic changes may be threatening the sustainability of irrigated terrace agriculture and overuse of shifting cultivation, grazing and charcoal production may be degrading highland areas, threatening the transhumance way of life (Barrow & Hicham, 2000).

Water captured in Morocco's Atlas Mountains by dams and diverted to river valleys supports cereal and potato growing and apple and walnut orchards (Hammi, et al., 2010). Saffron, or "red gold," is a high-value crop in the Anti-Atlas Mountain region and an important source of income for 3 000 smallholder farmers (Kohler & Maselli, 2009). The Tell Atlas Mountains of Algeria support some rain-fed wheat farming and potatoes; there has also been an observed increase in the growth of olive trees (Jacobs & van't Klooster, 2012).


Salvia officinalis flowers

Non-timber Forest Products

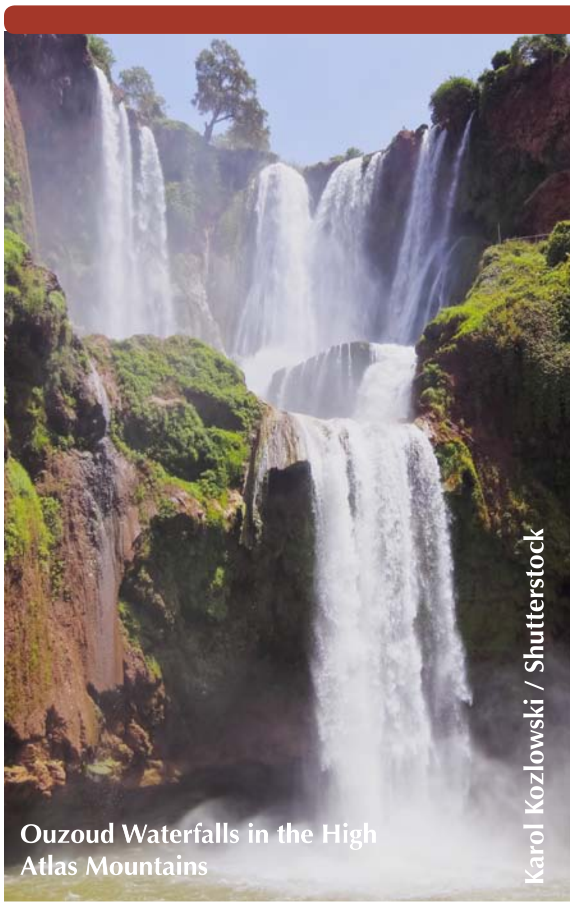
Many varieties of medicinal plants can be found in the Middle Atlas mountain region in Morocco. The leaves, fruits and seeds of at least 22 species are used to create medicine with several species, including *Olea europaea L.* and *Salvia officinalis L.*, used to manage and treat diabetes (Bousta, Boukhira, Aafi, Ghanmi, & el Mansouri, 2014). The remaining patchy forests on mountains in Algeria provide at least 50 different species of mushrooms for expert foragers, thyme and asparagus are harvested and tree stumps are used to make pipes and other crafts (Djema & Messaoudene, 2009).

Forests and Agroforestry

In Morocco, there are a few remaining forests in the High Atlas Mountains where local populations rely on them for foliage fodder, timber and firewood (Hammi, et al., 2010). Small areas of protected forest called *Agdal* (see Box 4.10 in Chapter 4) exist within villages. They are governed by rules about when a person can harvest within the protected zone and when they are excluded and must harvest from the surrounding forest (Hammi, et al., 2010). Woodland and shrub vegetation also serves as grazing ground for livestock that is herded on the mountains, although grazing has reduced the vegetation cover (Culmsee, 2005). In Algeria, forest covers only about 2 per cent of the country, but the Atlas cedar forests found among the Aurés Mountains and the Djurdjura Mountains are under pressure from both natural and human threats such as climate change, fire and pastoralism. However, actual wood harvest rates are low (Djema & Messaoudene, 2009).


Atlas cedar

Frank Fischbach / Shutterstock


Ouzoud Waterfalls in the High Atlas Mountains

Karol Kozlowski / Shutterstock

Tourism

With 10 summits over 4 000 m, the Atlas Mountains are popular places for tourism, including mountain trekking, riding and skiing (MNTO, 2014). A unique aspect of mountain tourism in Morocco is the trend of renting farmhouses in agricultural areas for lodging tourists on the way to the summits (Khalil, 2004). Countless waterfalls, such as the Ouzoud, cascade from atop the many high peaks, providing attractive refuges for climbers to rest and bathe. Mount Toubkal, northern Africa's highest peak in the High Atlas, is a popular destination for climbers (Smith, 2004). Tour guides take groups to visit the local Berber people who live in this mountainous region in villages called Kasbahs, to understand their nomadic culture (Smith, 2004). The Middle Atlas Mountains also have popular tourist destinations, such as the Ain Leuh cedar forest, the Virgin waterfalls and the Ifrane National Forest (MNTO, 2014). The diverse topography of the Atlas Mountains overlooking the Sahara desert attracts tourists at sunset to photograph the rare juxtaposition of the sandy dunes and the calcareous rocks that make up the range (Smith, 2004).

Sacred Places

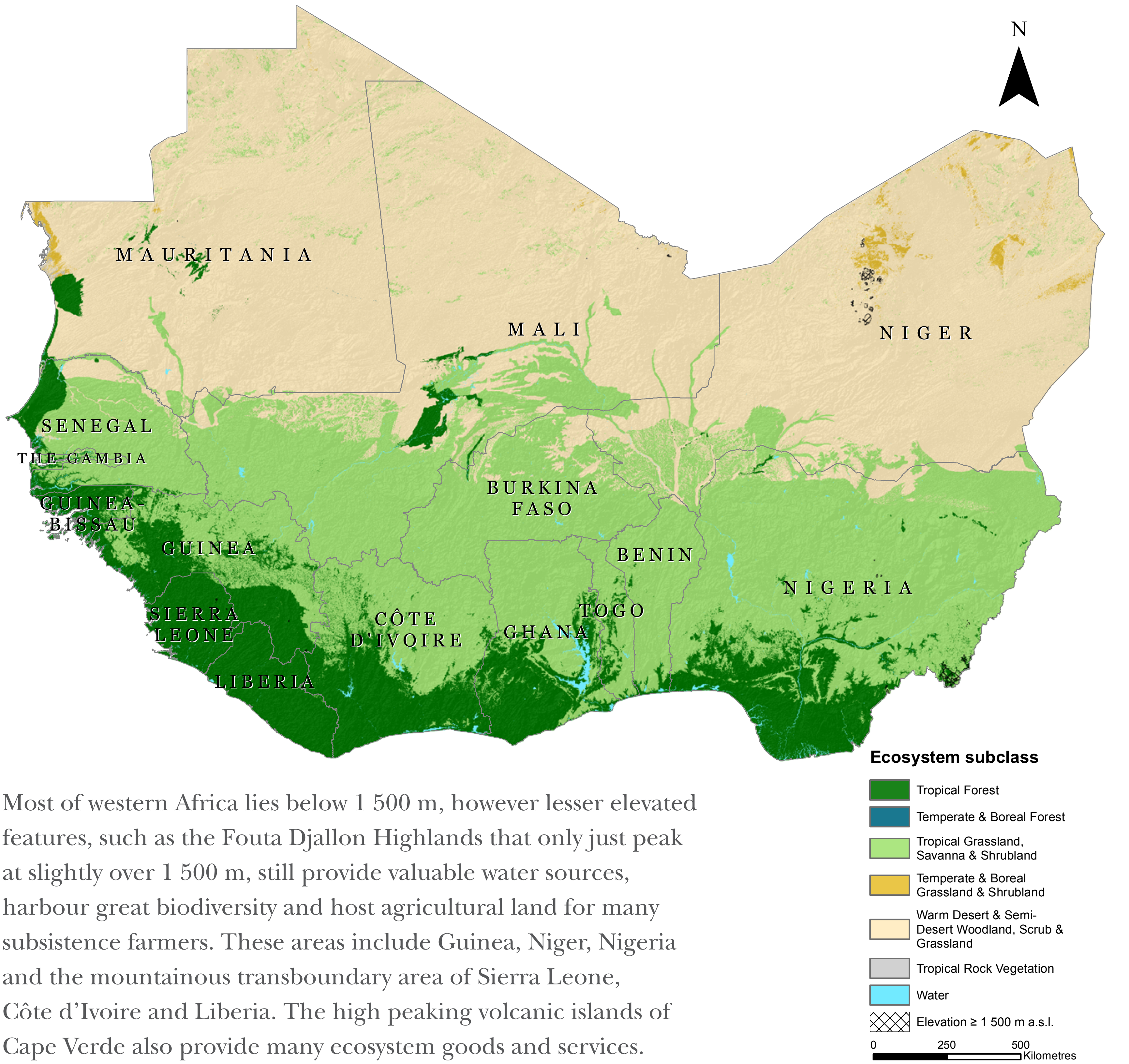
Egypt's Mount Sinai, also referred to as Jebel Musa and Mount Horeb, is a significant religious site. The Old Testament reports it is where God handed down the Tablets of the Law to Moses (UNESCO, 2014d). At the foot of Mount Sinai is the Saint Catherine Monastery, the oldest still-functioning Christian monastery. For over a thousand years, Saint Catherine has remained a point of convergence between various routes and stories, a destination for pilgrims and tourists and housing blessed objects (della Dora, 2009).


St. Catherine monastery next to Mount Sinai

Sophy Ru / Shutterstock

Western Africa

Figure 2.9: Ecosystem subclasses of western Africa



Source: USGS, 2014; elevated areas from USGS 7.5 arc second maximum DEM; UNEP/DEWA
Note: Ecosystem data for Cape Verde not available

Most of western Africa lies below 1 500 m, however lesser elevated features, such as the Fouta Djallon Highlands that only just peak at slightly over 1 500 m, still provide valuable water sources, harbour great biodiversity and host agricultural land for many subsistence farmers. These areas include Guinea, Niger, Nigeria and the mountainous transboundary area of Sierra Leone, Côte d'Ivoire and Liberia. The high peaking volcanic islands of Cape Verde also provide many ecosystem goods and services. Mountains in Niger fall into both the desert and the grasslands and shrublands classifications, but the other mountain regions in western Africa are mostly vegetated, falling into tropical forest, grassland savanna and shrubland classifications (Figure 2.9).

Water Towers

The Senegal and Gambia Rivers, important water resources of westen Africa, originate in the Fouta Djallon Highlands (FDH) in Guinea. The FDH also contribute an estimated 70 per cent of water to the Niger, Kaba, Kolenté and Koliba (FAO, 2002). The three main rivers – the Niger, Senegal and Gambia – flow through eight countries, providing water and drought relief along the way (Laaksom & Tyynelä, 2006). Two dams located on the Senegal River and its tributary, the Bafing, help capture the runoff from the FDH to provide water for rice irrigation; the Bafing dam has the potential to store 11 billion m^3 of water (Barron, Fox, & Biao Koudeoukpo, 2007). South of the FDH lies another highland region, which includes Mount Nimba. Mount Nimba spans Guinea, Liberia and Côte d'Ivoire and also serves as a prominent water tower for western Africa. Nearly 50 springs can be found in the vicinity (UNESCO, 2014b) and the Cavally and Ya Rivers and several tributaries of the Sassandra and Cess Rivers originate from the Nimba mountain region (Thieme, 2013).

The Loma Mountains of Sierra Leone and Mount Bintumani, western Africa's highest peak, are the origin of the Niger River and of several tributaries of the Sewa River, making it part of the most important watershed in the country (WWF, 2013b). In eastern Sierra Leone are the Tingi Hills, peaking at 1 850 m, which also source tributaries flowing to the Sewa River and contribute to the flow of the Mano River that separates the country from Liberia (Okoni-Williams, Thompson, Wood, Koroma, & Robertson, 2001).

Nearly all of the water for consumption on Cape Verde comes either from rainfall harvesting structures or groundwater (Heilweil, et al., 2006). Groundwater in coastal areas has been affected by sea-water intrusion, which causes salinity to increase, over-abstraction and unplanned urbanization (DGA-MAAP, 2004). Desertification is a disturbing trend and a cause of rural vulnerability in Cape Verde, affecting families' material and environmental resources. Combating desertification in Cape Verde is complex because it involves addressing a mixture of domestic drivers, such as manual agriculture, deforestation from fuelwood and fodder extraction as well as land-tenure systems and steep slopes that increase soil erosion. The results of such pressures include high rainfall variability, desertification, prolonged droughts or periods of heavy rainfall (Tavares, et al., 2014) and overfishing.

Although the Aïr massif lies in the Sahara Desert, it contains a very high water table, enabling inhabitants to conduct small-scale irrigated agriculture. Annual rainfall can vary from 50 mm to 200 mm and water is collected by the sparse rural population using wells (FEWS NET, 2011).

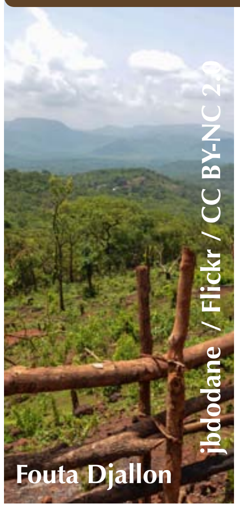
Sundevall's Leaf-nosed Bat (*Hipposideros caffer*)

Biodiversity

The Guinean Montane Forest grows on the high altitude peaks and plateaus that span four countries in western Africa's Upper Guinean region: Guinea, Sierra Leone, Liberia and Côte d'Ivoire. Knowledge of the region's biodiversity is limited, but it is known that 35 plant species are strictly endemic, and that unique plant species occur only on several mountains. One example is the orchid *Rhipidoglossum paucifolium*, which is found only on Mount Nimba (Johansson, 1974). There is also a high diversity of fauna with up to 15 strictly endemic vertebrate species. Some of these species can only be found on one mountain, such as Mount Nimba's endemic toad, *Nimbaphrynoides occidentalis* (WWF, 2014b) and the endangered *Hyperolius nimbae* (Mount Nimba Reed Frog), which is currently in decline and primarily found at the southeastern foot of Mount Nimba (Schiøtz & Rödel, 2013). The most diverse population of *Hipposideros* (a bat) in Africa may also be found on Mount Nimba, with at least seven distinct species (Monadjem, et al., 2013).

The Fouta Djallon Highlands in western Guinea also have many species of amphibians, with at least 25 different species including a recently discovered one (*Conraua sp.*) in the forests surrounding the Saala Waterfalls (Hillers, Loua, & Rödel, 2008). Some species, such as the *Leptopelis bufonides*, a frog found in the savanna, has been newly spotted in Guinea; the typical range for this frog is from Senegal to northern Cameroon (Hillers, Loua, & Rödel, 2008).

Agriculture



Fouta Djallon

jbdodane / Flickr / CC BY-NC 2.0

Small-scale family subsistence agriculture in western Africa is practiced in the Fouta Djallon Highlands of Guinea (FAO, 2013b). Small villages in rural areas of the FDH rely on home gardens for self-subsistence, for example, growing a variety of food including fruit trees such as orange, mango and avocado (Laaksom & Tyynelä, 2006). The proximity of forests to agricultural land means that leaves from the forest can be used for soil fertilizer, although the nutrient transfer may not always be sufficient for significant agricultural yields (Laaksom & Tyynelä, 2006).

The majority of the population on Cape Verde resides in rural areas and derives its livelihood from rain-fed agriculture. Farming is challenging since most precipitation is lost to evapotranspiration and runoff to the sea due to the warm climate, thin soils, steep topographic gradients and short distances to the sea (Heilweil, et al., 2006).

The highland areas of Nigeria, including the Jos Plateau, are more suited for livestock grazing than agriculture due to their natural grassland cover, but some market gardening does take place on a small scale as does cocoa farming (Aregheore, 2009b).

As mentioned previously, the high water table in the Aïr massif in Niger allows the Tuareg people to practice irrigated agriculture (FAO, 2006) to grow garden crops, millet and wheat (FEWS NET, 2011). The most valuable crop to grow in the area is onions, which can be sold in the national and regional markets. Irish potatoes and garlic are also able to be sold on a wider market, but at a smaller scale (FEWS-NET, 2011). Stockbreeders occupy lands that are not suitable for growing crops (FAO, 2006). At the foot of the western side of the Aïr Mountains lies some seasonal pastures used by transhumants and nomads (FEWS NET, 2011).

Non-timber Forest Products

The prevalence of fruit-tree planting in the FDH, representing more than 50 different species, brings not only fruit to the communities, but traditional medicinal remedies as well (Laaksom & Tyynelä, 2006). Many different parts of the néré (*Parkia biglobosa*) tree can be used in making various medicines as can the leaves and roots of fruit trees such as mango (Laaksom & Tyynelä, 2006). Additionally, more than 30 types of common plants that grow both in the wild and in home gardens in the FDH can be used for traditional medicines, and some plants, such as kola nuts, are used during traditional ceremonies (Laaksom & Tyynelä, 2006). Other non-timber forest products derived from the FDH include rubber, wild honey, oil derived from seeds and dyes extracted from dried leaves (Laaksom & Tyynelä, 2006).

Fruit of a kola tree

Scamperdale / Flickr / CC BY-NC

Néré fruit

CIFOR / Flickr / CC BY-NC 2.0

Forests and Agroforestry

Livestock graze in forests in the FDH, which also supply wood for cooking, while the animals provide a source of fertilizer for agriculture (Laaksom & Tyynelä, 2006). The néré can be considered the most important local tree species in the FDH forests since it supplies a multitude of uses over and above timber, such as spices, honey production and medicine (Laaksom & Tyynelä, 2006). Extensive deforestation over time and current logging practices, however, have left only fragmented forest stands (Hillers, Loua, & Rödel, 2008). The forests of the Loma Mountains and Tingi Hills in Sierra Leone are relatively closed off to activity since they are Forest Reserves, offering key habitats for many types of birds and other wildlife (Okoni-Williams, Thompson, Wood, Koroma, & Robertson, 2001).

Tourism

The Aïr Natural Reserve in Niger includes the Aïr massif and the Ténéré Desert; it is an increasingly popular tourist destination due to the unusual appearance of a mountain ecosystem surrounded by desert (ANH, 2009a). Tourists, mostly from Europe, come to explore the desert, mountains and Tuareg culture (Scholze, 2010). The life-size giraffe rock carvings located in the village of Dabous on the Aïr massif are also an attraction. Thought to have been carved between 10 000 and 8 000 years ago, the carvings, or petroglyphs, are among 828 images in the area depicting other animals such as ostriches and rare lions, as well as humans (Bradshaw Foundation, 2011). Tourism has also contributed to local employment opportunites as some Tuaregs have left their traditional practices of herding and gardening to become camel drivers, guides and cooks. There are at least 62 travel agencies in Agadez on the Aïr massif, and most are run by Tuaregs (Scholze, 2010).

In Sierra Leone, ecotourists are attracted to the Loma Mountains to view endangered flora and fauna in the Loma Mountains National Park. Mount Bintumani lies within the Loma Mountains and attracts hiking and rock climbing enthusiasts (NTBSL, 2012) and is also a popular destination for bird watchers (PAI & FJP, 2008). The Tingi Hills mountain area has potential for development as another ecotourism destination in Sierra Leone. Before civil war ravaged the area, the Hills had several ideal campsites and attracted adventurous mountain climbers. If properly re-developed and managed, tourism could be restored in the area (PAI & FJP, 2008).

Mountains in areas such as Kanyang, Obudu and Mambilla in Nigeria are attractive for their rugged, scenic terrain and visitors can use the local cable bus system to visit them (NHC, 2014). Tourism in Cape Verde has undergone a recent transformation turning a little-known island into a booming tourism destination with an increase from about 67 000 visitors in 1999 to over 280 000 visitors in 2009 (World Bank, 2013). Revenue from tourism (including direct, indirect and induced) makes up about 44.5 per cent of Cape Verde's GDP, which was over US$300 million between 2010 and 2013 (World Bank, 2013).

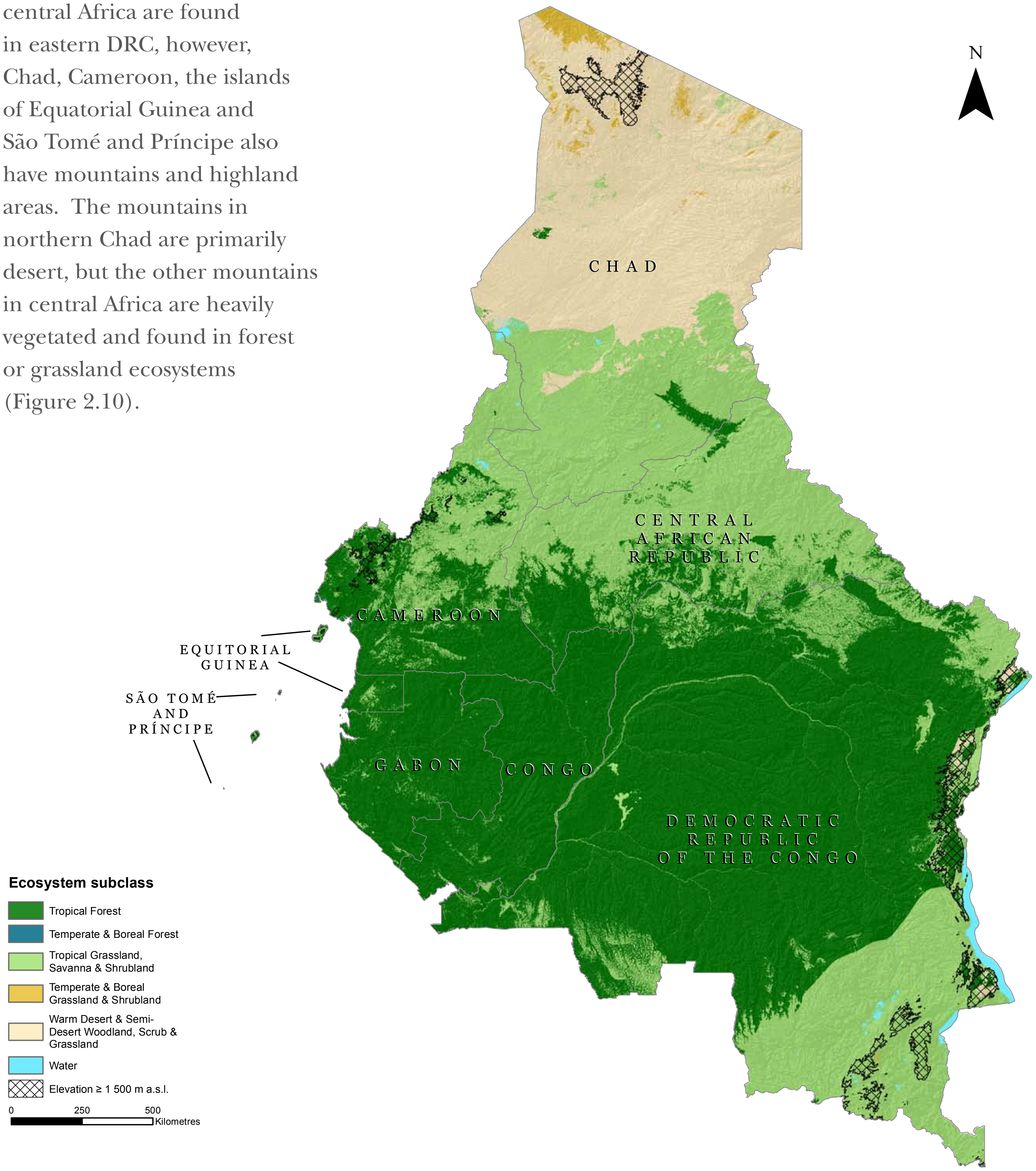

Ténéré Desert


Life-size carvings of giraffes in Dabous at the base of the Aïr massif

Central Africa

Most of the mountains in central Africa are found in eastern DRC, however, Chad, Cameroon, the islands of Equatorial Guinea and São Tomé and Príncipe also have mountains and highland areas. The mountains in northern Chad are primarily desert, but the other mountains in central Africa are heavily vegetated and found in forest or grassland ecosystems (Figure 2.10).

Figure 2.10: Ecosystem subclasses of central Africa



Source: USGS, 2014; elevated areas from USGS 7.5 arc second maximum DEM; UNEP/DEWA


Congo River

CIFOR / Flickr/CC BY-NC-ND 2.0

Water Towers

The Congo River, which is central to the Congo Basin, connects central Africa to the Atlantic Ocean and is the second-longest river in Africa and the world's fifth longest. It rises from the savanna highlands in Katanga Province in southeastern DRC (UNEP, 2011). The river's largest source, the Kwa-Kasai, rises from the Angolan Plateau to the south (UNEP, 2011). A large proportion of Lake Edward, a water body used for jobs, water and food, is found in the Virunga Mountains landscape in eastern DRC. The Virunga Mountains themselves also supply fresh water (WWF, 2013a). The high altitude area between Beni, north of Lake Edward, and Goma to the south, has the highest water yield (level of precipitation that does not evapotranspire) of all of the Greater Virunga Landscape, which also includes parts of Uganda and Rwanda (Kasangaki, et al., 2012).

In west-central Africa, the eastern slopes of Mount Cameroon are an essential rural water supply, providing water for more than 250 000 local residents for domestic and agriculture purposes, with easier access to water for those residing on steeper slopes. Water is channelled through streams and accumulates in ponds. In some areas, the water table is close enough to the surface to allow the use of direct taps (Lambi & Kometa, 2009).

Biodiversity

After the Amazon basin, central Africa contains the world's second-largest continuous block of rain forest. Afromontane forests grow in parts of the highest mountainous regions where rainfall is abundant (UNEP, 2009).

The DRC is part of the Albertine Rift region, which is at the centre of Africa's montane rain forests; its western side is contiguous with the Guinea-Congolian lowland rain forest. The Virunga Mountains, part of the Albertine Rift Mountains, are home to two subspecies of the eastern gorilla: the mountain gorilla and the eastern lowland gorilla, which can only be found in the DRC (ZSL, 2009). Of all protected areas in Africa, the Virunga National Park harbours the greatest diversity of vertebrate species, which includes the okapi (or forest giraffe) (ZSL, 2009).


Okapi, or forest giraffe, is a protected species found in the Virunga Mountains

Derek Keats / Flickr / CC BY

In west-central Africa, the lowland forests in Cameroon's highlands have 29 endemic plant species, but species diversity significantly decreases above 3 400 m (Bussman, 2006). In the Mount Cameroon area, there are 370 species of birds (Fotso, et al., 2007) and several mammal species, including forest elephants and chimpanzees (Forboseh, Eno-Nku, & Sunderland, 2007).

Although the Tibesti and Ennedi Mountains are located in the Sahara Desert, some species of fish can be supported in mountain wadis (streambeds that are usually dry but fill with water in the rainy season) and gueltas (a natural depression that captures water) and at least 350 plant species are found in the area (Scholte & Robertson, 2001).

A farmer in the Virunga Mountains, DRC

Joseph King / Flickr / CC BY-NC-ND

Agriculture

Almost all countries in central Africa grow coffee; Cameroon and the DRC grow *C. arabica* in their highlands (Figure 2.5). The fertile volcanic soils of Mount Cameroon also support other cash-crop plantations of rubber, tea and bananas that contribute to the world market (Nuesiri, 2008). In the mountainous areas of the DRC (the Virunga region, for example), farmers raise livestock and cultivate sugar cane and potatoes in addition to tea and coffee (FAO, 2012a). Offshore, on the islands of São Tomé and Príncipe, copra, cocoa and palm nuts are grown for export (AFDB, OECDdev, UNECA, & UNDP, 2013).

Non-timber Forest Products

In the Virunga Mountains, products such as nuts, leaves, roots, fungi and honey are not only valuable sources of nutrition and food security, but also generate income for local people (WWF, 2013a). Charcoal is also a common non-timber forest product of the Virunga Mountains as it supplies 90 per cent of the charcoal used in Goma, DRC and Northern Rwanda (ICCN, 2009). It is mostly conducted illegally from protected forests, however, which is severely threatening the forests and turning over US$30 million a year to illegal trading in the product (ACF, 2011).

The Cameroon highland area, including Mount Cameroon and Mount Oku (Kilum), is one of the leading locations for the commercial *Prunus africana* industry in Africa (see Chapter 5) (Ingram, Awono, Schure, & Ndam, 2009). Beeswax and honey are also non-timber forest products produced in Cameroon's montane forests (Ingram & Schure, 2010).

A honey shop in Bamenda, Cameroon

John Mauremootoo / Flickr / CC BY-NC-SA

Yams growing in the forest on Mount Cameroon

Matthias G. Ziegler / Shutterstock

Forests and Agroforestry

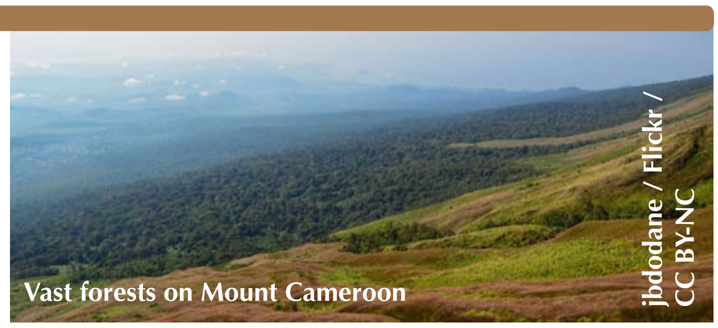
Seventy per cent of the Albertine Rift Montane Forest ecoregion is found in the DRC, where tropical and subtropical moist broadleaf forests thrive (WWF, n.d.). Approximately 15 per cent of the vegetation found in the Virunga National Park is montane forests. The Virunga Mountains also have Afroalpine vegetation, such as *Lobelias* and tree ferns (UNESCO, 2014e). Agroforestry has been introduced to these montane forests through small-scale programmes to engage women in the North Kivu region. They farm cocoa alongside bananas and cassava in the forests because these crops do not require land to be cleared for growth (Langford, 2013).

Agroforestry is promoted among the highlands of central Africa. Capacity is being built among farmer groups in the Cameroon highlands to focus on planting trees to improve food security, soil fertility and crop varieties, such as maize and potatoes. As a result, rural populations are benefitting from the domestication of fruit and nut trees. The agroforestry network in the highlands of Cameroon consists of over 10 000 farmers and 150 satellite tree nurseries in the west and northwest areas of the country (Asaah, et al., 2011). On São Tomé and Príncipe, forests are the primary source of fuelwood for domestic energy consumption (UNSD, 2011).

Carbon Sequestration

Reforestation of 18 ha of land in the Kitshanga area north of Goma, DRC is aimed at increasing the potential for earning carbon credits and for alleviating pressure on the outskirts of the Virunga National Park by grazing, biomass removal and charcoal production (Brotto, Pettenella, Damiani, & Zuliani, 2011). Since 2010, the project has resulted in the sale of nearly 3 000 carbon credits (FCP, 2014). Additionally, the Watalinga forest in the northern Virunga Mountains has been identified as a key area for other carbon and reforestation projects (ZSL, 2009).

The forests of Mount Cameroon have also been identified as having great potential for carbon sequestration projects. It is estimated that 200 000 ha of forest are lost annually, some of which is accounted for by *Prunus africana* exploitation and clearing the forest to make way for cash-crop plantations. The potential for forest management and contribution to REDD is possible, but there are challenges, such as the ambiguity over land-ownership rights, financial security for project funding and lack of knowledge of basic forest-management mechanisms (Sama & Tawah, 2010).


Vast forests on Mount Cameroon

Tourism


Lead runner in the Race for Hope in 2007

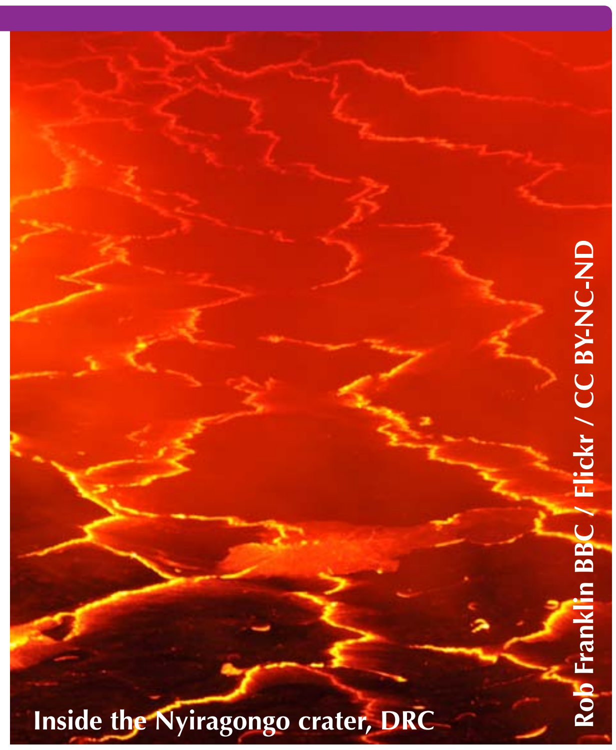
The introduction of guided tours has made ecotourism very popular in the Mount Cameroon area. This regional ecotourism attracts bird watchers, nature enthusiasts, mountaineers and adventurers to the many craters, lakes, waterfalls and old lava flows. Each year, the "Race for Hope" attracts runners from across the world, who race up to the top of the summit and back down (Mount CEO, 2008).

Virunga National Park in the DRC is a famous tourist destination where observers can watch the elusive and threatened mountain gorilla. War and conflict destroyed a lot of tourism infrastructure in the mountain park in the 1990s (ZSL, 2009), but tourism improved by 2004 with many tourists returning to the park to see these charismatic gorillas (Brotto, Pettenella, Damiani, & Zuliani, 2011). Future tourism revenues could potentially reach US$235 million through direct use of the park (WWF, 2013a).

Sacred Places

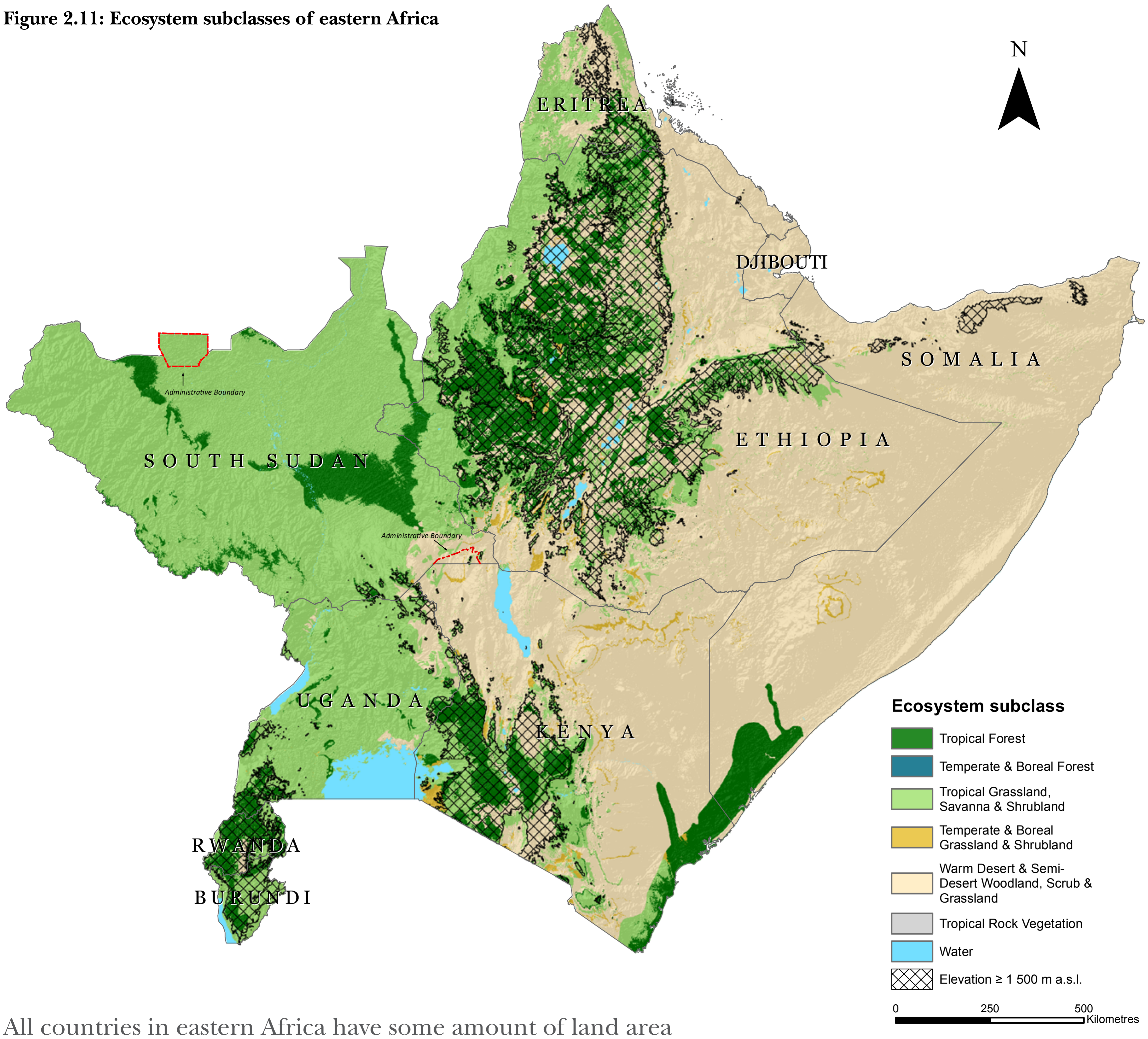
In the DRC, Nyiragongo is a spiritual mountain to the Bantu people. The Bantu believe that the volcanoes eruptions occur because of Ryang'ombe, its resident superior godly spirit, or *imandwa*. Nearby volcanoes, including Muhabura in Rwanda, also have been visited by Ryang'ombe (Leviton, 2006).

In Cameroon, many montane forests are considered to be sacred and worshipped by local people such as the Bakundu and Bakweri tribes (Kah Elvis, Tchindjang, Tonye, & Talla, 2008). Mount Cameroon itself is referred to as the "Chariot of the Gods". The name is derived from Hanno, a Carthaginian navigator, who in the year 600 B.C. discovered the volcano erupting, noting that the hot flames were shooting up towards the stars. Some local people also refer to the volcano as the "Seat of the Gods" (Makuchi, 2008).


Inside the Nyiragongo crater, DRC

Eastern Africa

Figure 2.11: Ecosystem subclasses of eastern Africa



Source: USGS, 2014; elevated areas from USGS 7.5 arc second maximum DEM; UNEP/DEWA

All countries in eastern Africa have some amount of land area above 1 500 m in elevation. The ecosystems are primarily grassland and forest in the western areas of the region and mostly desert in the eastern part (Figure 2.11). The vegetated highland areas provide valuable water and plant resources to the drier lowlands.

Water Towers

The headwaters of the Nile River can be found in the mountains of eastern Africa. The Atbara River and the Blue Nile, begin in the Ethiopian Highlands. The Atbara River joins the Nile River in Atbara, Sudan. The Semuliki River in the Rwenzori Mountains of Uganda supplies water to the tributaries of the White Nile, while waters running from Mount Elgon and the Kenya highlands eventually empty into Lake Victoria (Bagoora, 2012a). Five mountain forests of Kenya serve as water towers: Mount Kenya, Mount Elgon, the Cherangani Hills, the Aberdare Mountains and the Mau Forest Complex (see the Mau Forest Complex hotspot in Chapter 4). The forests of these water towers are the source of three major rivers in Kenya: the Athi, Tana and Ewaso Ng'iro (Ochego, 2003). The eastern slopes of the Aberdare range and the Taita Hills are the water sources of the Athi; the Tana is also sourced from the eastern side of the Aberdare range, and from the southern slopes of Mount Kenya and the Nyambene Hills; and Mount Kenya and the northern slopes of the Aberdare range provide water to the Ewaso Ng'iro (Ochego, 2003; Bussman, 2006). Mount Kenya serves as the only source of freshwater for more than seven million people (UNEP, 2012b). Water from the eastern slopes of the Aberdare Mountains and the neighbouring Taita Hills feed the Sasumua and Ndakaini dams, which are an important source of clean water for Nairobi, Kenya's densely-populated capital (Ochego, 2003). Mount Elgon, which crosses the border of both Kenya and Uganda, provides water for nearly 1.3 million people. The mountain is the head catchment for the Nzoia and Turkwel Rivers, provides to the Malakisi River and is also a major source of water for Lake Victoria. The Turkwel River feeds Lake Turkana (Laman, Khamati, & Milimo, 2001).


The White Nile flowing through Jinja, Uganda

Biodiversity


Mountain Nyala in the Bale Mountains

In eastern Africa, the Albertine Rift includes Rwanda, Burundi and Uganda. With its central location within Africa and its position among the diversity of habitat zones with altitudinal shifts, the Albertine Rift is globally outstanding for its high species diversity and large numbers of endemic species (WWF, 2014b). More than 400 mammals and 7 500 plant and animal species, of which at least 1 175 are endemic, have been recorded (Plumptre, et al., 2003). The Bwindi Impenetrable National Park (BINP) in Uganda has 20 Albertine Rift endemic mammal species and the Rwenzori National Park has 18 (Plumptre, et al., 2003). Additionally, the snow- and ice-capped Rwenzori Mountains host some of the rarest plant types in Africa between elevations of 3 500 m to about 4 400 m (ANH, 2009b) and are considered a Bird Life International Important Bird Area (BLI, 2014b). The BINP and particular areas of the Virunga Mountains in Rwanda (and the DRC) are home to the last remaining populations of the Mountain gorilla (see Chapter 4) (WWF, 2014a). The Aberdare Mountains and Mount Kenya are the only places that the snake *Vipera hindii* can be found and the flight range of the butterfly *Capys meruensis* is also restricted to Mount Kenya (BLI, 2014a).

The Ethiopian Highlands have over 500 endemic vascular plant species and 31 endemic mammals. Nearly 700 species of birds can be found, of which 5 have very restricted flight ranges in the southern highlands. Unique mammals such as the mountain nyala, endemic to the Afroalpine ecosystem, can also be found among the highlands (Mckee, 2007). The many lakes in the highlands region also harbour a great number of fish species, although it is not known how many, or which species are endemic. The *Barbus* and *Garra* are the primary fish species found in the highland streams (Getahun, 2013).

Agriculture

In general, eastern Africa is conducive to farming because rainfall is adequate and more reliable than in the lowlands and soils are generally fertile (FAO, 2013b). Tea and coffee are important cash crops in eastern Africa highlands such as those in Ethiopia and Kenya (see page 65), but the banana is also an important crop. The eastern Africa highland banana is not only an essential food crop, but also an important part of culture and social lives. Bananas have also been an integral part in hybridization studies in effort to reduce their vulnerability to disease and pests (Ssali, Nowankunda, Erima, Batte and Tushemereirwe, 2010).

Almost half (48 per cent) of all farmers grow cereals in the western portion of the Ethiopian Highlands where there is reliable moisture (Dorosh, et al., 2011; EDRI, 2009). Agriculture is the basis of the economy in the Ethiopian Highlands, accounting for nearly 50 per cent of the country's GDP (World Bank, 2014), and subsistence agriculture is the main source of domestic food (Bishaw & Abdelkadir, 2003). This is because climatic and ecological conditions in the highlands, which contain 90 per cent of its agriculturally suitable land, are more favourable than in the surrounding lowlands. As a result, most of Ethiopia's population and its livestock are concentrated in the country's highland areas (Bagoora, 2012b).

In the Rwenzori Mountains, the indigenous Bakonjo and Bamba people who live on the middle and lower slopes practice small-scale peasant farming based on local crops. The soils are largely shallow and the slopes are highly fragile, however, and poor farming practices have led to accelerated soil erosion and landslides (Bagoora, 2012a).


A farmer using oxen to plow a field in the Ethiopian Highlands

Local conditions also dictate the location of farming endeavours on Mount Kilimanjaro, where the southern slopes are more populated than the others because of the presence of wet and fertile lands suitable for agriculture (Røhr & Killingtveit, 2003). Agriculture is central to the very mountainous country of Burundi, dominating its economy and comprising more than 75 per cent of its land area. Crops grown include cassava, bananas and yams; most agricultural land is rainfed (Vololona, Kyotalimye, Thomas, & Waithaka, 2013).


Ugandan baskets

Non-timber Forest Products

The rich montane forests of Uganda in eastern Africa are prime areas for harvesting non-timber forest products, with building materials and medicines the most frequently extracted. The forests of Bwindi Impenetrable National Park produce *Loeseneriella apocynoides*, which is commonly harvested for use in basket weaving (Ndangalasi, Bitariho, & Dovie, 2007). As many as 57 different plant species in the Uzungwa Scarp Forest Reserve (USFR) in the United Republic of Tanzania are used for making medicines (Ndangalasi, Bitariho, & Dovie, 2007). In the Rwenzori Mountain forests of Bundibugyo District in Uganda, 12 species are used for building poles and rafters, including *Arundinaria alpine*; the stems are used for poles and the leaves as roofing material (Kakudidi, Oryem-Origa, Bukenya-Ziraba, & Katende, 1996). Harvesting these products, even at a local level, however, can still put pressure on the forests leading to disturbed habitats, which occurred in the USFR as a result of harvesting bark, stems and whole trees (Ndangalasi, Bitariho, & Dovie, 2007).

Forests and Agroforestry

Local forest projects in the highlands of the Mau Forest in Kenya have helped to establish community woodlots to increase forest cover and prevent soil erosion (Bishaw & Abdelkadir, 2003). In the montane forests of southern Ethiopia, native *Coffea arabica* can be found, which helps to preserve the dense forest cover, but can lower forest species richness. Coffee plants take up to four years to produce fruit, often preventing farmers from clearing forest to convert to annual crops, but tree species remain limited (Hylander, Nemomissa, Delrue, & Enkosa, 2013).

Forests in the Imatong Central Forest Reserve in South Sudan's Imatong Mountains provided protection during the conflict in the late 2000s, which contributed to a small increase in forest recovery (Gorsevski, Kasischke, Dempewolf, Loboda, & Grossman, 2012). Sacred forests in the Ethiopian Highlands also provided refuge during times of war, enabling women and children to hide in the stone structures that had been built in the forests (Assefa & Bork, 2014).

Agroforestry practices have proved to be beneficial near the Bwindi Impenetrable National Park in the Kigezi Highlands of Uganda. The highland region supports a high population density of more than 250 pp/km², and an initiative to grow nearly 80 woody species among agricultural lands has supported biodiversity management (FAO, 2011b). When coupled with forest monitoring, agroforestry could contribute to covering deforested slopes throughout eastern Africa (Hall, Gillespie, & Mwangoka, 2011). In Uganda, it has been common practice to raise animals alongside crops and trees, which has helped to maintain soil fertility, meet 95 per cent of rural energy demand and reduce soil erosion (Mukadasi, Kaboggoza, & Nabaleqwa, 2007).

Aerial view showing the border of the Bwindi Impenetrable Forest in Uganda

Carbon Sequestration

Most of Africa's ongoing carbon sequestration projects are taking place in eastern Africa, with several of them in mountain forests (Jindal, Swallow, & Kerr, 2008). One of these is a forest rehabilitation project in the Mount Elgon and Kibale National Parks in Uganda. This project is expected to sequester a total of 7.1 Mt C over a period of 99 years (Jindal, Swallow, & Kerr, 2008). The project has proved to be controversial, however, since at least 22 000 local villagers have been evicted from their homes to make way for new forest plantations (Grainger & Geary, 2011).

To address deforestation in the Bale Mountains of Ethiopia, a 20-year REDD project is being implemented to reduce forest loss to 1 per cent over the period. The mountains are covered with moist tropical forest, including wild coffee, between 2 600 and 1 500 m; dry forest, woodland, grassland and wetland ecosystems occur in the northern parts, including *Prunus africana*, between 2 500 and 3 500 m; and acacia woodland dominates the mountains below 1 500 m. Local communities have been removing the forest, however, to grow crops, graze livestock and provide timber and fuelwood. Between 1986 and 2009, the average annual deforestation rate in the Bale Mountains was 3.7 per cent, which is almost four times the national rate (Watson, Mourato, & Milner-Gulland, 2013). The Oromia Regional State Forest and Wildlife Enterprise, supported by the Bale Eco-Region Sustainable Management Program (BERSMP) is running the REDD project, which covers 923 593 ha, including 576 856 ha of tropical dry and moist forest. Participatory forest management is being implemented to reduce the forest loss. It includes establishing community-based organizations and sustainable forest management practices. Because of the dearth of forest data in developing countries, forest carbon stocks to calculate potential emissions reductions from stemming forest loss are estimated. This data imprecision combined with the uncertainty of a number of voluntary carbon market prices means that there is a substantial variation in calculations about the potential revenues over the 20-year project, which could range between US$9 and 185 million (Watson, Mourato, & Milner-Gulland, 2013).

Less than 3 per cent of Ethiopia's native forests remain untouched because of over-exploitation of forest resources. The village of Humbo has become a model for what could be done to reverse forest loss and degradation if such efforts were to be scaled up across the continent. It is the site of Africa's first registered large-scale Clean Development Mechanism (CDM) project (World Bank, 2012b). The Ethiopian Government has been so impressed with its success that it is considering mainstreaming carbon financing into its sustainable land management programme (World Bank, 2012a; Box 2.6, page 86).

Box 2.6: Humbo: A successful carbon credit project in southwestern Ethiopia

Humbo is in southwestern Ethiopia's moist tropical montane climate regime, about 420 km southeast of the capital Addis Ababa. Thirty years ago, these mountains were covered with dense forests and an abundance of wildlife, allowing the local people to thrive using forest resources as fodder for their livestock and firewood. Since the 1960s, people were forced to overuse the forest, however, because of land use change to farming, and poverty, hunger and drought. As the forest was cut, so the vegetation transformed from trees to bushes and the land became degraded by severe soil erosion. During heavy rains, lowland areas flooded and periodic mudslides killed people and livestock and caused heavy damage. As well, deforestation threatened groundwater supplies that 65 000 people relied on for drinking water.

The Humbo community responded by heeding the idea to cease using degraded areas and set them aside to regenerate naturally. World Vision and the World Bank developed the Humbo Assisted Natural Regeneration Project and registered it with the United Nations Framework Convention on Climate Change's (UNFCCC) Clean Development Mechanism (CDM), a programme that allows countries to earn carbon credits for reforestation and afforestation projects (World Bank, 2010). The project, which started in December 2005, supports forest regeneration by using more than 45 native tree species using the Farmer Managed Natural Forest Regeneration (FMNR) technique, which encourages new growth from the living root-stock of felled trees, seeds, barren areas, establishes fences of live trees, grows surplus grass for fodder and uses wood from pruning and fast-growing species for fuel. More than 90 per cent of the area devoted to the Humbo project has been reforested, with the successful restoration of 2 728 ha of land that is newly rich with biodiversity.

The area now sequesters carbon, as the forests absorb and store CO_2 from the atmosphere, making the project eligible for carbon credits. In 2009 it was validated as an Afforestation/Reforestation (A/R) project under the CDM and it started generating revenue for the community in 2010. In 2011 it achieved First Edition Gold Level validation under the Climate, Community and Biodiversity (CCB) Standards. In 2012, it was awarded Africa's first temporary Certified Emission Reductions, or carbon credits, for reforestation. Over the project's crediting period of 30 years, it will remove 880 000 tonnes of carbon dioxide from the atmosphere. In October of 2012, the CDM issued 73 000 credits, which the World Bank's BioCarbon Fund purchased, bringing Humbo residents revenues in payment for their reforestation efforts. The farmers are reinvesting these monies in community-driven activities (World Bank, 2012a), including micro-businesses such as beekeeping, livestock, a flour mill and a grain storage facility. In addition, the project protects the fragile water catchment, helps maintain springs and groundwater, prevents erosion and flooding and is reducing the amount of sediment runoff that threatens Lake Abaya, located 30 km downstream.

Sources: Compiled from World Bank, 2010; World Bank, 2012a; World Bank, 2012b; REDD Desk, 2014

Tracking chimpanzees in Nyungwe National Park

Tourism

Tourism, especially ecotourism, is extremely important to eastern African economies and it is a growing industry. In 2008, visitors spent over US$2.7 billion in Kenya, Uganda, Ethiopia and Rwanda combined (the data from Uganda are for 2009) (World Bank, 2013). Volcanoes National Park (VNP), located in the Virunga Mountains of Rwanda, is known for the critically endangered mountain gorilla as well as its caves (Rwanda Tourism, 2013). A relatively new (2006) luxury lodge that opened near the VNP has also helped to attract tourists (World Bank, 2013). The Mgahinga Gorilla National Park (MGNP), located in the Ugandan Virungas, is also a popular place for tourists to see mountain gorillas as well as African golden monkeys; primate viewing brought in over US$300 000 in revenue from the MGNP alone in 2010 (Sheil, et al., 2012). New ecotourism initiatives are underway for the Nyungwe National Park in Rwanda to promote the park's biodiversity, generate income for local communities and reduce threats to the park such as poaching and fires (DAI, 2012). Mount Kenya, Africa's second-highest peak, is a destination for climbing and viewing glaciers and wildlife, which include zebras, leopards and rhinos (UNESCO, 2014a). The Ethiopian Highlands, Bale Mountains and Simien Mountains are popular for trekking and mountain climbing (Tourism Ethiopia, 2014). The Aberdare Mountains attract over 50 000 tourists a year who come to see its diverse vegetation and animals (Ochego, 2003).

Sacred Places

In eastern Africa, the Rwenzori Mountains have more than 100 sacred sites in the form of trees, hills and rivers, among other natural features. Even some plants, such as *Euphorbia candelabrum*, an endemic plant of eastern Africa (USDA, 2008), are considered sacred because they are thought to be the homes of gods (FFI-UWA, 2012). The Bakonjo and Baamba people live in the foothills of the Rwenzori Mountains in Uganda. Their communities pray and make sacrifices at sacred mountain sites as a way of communicating with their ancestors, and they also pray for good crop harvests and against diseases and natural calamities (Stacey, 1996). Sacred sites are also visited for family planning, health and general blessings. Many of the sacred sites of the Rwenzoris may be developed to attract cultural tourism, but this could have implications for sustainable management (FFI-UWA, 2012).

There are 11 medieval churches in the mountainous northern Ethiopian region of Lalibela, found on both the north and south banks of the Jordan River. Carved out of monolithic blocks of rock, these churches are the focus of pilgrimages for people that belong to the Christian Coptic church (UNESCO, 2014c). Sacred forests are coveted on the summits and ridges of the Ethiopian Highlands, where they appear as islands of forests among cultivated land. These forests are used for sacrifices, primarily to ensure soil fertility, high yields and regular rainfall for the coming growing year, but also to ensure that women will give birth. In some of the highland sacred forests, such as the *Ewyrie*, firewood can be collected by women who have given birth and her neighbours or family can collect smaller pieces of wood. In other sacred forests like Negesse, however, cutting down trees or collecting wood is prohibited (Assefa & Bork, 2014).

Mount Kenya also holds great spiritual significance to local people. In fact, in the languages of the area's indigenous people, the word Kenya means "God's resting place". The doors of homes built by Gikuyu and Embu face the mountain, in respect for the belief that God chose to live on Mount Kenya when he came down from the sky. The Maasai also believe the mountain is the birth place of their ancestors (IUCN, 2010). The Karima Forest lies between Mount Kenya and the Aberdare range and is considered an *Ihoero*, a sacred natural site in the local language. Local people are fighting to protect the land, which is home to two shrines, as the forest has undergone much destruction and is threatened by the presence of exotic eucalyptus plantations (Adam, 2012).

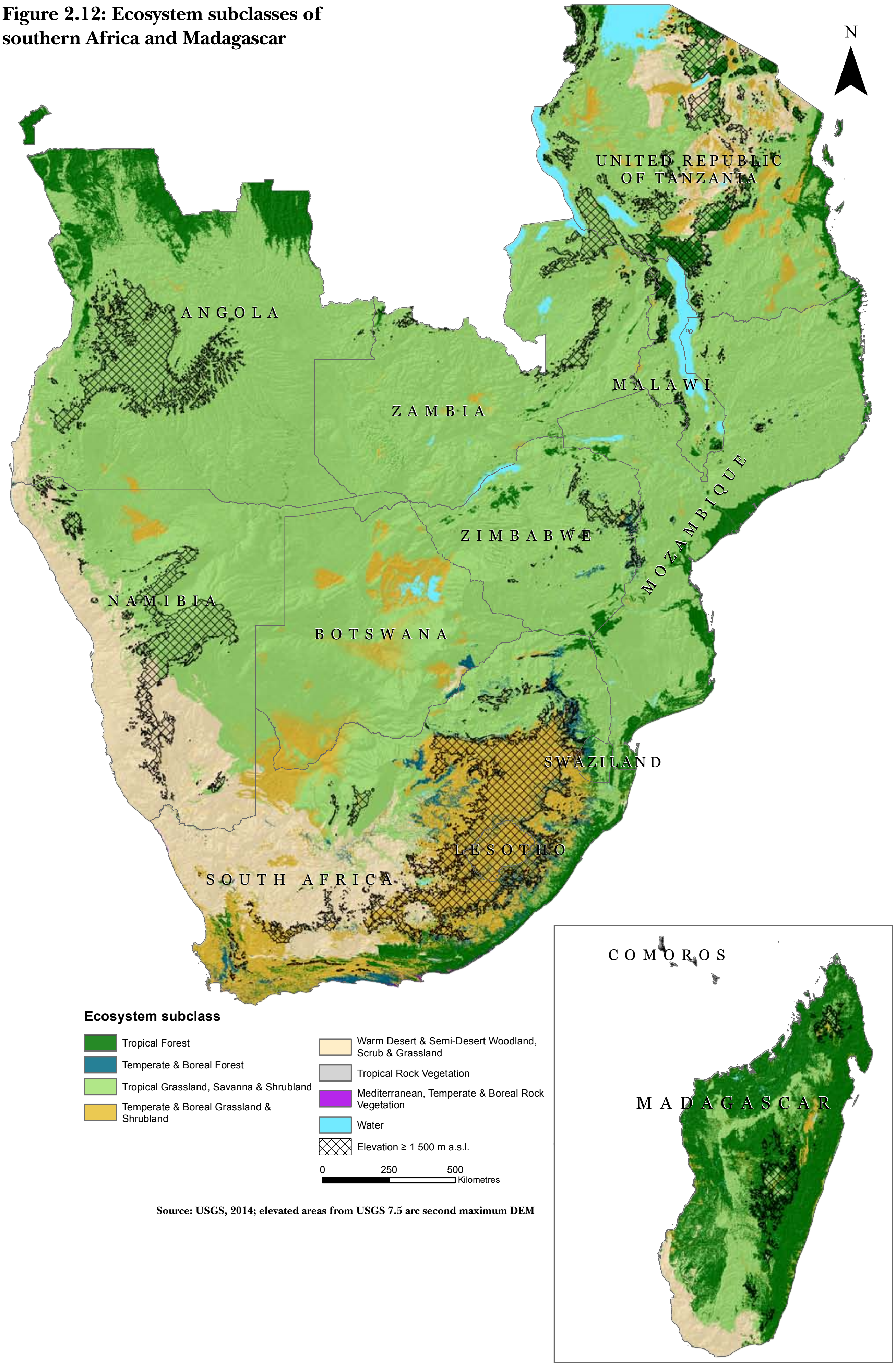
Church in Lalibela, Ethiopia

Pascal Rateau / Shutterstock

Southern Africa and Western Indian Ocean Islands

The mountainous and highland countries of Angola, Namibia, South Africa, Lesotho, Swaziland, Zimbabwe, Zambia, Malawi and the United Republic of Tanzania have ecosystems rich with resources. The southern Africa region and the West Indian Ocean islands, which include Madagascar, are primarily covered with tropical grasslands, savannas and shrublands as well as temperate and boreal grasslands and shrublands (Figure 2.12). These vegetated lands support agriculture and unique plant species. Madagascar is also heavily forested, harbouring many endemic species.

Figure 2.12: Ecosystem subclasses of southern Africa and Madagascar



Source: USGS, 2014; elevated areas from USGS 7.5 arc second maximum DEM

Water Towers

Plentiful rainfall in central Angola's highlands is an essential water source for the arid neighbouring countries of Namibia and Botswana (WFP/VAM Angola, 2005). Angola's Luanda Plateau gives rise to the Kwa-Kasaï, which provides an average of 10 000 m^3/s of water to the Congo River, making it the river's largest contributor (UNEP, 2011). The central highlands of Angola are also the source of the Cuanza and Cunene, which drain into the Atlantic Ocean (Cabral, Vasconcelos, Oom, & Sardinha, 2010) and the Cuito and Cubango Rivers that meet to become the Okavango River, which flows into the Okavango Delta in Botswana. The Okavango Delta is a valuable water source and site of biodiversity for the three countries that share its surrounding river basin: Namibia, Angola and Botswana (Green, Cosens, & Garmestani, 2013). Clean water can be difficult to access, however, due to the growing peri-urban and urban populations as a result of refugees fleeing conflict, putting additional pressure on clean water resources (USAID, 2010).

In the United Republic of Tanzania, Mount Kilimanjaro and the Eastern Arc Mountain range are essential to water systems in the southeastern region of the country and the Kipengere Mountains are important for the southwestern region. The montane cloud forests on Mount Kilimanjaro supply essential water to the densely populated areas below the summit, but forest loss is threatening this source (Schrumpf, Axmacher, Zech, & Lyaruu, 2011). The Eastern Arc Mountains provide 90 per cent of the United Republic of Tanzania's hydropower from the water that flows from its forests (CEPF, 2005). Cities with millions of residents, such as Dar es Salaam, also receive their water from these mountains (see Chapter 3). The headwaters of the Great Ruaha River, a major tributary of the Rufiji River, are in the Kipengere Mountains. The Great Ruaha River flows through the Usangu Plains, where it is a crucial water source for wildlife during the dry season, and ultimately joins the Little Ruaha River, to provide water to the Mtera hydropower plant (Kashaigili, 2008).

The Lufilian Arc area, another of Africa's important water towers, stretches across northern Zambia, southern DRC and dips slightly into eastern Angola. The highlands of Zambia are the starting point of the Zambezi River, which provides for over 40 million people in the eight countries that make up the Zambezi River Basin (Zambia, Angola, Zimbabwe, Mozambique, Malawi, Botswana, Namibia and the United Republic of Tanzania) (Kirchoff & Bulkey, 2008). The Zambezi River is a powerful river, carrying an annual average of 103 billion m^3 of water over the course of significant changes in elevation, creating a great potential for hydropower generation. The Mafinga Hills in northeastern Zambia give rise to the Luangwa River. The Luangwa River flows towards the southwest, eventually joining with the Zambezi River where the borders of Mozambique, Zimbabwe and Zambia meet (Gilvear, Winterbottom, & Sichingabula, 2000).

In Malawi, the natural landscape has several low mountains and mountain ranges that form important water catchments and habitats for a wide range of flora and fauna. Mount Mulanje, a massif feature in the southeastern part of the country, is the largest in Malawi and a major catchment acting as a source of water for an estimated population of over 700 000 people. It also supplies water to Lake Chinwa, supporting fisheries, hydropower generation and irrigated farming (Bagoora, 2012a).

The Cunene River begins in the Angola Highlands and forms the Ruacana falls on the Angola-Namibia border

Grobler du Preez / Shutterstock

Biodiversity

The rainforests of the Eastern Arc Mountains that run through the United Republic of Tanzania provide fuelwood, medicinal plants and naturally stabilize soils (Yanda & Munishi, 2007). The Usambara Mountains, part of the Eastern Arc Mountains, are recognized as one of 32 globally important "hot spots" for biodiversity (Bagoora, 2012a). There are at least 17 endemic tree species in the humid forests of these mountains (Hall, Gillespie, & Mwangoka, 2011) and a total of 800 endemic vascular plants (Burgess, et al., 2007b). Additionally, these mountains are home to many endemic vertebrate species. The Udzungwa Mountains alone have 96 species and an estimated eight vertebrate species are critically threatened with extinction (Burgess, et al., 2007b).

A centre of endemism is the Great Escarpment that runs north to south through central Namibia. In the northern part of the escarpment, there are 90 plants that are endemic to Namibia that can be found in the Brandberg Mountains and eight that are endemic to just the Brandbergs (Maggs, Craven & Kolberg, 1998).

The Cape Peninsula is part of the Fynbos biome and includes Table Mountain in South Africa; the area hosts 332 endemic species and 194 plant species found nowhere else on earth (Rebelo, Freitag, Cheney, & McGeoch, 2011). Table Mountain itself is home to 216 species from 63 families and 14 orders (Pryke & Samways, 2008).

Tsaratanana Integral Reserve is on the volcanic Tsaratanana massif in Madagascar and has a diversity of unique flora and fauna (MNP, 2014). The highest mountain on the island, Maromokotro, is protected within the reserve. Only researchers are allowed to enter the mountain region due to its IUCN classification, protecting its highly endemic and numerous endangered species from human impacts (Travel Madagascar, 2014). Afromontane forest patches also serve as sanctuaries for many bird species.

The Western Angola Endemic Bird Area, one of 19 in Africa, is home to 14 range-restricted species, of which the Angolan Highlands are central to the area (Ryan, et al., 2004).

Due to the relatively old age of the islands of Comoros and their isolation to the mainland, they are home to numerous endemic species of animals and plants, including 16 species of birds, two chiropterans, several *Phelsuma* day geckos, two *Furcifer* chameleons, other reptiles and amphibians and many invertebrates (Harris & Rocha, 2009).

Agriculture

Coffee is the main cash crop grown in the Mount Kilimanjaro region and crops such as maize and banana are common food crops. Smallholder farmers cultivate about 70 per cent of the area planted with coffee, with the remaining grown on plantations (Sarris, Savastano, & Christiansen, 2006). The Chagga indigenous people occupy the middle and lower slopes of Mount Kilimanjaro. Their basic livelihood is small-scale traditional crop farming (Bagoora, 2012a) typically in the form of small homegardens. These homegardens are complex agroforestry operations, intercropping bananas and coffee along with other plants and trees (Hemp, 2006).

The Huamo Province in the highlands of Angola has a long history as a productive agricultural sector, dating back to colonial times (Jul-Larsen & Bertelsen, 2011). Slash-and-burn cultivation is common practice and typical crops include maize, sorghum, beans and sweet potatoes (Bernabé, 2013). This age-old practice, also known as shifting cultivation, involves cutting trees and burning the vegetation to create an area in the forest to grow crops, which are fertilized by the ashes. Once the soil's fertility is exhausted, the farmer moves to another area to repeat the process, leaving the land to recuperate before returning. Most farming in Angola is smallholder agriculture with pigs or goats raised alongside crops and fruit trees (Jul-Larsen & Bertelsen, 2011). Crops are rain-reliant and harvesting only occurs once a year, creating vulnerability to food security issues when there is severe drought (Bernabé, 2013). The 2011-2012 crop season was the worst since 1978 due to a significant rainfall deficit affecting more than 350 000 households across 10 provinces of the country (Bernabé, 2013).

Only 5 per cent of Madagascar's land is suitable for cultivation since much of it is mountainous (De Laulanié, 2011), but agriculture accounts for almost 30 per cent of the country's GDP (World Bank, 2014). The agri-economy is mostly skewed towards rice production, which is grown in the highlands with other food crops, and lacks overall crop diversity (Vololona, Kyotalimye, Thomas, & Waithaka, 2013). Before the early 1980s, growing rice at altitudes around 1 500 m was an unprecedented practice, but has proven to be successful for intensive rice production (De Laulanié, 2011).

The montane grasslands of Zambia, mostly above an altitude of 1 400 m, are good for growing various types of herbs (Aregheore, 2009a).

Forests and Agroforestry

On the South African plateau, agroforestry has helped farmers cope with problems of declining soil fertility and crop yields, and planting *Sesbania sesban*, a woody shrub, in fallows alongside maize crops is helping to conserve the miombo woodlands on the South African plateau (CGIAR, 1996). Miombo refers to southern Africa's savanna woodlands, with characteristic tree and plant species that grow on nutrient poor and acidic soils (Ryan, 2013). Interplanting S*esbania sesban* with other crops like corn and beans also improves crop yields. Furthermore, this shrub provides fuelwood and its leaves make rich compost (Tropical Forages, n.d.).

Cardamom agroforestry, a practice that involves thinning the canopy cover and completely clearing the lower area of a formerly natural forest to plant the crop, has been practiced in the East Usambaras Mountains of the United Republic of Tanzania for 50 years (Hall, Gillespie, & Mwangoka, 2011). The small cardamom (*Elettaria cardamom*) crop is a valuable source of income for the local East Usambaras populations. On the other hand, it also threatens the forest's endemic species since the practice is altering the forest's composition (Reyes, Luukkanen, & Quiroz, 2006).

The extremely biodiverse miombo woodlands cover most of the central Angolan plateau, providing various ecosystem services to the local people such as fuel and cattle feed. The miombo are vulnerable to widespread clearing, which has continued at various rates near populated places since the early-1990s (Cabral, Vasconcelos, Oom, & Sardinha, 2010).


Measuring carbon, United Republic of Tanzania

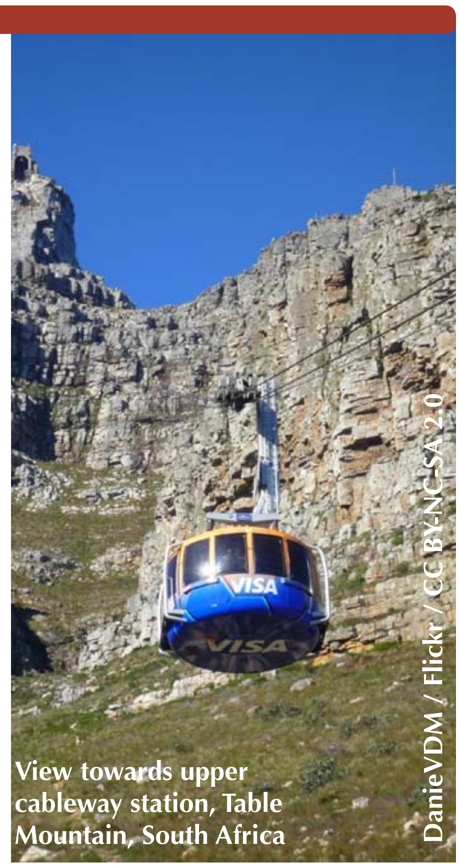
Carbon Sequestration

As one of the nine countries selected for the UN-REDD Quick Start pilot programme, the United Republic of Tanzania was one of the first seven to have entered the implementation phase (UN-REDD, 2011). Preparing for participation in the REDD programme involved activities such as capacity building and the development of a national strategy. The Eastern Arc Mountains have been identified as a focal point for studying carbon storage (Fisher, Swetnam, Burgess, McKenzie & Willcock, 2012).

Tourism

The beauty and diversity of the southern African mountain ranges is the source of significant tourism expenditures. Tourism in the United Republic of Tanzania brings in approximately US$1.3 billion per year, of which Mount Kilimanjaro generates $50 million (World Bank, 2013). Mount Kilimanjaro attracts trekkers and intense mountain climbers to its glaciated summit and thousands of local people benefit from the work generated by tourism (World Bank, 2013). In South Africa, Table Mountain and the Drakensberg Mountains are common tourist destinations. Named one of the New Seven Wonders of Nature, Table Mountain offers a diverse terrain for walkers and hikers in close proximity to busy Cape Town (SANP, 2014). The cliffs, waterfalls and forests of the Drakensberg Mountains attract ice climbers and white-water rafters (Tourism KZN, 2014) bringing in tourists from all across the globe.

With its dramatic peaks, waterfalls, and unusual landscape, the Andringitra National Park in Madagascar has been called Madagascar's most scenic national park. Andringitra is characterized by high mountains (the peak is 2 658 m high), deep valleys and ridges.



View towards upper cableway station, Table Mountain, South Africa

Sacred Places

In South Africa, the sandstone that undercuts the overlaying basaltic lava of the Drakensberg contains caves that serve as a canvas for bushman paintings (EECRG, 2013). The San people have a long history in these mountains and have produced thousands of rock-art paintings (Crowson, 2011). Also, the Gcaleka people regard the Amatole Mountains and its forests in the Eastern Cape as sacred grounds (Colvin, et al., 2013). The Holy Circle of Karamats in South Africa's Table Mountain National Park is sacred to the Sunnis of the Islamic faith (Mallarach & Papayannis, 2010).

Nyanga communities in Zimbabwe consider Mount Muozi as sacred, with varying local perceptions of meaning attributed to it. Located among the Nyaunguzi hills west of Mount Muozi, Nyabinga is considered sacred because traditional ceremonies take place there. The Hata people percieve Chitsanza hill as sacred and an ancient ruin on the hill is used for rain-making ceremonies. The VaNyama people regard Mount Muozi as sacred because it is where they initially established themselves (Mupira, 2003). According to the Shona people of northern Zimbabwe, some entire mountain ranges are sacred, along with forests and rivers, because these landscapes are linked to rain and land fertility. Their sacred beliefs about these ecosystems may contribute to their protection; deforestation rates in the Shona sacred forests are approximately 50 per cent less than in other forests and more than 100 native plants thrive there (Byers, Cunliffe, & Hudak, 2001).

On Madagascar, Andringitra Mountain has several natural features that are considered sacred. The Velontsoa, Tsaranoro and Ambohimana forests, lakes and marshes of Amboromena and waterfalls such as Riambavy and Riandahy are protected by spiritual beliefs and powerful taboos (Rabetaliana, Randriambololona, & Schachenmann, 1999). Located near Andringitra, the clouded peaks of Ambondrombe Mountain are believed to be the resting place for the souls of the Malagasy after death (Schachenmann, 2006).

Throughout Malawi, forests on almost all significant hills and mountains are associated with a particular spirit of the dead or rain deity. Because they have been protected from farming and fire for many generations, many are important ecological sites, with relatively intact forests and high biodiversity (Morris, 2009). Such sites can be important for ecological, anthropological and archaeological research (UNESCO, 2011).

Hundreds of sacred forest groves are also scattered among the densely populated regions of the Pare range in the Eastern Arc Mountains, at altitudes from 1 219 to 1 615 m. These mountains stretch from southeast Kenya to southern United Republic of Tanzania and are considered to be a biodiversity hotspot because of their high levels of both biodiversity and threats. The forest groves are sacred because they contain the graves of ancestors of the ruling clan and are sites of cultural and religious ceremonies. Community management rules govern the sacred groves in the Pare range, stipulating that no vegetation can be cut and the trees must be indigenous. The surrounding forest was once cut but was subsequently replanted with exotic trees such as coffee and eucalyptus (Sheridan, 2009).

Sunrise on Andringitra Mountain, Madagascar

Payment for Ecosystem Goods and Services (PES)

The preceding sections of this chapter defined and described the significance of the ecosystem goods and services mountains perform as water towers, places of high biodiversity, agricultural land for growing cash crops, livestock and small-scale subsistence farming, and as tourism destinations and sacred places.

These values need to be protected to ensure a sustainable future for both the environment and the human population it supports. Ecological values are rarely expressed in market prices, so policy interventions are needed to protect these indirect and non-tangible values (Bagoora, 2012b). In developed or industrialized countries, incentives or subsidies often exist to financially compensate mountain communities for providing ecosystem services such as drinking water. In less developed areas where these types of financing mechanisms may not be available, payment for ecosystem goods and services (PES) programmes are proving to be a promising alternative (FAO, 2011b). Such arrangements refer to a way in which those who benefit from ecosystem goods and services pay or otherwise compensate those who are protecting them (Box 2.7).

In many of Africa's mountain areas, ecological functions and services are increasingly recognized and valued, and there appears to be a shift away from economic production, such as forestry for timber. Environmental services, such as carbon sequestration and providing water, scenic resources and cultural heritage values are increasing in importance, especially where these values outweigh the direct economic value of the ecosystem's extractable products (Bagoora, 2012b). Where farmers or smallholders in Africa's mountains are actively protecting these services, there may be the potential for them to be compensated. For example, the World Agroforestry Centre (ICRAF) has recently initiated a programme called Pro-poor Rewards for Environmental Services in Africa (PRESA), which aims to improve smallholder livelihoods in Africa's Eastern and Western highlands by enhancing fair and effective environmental service rewards, or PES agreements (ICRAF, 2014).

Box 2.7: Payment for Ecosystem Services (PES)

The valuable services that ecosystems provide are often compromised by poor land management, which decreases or eliminates the value of the service. Since most landowners are not financially compensated for these services, they often make decisions that are not in the land's best interest. For example, when a person living in a mountain forests saves the trees that grow on land with steep slopes, the catchment is protected, as well as the water that supplies communities lower down the mountain. Additionally, soil erosion and the potential for a landslide to occur is prevented. But unless the mountain forest-dweller is compensated for this act, it is often more profitable for them to cut the trees for fuelwood or timber or to make room for agriculture. Thus, the dweller will only intervene to improve the land after the damage has been done, at which point they may engage in remedial measures, such as replanting after a flood or landslide. Payment for Ecosystem Services (PES) has become an attractive platform for addressing this problem by compensating the provider from the revenues made by charging those who benefit, while conserving land that is worth conserving. For this system to be effective, three principles must be heeded:

(1) Payments by users contribute to base payments for providers,

(2) Sound science needs to justify the service the land provides, and

(3) Mechanisms of the programme need to suit local conditions and needs.

Source: World Bank, 2011

South Africa

In South Africa, the true benefits of PES are being reaped in the Maloti-Drakensberg Mountains for improving conditions of the upper Thukela and Umzimvubu Rivers. The PES aims to increase the rivers' base flow, reduce storm-water runoff and sedimentation and increase carbon sequestration in the

Umzimvubu River is in the Eastern Cape, South Africa surrounding grasslands. Implementing this PES resulted in a reduction of 6.2 million m^3 of sediment per year between the two rivers, the sequestration of 472 070 tonnes of carbon per year and additional water sales of nearly US$3 (R28.18) per hectare, per year (van Zyl, 2009).

United Republic of Tanzania

In the United Republic of Tanzania, at least two PES programmes for watershed services (PWS) are being implemented — one in the Uluguru Mountains for the Ruvu River watershed and one in the East Usambaras Mountains for the Zigi River watershed. The Ruvu River watershed is integral to providing drinking water supplies for Dar es Salaam, United Republic of Tanzania's largest city, with over 4 million people, and the Zigi River watershed provides water for nearly 300 000 people, supplied by the Tanga Urban Water Supply and Sewerage Authority (Tanga UWASA) (Tanga UWASA; NBS, 2013; Kwayu, Sallu, & Paavola, 2014; FAO, 2013a; Tanga UWASA, 2010). Both watersheds are experiencing sedimentation and soil erosion problems that are financially impacting water users. Sedimentation decreases the clarity and quality of water when soil makes its way into the streams and rivers. This has a financial impact since water treatment plants spend more money on purifying the water, which can increase its price, and environmentally, it can alter the natural seasonal flow of the waterways (Kwayu, Sallu, & Paavola, 2014).


meaduva / Flickr / CC BY-ND

Pineapple farmer in Kibungo in the Uluguru Mountains, United Republic of Tanzania

The PWS in the Usambaras Mountains is expected to operate through 2015 in three phases that will establish baseline conditions, focus on restoring the Zigi River basin and create a mechanism for equitable payments between buyers and sellers in the watershed with local stakeholder management (FAO, 2013a). Ecosystem restoration will focus on reversing the impact of sedimentation on the Zigi River as a result of reduced vegetation cover upstream due to illegal mining, the impact on crops within 25 m of the riparian zone and conversion of forest to agricultural land (FAO, 2013a). Increased sedimentation in the river has decreased water quality in the basin and reduced reservoir capacity, compromising a crucial water supply for the City of Tanga; the city relies on this catchment for 90 per cent of its water supply (FAO, 2013a). The buyers in this PES system are the recipients of water and the sellers are those upstream who are expected to change their land use practices (for example, switching to agroforestry, terrace farming or strip cropping) to alleviate the sedimentation issues (Tresierra, 2013). Payments for


meaduva / Flickr / CC BY-ND

A rural farming family in the Uluguru Mountains of the United Republic of Tanzania

A cold stream at sunset, Maloti Mountains, Lesotho

Vincent Mounier / Shutterstock

services will come once land use changes begin to take place and the value of the services can be properly determined.

A similar issue is taking place in the neighbouring Uluguru Mountains in which farmers upstream on the Ruvu River are impacting the quality and availability of water for the residents of Dar es Salaam. The amount of cultivated land in the Uluguru Mountains doubled between 1995 and 2010 and increased 300 per cent in the Kibungo area (Lopa & Mwanyoka, 2010). The PWS programme being implemented in the Kibungo Juu Ward focuses on promoting sustainable land management practices to decrease the likelihood of soil erosion. It was found that those with larger plots of land were more inclined to participate in the programme and favourable land use changes included converting to agroforestry and reforestation, since terracing takes a long time to build and regain soil fertility, potentially compromising crop yields in the short term, and in turn, food security (Kwayu, Sallu, & Paavola, 2014). More than 300 000 trees, including *Grevillea robusta, Markhamia lutea* and fruit trees, totalling 370.11 ha of land have been planted under the programme in support of agroforestry and reforestation (weADAPT, 2012). *Grevillea robusta* was planted to ensure soil health through nitrogen fixation and fruit trees such as mango and avocado were planted to promote food security (Lopa & Mwanyoka, 2010). Because of the programme's improved agriculture practices, agricultural production increased three times, enabling households to eat an average of three meals a day compared to one-and-a-half meals before the project started in 2008 (weADAPT, 2012); it also allows surplus crop production to be taken to market, earning upwards of US$7 000 (Lopa, 2011). By 2009, 134 farmers and 3 institutions in 4 villages in Kibungo Juu Ward had been compensated with TSh 2.2 million (approximately US$1 600 at 2009 rates) through coordination between CARE-World Wildlife Fund and the Dar es Salaam Water Supply and Sewerage Corporation (DAWASCO) (Lopa & Mwanyoka, 2010). Although payments have been made, however, the infrastructure to ensure consistent payments is still lacking (weADAPT, 2012).

Conclusion

This chapter aimed to make abundantly clear how important mountains, their resources and ecological functions are to African wildlife, local livelihoods and national economies. Their forests need to be protected to ensure they can continue to act as water towers for the millions of people and important industries that use the water issuing from them. At the same time, mountain people need to earn their living in their local environments, gain support in using forest resources sustainably, build capacity to restore land degraded by over-use and prepare for the impacts of a changing climate. There is also a fine balance to be found between opening routes for the lucrative tourist industry in isolated mountain areas and ensuring the human footprint of their activities do not ruin the very environments and cultures they come to enjoy. Climate change will surely have an impact on the ecological services mountains provide and African countries will need to work together to protect them for present and future generations. The next chapter describes the human and natural forces that can change environmental conditions in mountain regions; some of these are also likely to be affected by global climate change with impacts on humans and natural resources.

References

ACF. (2011). Virunga National Park: A Resume of Success 2008 - 2012. Africa Conservation Fund (UK).

Adam, H. (2012). Recognising Sacred Natural Sites and Territories in Kenya: An analysis of how the Kenyan Constitution, national and international laws can support the recognition of sacred natural sites and their community governance systems. Institute for Culture and Ecology (Kenya), African Biodiversity Network, and the Gaia Foundation.

AFDB, OECDdev, UNECA, & UNDP. (2013). African Economic Outlook. African Development Bank Group. Retrieved March 10, 2014, from http://www.africaneconomicoutlook.org/en/countries/west-africa/cape-verde/

AIT. (2002). Small and Medium scale Industries in Asia: Energy and Environment, Tea Sector. Thailand: Asian Institute of Technology.

Ait Kadi, M., & Benoit, G. (2012). Agriculture 2030: A future for Morocco. The Futures of Agriculture.

Akinyemi, F. (2008). Value of Geographic Information Systems for Rwanda: Overview. Disaster Management Workshop. Kigali: National University of Rwanda.

ANH. (2009a). Aïr and Ténéré Natural Reserves - Niger. Retrieved January 17, 2014, from African Natural Hertiage: http://www.africannaturalheritage.org/Air-and-Tenere-Natural-Reserves-Niger.html

ANH. (2009b). Rwenzori National Park. Retrieved February 24, 2014, from African Natural Hertiage: http://www.africannaturalheritage.org/Rwenzori-Mountains-National-Park-Uganda/

Aregheore, E. (2009a). Country Pasture/Forage Resource Profiles: Zambia. Rome: Food and Agriculture Organization of the United Nations.

Aregheore, E. (2009b). Country Pasture/Forage Resource Profiles: Nigeria. Rome: Food and Agriculture Organization of the United Nations.

Ariza, C., Maselli, D., & Kohler, T. (2013). Mountains: Our Life, Our Future. Perspectives on Sustainable Mountain Development from Rio 1992 to Rio 2012 and Beyond (p. 90). Bern, Switzerland: Swiss Agency for Development and Cooperation (SDC), Centre for Development and Environment (CDE).

Arumugam, R., Wagner, A. & Mills, G. 2008. Hyaena hyaena: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. Retrieved May 1, 2014, from International Union for Conservation of Nature and Natural Resources (IUCN): http://www.iucnredlist.org/details/10274/0.

Asaah, E., Tchoundjeu, Z., Leakey, R., Takousting, B., Njong, J., & Edang, I. (2011). Trees, agroforestry and multifunctional agriculture in Cameroon. International Journal of Agricultural Sustainability, 9(1), 110 - 119.

Assefa, E., & Bork, H. (2014). Deforestation and Forest Management in Southern Ethiopia: Investigations in the Chencha and Arbaminch Areas. Environmental Management, 53, 284-299.

AU-DREA, 2010. Policy Framework for Pastoralism in Africa: Securing, Protecting and Improving the Lives, Livelihoods and Rights of Pastoralist Communities. Addis Ababa: African Union (AU) Department of Rural Economy and Agriculture (DREA).

Bacon, C. (2005). Confronting the coffee crisis: Can Fair Trade, organic and specialty coffees reduce small-scale farmer vulnerability in northern Nicaragua? World Development, 33(3), 497-511.

Bagoora, F. K. (2012a). Potential and Climate Change Vulnerability, Impacts and Adaptation Options In African Mountains. A paper presented at the International Conference of Mountain Countries Climate Change in Kathmandu, Nepal 5-6 April. Kampala: Nature-RIDD Uganda.

Bagoora, F. K. (2012b). Report on Progress In Implementation of Agenda 21 Commitments on Sustainable Mountain Development In Africa. Nairobi: United Nations Environment Programme.

Barnard, P. (ed.). (1998). Biological Diversity in Namibia: Namibian National Biodiversity Task Force. Windhoek: Directorate of Environmental Affairs.

Barron, J., Fox, P., & Biao Koudeoukpo, J. (2007). Water and Poverty Linkages in Africa: Senegal Case Study. Stockholm: Stockholm Environment Institute.

Barrow, C., & Hicham, H. (2000). Two complimentary and integrated land uses of the western High Atlas Mountains, Morocco: the potential for sustainable rural livelihoods. Applied Geography, 20, 369–394.

Bernabé, B. (2013). Coverage Assessment: Huambo Province, Angola. Huambo: World Vision, Coverage Monitoring Network.

Berrahmouni, N., & Regato, P. (2014). Northern Africa: Algeria and Morocco and Tunisia. Retrieved January 26, 2014, from World Wildlife Fund: http://worldwildlife.org/ecoregions/pa0513

BERSMP. (2009). Diminishing Grazing and Grassland Resources: Lessons from Livestock Management in the Bale Mountains. Addis Ababa: FARM-Africa and SOS Sahel Ethiopia Participatory Natural Resources Management Unit.

Bishaw, B., & Abdelkadir, A. (2003). Agroforestry and Community Forestry for Rehabilitation of Degraded Watersheds on the Ethiopian Highlands. International Symposium on Contemporary Development Issues in Ethiopia, (pp. 1 - 22). Addis Ababa.

BLI. (2014a). Important Bird Areas factsheet: Mount Kenya. Retrieved March 17, 2014, from BirdLife International: http://www.birdlife.org/datazone/sitefactsheet.php?id=6395

BLI. (2014b). Important Bird Areas factsheet: Ruwenzori (Rwenzori) Mountains National Park. Retrieved February 24, 2014, from BirdLife International: http://www.birdlife.org/datazone/sitefactsheet.php?id=7045

BMNP. (2014). People of Bale: Culture & History. Retrieved March 7, 2014, from Bale Mountains National Park: http://balemountains.org/the-park/people-of-bale/

Boudhar, A., Duchemin, B., Hanich, L., Jarlan, L., Chaponniere, A., Maisongrande, P., . . . Chehbouni, A. (2010). Long-term analysis of snow-covered area in the Moroccan High Atlas through remote sensing. International Journal of Applied Earth Observation and Geoinformation, 12S, S109 - S115.

Boudhar, A., Hanich, L., Boulet, G., Duchemin, B., Berjamy, B., & Chehbouni, A. (2009). Evaluation of the Snowmelt Runoff Model in the Moroccan High Atlas Mountains using two snow-cover estimates. Hydrological Sciences Journal, 54(6), 1094 - 1113.

Bousta, D., Boukhira, S., Aafi, A., Ghanmi, M., & el Mansouri, L. (2014). Ethnopharmacological Study of anti-diabetic medicinal plants used in the Middle-Atlas region of Morocco (Sefrou region). International Journal of Pharma Research and Health Sciences, 2(1), 75-79.

Bradshaw Foundation. (2011). Dabous Giraffes in Niger. Retrieved February 24, 2014, from Bradshaw Foundation: http://www.bradshawfoundation.com/journey/giraffe2.html

Brotto, L., Pettenella, D., Damiani, M., & Zuliani, F. (2011). Project Design Document Kitshanga Reforestation Project North Kivu (DRC). Italy: Department of Land, Environment, Agriculture and Forestry (LEAF) - University of Padova and ONG Association Cooperazione e Solidarietà (ACS).

Burgess, N., Balmford, A., Corderio, N., Fjeldsa, J., Kuper, W., Rahbek, C., . . . Williams, P. (2007a). Correlations among species distributions, human density and human infrastructure across the high biodiversity tropical mountains of Africa. Biological Conservation, 134, 164 - 177.

Burgess, N., Butynski, T., Cardeiro, N., Doggart, N., Fjeldsa, J., Howell, K., . . . Stuart, S. (2007b). The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. Biological Conservation, 134, 209 - 231.

Bussman, R. (2006). Vegetation zonation and nomenclature of African Mountains - An overview. Lyonia, 11(1), 41 - 66.

Byers, B., Cunliffe, R., & Hudak, A. (2001). Linking the conservation of culture and nature: a case study of sacred forests in Zimbabwe. Human Ecology, 29, 187-218.

Cabral, A., Vasconcelos, M., Oom, D., & Sardinha, R. (2010). Spatial dynamics and quantification of deforestation in the central-plateau woodlands of Angola (1990-2009). Applied Geography, 31, 1185-1193.

CEPF. (2005). Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya Briefing Book. Cape Town: Critical Ecosystem Partnership Fund.

CGIAR. (1996). Agroforestry. Retrieved January 15, 2014, from 25 Years of Food and Agriculture Improvement in Developing Countries: http://www.worldbank.org/html/cgiar/25years/agro.html

CI. (2014). The Biodiversity Hotspots. Retrieved May 5, 2014, from Conservation International (CI): http://www.cepf.net/resources/hotspots/africa/Pages/default.aspx

Clay, J. (2004). World Agriculture and the Environment. Washington, D.C.: Island Press.

Colvin, C., Nobula, S., Haines, I., Nel, J., Le Maitre, D., & Smith, J. (2013). An introduction to South Africa's Water Source Areas. Cape Town: World Wildlife Fund - South Africa.

CREE. (2014). Snail Farming - Mount Cameroon. Retrieved February 14, 2014, from Centre for Rural Empowerment and the Environment: http://www.conservationforpeople.org/snail-farming-mount-cameroon/

Crowson, J. (2011). Maloti Drakensberg Transfrontier Park Joint Management: Sethlabathebe National Park (Lesotho) and the uKhahlamba Drakensberg Park World Heritage Site (South Africa). United States Department of Agriculture (USDA) Forest Service.

Culmsee, H. (2005). Vegetation and pastoral use in the Western High Atlas Mountains (Morocco): An assessment of sustainability from the geobotanical perspective. (M. AÏT Hamza, & H. POPP, Eds.) Colloques et Séminaires, 67 - 80.

DAI. (2012). Strengthening Sustainable Ecotourism in and around Nyungwe National Park (SSENNP). Retrieved April 4, 2014, from DAI: Our Work: http://dai.com/our-work/projects/rwanda%E2%80%94strengthening-sustainable-ecotourism-and-around-nyungwe-national-park

De Laulanié, H. (2011). Intensive Rice Farming in Madagascar. Tropicultura, 29(3), 183-187.

della Dora, V. (2009). Taking Sacred Space out of Place: From Mount Sinai to Mount Getty Through Travelling Icons. Mobilities, 4(2), 225-248. Retrieved from 10.1080/17450100902906673

DGA-MAAP. (2004). Livro Branco sobre o Estado do Ambiente em Cabo Verde. Direção Geral do Ambiente - Ministério do Ambiente: Agricultura e Pescas.

Djema, A., & Messaoudene, M. (2009). The Algerian Forest: Current Situation and Prospects. In M. Palahi, Y. Birot, F. Bravo, & E. Gorriz (Ed.), EFI Proceedings No. 57 Modelling, Valuing and Managing Mediterranean Forest Ecosystems for Non-Timber Goods and Services (pp. 17-27). Joensuu: European Forest Institute.

Dorosh, P., Alemu, G., de Brauw, A., Malek, M., Mueller, V., Schmidt, E., . . . Thurlow, J. (2011). The Rural-Urban Transformation in Ethiopia. Addis Ababa: International Food Policy Research Institute.

Draper, I., Albertos, B., Garilleti, R., Lara, F., & Mazimpaka, V. (2007). Contribution to the biodiversity conservation in Morocco (North Africa): important areas for epiphytic bryophytes. Cryptogamie, Bryologie, 28(3), 211 - 236.

EC. (2009). Ecosystem Goods and Services. European Commission.

EDRI. (2009). Ethiopia Input Output Table and Social Accounting Matrix. Addis Ababa: Ethiopian Development Research Institute.

EECRG. (2013). The Drakensberg Mountains of South Africa and Lesotho. Retrieved January 23, 2014, from Ecological and Environmental Change Research Group: http://www.eecrg.uib.no/projects/AGS_BotanyExp/Drakensberg/Drakensberg.htm

ESRI. (2011a). Grounds for Change. San Diego, California, USA. Retrieved March 28, 2014, from http://video.esri.com/watch/471/grounds-for-change

ESRI. (2011b). Grounds for Change: GIS Plays Supporting Role in Improving Rwanda's Coffee and its Growers' Lives. ArcNews. Retrieved March 28, 2014, from http://www.esri.com/news/arcwatch/0811/user-conference.html

FAO. (2002). Sustainable Rural Development and Food Security: The Role of Mountain Development in Africa. Twenty-second Regional Conference for Africa. Cairo: Food and Agriculture Organization of the United Nations. Retrieved January 23, 2014, from http://www.fao.org/docrep/meeting/004/y6056e.htm#2

FAO. (2003). Forestry Outlook Study for Africa: African Forests, A View to 2020. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2006). Country Pasture/Forage Resource Profiles: Niger. Retrieved June 25, 2014 from, Food and Agriculture Organization of the United Nations (FAO): http://www.fao.org/ag/AGP/AGPC/doc/counprof/niger/niger.htm

FAO. (2010). Global Forest Resources Assessment 2010. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2011a). Mountain Forests in a Changing World Realizing Values, Addressing Challenges. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2011b). Why Invest in Sustainable Mountain Development. Rome: Food and Agricultural Organization of the United Nations.

FAO. (2012a). Foreign Agricultural Investment Country Profile. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2012b). MAFAP-SPAAA Analysis of Incentives and Disincentives for Tea in Uganda. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2013a). Equitable payments for watershed services: financing conservation and development in Tanzania. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2013b). Mountain Farming is Family Farming: A contribution from mountain areas to the International Year of Family Farming 2014. Rome: Food and Agriculture Organization of the United Nations, the Centre for Development and Environment of the University of Bern, the Centre for Development Research of the University of Natural Resources and Life Sciences, Vienna.

FAOSTAT. (2014). Tea, Production Quantity. Retrieved May 1, 2014, from FAOSTAT: http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QC/E

FCP. (2014). Kishanga Reforestation Project. Retrieved January 29, 2014, from Forest Carbon Portal: Tracking Terrestrial Carbon: http://www.forestcarbonportal.com/project/kitshanga-reforestation-project

Fernando, L. (2011). Beverage Crops: Tea Cultivation. Geneva: International Labour Organization. Retrieved February 26, 2014, from http://www.ilo.org/oshenc/part-x/agriculture-and-natural-resources-based-industries/beverage-crops/item/556-tea-cultivation

FEWS NET. (2011). Livelihoods Zoning "Plus" Activity in Niger. Retrieved June 25, 2014 from, the Famine Early Warning Systems Network (FEWS NET): http://www.fews.net/sites/default/files/documents/reports/Niger%20Livelihoods%20zoning%20report%20Final.pdf

Fisher, B., Swetnam, R., Burgess, N., McKenzie, E., Willcock, S. (2012). InVEST Scenarios Case Study: Eastern Arc Mountains Tanzania. World Wildlife Fund.

FFI-UWA. (2012). Current Status, Ownership and Management of Sacred Sites in the Rwenzori Mountains. Kampala: Fauna & Flora International, Uganda Wildlife Authority.

Forboseh, P., Eno-Nku, M., & Sunderland, T. (2007). Priority setting for conservation in south-west Cameroon based on large mammal surveys. Oryx, 41(2).

Fotso, R., Dowsett-Lemaire, F., Dowsett, R., Club, C. O., Scholte, P., Languy, M.,& Bowden, C. (2007). Important bird areas in Africa and associated island. Cameroon Birdlife International.

Getahun, A. (2013). Ecoregion Description: Ethiopian Highlands. Retrieved March 17, 2014, from Freshwater Ecoregions of the World: http://www.feow.org/ecoregion_details.php?eco=525

Getahun, K., Van Rompaey, A., Van Turnhout, P., & Poesen, J. (2013). Factors controlling patterns of deforestation in moist evergreen Afromontane forests of Southwest Ethiopia. Forest Ecology and Management, 304, 171-181.

Gilvear, D., Winterbottom, S., & Sichingabula, H. (2000). Character of Channel Platform Change and Meander Development: Luangwa River, Zambia. Earth Surface Processes and Landforms, 25, 421-436.

Global Post. (2011, April 25). Coffee prices highest in 34 years. Retrieved February 25, 2014, from CBS News: http://www.cbsnews.com/news/coffee-prices-highest-in-34-years/

Gorsevski, V., Kasischke, E., Dempewolf, J., Loboda, T., & Grossman, F. (2012). Analysis of the Impacts of armed conflict on the Eastern Afromontane forest region on the South Sudan - Uganda border using multitemporal Landsat imagery. Remote Sensing of Environment, 118, 10 - 20.

GoU. (2011). REDD Readiness Preparation Proposal for Uganda. Uganda: Government of Uganda.

Gove, A., Hylander, K., Nemomisa, S., & Shimelis, A. (2008). Ethiopian coffee cultivation – Implications for bird conservation and environmental certification. Conservation Letters, 1(5), 208-216.

Grainger, M., & Geary, K. (2011). The New Forests Company and its Uganda plantations. Oxford: Oxfam International.

Green, O., Cosens, B., & Garmestani, A. (2013). Resilience in Transboundary Water Governance: the Okavango River Basin. Ecology and Society, 18(2). doi:10.5751/ES-05453-180223

Grêt-Regamey, A., Brunner, S., & Kienast, F. (2012). Mountain Ecosystem Services: Who Cares? Mountain Research and Development, 32, S23 - S34.

Hall, J., Gillespie, T., & Mwangoka, M. (2011). Comparision of Agroforests and Protected Forests in the East Usambara Mountains, Tanzania. Environmental Management, 48(2), 237 - 247.

Hammi, S., Simonneaux, V., Cordier, J., Genin, D., Alifriqui, M., Montes, N., & Auclair, L. (2010). Can traditional forest management buffer forest depletion? Dynamics of Moroccan High Atlas Mountain forests using remote sensing and vegetation analysis. Forest Ecology and Management, 260, 1861 - 1872.

Harris, D. J., & Rocha, S. (2009). Comoros. In R. Gillesp, & D. Clague (Eds.), Encyclopedia of Islands (pp. 612–619). Berkeley: University of California Press.

Heilweil, V., Earle, J., Cederberg, J., Messer, M., Jorgensen, B., & Verstraeten, I. (2006). Evaluation of Baseline Ground-Water Conditions in the Mosteiros, Ribeira Paul, and Ribeira Fajã Basins, Republic of Cape Verde, West Africa. Reston: United States Geological Survey.

Hemp, A. (2006). The banana forests of Kilimanjaro: biodiversity and conservation of the Chagga homegardens. Forest Diversity and Management: Topics in Biodiversity and Conservation. 2, 133-155.

Hillers, A., Loua, N.-S., & Rödel, M.-O. (2008). A preliminary assessment of the amphibians of the Fouta Djallon, Guinea, West Africa. Salamandra, 44(2), 113-122.

Hindorf, H., & Omondi, C. (2011). A review of three major fungal diseases of Coffea arabica L. in the rainforests of Ethiopia and progress in breeding for resistance in Kenya. Journal of Advanced Research, 2, 109-120.

Hitimana, J., Mugiraneza, T., & Murasira, A. (2012). Use of GIS and SDI in Promoting Coffee Quality in Maraba Sector, South Province of Rwanda. Butare: National University of Rwanda.

Hylander, K., Nemomissa, S., Delrue, J., & Enkosa, W. (2013). Effects of Coffee Management on Deforestation Rates and Forest Integrity. Conservation Biology, 27(5), 1031-1040.

ICCN. (2009). Village Briquette Factories: Energy and Employment for Eastern Congo. Goma: Institut Congolais pour la Conservation de la Nature.

ICO. (2012). Trade Statistics. Retrieved February 26, 2014, from International Coffee Organization: http://www.ico.org/trade_statistics.asp?section=Statistics

ICO. (2014). Exporting Countries: Total Production. Retrieved March 17, 2014, from International Coffee Organization: http://www.ico.org/prices/po.htm

ICRAF. (2014). About PRESA: Pro poor Rewards for Environmental Services in Africa. Retrieved February 2, 2014, from World Agroforestry Centre (ICRAF): http://presa.worldagroforestry.org/?page_id=3820

IFAD. (2005). The traditional export crops sub-sector. Retrieved February 18, 2014, from Smallholder Cash and Export Crop Development Project: http://www.ifad.org/english/operations/pf/rwa/i596rw/web/c4B_subsector1.htm

Illy, A., & Viani, R. (1995). Espresso Coffee: The Chemistry of Quality. San Diego: Academic Press.

Ingram, V., Awono, A., Schure, J., & Ndam, N. (2009). Guidance for a National Prunus africana Management Plan Cameroon. Center for International Forest Research.

Ingram, V., & Schure, J. (2010). Review of Non Timber Forest Products (NTFPs) in Central Africa: Cameroon. Yaounde: Center for International Forestry Research.

ITC. (2011). Ethiopian Coffee Quality Improvement Project: 2011 Aid for Trade Global Review Case Study. Geneva: International Trade Centre.

IUCN. (2010). God's resting place – the sacred mountain of Kenya. Fact Sheet.

Jacobs, C., & van't Klooster, K. (2012). Water and agriculture in the Maghreb. Alterra Wageningen.

Jassogne, L., Läderach, P., & van Asten, P. (2013). The Impact of Climate Change on Coffee in Uganda: Lessons from a case study in the Rwenzori Mountains. Oxfam. Figure 2.6 on page 54 was adapted by UNEP/DEWA from "Figure 1: Possible changes in land use and crops induced by climate change In The Impact of Climate Change on Coffee in Uganda: Lessons from a case study in the Rwenzori Mountains" [http://policy-practice.oxfam.org.uk/publications/the-impact-of-climate-change-on-coffee-in-ugandalessons-from-a-case-study-in-t-277813] with the permission of Oxfam GB, Oxfam House, John Smith Drive, Cowley, Oxford OX4 2JY UK www.oxfam.org.uk Oxfam GB does not necessarily endorse any text or activities that accompany the materials, nor has it approved the adapted text.

Jindal, R., Swallow, B., & Kerr, J. (2008). Forestry-based carbon sequestration projects in Africa: Potential benefits and challenges. Natural Resources Forum, 32, 116-130.

Johansson, D. (1974). Ecology of vascular epiphytes in West African rain forest. Acta Phytogeographica Suecica, 59, 1-129.

Jul-Larsen, E., & Bertelsen, B. (2011). Social security, poverty dynamics and economic growth in Angola's small-holder agriculture: A case study of two communities in Huambo province. Bergen: CHR Michelsen Institute.

Kah Elvis, F., Tchindjang, M., Tonye, E., & Talla, T. (2008). Combined supervised classification methods in remote sensing for the evaluation of forest dynamics along the slopes of Mount Cameroon. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37, 1171-1176.

Kakudidi, E., Oryem-Origa, H., Bukenya-Ziraba, R., & Katende, A. (1996). Rwenzori Mountain Forest non-timber products and people. In L. Maesen, X. Burgt, & J. Medenbach de Rooy (Eds.), The Biodiversity of African Plants (pp. 732-740). Springer Netherlands.

Kasangaki, A., Kanyamibwa, S., Burgess, N.D., Baghabati, N., Nasero, N., Anderson, M., Asasira, J., Bruhke, H., Hall, H., & Maritim, Z. (2012). Capturing the benefits of ecosystem services to guide decision-making in the Greater Virungas Landscape of the Albertine Rift Region. Project Technical Report to MacArthur Foundation. ARCOS, University of Cambridge, WWF-US.

Kashaigili, J.J. (2008). Impacts of land-use and land-cover changes on flow regimes of the Usangu wetland and the Great Ruaha River, Tanzania. Physics and Chemistry of the Earth, Parts A/B/C, 33(8-13), 640-647.

Khalil, A. (2004). Environmental Services, Externalities and Agriculture: The Case of Mountain Tourism in Morocco. Journal of Agriculture and Development Economics, 63 - 86.

Kirchoff, C., & Bulkey, J. (2008). Sustainable Water Management in the Zambezi River Basin. The Journal of the International Institute, 15(2), 10.

Kohler, T., & Maselli, D. (2009). Mountains and Climate Change - From Understanding to Action. Bern: Centre for Development and Environment; Institute of Geography, University of Bern; Swiss Agency for Development and Cooperation.

Korner, C., & Ohsawa, M. (2005). Chapter 24: Mountain Systems. In R. Hassan, R. Scholes, & N. Ash, Ecosystems and Human Well-being: Current State and Trends, Volume 1 (Millennium Ecosystem Assessment) (pp. 681-716). Island Press.

Kwayu, E., Sallu, S., & Paavola, J. (2014). Farmer participation in the equitable payments for watershed services in Morogoro, Tanzania. Ecosystem Services, 7, 1-9.

Laaksom, A., & Tyynelä, T. (2006). Non-wood Forest Benefits and Agroforestry Practices in the Fouta Djallon Highlands of Guinea. Nordic Journal of African Studies, 579-590.

Laman, M., Khamati, B., Milimo, P. (2001). Mount Elgon Integrated Conservation and Development Project (MEICDP) External Evaluation Final Report. Amsterdam and Nairobi: Vrije Universiteit Amsterdam and Njenga.

Lambi, C., & Kometa, S. (2009). An Evaluation of Water Resources on the Eastern Slopes of Mount Cameroon. Journal of Human Ecology, 28(1), 47-55.

Langford, K. (2013). Cocoa in the DRC rainforest. Retrieved from World Agroforestry Centre: http://worldagroforestry.org/newsroom/media_coverage/cocoa-drc-rainforest

Leviton, R. (2006). Stars on the Earth: Domes and Stargates, and How to Interact with them. Lincoln: iUniverse.

Lopa, D. (2011). Equitable Payment for Watershed Services (EPWS) A CARE/ WWF Programme. Kagera Tamp-Regional Technical Workshop on Land Planning and Management. Kabale.

Lopa, D., & Mwanyoka, I. (2010). Equitable Payments for Watershed Services (EPWS) Programme: A Practical Experience in Delivering Conservation and Poverty Reduction in the Ulugurus, Morogoro, Tanzania. Morogoro: CARE Tanzania, World Wildlife Fund.

Maddox, G. H. (2009). African Sacred Groves: Ecological Dynamics and Social Change (review). African Studies Review, 52(1), 207-208.

Maggs, G.L., Kolberg, H.H., & Hines, C.J.H. (1998). Plant species richness, endemism and genetic resources in Namibia. Biodiversity and Conservation 7(4), 435-446.

Makuchi. (2008). The Sacred Door and Other Stories: Cameroon Folktales of the Beba. Athens: Ohio University Press.

Mallarach, J., & Papayannis, T. (2010). Sacred Natural Sites in Technologically Developed Countries: Reflections from the Experience of the Delos Initiative. In B. Verschuuren, R. Wild, J. McNeely, & G. Oviedo (Eds.), Sacred Natural Sites: Conserving Nature and Culture (pp. 198-208). London: Earthscan.

Mckee, J. (2007). Ethiopia: Country Environmental Profile. Addis Ababa: European Commission.

McPeak, J., & Turner, M. (2012). Mapping Transhumance Corridors in West Africa. Fort Collins: Adapting Livestock to Climate Change Collaborative Research Support Program.

Mitchell, H. (1988). Cultivation and Harvesting of the Arabica Coffee. In R. Clarke (Ed.), Coffee: Agronomy. New York: Elsevier Applied Science.

MNP. (2014). Tsaratanana. Retrieved January 17, 2014, from Madagascar National Parks: http://www.parcs-madagascar.com/fiche-aire-protegee_en.php?Ap=35

MNTO. (2014). The Atlas Mountains. Retrieved January 17, 2014, from Moroccan National Tourist Office: http://www.visitmorocco.com/index.php/eng/I-enjoy/Hiking-and-trekking/The-Atlas-mountains

Monadjem, A., Richards, L., Taylor, P., Denys, C., Dower, A., & Stoffberg, S. (2013). Diversity of Hipposideridae in the Mount Nimba massif, West Africa, and the Taxonomic Status of Hipposideros lamottei. Acta Chiropterologica, 15(2), 341-352.

Morris, B. (2009). Wildlife and Landscapes, In, Malawi: Selected Essays On Natural History. Bloomington: Trafford Publishing.

Mount CEO. (2008). Objective. Retrieved January 17, 2014, from Mount Cameroon Inter-communal Ecotourism Board: http://www.mount-cameroon.org/objectives.htm

Mukadasi, B., Kaboggoza, J., & Nabaleqwa, M. (2007). Agroforestry practices in the buffer zone area of Mt. Elgon National Park, eastern Uganda. African Journal of Ecology, 4(3), 48 - 53.

Mupira, P. (2003). The Case of Nyanga Cultural Landscape, N.E. Zimbabwe. 14th ICOMOS General Assembly and International Symposium: 'Place, memory, meaning: preserving intangible values in monuments and sites'. Victoria Falls.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature, 403, 853-858.

NBS. (2013). Tanzania in Figures 2012. Dar es Salaam: The United Republic of Tanzania National Bureau of Statistics Ministry of Finance.

Ndangalasi, H., Bitariho, R., & Dovie, D. (2007). Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. Biological Conservation, 134, 242-250.

Newmark, W. (2002). Conserving Biodiversity in East African Forests: A Study of the Eastern Arc Mountains (Vol. 155). (I. Baldwin, M. Caldwell, G. Heldmaier, O. Lange, H. Mooney, E. Schulze, & U. Sommer, Eds.) Berlin: Springer-Verlag.

NHC. (2014). Culture and Tourism. Retrieved February 24, 2014, from Nigeria High Commission: http://www.nigeriahc.org.uk/culture-tourism

NTBSL. (2012). Loma Mountains. Retrieved January 16, 2014, from National Tourist Board of Sierra Leone: http://www.ntb.sl/

Nuesiri, E. (2008). Forest Governance Challenges on Mount Cameroon. IHDP Update: Mountainous Regions: Laboratories for Adaptation (2), pp. 27 - 30.

Oba, G., & Lusigi, W. (1987). An Overview of Drought Strategies and Land Use in African Pastoral Systems. Marsabit: Kenya Aridlands Research Station.

Ochego, H. (2003). Application of Remote Sensing in Deforestation Monitoring: A Case Study of the Aberdares (Kenya). TS11 Management of Water Resources. Marrakech: 2nd FIG Regional Conference.

Okoni-Williams, A., Thompson, H., Wood, P., Koroma, A., & Robertson, P. (2001). Sierra Leone. In Important Bird Areas in Africa and Associated Islands: Priority Sites for Conservation (pp. 769-778). Cambridge: Pieces Publications.

Olson, D. M., Dinerstein, E., Wikramanayake, D., E., Burgess, N. D., Powell, G. V., . . . Wettengel, W. W. (2001). Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience, 51(11), 933-938 and USGS Africa GIS Atlas. Retrieved March 14, 2014, from https://worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

PAI, & FJP. (2008). Strategic Action Plan: Contract: Tourism Development - Sierra Leone. Public Administration International.

Perfecto, I., Rice, R., Greenberg, R., & Van der Voort, M. (1996). Shade coffee: A disappearing refuge for biodiversity. BioScience, 598-608.

Perrin, J.L., Raïs, N., Chahinian, N., Moulin, P., Ijjaali, M. (2014). Water quality assessment of highly polluted rivers in a semi-arid Mediterranean zone Oued Fez and Sebou River (Morocco). Journal of Hydrology, 510, 26-34.

Plumptre, A., Behangana, M., Davenport, T., Kahindo, C., Kityo, R., Ndomba, E., . . . Eilu, G. (2003). The Biodiversity of the Albertine Rift: Albertine Rift Technical Reports No. 3. Wildlife Conservation Society.

Price, M., Byers, A., Friend, D., Kohler, A., & Price, L. (2013). Mountain Geography: Physical and Human Dimensions. Berkeley and Los Angeles: University of California Press.

Pryke, J., & Samways, M. (2008). Conservation of invertebrate biodiversity on a mountain in a global biodiversity hotspot, Cape Floral Region. Biodiversity Conservation, 17, 3027-3043.

Putz, F., Zuidema, P., Pinard, M. B., & Sayer, J. (2008). Improved tropical forest management for carbon retention. PLoS Biology, 6(7), 1368-1369.

Quintan, T., & Morris, C. (1994). Implications of changes to the transhumance system for conservation of the mountain catchments in eastern Lesotho. African Journal of Range and Forage Science, 11(3), 76-81.

Rabetaliana, H., Randriambololona, M., & Schachenmann, P. (1999). The Andringitra National Park in Madagascar. Unasylva (196). Retrieved February 21, 2014, from Food and Agriculture Organization of the United Nations Corporate Document Repository: http://www.fao.org/docrep/x0963e/x0963e00.htm

Rappole, J., King, D., & Rivera, J. (2003). Coffee and conservation. Conservation Biology, 17, 334-336.

Rebelo, T., Freitag, S., Cheney, C., & McGeoch, M. (2011). Prioritising species of special concern for monitoring in Table Mountain National Park: The challenge of a species-rich, threatened ecosystem. Koedoe, 53(2). doi:10.4102/koedoe.v53i2.1019

REDD Desk. (2014). The Humbo Community-based Natural Regeneration Project. Retrieved March 23, 2014, from The REDD Desk: http://theredddesk.org/countries/initiatives/humbo-community-based-natural-regeneration-project

Reyes, T., Luukkanen, O., & Quiroz, R. (2006). Small Cardamom - Precious for People, Harmful for Mountain Forests. Mountain Research and Development, 26(2), 131 - 137.

Rice, R. (2003, Winter-Spring). Coffee Production in a Time of Crisis: Social and Environmental Connections. SAIS Review, 23(1), pp. 221-245.

Rice, R. (2010). The Ecological Benefits of Shade-grown Coffee. Retrieved February 25, 2014, from Smithsonian National Zoological Park: http://nationalzoo.si.edu/scbi/migratorybirds/coffee/bird_friendly/ecological-benefits-of-shade-grown-coffee.cfm

Røhr, P., & Killingtveit, Å. (2003). Rainfall distribution on the slopes of Mt Kilimanjaro. Hydrological Sciences Journal, 48(1), 65 - 77.

ROSA. (2011). A profile of the South African Black Tea Market Value Chain. Republic of South Africa Agriculture, Forestry and Fisheries.

ROSA. (2012). Production Guideline: Coffee. Pretoria: Republic of South Africa Department of Agriculture, Forestry and Fisheries.

Rwanda Tourism. (2013). Volcanoes Tourism. Retrieved January 15, 2014, from Rwanda Tourism: http://www.rwandatourism.com/index.php/volcanoes-destination

Ryan, C. (2013). A Very Brief Introduction to Miombo Woodlands. Retrieved April 9, 2014, from Science and Engineering at The University of Edinburgh, School of Geosciences: http://www.geos.ed.ac.uk/homes/cryan/miombo

Ryan, P. G., Sinclair, I., Cohen, C., Mills, M. S., Spottiswoode, C., & Cassidy, R. (2004). The conservation status and vocalizations of threatened birds from the scarp forests of the Western Angola Endemic Bird Area. Bird Conservation International, 14, 247 - 260.

Sahli, Z. (2010). Agriculture and Rural Development in Algeria: Status, Risks and Challenges. Bulletin UASVM Horticulture, 67(2), 213-218.

Sama, N., & Tawah, E. (2010). Legal Frameworks for REDD: Design and Implementation at the National Level. Case Study: Cameroon. the REDD desk. Retrieved March 17, 2014, from http://theredddesk.org/resources/legal-frameworks-redd-design-and-implementation-national-level-case-study-cameroon

SANP. (2014). Table Mountain National Park. Retrieved January 17, 2014, from South African National Parks: http://www.sanparks.org/parks/table_mountain/tourism/attractions.php#tablemountain

Sarris, A., Savastano, S., & Christiansen, L. (2006). The Role of Agriculture in Reducing Poverty in Tanzania: A Household Perspective from Rural Kilimanjaro and Ruvuma. CSAE Conference 2006: Reducing Poverty and Inequality: How can Africa be included? Oxford.

Schachenmann, P. (2006). Spiritual Values in Madagascar: The Starting Point for Endogenous Conservation Initiatives. Mountain Research and Development, 26(4), 323-327.

Schiøtz, A., & Rödel, M. (2013). Hyperolius nimbae. Retrieved March 5, 2014, from IUCN Red List of Threatened Species: http://www.iucnredlist.org/details/56170/0

Scholte, P., & Robertson, P. (2001). Chad. In M. Evans, & L. Fishpool (Eds.), Important Bird Areas in Africa and Associated Islands: Priority Sites for Conservation. Cambridge: Pisces Publications.

Scholze, M. (2010). Chapter 12: Between the Worlds: Tuareg as Entrepreneurs in Tourism. In A. Fischer, & I. Kohl (Eds.), Tuareg Society within a Globalized World: Saharan Life in Transition (pp. 171-190). New York: Tauris Academic Studies.

Schrumpf, M., Axmacher, J., Zech, W., & Lyaruu, H. (2011). Net precipitation and soil water dynamics in clearings, old secondary and old-growth forests in the montane rain forest belt of Mount Kilimanjaro, Tanzania. Hydrological Processes, 25, 418 - 428.

Senbeta, F., & Denich, M. (2006). Effects of wild coffee management on species diversity in the Afromontane rainforests of Ethiopia. Forest Ecology and Management, 232, 68-74.

Sheil, D., Ducey, M., Ssali, F., Mukasa Ngubwagye, J., van Heist, M., & Ezuma, P. (2012). Bamboo for people, Mountain gorillas, and golden monkeys: Evaluating harvest and conservation trade-offs and synergies in the Virunga Volcanoes. Forest Ecology and Management, 267, 163 - 171.

Sheridan, M. J. (2009). The Environmental and Social History of African Sacred Groves: A Tanzanian Case Study. African Studies Review, 52(1), 73-98.

Smith, K. (2004). Trekking in the Atlas Mountains: Toubkal, Mgoun Massif and Jebel Sahro. Milnthorpe: Cicerone Press.

SOS Sahel. (2008). Pastoralism in Ethiopia: its Total Economic Values and Development Challenges. IUCN and WISP.

Ssali, R.T., Nowankunda, K., Erima, R.B., Batte, M., & Tushemereirwe, W.K. (2010). On-Farm Participatory Evaluation of East African Highland Banana 'Matooke' Hybrids (Musa spp.). Acta Hort, 879, 585 - 592.

Stacey, T. (1996). Bakonzo identity and the protection of Rwenzori: The spiritual factor. In H. Osmaston, J. Tukahirwa, C. Basalirwa, & J. Nyakana (Eds.), The Rwenzori National Park. Kampala: Makerere University.

SWAC-OECD/ECOWAS. (2008). Livestock and regional market in the Sahel and West Africa. Paris: SWAC-OECD/ECOWAS.

Takahasi, R., & Todo, Y. (2013). The impact of a shade coffee certification program on forest conservation: A case study from a wild coffee forest in Ethiopia. Journal of Environmental Management, 130, 48-54.

Tanga UWASA. (2010). Tanga Urban Water Supply and Sewerage Authority. Tanga: Tanga UWASA.

Tavares, J., Ferreira, A., Reis, E., Baptista, I., Amoros, R., Costa, L., . . . Coelho, C. (2014). Appraising and selecting strategies to combat and mitigate desertification based on stakeholder knowledge and global best practices in Cape Verde archipelago. Land Degradation and Development, 25, 45-57.

TBK. (2012). Tea Growing and Production. Retrieved May 1, 2014, from the Tea Board of Kenya: http://www.teaboard.or.ke/industry/growing_production.html

TCTP. (n.d.) Tanzania Cultural Tourism Programme. Retrieved June 19, 2014, from Tanzania Cultural Tourism Programme (TCTP): http://www.tanzaniaculturaltourism.com/index.html

Tea USA. (2013). Tea Fact Sheet. Retrieved February 26, 2014, from Tea Association of the USA: http://www.teausa.com/14655/tea-fact-sheet

Tejeda-Cruz, C., Silva-Rivera, E., Barton, J., & Sutherland, W. (2010). Why shade coffee doesn't guarantee biodiversity conservation. Ecology and Society, 15(1), 13.

Thieme, M. (2013). 513: Mount Nimba. Retrieved March 5, 2014, from Freshwater Ecoregions of the World: http://www.feow.org/ecoregions/details/mount_nimba

Thompson, I., Ferreira, J., Gardner, T., Guariguata, M., Koh, L., Okabe, K., . . . van Vilet, N. (2012). Forest biodiversity, carbon and other ecosystem services: relationships and impacts of deforestation and forest degradation. In J. Parrotta, C. Wildburger, & S. Mansourian (Eds.), Understanding Relationships between Biodiversity, Carbon, Forests and People: The Key to Achieving REDD+ Objectives: A Global Assessment Report (Vol. 31, pp. 21-52). Vienna: International Union of Forest Research Organizations.

Tourism Ethiopia. (2014). Tourist Activities. Retrieved January 17, 2014, from Tourism Ethiopia: http://www.tourismethiopia.gov.et/English/Pages/Activities.aspx

Tourism KZN. (2014). Drakensberg. Retrieved January 17, 2014, from Tourism KwaZulu-Natal: http://www.zulu.org.za/index.php?districthome+22

Travel Madagascar. (2014). Tsaratanana Integral Reserve. Retrieved January 17, 2014, from Travel Madagascar: http://www.travelmadagascar.org/PARKS/Tsaratanana-Reserve.html

Tresierra, J. (2013). Training in Payments for Ecosystem Services Part III: Case studies. Bucharest: World Wildlife Fund, United Nations Environment Programme, Global Environment Facility.

TRFCA. (2013). Central and Southern African Teas. Retrieved February 20, 2014, from Tea Research Foundation of Central Africa: http://www.trfca.net/central.html

Tropical Forages. (n.d.). Sesbania sesban. Retrieved March 22, 2014, from Tropical forages: http://www.tropicalforages.info/key/Forages/Media/Html/Sesbania_sesban.htm

Tscharntke, T., Clough, Y., Bhagwat, S., Buchori, D., Faust, H., Hertel, D., . . . Wanger, T. (2011). Multifunctional shade-tree management in tropical agroforestry landscapes - a review. J. Appl. Ecol., 48, 619-629.

Turner, S. (2004). Chapter 11: A land without fences: range management in Lesotho. In C. Fabricius, E. Koch, S. Turner, & H. Magome, Rights, Resources and Rural Development: Community Supported Natural Resources Management in Southern Africa. Earthscan.

UCDA. (2012). Production. Retrieved March 17, 2014, from Uganda Coffee Development Authority: http://www.ugandacoffee.org/index.php?page&i=14

UCF. (2014). Introducing Uganda Coffee. Retrieved February 12, 2014, from Uganda Coffee Federation: http://www.ugandacoffeetrade.com/ugandacoffee.asp

UNDP. (2013). Saving Ugandan coffee from the effects of climate change. Retrieved February 26, 2014, from United Nations Development Programme: http://www.undp.org/content/undp/en/home/ourwork/crisispreventionandrecovery/successstories/saving-ugandan-coffee-from-climate-change/

UNEP. (2009). Africa Environment Outlook (AEO) 2. Nairobi: United Nations Environment Programme.

UNEP. (2010). Africa Water Atlas. Nairobi: United Nations Environment Programme (UNEP)

UNEP. (2011). Water Issues in the Democratic Republic of the Congo: Challenges and Opportunities. Nairobi: United Nations Environment Programme.

UNEP. (2012a). Greening the Tea Industry in East Africa. Booklet from the United Nations Framework Convention on Climate Change Conference (Cop18/CMP8). Doha: United Nations Environment Programme. Retrieved February 25, 2014, from http://www.unep.org/climatechange/ClimateChangeConferences/COP18/Booklet/GREENINGTHETEAINDUSTRYINEASTAFRICA.aspx

UNEP. (2012b). Why mountains matter for Africa: Sustainable Mountain Development Rio 2012 and Beyond. Nairobi: United Nations Environment Programme (UNEP). Retrieved June 13, 2013, from http://www.mountainpartnership.org/fileadmin/user_upload/mountain_partnership/docs/Print_Africa_Policy_Brief_RIO+20_2012-low.pdf

UNESCO. (2002). Biosphere Reserve Information: Algeria, Djurdjura. Retrieved March 17, 2014, from UNESCO MAB Biosphere Reserves Directory: http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?code=ALG+03&mode=all

UNESCO. (2011). Khulubvi And Associated Mbona Sacred Rain Shrines. Retrieved March 18, 2014, from UNESCO e World Heritage Centre Tentative List: http://www.worldheritagesite.org/sites/t5602.html

UNESCO. (2014a). Mount Kenya National Park/National Forest. Retrieved January 15, 2014, from United Nations: http://whc.unesco.org/en/list/800

UNESCO. (2014b). Mount Nimba Strict Nature Reserve. Retrieved January 23, 2014, from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/list/155

UNESCO. (2014c). Rock-Hewn Churches, Lalibela. Retrieved March 1, 2014, from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/list/18

UNESCO. (2014d). Saint Catherine Area. Retrieved February 19, 2014, from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/list/954

UNESCO. (2014e). Virunga National Park. Retrieved April 4, 2014, from United Nations Educational, Scientific and Cultural Organizations: http://whc.unesco.org/en/list/63

UN-REDD. (2009). UN-REDD Programme in Africa. Retrieved May 5, 2014, from UN-REDD Programme: http://www.un-redd.org/AfricaRegionalActivities/tabid/131890/Default.aspx

UN-REDD. (2011). The UN-REDD Programme Strategy 2011-2015. Geneva: The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries Secretariat.

UNSD. (2011). Workshop on environment statistics: Final Report. Yaounde: United Nations Statistics Division.

USAID. (2010). Angola: Water and Sanitation Profile. Washington, D.C.: United States Agency for International Development.

USDA. (2008). Taxon: Euphorbia candelabrum Kotschy. Retrieved March 28, 2014, from United States Department of Agriculture (USDA) Germplasm Resources Information Network (GRIN): http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?16354

USDA-FAS. (2013). Coffee: World Markets and Trade. United States Department of Agriculture - Foreign Agricultural Service.

USGS. (2014). Global Ecosystems, Africa Ecosystems Mapping: Labeled Ecosystems. Retrieved May 1, 2014, from United States Geological Survey (USGS): http://rmgsc.cr.usgs.gov/ecosystems/africa.shtml#LE

van der Wal, S. (2008). Sustainability Issues in the Tea Sector: A Comparative Analysis of Six Leading Producing Countries. Amsterdam: Centre for Research on Multinational Corporations.

van Zyl, H. (2009). PES in South Africa: Case Studies and Early Lessons. Ecosystem Services Workshop: Forests, Climate Change, and Ecosystem Services Training". Pretoria: United States Agency for International Development.

Vololona, M., Kyotalimye, M., Thomas, T., & Waithaka, M. (2013). East African Agriculture and Climate Change. In M. Waithaka, G. Nelson, T. Thomas, & M. Kyotalimye (Eds.). Washington, D.C.: International Food Policy Research Institute.

Watson, C., Mourato, S., & Milner-Gulland, E. (2013). Uncertain Emission Reductions from Forest Conservation: REDD in the Bale Mountains, Ethiopia. Ecology and Society, 18(3). doi:10.5751/ES-05670-180306

WCS. (2014). Endemic Species. Retrieved May 5, 2014 from Wildlife Conservation Society (WCS) Albertine Rift: http://www.albertinerift.org/Wildlife/Biodiversity/Endemicspecies.aspx

weADAPT. (2012). Equitable Payments for Watershed Services (EPWS) in the Uluguru Mountains, Tanzania. Retrieved March 14, 2014, from weADAPT: http://weadapt.org/knowledge-base/ecosystem-based-adaptation/the-equitable-payments-for-watershed-services-epws-project-in-the-uluguru-mountains-tanzania

WFP/VAM Angola. (2005). Food Security and Livelihood Survey in the Central Highlands of Rural Angola: Conducted in January 2005. Angola: World Food Programme.

World Bank. (2010). Turning it Around: Greening Ethiopia's Great Rift Valley. The World Bank News, pp. Available at: http://www.worldbank.org/en/news/feature/2010/03/12/greening-ethiopia-rift-valley.

World Bank. (2011). What is Payments for Environmental Services? Retrieved January 22, 2014, from The World Bank: http://go.worldbank.org/MNZZLXLMX0

World Bank. (2012a). BioCarbon Fund Experience Insights from Afforestation and Reforestation Clean Development Mechanism Projects. Washington, D.C.: World Bank.

World Bank. (2012b). Ethiopia Climate Project Receives Africa's First Forestry Carbon Credits under the CDM. Retrieved March 8, 2014 from The World Bank News: Feature Story: http://www.worldbank.org/en/news/feature/2012/10/09/ethiopia-climate-project-receives-africa-s-first-forestry-carbon-credits.

World Bank. (2013). Tourism in Africa: Harnessing Tourism for Growth and Improved Livelihoods. Washington, D.C.: The World Bank.

World Bank. (2014). World Development Indicators: Agriculture, value added (% of GDP). Retrieved March 13, 2014, from World DataBank: http://databank.worldbank.org/data/views/reports/tableview.aspx?isshared=true&ispopular=series&pid=17

WWF. (2013a). The Economic Value of Virunga National Park. Gland: World Wildlife Fund.

WWF. (2013b). Tropical and Subtropical Moist Broadleaf Forests: West Africa: Scattered across Guinea, Ivory Coast. Retrieved December 31, 2013, from World Wildlife Fund (WWF): http://worldwildlife.org/ecoregions/at0114

WWF. (2014a). Mountain Gorilla. Retrieved March 17, 2014, from World Wildlife Fund: https://worldwildlife.org/species/mountain-gorilla

WWF. (2014b). West Africa: Scattered across Guinea, Ivory Coast. Retrieved January 31, 2014, from World Wildlife Fund: http://worldwildlife.org/ecoregions/at0114

WWF. (n.d.). Albertine Rift Montane Forests - A Global Ecoregion. Retrieved April 4, 2014, from World Wildlife Fund: http://wwf.panda.org/about_our_earth/ecoregions/albertine_montane_forests.cfm

Yanda, P., & Munishi, P. (2007). Hydrologic and Land Use/Land Cover change analysis for the Ruvu River (Uluguru) and Sigi River (East Usambara) Watersheds. Dar es Salaam: World Wildlife Fund/CARE.

ZSL. (2009). Building conservation capacity in DRC: Conserving wildlife and forest in and around Virunga National Park. London: Zoological Society of London. Retrieved January 29, 2014, from http://static.zsl.org/files/drc-info-sheet-final-1027.pdf

Impacts on Africa's Mountains

3

Many natural forces and human activities impact Africa's mountains, changing environmental conditions over time and affecting mountain people and others who rely on their resources. Natural events include floods, landslides, volcanic eruptions, dust storms, floods, thunderstorms and earthquakes. Human activities can exacerbate the impacts of these events: for example, deforestation to create areas for farming and urban development makes sloping land more vulnerable to soil erosion, landslides and flash flooding, while damming rivers alters natural streamflow and increases sedimentation, reducing their potential to supply water and electricity and mining activities can contribute to stream pollution. Thus, altering or destroying montane environments compromises their ability to provide ecosystem goods and services. This chapter describes these natural and human impacts and uses satellite images to illustrate hotspots – areas that have undergone, or are undergoing, significant and widespread change in landscape due to human or natural forces—in some of Africa's mountain areas.

Masisi, Virunga Mountains, DRC

Julien Harnesi / Flickr / CC SA

Chapter Highlights

- ▲ The Tibesti and Ennedi Mountains form a wind tunnel over the Bodélé Depression, the largest single dust source in the world, transporting 45 million tonnes of dust across the Atlantic Ocean each year, to places as far away as the Amazon rainforests.
- ▲ More than 100 volcanoes are located in Africa and its islands. The Nabro volcano in Eritrea recorded its first eruption ever in 2011, causing disruption to visibility and air traffic in neighbouring Ethiopia, ejecting water vapour, volcanic ash and sulphur dioxide 13 km into the air, piercing the stratosphere.
- ▲ Average population density in mountain areas is approximately 105 pp/km^2, but can be even higher in rural areas such as Bududa District on the Ugandan side of Mount Elgon and mountainous urban centres such as Addis Ababa in the Ethiopian Highlands.
- ▲ Population pressure can also exacerbate natural meteorological events such as rainfall, by destabilizing soil and leading to fatal landslides. Since the beginning of the 20th century approximately 70 per cent of landslides that have occurred on Mount Elgon in Uganda have happened after 1997, mostly due to removal of forest cover to support a growing population.
- ▲ Increasing populations in coastal areas, such as Cape Town and Dar es Salaam, are putting pressure on water resources from nearby mountains. Dar es Salaam, which has grown to more than 4 million in 2012 from 1.4 million people in 1988, is putting pressure on water supplies from the Ruvu River, which originates in the Uluguru Mountains.
- ▲ Spread of settlements, increase of agriculture and fires are contributing to deforestation. Fire affects 0.53 per cent of Africa's mountainous land, the largest proportion in the world.

Impacts from Natural Processes

As described in Chapter 1, Africa's mountainous regions are the product of ancient movements in the earth's crust and long-term erosion. These processes are ongoing, causing many places to be susceptible to earthquakes, volcanic eruptions and other natural hazards of geologic origin. These hazards expose people to property loss, injury and even death. The East African Rift valley is affected by earthquakes, dyke intrusions and volcanic eruptions (d'Oreye, et al., 2011), while other places like Mount Elgon on the border of Kenya and Uganda, are vulnerable to regular landslides. When human activities such as agriculture, infrastructure development and settlements take place on mountain slopes, they often exacerbate such natural processes, increasing human vulnerability to natural hazards (FAO, 2011b).

Another way that mountains impact the environment and people living in their midst is through their influence on weather patterns. The presence of mountains in various locations throughout the continent, including near the coastline and far inland, influences climate and weather conditions, dictating where some human activities, such as agriculture and dam construction for hydropower, are best located.

Meteorological Influences

Weather and Climate

Mountains are important in weather making in a variety of ways. Even though climate zones can be generalized for Africa (Figure 3.1), the presence of mountains can create local weather conditions and affect general climate patterns and sometimes atmospheric circulation at planetary scales (Schär, 2002). Mountains cause significant variations in climatic conditions over short distances and over time because of their changes in elevation, topography and the existence of the mountain mass itself (Greenland, 2005).

Globally, mountain climates are dictated by latitude, proximity to the ocean and general atmospheric circulation (Greenland, 2005). Locally, mountains act as barriers, influencing wind-flow regimes by forcing air over or around the mountain (Schär, 2002), which in turn affects precipitation (Greenland, 2005). This is referred to as orographic lifting. These wind-flow regimes depend on factors such as the mountain's height and geographic location, and in some places, both flow regimes can occur (Schär, 2002). When wind is forced up and over the mountain, the higher elevations cool the air and water vapour condenses, resulting in orographic precipitation on the mountain's windward side (Greenland, 2005; Tucker , 2005). The tropical mountains in Africa between the Tropic of Cancer (23.5°N latitude) and the Tropic of Capricorn (23.5°S latitude) usually have a "belt" of maximum precipitation (Henry, 2005). It can range from 900 m (Greenland, 2005) to an altitude of 2 000 m or more, depending upon geography and slope direction (Griffiths, 2005). For example, on Mount Kilimanjaro, the precipitation belt exists at around 2 200 m (Mölg, Chiang, Gohm, & Cullen, 2009).

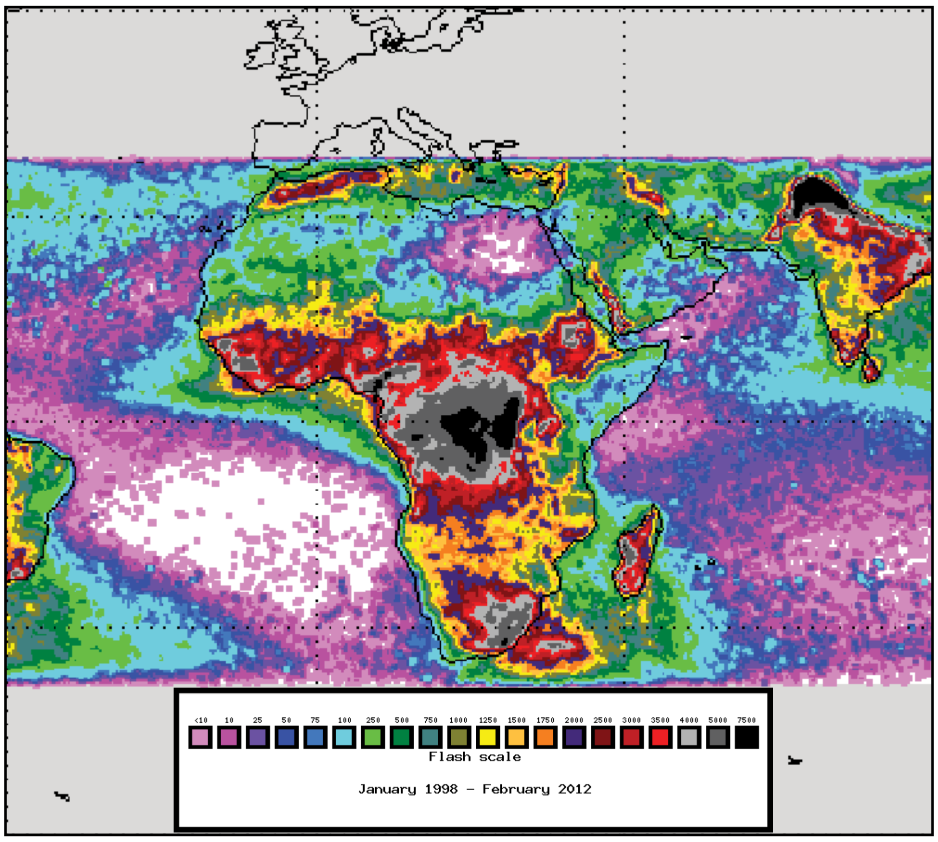
Figure 3.1: General climate zones

Source: Adapted from Chi-Bonnardel, 1973; UNEP/DEWA

Many of Africa's highland areas, such as those in Cameroon, Nigeria and eastern Africa, as well as the elevated plateau regions of Malawi, experience high rainfall (Nicholson, 2000; Malawi SDNP, 1994). These areas fall into climate zones that either continually have rainfall, such as the Equatorial Zone, or have peaks in precipitation and short dry seasons, such as the Humid Tropical Zone (Figure 3.1; Stock, 2004; Goudie, 1996). The areas surrounding Mount Cameroon receive an annual average rainfall of between 1 100 and 1 200 mm and the average annual rainfall on Mount Mulanje in Malawi is 3 000 mm (Msiska, Munthali, & Dzowela, 1988). At the highest altitudes, rain falls as snow and where conditions are favourable, glaciers and ice sheets can form. Glaciers occur on Mounts Kilimanjaro, Kenya and Rwenzori and ice sheets form in the Ethiopian Highlands, Atlas and Drakensberg Mountains (Bagoora, 2012a).

Forests play a climate regulating role in some of the more vegetated mountain regions of Africa. The Mau Forest Complex in Kenya (GoK, 2009), acts as a microclimate regulator, making the region an important tea-growing area (WWF, 2007). Therefore changes in land cover, such as reduction of forests, can alter cloud formation at higher altitudes, affecting the amount of insolation and precipitation. Removing forest cover at lower elevations on Mount Kilimanjaro has led to decreased precipitation and cloud cover, ultimately resulting in ice loss (see the Mount Kilimanjaro hotspot) (Fairman, Nair, & Christopher, 2011).

Figure 3.2: The number of lightning strikes from January 1998 to February 2012 recorded by the NASA/MSFC Lightning Imaging Sensor, a space-based sensor



Source: NASA/MSFC, 2012

The climate becomes increasingly arid along the southeastern slopes of North Africa's mountain ranges, towards the Sahara Desert, as rainfall drops sharply to less than 200 mm a year. Although snow regularly falls above 2 000 m for about three months a year in the Atlas Mountain range, there is no active glaciation (Bagoora, 2012a). The orographic effect of the Ahaggar Mountains, in conjunction with the Atlas Mountains to the north, however, creates wetter conditions over the Sahel than if orographic conditions didn't exist (Semazzi & Sun, 1997). The Atlas Mountains are a barrier between coastal lands and the Sahara Desert, creating several types of microclimates suitable for a wide variety of forest types of flora (Draper, Albertos, Garilleti, Lara, & Mazimpaka, 2007). The position of the Atlas Mountains near the Mediterranean Sea plays a part in rainfall distribution over the Spanish Mediterranean zone. Low-pressure systems from northern Africa create a warm, moist easterly flow over the Iberian Peninsula, bringing rain to various parts of Spain (Sotillo, Ramis, Romero, Alonso, & Homar, 2003).

Mountains also influence temperature. They can abstract water from moving winds, which has an adiabatic influence on temperature, meaning heat does not leave the system (Mölg, Chiang, Gohm, & Cullen, 2009). Also, the temperature gradient can rapidly change with altitude (Greenland, 2005). In a few high areas of Algeria, Morocco and South Africa, temperatures can fall below 0°C (Griffiths, 2005).

Physical characteristics of mountains can cause intense weather events such as thunderstorms and tornadoes to occur. Thunderstorms can be common in mountainous and high-plateau areas because the distance between an air mass high in the atmosphere and the land below it is shorter over a mountain than over lowlands, so the air warms faster on mountains, allowing for a low pressure system (precipitation) to form near the surface. When coupled with wind convergence over the mountain surface, a thunderstorm can form (Tucker, 2005).

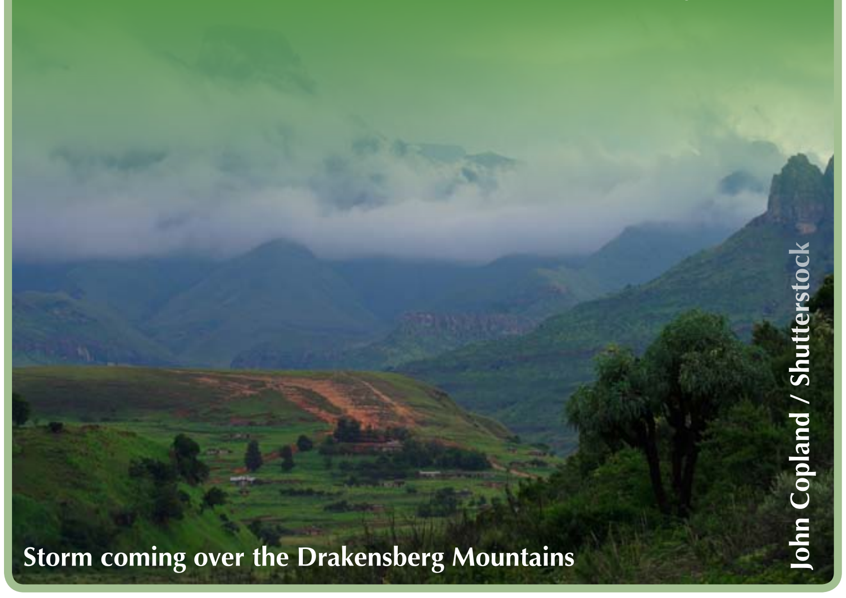
Box 3.1: Influences of lightning on mountain formation

Stoney fragments atop the high Drakensberg Mountains in Lesotho have long been thought to be debris remnants from weathering, which refers to the long-term physical and chemical impact of the atmosphere, vegetation and water that breaks apart rocks and minerals. New research from Knight & Grab (2014) shows that lightning may also play an integral role in creating the rock debris on these low-latitude mountains.

The study was conducted in Lesotho, 10 km northwest of Sani Pass near the border of South Africa, at elevations of nearly 3 400 m, with the goal of differentiating rock debris due to weathering processes from debris resulting from lightning strikes. According to the authors, debris in a lightning-strike area is more angular, younger and appears less weathered than the surrounding rock. Lightning breaks up the basalt bedrock and displaces the highly weathered surface rock, exposing the less-weathered rock below. In contrast, debris resulting from climatic-driven weathering processes occurs over large areas, such as the entire mountain summit, and all debris is similar in age, size and shape.

The research revealed that fracture patterns varied across all the sample sites, but all debris was very angular and freshly cut, indicating the important role of lightning.

Source: Knight & Grab, 2014



Storm coming over the Drakensberg Mountains

John Copland / Shutterstock

Thunderstorms are frequent in South Africa's Drakensberg Mountains and tornadoes also occur at times, mostly due to the meteorological implications of the proximity of the Drakensberg Mountains to the Indian Ocean. South Africa is the only African nation that has ever reported tornadoes. Tornadoes in this area can bring heavy flooding, hail, strong surface winds and fatal lightning strikes. In 1999, Africa's deadliest tornado occurred in Mount Ayliff because of winds influenced by the topography of the Drakensbergs (Clark & Rae, 2005). Lightning, which occurs very frequently in Africa (Figure 3.2), can accompany these thunderstorms. Lightning strikes can pose risks to human safety and can also influence mountain formation (Box 3.1).

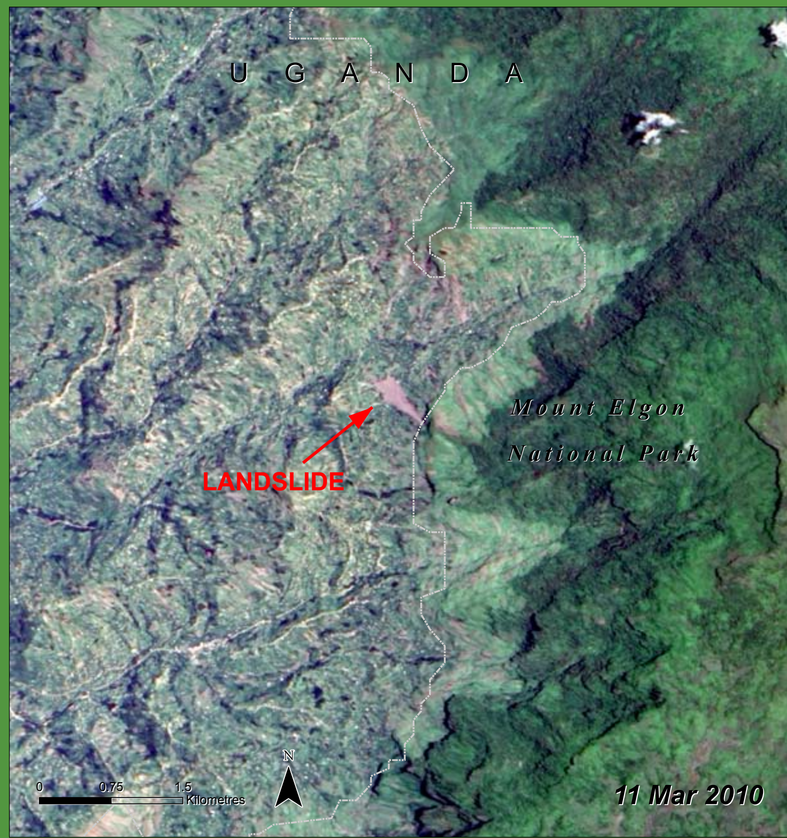
Landslides

The slopes in mountainous regions are often subject to landslides, typically brought on by heavy rains. There is a high likelihood of occurrence of landslides on mountains where the slope material has low shear resistance or high clay content

Box 3.2: Landslides on Mount Elgon

Historically, landslides rarely occurred on the Ugandan slopes of Mount Elgon, but over the past several years they happen more often and are becoming more deadly. Research has shown that 70 per cent of landslides since the beginning of the 20th century have occurred after 1997. While heavy rains may induce a landslide, a growing population settling on the mountain-sides and clearing forests on the slopes to make way for settlements and agriculture are exacerbating these events (see Chapter 5). A total of one-fifth of Mount Elgon's forest cover has been removed with almost all forest cover below 2 000 m cleared, as a result of encroachment. Additionally, cultivation takes place on steep slopes with little or no soil conservation practices to protect the land from erosion. Intense cultivation of coffee and maize take place in the upland farming areas in districts such as Bududa and Manafwa. This area also receives an average of 1 500 mm of rainfall per year, which can easily wash away degraded land.

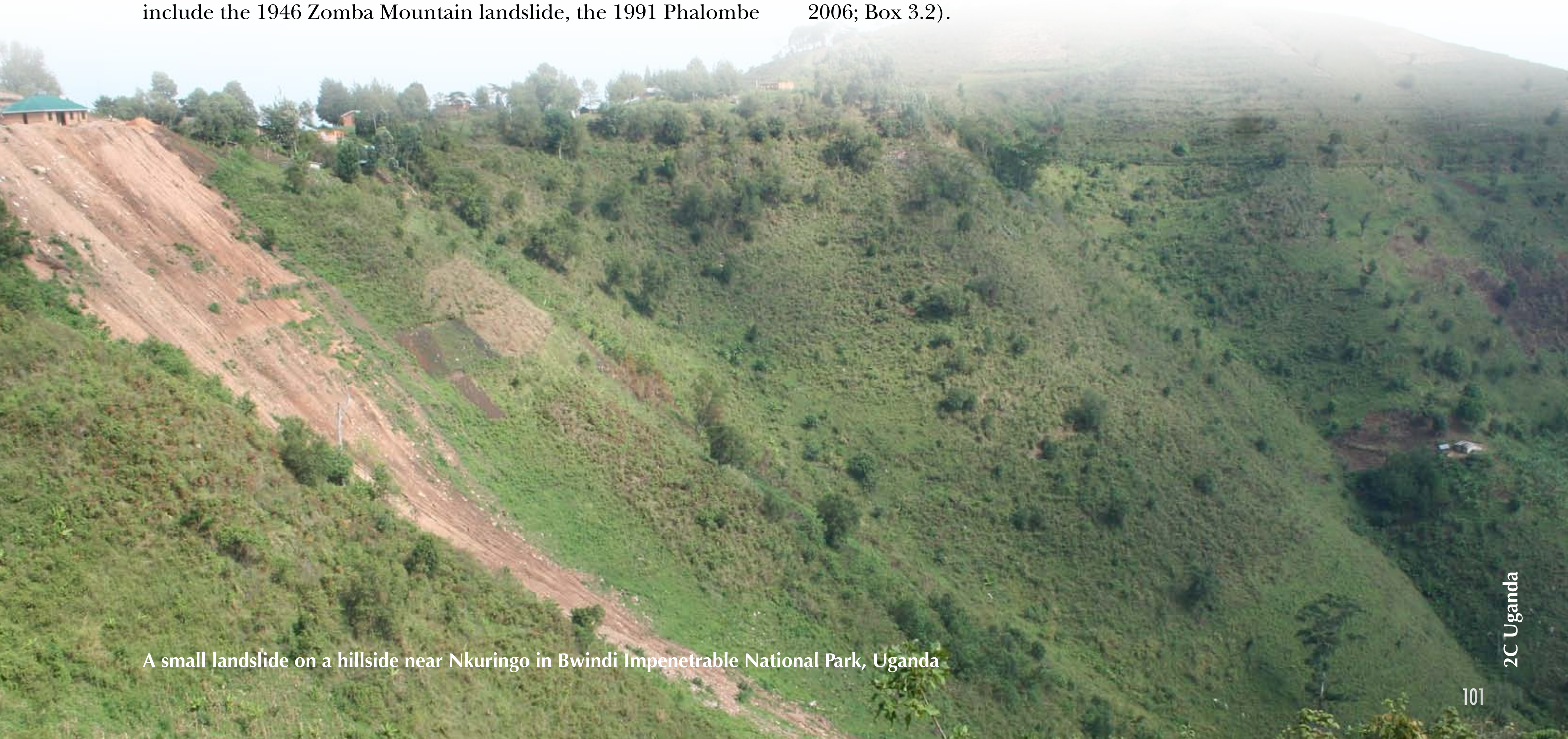
On 1 March 2010, unusually heavy rains caused a catastrophic landslide on the western slopes of Mount Elgon in eastern Uganda. A total of three villages in the area were demolished and an estimated 365 people were killed, the highest number of fatalities from a landslide since 1997. The satellite image shows the landslide that occurred in Nametsi. Reports say that 600 people were relocated after this 2010 landslide, although some have returned.



Landslides that devastate hundreds of people have continued to occur, including one in June 2012 that killed at least 100 people, with 250 remaining unaccounted for. In response to the 2012 landslide, the government designed relocation plans to help alleviate population pressure on the land.

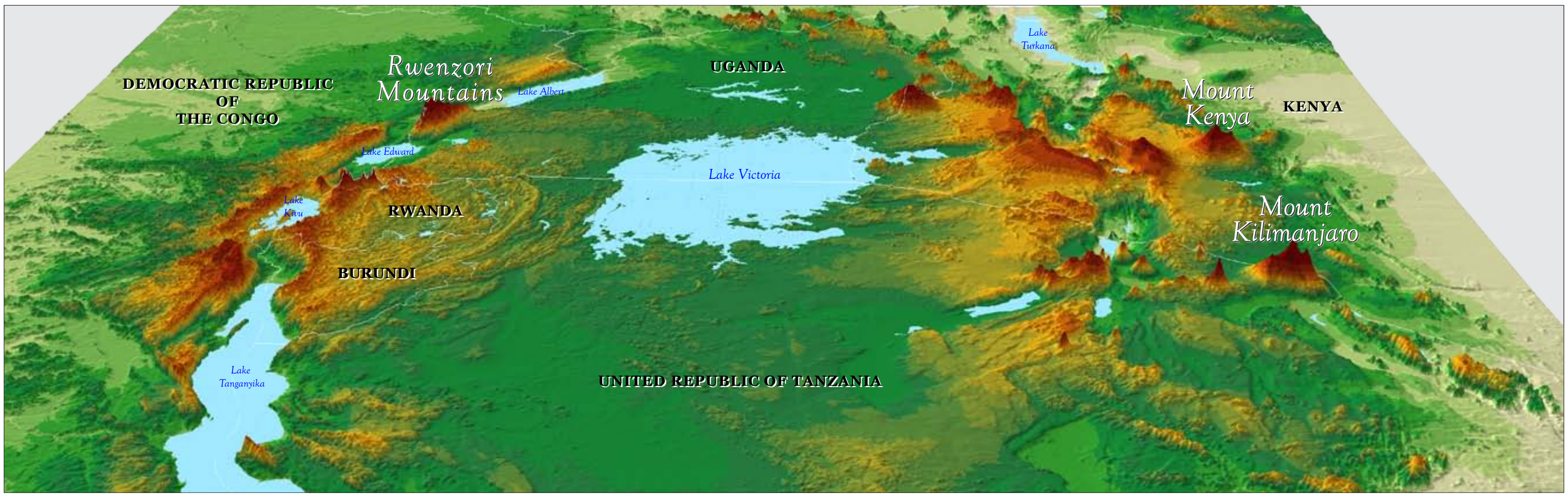
Sources: Compiled from NOAA, 2009; USDA, 2013; Haywick, 2008; Mugagga, Kakembo, & Buyinza, 2012; NASA 2010

(Knapen, et al., 2006). The frequency and intensity of landslides can be further exacerbated by human activity, especially deforestation. In Africa, many landslides have occurred in areas with high rainfall, the presence of significant rock weathering and high deforestation rates. Landslides have been reported in Cameroon, Kenya, Malawi, Uganda, Rwanda, United Republic of Tanzania and Ethiopia (Muwanga, Schuman, & Biryabarema, 2001; Knapen, et al., 2006). In Malawi, recorded landslides include the 1946 Zomba Mountain landslide, the 1991 Phalombe landslide and the 1997 Banga landslide (Msilimba & Holmes, 2005). Landslides and flooding are frequent in Limbe, Cameroon; the worst on record occurred in June 2001, killing 30 people and leaving 2 000 more homeless (Gaston, 2009). In Uganda, landslides have often been recorded on the southwestern slopes of Mount Elgon, where regular landslides have displaced at least 11 million m^3 of slope material over 154 km^2 since the beginning of the 20th century (Knapen, et al., 2006; Box 3.2).



A small landslide on a hillside near Nkuringo in Bwindi Impenetrable National Park, Uganda

Figure 3.3: Mountains with glaciers in the Rift Valley



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA

Receding Glaciers and Snow

Today, the continent's remaining glaciers are found in only three areas of the Rift Valley in eastern Africa near the equator: Mount Kenya in Kenya, Mount Kilimanjaro in the United Republic of Tanzania and the Rwenzori Mountains on the border of Uganda and the Democratic Republic of Congo (DRC) (Figure 3.3). Historically, there is evidence of glacial and periglacial activity as far north as the High Atlas Mountains in Morocco and as far south as the Drakensberg Mountains in South Africa (Young & Hastenrath, 1991). Since 1900, the East Africa glaciers have lost 82 per cent of their surface area (Russell, Eggermont, Taylor, & Verschuren, 2009). The retreating area of glaciers on East Africa's mountains is due to a decrease in rainfall and reduced amounts of cloud cover, resulting in higher solar radiation (Kaser, Mölg, Cullen, Hardy, & Winkler, 2010).

Glaciers inside the Kibo crater of Mount Kilimanjaro, United Republic of Tanzania

Hotspot: Mount Kilimanjaro, United Republic of Tanzania

Mount Kilimanjaro is composed of three main peaks: Shira, Mawenzi and Kibo. Glaciers used to exist on all three peaks, but they have rapidly retreated since the late-1880s (Kaser, Hardy, Mölg, Bradley, & Hyera, 2004; Table 3.1). Kibo is the tallest of the three at 5 895 m and is the only peak that still has ice fields (glaciers) (Cullen, et al., 2006), although they are rapidly thinning and shrinking (Thompson, Brecher, Mosley-Thompson, Hardy, & Mark, 2009). Figure 3.4 shows the notable changes in glacier coverage on Mount Kilimanjaro since 1962 and 2000.

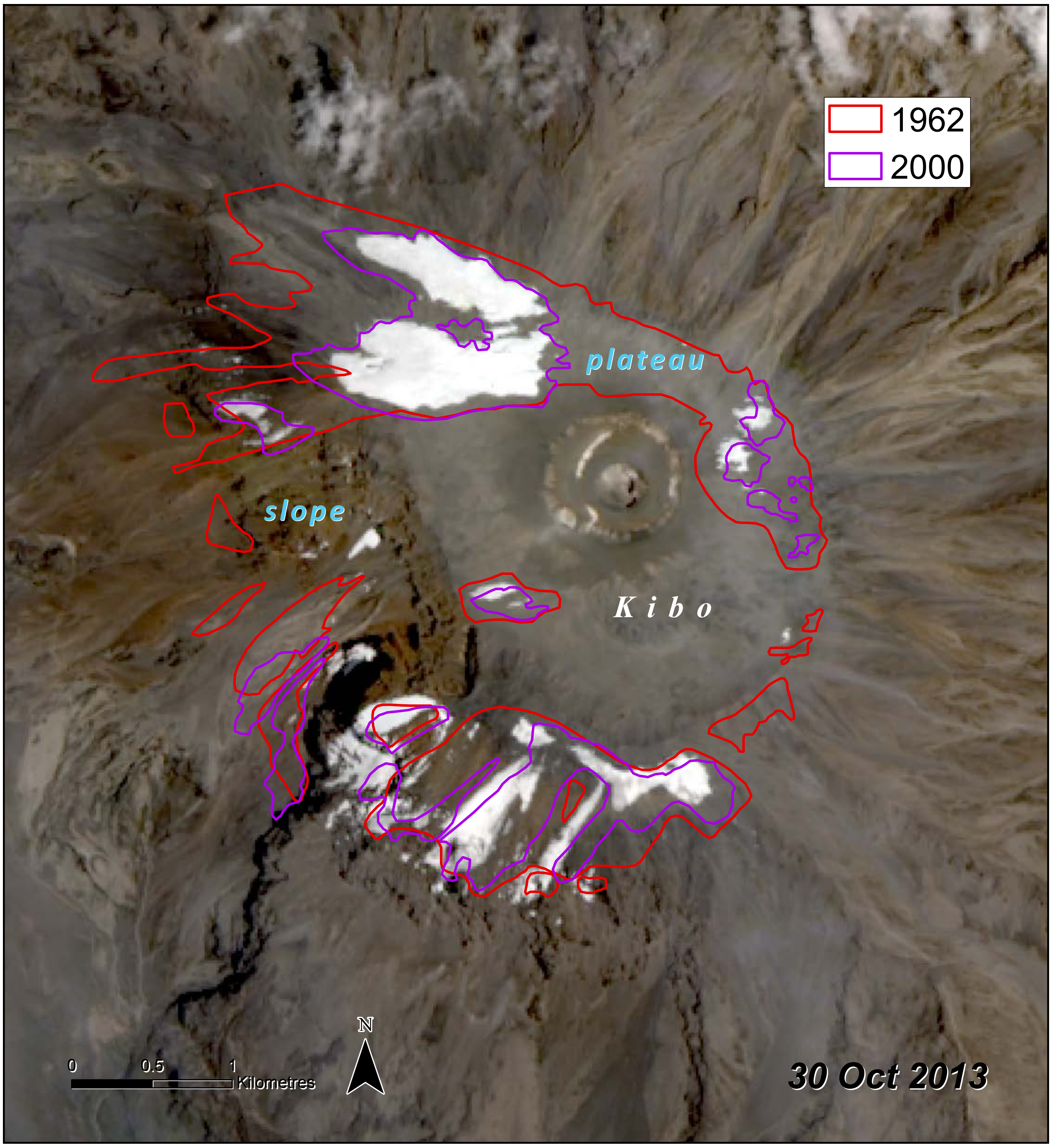
Two types of glaciers are found on Kibo peak: slope and plateau (Figure 3.4). Slope glaciers are located below 5 700 m and found on steeper slopes. Plateau glaciers are found above 5 700 m and are situated on a flat surface and with distinct vertical walls. The thickness of the plateau glaciers has remained while the retreating slope glaciers have separated from them (Kaser, Hardy, Mölg, Bradley, & Hyera, 2004). Slope glaciers accounted for 52 per cent of the glaciers in the early-2000s (Cullen, et al., 2006). Slope glaciers retreated rapidly between 1912 and 1953, but the rate of decline has since decreased. Plateau glaciers have been rapidly retreating in a near-linear fashion since 1912 (Cullen, et al., 2006).

Table 3.1: Total area of the glacier's on Mount Kilimanjaro

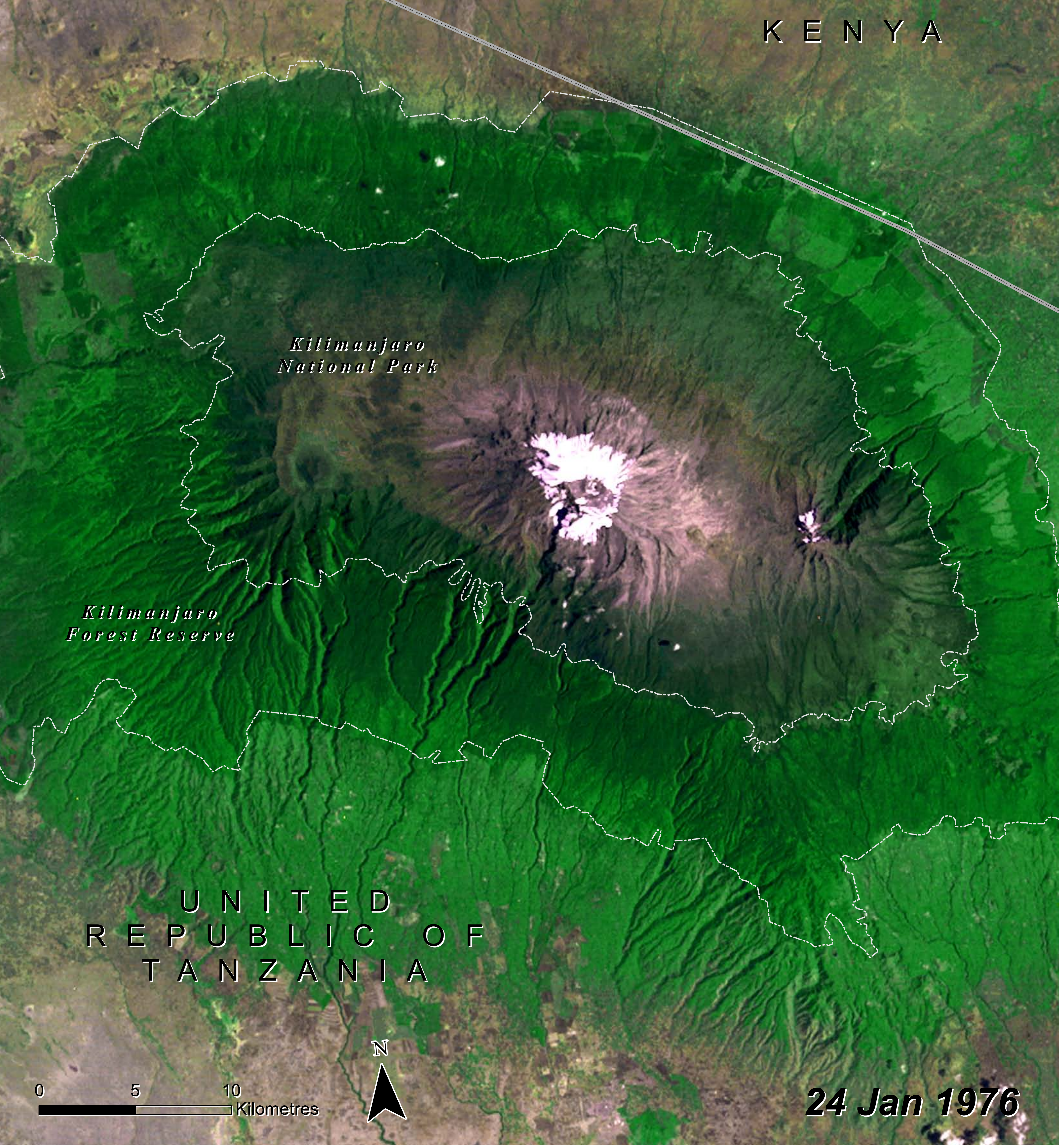
Year	Area (km^2)
1880	20
1912	12.1
1953	6.7
1976	4.2
1989	3.3
2000	2.6
2003	2.5
2007	1.85

Sources: USGS, 2014d; Thompson, Brecher, Mosley-Thompson, Hardy, & Mark, 2009

Figure 3.4: Extent of ice fields on Mount Kilimanjaro in 1962 and 2000

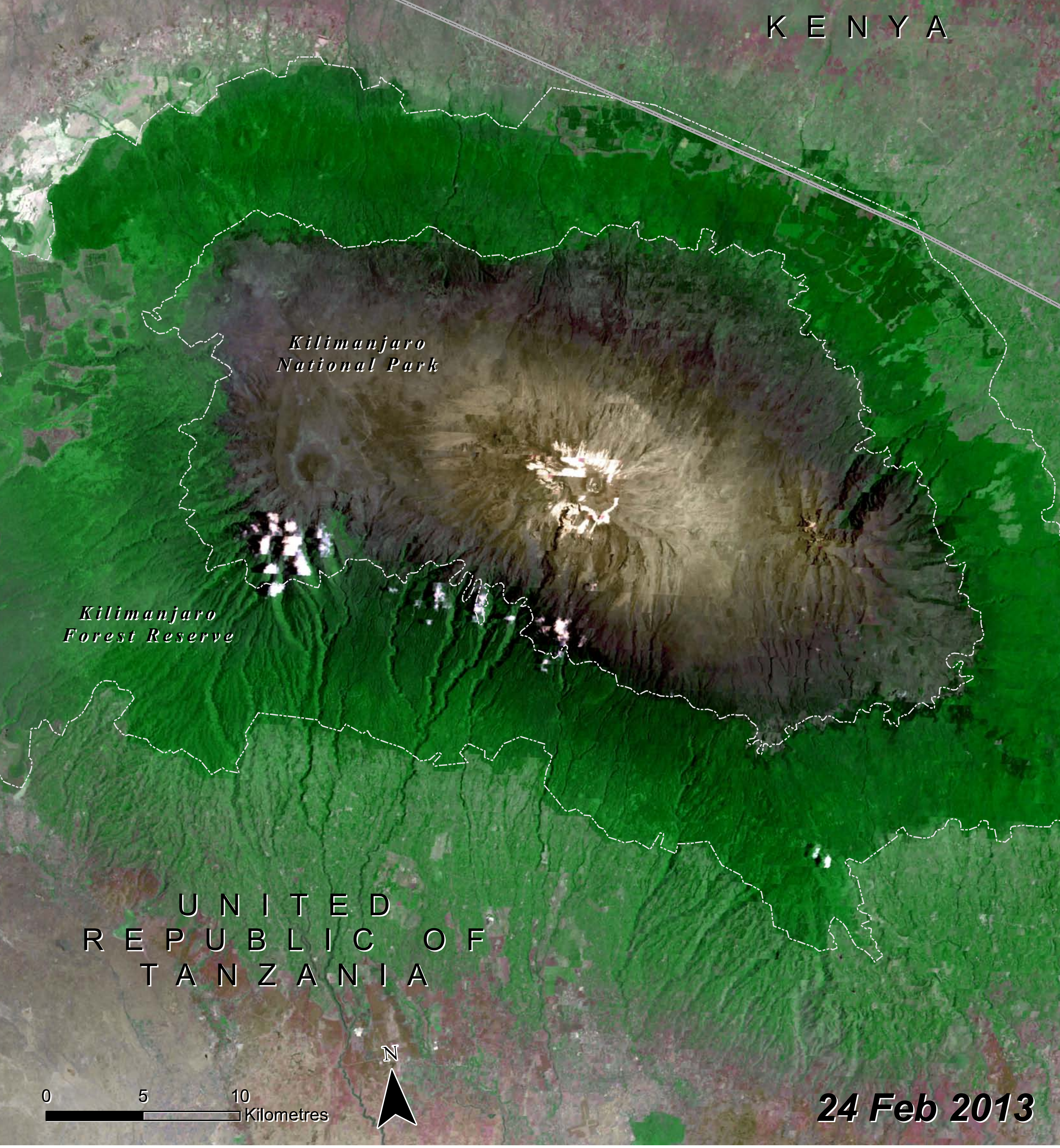


Source: Lambrechts, 2002; Landsat imagery
Note: Some displacement is visible due to relief



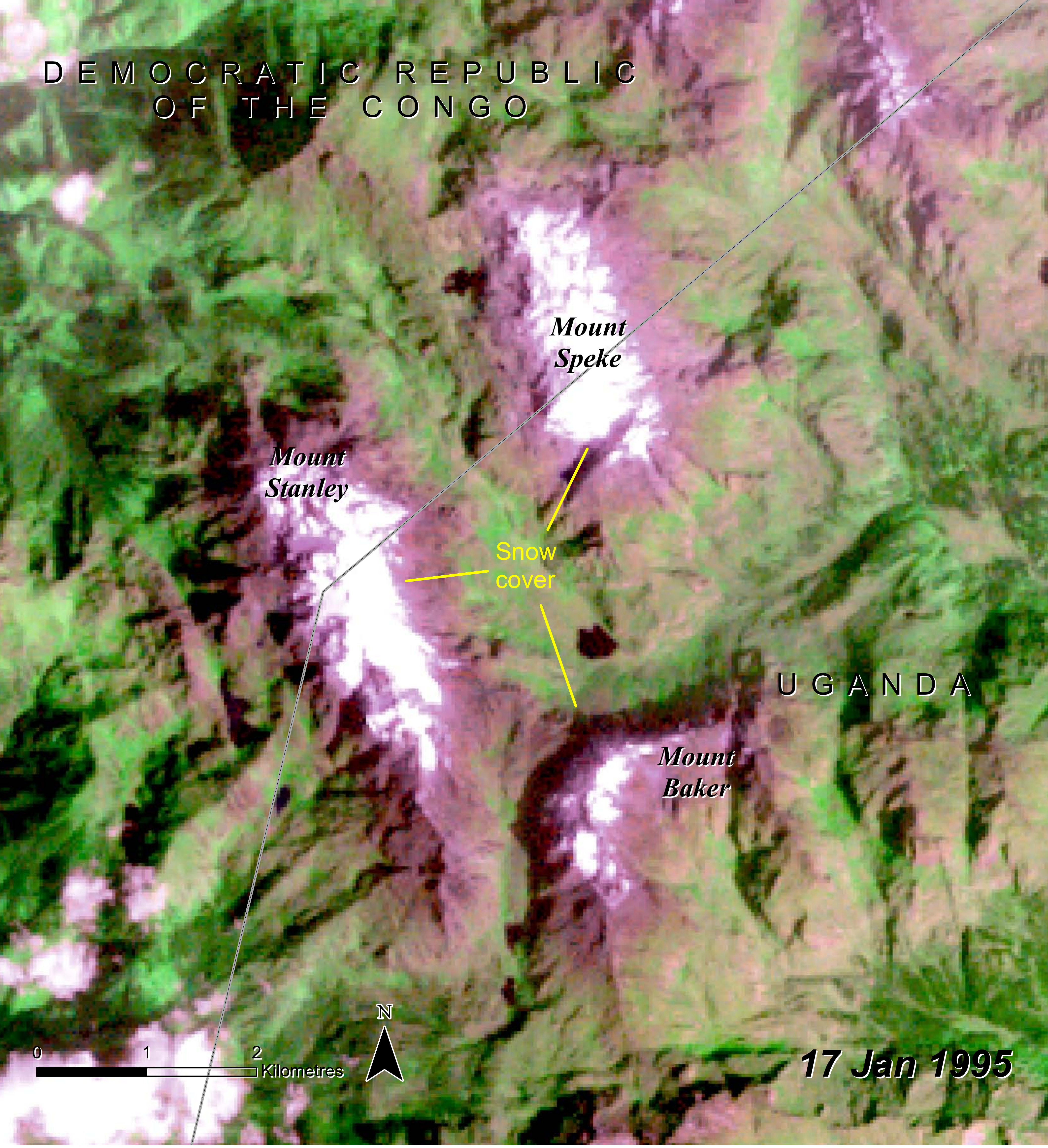
Hotspot: Mount Kilimanjaro, United Republic of Tanzania

Loss of glacier cover on Mount Kilimanjaro since 1880 can be attributed to the reduction in precipitation and air humidity moisture (Kaser, Hardy, Mölg, Bradley, & Hyera, 2004); global climate change only influences the loss indirectly, if at all (Mote & Kaser, 2007). Changes in solar radiation continue to contribute to both ice thinning and the lateral retreat of Kilimanjaro's ice cliffs, as it did in the last decades of the 19th century (Hastenrath, 2009). Warmer near-surface conditions and rising temperatures in the lower latitudes are also driving glacier decline on Kilimanjaro (Thompson,



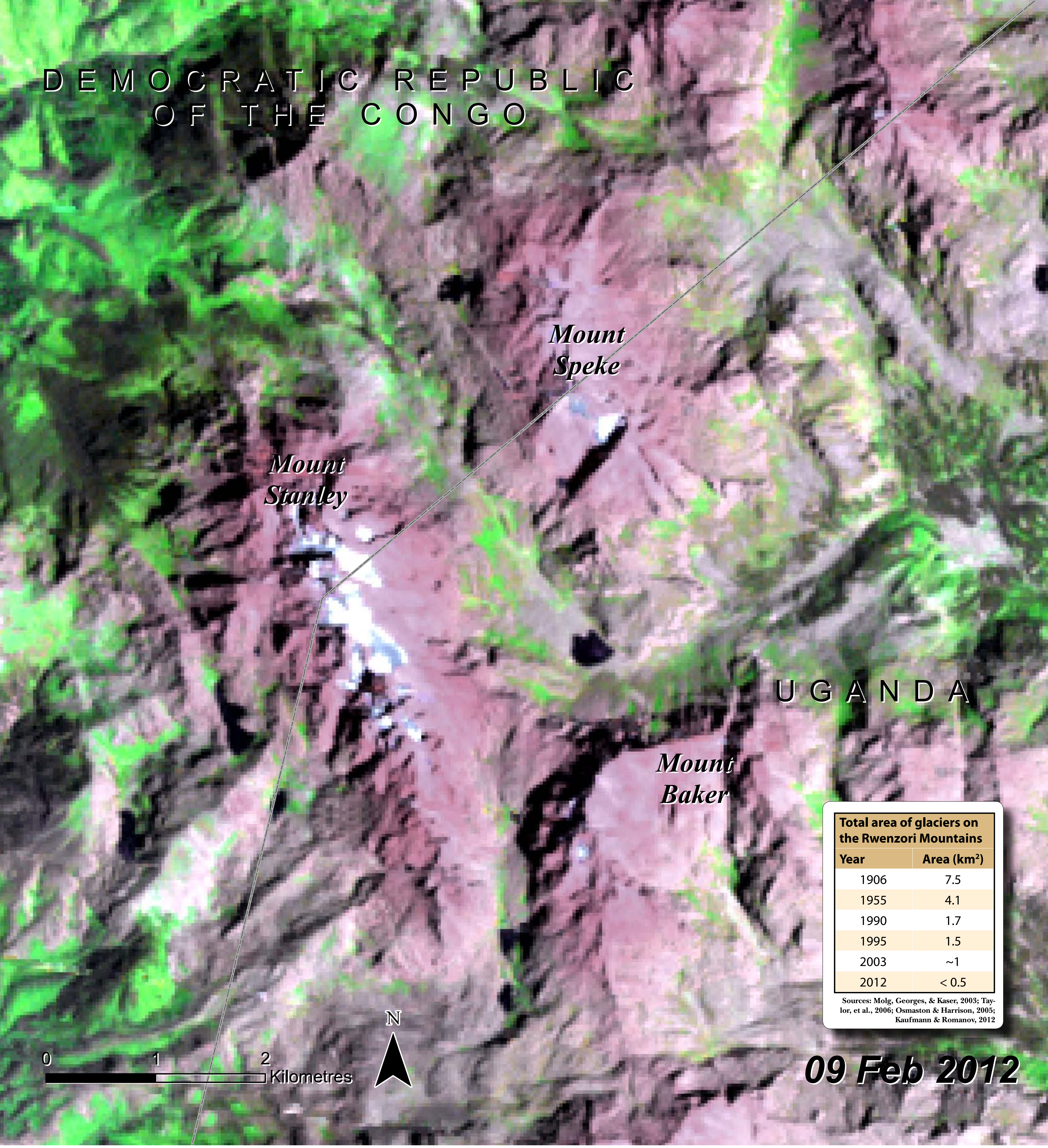
Brecher, Mosley-Thompson, Hardy, & Mark, 2009). Forest fires in Kilimanjaro's montane forest belt, which lead to reduced forest cover and precipitation, may also be a driver of ice loss (Hemp, 2005).

The mountain's remaining glaciers are too small to act as significant water reservoirs. Calculations by Mölg et al. (2008) show that if all the glaciers on Kilimanjaro were to melt at once, the amount of water yielded would be equivalent to about 13 mm of precipitation, an amount that can be received during one rainfall episode. Some have predicted that the ice fields on Kilimanjaro may completely disappear by 2022 (Thompson, Brecher, Mosley-Thompson, Hardy, & Mark, 2009).



Hotspot: Rwenzori Mountains, Uganda and the DRC

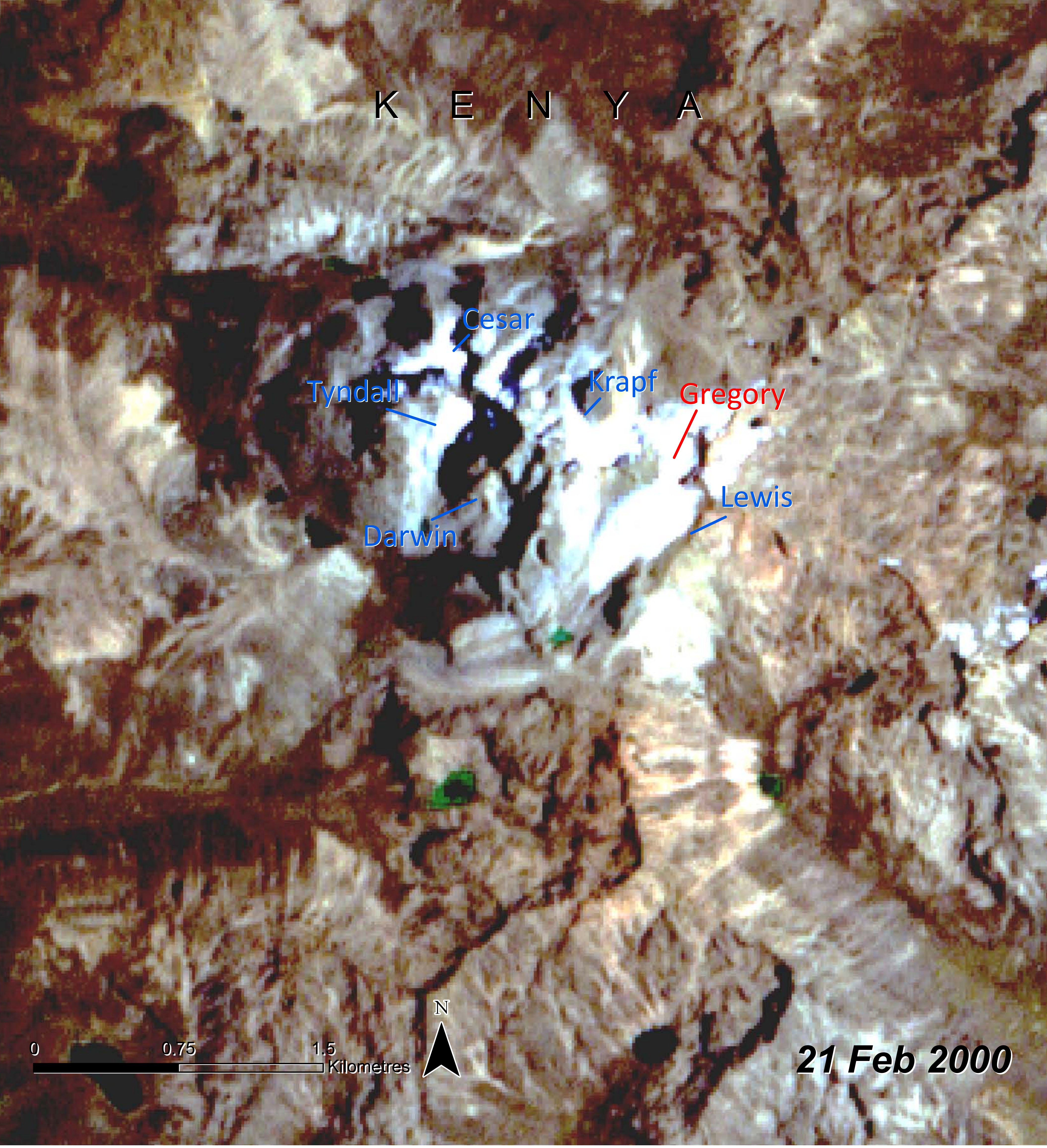
Glaciers on the Rwenzori Mountains are scattered among three peaks: Mount Baker, Mount Speke and Mount Stanley. The earliest glaciation on the Rwenzoris can be traced back to more than 300 000 years before present, covering approximately 500 km^2 (Osmaston and Kaser, 2001). Since the early 1900s the glaciers have begun to disappear at a rapid pace (on opposite page).



Total area of glaciers on the Rwenzori Mountains	
Year	Area (km²)
1906	7.5
1955	4.1
1990	1.7
1995	1.5
2003	~1
2012	< 0.5

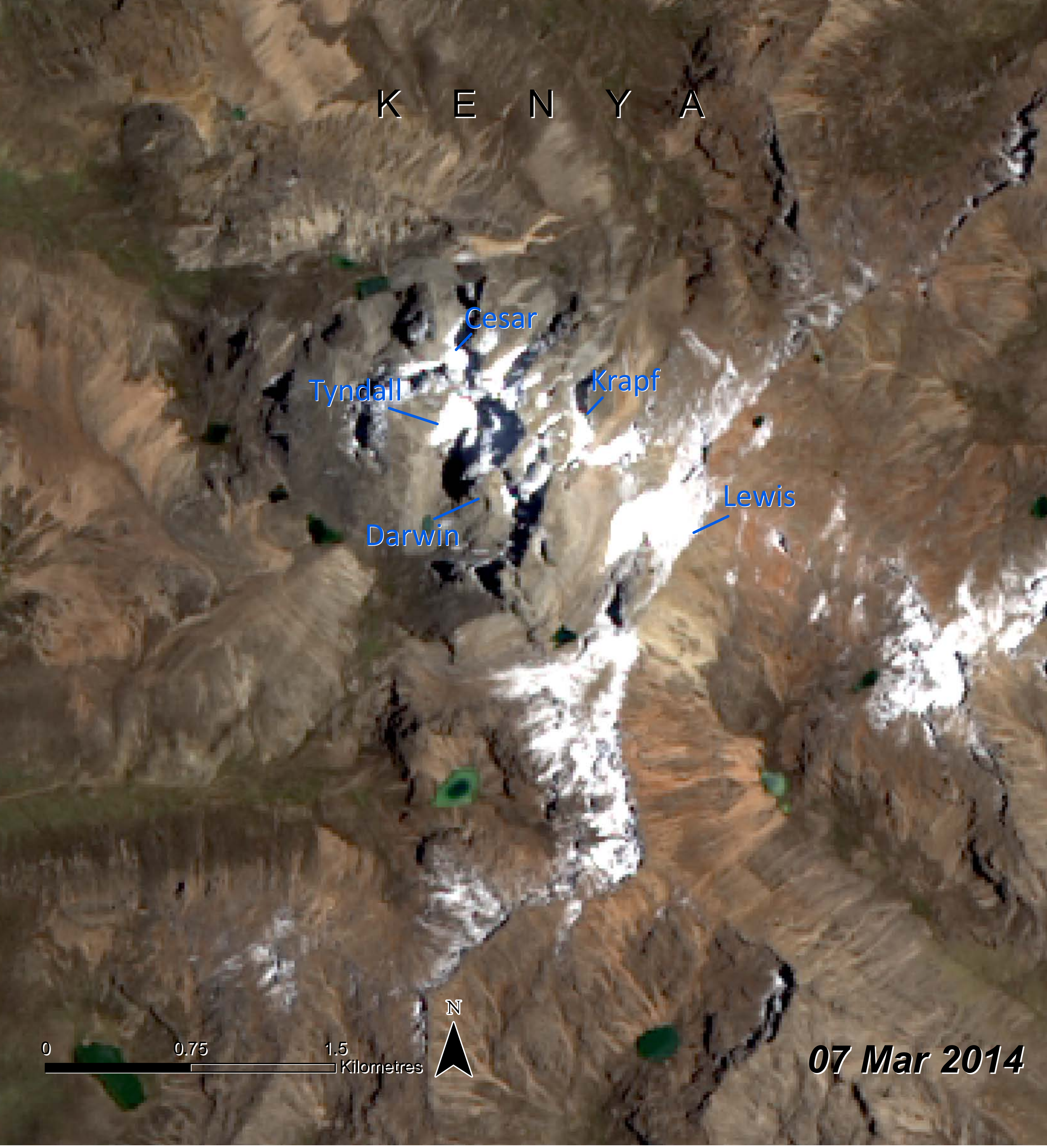
Sources: Molg, Georges, & Kaser, 2003; Taylor, et al., 2006; Osmaston & Harrison, 2005; Kaufmann & Romanov, 2012

Meltwater from glaciers on Mount Stanley and Mount Speke form the headwaters of the Mubuku River, which drains into Uganda, with some flow contributing to the Butawu and Lusilube Rivers that drain into the DRC. The remaining glaciers contribute a negligible amount to streamflow and current fluctuations in flow are likely attributed to changes in precipitation patterns. However, streamflow will be altered if the glaciers disappear altogether (Taylor, Mileham, Tindimugaya, & Mwebembezi, 2009). It is predicted that the glaciers could disappear by 2026 (Taylor, et al., 2006).



Hotspot: Mount Kenya, Kenya

Elevations above 4 500 m on Mount Kenya experience precipitation as snow and hail (Mizuno, 2005), resulting in glacier formation (Rostom & Hastenrath, 2007). The tropical glaciers of Mount Kenya have been studied since the late ice loss on lower Mount Kenya, which has been occurring since the middle of the 20th century as a product of slight increases in air temperature and humidity



(Hastenrath, 2009). In the late-19th century, 18 glaciers could be found on Mount Kenya, but now only half as many remain (Hastenrath, 2005; Prinz, Fischer, Nicholson, & Kaser, 2011; Table 3.2 on page 110). Six glaciers disappeared in 1926 or before, one glacier in early 1978 and two glaciers during the 2000s (Table 3.3). In 2004, researchers mapped 11 glaciers on Mount Kenya and observed that all of them were retreating rapidly (Rostom & Hastenrath, 2007). From 1993 to 2004, the glaciers lost a total of 14 600 km^2 in area, 13.9 m in thickness and 5.7 million m^3 in volume.

During this time, Joseph glacier, the lowest elevation glacier on Mount Kenya, disappeared. The only glacier that did not change in area or length during this study period was Diamond glacier, which is the highest glacier at an elevation of 5 150 m. A different study recorded that the Gregory glacier, which was previously connected to Lewis glacier, completely disappeared between 2006 and 2011 (Prinz, Fischer, Nicholson, & Kaser, 2011), becoming the eigth glacier to disappear since 1899 (Table 3.3) and leaving just nine glaciers remaining. Currently, the two largest glaciers left on Mount Kenya are Tyndall and Lewis (Mizuno, 2005; Hastenrath, 2005).

Table 3.2: Decrease in area and volume of the remaining glaciers on Mount Kenya

Glacier name	Area ($10^3 m^2$)			Decrease in volume from 1993 - 2004 ($10^3 m^3$)
	1899	1993	2004	
Krapf	85	21	14	268
Lewis	603	203	105 (2010)	2 761
Darwin	90	23	12	545
Diamond	(7)	3	3	14
Forel	(27)	15	12	50
Heim	(25)	15	5	233
Tyndall	165	65	51	852
Cesar	100	18	16	324
Northey	50	9	3	186

Sources: Compiled from Hastenrath, 2005; Prinz, Fischer, Nicholson, & Kaser, 2011; Rostom & Hastenrath, 2007
Note: Gregory and Joseph glaciers are omitted from the table due to their recent disappearance, see Table 3.3

The retreat of glaciers on Mount Kenya has resulted in advancing vegetation. These pioneer species, the first to grow in new ground, help to improve soil conditions and facilitate the growth of other plants (Mizuno, 2005). Mosses, lichen and endemic plant species such as groundsel (*Senecio keniophytum*) advanced with glacial retreat in the Tyndall glacier area (Mizuno, 2005).

Table 3.3: Year of disappearance of glaciers from Mount Kenya

Glacier name	Year of disapperance
Mackinder	1899
Arthur	1926
Barlow	1926
Kolbe	1926
NW Pigott	1926
Peter	1926
Melhuish	Feb 1978
Joseph	Between 1993 and 2004
Gregory	Between 2006 and 2011

Sources: Compiled from Hastenrath, 2005; Prinz, Fischer, Nicholson, & Kaser, 2011; Rostom & Hastenrath, 2007

Giant groundsel on Mount Kenya

Africanmoose / Shutterstock

Dust Storms

Mountain topography in southern Africa and the Sahara Desert plays a role in generating dust storms in Africa. The Sahara Desert is the largest dust-producing region in the world, with the majority of dust coming from the valley between the Tibesti and Ennedi Mountains, an area known as the Bodélé Depression (see the hotspot on the Tibesti and Ennedi Mountains) (Washington, Todd, Middleton, & Goudie, 2003; Washington, et al., 2006).

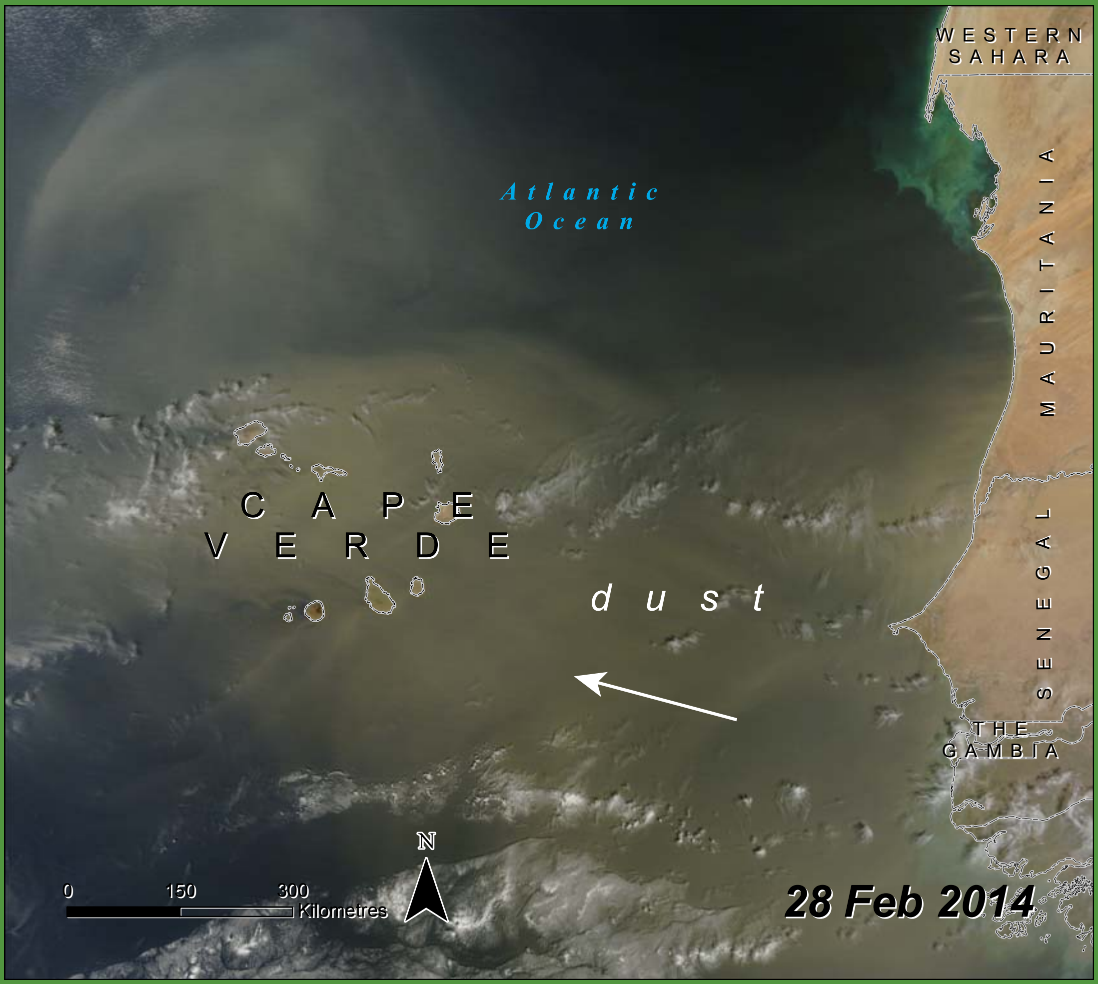
The southern foot of the Atlas Mountains makes up a significant portion of the northern boundary of the Sahara Desert, occupying up to 9 million km^2 of land (Tucker, Dregne, & Newcomb, 1991). Hundreds of millions of tonnes of Saharan dust can be blown over the Atlantic Ocean to the Caribbean, the Gulf of Mexico and even eastern South America (NASA, 2014a). The dust influences local, regional and global climates, promotes phytoplankton productivity in the ocean and fertilizes Amazonian rain forests (Prospero & Mayol-Bracero, 2013; USGS, 2013b; Koren, et al., 2006). Although the dust provides unique benefits to the ocean, it can compromise air quality (Box 3.3). When inhaled, it has been found to carry chemical contaminants, including pesticides (Garrison, et al., 2006).

In southern Africa, berg winds, or mountain winds, are hot, dry winds that typicall occur in the winter and blow from interior mountainous areas towards the coast. Berg winds occur due to very warm temperatures along the coast, compared to cooler temperatures in the mountainous interior (Nake, 2011). Mountains along western South Africa and central Namibia cause winds to pick up dust in the Namib Desert and blow over the Atlantic Ocean (NASA, 2014). Hazards of these winds include decreased visibility for ships and airplanes and can affect marine and coastal activities (Nake, 2011).

Box 3.3: Dust storms over Cape Verde

The islands that comprise Cape Verde are an example of a location that is affected by Saharan dust. During November to March of every year, an obscuring desert wind known as *harmattan* blows across the Sahara Desert from the east, over Cape Verde. The mountainous topography of Cape Verde interacts with the dust clouds, creating swirling eddies and triangular wakes, as shown in the satellite image to the right. Cape Verde's air quality can be significantly degraded when dust storms occur.

Sources: Compiled from NASA, 2014a; Almeida-Silva, et al., 2013



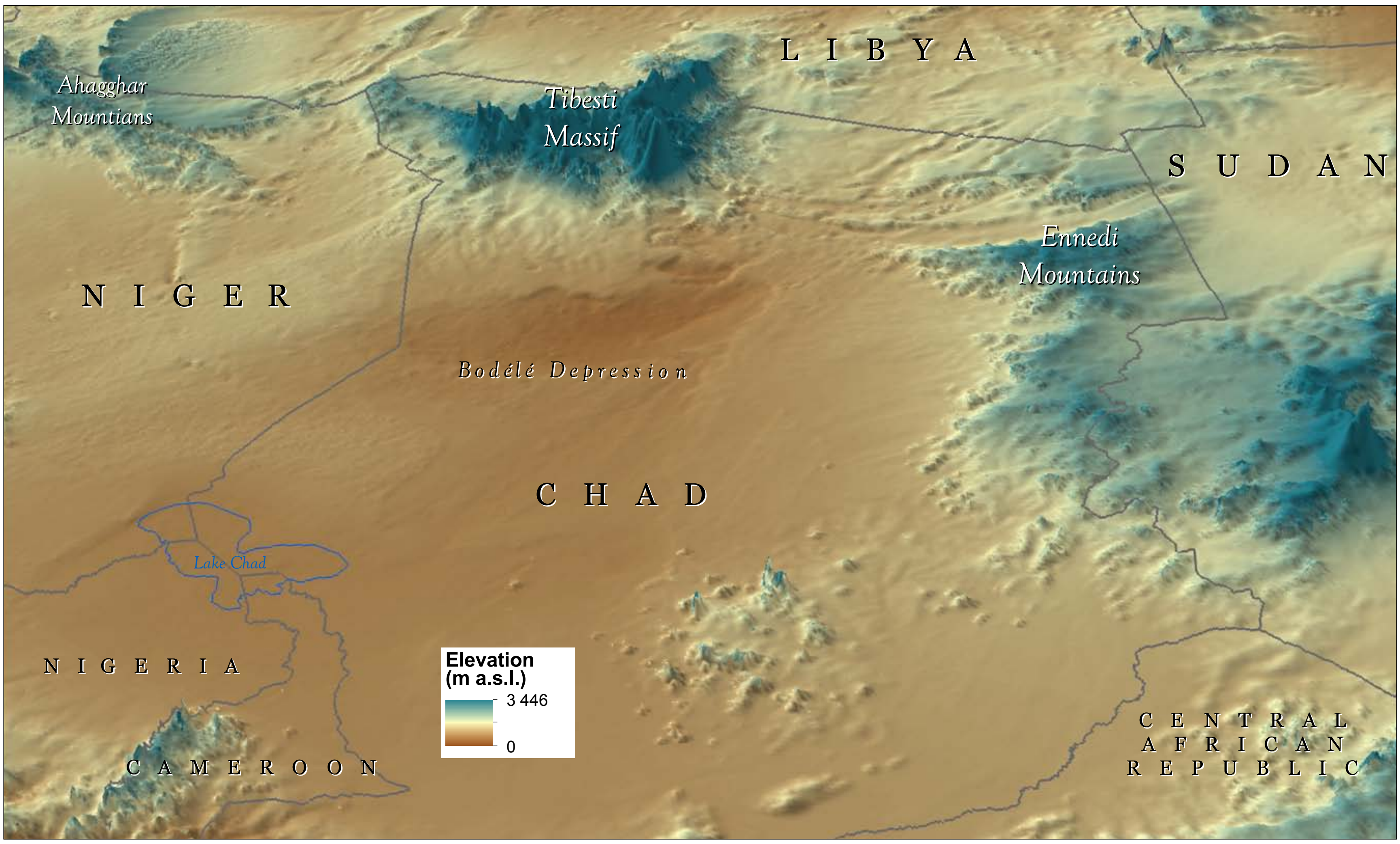
Hotspot: Tibesti Massif and Ennedi Mountains, Chad and Libya

The Bodélé Depression, located in northern Chad in the south-central Sahara Desert (Washington, Todd, Middleton, & Goudie, 2003), is the world's largest single source of dust, emitting an estimated 58 million tonnes of dust per year (Koren, et al., 2006; Washington, et al., 2006).

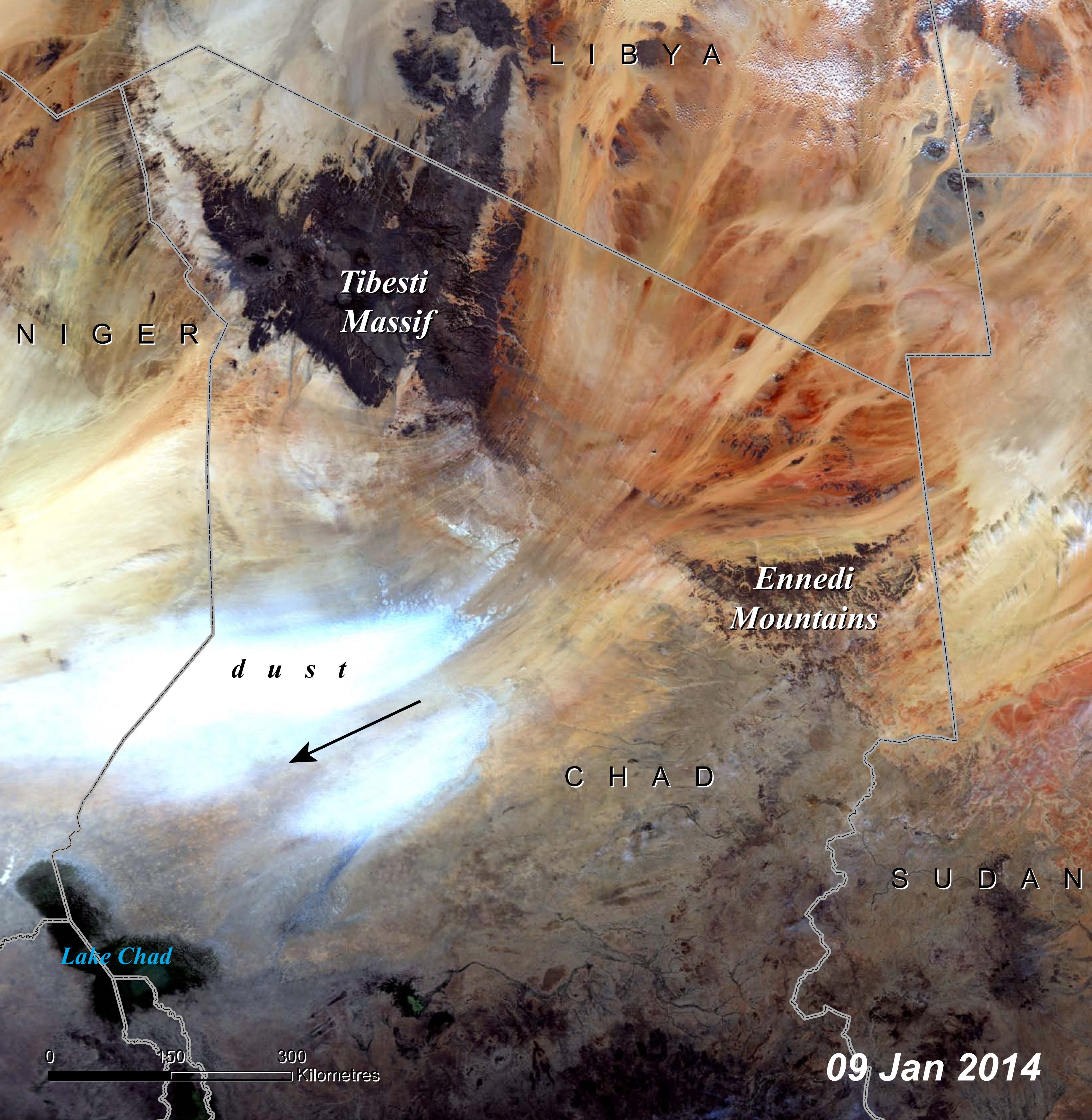
A wind tunnel of intense, erosive winds is created because of the position of the mountains relative to the Bodélé, with the Tibesti massif to the west and the Ennedi Mountains to the east, helping to generate large dust storms (Washington, et al., 2006; Figure 3.5). These winds are referred to as the Bodélé Low Level Jet (LLJ) (Washington, et al., 2006) and they create dust clouds of up to 700 km long (Giles, 2005). The dust carried by the high winds is not derived from sand or rock, but is actually remnants of microscopic freshwater organisms called diatomites that once lived in the Lake Megachad basin, giving dust in the depression a milky-white colour (Giles, 2005) like shown in the satellite image on the opposite page. The Bodélé Depression is the largest source of dust supply to the Amazon basin, carrying approximately 45 million tonnes of dust across the Atlantic Ocean every year (Koren, et al., 2006).

Hazy sunset over the Ennedi Mountains

Figure 3.5: The Bodélé Depression



Source: USGS 7.5 arc second maximum DEM; UNEP/DEWA



View of a Saharan dust storm from the International Space Station, taken on 21 August 2013 600 kilometres west of Cape Verde

Geological processes

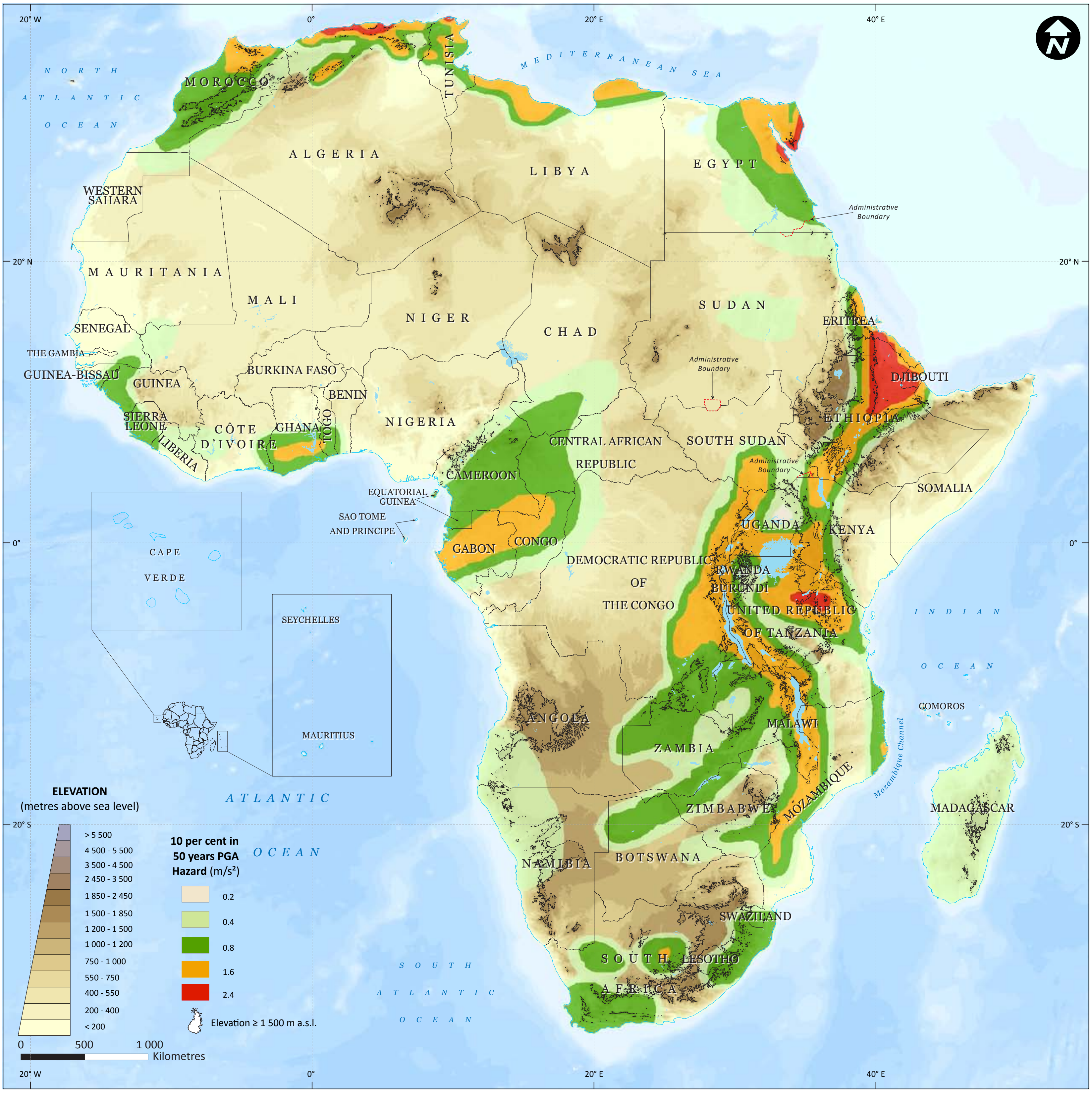
Earthquakes

Approximately 27 per cent of Africa's mountainous areas are susceptible to destructive earthquakes, defined as Level VIII or greater on the Modified Mercalli scale (Blyth, Groombridge, Lysenko, Miles, & Newton, 2002; Table 3.4). Seismic activity occurs in the north, east and southeast parts of Africa (Figure 3.6). This tectonic activity involves movements at the border of the African and Eurasian plates. The seismic activity in northern Africa is concentrated along the Atlas Mountain range, while in southeast Africa seismic activities are due to the East African Rift system, which extends from the Afar triple junction 3 000 km south to Lake Malawi, and is the largest active rift in the world.

The Rwenzori Mountains experience frequent seismic activity in the form of earthquake swarms—meaning that there is a gradual increase and then decrease in activity without having an identifiable primary earthquake—and is actually the most seismically active area in the East African Rift region (Lindenfeld, Rumpker, Link, Koehn, & Batte, 2012).

All along the rift there is frequent seismicity, producing earthquakes of moderate intensity (Yang & Chen, 2010). The Rift is divided into two branches: western and eastern. The western branch has more frequent earthquakes (Yang & Chen, 2010). The Virunga volcanoes, located north of Lake Kivu, are part of the western branch and located on the Rift floor. Major cities including Bukavu and Goma, DRC and Gisenyi, Rwanda are also located in this area and are vulnerable to not only volcanic eruptions, but the earthquakes characteristic of the area as well. The city of Bukavu is already vulnerable to landslides, but they have occurred more frequently since 1997 as a result of moderate earthquakes in the area (Wafula, et al., 2007). Major earthquakes in 2008 affected the Bukavu and Nyamuragira areas

Figure 3.6: Seismic hazards based upon ground motion values (Peak Ground Acceleration (PGA)) where probability exceeds 10 per cent in 50 years



Source: Adapted from USGS, 2014a; UNEP/DEWA

Table 3.4: Magnitude and intensity scales of earthquakes

Magnitude	Typical Maximum Modified Mercalli Intensity	Description
1.0 - 3.0	I	Not felt except by a very few under especially favourable conditions.
3.0 - 3.9	II	Felt only by a few persons at rest, especially on upper floors of buildings.
	III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0 - 4.9	IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
	V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.0 - 5.9	VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
	VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.0 - 6.9*	VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
	IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher**	X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
	XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
	XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: USGS, 2013a

Note: *6.0 - 6.9 can also fall be associated with VII intensity **7.0 and higher can also be associated with VIII or higher

in the DRC. The Bukavu earthquake in February 2008 devastated the region due to its magnitude and shallow depth (d'Oreye, et al., 2011; Box 3.4). In 1961, the town of Majete in Ethiopia was completely destroyed. In 1966, 160 people were killed in Uganda following the Tooro earthquake, and in 1989 the Salima earthquake killed 9 people (Midzi, et al., 1999).

Box 3.4: The 2008 Lake Kivu earthquake

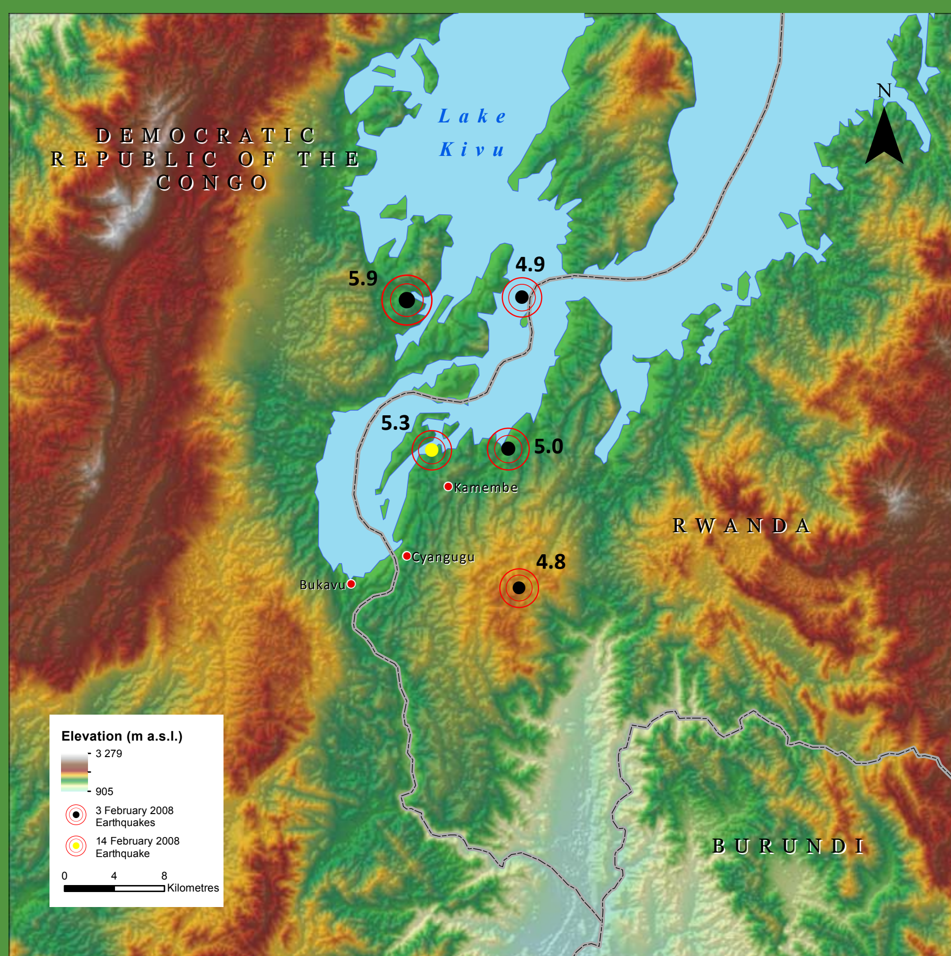
In the early morning of 3 February 2008, a magnitude 5.9 earthquake struck the Lake Kivu region, centred in the DRC, 20 km from the city of Bukavu. Three additional earthquakes, first a magnitude 5, then 4.9, then 4.8 followed in Rwanda and the DRC. A fourth struck later that evening in Rwanda, registering with a magnitude of 4.6. Aftershocks continued in the following days and another earthquake with a magnitude of 5.3 struck on 14 February in Rwanda.

The 3 February earthquakes caused houses and buildings to collapse, including a church in western Rwanda, which resulted in the death of 10 people, and healthcare facilities and schools in Bukavu and Rwanda. In total, at least 37 people in Rwanda were confirmed dead and another 200 seriously injured. At least seven people died in the DRC and 447 injured. These earthquakes were also felt in Burundi, where a power outage was caused, and as far away as Nairobi, Kenya.

Healthcare facilities in Bukavu were again damaged as a result of the earthquake on 14 February. In Rwanda, where the earthquake occurred, one person was reported dead and at least 65 were reported as injured.

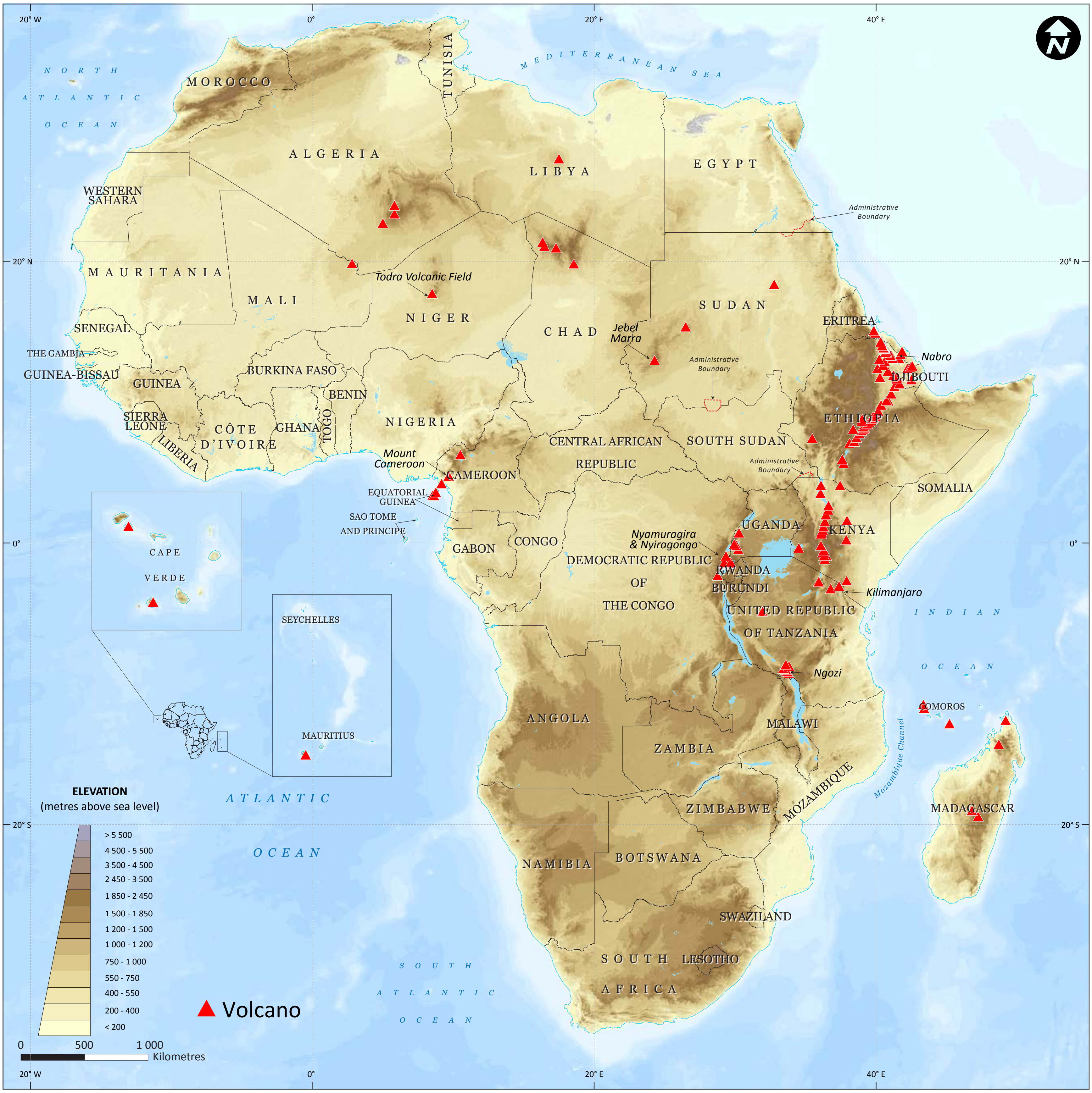
As a result of the earthquakes from the 3rd and the 14th, more than 2 500 families in the DRC received recovery assistance and close to 1 200 homes were destroyed in Rwanda.

Sources: Compiled from BBC, 2008; EERI, 2008; UNDAC, 2008; NASA, 2008; OCHA, 2008



Source: USGS, 2014c, CIAT SRTM 250 m DEM from NASA Data, Jarvis, 2008; UNEP/DEWA

Figure 3.7: Location of volcanoes



Sources: USGS, 2001; SIGVP, 2013b; UNEP/DEWA

Volcanic Eruptions

As shown in Chapter 1, volcanoes are scattered throughout Africa, but are primarily concentrated along the East African Rift (Figure 3.7); there are also some volcanic islands. The Rift was created by a fracture in the Earth's crust, causing a break between the Nubian (African) plate and the Somalian plate. Along the Rift, fissures can spew lava. There are also individual volcanoes (NASA, 2012), some of the most active of which are Mount Cameroon, Nyiragongo and Nyamuragira (both in DRC), the Oldoinyo Lengai in the United Republic of Tanzania and Fogo in Cape Verde.

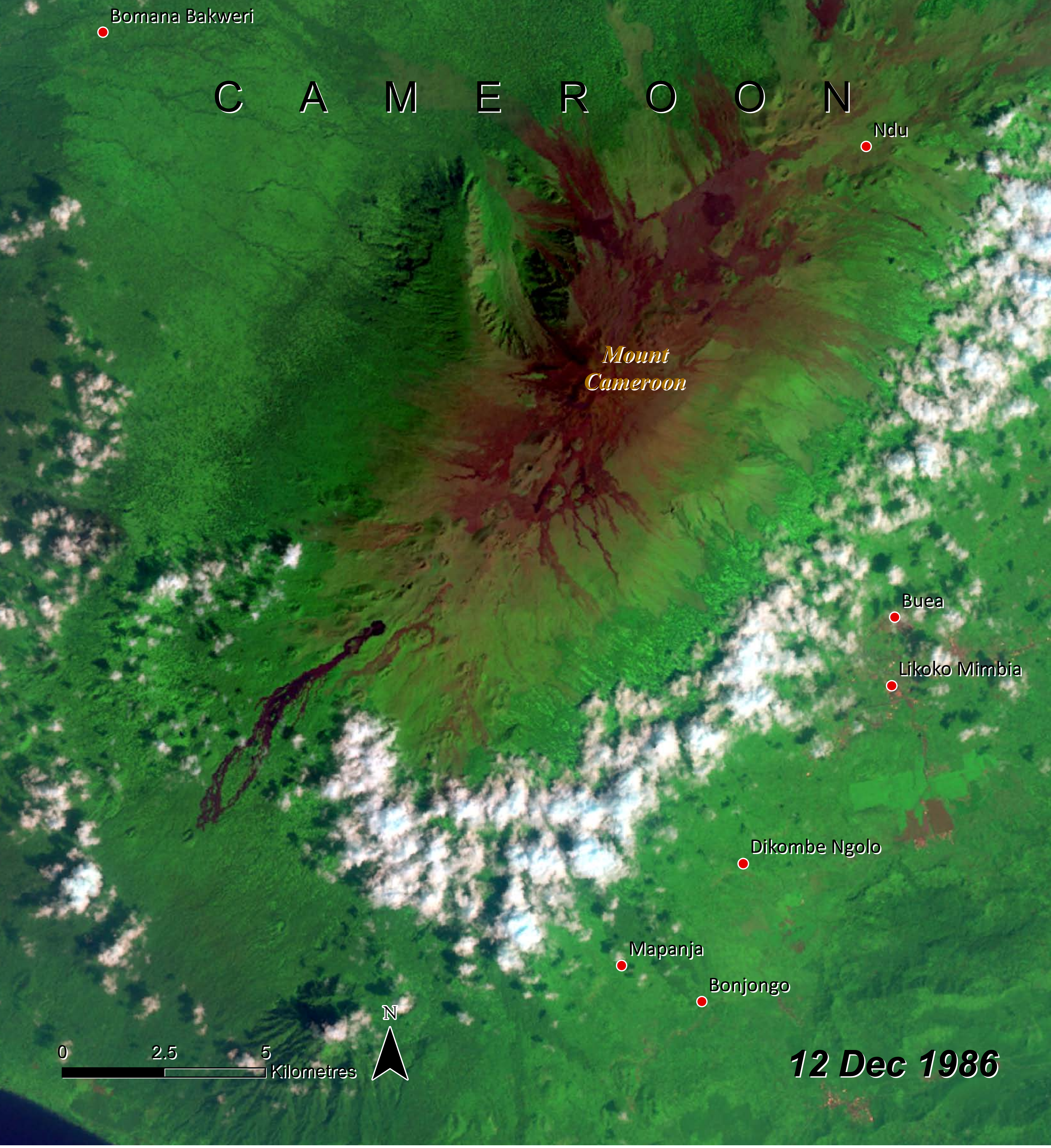
The Oldoinyo Lengai is unique as it is the only volcano in the world that has erupted carbonite lava, a very cool lava that is approximately 500-600°C compared to 1 160°C like some volcanic lava in Hawaii (USGS, 2003b). Because of a chemical reaction that occurs when it absorbs water, the lava turns white once it cools, instead of black as in the case of most volcanoes. Although the area surrounding Oldoinyo Lengai is relatively remote and sparsely populated, it is still home to many villagers living around the volcano who could be at risk during eruptions. Local residents, who refer to the volcano as the "Mountain of God," need proper risk reduction strategies to decrease their vulnerability to impacts from eruptions, which could contaminate water and endanger livestock (USGS, 2009).

Volcanic activity can have other types of environmental and human impacts. On Mount Cameroon, it has contributed to the conversion of forested areas to grassland (Bussman, 2006), and eruptions from Mount Nyiragongo affect the air quality and livelihoods of residents of Goma in the DRC (Wauthier, Cayol, Kervyn, & d'Oreye, 2012). The first recorded eruption of Nabro volcano in Eritrea occurred in 2011, displacing many Eritrean villagers, causing air quality and visibility issues in Ethiopia and potentially contaminating local crops (Vervaeck & Daniell, 2011; IRIN, 2011). On the other hand, remnants of volcanic eruptions can provide valuable minerals. The volcanoes of coastal-central Africa, such as Mount Cameroon and the Cape Verde volcanic island of Santo Antão, are mined for pozzolana, a type of volcanic rock that is crushed and used to make cement (Newman, 2012a; IPB, 2012).

In certain regions of Africa, volcanic activity can cause toxic gases to accumulate in lakes. Lake Nyos and Lake Monoun along the Cameroon Volcanic Line (See Chapter 1) are two volcanic crater lakes that continuously release carbon dioxide (CO_2) from their depths (Kusakabe, et al., 2008). In 1986, a huge bubble of CO_2 surfaced in Lake Nyos, killing over 1 700 people and 3 000 cattle that were engulfed by the fumes (Kling, et al., 1987). Lake Kivu lies southwest of the Nyiragongo and Nyamuragira volcanoes. The lake holds large amounts of methane and CO_2 below its surface, which threatens the millions of people in the surrounding communities of the Lake Kivu Basin with the potential for a lethal gas discharge should an earthquake or volcanic eruption occur (TCE, 2012). In 2000, CO_2 monitoring stations were installed at both Lake Nyos and Lake Monoum and pipes were installed to safely remove gas from the lake (Bang, 2012). The methane in Lake Kivu cannot be vented because it could be an environmental hazard, but there is the potential to extract the methane to use as an energy source (TCE, 2012).

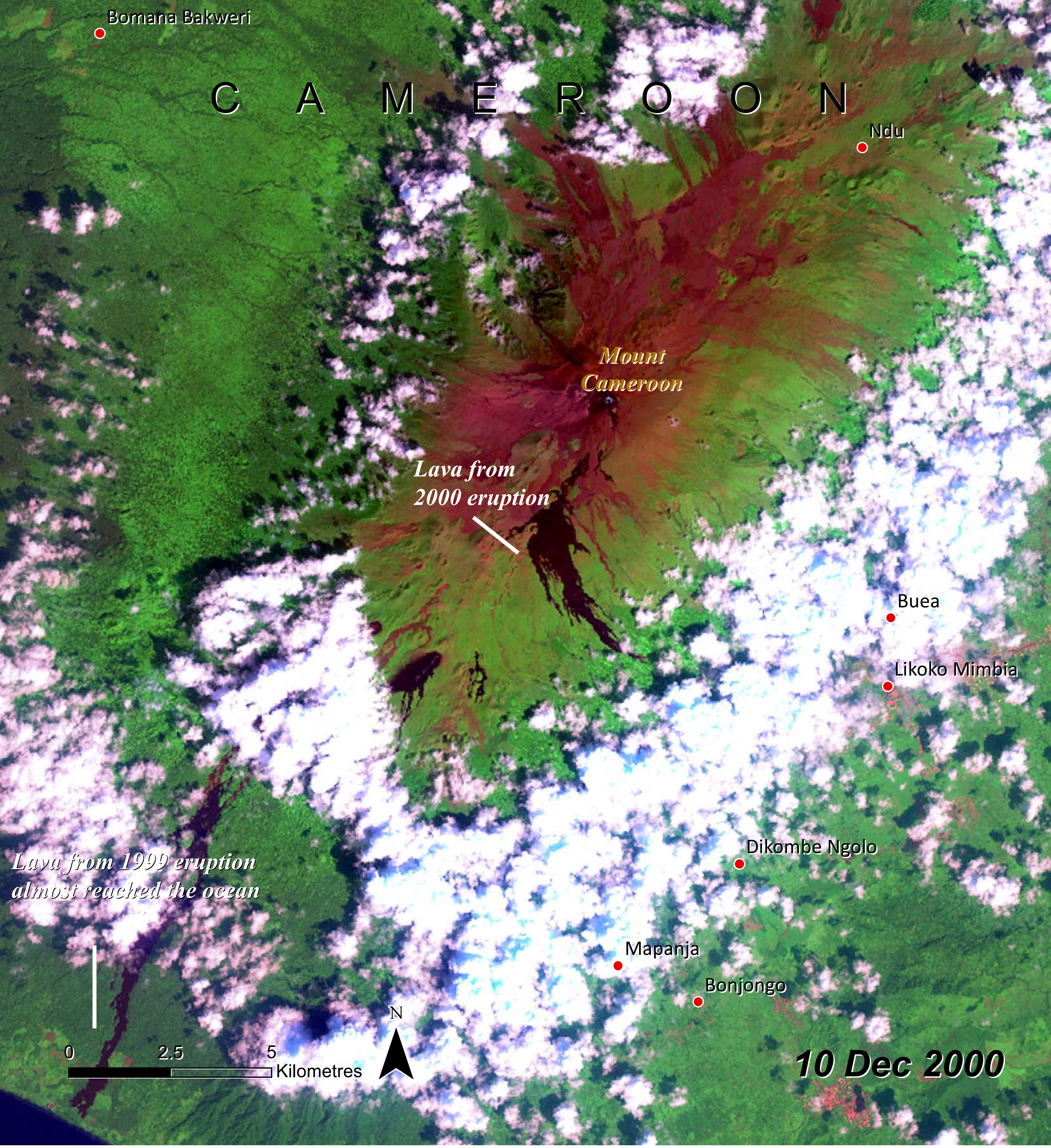
Oldoinyo Lengai

117

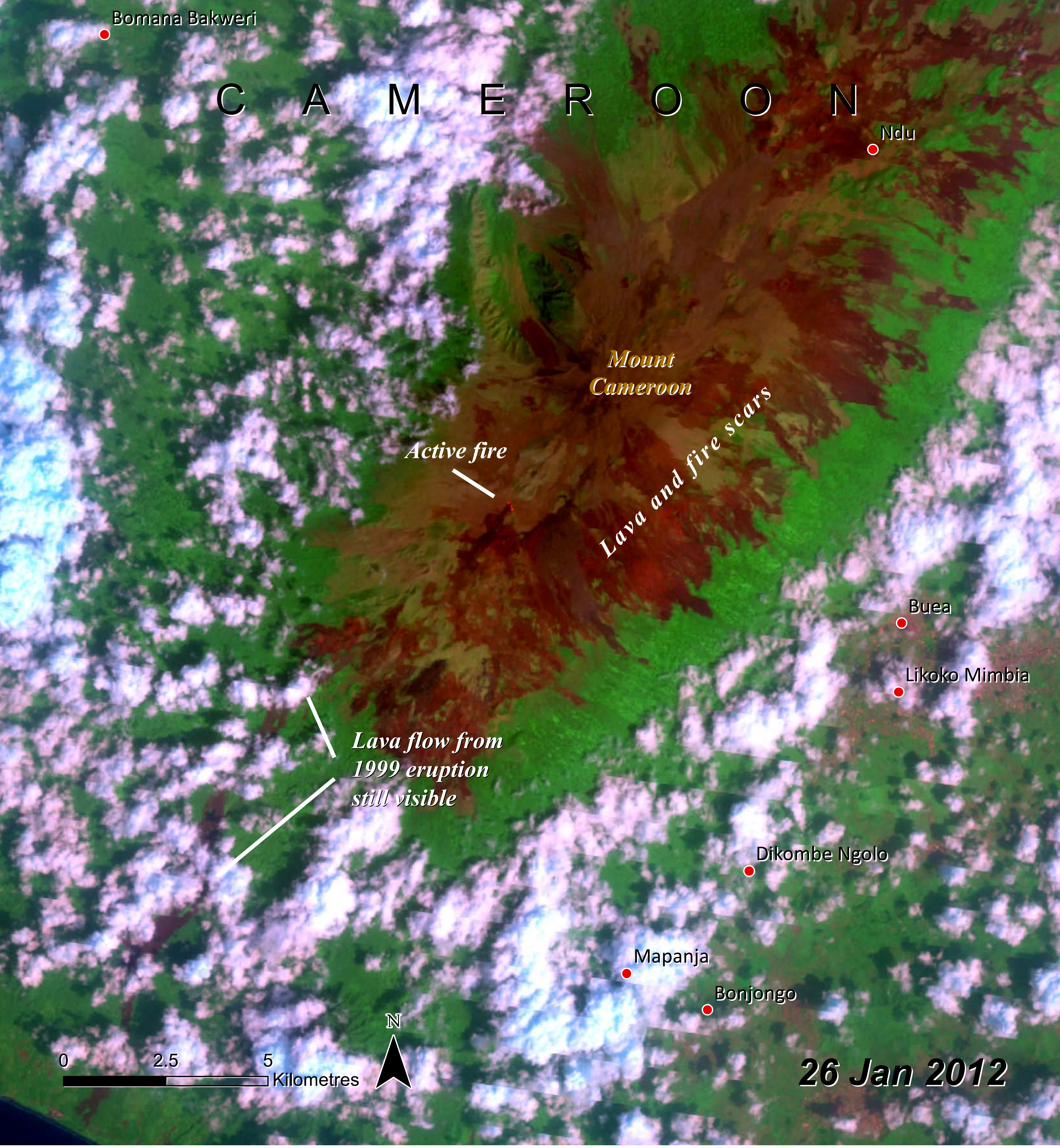


Hotspot: Mount Cameroon, Cameroon

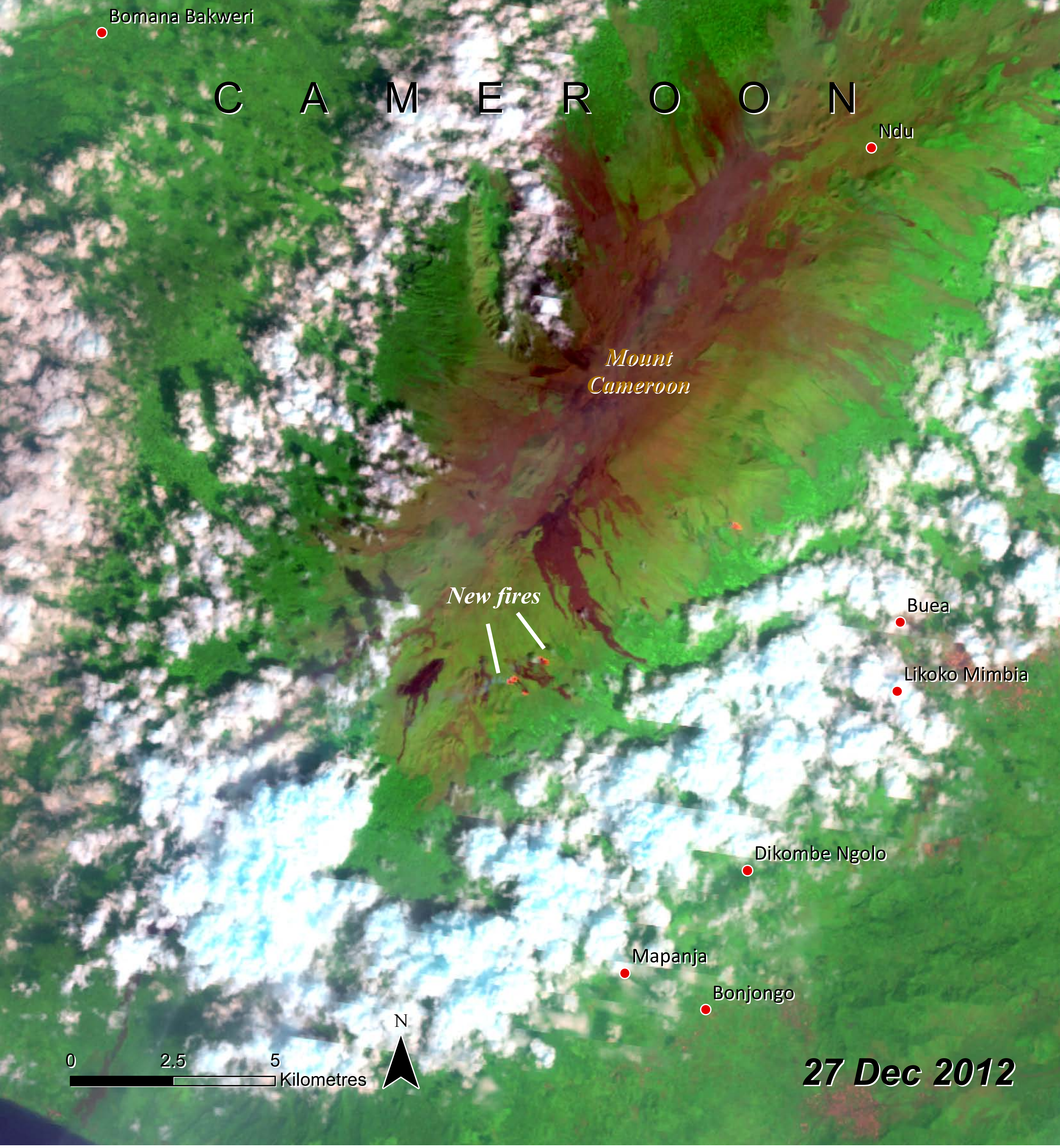
Mount Cameroon is a stratovolcano, emerging 4 095 m above the Atlantic coast of Cameroon in Central Africa. Its eruption history dates back as far as 450 BCE (plus or minus 50 years) and it has erupted at least 18 times since then (SIGVP, 2014) including in 1909 and 1922, followed by a 32 year period of dormancy and then erupted again in 1954 and 1959 (Tsafack, Wandji, Bardintzeff, Bellon, & Guillou, 2009). Then, there was another period of inactivity that lasted 22 years until an eruption in



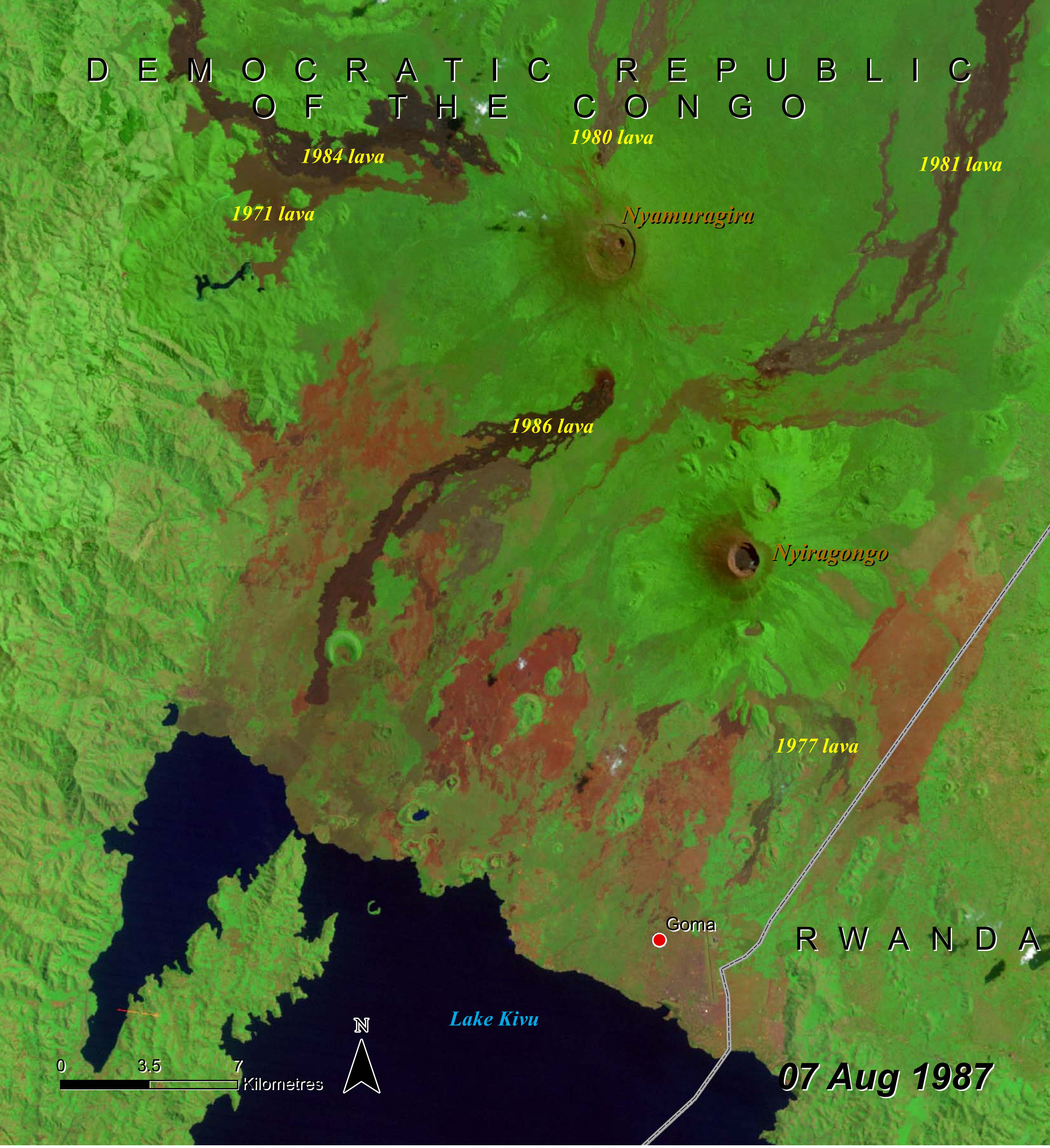
October of 1982. Subsequent eruptions occurred in 1989, 1999 and 2000 (SIGVP, 2014). The most recent significant eruption was recorded over a period of nearly two months from 28 May to 19 June 2000 (Suh, et al., 2003); some reports noted that the eruption lasted into September of 2000 (SIGVP, 2014; Wantim, Suh, Ernst, Kervyn, & Jacobs, 2011). During this eruption, activity was observed on the upper southwest flank of the volcano, at elevations of 2 750 m to 4 000 m (SIGVP, 2014). The satellite images show Mount Cameroon before and after the 2000 eruption.

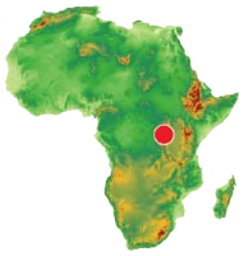


After nearly 12 years of little or no activity, tourists reported hearing loud explosions and seeing flames and ash being emitted from Mount Cameroon (SIGVP, 2014). These satellite images show the amount of change in land-cover type on the summit before and after the eruption in 2000 and the activity in 2012. Extensive fires, evident in the 2012 images, show the fire scars in the January image and vegetation regrowth in the December 2012 image. Hunters tend to set bush fires to the grasslands and forests during the dry season at high elevations on Mount Cameroon (Bele, Focho, Egbe, & Chuyong, 2011)



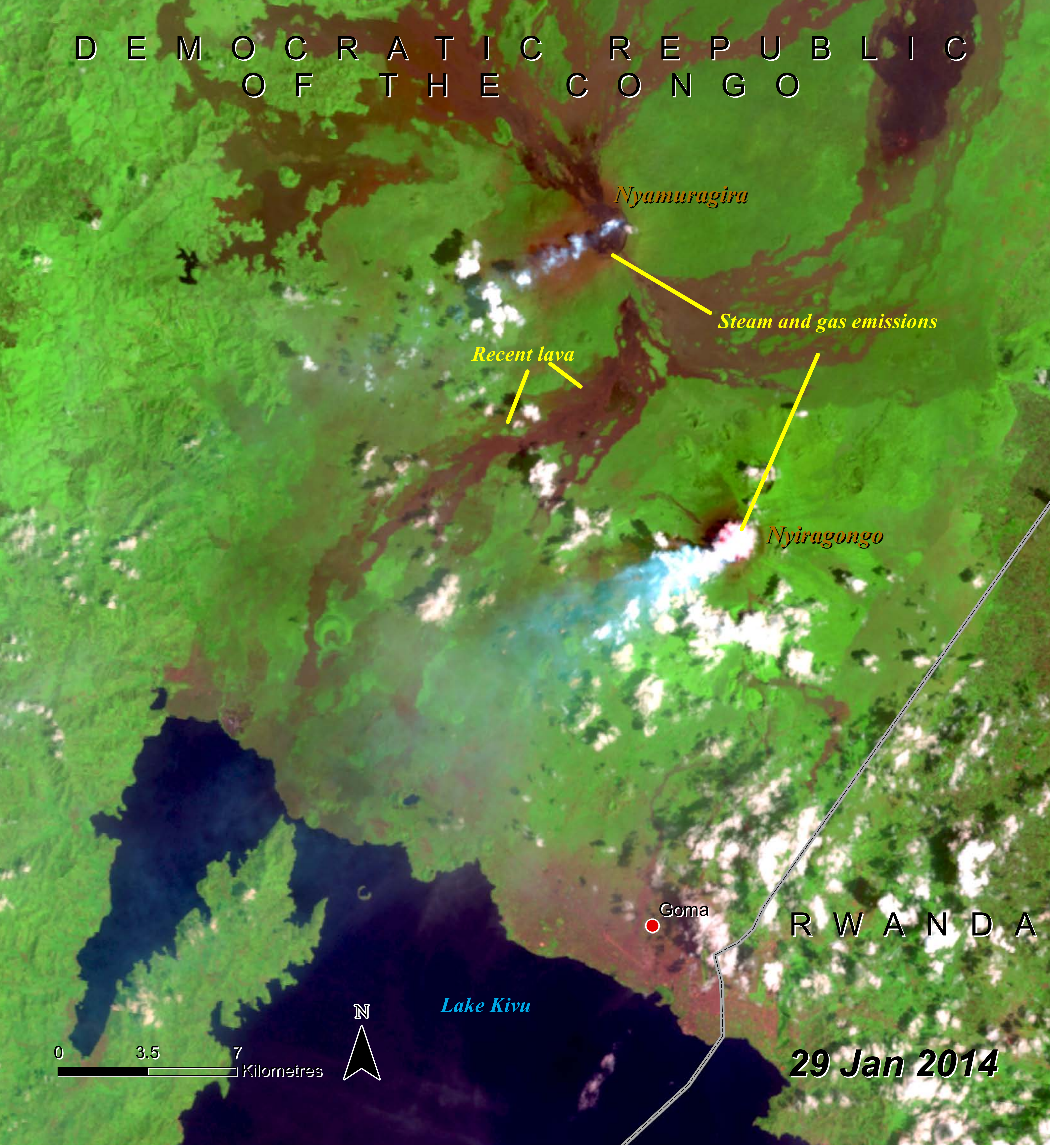
as a way to clear land to find bushmeat. Impacts of eruptions on the indigenous people that reside on Mount Cameroon include health hazards, such as exposure to ash and poisonous gases, destruction of ecosystems and property from lava flows and disruption of livelihoods (Atanga, Merve, Njome, Kruger, & Suh, 2010). Bush fires are also used to clear land for agriculture (Akumsi, 2003). Lava scars from the 2000 eruption are still visible in the December 2012 image.





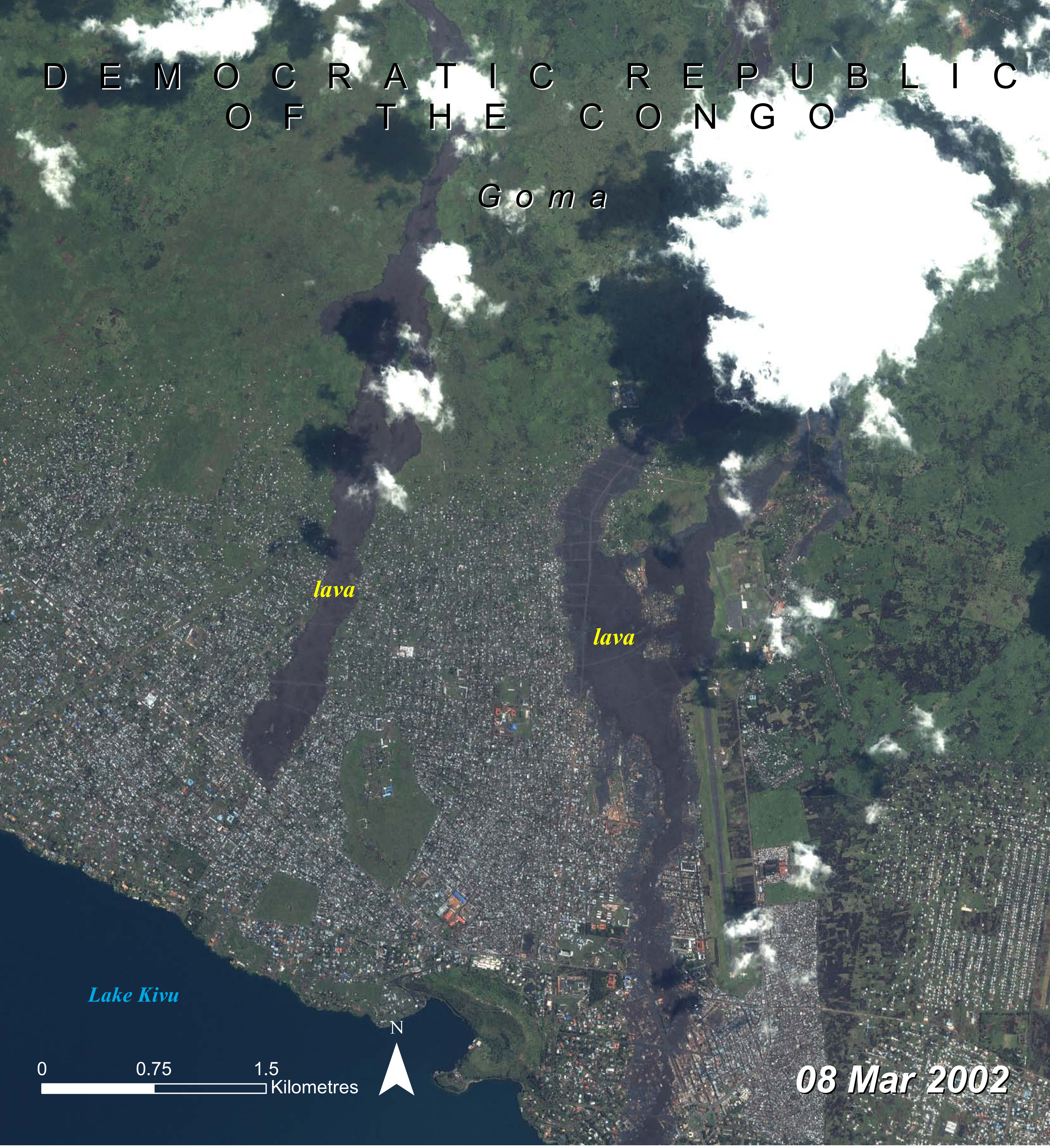
Hotspot: Nyamuragira, Nyiragongo and Goma, DRC

Nyiragongo, a stratovolcano, and Nyamuragira, a shield volcano, are located in the DRC north of the densely populated city of Goma and reach elevations above 3 000 m. High volcanic activity in this area is due to its location in the East African Rift, where two parts of the African Plate are moving apart (UNOPS, 2009). Nyiragongo has erupted almost 20 times since 1884 and Nyamuragira has erupted more than 30 times since 1865; scars of past lava flows are evident in the satellite images above (SIGVP, 2014).



Nyiragongo has the world's largest and most active lava lake in its 1.2 km-wide caldera, which contains lava that flows like water when drained (VD, 2014). Past lava flows from the volcano cover at least 1 500 km^2 of the East African Rift valley region (USGS, 2003a). On 29 January 2014, steam and volcanic gas were emitted from both Nyamuragira and Nyiragongo (NASA, 2014b), as shown in the satellite images above.

Eruptions from Nyamuragira produce large amounts of lava and can flow more than 30 km from the summit, sometimes reaching nearby Lake Kivu (USGS, 2003a). Lava



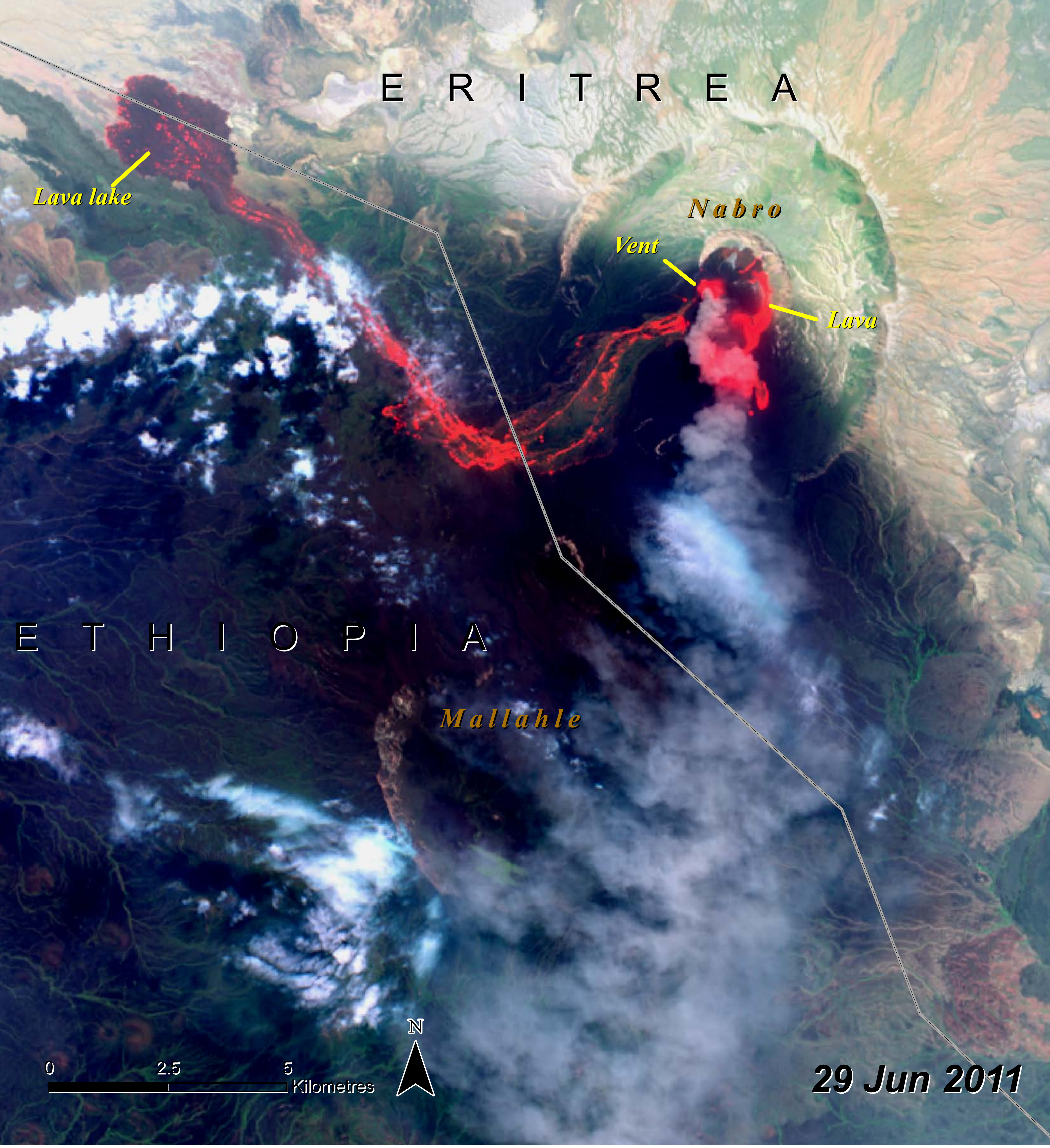
from Nyiragongo can also flow long distances, which can pose a threat to the residents of the city of Goma. The residents of Goma are at risk lava flows from volcanic eruptions, excessive carbon dioxide emissions from fractures and acid rain. Lava can pollute the water supplies if flows infiltrate rivers that serve as drinking water supplies. This was the case after a minor eruption of Nyamuagira in January 2010 in which three days after the eruption, lava continued to flow into nearby villages and polluted rainwater that had been collected for drinking (IRIN, 2010).

An eruption of Nyiragongo on 17 January 2002 forced the evacuation of 300 000 of Goma's residents, destroyed 15 per cent of Goma's infrastructure and caused 100 fatalities (Wauthier, Cayol, Kervyn, & d'Oreye, 2012). Lava from this eruption is evident in the March 2002 image. By 2013, the parts of Goma that were destroyed in the wake of the eruption had been rebuilt, as seen in the lighter areas of the satellite image, and the city had grown tremendously.

Hotspot: Nabro Volcano, Eritrea

Rising to 2 218 m, the Nabro volcano is the highest point of the Afar Triangle in the East African Rift Valley. It is located near the border of southern Eritrea and northeastern Ethiopia.

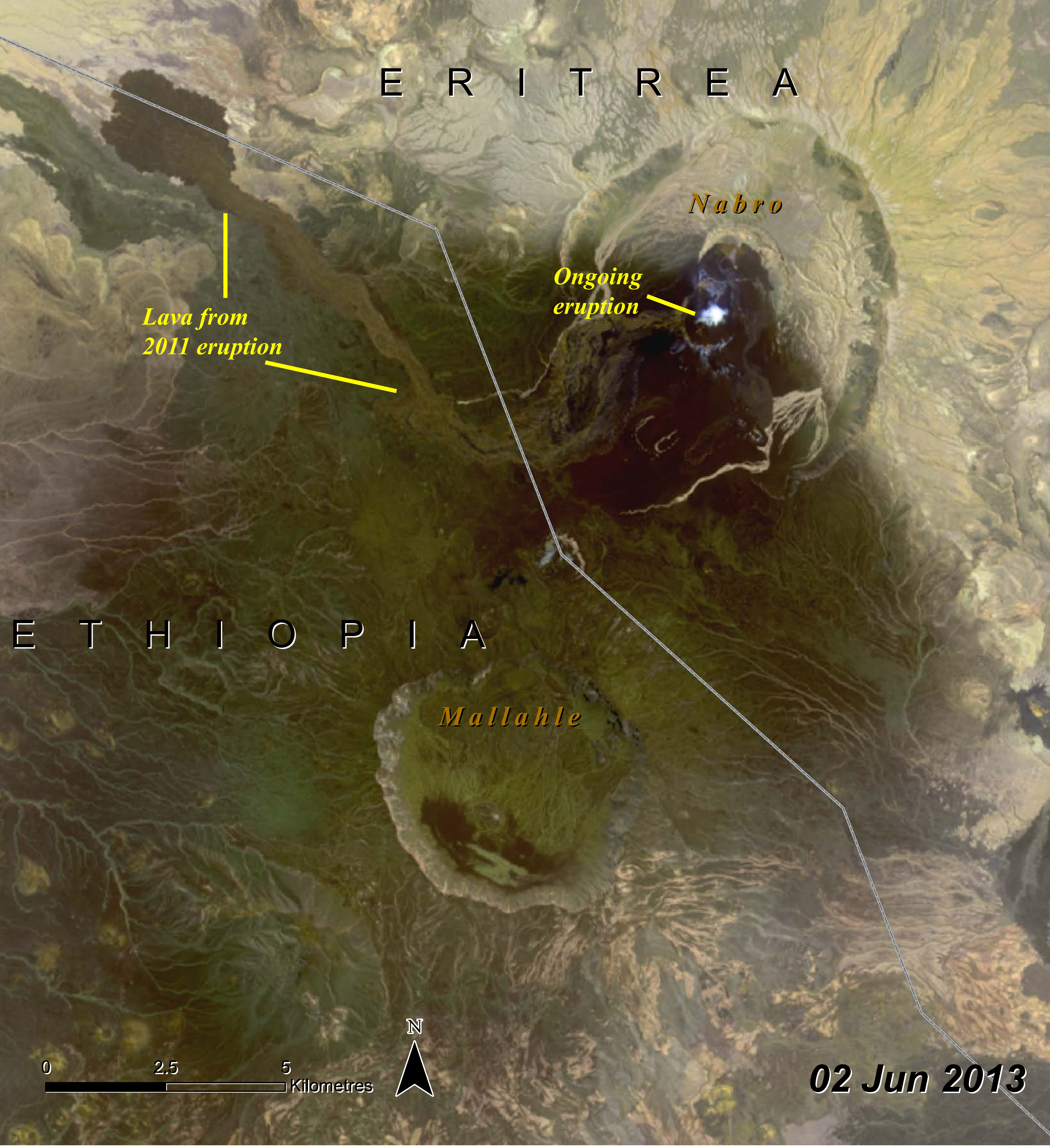
The Afar Triangle represents the junction of three tectonic plates: the Arabian, Somalian and Nubian (Sawamura, et al., 2012). Long thought to be dormant, Nabro erupted for the first time in history



in June 2011 (see inset) after a swarm of earthquakes struck the area on 12 June (SIGVP, 2013a). The volcano ejected water vapour, volcanic ash and sulphur dioxide 13 km into the air (Sawamura, et al., 2012), ultimately piercing the stratosphere (NRL, 2013). The eruption caused a residual earthquake in neighbouring Afambo, registering on the Richter scale with a magnitude of 5.4 (Mesfin, 2011). A second eruption followed three days later, piercing the stratosphere again (NRL, 2013).

Northwest winds carried the ash across Ethiopia, affecting air quality and air traffic, resulting in many cancelled domestic and international flights (Mesfin, 2011).

The eruption resulted in no casualties in Eritrea since the inhabitants of surrounding villages were able to relocate (Vervaeck & Daniell, 2011), but one report did indicate that 31 people in Bidu woreda, Ethiopia died as a result of impacts from the volcanic ash as did some livestock (IRIN, 2011). Furthermore, thousands of people in Bidu, Afdera, Erebti and Teru wordeas in Ethiopia were still trying to find adequate food,



water and healthcare a month after the eruption occurred (IRIN, 2011).

The satellite images show the volcano before, during and after the eruption and two years later. Although the initial eruption was on 13 June 2011, hot lava continued to flow late into the month as shown in the June 2011 image. Some heat and minimal lava was still evident in August 2011 (SIGVP, 2013a; Sawamura, et al., 2012). Evidence of the eruption still exists two years later.

Rural life in the pastoral valleys of the Rif Mountains, Morocco

Human Impacts

The majority of human impacts on Africa's mountain environments stem from Africa's growing population and urban expansion. It is projected that Africa's population will increase from 1 billion (2010 estimate) to 1.6 billion by 2030, representing nearly 20 per cent of the world's population (AfDB, 2012). As population increases, so does the need for resources to support it. This includes more land converted to agriculture, more trees for cooking fuel, more energy sources and more water supplies. This section of the chapter describes some of the impacts that human activities have had on Africa's mountainous areas.

Population Density and Growth

One of the main driving forces of environmental change everywhere on Earth is population growth and high population densities, which put pressure on local environments as well as the hinterlands that serve them. Taken together, the average population density in all African mountains is triple that in the lowlands: there is an estimated average of 105 persons per square kilometre (pp/km^2) living at elevations at or above 1 500 m a.s.l., compared to the Africa average of 35 pp/km^2 (Table 3.5). However, this average can be much higher or much lower than some specific mountain areas. Bududa District on Mount Elgon in Uganda has a population density of more than 900 pp/km^2 (BDLG, 2011) and some urban areas can have more than 1 000 pp/km^2 (Table 3.6). Other areas, like the Tibesti massif, have an average population density of less than 1 pp/km^2 (Figure 3.8). Furthermore, the average population density in sub-Saharan Africa is 24 pp/km^2, but the average population density in three of Africa's tropical mountain forest areas ranges from 29.9 pp/km^2 in the Eastern Arc Mountains to 41.2 pp/km^2 in Cameroon-Nigeria to 94.6 pp/km^2 in the Albertine Rift area (Burgess, et al., 2007a).

Table 3.5: Average population density (pp/km^2) for different regions

Region	Persons per km^2 (pp/km^2)
Land ≥ 1 500 m a.s.l.	105
Land < 1 500 m a.s.l.	31
Africa	35

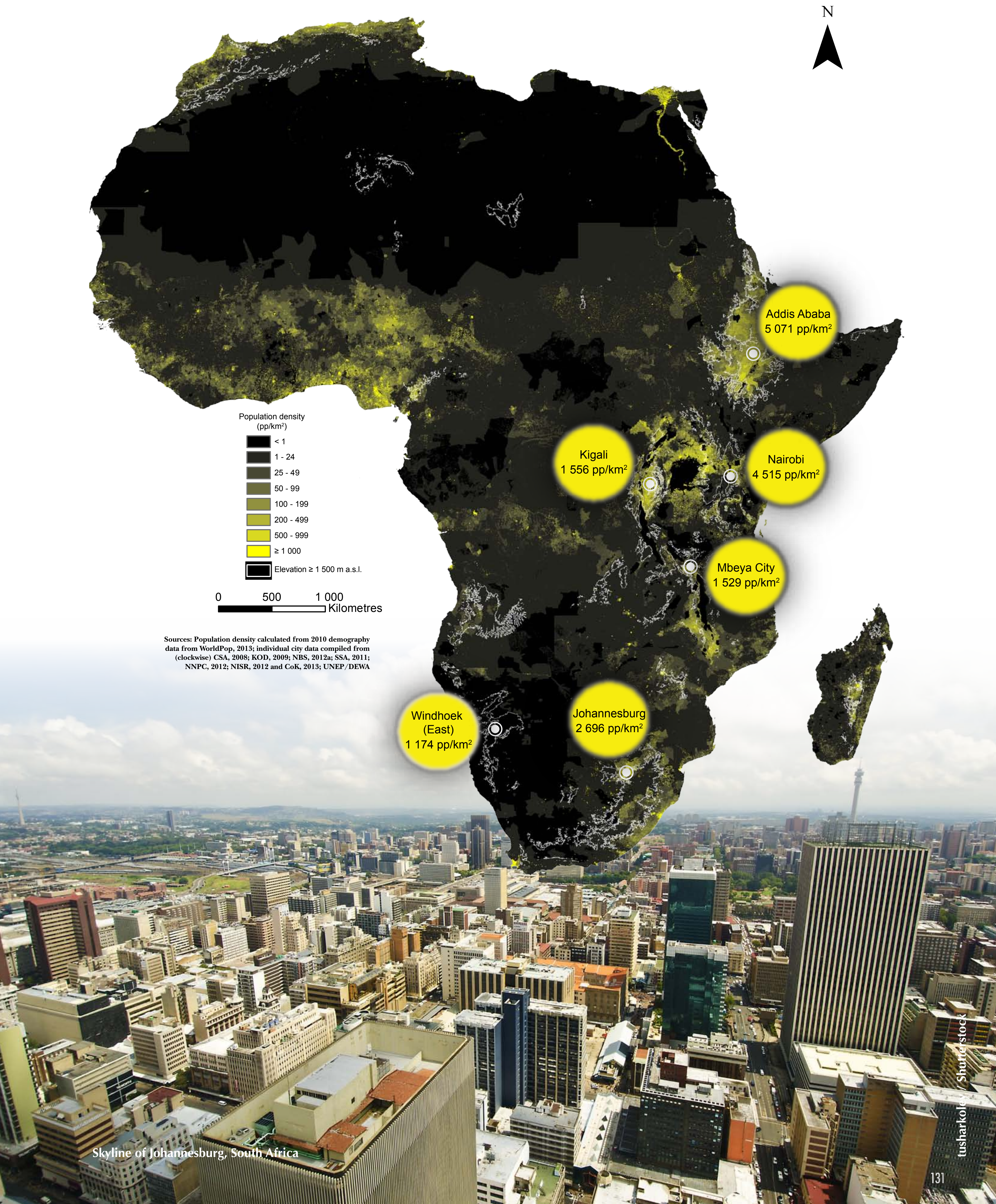
Source: Calculated from 2010 demography data from WorldPop, 2013

Table 3.6: Population density of selected cities located at or above 1 500 m a.s.l.

City	Country	Population density (pp/km^2)	Area (km^2)	Approximate Elevation (m a.s.l.)
Kigali	Rwanda	1 556	730	1 590
Johannesburg	South Africa	2 696	1 645	1 780
Nairobi	Kenya	4 515	695	1 720
Addis Ababa	Ethiopia	5 071	540	2 400
Windhoek (East)	Namibia	1 174	19	1 650
Mbeya City	United Rep. of Tanzania	1 529	252	1 770

Sources (from top to bottom): NISR, 2012 and CoK, 2013; SSA, 2011; KOD, 2009; CSA, 2008; NNPC, 2012; NBS, 2012a

Figure 3.8: Population density (pp/km²)



Sources: Population density calculated from 2010 demography data from WorldPop, 2013; individual city data compiled from (clockwise) CSA, 2008; KOD, 2009; NBS, 2012a; SSA, 2011; NNPC, 2012; NISR, 2012 and CoK, 2013; UNEP/DEWA

Skyline of Johannesburg, South Africa

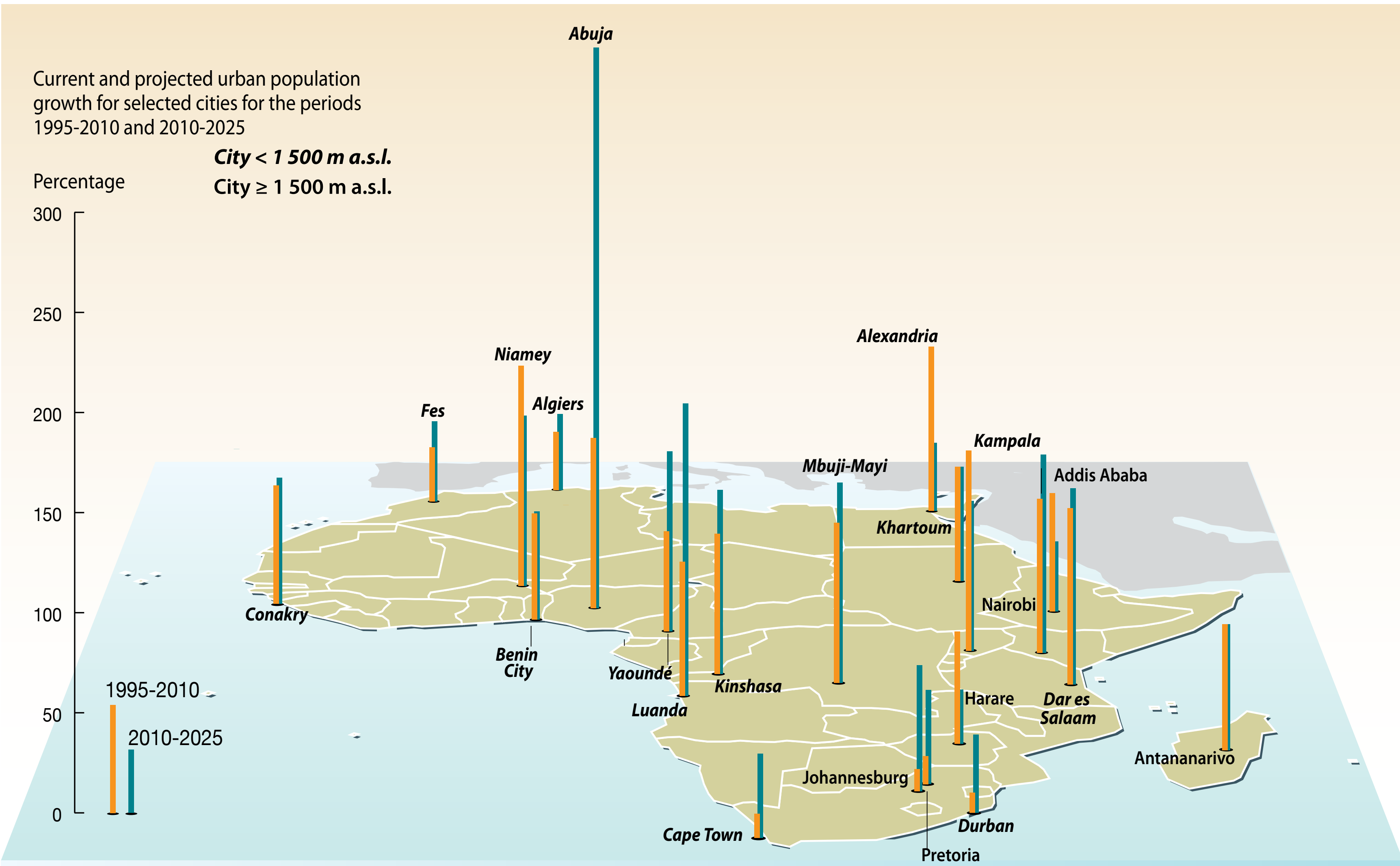

Aerial view of Windhoek, Namibia

Population growth in Africa's mountain ecosystems and surroundings varies according to region, but regardless of where the growth is happening, it can put a strain on mountain resources if resources are not properly managed. Figure 3.9 shows the past and projected population growth rates for selected highland cities and some lowland cities that depend on mountains for water, food and other resources.

Expanding settlements in mountains often leads to forest loss as people cut trees for building materials and to grow crops and graze livestock. Rural settlements are threatening the natural habitat as people exploit the natural forests for legal and illegal markets, use pesticides in farming and forest clearing, and in the Rif Mountains of Morocco, cultivate cannabis (Moore, Fox, Harrouni, & El Alami, 1998).

As explained in Chapter 2, the mountains of northern Africa provide valuable water resources for the surrounding land. Available arable land and water resources, however, can lead to population growth and subsequent pressure on land and water resources. Increased irrigated agriculture in the Tadla and Haouz valleys at the foot of the Atlas Mountains has led to a dramatic population rise in neighbouring cities, such as Marrakech (UF, 2002), which has more than one million inhabitants (2004 census) (CND, 2009) (see Marrakech hotspot). Increasing populations along the Oued Sebou, which rises in the Middle Atlas, and its tributary, the Oues Fez (Hunink, Terink, Droogers, Reuter, & Huting, 2011), is elevating pollution levels of the rivers due to dumping of domestic sewage and industrial effluents (Perrin, Raïs, Chahinian, Moulin, & Ijjaali, 2014). These rivers provide water for irrigation of food crops such as

Figure 3.9: Urban growth rate of lowland and high elevation cities



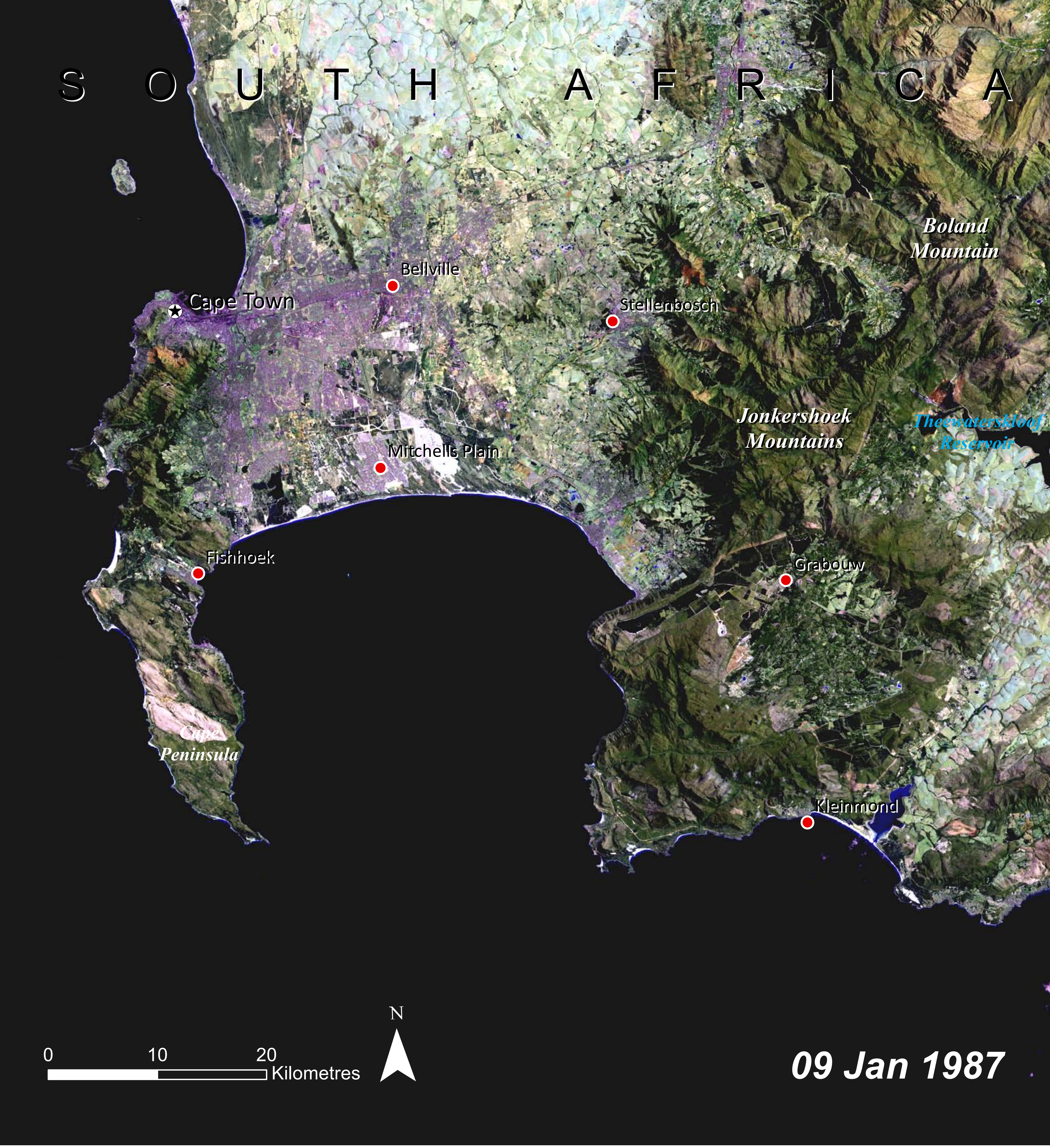
Source: UNDESA, 2010 modified from Pravettoni & UNEP/GRID-Arendal, 2011 rice, wheat and sugarbeet as well as for some olive groves and vineyards and thus, pollution could cause public health issues (Perrin, Raïs, Chahinian, Moulin & Ijjaali, 2014). The estimated economic losses per year are nearly US$247 million due to water pollution in the Oued Sebou (Bouchouata, Ouadarri, El Abidi, El Morhit, & Attarassi, 2012). For the populations surrounding the Ahagghar massif in neighbouring Algeria, continued growth is putting even more pressure on already scarce water resources. The water source for Tamanrasset, the biggest city near the massif, is nearly 600 km away and 1 000 m underground (Cuesta, Lavaysse, Flamant, Mimouni, & Knippertz, 2009).

Population growth in the Fouta Djallon Highland region of Guinea has led to land degradation, resulting in increased silt and sediments in watercourses and has caused springs to dry up (FAO, 2013a). This ecoregion is not well protected, resulting in fragmentation (WWF, 2014). A growing population has also led to an increase in fire instances and deforestation, which continue to threaten the forests with man-made fires, a direct cause of deforestation in the region (Allport, 1991). Sustainable management of these resources is essential to maintaining a balance between population demands and available resources (AU, 2010).

In several different areas of Africa, country conflict has contributed to direct pressure on mountain environments due to an influx of refugees leading to population growth and increased resource use. For example, The Imatong Mountains and Dongotana Hills have offered a place of hiding and refuge for many people of South Sudan during times of conflict and civil unrest. The mountain ecosystems provided protection as well as a place to hunt, gather and cultivate. Forest loss has remained minimal and people cultivated lands where they were allowed during periods of conflict. Some wildlife was affected due to poaching, however, and uncontrollable fires removed some forest cover (Gorsevski, Geores, & Kasischke, 2013). Conflict and unrest in the DRC in the 1990s led to an influx of two million refugees in the Virunga region, which includes the Virunga Mountains. The arrival of refugees has led to resource depletion on the mountains due to poaching, charcoal production and agriculture, among other human activities (ZSL, 2009).

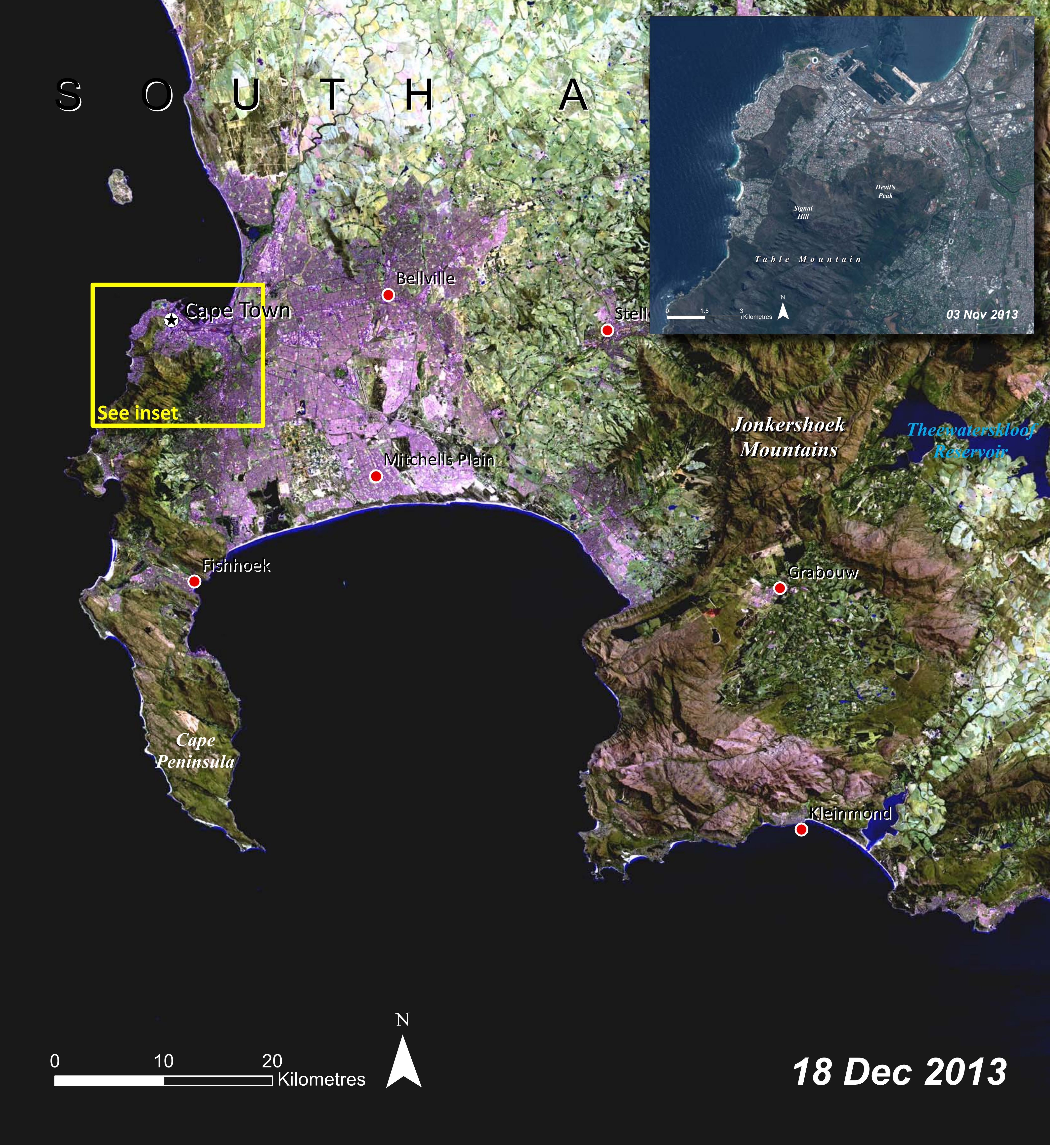
Satellite imagery in the following pages shows how urban sprawl in both mountain areas and lowlands areas, which rely on mountain areas, can impact the land and resources.

A small town in the distance in the Fouta Djallon Highlands

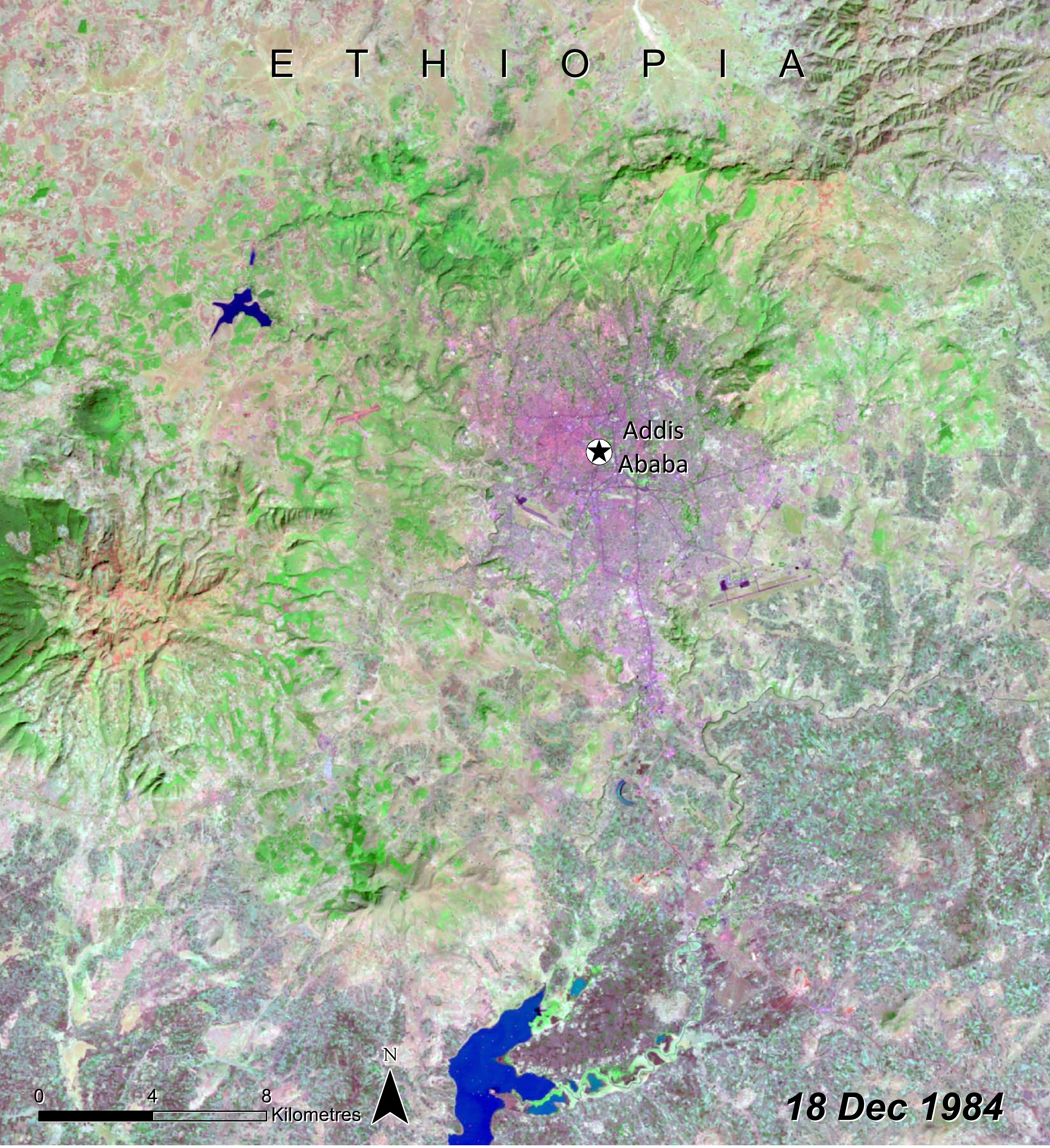


Hotspot: Cape Town and Table Mountain, Boland Mountain and the Matroosberg Mountains, South Africa

An estimated 97 per cent of Cape Town's water supply relies on surface water from mountain catchment areas (Lonsdale & Du, 2009). Cape Town wraps around Table Mountain National Park, the largest urban park in South Africa and a popular destination for tourists (Saayman, Saayman, & Rossouw, 2013). Because of the clean drinking water that trickles down from its slopes, Table Mountain is the reason Cape Town was established as a port city and trade route many centuries ago. The Platteklip

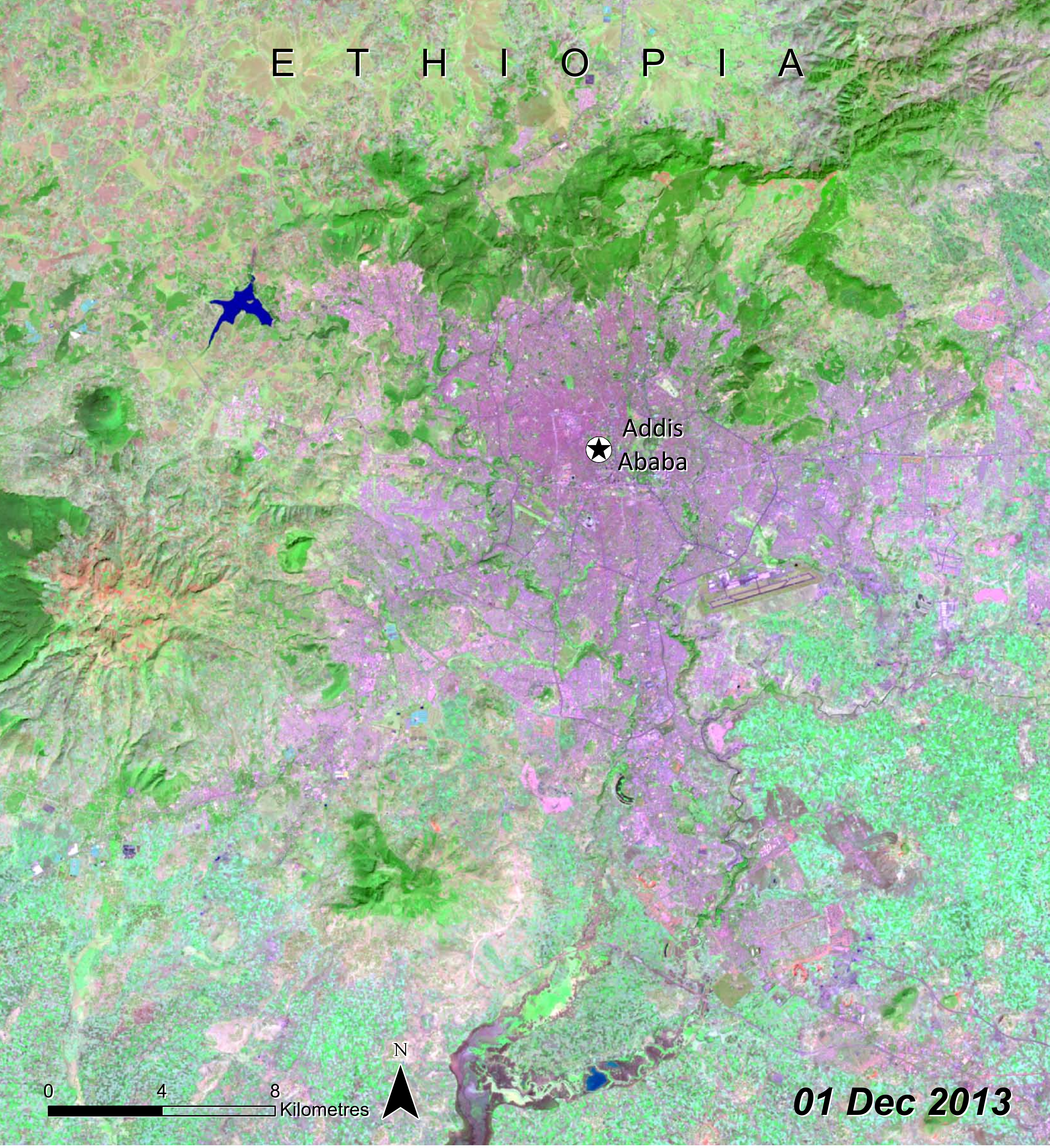


gorge and Oranjezicht springs were the first sources of water, and today, seven dams in the immediate area capture water to disperse throughout Cape Town. Population growth, however, has strained these sources and future climate change could have an impact on streamflow, evapotranspiration rates and rainfall patterns (Lonsdale & Du, 2009). Already the city has had to expand its reach to the Boland Mountain as a water source, using water from the Berg, Theewaters, Voelvlei and Steenbras dams to satisfy its water needs (WWF South Africa, 2013).

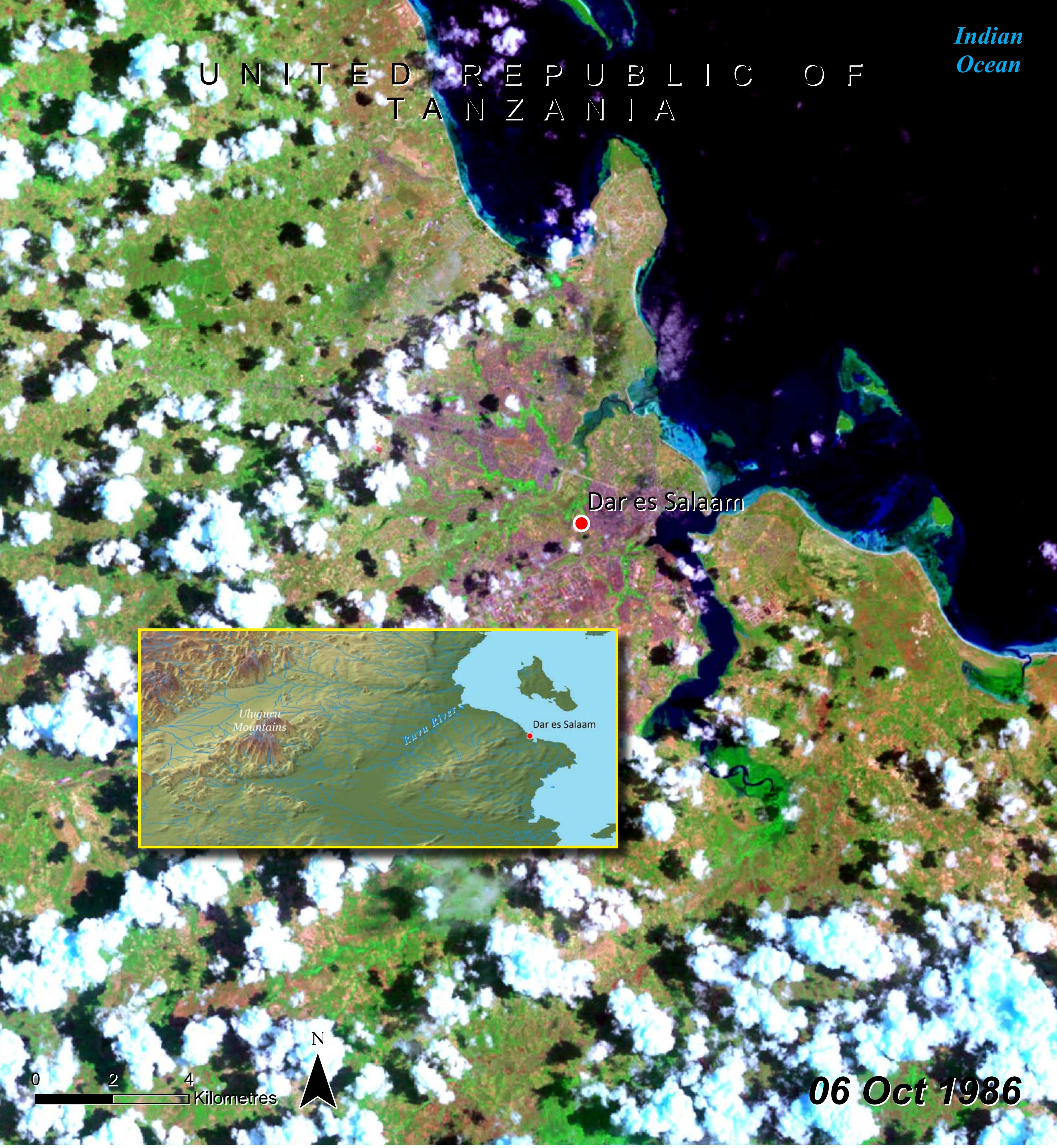


Hotspot: Addis Ababa, Ethiopian Highlands, Ethiopia

Located in the Ethiopian Highlands, Addis Ababa is the capital of Ethiopia and the centre of much of the country's industrial activity. Although the rugged terrain can inhibit expansion and growth, the city of Addis Ababa has grown rapidly over the past three decades (Dorosh, et al., 2011). The percentage of urban residents in Addis Ababa has risen from 61.2 per cent in 1984 (Schmidt & Kedir, 2009)

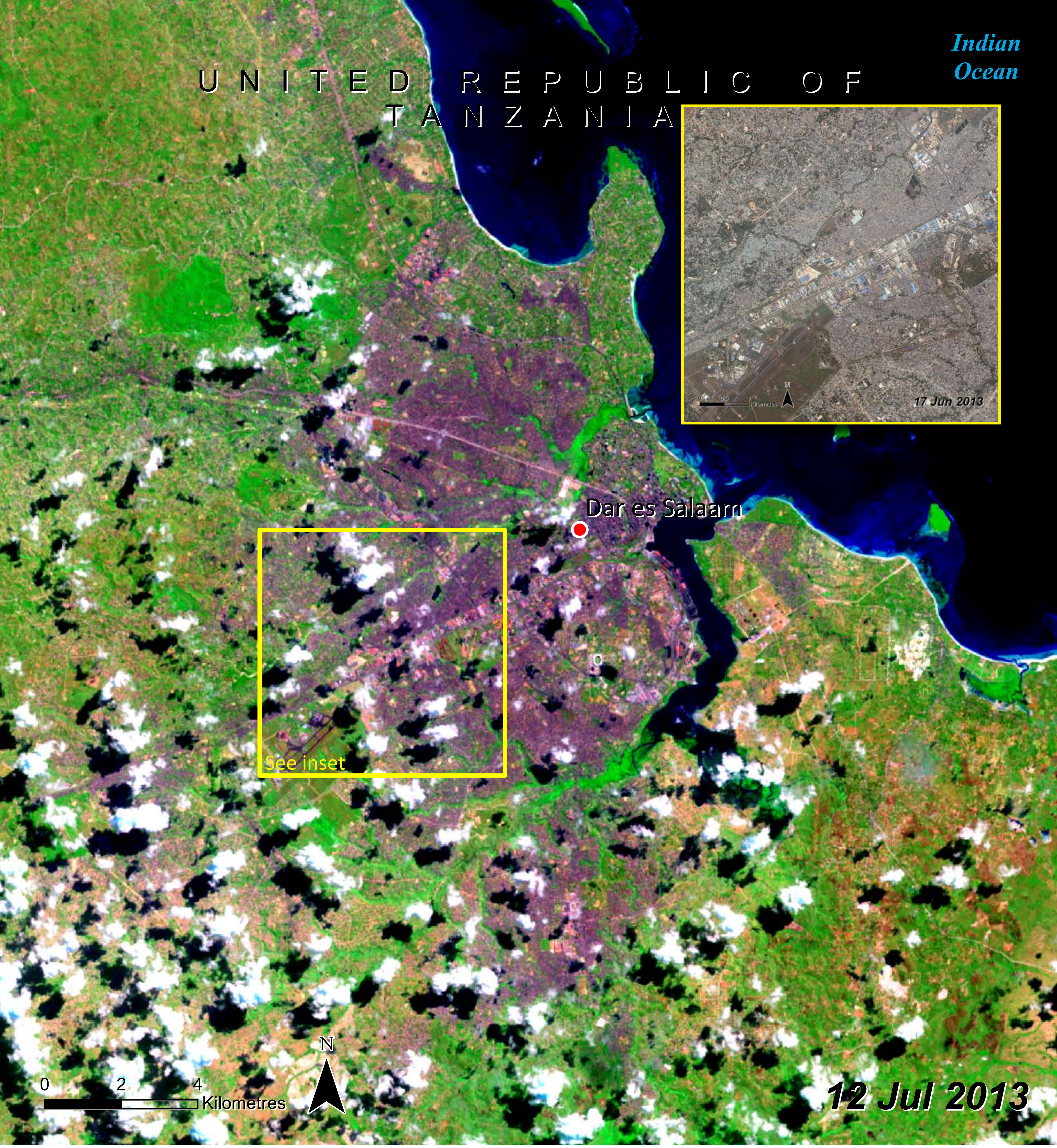


to 98.7 per cent in 1994 to 100 per cent in 2007. The city's population is projected to reach 3.4 million by 2017 and 5 million by 2037 (CSA, 2012a). Drivers of migration to the city include "push" factors such as the increasing lack of enough land to farm profitably in rural areas (Hunnes, 2012) and "pull" factors like education and job opportunities in the city (CSA, 2012b).



Hotspot: Dar es Salaam, Uluguru Mountains, United Republic of Tanzania

The montane forests of the Uluguru Mountains, part of the Eastern Arc Mountain range, capture and store water, but are under pressure from population growth, fire, agriculture and logging (Ngana, Mahay, & Cross, 2010). Deforestation has led to increased siltation of the Ruvu River, which begins in the Ulugurus and is the primary source of water for Dar es Salaam (Yanda & Munishi, 2007), the United Republic of Tanzania's largest city (NBS, 2012b). Approximately 262 million litres of water is taken



from the Ruvu River each day to be treated and piped to Dar es Salaam (START, TMA, & AU, 2011). However, much of this water goes to waste due to poor infrastructure resulting in leaks or unauthorized use, leading the city to look to other rivers and groundwater to supplement supply (Ngana, Mahay, & Cross, 2010). The population of Dar es Salaam grew from 1.4 million in 1988 to 4.4 million by 2012, the greatest change in population of all regions. The city now accounts for 9.7 per cent of the country's total population (NBS, 2013). With a projected population of 6 million by 2020 in Dar es Salaam, increased abstraction from the Ruvu and a growing agriculture sector along the river also increasing demand, serious pressure will be put on the water supply (Ngana, Mahay, & Cross, 2010).

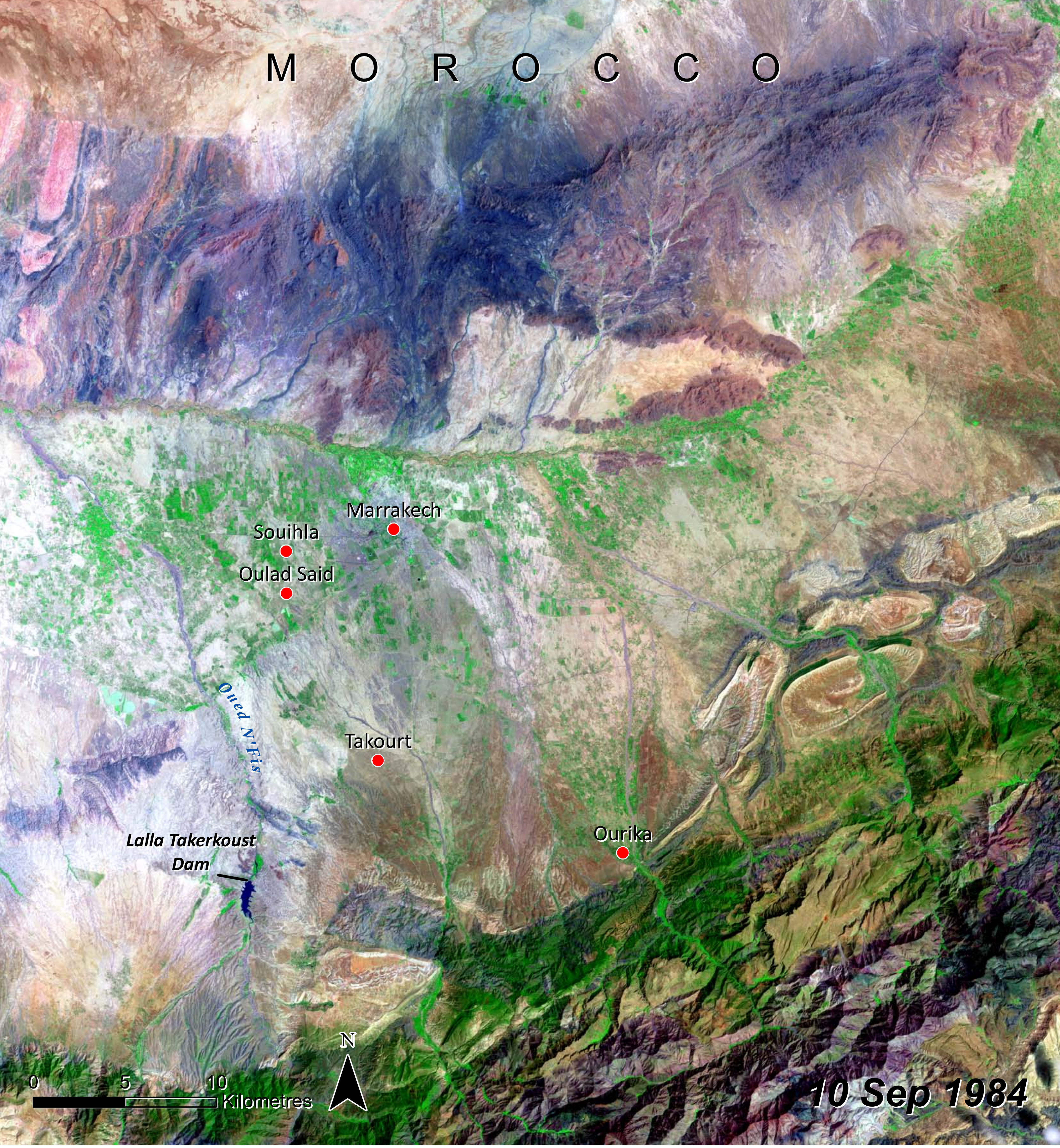
Mountain Agriculture

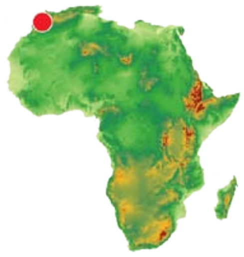
As already noted, most of Africa's mountain regions are more favourable for farming than the lowlands. Given the high dependence on agriculture in Africa, many mountain areas have high population densities. For example, the Ethiopian Highlands account for 95 per cent of the country's arable agriculture (FAO, 2002) and support 70 per cent of the population (FAO, 2011b). Best management practices are essential to maintain the land's ability to sustain both human livelihoods and ecosystem values. This is especially required now that many farmers are abandoning subsistence farming and planting more cash crops like vegetables and flowers for the European market and coffee for the international market (FAO, 2013b).

Besides fertile land, mountain ecosystems are also favoured for settlement as they offer good grazing pasture for livestock, as well as fuelwood, a major source of energy for rural communities. With high population densities, however, agriculture in mountainous areas can increase the susceptibility to soil erosion. Erosion occurs when natural vegetation is removed from slopes and land is converted agriculture, as occurs in Morocco's mountainous areas (Dahan, et al., 2012). The Rif Mountains are exceptionally vulnerable to soil erosion, losing an average of 10 m^3/ha/yr (Croitoru & Merlo, 2005). Soil degradation is further exacerbated due to tillage; tilling up and down slope has led to net soil transport in the tillage direction (Dahan, et al., 2012). Some crops, however, such as coffee, a major cash crop for eastern Africa (see Chapter 2), can help to

Steep agricultural terraces in Imlil, Morocco in the High Atlas Mountains maintain land cover and soil fertility when grown in their native forests and intermixed with other crops (Hylander, Nemomissa, Delrue, & Enkosa, 2013).

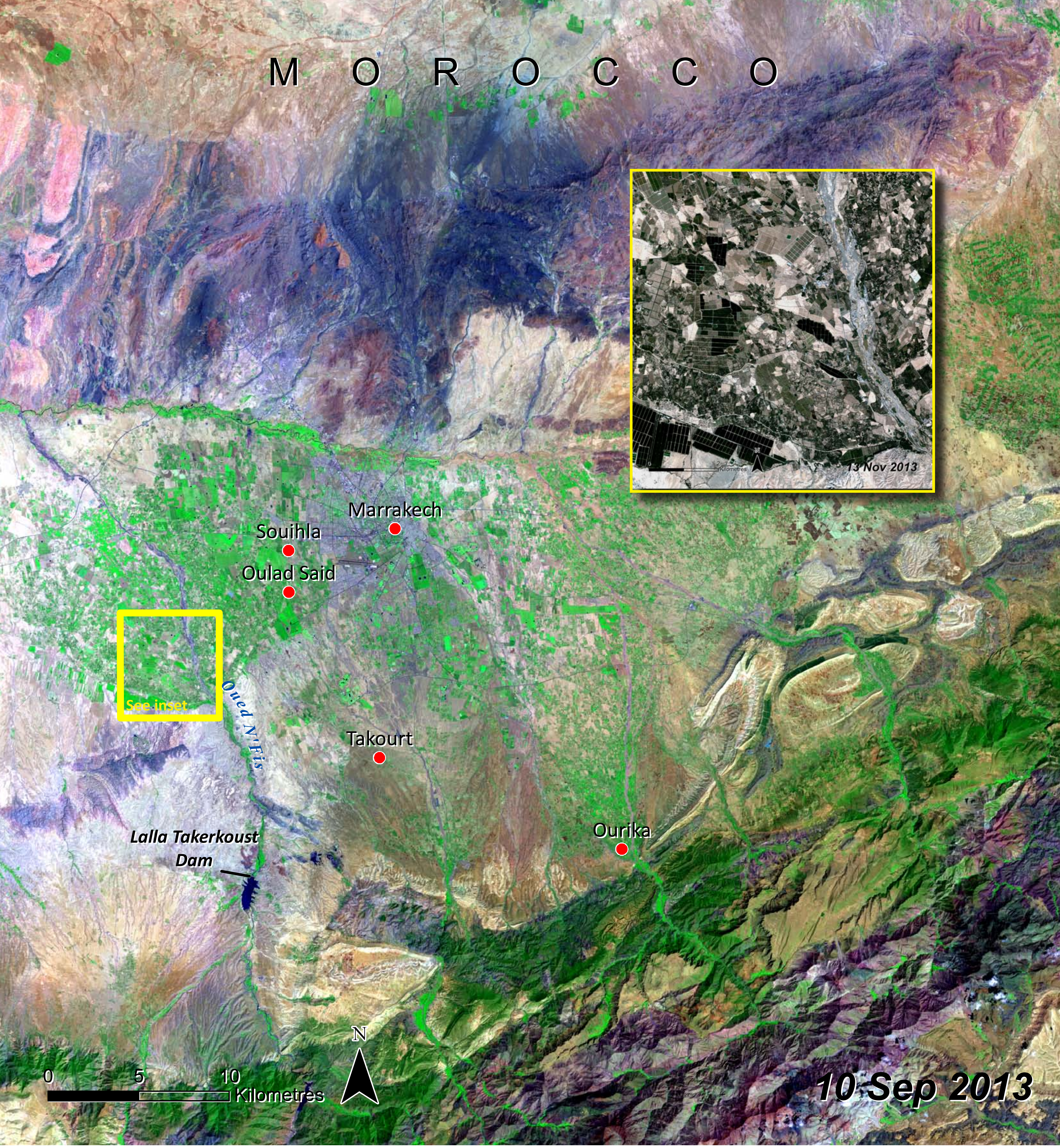
Irrigated agriculture is practised at very low levels in most African countries, but there is a significant potential to expand irrigation by using untapped water in originating rivers and lakes. Traditional and food-crop agriculture in Morocco occupies 80 per cent of usable agricultural area, including mountainous zones, but it is narrowly dependent on precipitation (AAD, 2009) and thus reliant on other sources for irrigation. The mountains help to generate rainfall, protecting lowland Morocco from the hot Saharan desert and providing a source of irrigated agricultural land; irrigated terraced agriculture can provide food for approximately 28 pp/km^2 (Barrow & Hicham, 2000; Ait Hamza, 1996). Irrigation could also be expanded in the Congo River catchment area, which covers 3.7 million km^2 and discharges an annual total of 1 269 km^3 of water. It could potentially irrigate about 8 685 000 ha in the DRC, Central African Republic, the Congo and Cameroon (Bagoora, 2012b). There is also great potential to use waters from the Niger, Volta and Senegal, whose headwaters are in mountains and highlands, for irrigation purposes. The Niger River has the estimated potential to irrigate 1 036 000 ha in Guinea, Ivory Coast, Mali, Burkina Faso, Benin and Niger. Of this area, only 13.2 per cent is currently irrigated (Bagoora, 2012b).



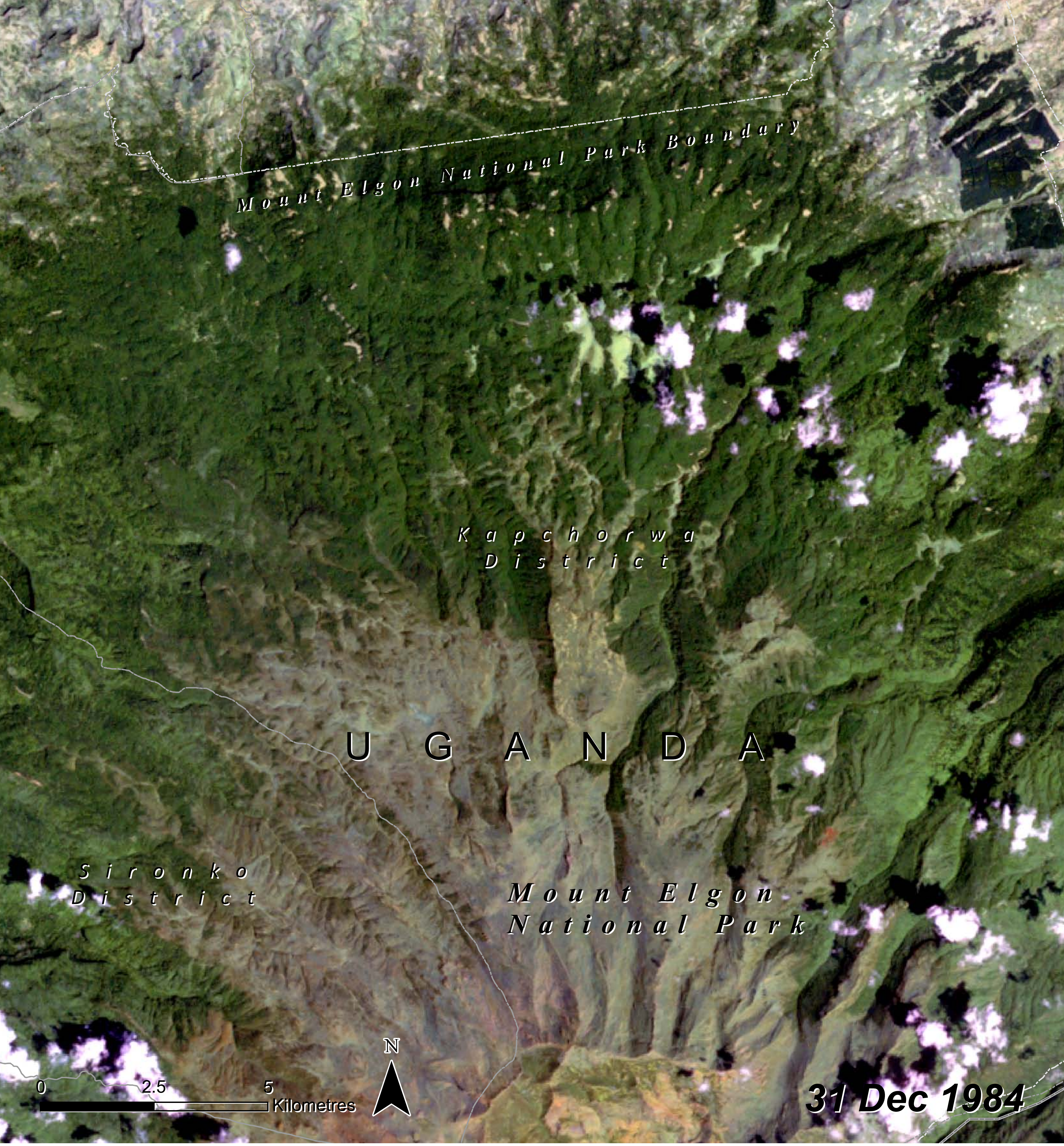


Hotspot: Marrakech, Atlas Mountains, Morocco

Agriculture currently consumes approximately 12 per cent of land in Morocco (Montanari, 2013) and along with agro-industry, contributes a combined 19 per cent of the Gross National Product (GNP) (AAD, 2009). Furthermore, the agriculture industry is responsible for the food security of 30 million people (AAD, 2009). Irrigated agriculture in the lowlands of Morocco depends on snow melt and rivers that flow from the highlands. Additionally, about 800 000 ha of irrigated agricultural lands

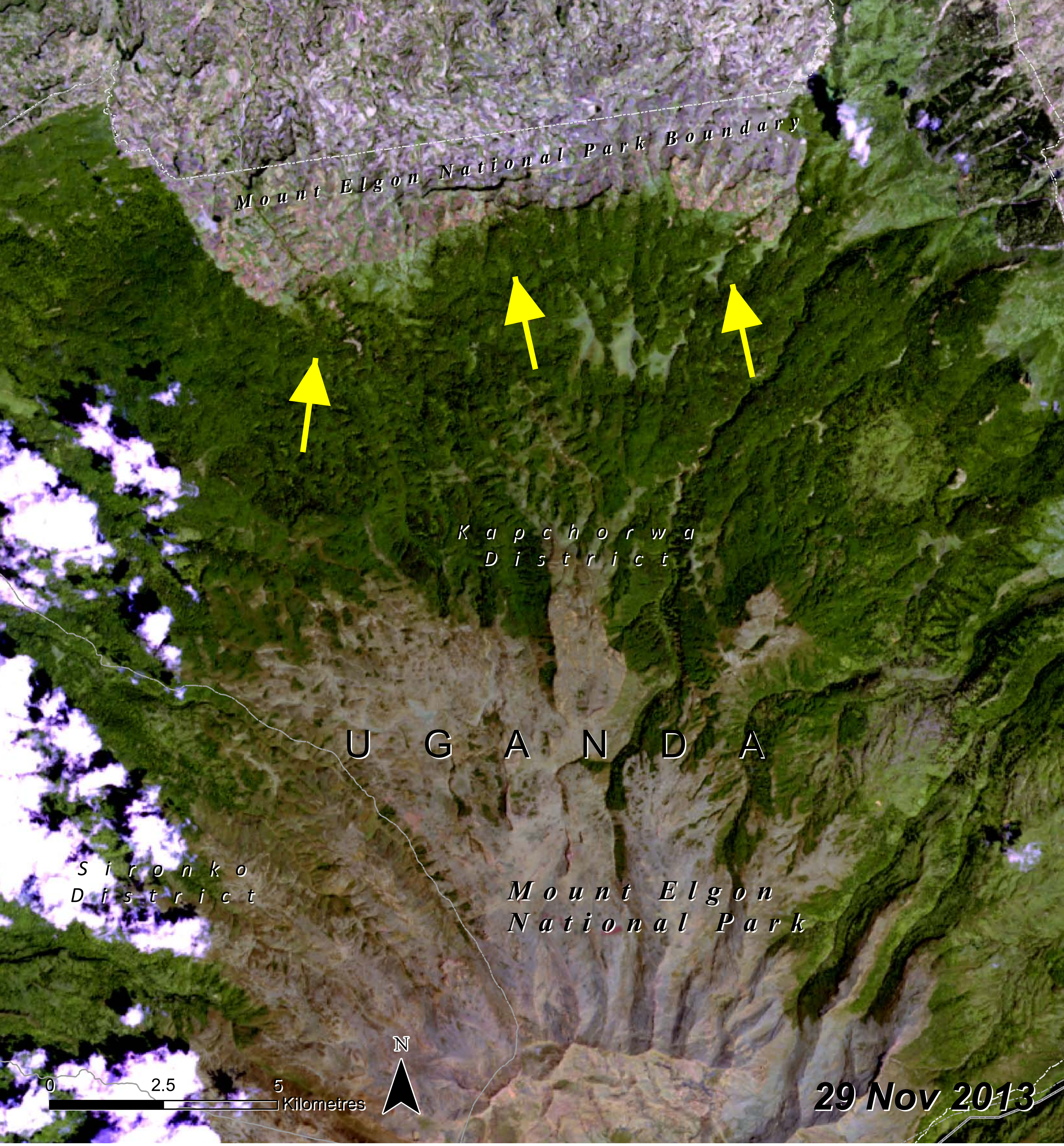


are in Morocco's Atlas Mountain regions, which can support 30 per cent of the population (Montanari, 2013). Marrakech is located in the Tensift Basin, which connects the High Atlas Mountains to the Mediterranean Sea (Rojat, 2007). The amount of agricultural land in this area increased dramatically between 1984 and 2013, especially around the Oued N'Fis (see inset), but this trend may soon change. Agriculture is expected to decrease to eight per cent by the end of the 21st century, likely due to impending water shortages brought on by climate change-induced precipitation decline (Montanari, 2013). However, to cope with future water shortages, the government of Morocco is implementing the Green Moroccan Plan for 2012 — 2020 to promote sustainable agricultural activities and promote socio-economic development (AAD, 2009).

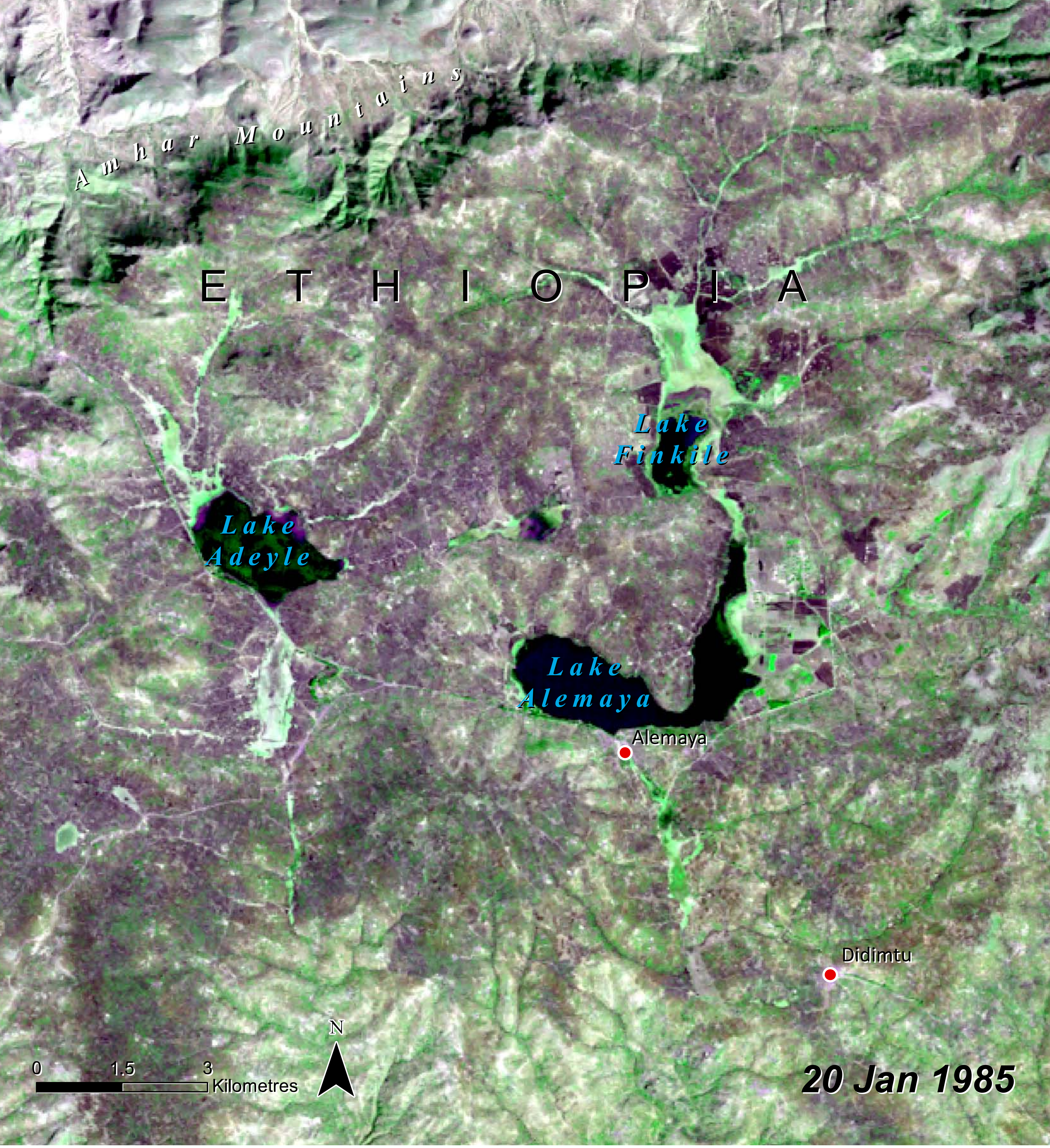


Hotspot: Mount Elgon, Uganda

Mount Elgon is a transboundary mountain, shared by Uganda and Kenya (see Chapter 4). The Benet Ndorobo people have indigenous claims on the land in the former Forest Park area, but in an effort for land managers to balance environmental and human needs, the Benet were resettled in 1983. They were provided 6 000 ha of resettlement area in Kapchorwa District by the Ugandan government. However, the Benet still heavily relied on the forest for their livelihoods, seeking out honey, fruit and medicinal plants. Additionally, lowland communities in search of land also began to push up the mountain

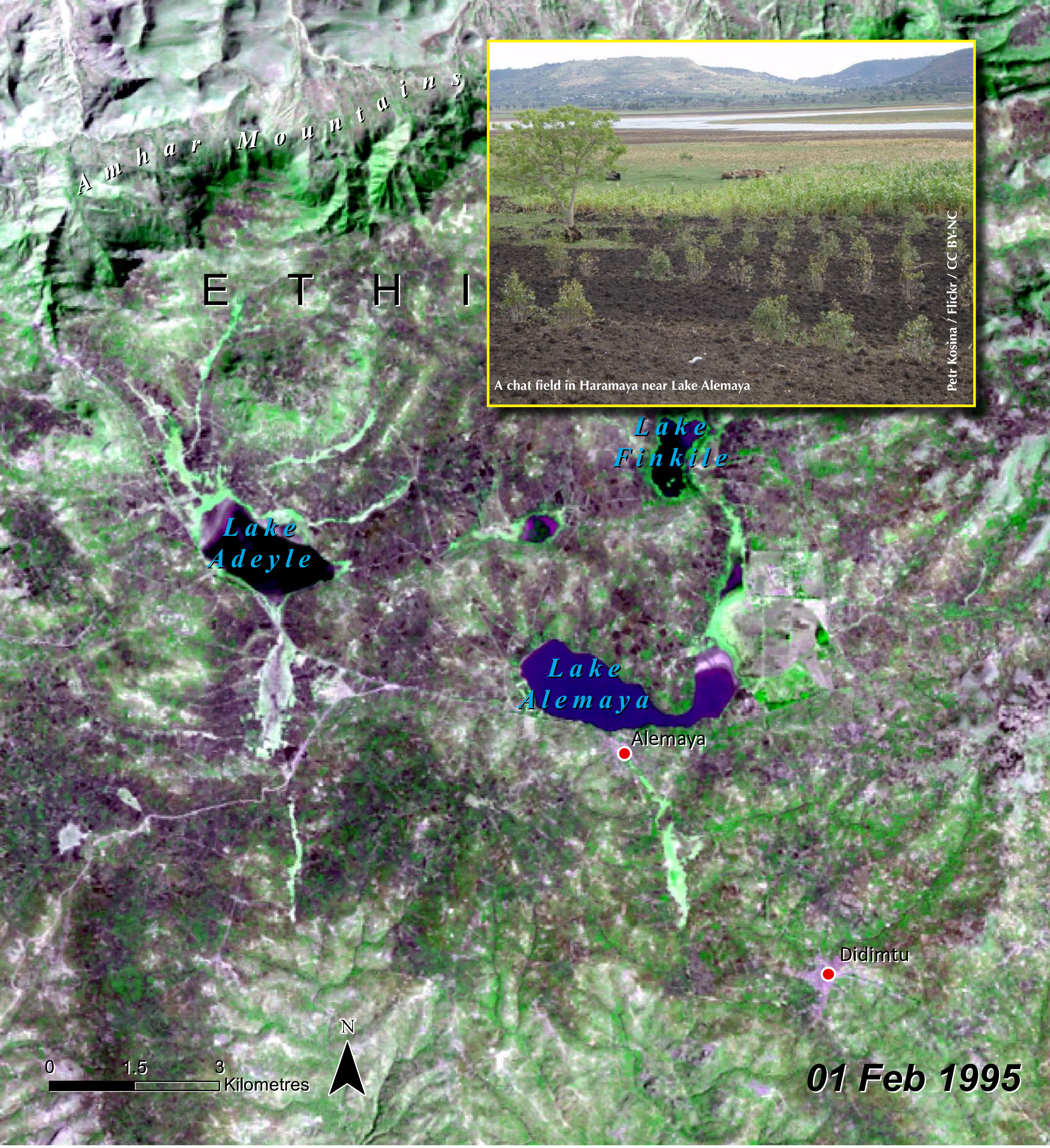


into the resettlement area. When the MENP was established in 1993 and management was assumed by the Uganda Wildlife Authority (UWA), border demarcations became an issue. Some Benet people had already begun to go back to their previous forest land, and so were now encroaching on the Mount Elgon National Park (MENP). The UWA resurveyed the resettlement area in 1993 and found that about 7 500 ha had been settled instead of the original 6 000 ha allocated. The extra area of resettlement resulted in increased areas of cultivation and widespread cutting of trees (WAC & IUCN, 2007).The yellow arrows on the satellite images above show the decreased forest cover and increase in cultivated land that occurred in Kapchorwa District between 1984 and 2013.



Hotspot: Lake Alemaya, Ethiopian Highlands, Ethiopia

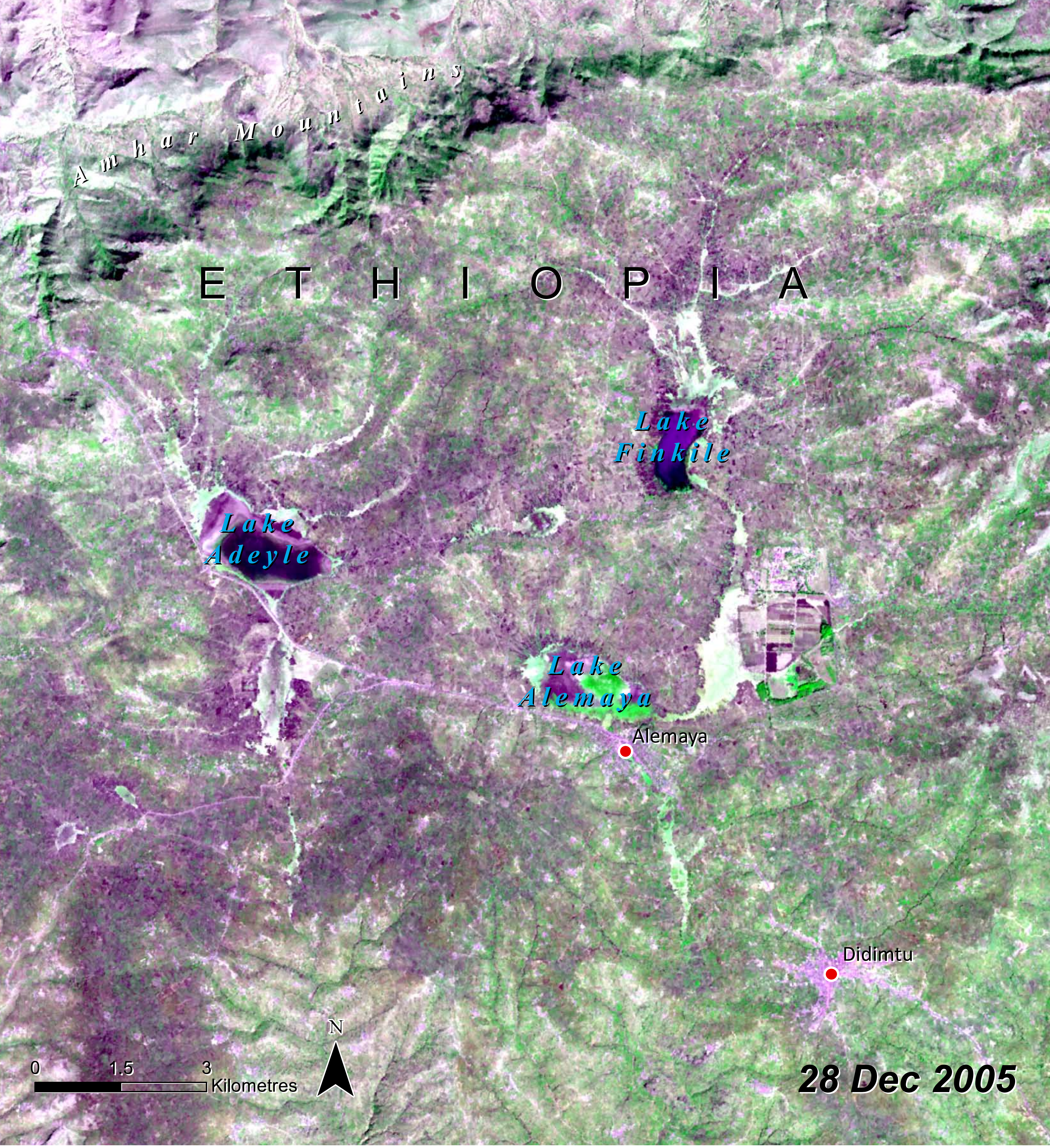
Lake Alemaya (Haramaya) is located at an elevation of approximately 2 000 m near the Amhara Mountains among the Ethiopian Highlands. The Lake Alemaya water catchment spans 50 km² (Yohannes, 2005). The lake's storage capacity has been significantly reduced over the past few decades as more water has been drawn to support agriculture and domestic needs in neighbouring towns. Soil erosion has led to increased sedimentation, compromising water



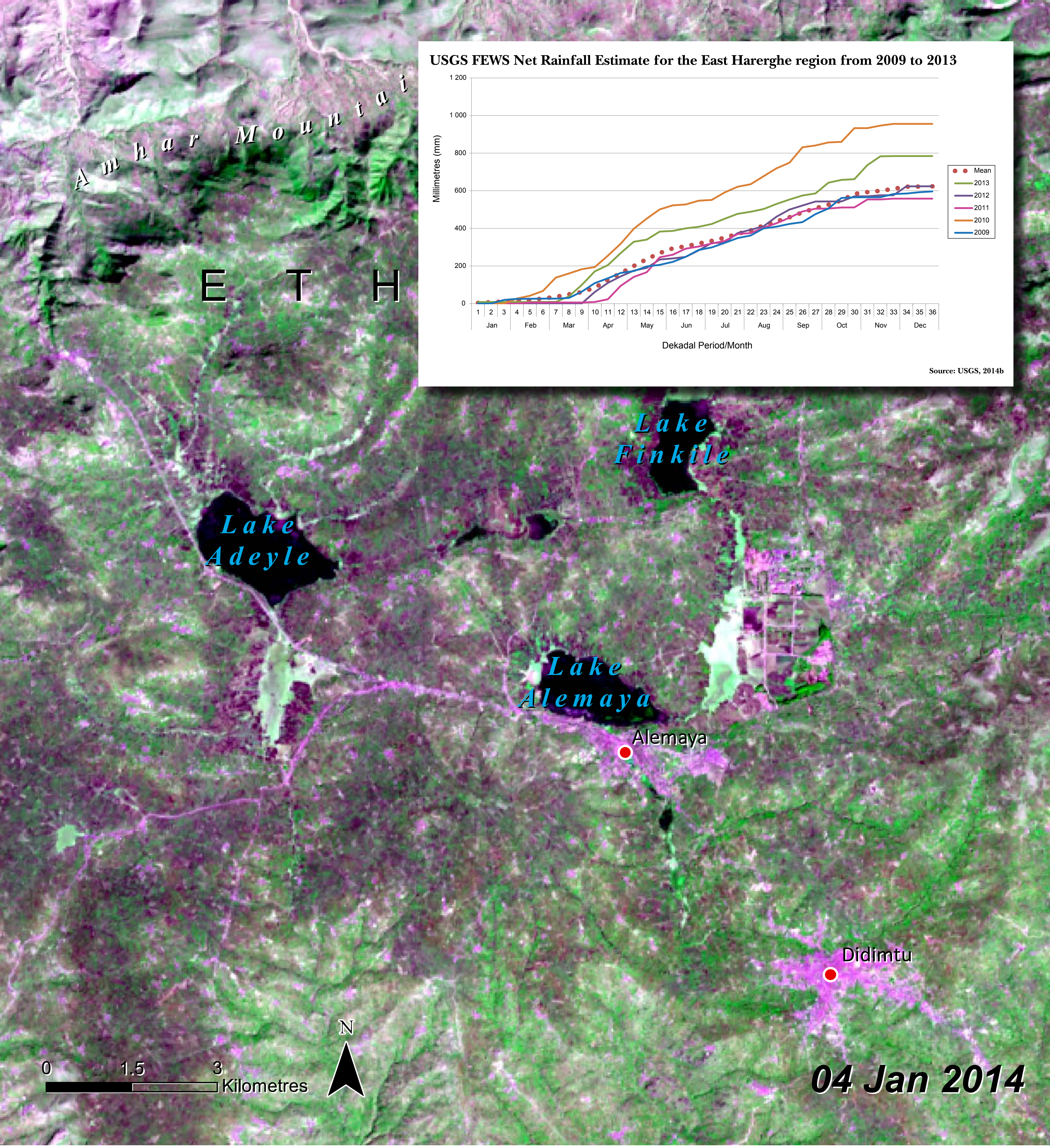
A chat field in Haramaya near Lake Alemaya

quality and quantity (Yohannes, 2005; UNICEF, 2004). Lake Alemaya catchment's annual soil erosion rate is 31 tons/ha, which exceeds the tolerable rate of 1-16 tons/ha for the varying Ethiopian agro-ecological zones (Yohannes, 2005). Overuse of its water resources caused it to completely dry up in 2005, but new imagery shows the lake may be returning.

Lake Alemaya is predominantly fed by rainfall and several small streams, but it also receives seasonal overflow from nearby Lake Finkile (BLI, 2011). Prior to, and during the 1960s, thick vegetation surrounded the lake, and reeds, bulrushes and sedges were plentiful in the lake water (BLI, 2011). Since then, cultivated land has replaced most of the vegetation. Small-scale



farmers use water from Lake Alemaya to irrigate food crops such as sorghum, various vegetables and an important cash crop called *Catha edulis* or "chat" (Yohannes, 2005), the leaves of which are traditionally chewed as a stimulant. Chat cultivation increased from 190 ha in 1996 to nearly 330 ha by 2002 (Setegn, Chowdary, Mal, Yohannes, & Kono, 2011). Aside from agriculture, Lake Alemaya also used to provide drinking water to the city of Alemaya and neighbouring Harar and Aweday (Yohannes, 2005; Zewdu, 2012). The Alemaya water treatment facility was initially constructed to support 70 000 people but was providing water to 160 000 people by the time it stopped functioning in 2004, 10 years past the due date (UNICEF, 2004).



Between 1965 and 2001, the lake's surface area decreased from 3.88 km² to 2.28 km², representing a 41 per cent decline, and the lake disappeared completely in 2005 (Yohannes, 2005). Abnormally heavy years of rainfall occurred in 2010 and 2013, however (see the graph in the inset), which could be a leading factor in the noticeable increase in lake levels visible in satellite imagery. By early 2014, the lake's surface area was approximately 1.5 km² (digitized from Landsat satellite imagery). At that time, it was reported that the lake had in fact recovered by at least 20 per cent and that local agencies would be implementing a five-year plan to continue to encourage the lake's restoration and proper watershed management (Ethiopian News, 2014; Yilma, 2014).

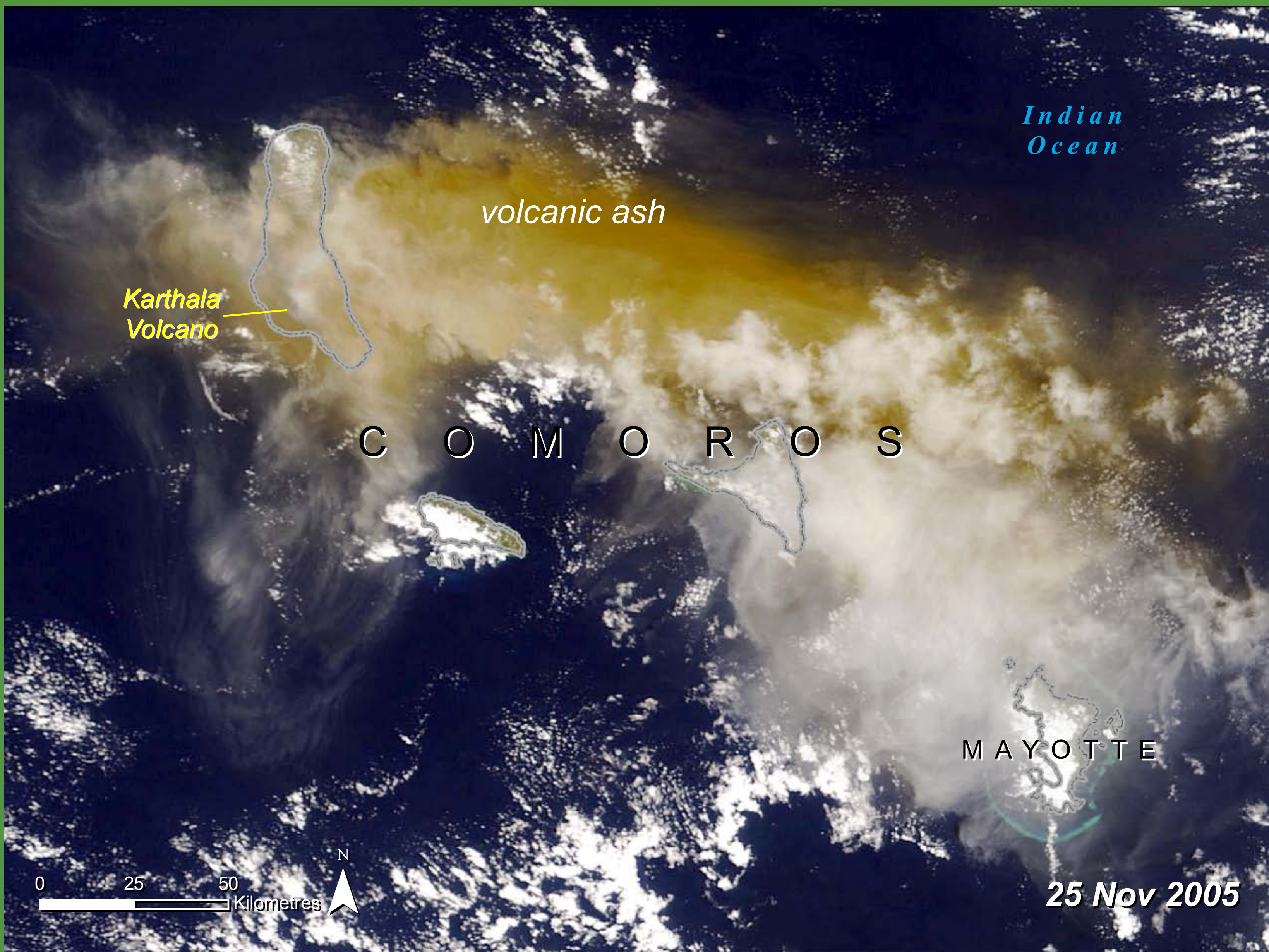
Mining

Africa is endowed with rich mineral resources and has some of the world's largest reserves of platinum, gold, diamonds, chromite, manganese and vanadium. Since the 1990s, many African countries have opened up to private mining investments (UNECA, 2010). Many mines are located in Africa's mountainous and highland areas (Figure 3.10), but some volcanic materials are also advantageous for mining (Box 3.5).

Mining operations are dispersed throughout Africa, but in mountainous terrain, mining is primarily concentrated in South Africa where coal, platinum and gold deposits are found. South Africa is one of the world's leading coal and platinum producers and exporters and mining is a growing economic activity (Yager, 2013). Much of South Africa's coal mining takes place in the highlands between Johannesburg and the western border of Swaziland (InfoMine, 2014b). Coal deposits are relatively shallow with wide seams, making it relatively cheap and easy to mine, but it can have many environmental impacts. Approximately 80 million tonnes of mining waste is dumped each year and underground coal mines can emit up to 7 million tonnes of CO_2 equivalent a year (Lloyd, 2002). In 2011, South Africa contributed 74 per cent of the world's share of platinum production (Yager, 2013), but worker strikes in early 2014 may have implications on the economy and the environment as production declines and mines are abandoned; there are already at least 6 000 abandoned mines across the country, which become catalysts for environmental problems (UNEP FI, 2012).

Figure 3.10: Mines located at or above 1 500 m a.s.l.

Sources: USGS, 2001; InfoMine, 2014a; UNEP/DEWA



Box 3.5: Mining volcanic sand from the Karthala volcano

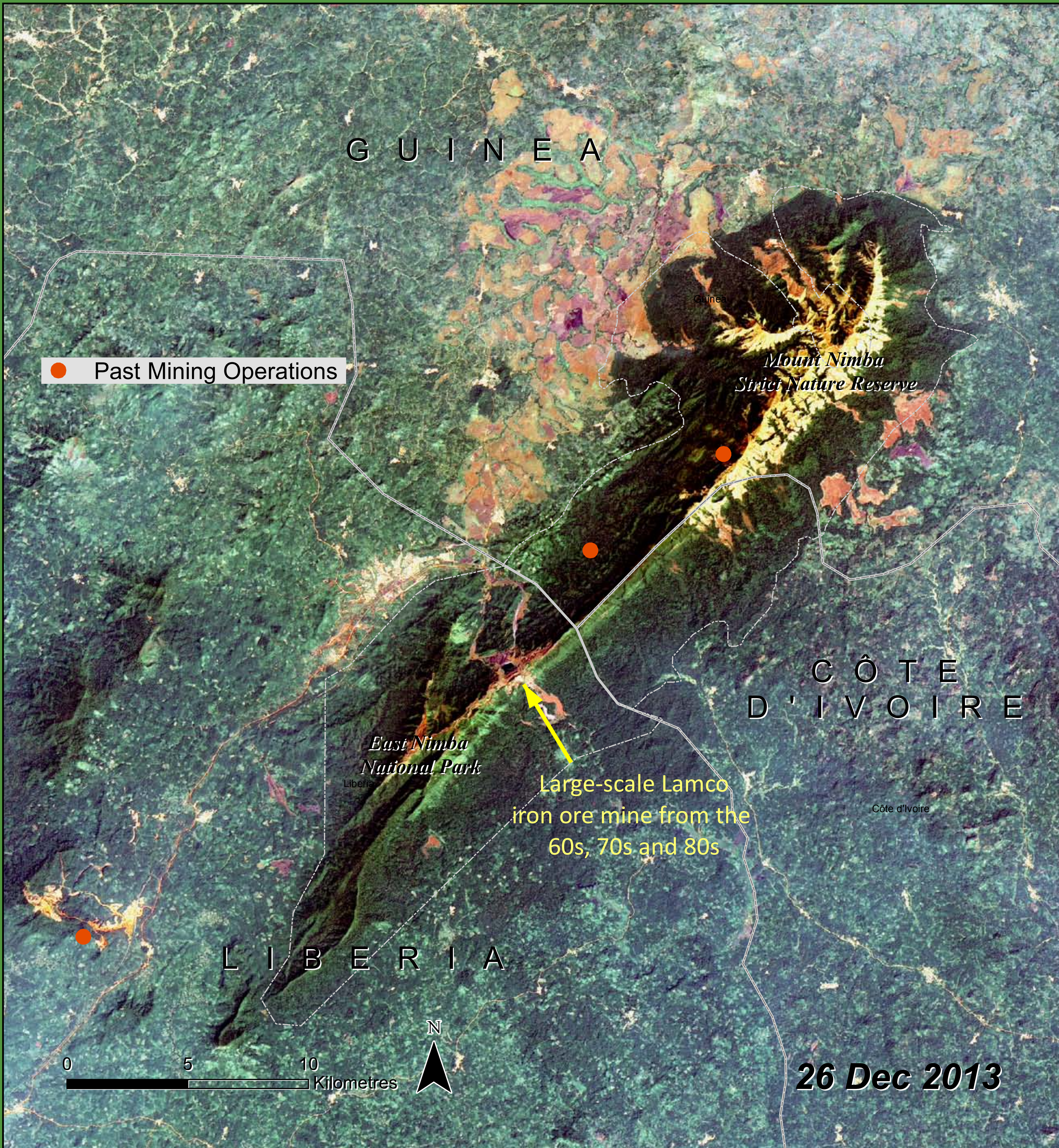
The Karthala volcano on Comoros Island has erupted five times since 1991 and at least 30 times since the early 1800s. After the Karthala volcano erupted on 25 November 2005, people abandoned the practice of extracting sand along coastal areas to use for construction, which caused erosion of beaches, reduced the number of anchoring points and led to ecosystem destruction. They began mining the sand from the volcanic debris that flowed down the mountain. After each heavy rainfall, dozens of people wait along the roads to gather the sand deposited by the hyper-concentrated volcanic flows. Mining has reduced the pressure on coastal areas that were previously mined for sand and has become a social benefit for the people of Comoros. Prior to the 2005 eruption, sand cost about 100 000 Comorian francs (US$275) per 5 m^3. Now, the resource is almost freely available. Some people have dug out canals to channel mud from eruptions directly to their properties. However, volcanic eruptions are still a threat to the people of Comoros.

Source: Compiled from Morin & Lavigne, 2009; NASA, 2005

Disposal of acid mine drainage (AMD) is an increasing problem at many gold and platinum mining operations in South Africa, as is cyanide leaching (Moodley, 2012). Acid mine drainage can occur when a mine is abandoned and groundwater flows back into the mine, causing water levels to rise and sometimes discharge into surrounding rivers (IMCCCG, 2010; UNEP FI, 2012). Reuse of AMD is prohibited because it could be hazardous to human health and harm agricultural crops (Moodley, 2012).

In 2012, Niger ranked as the fourth top producer of uranium in the world. Two of its largest producers are located at the western foot of the Aïr massif. Akouta is an underground mine and Arlit is an open pit mine (Bermúdez-Lugo, 2013). The Arlit mine produced 5 per cent (3 065 tonnes) of the world's uranium in 2012 and Akouta produced 3 per cent (1 506 tonnes) (WNA, 2013). It is expected that there will be continued discovery of uranium and development of the uranium mining industry in the future (Bermúdez-Lugo, 2013), but terrorist attacks could slow or prevent the discovery progress (WISE, 2014).

Diamond mining is common in the highland areas of Lesotho and Angola. The Maloti Mountains, part of the Lesotho Highlands, is known to have mineral deposits, although the rough terrain can make exploration difficult. It is most well-known, however, for producing the highest percentage of large, top-quality, pure diamonds (Merowe, 2013). The Letseng Diamond Mine (see the hotspot) also mines and treats low-grade ore through two recovery plants and one contracted plant (Merowe, 2013). As of 2009, it was the world's seventh-largest kimberlite diamond mine (Newman, 2011). The mine operates



Box 3.6: Mining near Mount Nimba

Despite the protected status of the Mount Nimba Strict Nature Reserve (See Chapter 4), the Mount Nimba area is vulnerable to many destructive activities such as mining and road construction as well as the building of some villages. Many immigrants and Liberian refugees have settled in the Mount Nimba area, drawn by the prospect of iron mining, as well as the agricultural potential and commercial forestry industry. Mount Nimba has a great wealth of iron ore deposits, totalling more than one billion tonnes at 65 per cent concentration, and is being increasingly explored for mining activities. Mining operations have contributed to heavy-metal pollution of streams that run through the Reserve. To transport the iron ore, up to 1 000 km of railroad tracks may need to be constructed, further disturbing the environment. To promote sustainable development in the area, however, several mining companies have expressed interest in cross-sectoral partnerships with governments and non-governmental organizations (NGOs). Some issues that may be addressed include bushmeat hunting and fish farming. The impacts of mining in the Mount Nimba area could serve as a warning to future mining developments under exploration in the Simandou Mountains of southeastern Guinea, which could annually produce upwards of 95 million tonnes of iron ore for export.

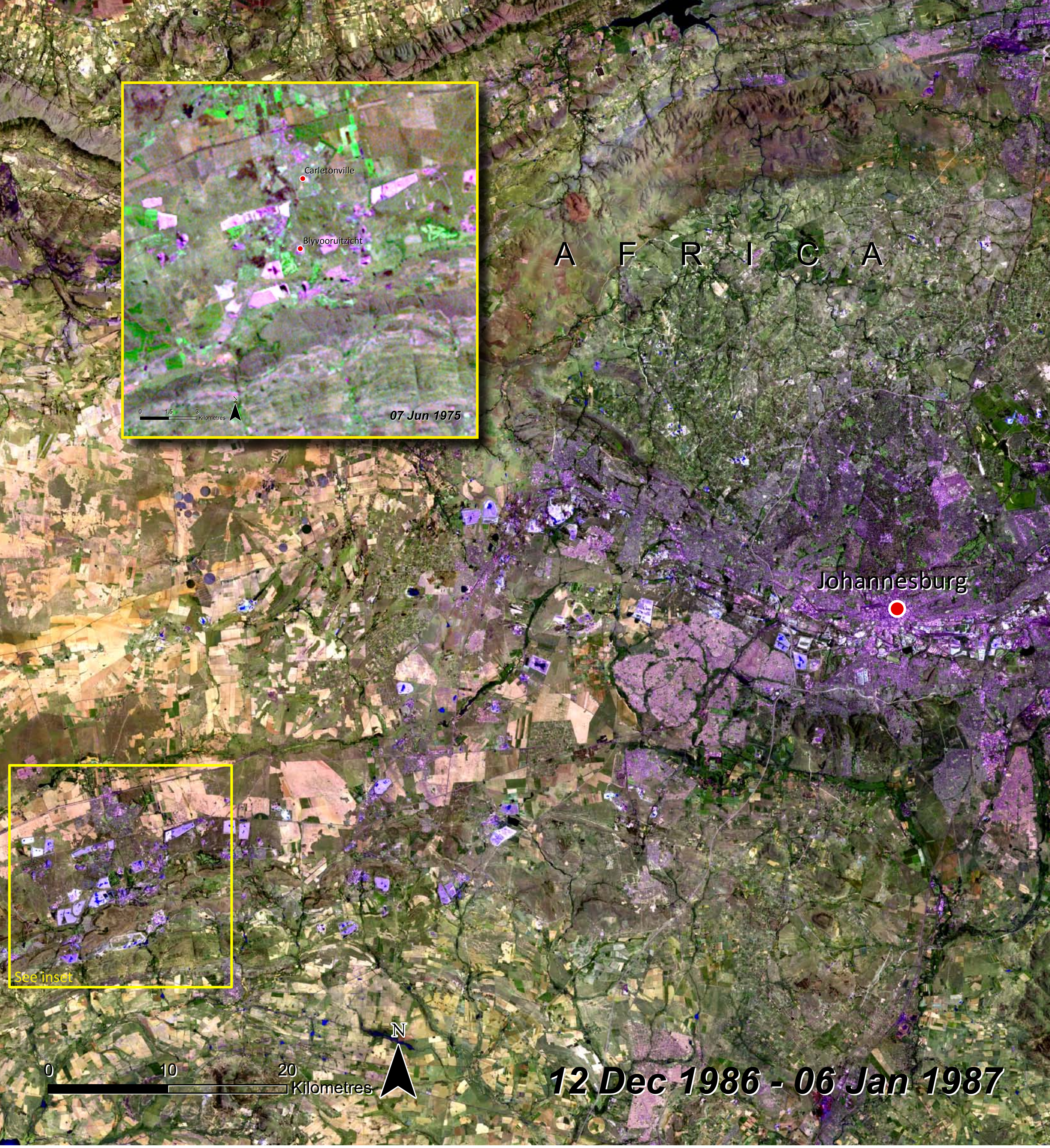
Sources: IUCN, 2012; Sayre, et al., 2011; FFI, 2009; USGS, 2001; Boyes, 2014 two kimberlite vertical pipes hosted in basaltic lavas — the main pipe and the satellite pipe — that reach depths of 793 m and 828 m, respectively (Merowe, 2013). The mining industry's expansion contributed to a modest increase in Gross Domestic Product (GDP) in 2012 (OECD, 2013). Mining impacts on land and other environmental resources are considered minimal in Lesotho. Environmental impact assessments (EIAs) must be conducted and approved by the Lesotho government before a company is issued a mining licence (Maleleka, 2007) and the operators are legally responsible for controlling and disposing of waste and treating pollution if needed (SARW, 2010). The results of EIAs are typically positive, but there is speculation that environmental monitoring of mining impacts in Lesotho could be weak (Maleleka, 2007).

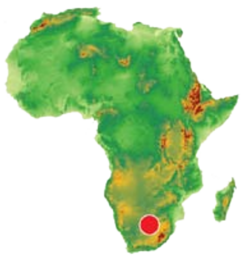
Also in southern Africa, the highlands of Angola in Huambo Province are known for alluvial diamond deposits and kimberlite diamond deposits are concentrated along a fault line running from the southwest part of the country through Huambo to the country's northeastern part, but precise locations are not known due to lack of detailed geologic mapping (Bermúdez-Lugo, 2011). Alluvial diamond mining alters natural river channels and the use of high pressure water hoses to wash and sift the natural alluvium in search of diamonds causes extensive damage to the environment (CII, 2008).

In northern Africa, the High Atlas Mountains are mined for copper and iron, the Anti-Atlas for gold and silver and the Rif Mountains for cobalt and antimony, among others (Newman, 2012b). Mining in this area can harm the vegetation (Sanaa, et al., 2011) and greatly stresses water supplies. There is an ongoing battle for water between the silver mining operations in Imider in the High Atlas Mountains and the local village, where water is already scarce in this arid region. The villagers claim that the mine is consuming too much water, causing groundwater levels to drop and polluting its water supply; they have attempted to cut off water supplies to the mine (Taipei Times, 2012). Villagers report that pollution from the mine is causing desertification, killing livestock and spreading disease. Mine managers dispute the claims, however, saying they are abiding by global environmental standards and completing EIAs (Alami, 2014).

As discussed, common environmental impacts shared by many of Africa's highland mining operations appear to be competition for water to conduct operations and leaching of contaminated water from both active and abandoned mines. Additionally, pressure to both mine and protect the mountains is an on-going issue in areas such as the Mount Nimba Strict Nature Reserve in Guinea (Box 3.6), which is a protected area, but is also increasingly vulnerable to mining exploration because of its significantly large and accessible iron-ore deposits (IUCN, 2012; see Chapter 4). Satellite imagery on the following pages shows the visual impacts that mining operations have in South Africa and Lesotho.

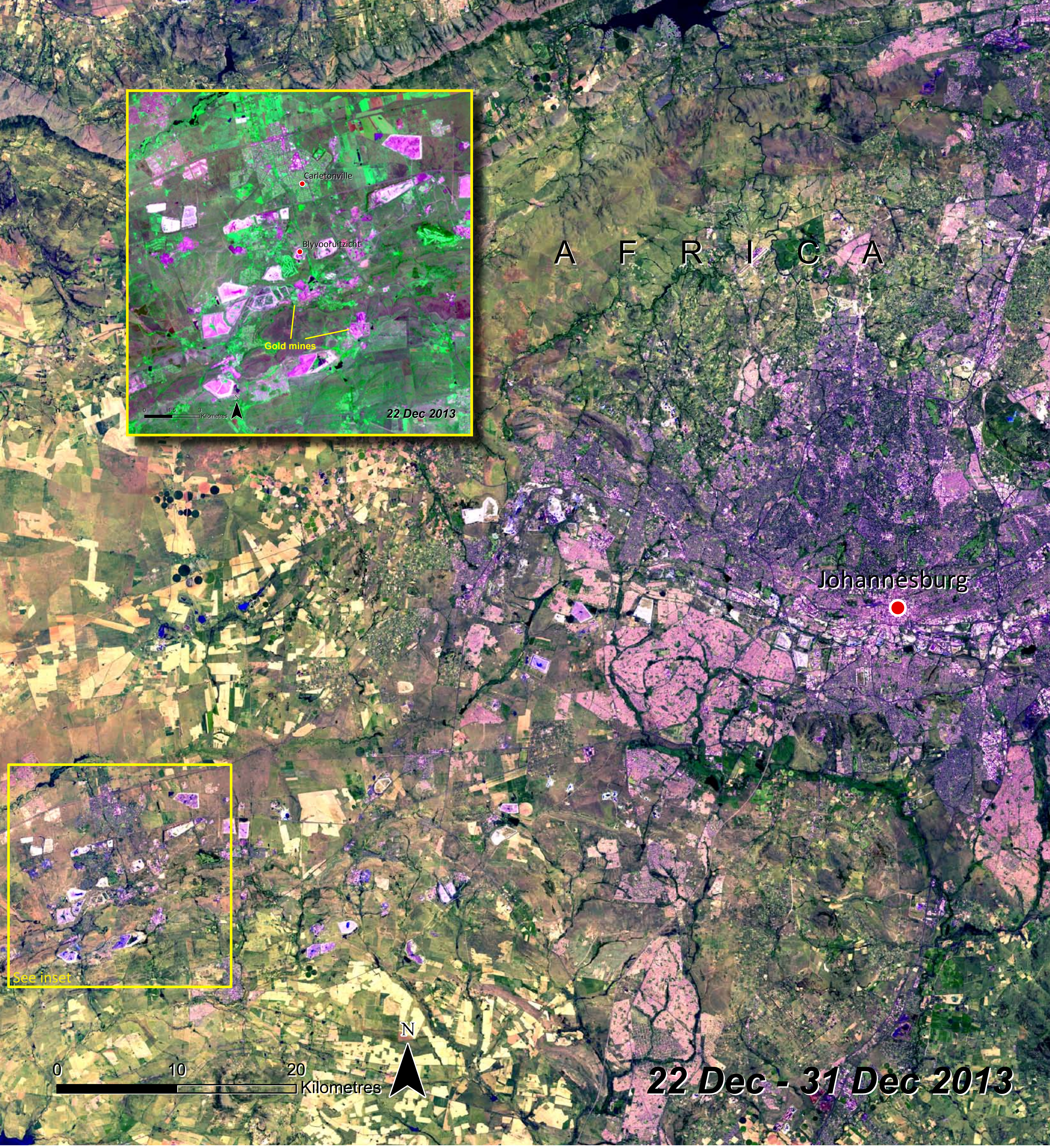

Mine tailings near Johannesburg, South Africa





Hotspot: Witwatersrand, South Africa

The Witwatersrand Mountains are a remnant of an ancient inland sea; they form the rich gold-bearing reefs located northwest of Johannesburg in the Gauteng Province. They are known as South Africa's "golden arc", where gold-mining activity has been concentrated in and around the mountain basin for a century (Chamber of Mines, 2008). Gold was first discovered in the area in 1886, which led to the



founding of Johannesburg and conversion of farmland to mining areas (Durand, 2012). Although the mining operations have been prosperous, there have been numerous environmental challenges. Acid mine drainage from the gold mines continually contaminates the Crocodile and Vaal River systems with heavy metals and radioactive particles so clean water must be brought in from as far as the Lesotho Highlands (IMCCCG, 2010). The satellite images show an increase in the number of mines and the expansion of Johannesburg.

Hotspot: Letseng Diamond Mine, Lesotho

Diamonds have long been mined at the Letseng Diamond Mine in the Maloti Mountains. They were first discovered at Letseng in 1967 and the Letseng Diamond Mine is now one of two operational mines in Lesotho. The mine is located at 3 100 m and is the highest diamond mine in the world as well as one of the coldest places in Africa (Newman, 2011). Production from the Letseng Mine accelerated after

1999 with the discovery of several large diamonds, dispersing an earlier claim that despite the common notion that mountains are rich in minerals, this was not the case in the Lesotho Highlands; diamond output increased significantly again after 2004 (Maleleka, 2007). Mining operations at Letseng can be water- intensive, consuming 1.3 million m^3 per year, but waste is managed on-site and only 12 per cent of the land leased for the mine has been disturbed with the result that it has been internationally recognized for its environmental management practices (InfoMine, 2010).

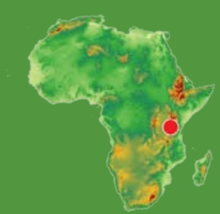
Deforestation

Between 2000 and 2010, an annual average of nearly 13 million ha of the world's forests were converted to other uses such as agriculture, or lost to natural causes (FAO, 2010). During the same period, Africa lost about 2.4 million ha of forest per year, consequently resulting in widespread biodiversity loss (FAO, 2011a). Box 3.7 explains some of the economic costs of deforestation.

Mountain forests are disappearing at a faster rate than any other type of forest ecosystem (Price, et al., 2011). As mountain forests are under human pressure to supply building materials, fuel for cooking, agricultural land and hunting grounds, their ecosystem services become increasingly vulnerable to the impacts of these activities. Deforestation is a serious issue in Africa's tropical mountains because forest removal releases carbon to the atmosphere (see Chapter 2) and the land becomes increasingly susceptible to flash flooding, shallow landslides and erosion (Price, et al., 2011). Agriculture is taking over montane forests


Deforestation in the jungle of Madagascar

Box 3.7: The cost of deforestation of Kenya's water towers



Kenya's five main water towers: the Mau Forest Complex on the Mau Escarpment, Mount Kenya, the Aberdare Mountains, Mount Elgon and the Cherangani Hills (See Chapter 2) are valuable montane forests. These forests, however, are under immense pressure from urbanization and demand, legal and illegal, for forest resources such as firewood and charcoal.

It is estimated that deforestation of Kenya's water towers between 2000 and 2010 resulted in a loss of approximately 50 000 ha. Deforestation affected the ability of rivers and streams to maintain their flow in the dry season, which in turn affected the amount of water available for irrigated agriculture and hydropower. Loss of forest cover also proliferated incidences of malaria and compromised water quality.

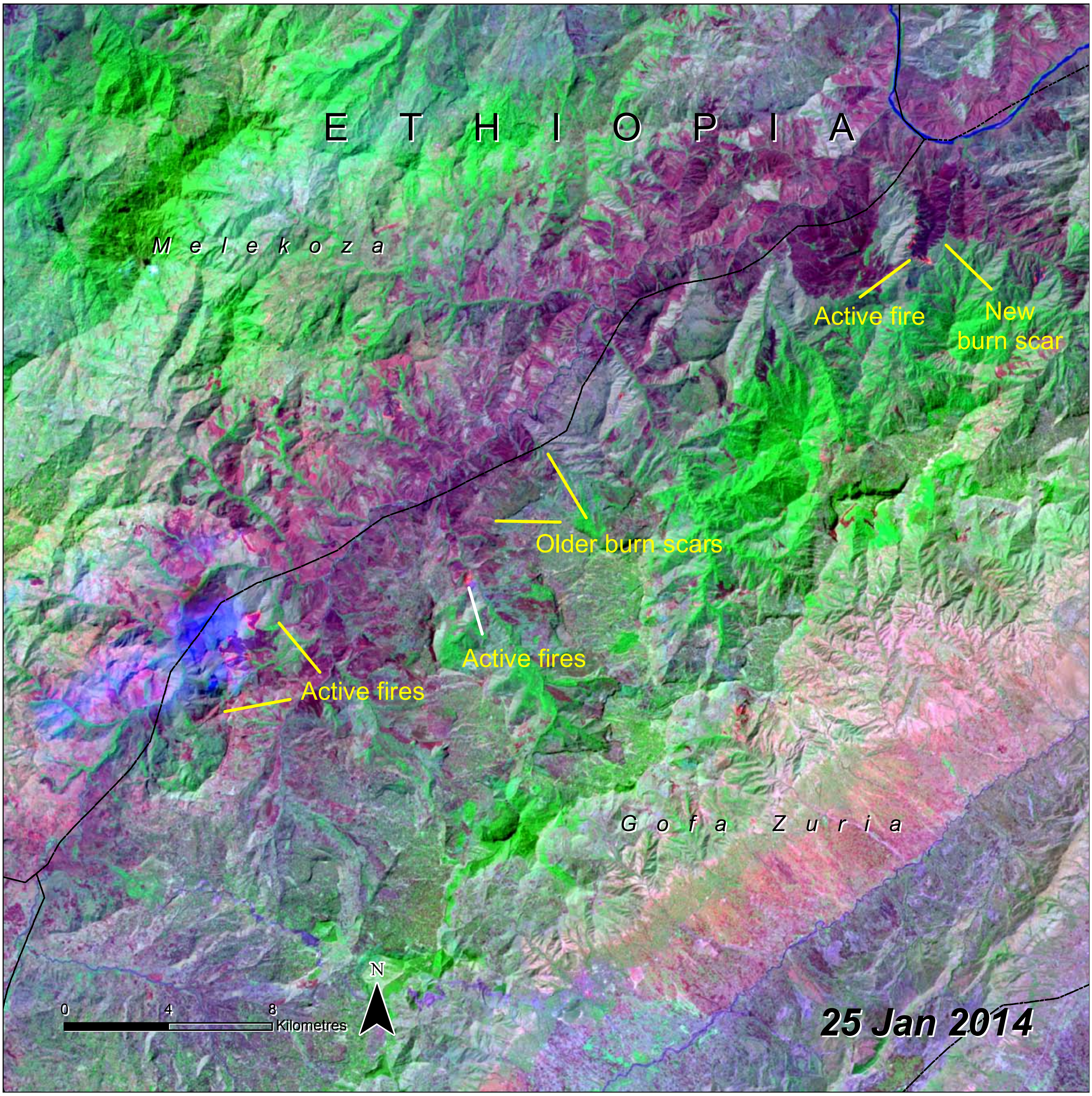
Revenue generated from deforestation, in the form of timber and fuelwood, is approximated at KSh1.4 billion (US$15.5 million) in 2010. However, the cost of this deforestation due to loss of all considered regulating services in 2010, was estimated to be nearly three times the revenue amount: KSh3.7 billion (US$66.2 million).

Retention of forest cover is essential to maintaining ecosystem services, such as water supply, as well as the economy.

Source: Compiled from Morin & Lavigne, 2009; NASA, 2005


Aberdare Mountain range

Figure 3.11: Dark red patches of land indicate recent fire activity in the southern Ethiopian Highlands



Source: Landsat imagery

in Uganda, Ethiopia, United Republic of Tanzania, Malawi and Zambia, among others (Bagoora, 2012b). Plantation agriculture is also a factor as more forests are being converted to rubber, coffee and tea plantations (Hall, Burgess, Lovett, Mbilinyi, & Gereau, 2009). Weak or non-existent legal protection and enforcement of sustainable harvest policies can also contribute to deforestation. Political instability in Ethiopia in the 1990s led to widespread deforestation in the Chencha and Arbaminch areas of the Ethiopian Highlands. Massive amounts of land were cleared to make way for agriculture, firewood and timber production (Assefa & Bork, 2014).

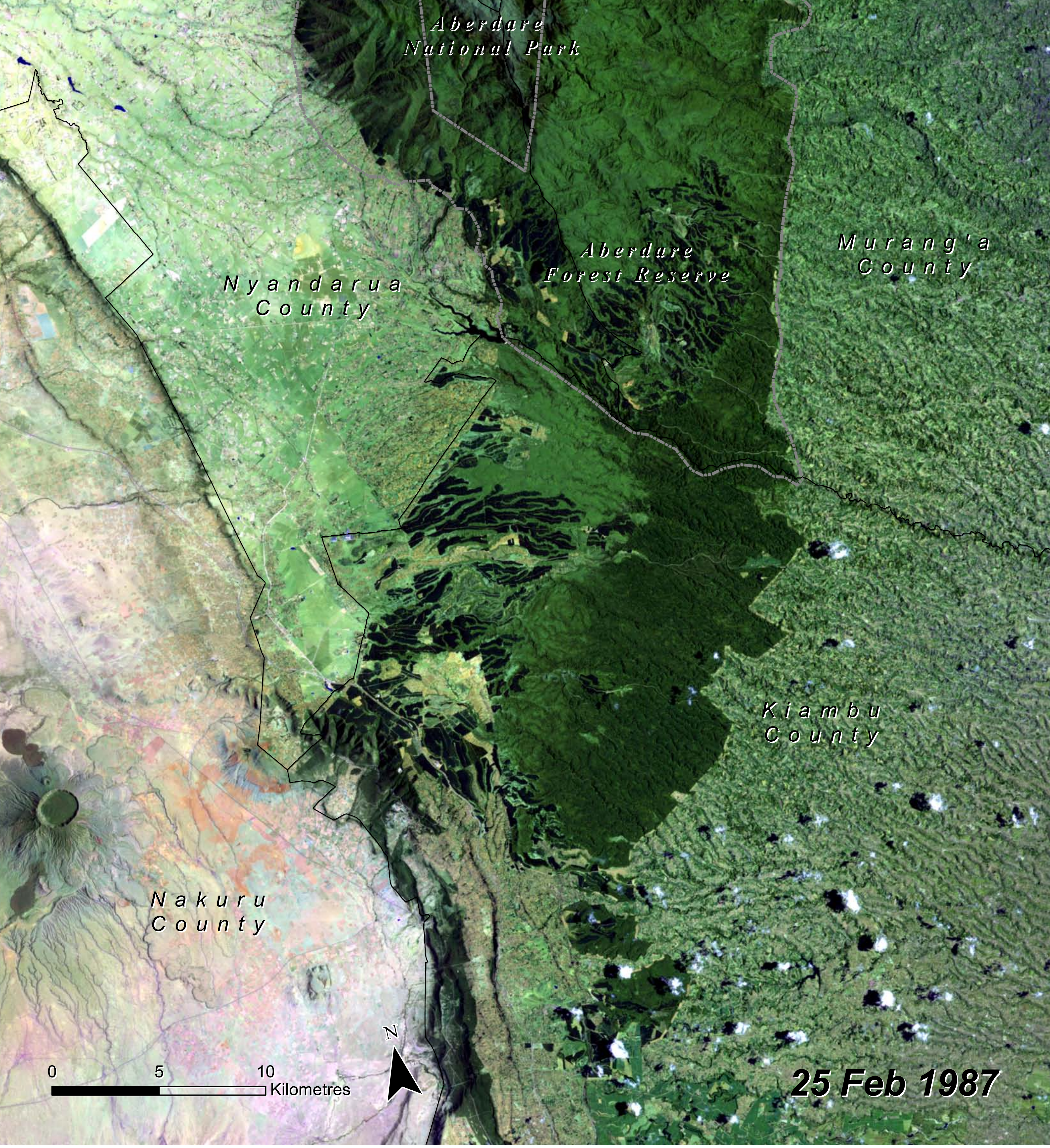
Fire is a common driver of deforestation in Africa's mountains. Fires occur naturally due to lightning and volcanic eruptions and humans intentionally use fire in slash-and-burn agriculture, clearing land for development or agriculture (Figure 3.11) or as an ecological management tool. Fire affects only 0.53 per cent of Africa's mountainous land, but this represents the largest percentage of all continents and impacts can be great at local and regional levels. Uncontrolled and unsustainable fire activity can threaten ecosystem goods and services, especially biodiversity, and human health (Blyth, Groombridge, Lysenko, Miles, & Newton, 2002).

Hotspot: Mount Moco, Angola

Afromontane forests used to widely cover Mount Moco, Angola's highest mountain (2 620 m), located in Huambo province, but impacts from the neighbouring community of Kanjonde have reduced forest cover to a total of 85 ha, comprised of small patches, most of which are no larger than 5 ha (Mills, Olmos, Melo, & Dean, 2011). Historic forest extent is unknown, but a local person, cited by Mills, Olmos, Melo, & Dean (2011), said the forest reached the community's edge in the early 1920s but the closest forest patch is now at least 500 m away; the forest has receded due to crop cultivation, intentional fires, hunting and wood collecting for firewood and building materials (Mills, Olmos, Melo, & Dean, 2011; Mendelsohn & Weber, 2013; Cáceres, Paulo, Tchalo, Mills, & Melo, 2013). Remaining forest

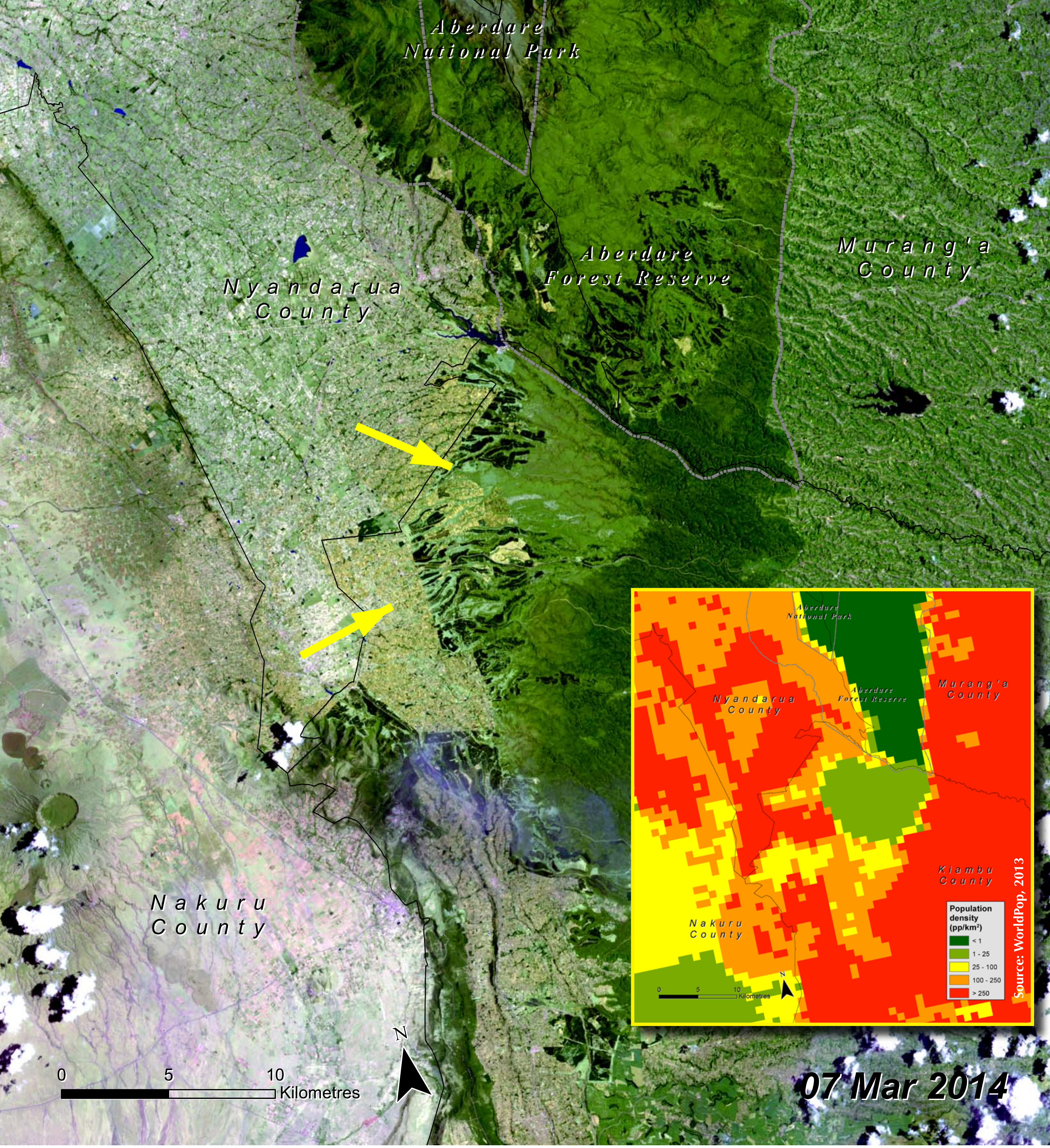
patches tend to follow drainage lines and any dense growth of the tallest trees is only found in deep ravines near the summit (Mills, Olmos, Melo, & Dean, 2011).

These patches of forest have created "islands" of endemism, habitats for certain bird and animal species that are found nowhere else on the continent (Mendelsohn & Weber, 2013), including Swierstra's Francolin, an endangered bird species (Mills, Olmos, Melo, & Dean, 2011). Despite their importance as crucial habitat, these Afromontane forests are currently not protected by any management legislation (Mendelsohn & Weber, 2013). Boundaries for a conservation area were proposed as early as the 1970s, but a plan has yet to be developed (Cáceres, Paulo, Tchalo, Mills, & Melo, 2013). Small-scale pilot projects to grow trees in nurseries then replant on the slopes of Mount Moco are underway, however, and will help to restore parts of the forest as well as create employment for the Kanjonde community (GAC, 2012). The yellow arrows indicate noticeable areas of forest cover loss.

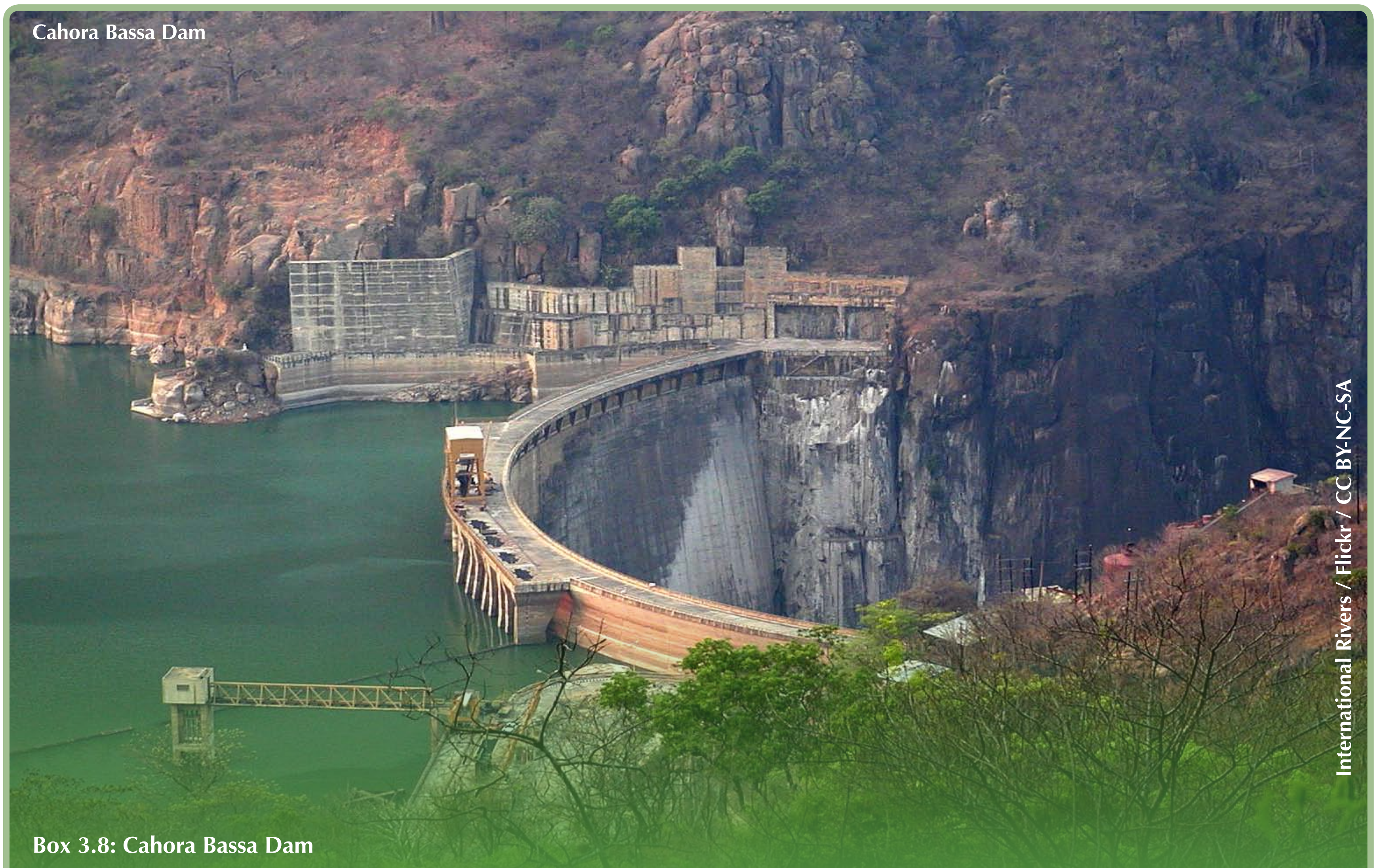


Hotspot: Aberdare Mountain Range, Kenya

Along the Aberdare Mountain Range, a relatively dense population surrounds the Aberdare forest, and some people also reside inside the Forest Reserve (see inset on next page). The millions of residents of Nairobi, 50 km away, depend on the forest to supply clean drinking water. Over the past few decades, population pressure has resulted in rapid deforestation and excisions of land from protected status have contributed to the loss of forest area. Common causes of deforestation include taking



wood for charcoal, illegal settlements, logging, cultivation and grazing in the adjacent forest areas (Ochego, 2003; KFS, 2009). Approximately 453 km^2 of forest was lost between 1987 and 2000, representing a 30 per cent decrease in total forest cover (Ochego, 2003). Satellite images from 1987 and 2014 show forest cover loss in the southern part of the Aberdares. Future management plans include replanting trees to increase carbon sequestration potential and promoting forest conservation and management to preserve its environmental goods and services, including energy and water (KFS, 2009).


Cahora Bassa Dam

Box 3.8: Cahora Bassa Dam

The Angolan Highlands give rise to the Zambezi River, which connects the Highlands to the Indian Ocean. The Cahora Bassa Dam, located in Mozambique, was constructed on the Zambezi River in 1974. As a result, the river experiences frequent problems due to sedimentation. Construction of the dam altered the streamflow of the Zambezi River, causing it to change course below the dam. The change in course has led to the disconnection of wetlands from the main channel and has deprived the coastal mangroves of replenishing floodwaters. Between 1974 and 2004 the Zambezi delta shrunk from 600 km in width to 150 km.

Source: Basson, 2004

Dams

Constructing dams along the many rivers that begin in Africa's mountains offers a way to increase water resources for agriculture and domestic use, especially during dry seasons, and they are a source of renewable energy. Africa has great potential for hydropower (see Chapter 5), but dam construction can be costly financially, environmentally and socially. Many dams already exist in Africa, serving as either water reservoirs or for generating hydropower (Table 3.7).

Construction can reduce and alter natural streamflow, leading to consequences downstream, especially on coastal ecosystems (Box 3.8). Sedimentation is often a problem, inhibiting streamflow and preventing a dam from reaching full capacity whether it is to generate electricity or to serve as a

Table 3.7: Africa's top ten mountain dams in elevation

	Name	Country	River	Major Basin	Year Constructed	Height (m)	Reservoir Capacity (thousand m³)	Purpose	Max Elevation (m a.s.l.)
1	Sasumua	Kenya	Sasumua	Athi Basin	1956	45	13 250	Water supply	2 508
2	Legadadi (Main)	Ethiopia	Sendafa	Rift Valley	1979	40	38 000	Water supply	2 421
3	Melka Wakena	Ethiopia	Wabi Shebele	Shabelle & Juba Basin	1988	–	750 000	Hydropower	2 316
4	Gibson	South Africa	Wilge	Orange Basin	1880	–	543	Water supply	2 282
5	Finchaa	Ethiopia	Finochaa	Nile Basin	1973	25	650 000	Hydropower	2 243
6	Abarda (Mai Nefhi)	Eritrea	–	Nile Basin	1970	40		Water supply	2 199
7	Gafarsa	Ethiopia	Petit Akabi	Rift Valley	1955	17	7 000	Water supply	2 057
8	Mohale	Lesotho	Senqunyane	Orange Basin		145	857 100	Water supply	2 049
9	Ruiru	Kenya	Ruiru	Athi Basin	1949	23	2 980	Water supply	1 983
10	Katse	Lesotho	Malibamatso	Orange Basin	1997	185	1 950 000	Hydropower	2 057

Source: FAO AQUASTAT, 2014; DWA, 2011; Elevation from USGS EROS 7.5 arc second Maximum DEM; - = no information

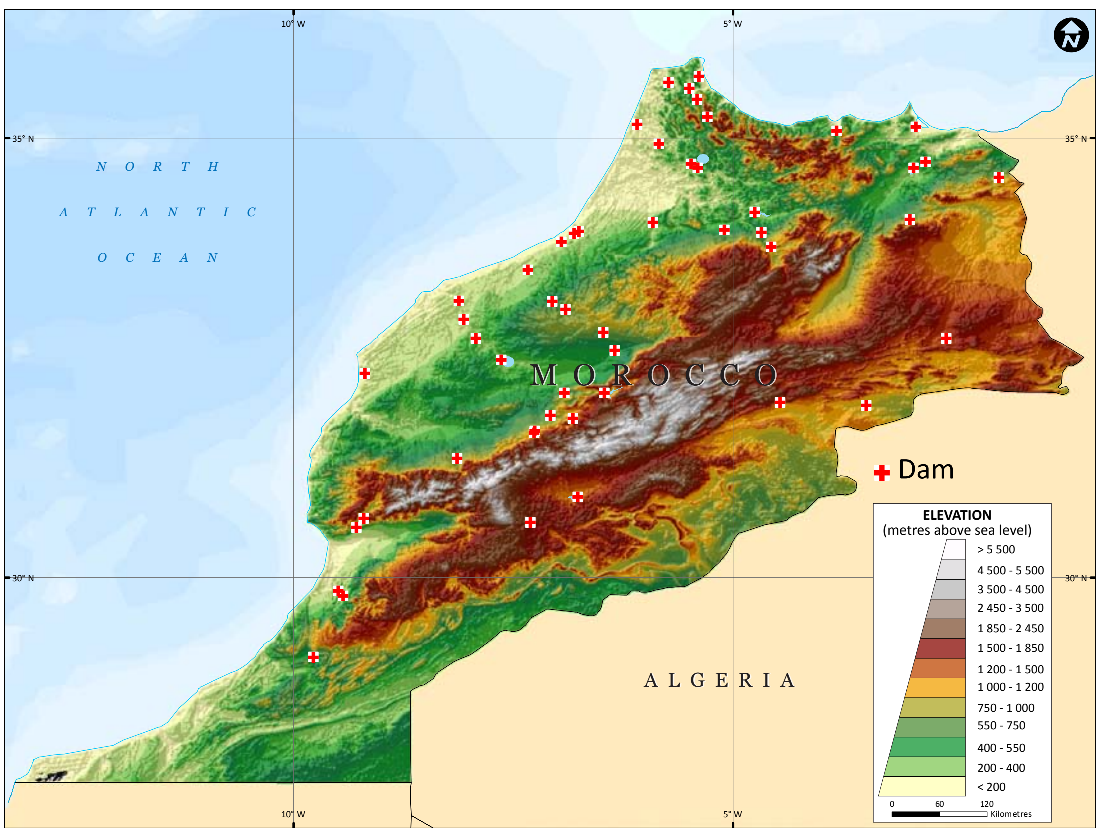
Figure 3.12: Dams located at or above 1 500 m a.s.l.

Source: FAO AQUASTAT, 2014; UNEP/DEWA

water reservoir. It is estimated that 80 per cent of hydropower dams in Africa will be filled with sediment by 2100 and 70 per cent of non-hydropower dams will be filled by 2090 (Basson, 2008).

The construction of larger dams has major impacts on local communities; their lives are completely disrupted and livelihoods affected when they must relocate to make way for the dam and reservoir, or they suffer the consequences of flooding downstream after installation, among other significant effects. Figure 3.12 shows some of Africa's highest elevation dams, but many dams are also built at lower elevations to catch water that flows down from the mountains and further help supply lowland populations, such as in Morocco (Figure 3.13).

Figure 3.13: Location of dams in Morocco



Source: FAO AQUASTAT, 2014; UNEP/DEWA

Hotspot: Lesotho Highlands Water Project, Lesotho

Water is one of Lesotho's most valuable natural resources. The Lesotho Highlands are an important water tower for Lesotho and parts of South Africa. The ongoing Lesotho Highlands Water Project (LHWP), established under the LHWP Treaty between Lesotho and South Africa (Willemse, 2007), aims to harness this natural resource to fulfil the water needs of both countries (Mwangi, 2007). For over 30 years, South Africa had attempted to negotiate access to Lesotho's natural water supply to help support the growing populations of Johannesburg and the mining and other industrial needs of the Gauteng Province (Mwangi, 2007). Local water supplies were dwindling and the plentiful rainfall in the highlands was a more promising water source. The treaty entitled South Africa to a large amount of water from Lesotho in return for annual payments and aid in construction to Lesotho (Mwangi, 2007). The plan was to build dams in Lesotho along the Sengu River, which becomes the Orange River in South Africa, and its tributaries, and to then transfer the stored water to South Africa through a tunnel (Wentworth, 2013).

The components of the project include five dams, 200 km of water-transfer tunnels and a hydroelectricity plant that is expected to generate 180 MW of energy (Mwangi, 2007) and will be completed over a series of phases. Two of the five planned dams have been completed as part of Phase 1A: the Katse Dam (185 m high) on the Malibamats'o River and the 'Muela Dam; and one dam has been completed as part of Phase 1B: the Mohale Dam (155 m high) on the Senqu River. Phase 1A was completed in 1998 with funding from 25 different entities for approximately ZAR20 billion ($US1.9 billion) and Phase 1B was completed in 2008 (Wentworth, 2013).

Mohale Dam, Lesotho

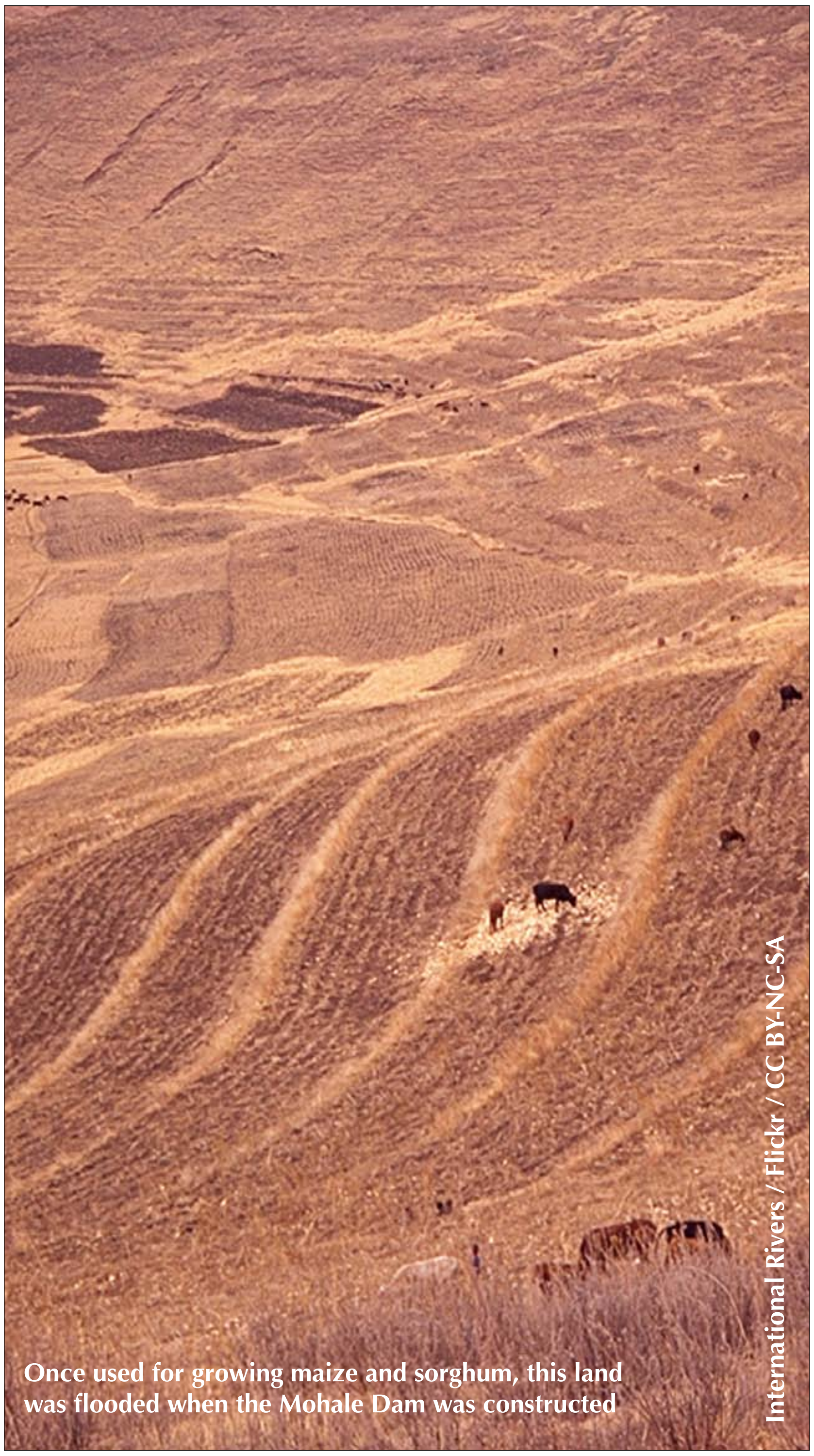
Katse Dam, Lesotho

AdeleD / Shutterstock

The Katse and Mohale Dams are intended for water storage and dispersal and are connected by a 32 km concrete tunnel that can deliver 9.6 m^3 of water per second (Willemse, 2007); the water is transported to the Vaal Dam in South Africa (DWAF, 1998). The 'Muela Dam is a hydropower station that generates 72 MW of electricity using water transferred from the Katse and Mohale Dams and it has enabled Lesotho to become less reliant on South Africa for electricity (LHDA, 2013).

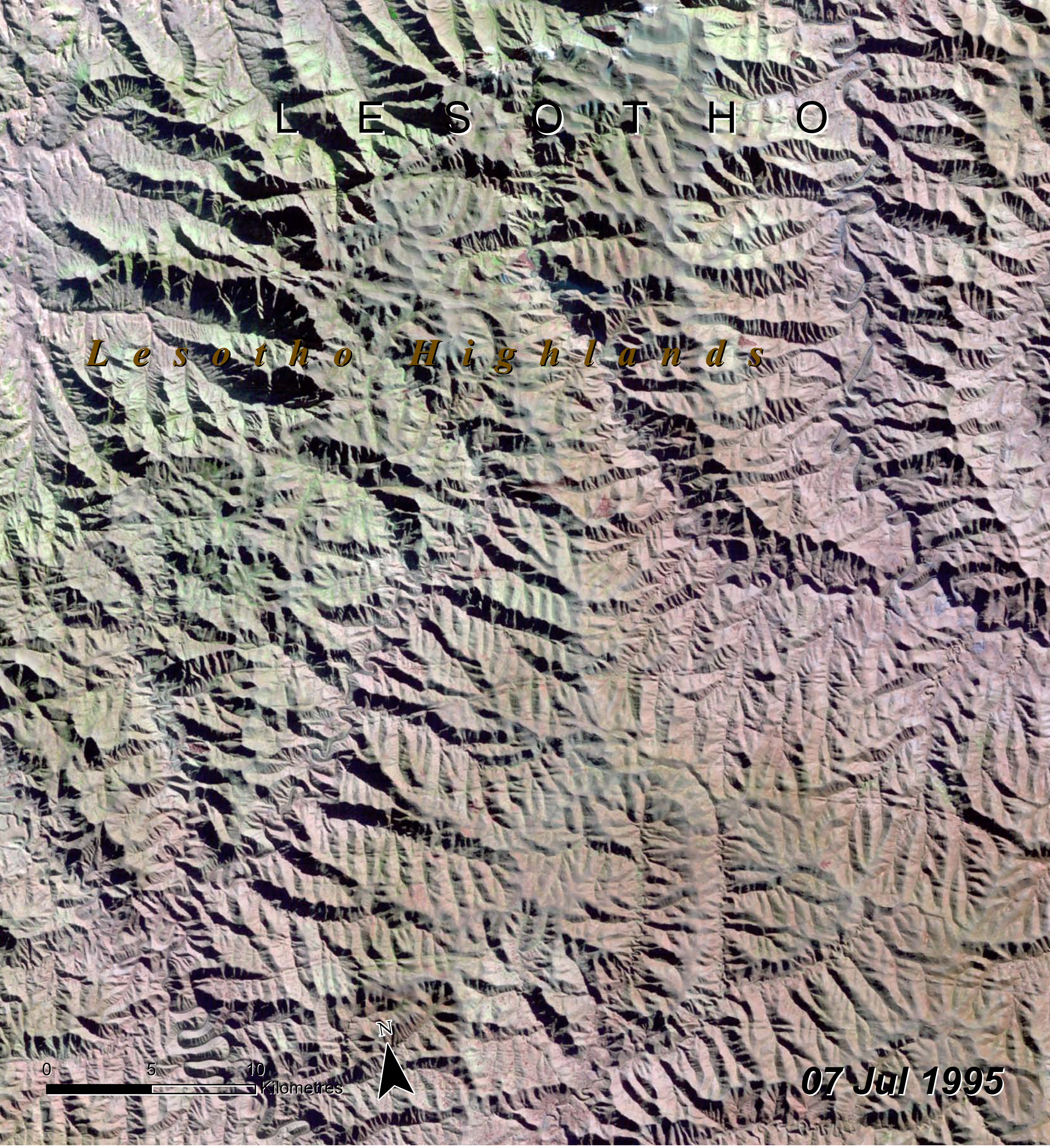
Several social and environmental issues have arisen out of this project, including an exacerbation of poverty and increased food insecurity for women. Hoover (2001) summarizes the impacts and compensation awarded: 1 900 ha of cropland were overtaken and 2 345 households lost fields in the submerged area and approximately 20 500 rural Basotho residents were displaced. The Lesotho Highlands Development Authority (LHDA) awarded them with several different forms of compensation, including cash payments, food, commercial property and household gardens over a certain time period (Slater & Mphale, 2009). The loss of land remained a grave concern for many, however, representing the loss of guaranteed future security (Braun, 2010). The construction of the Mohale Dam in Phase 1B displaced an additional 7 000 people (Hoover, 2001).

Environmentally, the downstream and transboundary impacts were not fully considered. There was no impact assessment before Phase 1A began (Willemse, 2007), but the experience led to a thorough impact assessment for Phase 1B, addressing environmental, social and economic impacts as well as some issues with the compensation policy during Phase 1A, although it neglected the transboundary implications (Willemse, 2007; Hoover, 2001). An Instream Flow Assessment (IFA) to assess the potential impacts of reduced flow downstream on aquatic ecosystems was completed after construction of the Mohale Dam was already underway (MC, 2002).



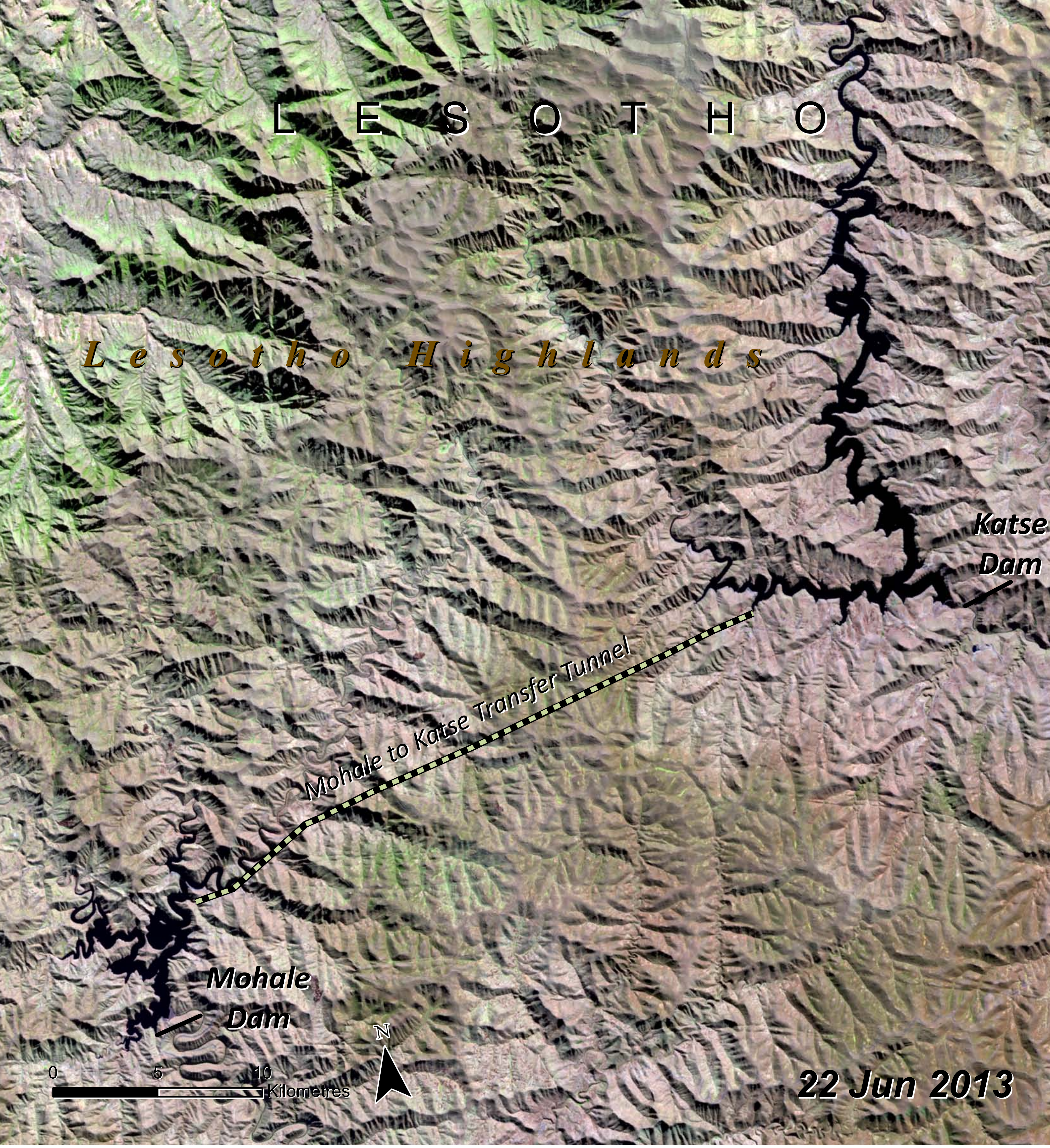
Once used for growing maize and sorghum, this land was flooded when the Mohale Dam was constructed

International Rivers / Flickr / CC BY-NC-SA

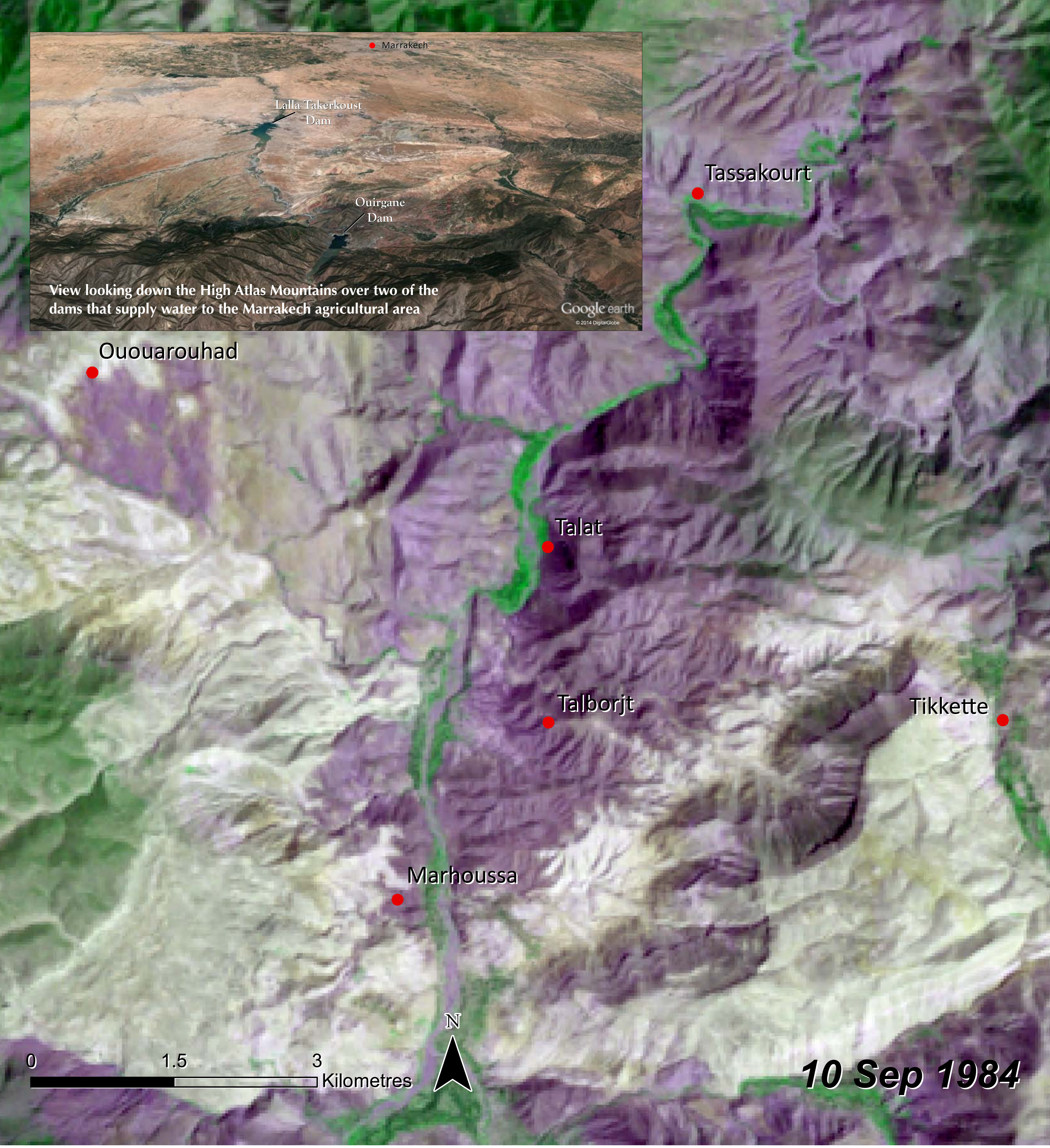


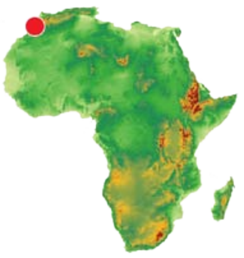
Hotspot: Lesotho Highlands Water Project, Lesotho

The satellite images show the vast change in terrain between 1995, before the LHWP dams were constructed, and 2013. The construction of the later Mohale Dam was more beneficial than Phase 1A. More than 4 000 jobs were created and transportation and telecommunications infrastructure improved, including the construction of a scenic route through the highlands that



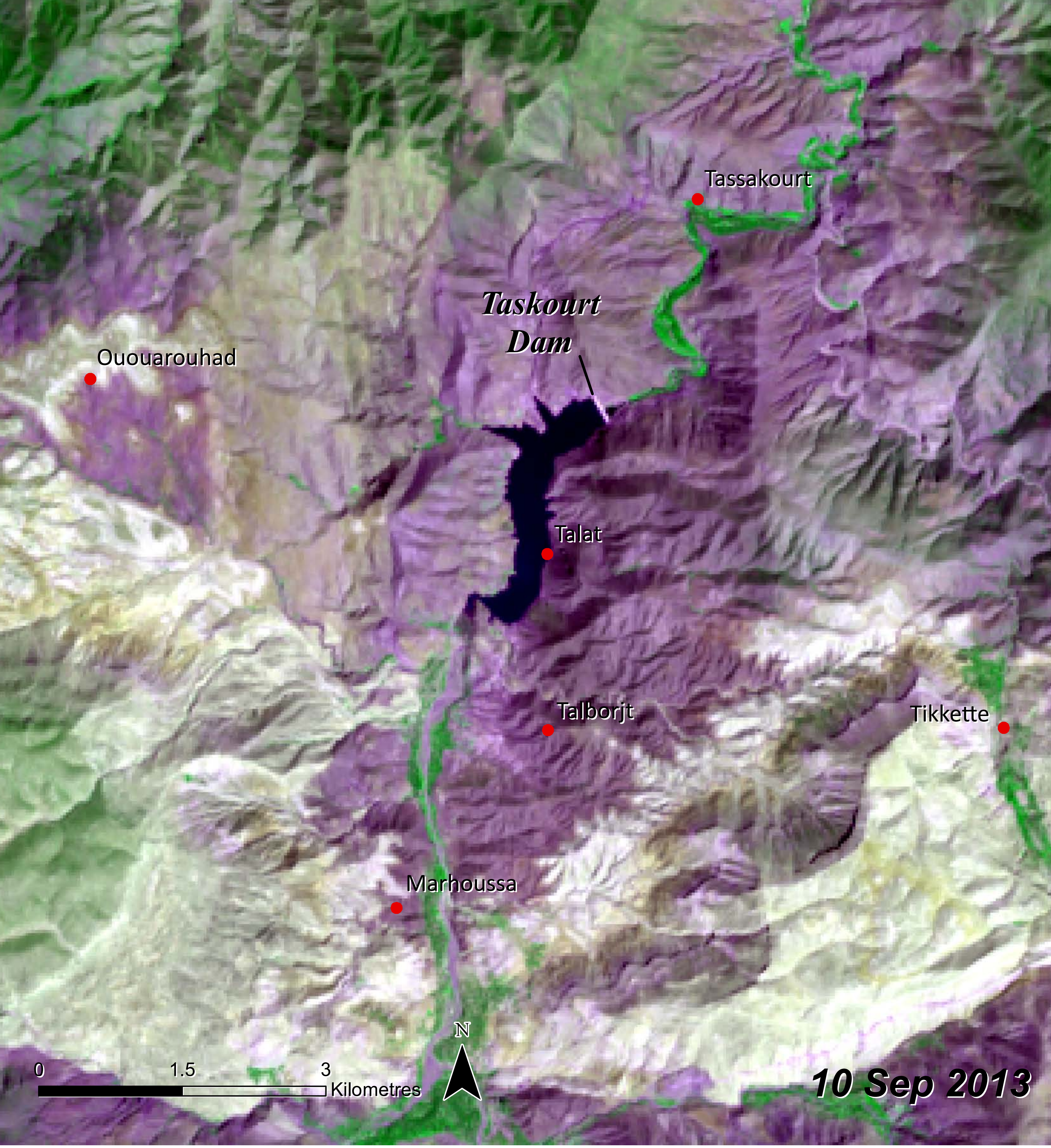
could attract ecotourism (Willemse, 2007). More people live downstream of the Mohale Dam than near it and since water was captured upstream, they were deprived of the water supplies they were used to (Willemse, 2007). According to some reports, Phase 2, which includes constructing the Polihali Dam and the Kobong pump storage hydroelectricity project at a total cost of $US1.45 billion, is aimed to start in March 2014 (Ralengau, 2014).





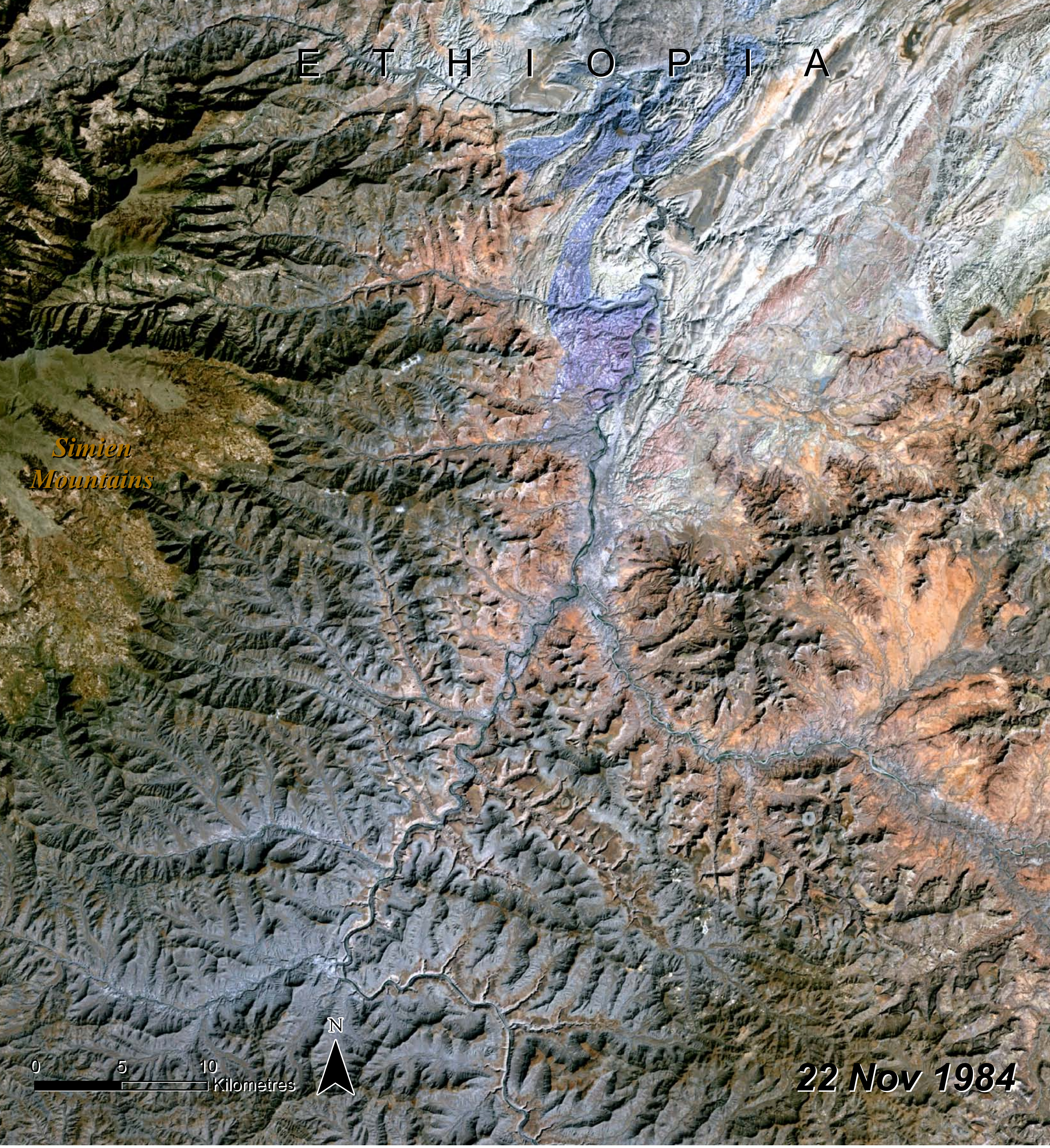
Hotspot: Taskourt Dam, Atlas Mountains, Morocco

Overexploitation of the Haouz groundwater table, under-performing dams and more domestic water usage than planned has contributed to water scarcity (Rojat, 2007). Several dams have been constructed in the Marrakech region to increase water supply for irrigation. Water captured by the Taskourt Dam, completed in 2011, provides a constant source of drinking water to Chichaoua Province in southwest Marrakech and neighbouring cities and villages (OFID, 2013). The 25 million m³ reservoir also



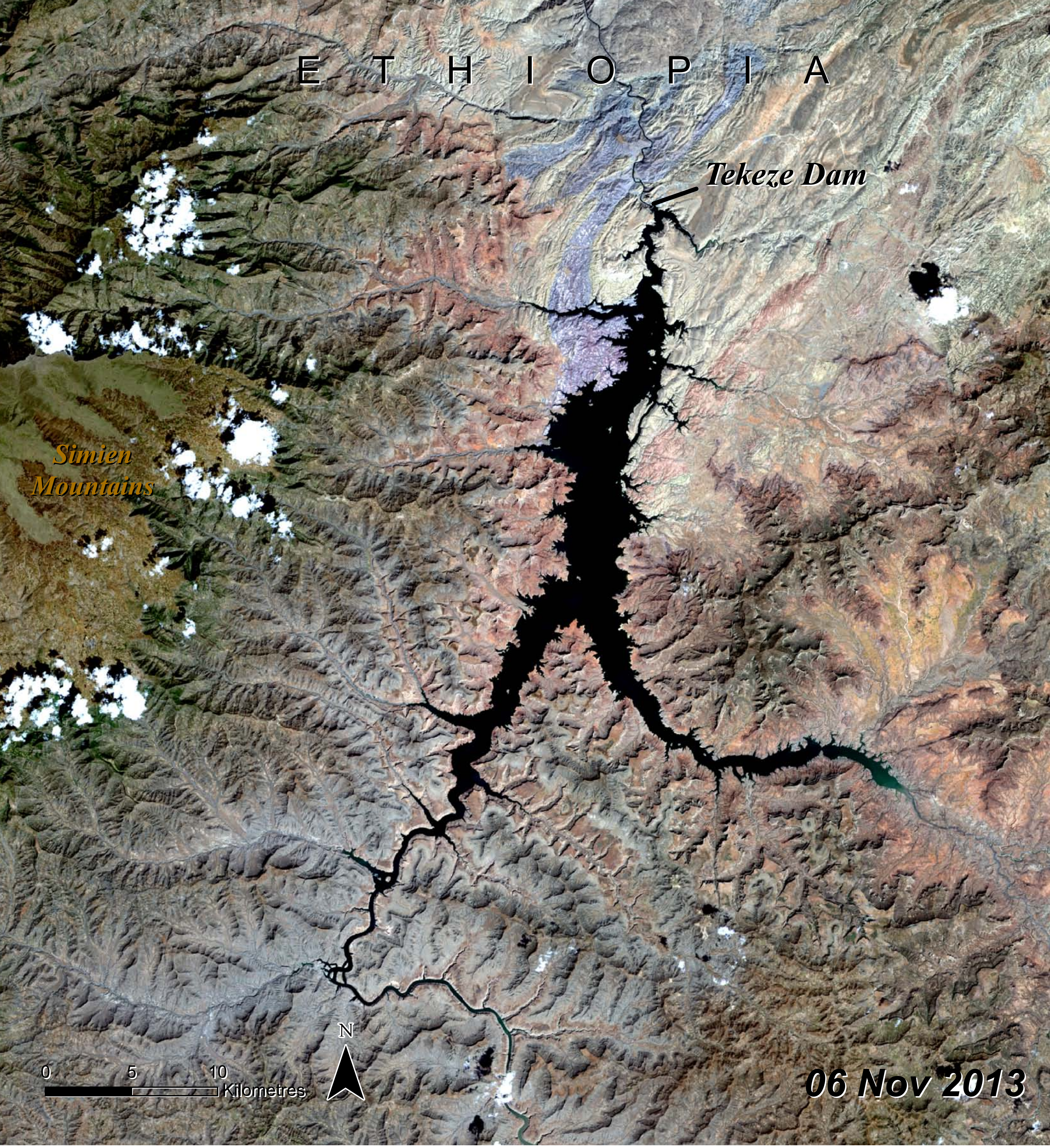
protected 16 800 ha of land (OFID, 2013) and irrigates 5 000 ha of agricultural land (OBG, 2009). The Ouirgane dam, completed in 2008, also supplies water to the region, providing 17 million m^3/yr of water (FM6E, 2011). It has helped alleviate some water scarcity because some dams, such as the Lalla Takerkoust, have not been operating at capacity due to siltation (Rojat, 2007).

Future plans include obtaining water from the Oum-er-Rbia River and the Al Massira Dam, which will contribute an additional 70 million m^3/yr of water, covering water needs for the Marrakech region until 2030 (FM6E, 2011). Ultimately, the goal is to rely on surface water alone by 2018 with no reliance of groundwater supplies at all (FM6E, 2011).



Hotspot: Tekeze Dam, Ethiopia

The Simien Mountains give rise to the Tekeze River, an important tributary of the Nile River. The Tekeze River flows westward out of Ethiopia, joining the Atbara River and eventually the Nile River approximately 300 km south of Khartoum, Sudan (Stevenson & Debebe, 2009). The Tekeze Dam, the tallest dam in Africa at 188 m, was completed in 2009 to harness this prominent river's



hydropower potential and provide clean energy to the 80 million people within its reaches. Initially planned to supply 300 MW of power, adding 40 per cent to Ethiopia's power supply (MWH Global, 2014), the dam has faced many social, environmental and economic issues. During construction in 2008, a massive landslide occurred, costing the developers an extra US$42 million to repair damage and reinforce the retaining walls to prevent future erosion (IR, n.d.).

Conclusion

The climate and soils make many mountainous areas and highlands favourable places to cultivate crops for subsistence and cash and to pasture livestock. They thus attract settlements and their populations are growing in numbers and density. This is putting additional pressure on delicate mountain environments, where slopes can be steep and risk eroding if activity is not properly managed. At the same time, Africa's mountains continue to evolve as the earth's crust shifts and weathering processes erode their surfaces. Many of them experience earthquakes, volcanic eruptions or landslides that change environmental conditions, with potential impacts on local people and their livelihoods, as well as on regional and national economies. Human activities often exacerbate these natural processes, while the growing populations in fragile mountain environments increase the number of people who may find themselves in harm's way if exposed to natural events such as eruptions and landsides, or to the impacts of unsustainable development such as deforestation and poorly planned dams and industrial activity. Thus, it is important to continue to protect mountains through conservation and management measures and to make a conscious and concerted effort to institute and strengthen appropriate legal frameworks so that sustainable development can occur. The next chapter, Chapter 4, outlines many of the ways that the international community, nations, transboundary alliances and local communities are already acting to protect Africa's mountains and explores what can be done in the future to build upon and expand these efforts.

References

AAD. (2009). Green Morocco Plan. Retrieved December 16, 2013, from Agency for Agricultural Development (AAD): http://www.ada.gov.ma/en/Plan_Maroc_Vert/plan-maroc-vert.php

AfDB. (2012). Briefing Notes for AfDB's Long-Term Strategy, Briefing Note 4: Africa's Demographic Trends. African Development Bank Group.

Ait Hamza, M. (1996). The mastery of water: SWC practices in the Atlas Mountains of Morocco. In C. Reji, I. Scoones, & C. Toulmin, Sustaining the soil: indigenous soil and water conservation in Africa (pp. 44-47). London: Earthscan.

Akumsi, A. (2003). Community Participation in Wildlife Management: The Mount Cameroon Experience. XII World Forestry Congress. Quebec City: Government of Canada. Retrieved March 24, 2014, from http://www.fao.org/docrep/ARTICLE/WFC/XII/0430-C1.HTM

Alami, A. (2014). On Moroccan Hill, Villagers Make Stand Against a Mine. Retrieved March 24, 2014, from The New York Times: http://www.nytimes.com/2014/01/24/world/africa/on-moroccan-hill-villagers-make-stand-against-a-mine.html?_r=0

Allport, G. (1991). The status and conservation of threatened birds in the Upper Guinea Forest. Bird Conservation International, 1, 53 - 74.

Almeida-Silva, M., Almeida, S., Freitas, M., Pio, C., Nunes, T., & Cardoso, J. (2013). Impact of Sahara dust transport on Cape Verde atmospheric element particles. Journal of Toxicology and Environmental Health, Part A: Current Issues, 76(4-5), 240-51.

Assefa, E., & Bork, H.-R. (2014). Deforestation and Forest Management in Southern Ethiopia: Investigations in the Chencha and Arbaminch Areas. Environmental Management, 53, 284-299.

Atanga, M.B.S., Merve, A., Njome, M.S., Kruger, W., Suh, C.E. (2010). Health System Preparedness for Hazards Associated With Mount Cameroon Eruptions: A Case Study of Bakingili Village. International Journal of Mass Emergencies and Disasters. 28(3), 298-325.

AU. (2010). Regional Programme for the Integrated Development of the Fouta Djallon Highlands (RPID-FDH). Retrieved January 31, 2014, from African Union (AU): http://rea.au.int/en/RO/FDH

Bagoora, F.K. (2012a). Potential and Climate Change Vulnerability, Impacts and Adaptation Options In African Mountains. A paper presented at the International Conference of Mountain Countries Climate Change in Kathmandu, Nepal 5-6 April. Kampala: Nature-RIDD Uganda.

Bagoora, F K. (2012b). Report on Progress In Implementation of Agenda 21 Commitments on Sustainable Mountain Development In Africa. Nairobi: United Nations Environment Programme.

Bang, H. (2012). Disaster management in Cameroon: the Lake Nyos disaster experience. Disaster Prevention and Management, 21(4), 489-506.

Barrow, C., & Hicham, H. (2000). Two complimentary and integrated land uses of the western High Atlas Mountains, Morocco: the potential for sustainable rural livelihoods. Applied Geography, 20, 369-394.

Basson, G. (2004). Hydropower Dams and Fluvial Morphological Impacts - An African Perspective. Proceedings of the United Nations Symposium on Hydropower and Sustainable Development. Beijing: United Nations.

Basson, G. (2008). Reservoir Sedimentation - An Overview of Global Sedimentation Rates, Sediment Yield & Sediment Deposition Prediction. International Workshop on Erosion, Transport and Deposition of Sediment. Berne: International Sediment Initiative.

BBC. (2008). Great Lakes hit by deadly earthquakes. Retrieved June 25, 2014 from, BBC: http://news.bbc.co.uk/2/hi/africa/7224925.stm

BDLG. (2011). Five-Year District Development Plan. Bududa: Bududa District Local Government.

Bele, M., Focho, D., Egbe, E., & Chuyong, B. (2011). Inventory and distribution of the Annonaceae along elevation gradient on Mount Cameroon. Journal of Horticulture and Forestry, 3(10), 307-319.

Bermúdez-Lugo, O. (2011). 2009 Minerals Yearbook: Angola. Reston: U.S. Geological Survey.

Bermúdez-Lugo, O. (2013). The Mineral Industries of Mali and Niger. 2011 Minerals Yearbook. Reston: U.S. Geological Survey.

BLI. (2011). Ethiopia: Ethiopian Wildlife and Natural History Society. In L. Fishpool, & M. Evans (Eds.), Important Bird Areas in Africa and Associated Islands: Priority Sites for Conservation (pp. 291-336).

Blyth, S., Groombridge, B., Lysenko, I., Miles, L., & Newton, A. (2002). Mountain Watch: map-based overview of environmental change in mountains. Nairobi: United Nations Environment Programme.

Bouchouata, O., Ouadarri, H., El Abidi, A., El Morhit, M., Attarassi, B. (2012). Bioaccumulation des métaux lourds par les cultures maraîchères au niveau du bassin de Sebou (Maroc). Bulletin de l'Institut Scientifique, section Sciences de la Vie, 34(2), 187–201.

Boyes, S. (2014). Rio Tinto Simandou: Exporting Iron Mountains (Part 1 of 2). Retrieved May 8, 2014, from National Geographic: http://newswatch.nationalgeographic.com/2014/01/27/riot-into-simandou-exporting-iron-mountains-part-1-of-4/

Braun, Y. (2010). Gender, large-scale development and food insecurity in Lesotho: an analysis of the impact of the Lesotho Highlands Water Project. Gender and Development, 18(3), 453-464.

Burgess, N., Balmford, A., Corderio, N., Fjeldsa, J., Kuper, W., Rahbek, C., Williams, P. (2007a). Correlations among species distributions, human density and human infrastructure across the high biodiversity tropical mountains of Africa. Biological Conservation, 134, 164 - 177.

Bussman, R. (2006). Vegetation zonation and nomenclature of African Mountains - An overview. Lyonia, 11(1), 41 - 66.

Cáceres, A., Paulo, S., Tchalo, F., Mills, M., & Melo, M. (2013). Human use of natural resources and the conservation of the afromontane forest in Mount Moco, Angola. Journal of Sustainable Development in Africa, 15(3), 91 - 101.

Chamber of Mines. (2008). Putting South Africa First. Retrieved February 7, 2014, from Chamber of Mines of South Africa: http://chamberofmines.co.za/content/?pid=84&pagename=Gold

Chi-Bonnardel, R. (1973). Atlas of Africa. Paris: Institut geographique national.

CII. (2008). 118/119 Biodiversity and Tropical Forest Assessment for Angola. Chemonics International Inc. (CII) and United States Agency for International Development (USAID).

Clark, L.-A., & Rae, K. (2005). Severe thunderstorm development over KwaZulu-Natal, South Africa (3 January 2005). Retrieved March 27, 2014, from EUMETSAT: http://oiswww.eumetsat.org/WEBOPS/iotm/iotm/20050103_convection/20050103_convection.html

CND. (2009). General Census of Population and Housing 2004. Retrieved April 8, 2014, from Haut-Commissariat au Plan du Maroc, Centre National de Documentation: http://www.hcp.ma/Recensement-general-de-la-population-et-de-l-habitat-2004_a633.htm.

CoK. (2013). Statistics. Retrieved May 8, 2014, from City of Kigali: http://www.kigalicity.gov.rw/spip.php?article9

Croitoru, L., & Merlo, M. (2005). Mediterranean Forest Values. In M. Merlo, & L. Croitoru (Eds.), Valuing Mediterranean Forests: Towards Total Economic Values (pp. 37 - 68). Oxfordshire: CABI Publishing.

CSA. (2008). Federal Democratic Republic of Ethiopia Population Census Commission. Summary and Statistical Report of the 2007 Population and Housing Census. Addis Ababa: Central Statistical Agency of Ethiopia (CSA).

CSA. (2012a). ICPS 2012 Projection Report. Addis Ababa: Central Statistics Agency of Ethiopia (CSA).CSA. (2012b). ICPS 2012 Report. Addis Ababa: Central Statistics Agency Ethiopia (CSA).

Cuesta, J., Lavaysse, C., Flamant, C., Mimouni, M., & Knippertz, P. (2009). Northward bursts of the West African monsoon leading to rainfall over the Hoggar Massif, Algeria. Quarterly Journal of the Royal Meteorology Society, 136(s1), 174-189.

Cullen, N., Mölg, T., Kaser, G., Hussein, K., Steffen, K., & Hardy, D. (2006). Kilimanjaro Glaciers: Recent areal extent from satellite data and new interpretation of observed 20th century retreat rates. Geophysical Research Letters, 33(L16502). doi:10.1029/2006GL027084

d'Oreye, N., Kervyn, F., Wauthier, C., Calais, E., Cayol, V., Fernández, J., . . . Marinkovic, P. (2011). Source parameters of the 2008 Bukavu-Cyangugu earthquake estimated from InSAR and teleseismic data. Geophysical Journal International, 184(2), 934-948.

Dahan, R., Boughlala, M., Mrabet, R., Laamari, A., Balaghi, R., & Lajouad, L. (2012). A review of available knowledge on land degradation in Morocco. Aleppo: International Center for Agricultural Research in the Dry Areas.

Dorosh, P., Alemu, G., de Brauw, A., Malek, M., Mueller, V., Schmidt, E., . . . Thurlow, J. (2011). The Rural-Urban Transformation in Ethiopia. Addis Ababa: International Food Policy Research Institute.

Draper, I., Albertos, B., Garilleti, R., Lara, F., & Mazimpaka, V. (2007). Contribution to the biodiversity conservation in Morocco (North Africa): important areas for epiphytic bryophytes. Cryptogamie, Bryologie, 28(3), 211 - 236.

Durand, J. (2012). The impact of gold mining on the Witwatersrand on the rivers and karst system of Gauteng and North West Province, South Africa. Journal of African Earth Sciences, 68, 24-43.

DWA. (2011). Development of Reconciliation Strategies for All Towns in the Central Region. Pretoria: Department of Water Affairs Republic of South Africa.

DWAF. (1998). Overview of the Lesotho Highlands Water Project. Retrieved January 30, 2014, from Department of Water Affairs and Forestry: http://www.dwaf.gov.za/orange/Up_Orange/lhwpover.htm

EERI. (2008). Learning from Earthquakes: February 3, 2008, Lake Kivu Earthquake. Earthquake Engineering Research Institute (EERI) Newsletter. 42(3), 12.

Ethiopian News. (2014). Haromaya Lake has recovered 20%. (G. Senay, Trans.) Retrieved March 11, 2014

Fairman, J., Nair, U., & Christopher, S. (2011). Impact of land use change on the regional climate of Mount Kilimanjaro. Journal of Geophysical Research, 116(D3). doi:10.1029/2010JD014712

FAO. (2002). Sustainable Rural Development and Food Security: The Role of Mountain Development in Africa. Twenty-second Regional Conference for Africa. Cairo: Food and Agriculture Organization of the United Nations. Retrieved January 23, 2014, from http://www.fao.org/docrep/meeting/004/y6056e.htm#2

FAO. (2010). Global Forest Resources Assessment 2010 Main Report. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2011a). Water for Agriculture and Energy in Africa: the Challenge of Climate Change. Rome: Food and Agriculture Organization of the United Nations (FAO).

FAO. (2011b). Why Invest in Sustainable Mountain Development? Rome: Food and Agriculture Organization of the United Nations.

FAO. (2013a). Fouta Djallon Highlands Integrated Natural Resources Management Project. Retrieved January 31, 2014, from Food and Agriculture Organization of the United Nations (FAO): http://www.fao.org/forestry/watershedmanagementandmountains/74917/en/

FAO. (2013b). Mountain Farming is Family Farming: A contribution from mountain areas to the International Year of Family Farming 2014. Rome: Food and Agriculture Organization of the United Nations (FAO), the Centre for Development and Environment of the University of Bern, the Centre for Development Research of the University of Natural Resources and Life Sciences, Vienna.

FAO AQUASTAT. (2014). Geo-referenced dams database. Retrieved December 15, 2013, from Aquastat Food and Agriculture Organization of the United Nations: http://www.fao.org/nr/water/aquastat/dams/index.stm

FFI. (2009). Cross-sectoral partnerships for conservation, sustainable management and improved livelihoods at the Nimba Biosphere Reserve, Republic of Guinea. Fauna & Floral International.

FM6E. (2011). The city of Marrakech. Retrieved December 16, 2013, from Fondation Mohammed VI Pour La Protection de l'Environnement: http://www.fm6e.org/en/weec-2013/presse/toutes-les-revus-de-presse/revu-de-presse-categorie/788-la-ville-de-marrakech-gestionnaire-modele-de-ses-eaux.html

GAC. (2012). Mount Moco reforestation boosted by GAC support. Retrieved January 9, 2014, from Gulf Agency Company: https://www.gac.com/gacen/news_show.aspx?id=57308

Garrison, V., Foreman, W., Genualdi, S., Griffin, D., Kellogg, C., Majewski, M., . . . Smith, G. (2006). Saharan dust – a carrier of persistent organic pollutants, metals and microbes to the Caribbean. International Journal of Tropical Biology and Conservation, 54, 9-21.

Gaston, B. (2009). Geographic Information Systems-based Demarcation of Risk Zones: the case of the limbe Sub-Division – Cameroon. JAMBA: Journal of Disaster Risk Studies, 2(1).

Giles, J. (2005, April 13). Climate science: The dustiest place on Earth. Nature. doi:10.1038/434816a

GoK. (2009). Rehabilitation of the Mau Forest Ecosystem. Nairobi: Interim Coordinating Secretariat, Office of the Prime Minister, on behalf of the Government of Kenya.

Gorsevski, V., Geores, M., & Kasischke, E. (2013). Human dimensions of land use and land cover change related to civil unrest in the Imatong Mountains of South Sudan. Applied Geography, 38, 64 - 75.

Goudie, A. (1996). Climate: Past and Present. In W. Adams, A. Goudie, & A. Orme (Eds.), The Physical Geography of Africa (pp. 34-59). Oxford: Oxford University Press.

Greenland, D. (2005). Mountain Climates. In J. Oliver (Ed.), Encyclopedia of World Climatology (pp. 517-523). Springer Netherlands.

Griffiths, J. (2005). Africa: Climate of. In J. Oliver (Ed.), Encyclopedia of World Climatology (pp. 6-14). Springer Netherlands.

Hall, J., Burgess, N., Lovett, J., Mbilinyi, B., & Gereau, R. (2009). Conservation implications of deforestation across an elevational gradient in the Eastern Arc Mountains, Tanzania. Biological Conservation, 142, 2510 - 2521.

Hastenrath, S. (2005). The glaciers of Mount Kenya 1899 - 2004. Erdkunde, 59(2), 120 - 125.

Hastenrath, S. (2009). Climatic forcing of glacier thinning on the mountains of equatorial East Africa. International Journal of Climatology, 30(1), doi: 10.1002/joc.1866.

Hemp, A. (2005). Climate change-driven forest fires marginalize the impact of ice cap wasting on Kilimanjaro. Global Change Biology, 11, 1013-1023.

Henry, J. (2005). Tropical and Equatorial Climates. In J. Oliver (Ed.), Encyclopedia of World Climatology (pp. 742-750). Springer Netherlands.

Hoover, R. (2001). Pipe Dreams: The World Bank's Failed Efforts to Restore Lives and Livelihoods of Dam-Affected People in Lesotho. Berkeley: International Rivers Network.

Hunink, J., Terink, W., Droogers, P., Reuter, H., Huting, J. (2011). Towards a Proof-of-Concept of Green Water Credits for the Sebou Basin, Morocco. Wageningen: FutureWater.

Hunnes, D. (2012). An Analysis of Ethiopian Rural-to-Urban Migration Patterns from Primary Interviews. Journal of Global Health Perspectives. Retrieved January 29, 2014, from http://jglobalhealth.org/article/an-analysis-of-ethiopian-rural-to-urban-migration-patterns-from-primary-interviews-2/

Hylander, K., Nemomissa, S., Delrue, J., & Enkosa, W. (2013). Effects of Coffee Management on Deforestation Rates and Forest Integrity. Conservation Biology, 27(5), 1031-1040.

IMCCCG. (2010). Mine water management in the Witwatersrand gold fields with special emphasis on acid mine drainage. Expert Team of the Inter-Ministerial Committee under the Coordination of the Council for Geoscience.

InfoMine. (2010). Letseng la Terai Mine. Retrieved from InfoMine: http://www.infomine.com/minesite/minesite.asp?site=letseng

InfoMine. (2014a). All Operating Mine Sites. Retrieved January 30, 2014, from Infomine: http://www.infomine.com/minesite/welcome.asp?region=africa/middle%20east

InfoMine. (2014b). Top Coal Producing Countries. Retrieved April 2, 2014, from InfoMine: http://coal.infomine.com/countries/

IPB. (2012). Cape Verde Mineral & Mining Sector Investment and Business Guide. Washington, D.C.: International Business Publications.

IR. (n.d.). Tekeze Dam, Ethiopia. Retrieved April 1, 2014, from International Rivers: http://www.internationalrivers.org/resources/tekeze-dam-ethiopia-3607

IRIN. (2010). DRC: Watching the volcanoes. Retrieved June 26, 2014 from, IRIN: humanitarian news and analysis: http://www.irinnews.org/report/88115/drc-watching-the-volcanoes

IRIN. (2011). Eritrea-Ethiopia: Thousands need aid after volcano eruption. Retrieved January 31, 2014, from IRIN: Humanitarian news and analysis, a service of the UN Office for the Coordination of Humanitarian Affairs: http://www.irinnews.org/report/93161/eritrea-ethiopia-thousands-need-aid-after-volcano-eruption

IUCN. (2012). Mining Sector Development in West Africa and its Impact on Conservation. Ouagadougou: International Union for the Conservation of Nature and its Resources.

Jarvis, A., Reuter, H.I., Nelson, A., Guevara, E. (2008). Hole-filled SRTM for the globe Version 4. Retrieved June 25, 2014, from the CGIAR-CSI SRTM 90m Database: http://srtm.csi.cgiar.org

Kaser, G., Hardy, D., Mölg, T., Bradley, R., & Hyera, T. (2004). Modern Glacier Retreat on Kilimanjaro as Evidence of Climate Change: Observations and Facts. International Journal of Climatology, 24, 329-339.

Kaser, G., Mölg, T., Cullen, N., Hardy, D., & Winkler, M. (2010). Is the decline of ice on Kilimanjaro unprecedented in the Holocene? The Holocene, 20(7), 1079 - 1091.

Kaufmann, G., & Romanov, D. (2012). Landscape evolution and glaciation of the Rwenzori Mountains, Uganda: Insights from numerical modeling. Geomorphology. 138, 263-275.

KFS. (2009). Aberdare Forest Reserve Management Plan 2010 - 2019. Kenya Forest Service.

Kling, G., Clark, M., Compton, H., Devine, J., Evans, W., Humphrey, A., . . . Wagner, G. (1987). The 1986 Lake Nyos Gas Disaster in Cameroon, West Africa. Science, 236(4798), 169-175.

Knapen, A., Kitutu, M., Poesen, J., Breugelmans, W., Deckers, J., & Muwanga, A. (2006). Landslides in a densely populated county at the footslopes of Mount Elgon (Uganda): Characteristics and causal factors. Geomorphology, 73, 149 - 165.

Knight, J., & Grab, S. (2014). Lightning as a geomorphic agent on mountain summits: Evidence from southern Africa. Geomorphology, 204, 61-70.

Kohler, T., & Maselli, D. (2009). Mountains and Climate Change - From Understanding to Action. Bern: Centre for Development and Environment; Institute of Geography, University of Bern; Swiss Agency for Development and Cooperation.

Koren, I., Kaufman, Y., Washington, R., Todd, M., Rudich, Y., Martins, J., & Rosenfeld, D. (2006). The Bodele depression: a single spot in the Sahara that provides most of the mineral dust to the Amazon forest. Environmental Research Letters. doi:10.1088/1748-9326/1/1/014005

Kusakabe, M., Ohba, T., Issa, Yoshida, Y., Satake, H., Ohizumi, T., . . . Kling, G. (2008). Evolution of CO_2 in Lakes Monoun and Nyos, Cameroon, before and during controlled degassing. Geochemical Journal, 42, 93-118.

Lambrechts, C. (2002). Aerial Survey of the Threats to Mt. Kilimanjaro Forests – Data CD-ROM. Division of Early Warning and Assessment, United Nations Environment Programme.

LHDA. (2013). Lesotho Highlands Water Project Phase 1. Retrieved April 4, 2014, from Lesotho Highlands Development Authority: http://www.lhda.org.ls/Phase1/?page_id=733

Lindenfeld, M., Rumpker, G., Link, K., Koehn, D., & Batte, A. (2012). Fluid-triggered earthquake swarms in the Rwenzori region, East African Rift - Evidence for rift initiation. Tectonophysics, 566-567, 95-104.

Lloyd, P. (2002). Coal and the environment. Durban: IBA.

Lonsdale, K., & Du, M. (2009). Cape Town Learning Example: Urban Water Supply. Retrieved April 2, 2014, from ADaption and Mitigation Strategies (ADAM): Supporting European Climate Policy: http://adam-digital-compendium.pik-potsdam.de/learning-examples/the-learning-examples/urban-water-supply/

Malawi SDNP. (1994). The Action Plan. Blantyre: Malawi Sustainable Development Network Programme (SDNP).

Maleleka, D. (2007). Diamond Mining in Lesotho. Johannesburg: Southern Africa Resource Watch.

MC. (2002). Lesotho Highlands Water Project. Metsi Consultants.

Mendelsohn, J., & Weber, B. (2013). An atlas and profile of Huambo: its environment and people. Luanda: Development Workshop.

Merowe, A. (2013). The mine planning process for an open-pit diamond mining operation - a case study on Letseng diamond mine in Lesotho. The Journal of the Southern African Institute of Mining and Metalurgy, 113, 547 - 554.

Mesfin, M. (2011). Eritrean Volcano Erupts Economic Mayhem for Ethiopia. Retrieved January 24, 2014, from Addis Fortune: http://addisfortune.com/Vol_10_No_581_Archive/Eritrean%20Volcano%20Erupts%20Economic%20Mayhem%20for%20Ethiopia.htm

Midzi, V., Hlatywayo, D., Chapola, L., Kebede, F., Atakan, K., Lombe, D., . . . Tugume, F. (1999). Seismic hazard assessment in Eastern and Southern Africa. Annali di Geofisica, 42(6).

Mills, M. S., Olmos, F., Melo, M., & Dean, W. R. (2011). Mount Moco: its importance to the conservation of Swierstra's Francolin Pternistis swierstrai and the Afromontane avifauna of Angola. Bird Conservation International, 21, 119 - 133. doi:10.1017/S0959270910000493

Mizuno, K. (2005). Glacial Flucuation and Vegetation Succession on Tyndall Glacier, Mt. Kenya. Mountain Research and Development, 25(1), 68 - 75.

Mölg, T., Chiang, J., Gohm, A., & Cullen, N. (2009). Temporal precipitation variability versus altitude on a tropical high mountain: Observations and mesoscale atmospheric modelling. Quarterly Journal of the Royal Meteorological Society, 135, 1439 - 1455.

Mölg, T., Georges, C., & Kaser, G. (2003). The Contribution of increased incoming shortwave radiation to the retreat of the Rwenzori glaciers, East Africa, during the 20th Century. International Journal of Climatology, 23, 291 - 303.

Mölg, T., Hardy, D., Cullen, N., & Kaser, G. (2008). Tropical glaciers, climate change and society: focus on Kilimanjaro (East Africa). In B. Orlove, E. Wiegandt, & B. Luckman (Eds.), The Darkening Peaks: Glacier Retreat, Science and Society (pp. 168 - 182). Los Angeles: University of California Press.

Montanari, B. (2013). The Future of Agriculture in the High Atlas Mountains of Morocco: The Need to Integrate Traditional Ecological Knowledge. In S. Mann (Ed.), The Future of Mountain Agriculture (pp. 51-72). Berlin: Springer-Verlag.

Moodley, S. (2012). SA increasing use of clean mining technology. Retrieved April 4, 2014, from Mining Weekly: http://www.miningweekly.com/article/sa-increasing-use-of-clean-mining-technology-2012-09-14

Moore, H. M., Fox, H. R., Harrouni, M. C., & El Alami, A. (1998). Environmental challenges in the Rif Mountains, northern Morocco. Environmental Conservation, 25(4), 354 - 365.

Morin, J., & Lavigne, F. (2009). Institutional and social responses to hazards related to Karthala volcano, Comoros. Shima: The International Journal of Research into Island Cultures, 3, 54-71.

Mote, P. W., & Kaser, G. (2007, July - August). The Shrinking Glaciers of Kilimanjaro: Can Global Warming be Blamed? Retrieved 12 26, 2013, from American Scientist: http://www.americanscientist.org/issues/page2/the-shrinking-glaciers-of-kilimanjaro-can-global-warming-be-blamed

Msilimba, G., & Holmes, P. (2005). A landslide hazard assessment and vulnerability appraisal procedure; Vunguvungu/Banga Catchment, Northern Malawi. Natural Hazards, 24, 99 - 216.

Msiska, H., Munthali, J., & Dzowela, B. (1988). Distribution of potential forage plants in Malawi. African forage plant genetic resources, evaluation of forage germplasm and extensive livestock production systems. Proceedings of the Third Workshop held at the International Conference Centre, Arusha, Tanzania, 27-30 April 1987. Addis Ababa: International Livestock Centre for Africa.

Mugagga, F., Kakembo, V., & Buyinza, M. (2012). Land use changes on the slopes of Mount Elgon and the implications for the occurrence of landslides. Catena, 90, 39 - 46.

Muwanga, A., Schuman, A., & Biryabarema, M. (2001). Landslides in Uganda: Documentation of natural hazards. Documenta Natuae, 136, 111 - 115.

Mwangi, O. (2007). Hydropolitics, Ecocide and Human Security in Lesotho: A Case Study of the Lesotho Highlands Water Project. Journal of Southern African Studies, 33(1), 3-17.

MWH Global. (2014). Tekeze Hydropower Project. Retrieved April 1, 2014, from MWH Global: http://www.mwhglobal.com/mwh-projects/tekeze-river-hydropower-project

NASA. (2005). Karthala Volcano in Comoros Erupts. Retrieved February 1, 2014, from NASA Earth Observatory: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=14866

NASA. (2008). Earthquakes hit East Africa. Retrieved June 25, 2014, from NASA Earth Observatory: http://earthobservatory.nasa.gov/IOTD/view.php?id=8458

NASA. (2010). Large Landslide in Uganda. Retrieved January 22, 2014, from NASA Earth Observatory: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=43130

NASA. (2012). East African Rift Valley, Kenya. Retrieved January 31, 2014, from NASA Earth Observatory: http://earthobservatory.nasa.gov/IOTD/view.php?id=77566

NASA. (2014a). Cape Verde Under Dust. Retrieved March 1, 2014, from NASA Earth Observatory: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=83260

NASA. (2014b). Nyamuragira and Nyiragongo Venting Gas. Retrieved February 25, 2014, from NASA Earth Observatory: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=83029&src=nha

NASA/MSFC. (2012). Global Lightning Image. Retrieved May 6, 2014, from National Aeronautics and Space Administration (NASA) and Marshall Space Flight Center (MSFC): http://thunder.msfc.nasa.gov/data/query/mission.png

NBS. (2012a). 2012 Tanzania Population and Housing Census. Retrieved May 8, 2014, from National Bureau of Statistics – Tanzania: http://www.nbs.go.tz/sensa/new.html

NBS. (2012b). Dar-es-Salaam Region Population. Retrieved January 30, 2014, from National Bureau of Statistics - Tanzania: www.nbs.go.tz/sensa/popu2.php

NBS. (2013). Tanzania in Figures 2012. Dar es Salaam: The United Republic of Tanzania National Bureau of Statistics; Ministry of Finance.

Newman, H. (2011). Minerals Yearbook, 2009, V. 3, Area Reports, International Africa and the Middle East. Reston: U.S. Geological Survey Government Printing Office.

Newman, H. (2012a). The Mineral Industries of Cameroon and Cape Verde. Reston: U.S. Geological Survey.

Newman, H. (2012b). The Mineral Industries of Morocco and Western Sahara. Reston: U.S. Geological Survey.

Ngana, J., Mahay, F., & Cross, K. (2010). Ruvu Basin: A Situation Analysis. Nairobi: International Union for Conservation of Nature and Natural Resources.

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

NISR. (2012). 2012 Population and Housing Census Report on the Provisional Results. Kigali: National Institute Statistics Rwanda (NISR).

NNPC. (2012). Namibia 2011 Population and Housing Census Preliminary Results. Windhoek: Republic of Namibia National Planning Commission (NNPC).

NRL. (2013, February 08). Violent Nabro Eruption Shown to Pierce Stratosphere. Retrieved January 27, 2014, from U.S. Naval Research Lab: www.nrl.navy.mil/media/news-releases/2013/violent-nabro-eruption-shown-to-pierce-stratosphere

OBG. (2009). The Report: Morocco 2009. Oxford: Oxford Business Group.

OCHA, 2008. Earthquake in the Great Lakes Region OCHA Situation Report 15 Feb 2008. Retrieved June 26, 2014 from the UN Office for the Coordination of Humanitarian Affairs: http://reliefweb.int/report/democratic-republic-congo/earthquake-great-lakes-region-ocha-situation-report-15-feb-2008

Ochego, H. (2003). Application of Remote Sensing in Deforestation Monitoring: A Case Study of the Aberdares (Kenya). TS11 Management of Water Resources. Marrakech: 2nd FIG Regional Conference.

ODK. (2009). 2009 Census Vol 1 B Table 1 Population and Density by Constituency. Retrieved May 8, 2014, from Open Data Kenya: https://www.opendata.go.ke/Population/2009-Census-Vol-1-B-Table-1-Population-and-Density/j2vg-j63y

OECD. (2013). African Economic Outlook 2013: Structural Transformation and Natural Resources. OECD Publishing. doi:10.1787/aeo-2013-en

OFID. (2013). Morocco: Project Portfolio. Retrieved December 16, 2013, from The OPEC Fund for International Development: http://www.ofid.org/COUNTRIES/Africa/Morocco.aspx

Osmaston, H.A., & Harrison, S.P. (2005). The Late Quaternary glaciation of Africa: a regional synthesis. Quaternary International. 138-139, 32-54.

Osmaston, H.A., & Kaser, G. (2001). Glaciers and Glaciations of the Rwenzori Mountains, Uganda. Rwenzori Mountains National Park, Uganda and Park National des Virungas, Democratic Republic of Congo. 4 maps 1:100,000 and 1:60,000. Innsbruck: Department of Geography, University of Innsbruck.

Perrin, J.L., Raïs, N., Chahinian, N., Moulin, P., Ijjaali, M. (2014). Water quality assessment of highly polluted rivers in a semi-arid Mediterranean zone Oued Fez and Sebou River (Morocco). Journal of Hydrology, 510, 26-34.

Pravettoni, R., & UNEP/GRID-Arendal. (2011). Urban growth rate in Africa. Retrieved June 10, 2014 from, UNEP/GRID-Arendal: http://www.grida.no/graphicslib/detail/urban-growth-rate-in-africa_12bb#

Price, M., Gratzer, G., Duguma, L., Kohler, T., Maselli, D., & Romeo, R. (2011). Mountain Forests in a Changing World: Realizing values, addressing challenges. Rome: Food and Agriculture Organization of the United Nations Mountain Partnership Secretariat (FAO/MPS) and Swiss Agency for Development and Cooperation (SDC).

Prinz, R., Fischer, A., Nicholson, L., & Kaser, G. (2011). Seventy-six years of mean mass balance rates derived from recent and re-evaluated ice volume measurements on tropical Lewis Glacier, Mount Kenya. Geophysical Research Letters, 38, L20502. doi:10.1029/2011GL049208

Prospero, J., & Mayol-Bracero, O. (2013). Understanding the Transport and Impact of African Dust on the Caribbean Basin. Bull. Amer. Meteor. Soc., 94, 1329–1337.

Ralengau, M. (2014, April 4). Lesotho Highlands Water Project Phase II to Start on March 27. Retrieved from Bloomberg: http://www.bloomberg.com/news/2014-02-28/lesotho-highlands-water-project-phase-ii-to-start-on-march-27.html

Rojat, D. (2007). Assessing the full cost and value of water in Morocco - AFD/SCP study results. Morocco: Agence Française de Développement (French Agency for Development).

Rostom, R., & Hastenrath, S. (2007). Variations of Mount Kenya's glaciers 1993 - 2004. Erdkunde, 61(3), 277 - 283. doi:10.3112/erdkunde.2007.03.05

RoU. (2012). The State of Uganda Population Report 2012. Republic of Uganda.

Russell, J., Eggermont, H., Taylor, R., & Verschuren, D. (2009). Paleolimnological records of recent glacier recession in the Rwenzori Mountains, Uganda-D. R. Congo. Journal of Paleolimnology, 41(2), 253-271.

Saayman, M., Saayman, A., & Rossouw, R. (2013). The Socio-economic impact of the Table Mountain National Park. Journal of Economic and Financial Sciences, 6(2), 439 - 458.

Sanaa, D., Zahraoui, M., El Wartiti, M., Jebrak, M., Nahraoui, F., & Fadli, D. (2011). Environment mining and sustainable development. Present Environment and Sustainable Development, 5(2), 17-22.

SARW. (2010). Rethinking the Management of Mineral Resources in Lesotho: Report on the National Conference on Extractive Resources. Johannesburg: Southern Africa Resource Watch (SARW).

Sawamura, P., Vernier, J., Barnes, J., Berkoff, T., Welton, E., Alados-Arboledas, L., . . . Sicard, M. (2012). Stratospheric AOD after the 2011 eruption of Nabro volcano measured by lidars over the Northern Hemisphere. Environmental Research Letters, 7, 034013.

Sayre, R., Hernandez, M., Spencer, D., Cecere, T., Morganwalp, C., Hamann, S., . . . Cardenas, M. (2011). From Space to Place - An Image Atlas of World Heritage Sites on the 'In Danger' List. Paris: United Nations Education, Scientific and Cultural Organization (UNESCO).

Schär, C. (2002). Mesoscale Mountains and the Larger-Scale Atmospheric Dynamics: A review. International Geophysics, 83, 29 - 42.

Schmidt, E., & Kedir, M. (2009). Urbanization and Spatial Connectivity in Ethiopia: Urban Growth Analysis Using GIS. Addis Ababa: International Food Policy Research Institute.

Semazzi, F., & Sun, L. (1997). The Role of Orography in Determining the Sahelian Climate. International Journal of Climatology, 17, 581 - 596.

Setegn, S., Chowdary, V., Mal, B., Yohannes, F., & Kono, Y. (2011). Water Balance Study and Irrigation Strategies for Sustainable Management of a Tropical Ethiopian Lake: A Case Study of Lake Alemaya. Water Resource management, 25, 2081 - 2107.

SIGVP. (2013a). Nabro. Retrieved January 27, 2014, from Smithsonian Institution Global Volcanism Program: volcano.si.edu/volcano.cfm?vn=221101

SIGVP. (2013b). Products and Google Earth Placemarks. Retrieved January 20, 2014, from Smithsonian Institution National Museum of Natural History Global Volcanism Program: http://www.volcano.si.edu/learn_products.cfm?p=9

SIGVP. (2014). Database Search. Retrieved February 25, 2014, from National Museum of Natural History Global Volcanism Program: http://www.volcano.si.edu/search_volcano.cfm

Slater, R., & Mphale, M. (2009). Compensation, Welfare and Development: One-off lump-sum and regular transfers in the Lesotho Highlands Water Project. London: Overseas Development Institute.

Sotillo, M., Ramis, C., Romero, R., Alonso, S., & Homar, V. (2003). Role of orography in the spatial distribution of precipitation over the Spanish Mediterranean zone. Climate Research, 23, 247 - 261.

SSA. (2011). 2011 Census. Retrieved May 8, 2014, from Statistics South Africa (SSA): http://beta2.statssa.gov.za/?page_id=1021&id=city-of-johannesburg-municipality

START, TMA, & AU. (2011). Urban Poverty & Climate Change in Dar es Salaam: Tanzania: A Case Study. Dar es Salaam: Pan-African START Secretariat, International START Secretariat, Tanzania Meteorological Agency, Ardhi University, Tanzania.

Stevenson, J., & Debebe, M. (2009). Hydro power in Ethiopia - the staged construction of Tekeze Arch Dam. Retrieved April 2, 2014, from International Water Power and Dam Construction: http://www.waterpowermagazine.com/features/featurehydro-power-in-ethiopia-the-staged-construction-of-tekeze-arch-dam/

Suh, C., Sparks, R., Fitton, J., Ayonghe, S., Annen, C., Nana, R., & Luckman, A. (2003). The 1999 and 2000 eruptions of Mount Cameroon: eruption behaviour and petrochemistry of lava. Bulletin of Volcanology, 65, 267 - 281.

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

Taipei Times. (2012). Thirst silver mine angering villagers in Morocco. Retrieved from Taipei Times: http://www.taipeitimes.com/News/world/archives/2012/03/20/2003528260

Taylor, R., Mileham, L., Tindimugaya, C., & Mwebembezi, L. (2009). Recent glacial recession and its impact on alpine riverflow in the Rwenzori Mountains of Uganda. Journal of African Earth Sciences, 55, 205 - 213.

Taylor, R., Mileham, L., Tindimugaya, C., Majugu, A., Muwanga, A., & Nakileza, B. (2006). Recent glacial recession in the Rwenzori Mountains of East Africa due to rising air temperature. Geophysical Research Letters, 33, L10402. doi:10.1029/2006GL025962

TCE. (2012). Kivu Energy. The Chemical Engineer (852).

Thompson, L., Brecher, H., Mosley-Thompson, E., Hardy, D., & Mark, B. (2009). Glacier Loss on Kilimanjaro Continues Unabated. Proceedings of the National Academy of Sciences of the United States of America, 106(47), 19770 - 19775.

Tsafack, J., Wandji, P., Bardintzeff, J.-M., Bellon, H., & Guillou, H. (2009). The Mount Cameroon stratovolcano (Cameroon Volcanic Line, Central Africa): Petrology, geochemistry, isotope and age data. Geochemistry, Mineralogy and Petrology, 47, 65 - 78.

Tucker, C., Dregne, H., & Newcomb, W. (1991). Expansion and Contraction of the Sahara Desert from 1980 to 1990. Science, 253(5017), 299-301.

Tucker, D. (2005). Orographic Precipitation. In Encyclopedia of World Climatology (pp. 552-555). Springer Netherlands.

UF. (2002). Mountains and Lowlands: Enemies or Partners?: Example of the High Atlas, Morocco. Fribourg: University of Fribourg.

UN OCHA. (2010). Uganda: Eastern Uganda Landslides and Floods Situation Report #1 7 March 2010. Kampala: United Nations Office for the Coordination of Humanitarian Affairs.

UNDAC. (2008). Democratic Republic of Congo Earthquake in the Great Lakes Region 10th - 22nd February 2008, Mission Report. United Nations Disaster Assessment & Coordination (UNDAC).

UNDESA. (2010). The World Urbanisation Prospects, the 2009 Revision. United Nations Department of Economic and Social Affairs (UNDESA).

UNECA. (2010). Africa Review Report on Mining (Executive Summary). United Nations Economic Commission for Africa.

UNEP. (2012a). Kenya Integrated Forest Ecosystem Services: Technical Report. Nairobi: United Nations Environment Programme (UNEP).

UNEP. (2012b). The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy. Nairobi: United Nations Environment Programme (UNEP).

UNEP FI. (2012). Chief Liquidity Series Issue 3: Extractive Industries. Geneva: United Nations Programme Finance Initiative.

UNICEF. (2004). Responding to Water Disaster in Harar. Addis Ababa: United Nations Children's Fund Communication Section.

UNOPS. (2009). Mount Nyiragongo Risk Management Unit: Monitoring volcanic risk and raising awareness. Copenhagen: United Nations Office for Project Services.

USGS. (2001). Global GIS Database: Digital Atlas of Africa. U.S. Geological Survey (USGS) Digital Data Series DDS – 62-B.

USGS. (2003a). Lava Lakes. Retrieved April 1, 2014, from USGS Cascades Volcano Observatory: http://vulcan.wr.usgs.gov/Glossary/LavaLakes/description_lava_lakes.html

USGS. (2003b). World's Coolest Lava is in Africa. Retrieved October 31, 2013, from United States Geological Survey Hawaiian Volcano Observatory: http://hvo.wr.usgs.gov/volcanowatch/archive/2003/03_04_17.html

USGS. (2009). Tanzanian Villagers Encouraged to Learn Hazards of Living Near Erupting Volcano. Retrieved January 31, 2014, from U.S. Geological Survey Newsroom: http://www.usgs.gov/newsroom/article.asp?ID=2159#.UuvVZvSrw30

USGS. (2013a). Magnitude/Intensity Comparison. Retrieved June 25, 2014 from, the U.S. Geological Survey (USGS): http://earthquake.usgs.gov/learn/topics/mag_vs_int.php

USGS. (2013b). The Effects of African Dust on Coral Reefs and Human Health. Retrieved March 5, 2014, from United States Geological Survey: http://coastal.er.usgs.gov/african_dust/documentary.html

USGS. (2014a). Africa: Seismic Hazard Map. Retrieved from Earthquake Hazards Program: http://earthquake.usgs.gov/earthquakes/world/africa/gshap.php

USGS. (2014b). Data Viewer. Retrieved February 21, 2014, from FEWS NET: Famine Early Warning Systems Network: http://earlywarning.usgs.gov/fews/mapviewer/?region=af

USGS. (2014c). Earthquake Archive Search & URL Builder. Retrieved June 25, 2014, from U.S. Geological Survey (USGS) Earthquake Hazards Program: http://earthquake.usgs.gov/earthquakes/search/.

USGS. (2014d). The Glaciers of Kilimanjaro. Retrieved June 26, 2014 from, U.S. Geological Survey (USGS) Earthshots: http://earthshots.usgs.gov/earthshots/Mount-Kilimanjaro#

VD. (2014). Nyiragongo volcano. Retrieved from Volcano Discovery: http://www.volcanodiscovery.com/nyiragongo.html

Vervaeck, A., & Daniell, J. (2011). Eritrea Nabro volcano eruption - Air traffic disruption and the aid of NASA HD satellite images (day 3, 4, 5). Retrieved from Earthquake-Report: earthquake-report.com/2011/06/23eritrea-nabro-volcano-eruption-air-traffic-disruption-and-the-aid-of-nasa-hd-satellite-images-day-3-4-and-5/

Volcano Discovery. (2012). Nyamuragira volcano (DR Congo), update: eruption continues with active lava lake and lava flow from new NE vent. Retrieved February 27, 2014, from Volcano Discovery: http://www.volcanodiscovery.com/view_news/4622/Nyamuragira-volcano-DR-Congo-update-eruption-continues-with-active-lava-lake-and-lava-flow-from-new-.html

WAC & IUCN. (2007). Mount Elgon Regional Ecosystem Conservation Programme (MERECP) Final Report. Activities undertaken between June 2006 and March 2007. World Agroforestry Centre (WAC) and The World Conservation Union (IUCN).

Wafula, D.M., Yalire, M., Kasereka, M., Ciraba, M., Kwetuenda, M., Hamaguchi, H., 2007. Natural disasters and hazards in the Lake Kivu basin, Western Rift Valley of Africa. Report on the International Workshop on Natural and Human Induced Hazards and Disasters in Africa. IUGG-Georisk Commission.

Wambi, M. (2012). Overpopulation on Uganda's Mount Elgon Kills Hundreds. Retrieved January 22, 2014, from Inter Press Service News Agency: http://www.ipsnews.net/2012/07/overpopulation-on-ugandas-mount-elgon-kills-hundreds/

Wanjiru, A. (2010). Uganda: Deadly landslide devastates villages despite early warnings. Retrieved January 22, 2014, from ReliefWeb: http://reliefweb.int/report/uganda/uganda-deadly-landslide-devastates-villages-despite-early-warnings

Wantim, M., Suh, C., Ernst, G., Kervyn, M., & Jacobs, P. (2011). Characteristics of the 2000 fissure eruption and lava flow fields at Mount Cameroon volcano, West Africa: a combined field mapping and remote sensing approach. Geological Journal, 46, 344-363.

Washington, R., Todd, M., Lizcano, G., Tegen, I., Flamant, C., Koren, I., . . . Prospero, J. (2006). Links between topography, wind, deflation, lakes and dust: The case of the Bodélé Depression, Chad. Geophysical Research Letters, 33(L09401). doi:10.1029/2006GL025827

Washington, R., Todd, M., Middleton, N., & Goudie, A. (2003). Dust-Storm Source Areas Determined by the Total Ozone Monitoring Spectrometer and Surface Observations. Annals of the Association of American Geographers, 93(2), 297-313.

Wauthier, C., Cayol, V., Kervyn, F., & d'Oreye, N. (2012). Magma sources involved in the 2002 Nyiragongo eruption, as inferred from an InSAR analysis. Journal of Geophysical Research, 117(B05411). doi:10.1029/2011JB008257

Wentworth, L. (2013). Lesotho Highlands: Water Woes or Win-Wins? Johannesburg: European Centre for Development Policy Management.

Willemse, N. (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.

WISE. (2014). New Uranium Mining Projects - Niger. Retrieved June 30, 2014 from, World Information Service on Energy: Uranium Project (WISE): http://www.wise-uranium.org/upne.html

WorldPop. (2013). Afripop dataset. Retrieved January 20, 2014, from WorldPop: http://www.worldpop.org.uk/data/summary/?contselect=Africa&countselect=Whole+Continent&typeselect=Demography+2010

WNA. (2013). World Uranium Mining Production. Retrieved June 30, 2014 from, World Nuclear Association (WNA): http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Mining-of-Uranium/World-Uranium-Mining-Production/

WWF. (2007). Proceedings of the regional workshop on the conservation of eastern African mountain ecosystems as water towers 2 - 5 August, 2005. Programme Report No. 2/07 (p. 45). Nairobi: World Wildlife Fund Eastern Africa Regional Programme Office.

WWF. (2014). West Africa: Scattered across Guinea, Ivory Coast. Retrieved January 31, 2014, from World Wildlife Fund: http://worldwildlife.org/ecoregions/at0114

WWF South Africa. (2013). Journey of Water. Retrieved April 2, 2014, from World Wildlife Fund South Africa: http://www.journeyofwater.co.za/catchments/western-cape/table-mountain

Yager, T. (2013). 2011 Minerals Yearbook: South Africa. Reston: U.S. Geological Survey.

Yanda, P., & Munishi, P. (2007). Hydrologic and Land Use/Land Cover change analysis for the Ruvu River (Uluguru) and Sigi River (East Usambara) Watersheds. Dar es Salaam: World Wildlife Fund/CARE.

Yang, Z., & Chen, W.-P. (2010). Earthquakes along the East African Rift System: A multiscale, system-wide perspective. Journal of Geophysical Research. 115, B12309.

Yilma, S. (2014, 10 January). Haramaya University to organize training on Lake Haramaya watershed. Retrieved March 11, 2014, from Haramaya University: http://www.haramaya.edu.et/haramaya-university-to-organize-training-on-lake-haramaya-watershed/

Yohannes, F. (2005). Soil Erosion and Sedimentation: The Case of Lake Alemaya. Proceedings of the Second Awareness Creation Workshop on Wetlands in the Amhara Region (pp. 26-36). Addis Ababa: Ethio Wetlands and Natural Resources Association.

Young, J. A., & Hastenrath, S. (1991). Satellite Image Atlas of Glaciers of the World: Middle East and Africa. Washington: United States Geological Survey (USGS).

Zewdu, Z. (2012). Ground Water Quality Determination of former Lake Haramaya, Haramaya District, Eastern Haranghe Zone, Oroma Regional State, Ethiopia. Journal of Applied Sciences and Environmental Management, 16(3), 245-252.

ZSL. (2009). Building conservation capacity in DRC: Conserving wildlife and forest in and around Virunga National Park. London: Zoological Society of London. Retrieved January 29, 2014, from http://static.zsl.org/files/drc-info-sheet-final-1027.pdf

4

Protecting Africa's Mountains

Mountain habitats are of immense significance since they host an enormous diversity of ecosystems, species and genes, usually exceeding the biodiversity richness of surrounding lowlands. They also play crucial roles in stabilizing mountain slopes, providing food, fodder, fibre and other forest products, ensuring domestic and industrial water supply and offering attractive landscapes. Protecting individual species is extremely important, but habitat conservation remains the key tool for protecting both ecosystems and their flora and fauna, especially where species protection is lacking and where even the extent of biodiversity in an ecosystem is still not known.

The international community, national governments and regional associations have instituted policies and laws and entered into agreements to protect mountain ecosystems, resources and species while participatory action by local communities is strengthening traditional approaches to maintaining them. Such attention to protecting mountains is ongoing in Africa, but much more needs to be done to ensure that protected areas are being honoured and policies are enforced to sustain the present and future viability of their ecosystem services to surrounding human populations.

Huts in the Bale Mountains National Park, Ethiopia

Chapter Highlights

- ▲ Establishing protected areas such as National Parks protects biodiversity and habitats, controls development pressures and safeguards resources. Approximately 27 per cent of Africa's 468 National Parks are found in mountainous areas in 26 different countries.
- ▲ Social groups and communities are often successful in protecting montane forest resources using traditional and participatory approaches. Community members of the Kilum-Ijim Forest in Cameroon have planted 10 000 *Prunus africana* trees in an effort to replace previous forest loss.
- ▲ Reforestation is also underway in the Mau Forest Complex along the Mau Escarpment. More than 160 000 indigenous trees have been planted to protect its status as the contributor to 12 rivers that feed five major lakes in the Rift Valley.
- ▲ Threats such as human encroachment, mining, conflict and deforestation still persist, even with protected area designations. Of the 44 sites listed on the UNESCO World Heritage Sites in Danger, five are in Africa's mountains.

The Global Context: International Designations to Protect Mountain Biodiversity

One of the earliest references to mountain protection on the international policy agenda was in 1992, at the United Nations Conference on Environment and Development (UNCED). Chapter 13 of "Agenda 21", the Conference's outcome document, highlighted the need to manage mountain resources. Entitled Managing Fragile Ecosystems: Sustainable Mountain Development, the chapter set the precedent for several other global laws and conventions to incorporate sections pertaining to mountains, either directly or implicitly, within their specific thematic contexts. The Chapter explained two programme areas aiming to (1) generate and strengthen knowledge about the ecology and sustainable development of mountain ecosystems and (2) promote the integration of watershed development and opportunities for alternative livelihoods (UNSD, 1992).

Subsequently at the UNCED in 1992, the Convention on Biological Diversity (CBD) was first opened for signature. The CBD remained open from 5 June 1992 until 4 June 1993. Serving as a legal instrument for the conservation and sustainable use of biological diversity, the international CBD came into force on 29 December 1993 (CBD, n.d.). In paragraph 7, Article 20 of the CBD document, mountain areas, along with arid and semi-arid zones and coastal areas, are identified as being most environmentally vulnerable. Also, developed countries were urged to consider such ecosystems in their own agendas regarding funding and technology transfer. Mountain biodiversity was again highlighted during the fourth meeting of the CBD in 1998 as a topic for in-depth consideration at its seventh meeting. In its eighth meeting, the Subsidiary Body on Scientific, Technical and Technological Advice adopted a structure and established elements and goals on a proposed programme of work for mountain biodiversity. During the

Nyungwe National Park, Rwanda

Teseum / Flickr / CC BY-NC

ninth meeting, under recommendation IX/12, the programme of work for Mountain Biological Diversity, was adopted. Recommendation IX/12 called for a significant reduction in the loss of mountain biological diversity by 2010 and aimed to protect, recover and restore mountain biodiversity and promote the sustainable use of mountain resources (CBD, n.d.).

In 1998, the United Nations General Assembly adopted resolution A/RES/53/24, declaring 2002 as the International Year of Mountains. The resolution called for voluntary support from governments, national and international organizations and non-governmental organizations to promote and increase awareness of sustainable mountain development (UNGA, 1998). This declaration also led to the designation of 11 December of each subsequent year to be International Mountain Day. The Food and Agriculture Organization of the United Nations coordinates preparations and the Watershed Management and Mountains programme of the Forestry Department coordinates the global celebration. The first International Mountain Day was celebrated in 2004. Each year has a different theme pertaining to mountain life, ranging from topics such as obtaining peace to developing tourism to food security to mountain forests (FAO, 2014).

More recently, paragraphs 210 - 212 of the outcome document from the UN Conference on Sustainable Development (UNCSD) held in Rio de Janeiro, Brazil in 2012 specifically recognize the importance of mountains, their role in providing water, homes and land for indigenous peoples and communities and as centres of biodiversity (UN, 2012). The paragraphs also state that conservation of mountain areas is necessary due to their vulnerability to land degradation, deforestation and natural disasters. Furthermore, the paragraphs also explain that mountain areas are home to significant indigenous populations, creating a need to address poverty and sustainable development of all mountain ecosystems.

Protecting Habitats at a Global Scale

To fulfill the need to protect mountain ecosystems and their human and wildlife inhabitants, as well as promote sustainable development, several global protection designations have been established. These include the protection areas under the International Union for Conservation of Nature (IUCN), United Nations Educational, Scientific, Cultural Organization (UNESCO) World Heritage Sites, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) treaty and the IUCN Red List of Endangered Species.

International Union for Conservation of Nature (IUCN) Protected Areas

For all countries across the globe, the IUCN recognizes six general categories of protected area management, each of which can be found in various mountain areas of Africa (Table 4.1). The IUCN considers protected areas as those that are essential for biodiversity conservation, and for preventing the extinction of threatened or endemic species. They can come in many shapes and sizes with many different management approaches (IUCN, 2008). The IUCN also explains that protected areas contain important elements of earth history and processes and can also contain cultural value. Thus, adequate protection is necessary to both preserve nature and culture for future generations.

Table 4.1: IUCN Categories of Protected Area Management

	Designation	Description	Examples
(Ia)	Strict Nature Reserve	This classification confers strict protection on geological features or biological organisms. They are useful for research and monitoring and human activity and use within them is limited.	Mount Nimba Strict Nature Reserve shared by Côte d'Ivoire, Guinea and Liberia; Tsaratanana Strict Nature Reserve, Madagascar
(Ib)	Wilderness Area	As the name implies, these areas are maintained in their natural state, undisturbed by human activity. The main aim is to protect functioning ecosystems.	The Cederberg Wilderness Area in the Cederberg Mountains, South Africa; Uzungwa Scarp Forest Reserve, United Republic of Tanzania; Caldera de Luba Scientific Reserve, Equatorial Guinea
(II)	National Parks	These can be quite large and are designed to protect biodiversity within the ecosystem and to support research, recreation and education. To that end, human visitation is encouraged.	Kilimanjaro National Park, United Republic of Tanzania; Akagera National Park, Rwanda; Tassili N'Ajjer National Park, Algeria
(III)	Natural Monument or Feature	The category protects unique natural or cultural features and their biodiversity, habitats or cultural significance. Human visitation is encouraged.	Wolkberg Caves Nature Reserve, part of the Great Escarpment, in Transvaal, South Africa; Nyakazu Gorge Nature Monument in Burundi's Nkoma Mountains
(IV)	Habitat/Species Management Area	As the name suggests, these areas are meant to assist in the preservation, protection and restoration of biodiversity (species) or habitats.	Sehlabathebe National Park in the Maloti Mountains, Lesotho; Mbi Crater Faunal Reserve, the Bamenda Highlands of Cameroon; Ambohitantely Special Reserve near Antananarivo in Madagascar; Gishwati Forest Reserve in Rwanda
(V)	Protected Landscape/ Seascape	This category aims to protect important landscapes that over time have developed important natural and other values through interactions with people, including traditional management practices.	Saint Catherine Monastery near Mount Sinai in Egypt
(VI)	Protected area with sustainable use of natural resources	These combine the protection of natural ecosystems with the wise use of its natural resources.	Losai National Reserve, located in the Losai Mountains at the foothills of the Mathew and Ndotu Mountains in northern Kenya; Rutshuru Hunting Domain in the Virunga Mountains, DRC

Sources: Designation and description: IUCN, 2008; Examples: IUCN & UNEP-WCMC, 2013

World Heritage Sites

The UNESCO World Heritage Convention (1972) is responsible for the World Heritage List, which names sites from around the world that are of outstanding universal value. A total of 187 countries have ratified the Convention and 981 sites are on the list (UNESCO, 2014i). In Africa, there were 48 cultural sites, 36 natural sites and 4 sites considered natural and cultural, as of 2014. Of these, 9 cultural, 10 natural and 2 mixed sites are located in Africa's mountains (Figure 4.1). They include mountain ecosystems like the Simien Mountains and Mount Kilimanjaro as well as transboundary areas such as Mount Nimba and the Maloti-Drakensberg Mountains.

These sites need to meet 10 criteria to be considered for either the list of "natural" or "cultural" sites (Table 4.2). Additionally, the selection process considers the site's protection and management activities as well as the area's authenticity and integrity (UNESCO, 2014i).

The listing of these outstanding sites and the signing of the Convention by the home country (or countries) is a way of responding to the need to preserve and restore some of the world's protected areas (IUCN, 2014). The Mount Kenya National Park, for example, was vulnerable to illegal logging and marijuana cultivation, but an action plan to increase patrolling, train guards and elevate community awareness led to its inscription as a World Heritage Site and improved site management (UNESCO, 2014h).

World Heritage Site designation also serves as a measurable way to gauge the performance of these protected areas.

Figure 4.1: World Heritage Sites

Source: UNESCO, 2014l; IUCN & UNEP-WCMC, 2013; UNEP/DEWA

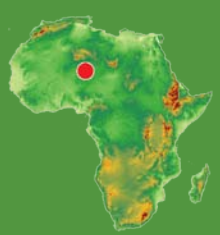
Table 4.2: UNESCO criteria for natural World Heritage Sites

Criteria	Description
(i)	To represent a masterpiece of human creative genius
(ii)	To exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design
(iii)	To bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared
(iv)	To be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history
(v)	To be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change
(vi)	To be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance
(vii)	To contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance
(viii)	To be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features
(ix)	To be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals
(x)	To contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation

Source: Adapted from UNESCO, 2014i

Inclusion on the list heightens awareness of the importance of protecting the site and can also warrant receipt of financial assistance to increase management capabilities (IUCN, 2014). When environmental or human influences threaten sites, they are moved to the List of World Heritage in Danger as a means of increasing the focus on conservation needs. There are 44 sites on the List of World Heritage in Danger and of those, five natural sites are in Africa's mountains: Aïr and Ténéré Natural Reserves (Box 4.1), the transboundary Mount Nimba Strict Nature Reserve, Rainforests of the Atsinanana, Virunga National Park and Simien National Park.

Box 4.1: Aïr and Ténéré Natural Reserves, Niger: A World Heritage Site in Danger

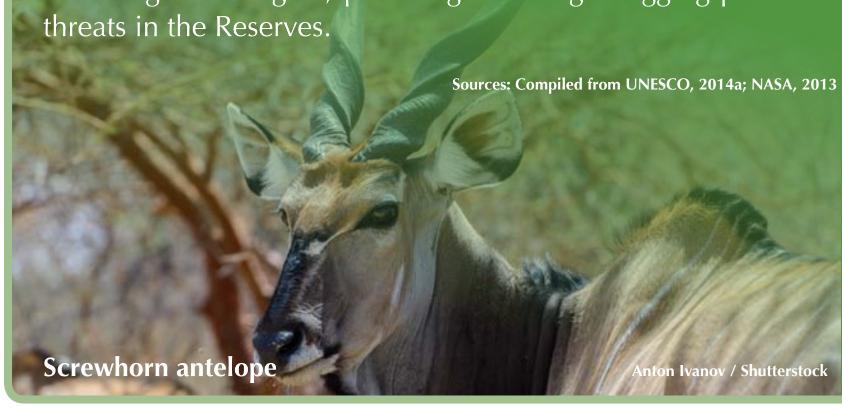


The Aïr and Ténéré Natural Reserves, the largest protected area in Africa, encompasses the Aïr massif and the Ténéré desert in Niger, spanning more than 7.7 million ha.

Despite its desolate desert environment, the reserve is known for its breadth of landscapes, plants and animals. The reserve is home to three species of antelope on the IUCN Red List of Threatened Species: the Dorcus gazelle (*Gazella dorcas dorcas*), the Leptocere gazelle (*Gazella leptoceros*) and the Addax (screwhorn antelope) (*Addax nasomaculatus*).The reserve's centre is the Addax Sanctuary, a strict reserve that does not allow any human entry. The Aïr massif is a transit corridor for many Afrotropical and palaearctic birds. Many of these species have continued to survive due to the distance from dense populations.

The Reserves were inscribed as a World Heritage Site in 1991, but civil unrest and military conflict in the region, including when six staff members of the Reserve were held hostage in 1992, led to the addition of the Reserves to the List of World Heritage in Danger that year. Although some civil unrest has subsided and it has been recommended that management should be strengthened again, poaching and illegal logging persist as threats in the Reserves.

Sources: Compiled from UNESCO, 2014a; NASA, 2013



Screwhorn antelope

Anton Ivanov / Shutterstock

View of the Aïr massif from the International Space Station

Johnson Space Center / NASA

Box 4.2: Re-introduction of the Kihansi spray toad

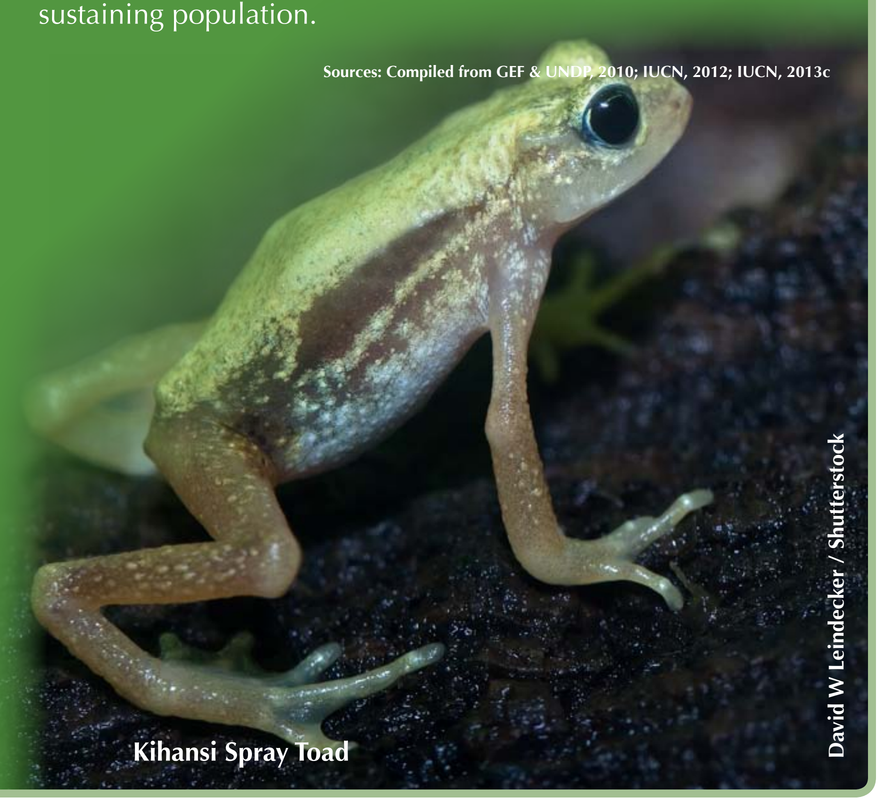
The IUCN Red List of Threatened Species classifies many of the endemic species in the Eastern Arc Mountains as Critically Endangered or Endangered. One of these is the Kihansi Spray Toad (*Nectophrynoides asperginis*). Its habitat in the wild is in eastern Tanzania's Udzungwa Mountains and only in a tiny area of less than two hectares around the Kihansi Falls in the Kihansi Gorge, at 600 - 940 m where the vegetation remains soaked by spray from the waterfall.

It is thought the population originally numbered 17 000, but after a dam was built upstream of the waterfall as part of theLower Kihansi Hydropower Project, water flow in the gorge was reduced by 90 per cent, the vegetation was degraded and toad numbers declined drastically. To prevent further losses, a sprinkler system was installed in 2000 to reproduce the water spray conditions necessary for the toad's survival and to restore the vegetation. At the same time, the Tanzanian government stepped in to stop the species' demise, inviting the Wildlife Conservation Society to take some specimens to the United States, where they were bred in captivity at the Bronx and Toledo Zoos.

Meanwhile, in the wild, numbers declined to only 1 000 individuals by 2002 and by 2005, the species was considered extinct. A number of factors may be implicated in its demise, including a fungus found in deceased specimens, but the actual reasons for the toad's disappearance are not fully understood.

On the other hand, the toad population bred in the zoos grew from an initial 499 to over 6 000. In 2010 a plan was put in motion to re-introduce the toad to its natural habitat through the efforts of a team of conservation experts including the IUCN SSC Amphibian Specialist Group and the IUCN SSC Re-introduction Specialist Group. In 2012, 2 500 toads were flown from the United States to Tanzania and after successful trials an initial batch was released into the natural habitat on 29 October 2012. More will be released in the future with the goal of re-establishing a self-sustaining population.

Sources: Compiled from GEF & UNDP, 2010; IUCN, 2012; IUCN, 2013c



Kihansi Spray Toad

David W Leindecker / Shutterstock

Protecting Species at a Global Scale

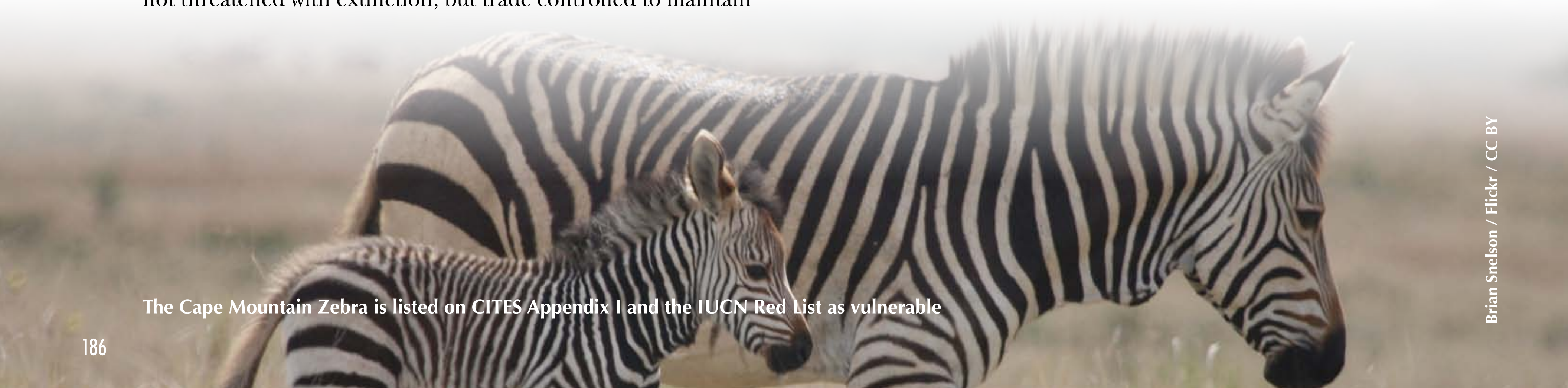
In addition to protecting their habitat, mountain biodiversity can be protected through laws or other mechanisms that safeguard specific species that have been designated as threatened. Such mechanisms include the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the International Union for the Conservation of Nature's (IUCN) Red List.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

CITES, an international agreement among governments that was signed in 1973 and put into force in 1975, aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Most African countries are Party to this agreement. The agreement is made up of Convention text and then three appendices that list species based upon the amount of protection they need. Appendix I contains species threatened with extinction, Appendix II contains species that are not threatened with extinction, but trade controlled to maintain their chances for survivial and Appendix III lists species that are protected by at least one country and that country has requested other CITES Parties to help control trade. The mountain gorilla, for example, is listed in Appendix I of CITES, meaning international trade in specimens of these species is prohibited. There are also national laws regarding illegal trading in species to protect threatened flora and fauna (CITES, n.d.).

IUCN Red List

Globally, the IUCN Red List of Threatened Species is a recognized standard that scientifically determines the level of threat to all known species. The mountain gorilla, for example, is listed as critically endangered on the Red List, which identifies seven categorizes of threat from "least concern" to "extinct" (IUCN, 2013c). Many African mountain species of flora and fauna are listed as threatened, although it is difficult to know the numbers. Species on the Red List warrant the strongest protection measures. Box 4.2 is a success story of how the government of the United Republic of Tanzania protected a species on the Red List from extinction.



The Cape Mountain Zebra is listed on CITES Appendix I and the IUCN Red List as vulnerable

Brian Snelson / Flickr / CC BY

The Regional Context: Mountain Law and Policies in Africa

Regional Initiatives

One of the first regional initiatives in Africa to protect mountain ecosystems was the adoption of the African Mountains and Highlands Declaration in 1997 at the International Workshop of the African Mountains Association held in Antananarivo, Madagascar. The Declaration outlined the major issues occurring in mountain ecosystems and recommended policies to address them (FAO, 2002). Since then, several other regional legal instruments have been implemented that compel states to move towards protecting and conserving mountain ecosystems (especially watersheds) including the East Africa Community Treaty, the African Highlands Initiative, the New Partnership for Africa's Developments and the Lusaka Agreement Task Force. Public-private partnerships are also used to protect environmental assets at the regional level (Box 4.3).

East African Community Treaty

The East African Community (EAC) Treaty was signed on 20 November 1999, and came into force on 7 July 2000 with three partner countries: Kenya, Uganda and the United Republic of Tanzania. In 2007, Burundi and Rwanda were added as members. The EAC treaty serves as a framework for regional co-operation among partner countries for a variety of sectors including science, technology, labour, the environment and tourism, among others (CCPA, 2010).

Specifically, Chapter 19, entitled Cooperation in Environment and Natural Resources Management, addresses environmental management issues and actions. It contains four Articles outlining the recognition of environmental issues and natural resources, cooperation for the management of the environment, taking a stance against illegal trade and movement of toxic chemicals, substances and hazardous wastes, and establish cooperating in the management and sustainable use of natural resources (EAC, 1999). Chapter 20 addresses cooperation in tourism and wildlife management with aims for partner countries to harmonize policies for wildlife conservation inside and outside of protected areas, share information, training and research and also standardize elements of tourism (EAC, 1999).

Stemming from Chapters 19 and 20 of the Treaty, the Protocol on Environment and Natural Resources Management was drafted in 2005. Article 20 of the Protocol specifically addresses mountains. The Article calls for harmonized policies for the sustainable development and protection of mountain ecosystems, recognizing their role as water catchments and their value as areas for conservation and heritage. Box 4.4 provides the specific stipulations of Article 20 (EAC, 2005).

African Highlands Initiative (AHI)

The AHI is an eco-regional programme that works towards improving the livelihoods of the densely populated highland areas of Ethiopia, Kenya, Uganda, Rwanda and the United Republic of Tanzania while also reducing natural resource degradation (AHI, 2006). Conceptualized out of a regional meeting of the directors of the National Agricultural Research

Box 4.3: The use of public-private partnerships to protect environmental assets

One example of a public-private partnership used to protect environmental assets is the African Union project Leadership for Conservation in Africa. The project was initiated in 2006 by South African National Parks (SANP), Gold Fields Limited and the IUCN. Its aim is to "positively influence, accelerate or bring about the protection of 20 million hectares of rain forests and selected eco-systems in sub-Saharan Africa by the year 2020". Its activities potentially include conserving mountain ecosystems. It now involves the 16 countries of Burkina Faso, Botswana, Cameroon, Ethiopia, Gambia, Ghana, Malawi, Mozambique, Namibia, Republic of Congo, Senegal, South Africa, United Republic of Tanzania, Uganda, Zambia and Zimbabwe and over 20 African and international agencies and business leaders.

Source: LCA, 2012

Box 4.4: Stipulations of Article 20: Management of Mountain Ecosystems in the EAC Protocol on Environment and Natural Resources Management

The Partner States shall:

(a) promote integrated watershed management and develop alternative livelihood opportunities;

(b) promote regional cooperation and exchange of data and information on transboundary mountain ecosystems;

(c) establish or strengthen institutions and a knowledge base on land and water for sustainable development of mountain ecosystems;

(d) promote policies which provide incentives to local people for the use and transfer of environment-friendly technologies and conservation practices;

(e) diversify mountain economies by creating and strengthening productivity;

(f) integrate forestry, rangeland and wildlife activities so as to maintain specific mountain ecosystems;

(g) build an inventory of different forms of soils, forests, water use, and crop, plant and animal genetic resources, giving priority to those under threat of extinction;

(h) improve traditional farming and animal husbandry activities and establish programmes for evaluating the potential value of mountain resources;

(i) develop early warning systems to forecast potential mountain disasters;

(j) develop appropriate land use plans and management for both arable and non-arable land in mountain watersheds to prevent soil erosion, mountain disasters, floods, and increase biomass production and maintain the ecological balance

Source: EAC, 2005

Farmers weeding a faba beans farm in the Bale Mountains

Institute (NARI) and International Agricultural Centers (IARCs), the AHI is driven by impacts of natural resource management issues on rural livelihoods and evident impacts on their farms and landscapes (German, Mowo, Amede, & Masuki, 2012). The programme targets community-based organizations and male and female farmers as well as larger scale entities such as international research organizations (AHI, 2006). The outcomes of AHI include an increased knowledge of technologies by both male and female farmers, increased farm productivity and increased adoption of conservation practices (German, Mowo, Amede, & Masuki, 2012).

New Partnership for Africa's Development (NEPAD)

The NEPAD Action Plan for the Environment is a framework for development in Africa. NEPAD developed from three parallel initiatives that led to the creation of NEPAD in 2001: the Millennium Africa Recovery Plan led by South Africa, the Omega Plan led by Senegal and the New African Initiative. The African Union ratified NEPAD in 2002 (NEPAD, 2012). NEPAD is clear on the need to manage watersheds across the continent, specifically mentioning those in the mountain countries of Tunisia, Morocco and Algeria (NEPAD, 2003). Regional cooperation is also evident through joint water projects such as the Kornati Basin Project (South Africa and Swaziland) and the Lesotho Highlands Water Project (between Lesotho and South Africa).

Lusaka Agreement

The Lusaka Agreement on Cooperative Enforcement Operations Directed at Illegal Trade in Wild Fauna and Flora, an agreement that culminated out of a meeting of eight African countries in December 1992. The Agreement was adopted on 6 September 1994 and ratified into action in 10 December 1996. It is an example of a regional or transboundary initiative that addresses species protection. There are currently seven Parties to the Agreement (The Republics of Congo (Brazzaville), Kenya, Libya, the United Republic of Tanzania, Uganda Zambia and Lesotho) and three signatories (South Africa, Ethiopia and Swaziland) (LATF, 2013). Its role is to investigate violations of national laws pertaining to illegal trade in wild fauna and flora, which includes mountain species. Under the Agreement, emphasis is placed on transboundary law enforcement and facilitating harmonious communication between wildlife institutions, such as those from Kenya and Uganda (FAO, 2009).

Protecting Transboundary Areas

One of the most fruitful opportunities to protect and sustainably manage ecosystems is when they cross political boundaries and their resources and the services they provide are shared among various users in different countries. Although states have sovereign rights to exploit their natural resources according to their own policies, international customary law implies that states should not cause harm to such resources. Thus, cooperation is the most effective way to protect and conserve a shared, or transboundary, ecosystem in the long term (Bronkhorst, 2005), although this can be more challenging when conflicts exist between neighbouring states (Martin, Rutagarama, Cascão, Gray, & Chhotray, 2011). Protecting transboundary areas requires that governments, managers, scientists and community members in the adjacent countries collaborate to ensure they are equitably managed for all parties and for future generations. It requires identifying and measuring the threats to those resources and devising strategies to address them that transcend political and cultural differences (UNEP, 2014). A definition of transboundary protected areas (TBPA) is provided in Box 4.5.

Box 4.5: Definition of Transboundary Protected Areas

The IUCN defines a Transboundary Protected Area (TBPA) as "an area of land and/or sea that straddles one or more borders between states, sub-national units such as provinces and regions, autonomous areas and/or areas beyond the limit of national sovereignty or jurisdiction, whose constituent parts are especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed cooperatively through legal or other effective means."

Source: Sandwith, Shine, Hamilton, & Sheppard, 2001

Women in the transboundary Gashaka Gumti National Park, Nigeria

Figure 4.2: Transboundary protected areas in Africa's mountainous regions

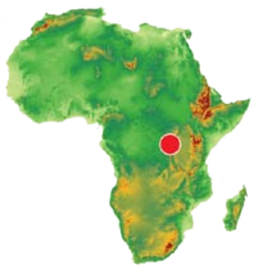
Sources: IUCN & UNEP-WCMC, 2013; UNEP/DEWA

Transboundary conservation and protection is not new in African mountains, with cross-border management in the Virunga Mountains beginning in the 1920s (UNEP, 2011). Within these transboundary regions, bordering governments, non-governmental organisations and neighbouring communities are taking action to share resources more equitably, but also to increasingly protect them for their rich biodiversity and habitat values. Protected areas have been set up within these transboundary ecosystems, such that international cooperation is required to manage the Parks, Reserves and other such conservation areas that stretch across political borders. According to Martin, Rutagarama, Cascão, Gray, & Chhotray (2011), transboundary protected areas can create opportunities for enhanced cooperation across all associated countries in their management. The most successful mechanisms for international cooperation are being practiced in managing transboundary waterways, but there are still inadequacies in caring for many of Africa's other shared resources, such as forest belts and protected areas (UNEP, 2008).

Over the last several decades, cooperative transboundary conservation efforts in Africa have increased (Nakileza, Ferguson, & Bagoora, 2012). For example, Mount Elgon, which straddles the border between Kenya and Uganda, and the Rwenzori Mountains, which stretch along the frontier between western Uganda and the Democratic Republic of Congo, required higher protection than provided by forest reserves so have been upgraded to national parks (UNEP, 2011). Figure 4.2 shows the location of TBPA's in Africa's mountainous areas.

Road leading to the Volcanoes National Park in Rwanda

Transboundary Protection in Central and Eastern Africa



Transboundary Collaboration in the Central Albertine Rift

This mechanism is oriented to coordinating conservation and natural resource management initiatives in the Central Albertine Rift (also known as the Greater Virunga Landscape). It started with informal meetings among park staff of the Uganda Wildlife Authority (UWA), the Institut Congolais Pour la conservation de la Nature (ICCN) of the DRC and the Office Rwandaise du Tourism et des Parcs Nationaux, which is now the Rwanda Development Board (RDB). Its first aim was to protect mountain gorillas (GVTC, 2012). The scope of initiatives has expanded to include tourism, community conservation and research and monitoring. As well, the geographical area under the cooperation has expanded, such that the geographical parameters for the work of the Greater Virunga Transboundary Collaboration include the transboundary ecosystem of the Central Albertine Transfrontier Protected Area Network (GVTC, 2012; Box 4.6).

The Central Albertine Rift Network of Protected Areas (CARNPA) refers to the contiguous protected areas found in Uganda, the DRC and Rwanda and was established in 2001. The protected areas within this network include the Virunga (ViNP) in DRC, Mgahinga Gorilla (MGNP), Bwindi Impenetrable (BINP), Queen Elizabeth (QENP), Rwenzori Mountains (RMNP), Semuliki (SNP) and Kibale (KNP) National Parks in Uganda and Volcanoes National Park (PNV) in Rwanda (TCS, 2006). Within these Parks are habitats that support extremely rich biodiversity, including chimpanzees, golden monkeys and forest elephants as well as many bird, reptile and amphibian species and exceptional endemic animal species (AWF, n.d.).

Box 4.6: Milestones in the Greater Virunga Transboundary Collaboration

- **2004:** Trilateral Memorandum of Understanding between the three Protected Area Authorities on the Collaborative Conservation of the Central Albertine Rift Transfrontier Protected Area Network.
- **2005:** Tripartite Ministerial Declaration of Goma on the Transboundary Natural Resources Management of the Transfrontier Protected Area Network of the Central Albertine Rift.
- **2005**: Tripartite Memorandum of Understanding on Tourism Revenue Sharing from the Transboundary Gorilla Tourism Groups.
- **2006:** 10-Year Transboundary Strategic Plan authorizing the establishment of a permanent secretariat.
- **2007:** Procurement of four years of funding from the Kingdom of the Netherlands to implement transboundary collaboration and support revenue sharing and conservation enterprises across the Greater Virunga Landscape.
- **2008:** Establishment of a fully functioning Executive Secretariat, temporarily based in Kigali, to coordinate the implementation of the 10-Year Transboundary Strategic Plan.
- **2008:** Rubavu Ministerial Declaration for the Greater Virunga Transboundary Collaboration.
- **2009:** Institutionalization of the Greater Virunga Transboundary Collaboration by the Inter-Ministerial Board.
- **2010:** Refined Five-Year Transboundary Strategic Plan.
- **2011:** Legalization of the Greater Virunga Transboundary Collaboration through a treaty signed by the Heads of State of the Democratic Republic of Congo, Rwanda and Uganda. This milestone is still in process, pending signatures.

Source: GVTC, 2012

The natural habitat of the world's remaining population of wild mountain gorillas, one of Africa's most charismatic flagship species, lies within the Virunga volcanoes and the BINP (AWF, n.d.; Blom & Bowie, 2001). Threats to the area include volcanic eruptions, population pressure, socio-economic development and land use change (Kanyamibwa, 2013).

The 10-year Transboundary Strategic Plan (TSP) for the CARNPA was adopted in 2006 by the UWA, the ICCN of the DRC and RDB. The TSP is also supported by a variety of stakeholders involved in biodiversity conservation and socio-economic development in the region. The goal of the TSP is to engage in transboundary collaborative management to ensure the sustainable conservation of biodiversity and long-term socio-economic development in the Central Albertine Rift. The transboundary natural resources are managed through formal structures, including a Transboundary Inter-Ministerial Board; the Transboundary Core Secretariat (TCS); Technical Committees for Research, Tourism, Community Conservation and Enterprise, Security and Law Enforcement; and a Regional Forum to foster collaboration and harmony amongst stakeholders (GVTC, 2006).

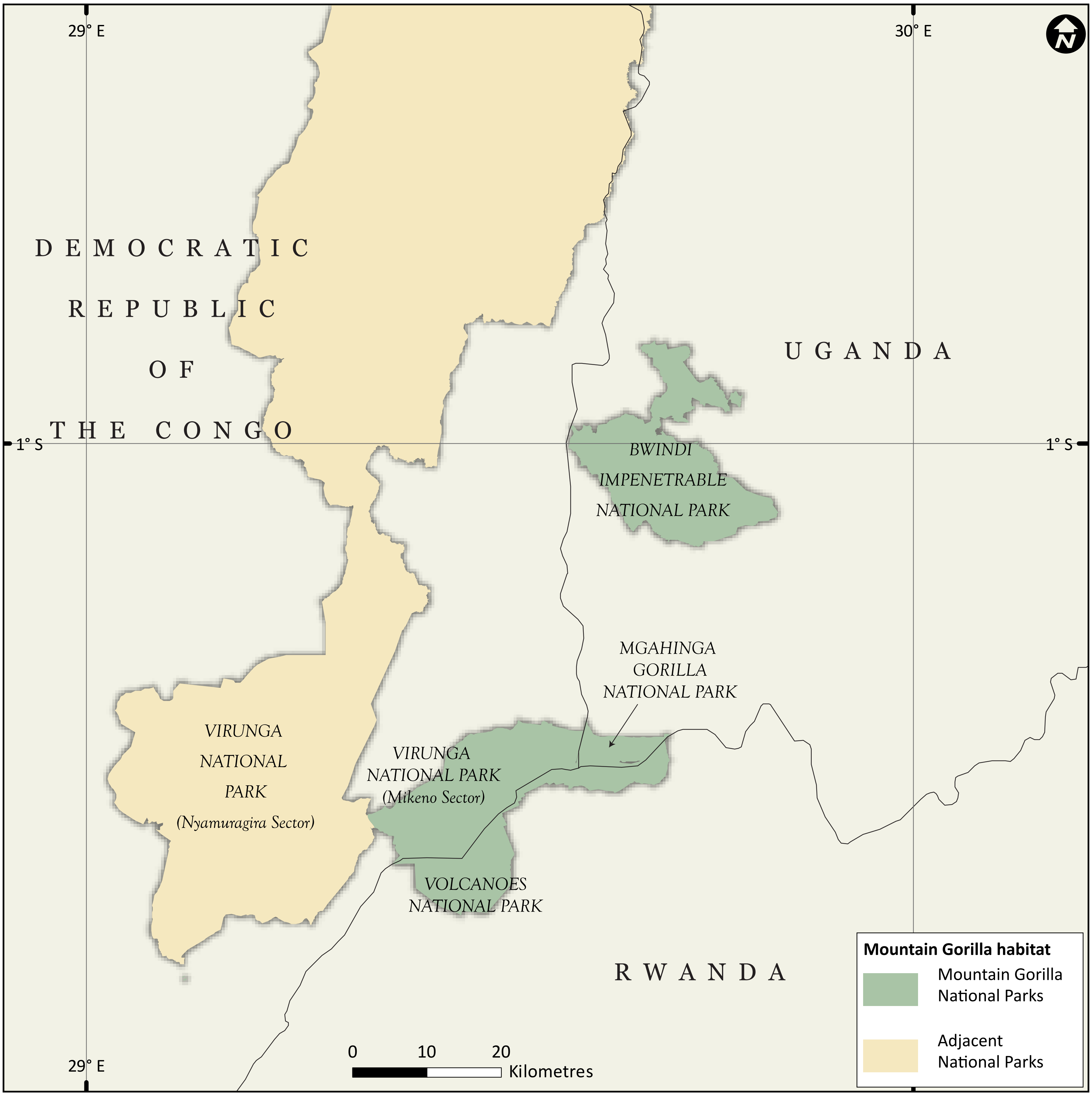
Although the TSP exists for overarching collaboration, conservation efforts occur within very different governance structures in each Albertine Rift country. In 2008, an assessment noted the following signs of progress: "Conservation practitioners have changed their approaches over time in the Albertine Rift. They have learned to use a wide set of tools designed to improve governance, including conflict resolution techniques, transboundary collaboration, community conservation committees, revenue sharing, community development associations, land use planning techniques, and enterprise development skills" (Plumptre, Kujirakwinja, & Nampindo, 2008). Two years later, in 2010, a refined five-year transboundary strategic plan was made (GTVC, 2012).

Milestones in collaborative action include landscape management projects, such as bamboo plantations to control erosion and provide raw materials for crafts, community agroforestry nurseries and research and monitoring wildlife, especially gorillas; law enforcement security activities such as coordinated patrols, intelligence sharing and regular meetings on immigration, customs and security; education and awareness activities; economic development, including constructing community facilities, training for tourism and bee keeping; and supporting financial sustainability, such as rehabilitating roads that support tourism and revenue sharing from gorilla viewing (Mwandha, n.d.).

Among the conclusions of the 2013 Albertine Rift Conservation Status Report, however, were the need for a regional approach and transboundary mainstreaming in national strategies and policies; governmental consideration of wider landscape planning, ecosystem-based approaches and connectivity, particularly in face of increasing climate change; and to balance economic needs and the sustainability of ecosystem services (Kanyamibwa, 2013). The report also noted that the collaborative process in the Greater Virunga Landscape has been extremely unique because "it is probably the only transboundary process in Africa that started from the field and progressively secured buy-in from the senior government decision makers" rather than the usual top-down process (Sengalama, 2013).

Entrance to Bwindi National Park

Figure 4.3: Mountain gorilla habitat



Sources: Adapted from Sengalama, 2013; IUCN & UNEP-WCMC, 2013; UNEP/DEWA

Transboundary Protection of the Mountain Gorilla in the Albertine Rift

One of Africa's most charismatic mountain species is the critically endangered mountain gorilla (*Gorilla beringei beringei*) (Robbins & Williamson, 2013). The mountain gorilla population as a whole has been under threat due to rebel infiltration of the Virunga National Park since the 1990s and civil unrest since the 1994 genocide in Rwanda, as well as the impacts of the high human population density, including human encroachment, the introduction of human diseases, habitat destruction, poaching, deforestation and charcoal making (WWF, 2014b; Gray, et al., 2013; Bronkhorst, 2005; AWF, n.d.).

The last remaining wild mountain gorilla populations are divided into two subsets among three countries: Rwanda, the DRC and Uganda. In the Virunga Mountains, gorillas can be sighted in parks such as Volcanoes National Park in Rwanda, Mgahinga Gorilla National Park in Uganda and Virunga National Park in DRC (WWF, 2014b). The gorillas that live among these Parks in the Virungas are considered one population. The other population lives in the Bwindi Impenetrable National Park in Uganda. The Virunga population is found at higher elevations, reaching to almost 4 500 m and the Bwindi population remains in areas of 1 500 to 2 300 m (WWF, 2014b; Figure 4.3).

Gorillas in Volcanoes National Park

Due to the many threats they encounter and their endangered status, the mountain gorilla has been the focus of effective recent conservation efforts in the region (Blom & Bowie, 2001).The Virunga Mountains population declined to a very low count in 1981, at which time only 250 mountain gorillas could be accounted for, but it rebounded to 380 by 2003 (Gray, et al., 2013) and to 480 in 2011 (AWF, n.d.). By 2011, there were at least 400 gorillas living in Bwindi Impenetrable National Park, up from 302 in 2006 (AWF, n.d.).

Collaborative conservation efforts among many organizations in the DRC, Rwanda and Uganda have contributed to these population rebounds in recent decades (AWF, 2010). One example of a conservation effort is the Dian Fossey Gorilla Fund's Karisoke Research Center (KRC) in the Volcanoes National Park. A small habituated gorilla population, monitored by the KRC (Grueter, Robbins, Ndagijimana, & Stoinski, 2013) may have grown faster than unhabituated populations because they receive almost daily protection and veterinary intervention when necessary (Gray, et al., 2013). It is very important to further these positive impacts on the mountain gorilla population since it is the only great ape in Africa whose population continues to increase.

International Gorilla Conservation Programme (IGCP)

Another example is the IGCP, a partnership of three international conservation organizations: the African Wildlife

Karisoke Research Center in Volcanoes National Park, Rwanda

Foundation (AWF), Fauna and Flora International and the World Wildlife Fund (WWF) (AWF, n.d.). It fosters collaboration between the park authorities of Rwanda, Uganda and DRC to strengthen their capacity to effectively manage the parks as a regional ecosystem. The partnership also works directly with local communities in the three countries, along with other conservation and development agencies in the region (Martin, Rutagarama, Cascão, Gray, & Chhotray, 2011).

The IGCP has successfully encouraged the three protected area authorities to coordinate and jointly manage the Virunga, Volcanoes and Bwindi Impenetrable National Parks. In 2006, the IGCP helped to develop a 10-year Transboundary Strategic Plan for the Greater Virunga Landscape and this experience became a model for all the contiguous protected areas linked to the Virunga National Park to work towards (WCS, 2009).

Some of the projects taking place include mountain gorilla monitoring, other conservation actions and designing and constructing community-owned tourist lodges that benefit local people who share the region with mountain gorillas and other wildlife (AWF, n.d.). In the Bwindi Impenetrable National Park, gravity water is provided and microfinance schemes and ecotourism development are underway (FAO, 2009). Projects that increase collaboration across the borders are supported by AWF to mitigate conflict between wildlife and local people. The IGCP has helped communities in the three countries to construct a stone wall around Rwanda's Volcanoes National Park to prevent buffalo and elephants from leaving the park to raid farmer's fields. Similarly, to discourage people from entering the parks to fetch water, IGCP has helped communities build tanks to harvest and store rainwater (AWF, n.d.).

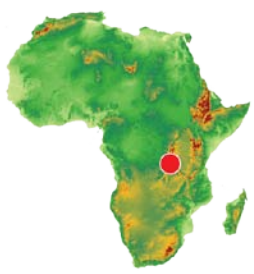
A baby mountain gorilla in Bwindi Impenetrable National Park, Uganda

Illegal clear cutting and burning in the Nyungwe Forest

John and Melanie (Illingworth) Kotso-poulos / Flickr /CC BY-NC-ND

Transboundary Protection in Eastern Africa

Nyungwe and Kibira National Parks



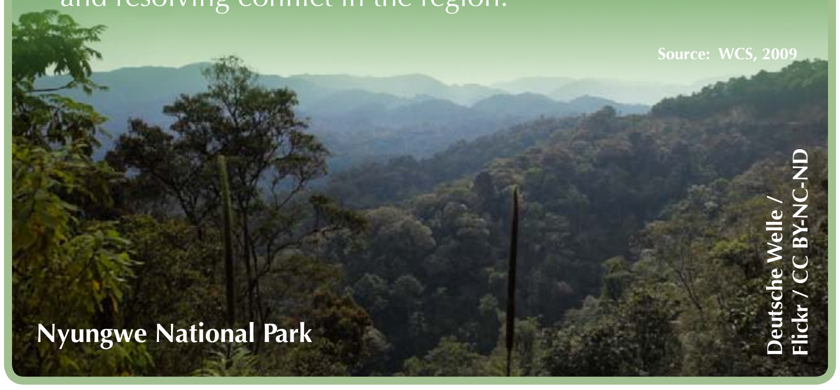
The transboundary Nyungwe-Kibira ecosystem encompasses the Nyungwe National Park (NNP) in southwestern Rwanda and the Kibira National Park (KNP) in northwestern Burundi along the Congo-Nile divide. Including the recently annexed Nyungwe forest at Cyamudongo (WCS, 2009), the NNP encompasses more than 1 000 km², making it Africa's largest protected rainforest (RDB, 2013). First protected as a Forest Reserve in 1903 (Crawford, 2012), the forest serves as the rainfall catchment area for over 70 per cent of Rwanda with its streams feeding into both the Congo and Nile Basins. Between 1958 and 1979, farmers encroached on the forest contributing to a reduction in the reserve area from 1 141 km² to its present size. It was declared a National Park in 2005 (Crawford, 2012). Kibira National Park contains Burundi's largest protected mountainous forest ecosystem (WCS, 2009). The shared Nyungwe-Kibira forest catchment also sustains a hydropower plant that produces 90 per cent of Burundi's electricity. Weak law enforcement in KNP and along its shared border with Rwanda has resulted in conflicts as well as illegal activities in the protected areas of both countries (Crawford, 2012).

The Rwanda Development Board (RDB) and Burundi's Institut National pour l'Environnement et la Conservation and de la Nature (INECN) together with key partners have developed a 10-year Transboundary Strategic Plan to collaboratively manage the transboundary protected area along with a variety of stakeholders related to biodiversity conservation and socio-economic development within the region. This strategic plan and its process follows the 2001 Albertine Rift Transboundary Strategic Planning Process and succeeds several years of informal collaboration between the two national parks, which focused on curbing illegal activities across the border. In 2008, a formal Memorandum of Understanding was signed between the RDB and INECN, the two agencies committed to the Transboundary Natural Resource Management approach in cooperating across boundaries (WCS, 2009). Box 4.7 sets out the objectives of this transboundary collaboration.

Box 4.7: Transboundary collaboration in the Nyungwe and Kibira National Parks

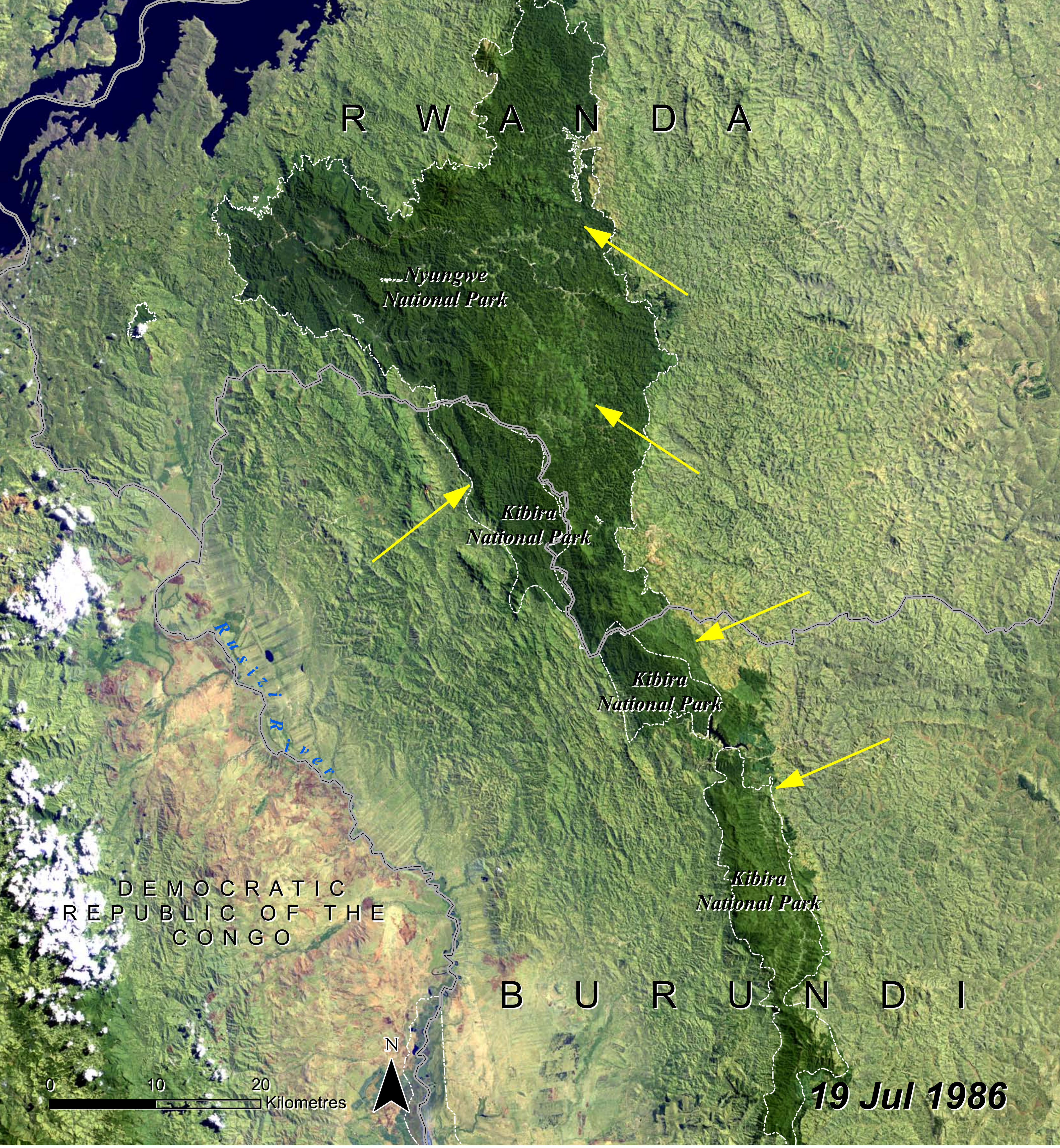
- Cooperate in the conservation of biodiversity, natural resources and associated cultural values and in research, monitoring and ecotourism for both parks in the two countries;
- Promote landscape conservation through planning and better management of the two protected areas;
- Lobby for planning, sustainable use and management of natural resources in the transboundary region in order to reduce the threats affecting these protected areas;
- Improve trust, understanding and cooperation between the two parties and other players for sustainable conservation and peace in the region;
- Work together to enhance and share experience and good practices in the area of management and research and ecological monitoring, for a sound and effective management of biodiversity and cultural values;
- Promote the advantages derived from conservation and sensitization for benefit sharing at national and international levels;
- Improve the understanding of the importance of conservation among partners and the general public;
- Promote biodiversity conservation aimed at reducing poverty and resolving conflict in the region.

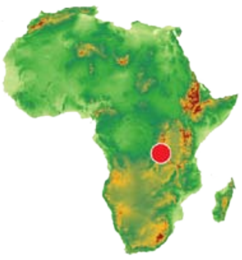
Source: WCS, 2009



Nyungwe National Park

Deutsche Welle / Flickr / CC BY-NC-ND

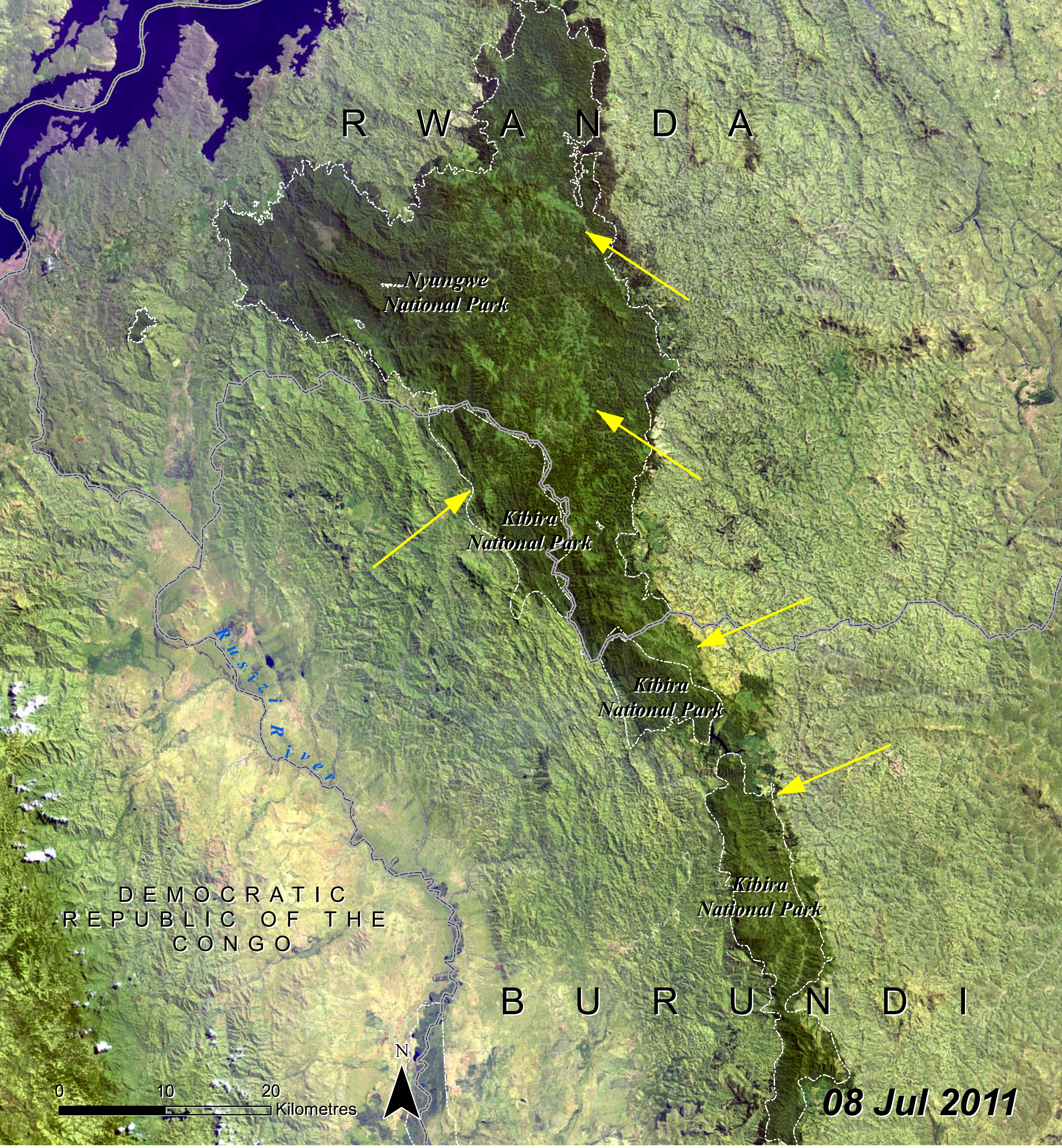




Hotspot: Nyungwe and Kibira National Parks , Rwanda and Burundi

This ecosystem contains a high level of biodiversity with many endemic species that are invaluable both locally and internationally. The two parks face similar threats that require collaborative efforts to strengthen biodiversity conservation and management across the border (WCS, 2009).

With 416 people/km², Rwanda is the most densely populated country in continental Africa (NISR, 2012) and Burundi is second with 372 people/km² (World Bank, 2011). Both the population surrounding the NNP and the population within it is increasing. As a result, there are many conflicts between humans and

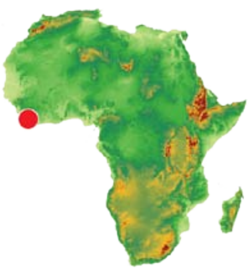


wildlife, tourists, the military and people along the main road that goes through the park (Crawford, 2012). Some of these threats include habitat alteration, over-exploitation of natural resources and deforestation. Yellow arrows in the satellite images indicate where deforestation has occurred. Bushmeat hunting is also a threat. Hunting has led to significant reductions in populations of ungulates and the elimination of elephant and buffalo within the NNP limits (Crawford, 2012). Most of these threats are a result of human presence, increasing populations and the need for food. The yellow arrows in the images indicate areas where forest loss is visually apparent.

The Nimba World Heritage Site sign in Guinea

Transboundary Protection in Western Africa

Mount Nimba Strict Reserve, Guinea and Côte d'Ivoire



The Mount Nimba Strict Reserve is a transboundary protected area with 12 540 ha in Guinea and 5 000 ha in Côte d'Ivoire (UNESCO, 2014d). It became a UNESCO World Heritage site in 1981 and was inscribed on the List of World Heritage in Danger in 1992. Part of the Mount Nimba massif extends into Liberia, but this part is not protected and has been vulnerable to mining activities. Natural waterways clearly delineate the Reserve's boundaries, and residents have been fairly respectful of its demarcation, but population pressure is threatening the Reserve. Most of the forests in the area have remained intact although the animals inhabiting the mountain are victims of poaching (UNESCO, 2014d).

Threats to the Reserve's integrity include the degradation already seen in the part of the massif in Liberia due to former mining activities and the potential negative impact from mining in part of Guinea directly adjacent to the Reserve (UNESCO, 2014d). The mountain range contains some of the world's highest-grade iron ore (see Chapter 3), and the protected status of the Reserve has been compromised because mining interests in the Liberian sector have been favoured over protection values and there has been an extensive excision on the Guinean side (ANH, 2009).

Population pressures adjacent to the protected area have led to intense poaching of fauna and the use of fire to clear land for agriculture. Fires also occur regularly inside the Reserve, which is a challenge for the administration (UNESCO, 2014d). It also suffered from enormous infiltration and exploitation following the Ivorian political crisis that began in 2002, and from refugee movements in both Guinea and Côte d'Ivoire from the earlier large influx of Liberian refugees (RRF, 2012).

Guinea and Côte d'Ivoire instituted the strict protected status of the northern part of the Reserve in 1944. Its status in Côte d'Ivoire was strengthened in 2002, prohibiting any human activity. The 1944 status is still the legal basis for protection in Guinea, pending a legal process to transcribe this protection into law. Guinea's Centre for the Management of the Environment of Mount Nimba-Simandou (CEGENS), under the Ministry of Environment, Water and Forests and Sustainable Development, administers the Reserve. The Guinean part became a Biosphere Reserve in 1980 (UNESCO, 2014d).

A number of stakeholders, including the World Heritage Fund (WHF), Rio Tinto and several NGOs involved in conservation have come together over the years to settle issues of mutual interest, including fostering transboundary cooperation and relations with local communities, fund raising and delineating clear boundaries. By 2002, Liberia had joined the Convention, cross-border collaboration was improving and the WHF was urging Guinea and Côte d'Ivoire to settle their disagreement over the Dere-Tiapleu forest border (EoE, 2008). UNESCO considers the participation of neighbouring communities in conservation measures to be indispensable in solving problems, requires the property to be properly patrolled to ensure there is no damage to its integrity and recommends that the technical, financial and human-resource capacities of management authorities need to be strengthened (UNESCO, 2014d).

Transboundary Protection in Central and Western Africa

Gashaka-Gumti National Park, Nigeria and Tchabal Mbabo, Cameroon

The Gashaka-Gumti National Park (GGNP) is located north of the Mambilla Plateau in the mountainous states of Adamawa and Taraba in Nigeria. It is the largest National Park in Nigeria, spanning more than 6 730 km^2 (NPS, 2012). The GGNP was created by federal Decree in 1991 (Dunn, 1999). Boundaries for Tchabal Mbabo have been delineated, but designation is pending (Ingram, Awono, Schure, & Ndam, 2009), despite needed transboundary protection. The Tchabal Mbado and Faro National Park in Cameroon converge with the GGNP on its eastern edge.

The ecosystem the two parks share is very unique because it is an ecotone (a transitional area between two different types of vegetation), linking a forest ecosystem with a savanna, which is not common in transboundary areas of Central and West Africa (Tagowa & Buba, 2013). The well-developed montane forest ecosystem is the Tchabal Mbabo's most important botanical feature because its represents a rare northern (dry) type of forest flora rich in montane plant species. They include species that are endemic to this isolated transboundary mountain block, the most important of which occur on the steep northern slope (UNEP, 2001). A very small population of leopard (*Panthera pardus*) still remains in Nigeria and GGNP may provide a habitat for this population (WCS, 2012). The Nigeria–Cameroon Chimpanzee (Pan troglodytes ellioti), endemic to Nigeria and southwest Cameroon, is currently endangered and the GGNP is home to the largest population. This group will be the focus of a new Wildlife Conservation Society project that aims to strengthen protection for the species as well as increase community awareness and promote transboundary cooperation between GGNP and Tchabal Mbabo (WCS, 2012).

Because these shared montane forest habitats are isolated and small in size and there are significant human pressures on the ecosystem, the populations of endemic species are at high risk of extinction. Pressures on forest resources and biodiversity include pastoralism and cultivation, which are permitted within six designated enclaves within the GGNP, and from larger settlements adjacent to the park. Threats include deforestation, unsustainable commercial hunting, unsustainable use of other natural resources, livestock overgrazing and un-prescribed fire (UNEP, 2001).

Projects that foster transboundary cooperation between the GGNP and Tchabal Mbabo can galvanize the goodwill of governments, NGOs and local communities in Cameroon and Nigeria to prevent commercial hunting, overgrazing and deforestation for farmland and fuelwood. These activities fragment and degrade the environment and threaten ecosystem and species diversity. Participatory approaches to conservation and park planning combine biodiversity objectives with respect for the rights and needs of local people (UNEP, 2001). To this end, a Global Environment Facility (GEF) project focuses on maintaining harmonious transboundary management and ensuring that conflicts between farmers, pastoralists and protection managers are kept to a minimum (Tagowa & Buba, 2013).

Cathedral Peak area trail in Ukhahlamba Drakensberg National Park South Africa

Transboundary Protection in Southern Africa

Maloti – Drakensberg Park

The Maloti-Drakensberg Park is a transboundary protected area comprised of the uKhahlamba Drakensberg National Park in South Africa and the Sehlathebe National Park in Lesotho. In 2001, the governments of South Africa and Lesotho agreed to establish a transboundary park that would include the 12 protected areas in South Africa as well as Lesotho's only National Park, Sehlabathebe (IUCN, 2013b). The 12 protected areas in the uKhahlamba Drakensberg Park were established between 1903 and 1973. It covers an area of 242 813 ha. In 2013, UNESCO inscribed the parks as a transboundary World Heritage Site, with the new name of the Maloti-Drakensberg Park (IUCN, 2013b).

Four areas, covering almost half the park, are proclaimedas Wilderness areas and are not to be infringed upon by human development. There are potential threats from external land uses, like agriculture, plantations, ecotourism, invasive species, fire, land claims, poaching and infrastructure (UNESCO, 2014b).

The transboundary park has exceptional biodiversity with a high level of endemic and globally important plants and endangered species. The Park is the spiritual home of the indigenous San people and caves in the Park contain Africa's largest and most concentrated group of paintings south of the Sahara Desert. The Park provides protection for endangered species such as the Cape vulture (*Gyps coprotheres*) and the bearded vulture (*Gypaetus barbatus*) on the South African side and the critically endangered Maloti minnow (*Pseudobarbus quathlambae*) on the Lesotho side (UNESCO, 2014b). The Park is the most important water catchment area for the people of South Africa and Lesotho (IUCN, 2013b).

Conservation management in the uKhahlamba Drakensberg National Park has been effective over many years (UNESCO, 2014b). Threats have been managed through agreements between Ezemvelo KZN Wildlife (the Republic of South Africa's provincial agency responsible for biodiversity conservation and associated activities in KwaZulu-Natalin (Ezemvelo KZN Wildlife, n.d.) and local stakeholders, while activities over the border in Lesotho have challenged efforts to protect the mountain ecosystem (UNESCO, 2014b).

Since the transboundary park was established, and in compliance with the World Heritage Convention, National Environmental Management Acts, Conservation Acts and national wildlife policies and an Integrated Management Plan with subsidiary plans have guided conservation efforts. Like all World Heritage Sites, mining or prospecting is prohibited in the park and its buffer zone and all development that can impact its integrity is forbidden (UNESCO, 2014b).

The transboundary agreement will foster more harmonious and effective park management. Ongoing cooperation between South Africa and Lesotho focuses on developing appropriate plans for sustainable tourism development that will both protect the environment's long-term integrity and provide employment and business opportunities that benefit people in both nations (IUCN, 2013b).

Park managers are now actively removing alien species, although UNESCO suggests that both invasive species and fire management need to be jointly undertaken by the two countries, ideally within the framework established for transboundary protected area cooperation (UNESCO, 2014b). In addition, the Drakensberg Maloti Transfrontier Conservation and Development Area has recognised the importance of a Transboundary Peace Park linking the Sehlabathebe National Park in Lesotho with uKhahlamba Drakensberg Park and Project Coordinating Committees in both KwaZulu-Natal and Lesotho are cooperating in a planning process (UNESCO, 2014b).

Bearded vulture (*Gypaetus barbatus*)

The National Context: Laws, Policies and Designated Protected Areas

Some sectoral laws and policies that incorporate mountain ecosystems, like the ones related to forestry and agriculture are used to address habitat loss in Africa. While many sectoral policies may incorporate mountain issues, they are usually not tailored to the unique conditions or needs of mountain areas. This may be due to a lack of policy-level recognition of these areas as unique ecosystems. South Africa's Agenda 21 implementation report identified the need to harmonize sectoral policies and formulate new mountain-specific legislation, as an example (DEAT, 1996). Table 4.3 is a summary of mountain-related policies and laws. As more countries take the lead in enacting legislation specifically related to mountains, others are likely to institute similar legislation according to their needs.

In addition, as described in Chapter 2, some cultures honour mountains as sacred sites, protecting them from activities that might harm them. A number of countries have recognised sacred sites and have protected them under various national laws such as those governing the environment, land use, customary governance, heritage and museums, biodiversity and forests, among others (Adam, 2012). While these do provide a measure of protection, it could be strengthened if incorporated as part and parcel of a mountain policy or law.

There are many different types of national protected area designations such as National Parks, Nature Reserves and Forest Reserves. Table 4.4 (next page) lists some of the national level protected areas in Africa's mountains. Protected areas can only be effective, however, if their protection measures are enforced.

Table 4.3: Summary of mountain-related laws and policies

Country	Mountain law/policy
Algeria	• Law No. 04-03 on the protection of mountain areas in the context of sustainable development, 2004 • Executive Decree No. 06-07 establishing the composition of the National Council of the mountain, its functions, organization and manner of operation, 2006 • Executive Decree No. 07-59 completing the Executive Decree No. 06-07 establishing the composition of the National Council of the mountain, its functions, organization and manner of operation, 2007 • Executive Decree No. 05-469 fixing studies and prior consultation required and all terms, conditions and procedures to enable the identification and classification of mountain areas and their grouping into mountains, 2005 • Executive Decree No. 07-85 laying down the procedures for the development and adoption of Regulation land of the mountain, studies and preliminary consultations to be conducted and the arbitration proceedings related thereto, 2007
Burundi	• Forest Act of 1985
Egypt	• Decree No. 701 of 1982 establishing a natural protected zone in El-Amid-Province of MarsaMatrouh
Equatorial Guinea	• Law No. 1/1997 - Use and management of forests
Kenya	• Environmental Management and Co-ordination Act (Part V), 1999, revised 2012
Morocco	• Green Morocco Plan (2010-2020) • Dahir No. 1-03-59 promulgating Law No. 11-03 on the protection and enhancement of the environment
Namibia	• Mountain Catchment Areas Act, 1970.
Nigeria	• National Environmental Regulations (Watershed, Mountainous, Hilly and Catchments Areas) 2009
South Africa	• Mountain Catchment Areas Act (MCAA) of 1970 • Assignment to provinces under the Mountain Catchment Areas Act in accordance with section 235(8) of the Constitution of South Africa (GN. R. 28 of 1995) • Regulations made under the Mountain Catchment Areas Act, 1971 • National Environmental Management Protected Areas Act, 2003 • National Environmental Management Protected Areas Act, 2003 (No. 57 of 2003) • Notice Declaring the Table Mountain National Park Marine Protected Area under section 43 of the Marine Living Resources Act (No. 695 of 2004) • Conservation of Agricultural Resources Act, 1983 • Limpopo Environmental Management Act (No. 7 of 2003) • World Heritage Convention Act 1999(Act No. 49 of 1999) • National Environment Management Biodiversity Act, 2004(Act No.10 of 2004) • Management Amendment Act (No.5 of 1999)
Tanzania	• Environmental Management Act, 2004 (No. 20 of 2004).
Rwanda	• Organic Law determining the modalities of protection, conservation and promotion of environment in Rwanda, 5 (No. 04/2005 of 08/04/2005)
Uganda	• National Environment (Minimum Standards for Management of Soil Quality) Regulations, 2001 (S.I. No. 59 of 2001) • Soil Conservation Measures and Guidelines • Guidelines on the management of hilly and mountainous areas • National Environment Act • National Environment (Mountainous and Hilly Areas Management) Regulations, 2000 (No. 3 of 2000)

Source: FAO, n.d.

Table 4.4: Examples of National Parks and other protected mountain areas

COUNTRY	MOUNTAIN NAME	GENERAL SUMMARY (location, key biodiversity facts, ecosystem services, threats, etc.)	PROTECTION STATUS	MANAGEMENT INTERVENTIONS	Source
Algeria	Tassili n'Ajjer Mountains	Located in Tamanrasset province, southeastern Algeria, at the borders of Libya, Niger and Mali. Area: 72 000 km^2	Tassili n'Ajjer National Park	National park (established 1972), Biosphere Reserve (1986) and World Heritage Site (1982).Legislation includes: Law98-04 on the Protection of Cultural Heritage; Law No. 83-05 on the Protection of the Environment; and a law on protected areas adopted in 2011. Managed by the Ministry of Communication and Culture and the Ministry of Environment.	Coulson & Campbell, 2013; CBD, n.d.; UNDP, 2003
Algeria	Ahaggar (Hoggar Mountains)	Located in the southern part of Algeria near Tamanrasset city. Area: 450 000 km^2	Ahaggar National Park	National Park established in 1987. Legislation includes: Law 98-04 on the Protection of Cultural Heritage; Law No. 83-05 on the Protection of the Environment; and a law on protected areas adopted in 2011. Managed by the Ministry of Communication and Culture and the Ministry of Environment.	Wacher, et al., 2005; UNDP, 2010
Niger	Aïr massif	The largest protected area in Africa with 7.7 million ha under protection and nearly 1.3 million ha specifically protected as a sanctuary for the endangered addax (white antelope).	Aïr and Ténéré National Nature Reserves	The National Nature Reserve established in 1988. Managed by Niger Wildlife Service World Heritage Site established in 1991. World Heritage site in Danger, 1992. Man and the Biosphere (MAB) Reserve, 1997.	UNESCO, 2014a
Cameroon	Mount Cameroon	Located in southwest Cameroon on the coast, in the Gulf of Guinea. One of Africa's largest volcanoes, it peaks at 4 095 m.	Mount Cameroon National Park	Created by Prime Ministerial Order N° 2009/2272/PM of 2009. Relevant laws include: Law No. 1996/12 on environmental management in Cameroon and Law No. 94-01 establishing Forestry, Wildlife and Fisheries regulations (1994 Forestry Law). Guided by a Management Plan of 2006. Institution: Ministry of Forestry and Wildlife.	Tafon, 2013
Ethiopia	Bale Mountains	Located on the Bale-Arsi massif, which forms part of the western section of southeastern Ethiopia Highlands. Area: 2 200 km^2. The highest peak in the park is Tullu Dimtu at 4 377 m	Bale National Park	Established in 1970. Managed by the Ethiopian Wildlife Conservation Authority under the following laws: Wildlife Proclamation No. 541/2007 and Forestry Proclamation (Proclamation No.94/1994). There is a General Management Plan (2007-2017).	EWCA, 2012a; FZS, 2007
Ethiopia	Simien Mountains	Located on the Amhara plateau in northern Ethiopia in the western Simien Mountains. Highest peak is Ras Dashen (4 550 m). Area: 2 200 km^2 of National Park	Simien National Park	The Park was established by Order No. 59 of 1969. World Heritage Site in1978. World Heritage Site in Danger: 1996. Managed by the Ethiopian Wildlife Conservation Authority under the following laws: Wildlife Proclamation No. 541/2007; Forestry Proclamation (Proclamation No.94/1994); Ethiopia Wildlife Conservation and Development Policy and Strategy 2009.	EWCA, 2012b
Kenya	Mount Kenya	Located east of the Great Rift Valley. Second-highest peak in Africa at 5 199 m. Area: 717 km^2 of National Park and 705 km^2 of Forest Reserve	Mount Kenya National Park and Natural Reserve	The Park, established in 1949, is managed by Kenya Wildlife Service with parts of the forest reserve managed by the Kenya Forest Service (KFS). Relevant legislation includes the Wildlife Act, Water Act (2002), the Forest Act (2005), Environment Management and Conservation Act (1999). In 1978 designated a UNESCO Biosphere Reserve and a World Heritage Site in 1998.	UNEP-WCMC, 1998; Kenya Forest Service, 2012; UNESCO, 2014c
Kenya Uganda	Mount Elgon	Crosses the border of Kenya and Uganda. Area: 169 km^2 in Kenya and 1 110 km^2 in Uganda	Mt Elgon National Park	On the Kenyan side, established in 1968. Some of the montane forest is gazetted as forest reserve and managed by the Kenya Forest Service under the Forest Act of 2005. The rest of the NP is managed by the Kenya Wildlife Service (KWS). Guiding laws include: Wildlife Conservation and Management Act, Cap. 376; Trust land; Wildlife Conservation and Management Act, Cap. 376. In Uganda, established in 1992. Managed by the Uganda Wildlife Authority (under the Uganda Wildlife Act Cap 200 of 2000).	IUCN & UNEP-WCMC, 2013
Madagascar	Amber Mountains	At the northern tip of Madagascar. Area: 182 km^2 of National Park and 48.1 km^2 of Forest Reserve.	Amber Mountains National Park	T he NP was established in 1958. Managed by Madagascar National Parks, guided by Law No. 2001-05 of 2005 on the code of protected areas; the Gestion Locale Sécurisée1996 put in place a framework for community- based management of natural resources. Décret d'Application No 848-05) for the existing Code des Aires Protégées (COAP)System of Protected Areas made the process of creating protected areas easier and allowed other stakeholders other than government to manage protected areas.	Durbin, 2007; Rocliffe, 2010
Malawi	Mulanje Mountain	Mulanje is located in southeastern Malawi with a peak elevation of 3 002 m. Area: 650 km^2	Mulanje Mountain Forest Reserve	Established in 1927 as a forest reserve. Managed by the Mulanje Mountain Conservation Trust (MMCT). Global Biosphere Reserve in 2000. National Environmental Policy 1996 revised in 2004. Legal framework: The Forestry Act No. 11 of 1997; National Parks & Wildlife Act No. 11 of 1992; The National Wildlife Policy 2000; The National Forestry Policy 1996.	Mthandi, n.d.; Wisborg & Jumbe, 2010; Nyondo, 2003
Morocco Tunisia Algeria	Atlas Mountains	Located in the central High Atlas Mountains in central-western Morocco. Includes the highest point of the Atlas Mountain range: Djebel Toubkal at 4 167 m. Area: 360 km^2	Toubkal National Park	Established in 1942. Managed by the Regional Directorate for Water, Forest and Conservation of Soils of the Ministry of Agriculture. Outdated Law of Forest Protection and Exploitation (1917); Law N° 22-07 on protected areas of 2010.Guided by the Overall Management Plan for Morocco's ProtectedAreas of 1992,The High Commission for Water, Forestry and Desertification Control.	IUCN, 2006
South Africa Lesotho	Drakensberg Mountains	The highest peak in the park is the Thabana Ntlenyana at 3 482 m. The Maloti Drakensberg Transfrontier Conservation Area protects areas in both South Africa and Lesotho. Area: 14 750 km^2 of which 5 850 km^2 is in Lesotho	Maloti Drakensberg Park; uKhahlamba Drakensberg National Park in South Africa; Sehlathebe National Park in Lesotho; Golden Gate Highlands National Park in South Africa; Sehlabathebe National Park: Lesotho; Ts'ehlanyane Nature Reserve in Lesotho; Bokong Nature Reserve in Lesotho	Institutions: In South Africa - Ezemvelo KwaZulu-Natal Wildlife responsible for uKhahlamba Drakensberg Park World Heritage Site,and in Lesotho, the Ministry of Tourism, Environment and Culture, responsible for Sehlabathebe National Park. There is a 5-year Joint Management Plan, although each park has its own individual management plan. In 2013 the Sehlabathebe National Park was inscribed as an extension to the UNESCO uKhahlamba Drakensberg World Heritage Site.	Zunckel, Mokuku, & Stewart, 2011; MDTP, 2012
South Africa	Table Mountain	Located along the range of mountains that make up the mountainous spine of the Cape Peninsula. Area: 1 250 km^2	Table Mountain National Park	Established 19 May 1998. Managed by SAN Parks. World Heritage Site in 2003. There is a 5-year park management plan in line with the National Environment Management: Protected Areas Act No. 57 of 2003.	Standish, Boting, van Zyl, Leiman, & Turpie, 2004; SANParks, 2008; SANParks, 2014
Uganda Rwanda DRC	Virunga Mountains	The Virungas are mountain chain located along the border of northern Rwanda, DRC and Uganda and the Rwenzoris cross the DRC and Uganda. Both mountain areas are part of the mountains found in the Central Albertine Rift.	Mgahinga Gorilla National Park; Virunga National Park; Volcanoes National Park; Queen Elizabeth National Park, Rwenzori Mountains National Park; Semuliki National Park	Part of the Protected Area Network of the Central Albertine Rift managed by the Uganda Wildlife Authority; Institut Congolais Pour La Conservation De La Nature (in DRC); and Rwanda Development Board.	Milner-Gulland & Mace, 2009; UWA, ICCN & ORTPN, 2006

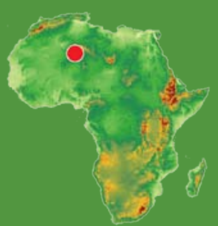
Richtersveld Transfrontier National Park, South Africa

National Parks

Designation as a National Park creates opportunities for recreation, research and education in addition to protection (IUCN, 2008). National Parks can help to conserve and manage biodiversity as well as protect cultural and heritage values (Box 4.8).

According to the World Database on Protected Areas, there are 468 National Parks in Africa; of these, 125, or about 27 per cent, are found in areas of 1 500 m or higher in elevation (IUCN & UNEP-WCMC, 2013; Figure 4.4). Examples of mountainous National Parks include the Richtersveld Transfrontier National Park, South Africa located in in the mountains between South Africa and Namibia. It contains the

Box 4.8: Protecting cultural and natural heritage in Ahaggar National Park, Algeria



The Ahaggar National Park, located among the Ahaggar Mountains (also known as the Hoggar Mountains) in southern Algeria, was established in 1987 to protect, conserve and enhance the mountains' cultural and natural heritage. It is an extremely large protected area, covering 450 000 km^2 of the Sahara Desert. The Ministry of Culture, based in Algiers, manages the park. It ranges in elevation from 1 500 m to 2 981 m, peaking at Mount Tahat. Culturally, the mountains are home to archaeological sites that are older than 600 000 years, with some dating to more than a million years ago. The rock art is a source of tourism in the park. Although the ANP is located in an arid region, it contains Les Gueltates d'Issakarassene, a Ramsar Wetland of International Importance. A guelta is not a typical wetland; it is a type of wetland specific to the Ahaggar Mountains and the neighbouring Tassili. Gueltas can be found in rocky basins or depressions hollowed out of a riverbed. They can be permanent or intermittent. The Les Gueltates d'Issakarassene is home to several fish species, including the barbell, catfish and tilapia. Many reptiles and amphibians can be found as well.

Tree species such as *Acacia* and *Tamarixare* are commonly found in the park where they provide good cover, making it an important habitat for cheetah. A small, elusive population of cheetah still exists in the ANP and is protected under "Décret no 83-509 du 20 Août 1983"of Algeria's National list of Protected Species. Antelope species such as the Addax and the dama gazelle used to roam in the park, but are now considered to be extinct in the park area, although scientists consider the park to be potentially conducive for reintroducing these species.

Sources: Compiled from Ghabbour, 1997; Wacher, et al., 2005; BLI, 2014; Ramsar, 2001

Landsat 8 image of Mount Tahat and the unique mountainous terrain inside the Ahaggar National Park

Dama gazelle

Figure 4.4: National Parks located at or above 1 500 m a.s.l.

Source: IUCN & UNEP-WCMC, 2013; UNEP/DEWA

vulnerable Succulent Karoo ecoregion, of which only 2.5 per cent is protected (FAO, MPS, UNCCD, SDC, & CDE, 2011). Conglomerations of protected areas, such as the eight individual areas ranging from National Parks to Wilderness Areas that make up the Cape Floristic Region World Heritage Site, which includes Table Mountain, the Boland Mountain Complex and the Cederberg Wilderness Area, contribute to protecting large areas of important mountain habitat (UNEP-WCMC, 2011). About 14 per cent of South Africa's Cape Floristic province, which covers half of the country's mountain areas, is legally protected (FAO, MPS, UNCCD, SDC, & CDE, 2011).

Calitzdorpensis flowers from Succulent Karoo, Western Cape, South Africa

Protection Mechanisms: Species

As described in Chapter 2, Africa's mountainous areas are rich in biodiversity. From the Albertine Rift to the Cape Floristic Region, a significant amount of rare and endemic species can be found. Historically, mountains have been generally unsettled, but as development increases and populations creep up the mountains, valuable species habitat is threatened through deforestation and land degradation (WWF, 2014a). Protected area designation, such as National Parks, can help not only protect the land and its resources, but also habitat for some of Africa's most precious mountain species. The following case study describes how the creation and presence of the Simien Mountains National Park and World Heritage Site have helped to reduce agriculture activity in the area and improve wildlife habitat.

Hotspot

Hotspot: Simien Mountains National Park, Ethiopia

Erosion of the Ethiopian plateau created the impressive Simien Mountains in northern Ethiopia, which peak at Ras Dashen at an altitude of 4 620 m. This striking feature is recognized largely for its geological features and its biodiversity (Asrat, Metasebia, & Aberra, 2012). The Simien Mountains National Park (SMNP) in the Ethiopian highlands was established in 1969 and is one of only two currently legally protected areas out of the country's 14 planned national parks and sanctuaries (FAO, MPS, UNCCD, SDC, & CDE, 2011).

Protecting 225 km^2 of land (UNDP & GEF, 2006), SMNP was established to capture and preserve the region's beautiful scenic value defined by its unique topographical variations, extreme geological features and rich vegetation (UNESCO, 2014f). The park was designed to protect the Walia

Walia ibex in the Simien Mountains

ibex, a critically endangered species with a meagre population of approximately 623 individuals found exclusively in the Simien Mountain region (November 2005 census) (Debonnet, Melamari, & Bomhard, 2006; EWCA, 2012b). Other threatened flora and fauna are also managed within the park, including Afroalpine vegetation, the Gelada baboon and the Ethiopian wolf, which are both endemic to Ethiopia (UNDP & GEF, 2006; UNESCO, 2014f). In 1978, the park was listed as a UNESCO World Heritage Site for its key role in preserving the Walia ibex population and its intrinsic biodiversity.

While many protected parks around the world restrict human access, there were many villages within the park before it was established and 30 per cent of the land had been cultivated (Asrat, Metasebia, & Aberra, 2012). Thus, it is a common space shared between humans, plants and animals (UNDP & GEF, 2006). As a result, population pressure has had significant impacts on land cover, which can subsequently affect wildlife, hydrology, climate and biogeological cycles. In 1984, approximately half of the SMNP land cover was under grassland and agriculture (Wondie, Schneider, Melesse, & Teketay, 2011). Additionally, encroachment onto animal territory had sparked human-wildlife conflict over natural resources, such as invasions of poor farmers' lands and crop theft by the Gelada baboon (Yihune, Bekele, & Tefera, 2008b), and conflict between farmed and wild animals, including a number of incidents of sheep killings by the Ethiopian wolf (Yihune, Bekele, & Tefera, 2008a).

In 1986, a management plan was designed to address sustainable development in the region. It included plans to preserve the Afrotropical Highlands Biome, an ecozone with a distinctive climate hosting particular plant and animal groups and which serves as the catchment area and source for Ethiopia's major rivers (IUCN, 2003). Plans include conserving endangered flora and fauna including the *Walia ibex*; managing the watershed and its ecosystem services; promoting the park to tourists and scientists; and protecting its beauty as a World Heritage Site (Hurni, 1986). The civil war interrupted the plan, however, and it was never implemented (SMNP & EWCA, 2013). Subsequently, the park was placed on the World Heritage Danger list in 1996 because of a declining population of ibex and human activities that were causing further degradation (Debonnet, Melamari, & Bomhard, 2006).

In 2001, the national government handed over the SMNP's management to the Amharan Regional Government. In that

Simien Mountains

Gelada baboon in the Simien Mountains

same year, the IUCN and the World Heritage Commission (WHC) agreed on benchmarks to ensure that the SMNP was removed from the list of World Heritage Sites in Danger. The benchmarks included:

(1) Re-aligning the park's boundary to exclude certain villages;

(2) Extending the park to include untouched land and wildlife reserves;

(3) Reducing human population density; and

(4) Conserving larger populations of the Walia ibex and the Ethiopian wolf (UNESCO, 2002).

Protection of the park's natural resources and wildlife habitat improved during this time, attributed to a decline in agricultural activity between 1984 and 2003. By 2003, pure forest increased from 11.71 to 15.63 per cent of the total land area. Additionally, government enforcement of the IUCN-WHC's management plan contributed to these changes (Wondie, Schneider, Melesse, & Teketay, 2011).

In 2006, a follow-up mission to observe progress noted that benchmarks 1, 2, and 4 had been adequately addressed, but benchmark 3, regarding population density, was still an issue (Debonnet, Melamari, & Bomhard, 2006). Following a second evaluation mission, the IUCN-WHC updated their benchmarks to include: (1) re-aligning the park's boundary to exclude certain villages; (2) extending the park to include untouched land and wildlife reserves; (3) reducing the impact of livestock grazing; and (4) supporting alternative livelihoods for people living within the park (UNESCO, 2010).

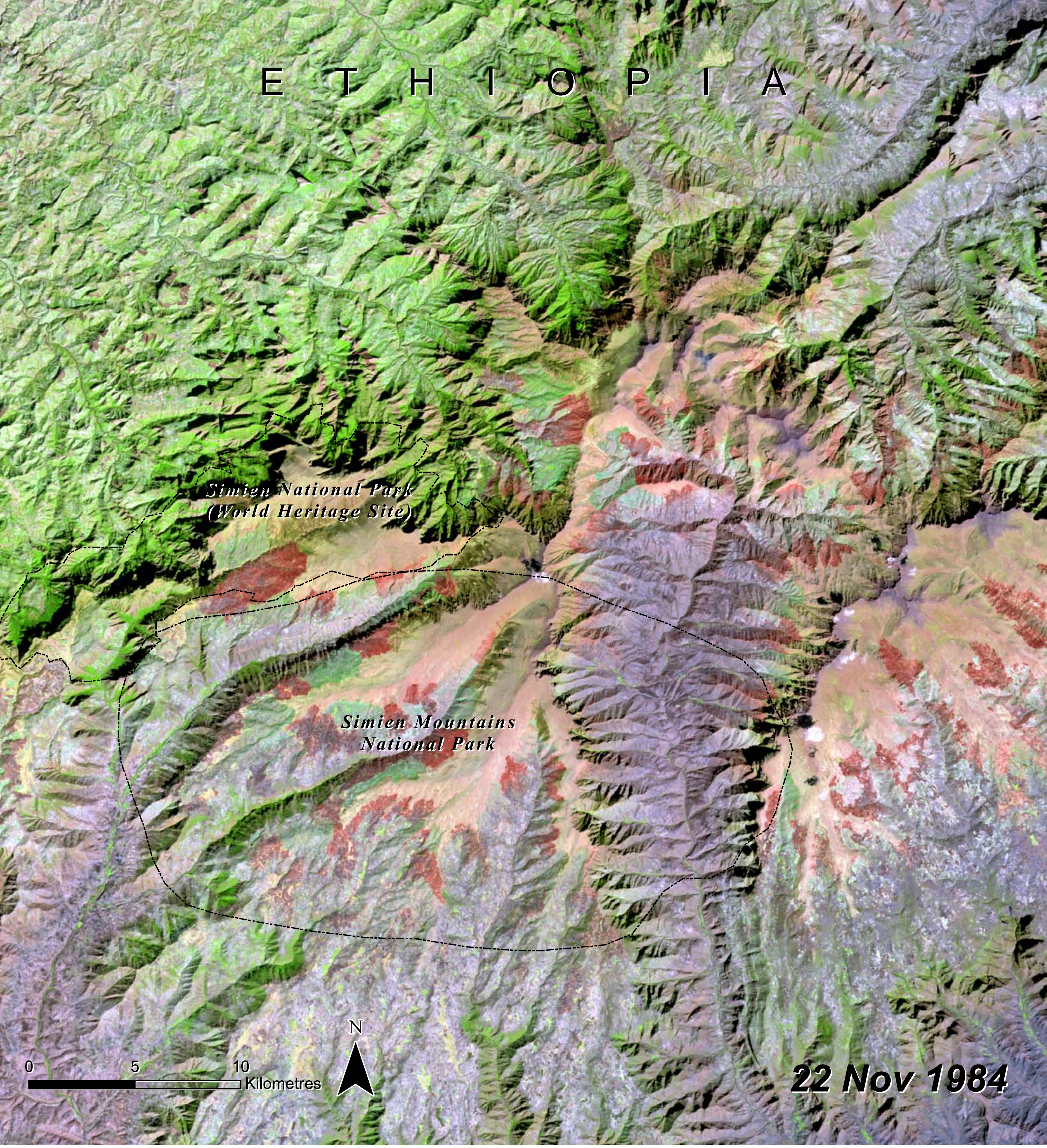
In 2010, a report noted progress on the updated benchmarks: the park had been extended successfully, fully satisfying benchmark number 2. In fact, 165 households voluntarily moved their houses out of the wildlife reserves to accommodate the extension and they received funding to improve their livelihoods after resettlement (UNESCO, 2010). Moreover, the population of Walia ibex nearly doubled between 1996 and 2008 (Geberemedhin & Grubb, 2008).

Despite this progress, implementing the other benchmarks remains a challenge. New boundary laws have made it difficult for the SMNP to re-align them to exclude certain villages.

Simien National Park

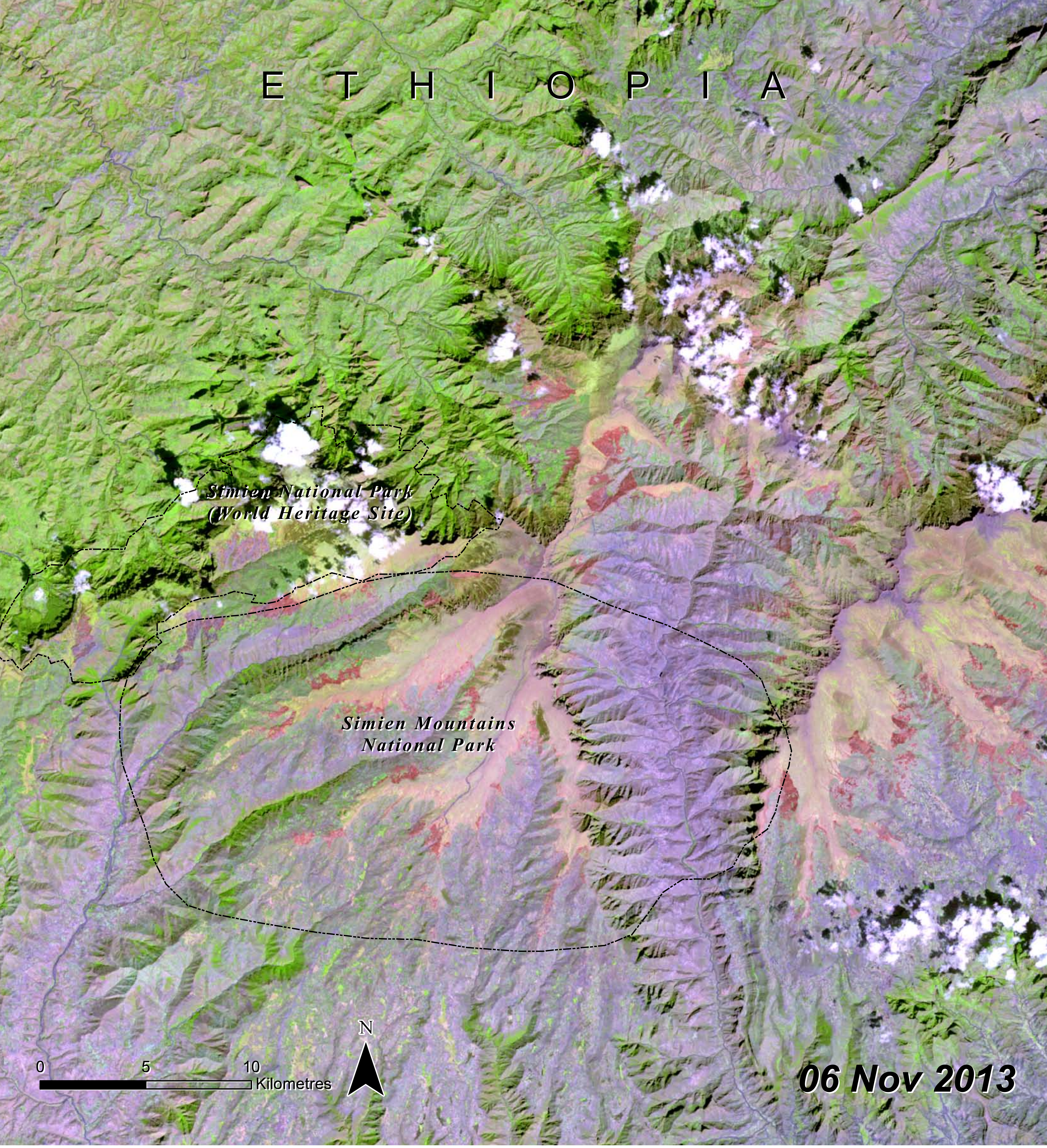
Secondly, a Grazing Pressure Reduction Strategy (GPRS) document prepared in 2007 had still not been presented to potential donors. Finally, funding has yet to be sought for a strategy in which private businesses would support moving 586 households out of the park and finding them alternative livelihoods. This relocation of human settlements and subsequent creation of buffer zones are essential to ensuring the park's proper conservation (UNDP & GEF, 2006), but the cost of implementing such a project remains high (UNESCO, 2010).

Thus, the SMNP remains on the list of World Heritage Sites in Danger (UNESCO, 2010) and the management plan is still in progress. Ensuring the park's complete environmental protection is difficult in the presence of humans, but if the IUCN-WHC's management plan is properly implemented, it can be effective (UNESCO, 2010).



Hotspot: Simien Mountains National Park, Ethiopia

Additionally, geospatial analysis using tools like remote sensing and Landsat images can be important for monitoring trends in land-cover change in the Simien Mountains. This method, coupled with others that monitor land use, such as socio-economic surveys and wildlife censuses, are effective ways to continually track the state of the Simien Mountains and help to prevent further degradation (Wondie, Schneider, Melesse, & Teketay, 2011).



Although it remains on the World Heritage Sites in Danger list, some management has helped to reduce agricultural impact. Burn areas (in red) are evident in the satellite images. The fire season variesand it can leave scars that last for months or years. The 2013 satellite image shows a marked reduction in the number of fires, which can be frequent in the tree-heather forest (UNESCO, 2014f), as compared to the same month in 1984.

Protection Mechanisms: Ecosystems

Protecting Glaciers

Protected area designation also benefits particular environments that lack other forms of protection. As described in Chapter 3, the few glaciers that remain on some of Africa's peaks are rapidly shrinking. These glaciers, found atop Mount Kenya (Kenya), Rwenzori (shared by Uganda and DRC) and Mount Kilimanjaro (Tanzania), are not protected under any specific ordinance or law. The glaciers are found within protected area designations such as national parks, however, and are recognized for their unique habitats by international treaties such as the World Heritage Convention and the Ramsar Convention. These designations help to protect the area from illegal activities, mining and population pressures and promote sustainable uses of natural resources (UNESCO, 2014j; Ramsar, 2009b). In addition to retaining the iconic existence of glaciers in Africa, protecting them is a way to preserve the long-term climatological records from ice cores, such as those from Kilimanjaro that date back as far as 11 700 years ago (Carey, 2007).

The Rwenzori Mountains National Park (RMNP) encompasses the glaciers on Mounts Baker, Speke and Stanley in Uganda and is also recognized as a UNESCO World Heritage Site. Delineation of park boundaries has helped to maintain the integrity of the Rwenzori's function as a water tower for the growing population surrounding the mountain, despite pressure from threats such as agriculture and bamboo extraction (UNESCO, 2014e). Furthermore, because the RMNP receives ample rain and is subject to snowmelt from its peaks, the mountains support unique high-altitude wetlands that have been recognized as Wetlands of International Importance by the Ramsar Convention (Ramsar, 2009a).

Mount Kilimanjaro's glaciers are located within the Kilimanjaro National Park; with recent observations of forest loss affecting the mountain's ability to adequately contribute to the ecosystem's water balance, reforestation may prove another way to protect Kilimanjaro's glaciers (Mason, 2003; Hemp, 2005).

Cloud forest on Mount Kilimanjaro, United Republic of Tanzania

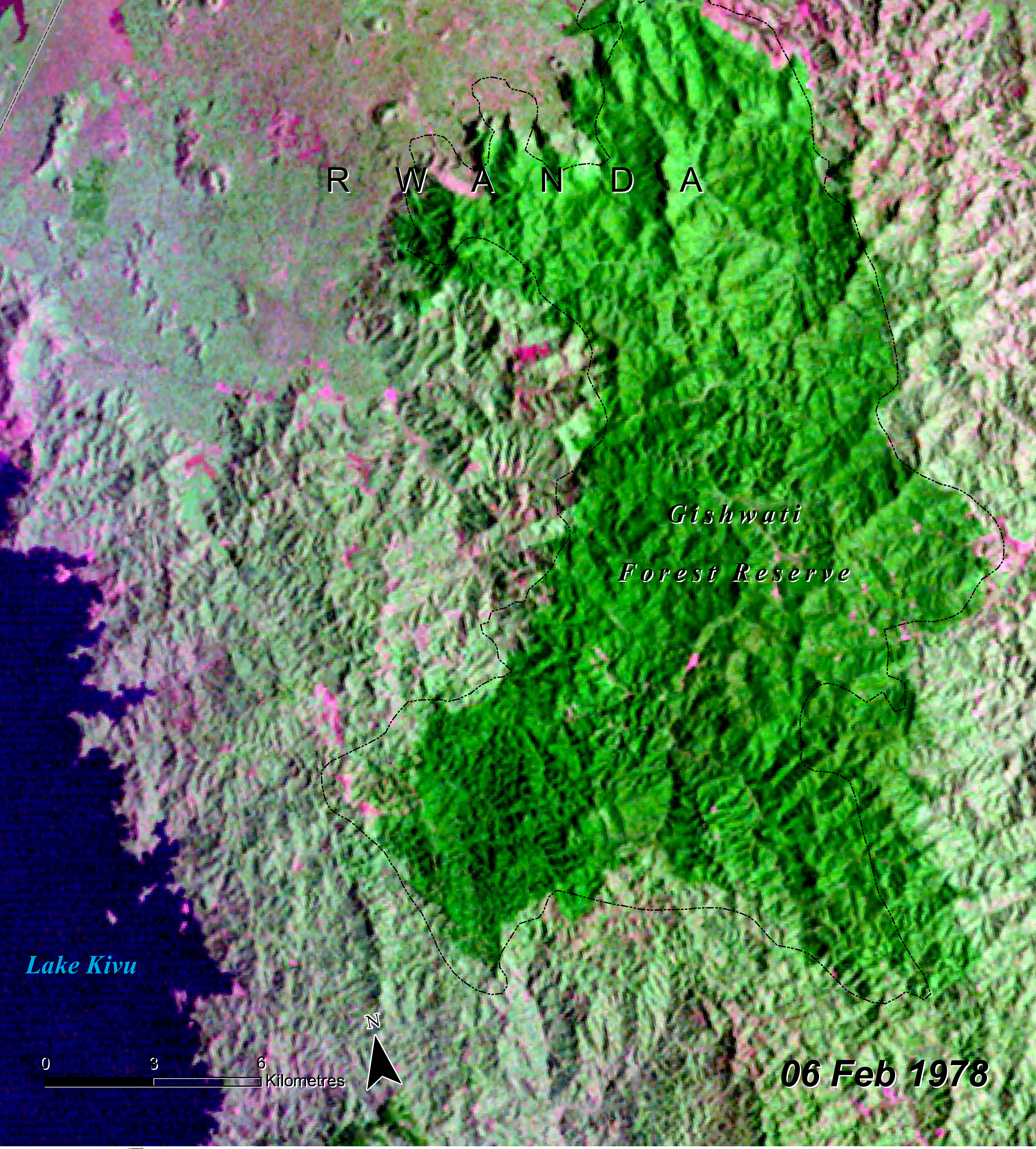
Figure 4.5: Forest reserves located at or above 1 500 m a.s.l.

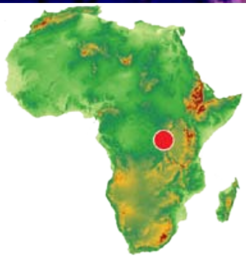
Source: IUCN & UNEP-WCMC, 2013; UNEP/DEWA

Protecting Forests

Countries that do not have national mountains laws may protect mountain forests through forest legislation or other regulations or guidelines, as have Burundi, Kenya, Mauritius, Seychelles and Uganda. Other regional policy efforts underway to protect mountain forests include the Draft EAC Water Vision 2025, which recognizes the need to sustainably manage mountain forests. It highlights the example of Uluguru Mountains in the United Republic of Tanzania where a 13 per cent decline in forest cover led to a drop in river flows. This adversely affected the Ruvu River, which supplies water to the coastal city of Dar es Salaam (see hotspot in Chapter 3) and degraded the river's natural capacity to act as a buffer during floods (EAC Secretariat, 2012). Similarly, the Vision plan acknowledges the loss of natural forest on Mount Kilimanjaro's southern slopes, which amounts to 41 km^2 in the past few decades.

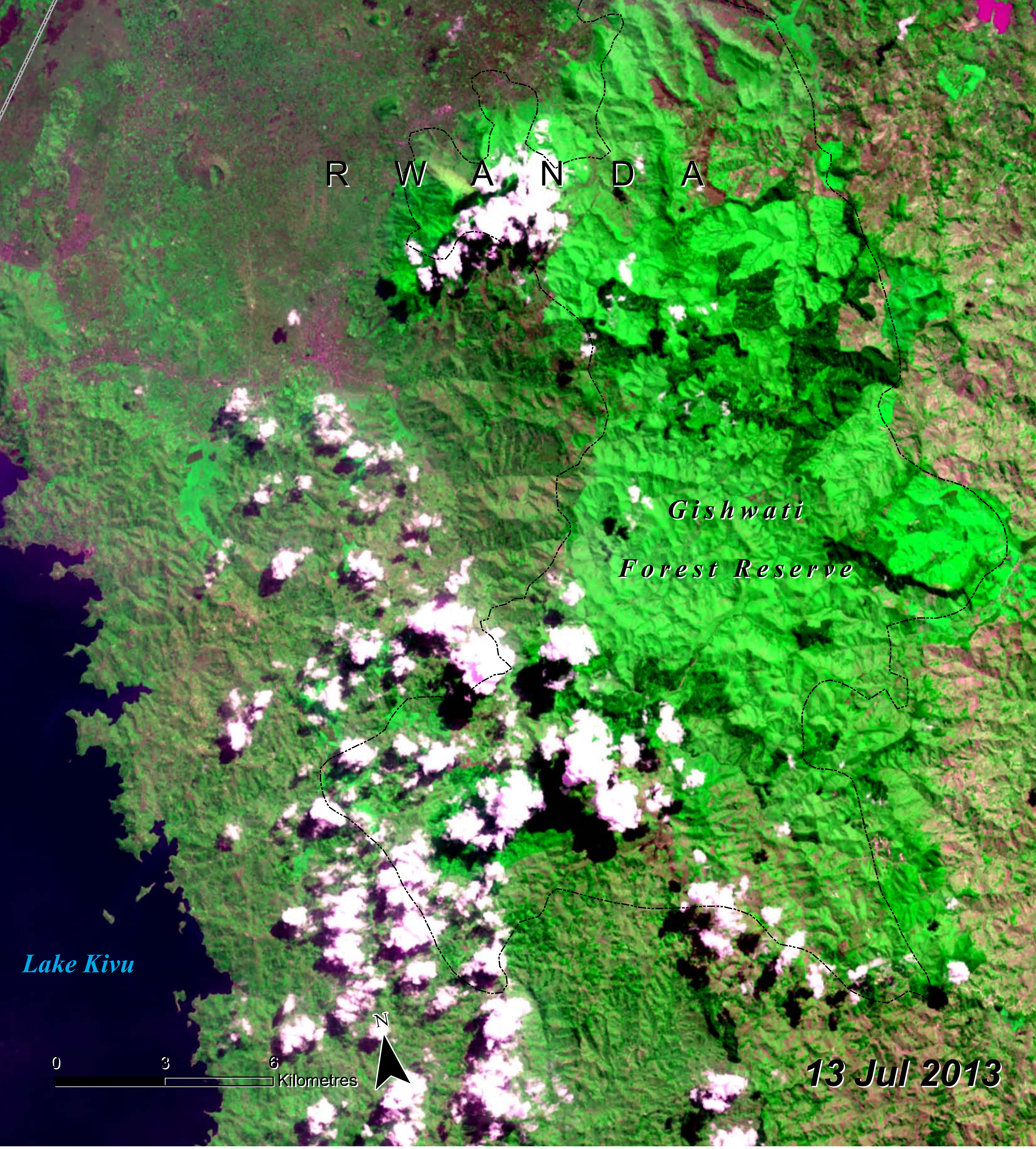
Another protection measure is through Forest Reserve designation. There are numerous Forest Reserves located throughout eastern Africa in mountainous areas (Figure 4.5). In the United Republic of Tanzania, Forest Reserve designations are assigned to a network of forests in the Eastern Arc Mountains as a means of promoting global awareness of, and protection for, their role as water suppliers and prime areas of biodiversity (FBD, 2006). In Rwanda, the Gishwati Forest Reserve has historically suffered widespread deforestation, however the government of Rwanda's reforestation programme, undertaken through the National Forest Policy of 2004 (updated in 2010), has helped reversed some of the damage.





Hotspot: Gishwati Forest, Rwanda

The Gishwati Forest Reserve is located in northwestern Rwanda. The forest has suffered extraordinary loss of forest cover, declining from 70 000 ha in 1930 to 28 000 ha in the 1970s to a mere 600 ha in 2005 (USAID, 2014; FLR, 2011). The forest was exploited for land to support cultivation, ranching and human settlements (FLR, 2011) and as a result has become vulnerable to soil erosion and landslides, leading to a



significant loss of biodiversity (Njoroge & Muli, 2011). A tree-planting programme has allowed the forest to recover somewhat. Forest cover increased to 886 ha by 2008 and increased to 1 484 ha by 2011 (FLR, 2011). The Gishwati Forest Reserve is now known as the "Forest of Hope" (FLR, 2011).

In the satellite images, the forest appears nearly fully intact in the 1978 image. However, extensive deforestation is evident in the 2013 image. Lighter green areas show where forest has been removed and dark green patches show where thick forest remains. Purple and pink areas indicate areas of cultivation.


A waterfall in the Rwenzori Mountains

Protecting Water Catchments

In a continent dominated by arid and semi-arid areas, water resources for human consumption, irrigation and livestock production depend on the river flow, groundwater or water stored in snow and glaciers from mountain areas. As explained in Chapter 2, the mountains of Africa are water towers and are of great importance to providing water both near and far from the sources. The Africa Water Vision 2025 highlights the degradation of water catchment areas as a key challenge in managing water in Africa and aims to improve watershed and floodplain management (UNECA, 2004).

Africa's water towers need to be protected from unsustainable activities so they can continue to function as freshwater sources. It is well established that natural forests and tree plantations improve the water cycle by diminishing runoff and replenishing water tables; thus, human activities that lead to deforestation could threaten the very integrity of the mountain ecosystem, and especially the water cycle. Degradation can reduce water availability and quality and alter river flows, all leading to serious downstream consequences (Barr & Mafuta, 2007). Threats to forests and related vegetation also come from over-dependence on biomass sources of energy, especially in rural areas. Proper forestry management can in turn help to protect water resources.

At national levels, policies that comprehensively address water catchment management are extremely rare. This is mainly because this issue overlaps several sectors, including wetlands, land use (forestry, agriculture, etc.) and water. Some countries, such as South Africa, Kenya and Uganda, however, have instituted recent reforms to ensure water catchments are better managed. In 2012, Kenya put in place a master plan for the conservation and sustainable management of water catchment areas (MEMR, 2012), and under South Africa's National Water Act of 1998, nine Catchment Management Agencies were established in 2012 to improve the country's management of water resources through a decentralized approach (DWAF, 2012).

In Uganda, the Ministry of Water and Environment designed a management plan for the North Rwenzori Central Forest Reserve that includes specific mention of the need to protect the area as an important water catchment area. The plan aims to restore lost and degraded forest cover and sustainably regulate plantation use, recognizing that forests are important for maintaining water resources and river flows and improving water quality (NFA, 2012).

The following pages describe how collaboration of governments, NGOs and other organizations has helped to partially restore the Mau Forest Complex in Kenya, an important water tower and catchment area.

Hotspot

Hotspot: Mau Forest Complex, Kenya

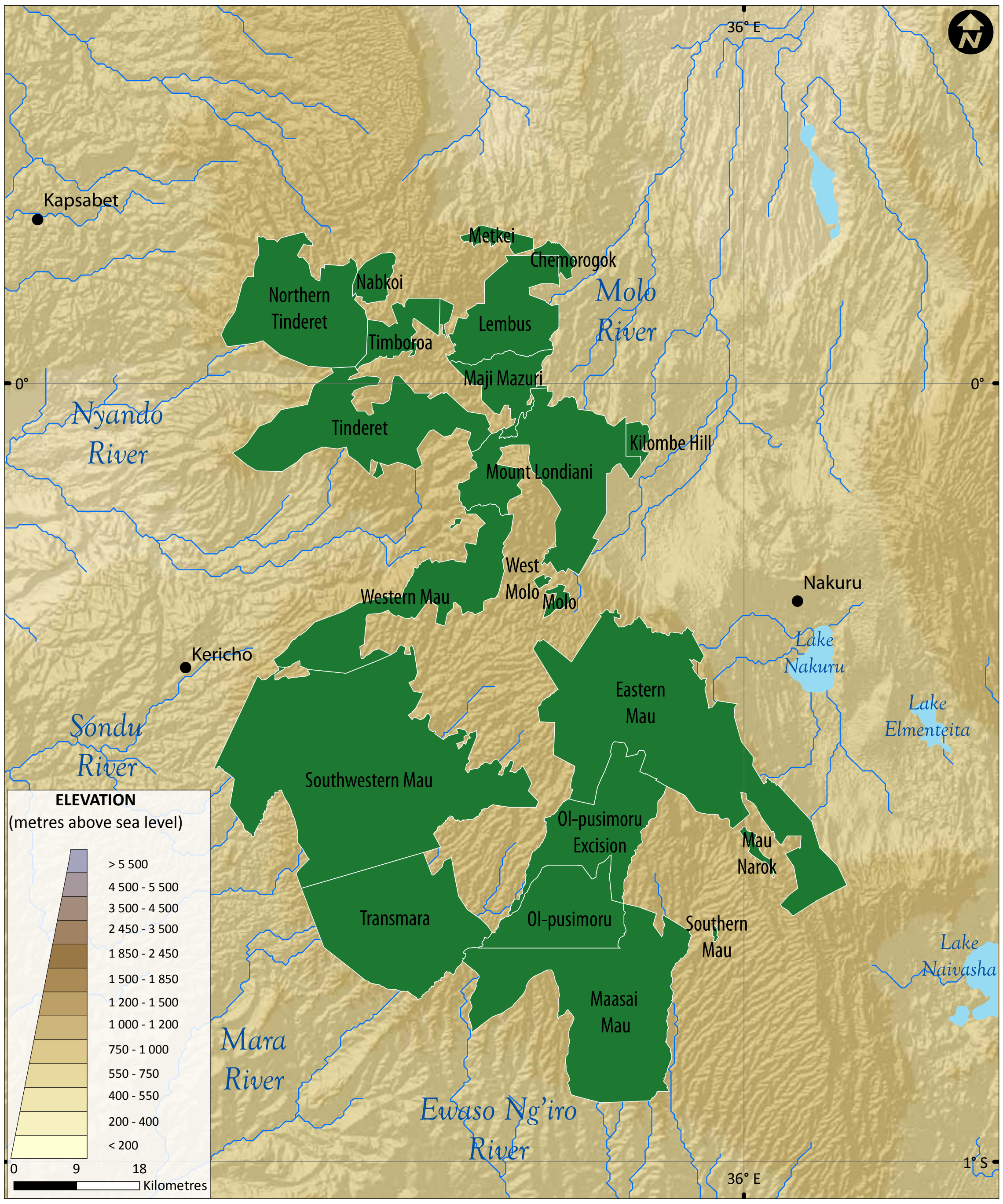
One way of protecting water catchments is by protecting forests. The Mau Forest Complex, located in the Kenyan Rift Valley, is an essential water tower for Kenya. It is comprised of 22 forest blocks, 21 of which are managed by the Kenyan Forest Service (Figure 4.6). The other block is the Maasai Mau Trust Land Forest managed by the Narok County Council (GoK, 2009). The forest spans the Mau Escarpment, which reaches to 3 000 m in elevation and serves as the source for many bodies of water in Kenya, contributing to five major lakes, including Lake Victoria and Lake Turkana, and forming the upper catchment of most rivers west of the Rift Valley (UNEP, KWS, KFWG, & ENSDA, 2008; Table 4.5).

Table 4.5: Flow of water from the Mau Forest to rivers to lakes

River	Flows to
Nzoia	
Yala	
Nyando	Lake Victoria
Sondu	
Mara	
Kerio	Lake Turkana
Molo	Lake Baringo
Ewaso Ng'iro	Lake Natron
Njoro	
Nderit	Lake Nakuru
Makalia	
Naishi	

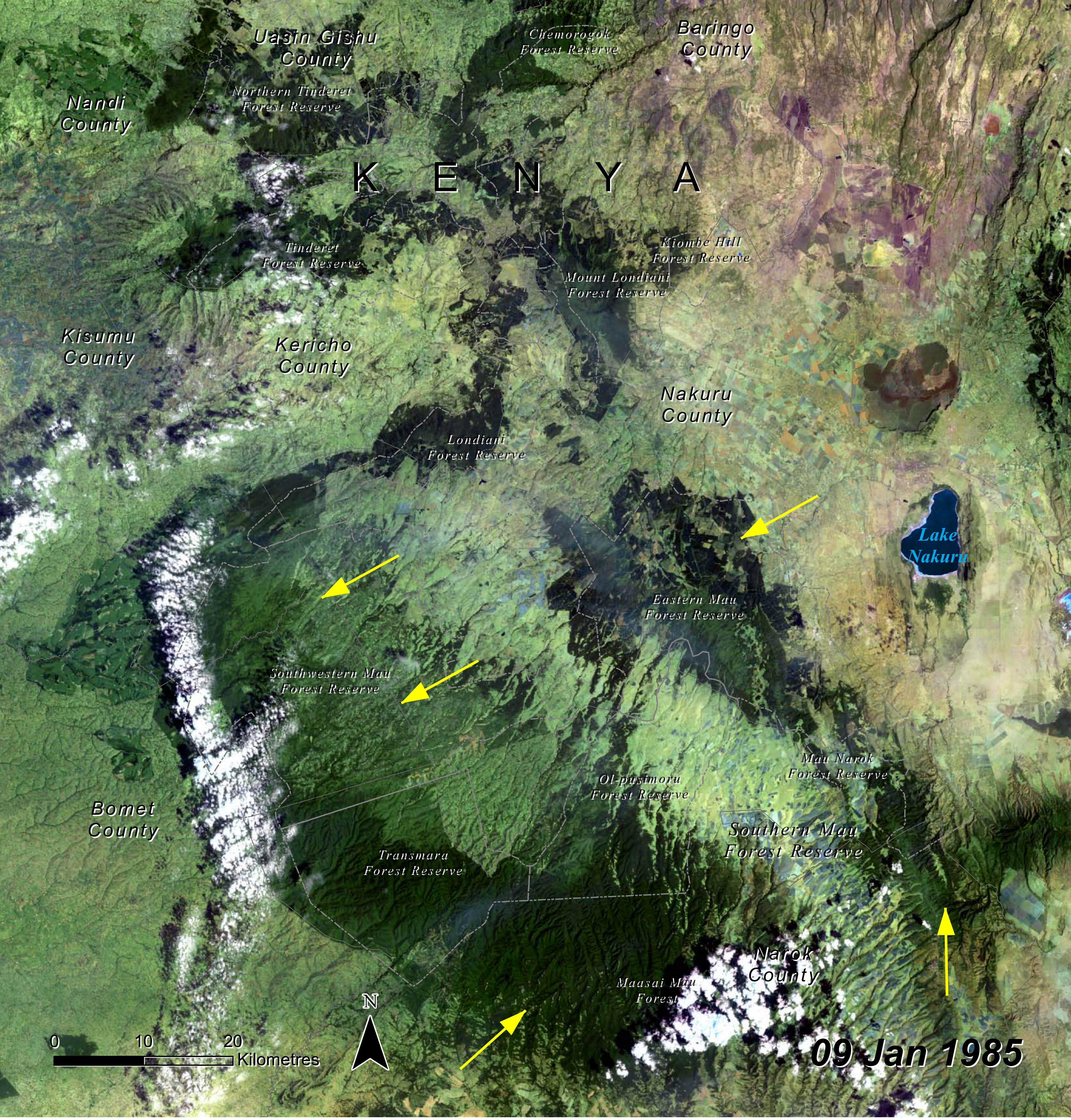
Source: Adapted from UNEP, KWS, KFWG, & ENSDA, 2008

Figure 4.6: Kenya's Mau Forest Complex



Source: Adapted from UNEP, 2009; UNEP/DEWA

Looking out over tea fields to the Mau Forest, Kenya



Hotspot: Mau Forest Complex, Kenya

The Mau Forest has undergone many land use changes over the past four decades, notably a decrease in forest cover (Were, Dick, & Singh, 2013). Approximately 15 per cent of the forest was excised in 2001 and since the 1990s, a total of over 25 per cent (107 000 ha) has been excised from protection or encroached upon for activities such as illegal logging and charcoal production (GoK, 2009). Land cover in the Nakuru drainage basin, which encompasses the Eastern Mau Forest, was predominantly forest-shrubland from the early 1970s to 2000, but then gave way to cropland and grasslands by 2011 (Were, Dick, & Singh, 2013). Yellow arrows indicate areas of change in forest cover.

Environmental impacts have not been thoroughly assessed, although reduced streamflow due to forest-cover loss has been shown to negatively impact development investments (GoK, 2009). For example, the Sondu-Miriu Hydropower operation cannot run at full capacity in dry seasons because of reduced flow from the Sondu-Miriu River (GoK, 2009).

Political entities have become aware of the grave impacts and the European Union, UNEP and the Government of Kenya (GoK) formed a partnership to help restore the northwestern section of the Forest Complex. Part of the project will support establishing wood lots for local residents' cooking needs (Akasa & Aisi, n.d.). Other projects, such as the reforestation partnership between the African Wildlife Foundation and Kenya Forest Service, are also in effect. By early 2013, the project had planted more than 160 000 indigenous trees and weeded more than 18 000 seedlings (AWF, 2013).

Mount Sabyinyo in Mgahinga Gorilla National Park, Uganda

The Local Context: Traditional Knowledge and Community-level Protection

Communities may also take responsibility for forest management and traditional community practices are used to control natural resources in some mountain areas around the globe (Colchester, 1994; Genin, Herve, & Riviere, 1995; Berkes, 1999; Uprety, 2008). Villagers and rural populations are often unfamiliar with modern management practices and state-level management regimes, but rather have a better community-level understanding of conservation needs and employ their own organizational systems (Cuny, Ango, & Ondoa, 2007). Generally, within those customary systems, one social group is charged with managing extraction and appropriation (Venema, 2002) as in the case of *Agdal* forests in the High Atlas Mountains.

At the community level, environmental policy is increasingly taking an approach to conservation that includes the participation of local communities and accounts for the traditional values and cultural identity of different social groups as a complement to scientific research and practical management (Ruiz-Mallen & Corbera, 2013). By showing local populations that protected areas can protect both local and global values through highlighting protected areas as cultural entities, local interest in actually keeping the area protected may increase (FFI-UWA, 2012). For example, the traditional knowledge and beliefs of local people in the Rwenzori Mountains regarding natural resource use could potentially improve the area's biodiversity conservation, but their practices need to be integrated with the management of established protected areas (FFI-UWA, 2012).

In another example, the Cameroon Mountains Conservation Foundation works to promote biodiversity conservation through educating local communities on how to manage and protect the montane forests themselves. Support is provided by the public sector, local civil socities and research institutions (ACF, 2014). A possible way of achieving this is through the Culture, Values and Conservation Project conducted by Fauna & Flora International and the Uganda Wildlife Authority, which aims to integrate cultural values into

Box 4.9: The socio-cultural dimension of mountain governance in Cameroon

In mountain governance, it is important to consider the socio-cultural needs of communities living in and around mountain ecosystems. Such communities have indigenous and traditional lifestyles that differ from others and have shaped their protection paradigm of mountain ecosystems. In northern Cameroon for example, the *bororo* people, who have been considered by international legal instruments together with the pygmies, as classes of indigenous people, live in mountain and highland areas where transhumance and other livestock activities constitute their main socio-cultural lifestyle. Rather than move the *bororo* away, any well crafted governance regime of a maintain ecosystem could instead adopt an integrated approach which considers them as part of the mountain ecosystem to encourage sustainable development.

Source: Tamasang, 2007

the management of Rwenzori Mountains National Park (FFI-UWA, 2012). This type of protection and management approach, that considers culture, could be implemented in other areas such in the mountainous areas of Cameroon where the culture of the *bororo* people needs to be maintained along with the environment (Box 4.9).

Box 4.10 provides an example of how local participation can protect both the needs of humans and wildlife. Similarly, in the Bwindi Impenetrable National Park (BINP), communities and park management have found ways to create synergy between the need to protect mountain resources from human activities and the need for local communities to benefit from those same resources. Several community conservation approaches in the BINP have been relatively successful since about the mid-1980s. These include a revenue sharing program in which local people receive 20 per cent of annual total gate collections from national parks, which they invest in community development; and a multiple-use programme in which people living around the park and park authorities have an agreement allowing locals to harvest medicinal plants and handicraft materials and to keep bees, although some other resources important to community livelihoods remain out-of-bounds (Kasangaki & Bitariho, 2013).

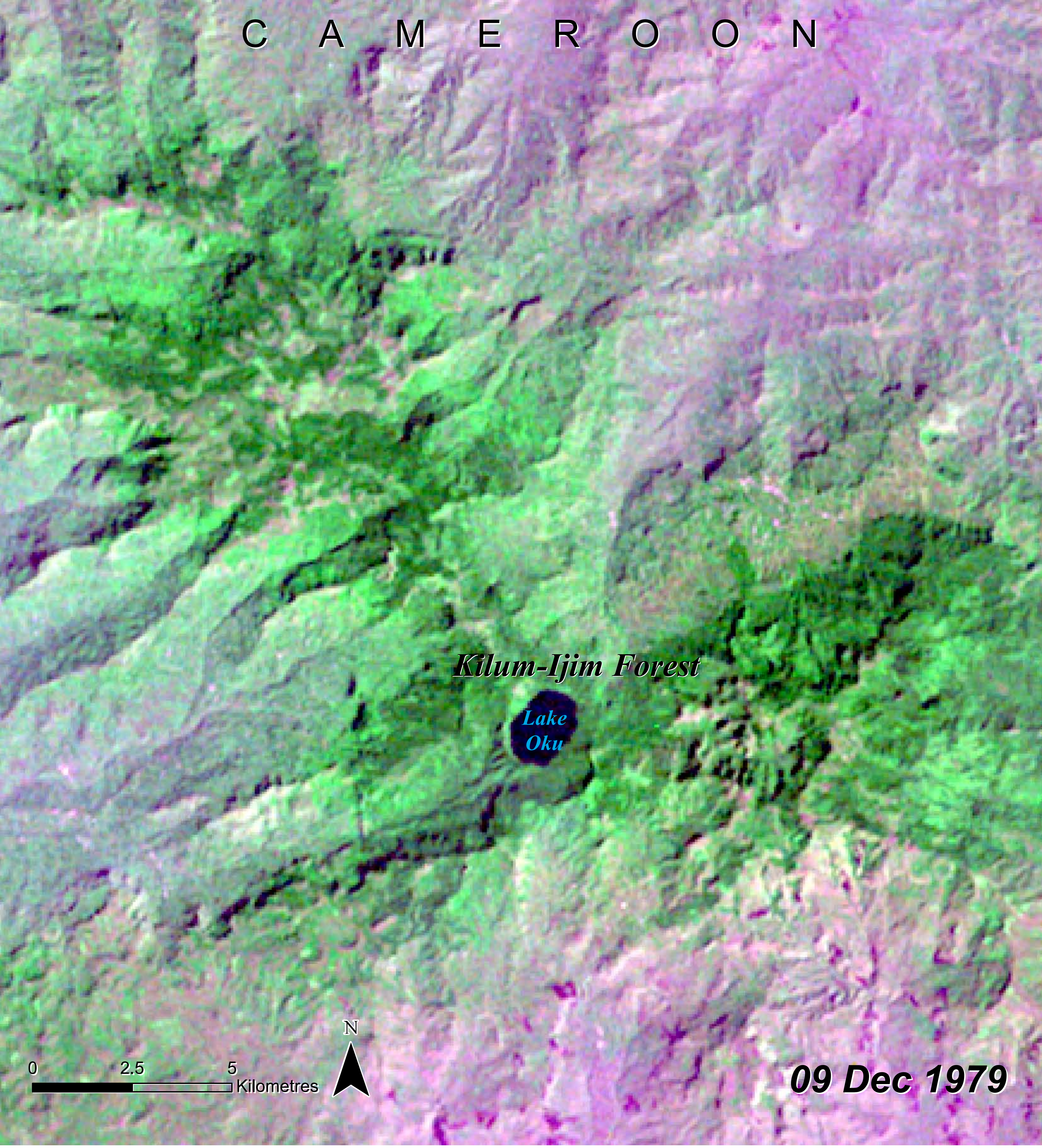
Box 4.10: Synergistic protection in the Mgahinga Gorilla National Park, Uganda

In areas where mountain ecosystems need to support both human and non-human populations, proper synergistic protection needs to be enforced. The establishment of the Mgahinga Gorilla National Park (MGNP) in the Virunga Mountains stopped locals from harvesting bamboo, a valuable food source for native fauna, but subsequently caused some unrest among local people who also depend on the bamboo. Thus, synergistic approaches to meet the needs of both local populations and fauna were needed for effective and equitable land management.

In the MGNP, bamboo can be found between 2 450 and 3 000 m. It occupies nearly 16 km^2 of land, some of which is mixed with trees. Before the MGNP was established in 1992, local residents cut bamboo for construction, basket-making and fuel. The MGNP's laws, however, protected the bamboo, since it is also an essential food source for threatened Mountain gorillas and African golden monkeys; local communities were prevented from entering the area to harvest the plants. Nevertheless, contrary to expectations, park officials noted that without the harvesting activities, bamboo production actually declined. It appears that if the stems are not removed, the bamboo is not stimulated into producing new sprouts. In response, in May and June of 2009, a small area (0.06 km^2) was opened to about 30 people to harvest one load of mature and dead bamboo four times a week. Over a year later, researchers investigated stem diameter, density and overall growth patterns. The results revealed that, overall, bamboo density was three to four times that of the surrounding forested areas and sprout density was also high. The study recommends that controlled harvest be continued with caution, avoiding the sprout season, and encourages rotational harvests allowing 4 to 5 years between harvesting periods in any given area.

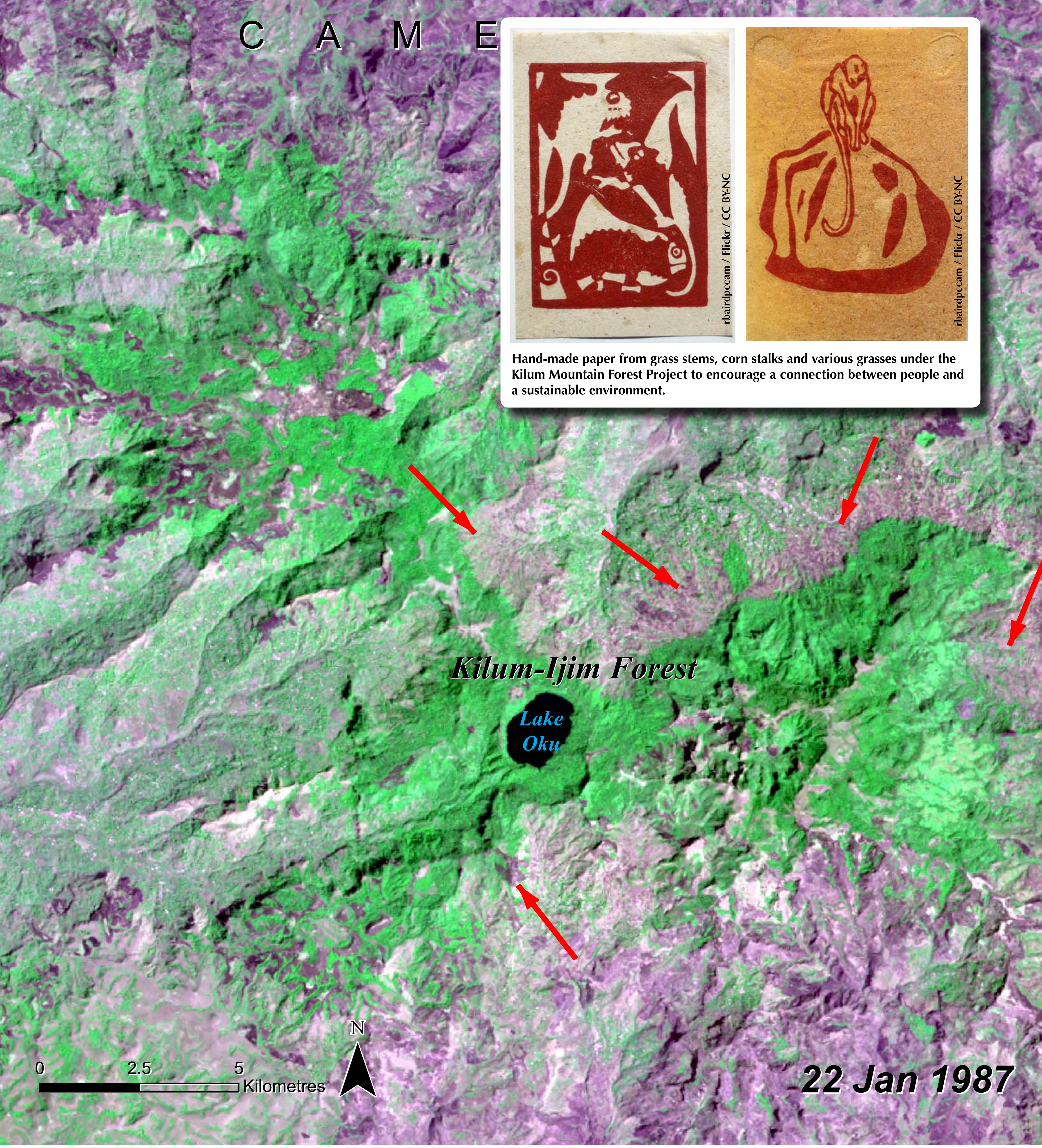
Source: Sheil, et al., 2012

Mountain gorilla in MGNP



Hotspot: Kilum-Ijim Forest, Cameroon

The Kilum-Ijim Forest is located in the Bamenda Highlands of northwestern Cameroon. The Oku villages call the northern part of the mountain where the forest is located Kilum Mountain and the Kom villages refer to the southern part as Ijim Mountain; geographers refer to the highest peak of the mountain area as Mount Oku, which has an elevation of 3 011 m (Ndenecho, 2011). The forest is an important resource for these village populations and essential habitat for the largest population of

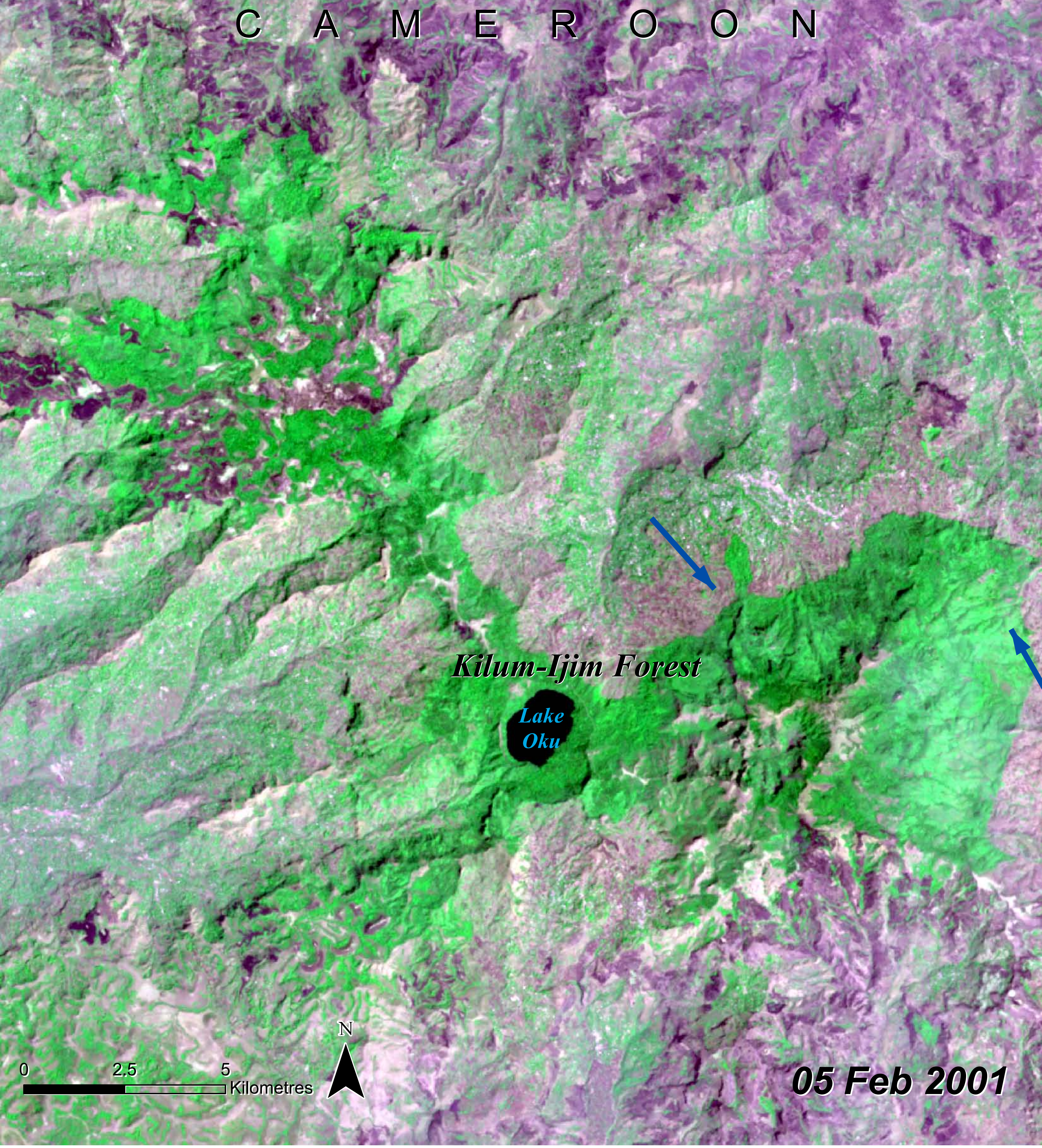


Hand-made paper from grass stems, corn stalks and various grasses under the Kilum Mountain Forest Project to encourage a connection between people and a sustainable environment.

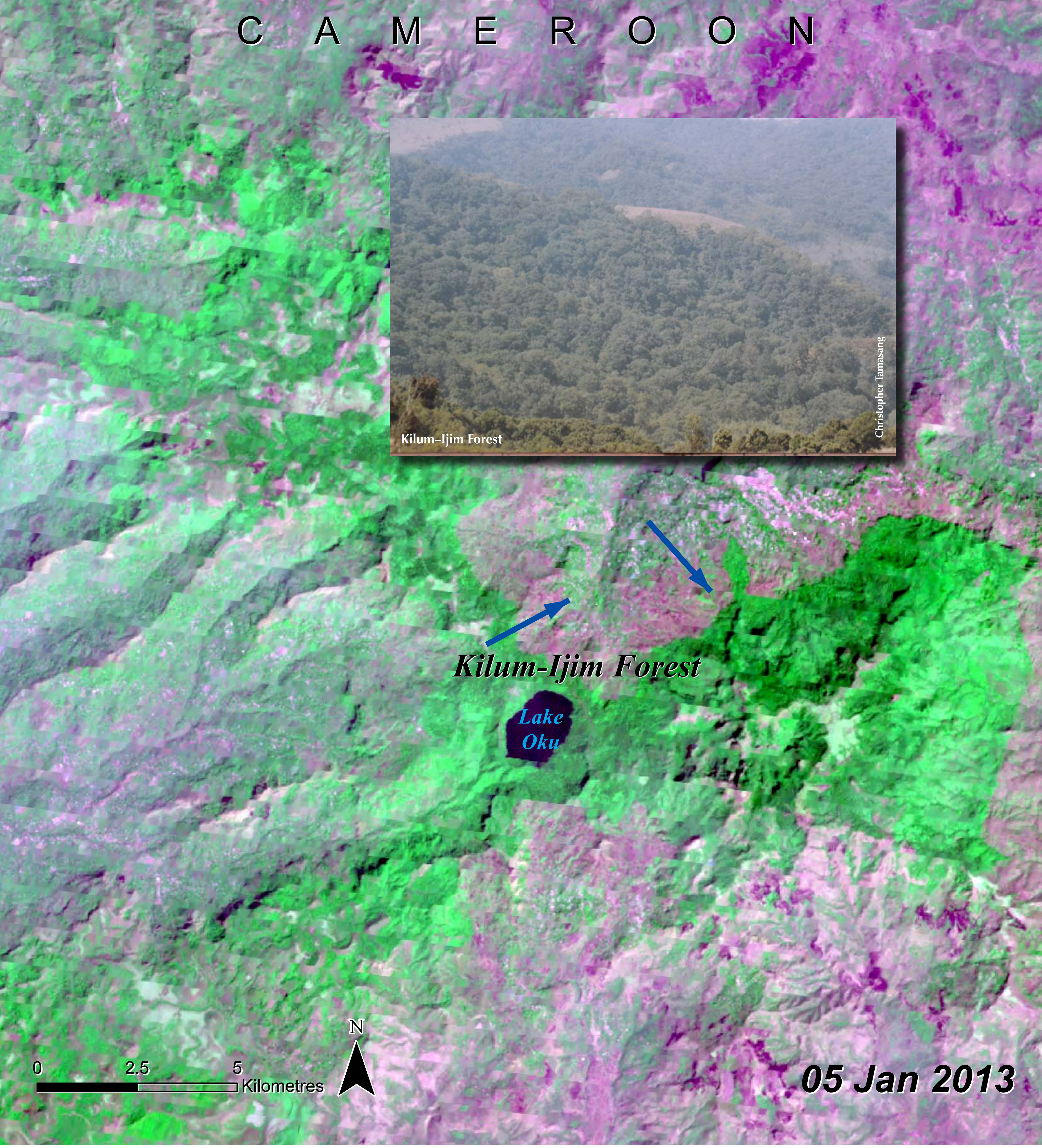
Red arrows denote forest loss; blue arrows denote forest gain

two globally threatened bird species: the Bannerman's Turaco (*Tauraco bannermani*) and the Banded Wattle-eye (*Platysteira laticincta*) (BLI, 2008). Land use change analysis conducted by Solefack, et al. (2012) found that forest cover on Mount Oku declined by 62.1 per cent between 1978 and 2001, with the majority of loss occurring between 1978 and 1988. In a similar study, the Kew GIS Unit (2003) found a 50 per cent decline in forest cover between 1958 and 1988.

Community forest management began in 1987 under a BirdLife International programme that aimed to establish



forest boundaries, support sustainable forest resource planning, improve agricultural practices and encourage alternative forms of income (BLI, 2008). After 1988, forests started to regenerate with the help of community forest management and other biodiversity programmes (BLI, 2008; Kew GIS Unit, 2003) and small fragments of secondary forest appeared after 2001 (Solefack, et al., 2012). Continuation of community-based planting projects has occurred with the planting of 10 000 *Prunus africana* trees in the Oku community forest between 1 July and 28 August 2013 to promote regeneration of the forest and apiculture practices (Ngalame, 2014).



Red arrows denote forest loss; blue arrows denote forest gain

There is still some deforestation, however, evident by the loss in the proportion of forest cover that was present before 1978 (Solefack, et al., 2012). Solefack et al. (2012) predict that the last fragments of primary cloud forest on Mount Oku will be lost within the next few decades. Nevertheless, in a study of Cameroon's forest zone, Zapfack et al. (2002) found high species richness in secondary forests, which may indicate the potential for high biodiversity to regenerate.

In the High Atlas Mountains, forested areas protected by traditional methods are called *Agdal* forests. *Agdal* is a Berber term that refers to a traditional land use management system in which a local institution oversees access rights and natural resource use in a particular region. The *agdal* concept can be applied to forest cover, water supply, marine resources and other natural goods and areas (Auclair, Baudot, Genin, Romagny, & Simenel, 2011). The traditional *Agdal* system is regulated by closing and opening dates, ensuring that a supply of resources is available if critical times were to arise, much like an emergency cellar stocked with canned goods in the event of a crisis situation (Hammi, et al., 2010). Once the *Agdal* is open to the community for use, people work together to share the resources equally amongst themselves. To avoid conflict within communities, a frontier is created to identify which group within the village manages the forest. Examples of resources shared within the Ait Bouguemez Valley in Morocco can range from leaf fodder for animal feed to timber for domestic use (Auclair, Baudot, Genin, Romagny, & Simenel, 2011; Box 4.11).

For a community-based approach to be successful, however, an appropriate legal framework needs to support such initiatives to ensure communities retain the rights to their traditional and customary lands while also conserving biodiveristy. In south-central Madagascar's Andringitra Mountain National Park (AMNP), which was established in 1993 by the Malagasy Environmental Action Plan, education and research is used as a mechanism to understand people's rights. Its aim is to encourage collaborative research by national and international scientists to create a geographical survey of the area to protect the environment and the traditional ways and preserve the legal

Box 4.11: *Agdal* forest management in the High Atlas Mountains, Morocco

The local people of the Ait Bouguemez manage their *Agdal* forest in an effective traditional way. The Ait Bouguemez Valley lies at an elevation of 2 000 m and stretches across 13 000 ha of the valley in Azilal province, Morocco. The upper part of the valley is home to 15 000 people inhabiting 30 villages. The area is fairly isolated and surrounded by high mountains; the vegetation in the region, dominated by forests and shrubs, is adapted to the elevation. Tree species range from red juniper at lower elevations to holm oak and prickly juniper at medium levels, followed by Spanish juniper at higher altitudes. The population speaks Berber and tends to be transhumant (see Chapter 2) and settled agro-pastoralist with a focus on agriculture and livestock herding and management, making natural resources essential to their livelihood.

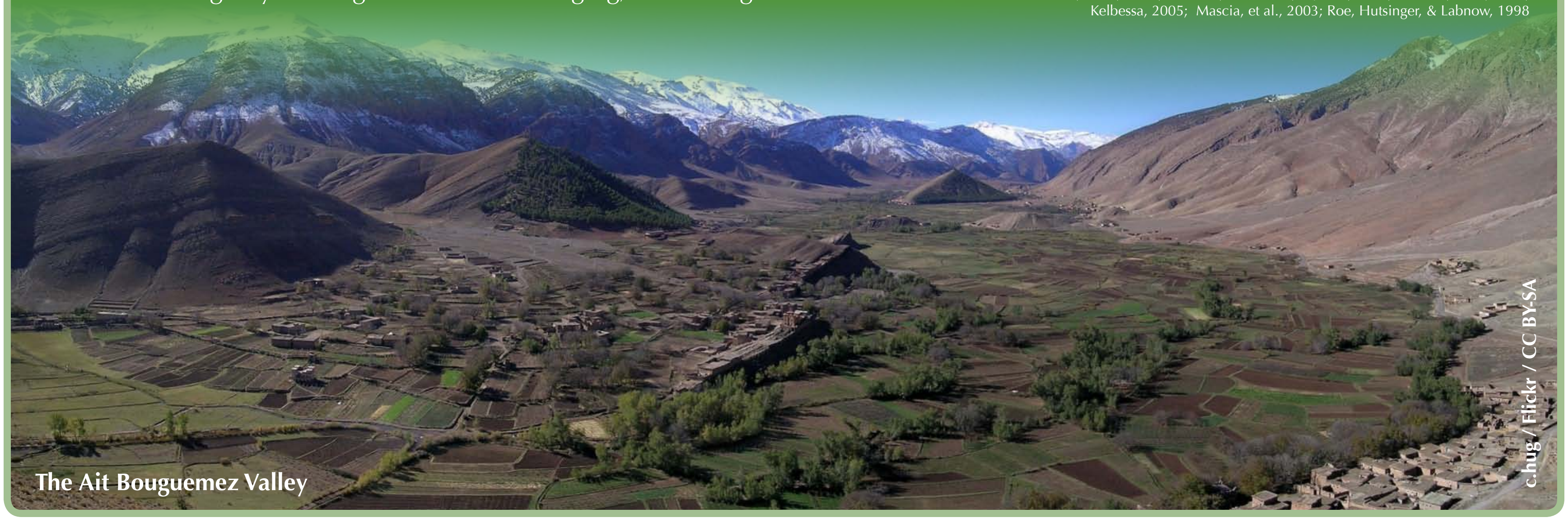
The *Agdal* forest system in the Ait Bouguemez Valley is used to maintain forest cover and biodiversity. It plays a large role in improving ecological resilience in the region, which can become vulnerable when natural resources are overused. The *Agdal* forest is also considered a cultural heritage space as the rights to the land are passed on from one generation to the next within the group that manages it. Thus, the local people have an intrinsic desire to preserve the resources before passing them on. This is a holistic approach to forest management that considers ecological and environmental factors while keeping in mind local people's social and cultural perspectives.

Community tree-cutting projects create financial security within the village by sharing the cost of managing, harvesting and distributing goods evenly, much like buying merchandise in bulk. Furthermore, the traditional method successfully addresses the ecological issue of deforestation in the *Agdal* region of Ait Bouguemez Valley and has proven to be an effective natural resource management mechanism.

The state of the forested mountain ecosystem under the *Agdal* in the Ait Bouguemez Valley has improved over time. A study between 1964 and 2002 that used remote sensing tools, mapping software and ground data compared a region close to the village managed by the *Agdal* system with an area of high forests outside the region. It noted some significant differences in the ecology and environment of both areas. Within the *Agdal* region, trees were much bigger and in better condition, showing an improvement in the forest cover. The area outside the *Agdal* region was noticeably exploited and degraded.

This type of management can be beneficial in the short-term since indigenous knowledge of environmental conditions and social science factors can provide decision-makers and managers with a specific type of information. The customary way to manage the Ait Bouguemez Valley forest may not be sustainable in the long-term, however, without collaboration with state-based management measures and technology. For the management system to remain effective during a disaster situation or conflict, traditional management techniques should be merged with more modern systems, integrating culture and heritage with scientific analysis methods and forest management models. This could be an effective way to incorporate modern knowledge with traditional social and cultural norms to create a harmonious and effective solution to natural resource management systems in mountain areas.

Sources: Compiled from Auclair, Baudot, Genin, Romagny, & Simenel, 2011; Becker & Ghimire, 2003; Bourbouze, 1999; Dalle, De Blois, Caballero, & Johns, 2006; Hammi, et al., 2010; Kelbessa, 2005; Mascia, et al., 2003; Roe, Hutsinger, & Labnow, 1998



The Ait Bouguemez Valley

rights of the local people within and outside of the AMNP's boundaires (Rabetaliana, Randriambolololona, & Schachenmann, 1999). Additionally, conservation practices need to be able to continue within the context of increasing climate variability and overall environmental change (Ruiz-Mallen & Corbera, 2013). Satellite images in the next few pages illustrate the importance of community and participatory approaches to mountain protection for both humans and biodiversity.

Threats to Protected Areas

Although legal frameworks or designations may offer some sort of protection to biodiversity and the environment, protected areas can still fall under threat, and thus compromise their effectiveness as protection mechanisms. Common threats include habitat destruction, poaching, encroachment and natural resource exploitation. However, increased visibility of these threats and their impacts may create opportunities to highlight the many values that natural ecosystems hold and the goods and services they are able to provide (Lopoukhine, et al., 2012).

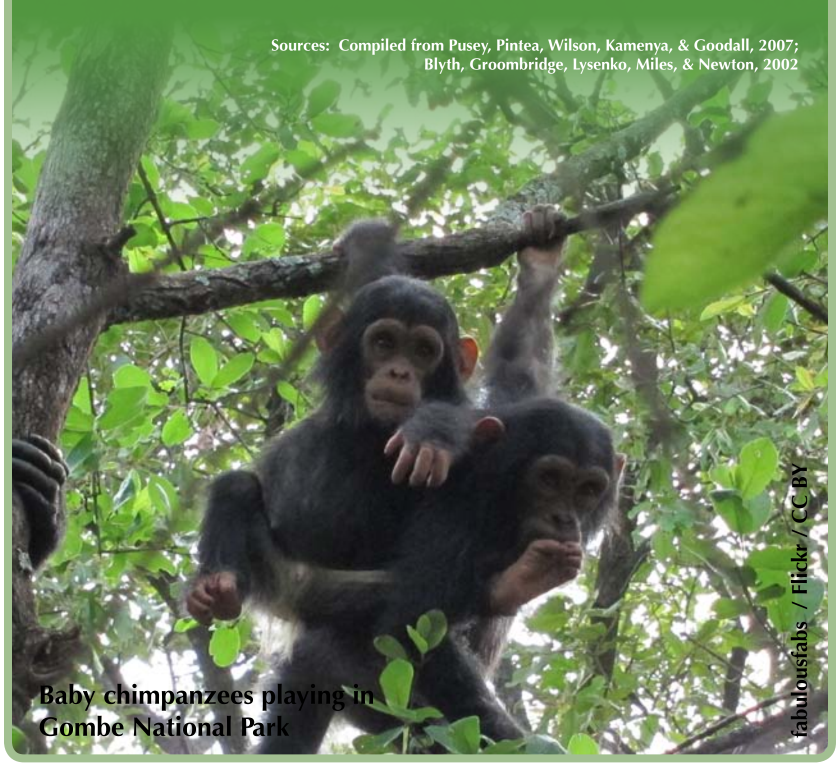
Habitat destruction is a pervasive threat affecting biodiversity in protected areas. For instance, the original habitat of the particularly species-rich and threatened sections of the Eastern Afromontane system, which runs along the eastern edge of Africa from Saudi Arabia in the north to Zimbabwe in the south, has been reduced from 1 017 806 km^2 to 106 870 km^2, leaving only 10 per cent remaining (CI, 2014). Such loss can leave isolated patches of habitat that restricts the movement of some species, contributing to their decline. In the mountains of Morocco and Algeria, small patches of forest serve as the last remaining home in Africa for the Barbary macaque (Macacasylvanus), the only macaque species found outside of Asia (van Lavieren & Wich, 2009). Forest habitat favoured by Chimpanzees in the Gombe National Park in the United Republic of Tanzania is also under threat of fragmentation (Box 4.12).

An additional consideration to make is for the lands adjacent to, or outside of, protected areas. In most countries, the areas with critical biodiversity assets usually occur within existing protected areas, although the reality is that a significant proportion of Africa's biodiversity is found outside these protected areas. In Kenya, for example, more than 70 per cent of the country's biodiversity occurs outside its protected areas system (NEMA, 2011). Another example regards the protection

Box 4.12: Fragmentation of chimpanzee habitat in Gombe National Park, United Republic of Tanzania

The Gombe National Park (GNP) is located on the mountainous shores of Lake Tanganyika in the Albertine Rift area of western United Republic of Tanzania. GNP is known for its chimpanzee population, but deforestation is causing significant habitat fragmentation. Chimpanzees need relatively large roaming spaces because they eat ripe fruit and always need some evergreen or riverine forest in their habitat range. Due to increased cultivation, expansion of human settlements and flash flooding, only small isolated patches of evergreen forests remain. Rapid population growth in the surrounding area and immigration of refugees from Burundi and the DRC has also driven deforestation.

Sources: Compiled from Pusey, Pintea, Wilson, Kamenya, & Goodall, 2007; Blyth, Groombridge, Lysenko, Miles, & Newton, 2002



Baby chimpanzees playing in Gombe National Park

fabulousfabs / Flickr / CC BY

Neighboring communities of Mount Elgon National Park in the Suam catchment are having conflicts with Park managers as they want to cultivate land inside the park boundaries

John Owino / IUCN

Box 4.13: Protecting Virunga National Park from oil exploitation

Virunga National Park (ViNP) in the DRC has been on the UNESCO List of World Heritage in Danger since 1994 due to conflict in neighbouring Rwanda that resulted in an influx of refugees settling in the park, poaching and clearing trees. The Park has remained on the list due to continued deforestation and a growing population in the fishing village near Lake Edward. As of early 2014, approximately 4 per cent of the park is settled or used for agriculture. Furthermore, recent interest in expanding oil extraction activities into the Park has made enforced management and protection of the land more urgent.

In December 2007, the DRC government granted oil concessions covering 85 per cent of the territory of ViNP. Already one company that was granted exploration rights has decided not to exercise the rights. However, another company plans to begin seismic exploration in mid-2014. UNESCO has urged the company not to explore for oil inside ViNP or any other World Heritage Site. Although it may seem economically advantageous for some parties to exploit oil in ViNP, it may not be the case. Preserving the ecosystems within ViNP and encouraging more stable management, may prove more beneficial than exploiting its resources.

According to a World Wildlife Fund (WWF) study on the economic and social impacts of oil exploitation, without oil exploitation and by taking advantage of non-extractive opportunities, the park could generate substantial revenues. It estimated Virunga's annual economic value at US$48.9 million under present circumstances. In a scenario in which the country is stable and economic growth and tourism are possible, ViNP's value could be higher than US$1.1 billion per year and there would be jobs for more than 45 000 people, including existing positions.

These potential revenues would derive directly from tourism, fisheries and hydropower; indirectly from ecosystem services including carbon sequestration, water supply and savings on erosion control; and non-use values, which refer to the value of knowing the ViNP resources can be used in the future. Thus, oil extraction may not be the most lucrative long-term use of the park's resources. Regardless, it is important that any and all development in the Virunga National Park is conducted in a way that sustains the ecosystem and its services for both present and future generations.

Sources: Compiled from UNESCO, 2014g; WWF, 2013; UNESCO, 2014k

Virunga Volcanoes in Uganda

floschen / Flickr / CC BY NC SA

of cheetahs. Several protected areas are home to cheetahs, including the mountainous Ahaggar National Park, but most reside outside protected areas where they are vulnerable to human-wildlife conflict, indicating the need for conservation action on a landscape scale (IUCN, 2013a).

Protected areas not only aim to manage and conserve biodiversity, but also to maintain the ecosystem services they provide (Lopoukhine, et al., 2012). However, some ecosystem services, such as natural resource provision, can be threated if they are overexploited. The case of iron ore mining was discussed in Chapter 3 and previously in this chapter, but another natural resource case is the prospect of oil reserves in Virunga National Park in the DRC (Box 4.13). The threat of overexploitation of natural resources can have negative implications on both the environment and on people living nearby or who rely on the protected areas for their livelihoods and cultural values.

Threats to transboundary protected areas

Transboundary ecosystems also face some of these same challenges. Unsustainable land use, usually associated with increasing population pressures, can lead to cross-border crimes such as poaching and international commercial exploitation of natural resources (Nakileza, Ferguson, & Bagoora, 2012). In a presentation made at the Planet Under Pressure conference in 2012, the authors make the following observations about the lessons learned in transboundary conservation initiatives in African mountains:

- In working with existing initiatives, transboundary conservation areas have succeeded in promoting awareness of the need to conserve biodiversity;
- Problems with soil and water conservation persist;
- Governments and local NGOs have initiated efforts towards water provision through regional development;
- Relative peace has been realised in Virunga, while in Mount Elgon stability is hard to attribute solely to transboundary conservation initiatives;
- Regional transboundary policy and implementation has been catalysed, for instance in the East African Community;
- Sustainable institutions and governance is needed in pursuing transboundary protection goals;
- Improving livelihoods needs to be given stronger emphasis (Nakileza, Ferguson, & Bagoora, 2012).

A number of challenges remain, however, given the difficult circumstances in transboundary situations:

- Conflicting conservation policies;
- Lack of protocols and non-compliance measures;
- Differing legal systems;
- Cultural and language differences;
- Unequal levels of professional standards and economic development.

Box 4.14: Coping with threats to the transboundary Rwenzori Mountains with integration of cultural values

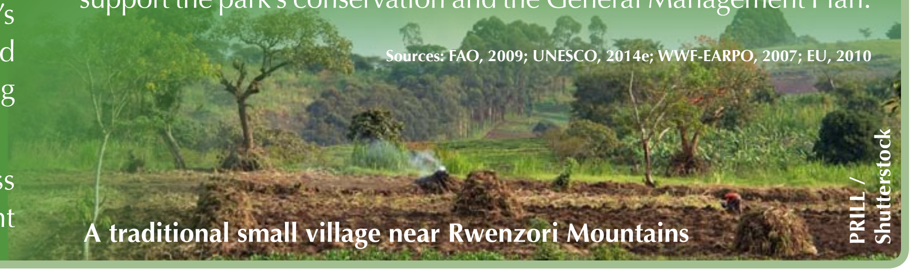
The Rwenzori Mountains National Park (RMNP) in Uganda, established in 1991, extends for over 990 km^2 in western Uganda and is contiguous with the northern section of Virunga National Park (ViNP) in the DRC. In 1994, the RMNP became a UNESCO World Heritage Site and in 2009, its high-altitude wetlands (224 km^2) were included on the Ramsar list of Wetlands of International Importance. The Uganda Wildlife Authority (UWA) manages the park.

The European Union Land Resource Management Unit's index of biodiversity and habitat value categorizes the shared protected mountain areas of the Rwenzori Mountains as being of high value and experiencing high pressure.

Threats to the ecosystem include illegal logging, snow loss due to global warming, human population pressure adjacent to the park and managing the waste generated by tourism. Transboundary initiatives between the DRC and the UWA are helping to address these threats, although they are hampered by the differences in languages spoken on either side of the border, policy and legal issues and problems in sharing monitoring and research information.

The innovative approach of the RMNP's Protected Area Management framework to integrating cultural values into resource management and fostering the embrace of management activities by local communities was the first of its kind in Africa and has become a model for others. Recognizing the rich biodiversity of the Albertine Rift region, numerous local and international NGOs support the park's conservation and the General Management Plan.

Sources: FAO, 2009; UNESCO, 2014e; WWF-EARPO, 2007; EU, 2010



A traditional small village near Rwenzori Mountains

PRILL / Shutterstock

The survey concludes by noting that there is still a lack of political will and sustainable provision of resources for these transboundary initiatives, and they stress that it is crucial that communities, governments and development partners continue to engage in constructive collaboration to protect the mountain resources shared among African countries (Nakileza, Ferguson, & Bagoora, 2012).

In response to such threats, cross-border collaboration provides opportunities for the countries that share responsibility for the protected area to work together to improve habitat protection for both wildlife and humans. As highlighted throughout this chapter, local communities often use natural resources within or adjacent to these protected areas for food and building and other craft materials, while populations outside them benefit from ecosystem services such as water supplies from the water catchment. Collaboration can improve regional governance structures, promote sustainable livelihoods through tourism, employment and business ventures and improve local capacities to adapt to environmental change (Nakileza, Ferguson, & Bagoora, 2012). Transboundary protected areas promote international cooperation, increase the efficiency in managing shared natural resources, foster more effective research, strengthen cross-border control of issues such as fire, pests, poaching, pollution and smuggling and help to reduce political tension and promote peace (Martin, Rutagarama, Cascão, Gray, & Chhotray, 2011).

With scattered laws and multiple institutions with responsibilities towards protected areas, insufficient funding, and outdated regulatory approaches that fail to link conservation ideals with the needs of neighbouring communities, effective ecosystem management to address threats can be a challenge. This exclusionary approach to conservation work was common in Africa in past decades, but the situation is changing. In South Africa, Kenya and Uganda, community-based approaches are becoming more common. For example, the Rwenzori Mountains National Park has aims to balance community and conservation issues using an innovative approach (Box 4.14). Its management method is now a model for integrating cultural values into the Protected Area Management framework for the Central Albertine Rift Region.

Conclusion

Since the launch of Agenda 21 of the United Nations Conference on Environment and Development and the inclusion of sustainable mountain development (Chapter 13), too few mountain-specific policy tools have been created to guide protection of mountain resources at both international and national levels. There is need to address the gaps in policies and laws that will protect the unique needs of mountain people and ecosystems. This should take a framework approach incorporating different development issues such as transport, culture, education, forestry, biodiversity and tourism, among others. Institutional and legal frameworks to administer the laws will also need to be put in place supported by appropriate policies and strategies. Policy and management matters are included in the challenges outlined in Chapter 5, which also looks at the opportunities for overcoming the many barriers to socio-economic development in Africa's mountain areas.

References

ACF. (2014). Cameroon Mountains Conservation Foundation (CAMCOF). Retrieved March 28, 2014, from African Conservation Foundation: http://www.africanconservation.org/explorer/item/cameroon-mountains-conservation-foundation-camcof

Adam, A. (2012). Recognising Sacred Natural Sites and Territories in Kenya: An analysis of how the Kenyan Constitution, national and international laws can support the recognition of sacred natural sites and their community governance system. Institute for Culture and Ecology (Kenya), African Biodiversity Network, and the Gaia Foundation.

AHI. (2006). African Highlands Initiative. Retrieved June 2, 2014 from African Highlands Initiative (AHI): http://www.worldagroforestry.org/programmes/african-highlands/index.html

Akasa, E., & Aisi, T. (n.d.). Kenya Forest Service. Retrieved April 2, 2014 from European Commission, UNEP to support Kenya's Mau Forest Restoration: http://www.kenyaforestservice.org/index.php?option=com_content&view=article&id=238:european-commission-unep-to-support-kenyas-mau-forest-restoration-&catid=223:hict&Itemid=98

ANH. (2009). Mount Nimba Strict Nature Reserve - Guinea and Cote d'Ivoire. Retrieved January 29, 2014, from African Natural Heritage (ANH): http://www.africannaturalheritage.org/Mount-Nimba-Strict-Nature-Reserve-Guinea-and-Cote-Divoire/

Asrat, A., Metasebia, D., & Aberra, M. (2012). Geoheritage Conservation in Ethiopia: The Case of the Simien Mountains. Quaestiones Geographicae, 31(1), 9-23.

Auclair, L., Baudot, P., Genin, D., Romagny, B., & Simenel, R. (2011). Patrimony for resilience: evidence from the forest Agdal in the Moroccan High Atlas Mountains. Ecology and Society, 16(4), 24. doi:http://dx.doi.org/10.5751/ES-04429-160424

AWF. (2010). Mountain Gorilla Census Reveals Increase in Population. Retrieved January 29, 2014, from African Wildlife Foundation: http://www.awf.org/news/mountain-gorilla-census-reveals-increase-population

AWF. (2013). Mau Reforestation: Planting trees in a critical forested ecosystem. Retrieved February 4, 2014, from African Wildlife Foundation: http://www.awf.org/projects/mau-reforestation

AWF. (n.d.). Virunga. Retrieved January 27, 2014, from African Wildlife Foundation: http://www.awf.org/landscape/virunga

Barr, J. & Mafuta, C. (2007). Chapter 6: Regional Perspectives. Global Environment Outlook 4 (GEO4). Nairobi: United Nations Environment Programme.

Becker, C., & Ghimire, K. (2003). Synergy between traditional ecological knowledge and conservation science supports forest preservation in Ecuador. Conservation Ecology, 8(1).

Berkes, F. (1999). Sacred Ecology: Traditional Ecological Knowledge and Resource Management. Philadelphia: Taylor & Francis.

BLI. (2008). Community management of forest on Mount Oku, Cameroon, has led to significant habitat regeneration. Retrieved February 12, 2014, from BirdLife State of the world's birds: http://www.birdlife.org/datazone/sowb/casestudy/253

BLI. (2014). Important Bird Areas factsheet: Parc National de l'Ahaggar. Retrieved February 5, 2014, from BirdLife International: http://www.birdlife.org/datazone/sitefactsheet.php?id=6184

Blom, A., & Bowie, R. (2001). Central Africa: Eastern Democratic Republic of the Congo. In D. M. Olson, The Global 200: The Most Outstanding and Representative Areas of Biodiversity. World Wildlife Fund.

Blyth, S., Groombridge, B., Lysenko, I., Miles, L., & Newton, A. (2002). Mountain Watch: map-based overview of environmental change in mountains. Nairobi: United Nations Environment Programme.

Bourbouze, A. (1999). Gestion de la mobilité et résistance des organisations pastorales des éleveurs du haut Atlas marocain face aux transformations du contexte pastoral maghrébin. In M. Niamir-Fuller (Ed.), Gestion de la mobilité et résistance des organisations pastorales des éleveurs du haut Atlas marocain face aux transformations du contexte pastoral maghrébin. (pp. 146-171). London: Immediate Technology Publications.

Bronkhorst, S. (2005). Part 2: Legal Analysis: The Virunga Volcanoes and the Bwindi Impenetrable National Park: Cooperation in the management of shared natural resources and the concept of Transboundary Protected Areas. In Prototype EnviroSecurity Assessments, Great Lakes region of Africa. The Hague, Netherlands: Institute for Environmental Security.

Carey, M. (2007). The History of Ice: How Glaciers Became an Endangered Species. Environmental History, 497 - 527.

CBD. (n.d.). Convention on Biological Diversity. Retrieved March 15, 2014, from Convention on Biodiversity (CBD): http://www.cbd.int/

CCPA. (2010). About the Treaty. Retrieved June 3, 2014, from Treaty Establishing the East African Community: http://www.eac.int/treaty/

CITES. (n.d.). Convention on International Trade in Endangered Species of Wild Fauna and Flora. Retrieved March 6, 2014, from Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES): http://www.cites.org/eng

CI. (2014). Hotspots Revisited. Retrieved March 5, 2014, from Conservation International (CI): http://www.conservation.org/where/priority_areas/hotspots/hotspots_revisited/Pages/hotspots_revisited.aspx

Colchester, M. (1994). Sustaining the forests: the community based approach in South and South-East Asia. Dev. Chang., 25, 69-100.

Coulson, D., & Campbell, A. (2013). Rock Art of the Tassili n'Ajjer, Algeria. Nairobi: Trust for African Rock Art (TARA).

Crawford, A. (2012). Conflict-Sensitive Conservation in Nyungwe National Park: Conflict analysis. Winnipeg, Manitoba, Canada: International Institute for Sustainable Development (IISD).

Cuny, P., Ango, A., & Ondoa, Z. (2007). Local and Decentralized Forest Management in Cameroon: The Case of the Kongo Community Forest. A Cut for the Poor: FAO Conference Proceedings Publications. Food and Agriculture Organization of the United Nations.

Dalle, S., De Blois, S., Caballero, J., & Johns, T. (2006). Integrating analyses of local land use regulations, cultural perceptions and land use/land cover for assessing the success of community-based conservation. Forest Ecology Management, 22, 370-383.

DEAT. (1996). South Africa: Implementation of Agenda 21: Review of progress made since the United Nations Conference on Environment and Development, 1992. Pretoria, South Africa Department of Environmental Affairs and Tourism (DEAT).

Debonnet, G., Melamari, L., & Bomhard, B. (2006). Mission Report: Reactive Monitoring Mission to Simien Mountains National Park Ethiopia 10 - 17 May 2006. Addis Ababa: World Heritage Centre; International Union for Conservation of Nature.

Durbin, J. (2007). Madagascar's new system of protected areas – Implementing the 'Durban Vision'. Bonn and Eschborn: Conservation and Development, GTZ.

Dunn, A. (1999). Gashaka-Gumti National Park: A guide book. Lagos: Gashaka-Gumti National Park, NCF/WWF-UK.

DWAF. (2012). Minister establishes nine Catchment Management Agencies. Johannesburg: Department of Water Affairs.

EAC. (1999). EAC Treaty – 1999. Arusha: East African Community (EAC).

EAC. (2005). Protocol on Environment and Natural Resources Management, Draft 5. Arusha: East African Community.

EAC Secretariat. (2012). Draft EAS Water Vision 2025. Arusha: East African Community.

EoE. (2008). Mount Nimba Strict Nature Reserve, Guinea and Côte d'Ivoire. Retrieved January 29, 2014, from The Encyclopedia of Earth: http://www.eoearth.org/view/article/154709/

EU. (2010). Protected Areas Report. Retrieved January 23, 2014, from EU Joint Research Centre, Land Resource Management Unit: http://bioval.jrc.ec.europa.eu/APAAT/

EWCA. (2012a). Bale Mountains National Park. Retrieved March 14, 2014, from Ethiopian Wildlife Conservation Authority (EWCA): http://www.ewca.gov.et/en/node/17

EWCA. (2012b). Simien Mountains National Park. Retrieved January 30, 2014, from Ethiopian Wildlife Conservation Authority (EWCA): http://www.ewca.gov.et/node/24

Ezemvelo KZN Wildlife. (n.d.). About Us. Retrieved January 30, 2014, from Ezemvelo KZN Wildlife: http://www.kznwildlife.com

FAO. (n.d.). FAOLEX. Retrieved March 5, 2014, from Food and Agricultural Legislation: http://faolex.fao.org/

FAO. (2002). Law and Sustainable Development since Rio – Legal Trends in Agriculture and Natural Resource Management. Retrieved June 3, 2014, from: http://www.fao.org/docrep/005/y3872e/y3872e00.htm#Contents

FAO. (2009). Sustainable Mountain Development in Uganda. Food and Agriculture Organization of the United Nations. Retrieved from Food and Agriculture Organization of the United Nations: http://www.fao.org/forestry/18493-041acb47f8039899992e92d7f049c69c0.pdf

FAO. (2014). International Mountain Day. Retrieved June 30, 2014 from, Food and Agriculture Organization of the United Nations (FAO): http://www.fao.org/forestry/internationalmountainday/78425/en/

FAO, MPS, UNCCD, SDC, & CDE. (2011). Highlands and Drylands – mountains, a source of resilience in arid regions. Rome: Food and Agriculture Organization of the United Nations (FAO), United Nations Convention to Combat Desertification (UNCCD), Mountain Partnership Secretariat, Swiss Agency for Development and Cooperation (SDC), Centre for Development and Environment (CDE).

FBD. (2006). Eastern Arc Mountains Strategy: Coding Forest Reserves as Protected Areas. Morogoro: Conservation and Management of the Eastern Arc Mountain Forests, Forestry and Beekeeping Division (FBD).

FFI-UWA. (2012). Current status, ownership and management of sacred sites in Rwenzori Mountains National Park. Kampala: Fauna & Flora International (FFA), Uganda Wildlife Authority (UWA).

FLR. (2011). Gishwati. Retrieved March 28, 2014, from Forest Landscape Restoration: http://www.forestlandscaperestoration.org/learning-site-gishwati

FZS. (2007). Bale Mountains National Park. General Management Plan 2007-2017. Addis Ababa: Frankfurt Zoological Society (FZS).

Geberemedhin, B., & Grubb, P. (2008). Capra walie. Retrieved March 20, 2014, from IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2.: www.icunredlist.org

GEF & UNDP. (2010). Eastern Arc Mountains Strategy, Biodiversity Conservation Thematic Strategy, Conservation and Management of the Eastern Arc Mountain Forests, Tanzania: GEF-UNDP-URT/01/00015426. Dar es Salaam: Ministry of Natural Resources and Tourism.

Genin, D., Herve, D., & Riviere, G. (1995). Relation societe environnement: la reproduction. Cah. Rech. Dev., 41, 20-30.

German, L., Mowo, J., Amede, T., & Masuki, K. (eds.) (2012). Integrated Natural Resource Management in the Highlands of Eastern Africa: From concept to practice. Oxon: Earthscan.

Ghabbour, S. (1997). Identification of Potential Natural Heritage Sites in Arab Countries: Report to the World Heritage Center UNESCO. Cairo: Department of Natural Resources, Institute of African Research and Studies, Cairo University.

GoK. (2009). Rehabilitation of the Mau Forest Ecosystem. Nairobi: Interim Coordinating Secretariat, Office of the Prime Minister, Government of Kenya.

Gray, M., Roy, J., Vigilant, L., Fawcett, K., Basabose, A., Cranfield, M., . . . Robbins, M. (2013). Genetic census reveals increased but uneven growth of a critically endangered mountain gorilla population. Biological Conservation, 158, 230 - 238.

Grueter, C. C., Robbins, M., Ndagijimana, F., & Stoinski, T. (2013). Possible tool use in a mountain gorilla. Behavioural Processes, 100, 160 - 162.

GVTC. (2006). Ten year transboundary Strategic Plan - Central Albertine Rift Transboundary Protected Area Network. Kigali, Rwanda: Greater Virunga Transboundary Collaboration, Transboundary Core Secretariat.

GVTC. (2012). About Us. Retrieved January 28, 2014, from Greater Virunga Transboundary Collaboration: http://www.greatervirunga.org/spip.php?rubrique1

Hammi, S., Simonneaux, V., Cordier, J., Genin, D., Alifriqui, M., Montes, N., & Auclair, L. (2010). Can traditional forest management buffer forest depletion? Dynamics of Moroccan High Atlas Mountain Forests using remote sensing and forest analysis. Forest Ecology and Management, 260, 1861 - 1872.

Hemp, A. (2005). Climate change-driven forest fires marginalize the impact of ice cap wasting on Kilimanjaro. Global Change Biology, 1013 - 1023.

Hurni, S. (1986). Management Plan: Simien Mountains National Park and surrounding rural area. Switzerland: UNESCO World Heritage Committee.

Imong, I., & Wood, K. L. (2008). Important Forest Corridor for Gorillas under Threat. Gorilla Journal, 36.

Ingram, V., Awono, A., Schure, J., & Ndam, N. (2009). Guidance for a National Prunus africana Management Plan Cameroon. Center for International Forestry Research.

IUCN. (2003). Wetlands of Ethiopia: Proceedings of a seminar on the resources and status of in Ethiopia's wetlands. In Y. Abebe, & K. Geheb (Ed.), IUCN Wetlands and Water Resources Programme Blue Series (p. 123). Gland: International Union for Conservation of Nature Wetlands and Water Resources Programme.

IUCN. (2006). IUCN Evaluation of Nominations of Natural and Mixed Properties to the World Heritage List. Convention Concerning the Protection of the World Cultural and Natural Heritage. Gland: The World Conservation Union (IUCN).

IUCN. (2008). Guidelines for Applying Protected Area Management Guidelines. (N. Dudley, Ed.) Gland, Switzerland: International Union for Conservation of Nature and Natural Resources (IUCN).

IUCN. (2012). Kihansi Spray Toad returns to the wild. Retrieved March 10, 2014, from The IUCN Red List of Threatened Species.

IUCN. (2013a). Acinonyx jubatus, 2013.2. Retrieved February 5, 2014, from IUCN Red List of Threatened Species: http://www.iucnredlist.org/details/219/0

IUCN. (2013b). Lesotho and South Africa's Transboundary World Heritage wonder: Maloti-Drakensberg Park. Retrieved January 23, 2014, from IUCN, World Commission on Protected Areas: https://www.iucn.org/fr/propos/union/commissions/wcpa/?13460/Lesotho-and-South-Africas-Transboundary-World-Heritage-wonder-Maloti-Drakensberg-Park

IUCN. (2013c). The IUCN Red List of Threatened Species. Version 2013.2. Retrieved March 5, 2014, from International Union for Conservation of Nature and Natural Resources: http://www.iucnredlist.org

IUCN. (2014). Natural World Heritage sites are globally recognized as the world's most important protected areas. Retrieved February 12, 2014, from International Union for Conservation of Nature: https://www.iucn.org/about/work/programmes/wcpa_worldheritage/

IUCN/UNEP. (1987). lUCN Directory of Afrotropical Protected Areas. Gland: International Union for the Conservation of Nature/United Nations Environment Programme (UNEP).

IUCN & UNEP-WCMC (2013). The World Database on Protected Areas (WDPA) [On-line]. Cambridge, UK. Retrieved March 21, 2014 from UNEP- WCMC: www.protectedplanet.net

Kanyamibwa, S. (2013). Albertine Rift Conservation Status Report. Albertine Rift Conservation Series No 1. Kampala: ARCOS Network.

Kasangaki, A., & Bitariho, R. (2013). A Review of Benefit Sharing and Community Conservation Approaches in the Albertine Rift Region. In S. Kanyamibwa, Albertine Rift Conservation Status Report (Vol. Albertine Rift Conservation Series No 1.). Kampala and UK: ARCOS Network.

Kelbessa, M. (2005). The rehabilitation of indigenous environmental ethics in Africa. Diogenes, 52, 17-34.

Kenya Forest Service. (2012). Mt. Kenya Forest Reserve Management Plan 2010-2019. Nairobi: Kenya Forest Service (KFS).

Kew GIS Unit. (2003). GIS Unit - Mount Oku and Ijim Ridge (Cameroon): Monitoring vegetation cover changes in Mount Oku and the Ijim Ridge (Cameroon), using satellite and aerial sensor detection. Retrieved December 31, 2013, from Kew Botanical Gardens: http://www.kew.org/science-research-data/kew-in-depth/gis/vegetation-mapping/mount-oku-and-ijim-ridge/

LATF. (2013). Welcome: Fighting Wildlife Crime in Africa. Retrieved January 27, 2014, from Lusaka Agreement Task Force: http://lusakaagreement.org

LCA. (2012). Leadership for Conservation in Africa. Retrieved March 5, 2014, from http://www.lcafrica.org

Lopoukhine, N., Crawhall, N., Dudley, N., Figgis, P., Karibuhoye, C., Laffoley, D., Londono, J.M., MacKinnon, K., & Sandwith, T. (2012). Protected areas: providing natural solutions to 21st century challenges. S.A.P.I.E.N.S., 5(2), online.

Martin, A., Rutagarama, E., Cascão, A., Gray, M., & Chhotray, V. (2011). Understanding the co-existence of conflict and cooperation: Transboundary ecosystem management in the Virunga Massif. Journal of Peace Research, 48(5), 621-635.

Mascia, M., Brosius, J., Dobson, T., Forbes, B., Horowitz, L., & McKean, M. (2003). Conservation and the social sciences. Conservation Biology, 17, 649-650.

Mason, B. (2003). African ice under wraps: Secrets locked in Kilimanjaro's ice cap need urgent protection. Nature. doi:10.1038/news031117-8

MDTP. (2012). Maloti Drakensberg Transfrontier Park (uKhahlamba Drakensberg Park World Heritage Site/Sehlabathebe National Park): Joint Management Programme. Johannesburg/Maseru: Maloti Drakensberg Transfrontier Programme (MDTP).

MEMR. (2012). Master Plan for the Conservation and Sustainable Management of Water Catchment Areas in Kenya. Nairobi: Ministry of Environment and Mineral Resources.

Milner-Gulland, E. J., & Mace, R. (2009). Conservation of Biological Resources. John Wiley & Sons.

Mthandi, J. (n.d.). Managing the Biodiversity of Mulanje Mountain through promotion of clay stoves - A German financed SADC Regional Biomass Energy Project. Mulanje Renewable Energy Agency.

Mwandha, S. (n.d.). Presentation: The Greater Virunga Transboundary Collaboration. GVTC Secretariat.

Nake, S. (2011). Berg Wind Effect and Dust Plumes of the 17th June 2010. South African Weather Service: Aviation Weather. 2(7), 1 - 4.

NFA, 2012. Forest Management Plan for North Rwenzori Central Forest Reserve. Uganda: National Forestry Authority (NFA).

Nakileza, B., Ferguson, W., & Bagoora, F. (2012). Transboundary Conservation in African Mountains: Challenges and opportunites for addressing global change. Presentation at Planet Under Pressure [PUP] Conference, 26-29 March. London, UK.

NASA. (2013). Aïr and Téneré Natural Reserves. Retrieved December 6, 2013, from NASA Earth Observatory: http://earthobservatory.nasa.gov/IOTD/view.php?id=82487&src=eoa-iotd

NASA. (2014). Dust Plumes, Namib Desert. Retrieved July 9, 2014 from, NASA Earth Observatory: http://earthobservatory.nasa.gov/IOTD/view.php?id=83971&src=eoa-iotd

Ndenecho, E.N. (2011). Ethnobotanic Resources of Tropical Montane Forests: Indigenous Uses of Plants in the Cameroon Highland Ecoregion.

NEMA. (2011). State of the Environment and Outlook 2010. Supporting the Delivery of Vision 2030. Nairobi: National Environment Management Authority (NEMA).

NEPAD. (2003). New Partnership for Africa's Development: Action Plan for the Environment Initiative. Midrand: New Partnership for Africa's Development.

NEPAD. (2012). History. Retrieved June 4, 2014, from The New Partnership for Africa's Development (NEPAD): http://www.nepad.org/history

Ngalame, E. (2014). Organisation Embarks on Tree Planting. Retrieved March 7, 2014, from Eden Newspaper: http://edennewspaper.net/2014/02/13/organisation-embarks-on-tree-planting/

NISR. (2012). 2012 Population and Housing Census: Report on the Provisional Results. Kigali: Republic of Rwanda National Institute of Statistics of Rwanda.

Njoroge, E., & Muli, G. (2011). Economic and Social Significance of forests for Rwanda's sustainable development. Nature & Faune (25)2, 10-13.

NPS. (2012). Gashaka Gumti National Park. Retrieved February 4, 2014, from Nigeria Park Service: http://ggnp.nigeriaparkservice.org/

Nyondo, W. A. (2003). Tropical Secondary Forest Management in Africa: Reality and perspectives. Malawi Country Paper. Rome: Food and Agriculture.

Plumptre, A., Kujirakwinja, D., & Nampindo, S. (2008). Conservation of Landscapes in the Albertine Rift. In K. H. Redford, & C. Grippo, Protected Areas, Governance and Scale: Working Paper No. 36 (27-34). Bronx, New York, USA: Wildlife Conservation Society.

Pusey, A., Pintea, L., Wilson, M., Kamenya, S., & Goodall, J. (2007). The Contribution of Long-Term Research at Gombe National Park to Chimpanzee Conservation. Conservation Biology , 21 (3), 623-634.

Rabetaliana, H., Randriambololona, M., & Schachenmann, P. (1999). The Andringitra National Park in Madagascar. Unasylva, 50, 31-34.

Ramsar. (2001). Summary Description Algeria 1DZ010. Retrieved April 17, 2014, from Ramsar: http://sites.wetlands.org/reports/dbdirectory.cfm?CFID=fc4e0db3-4236-4927-b14d-11c48e2df26d&CFTOKEN=0&site_id=20

Ramsar. (2009a). Rwenzori Mountains site added to the Ramsar List. Retrieved February 12, 2014, from The Ramsar Convention on Wetlands: http://www.ramsar.org/cda/en/ramsar-news-archives-2009-rwenzori-mountains-site/main/ramsar/1-26-45-84%5E22907_4000_0__

Ramsar. (2009b). What is the Ramsar Convention on Wetlands? Retrieved February 12, 2014, from The Ramsar Convention on Wetlands: http://www.ramsar.org/cda/en/ramsar-about-faqs-what-is-ramsar/main/ramsar/1-36-37%5E7718_4000_0__

RDB. (2013). About Nyungwe Forest. Retrieved March 20, 2014, from Rwanda Development Board: http://www.rwandatourism.com/index.php/destinations-and-activities/nyungwe-national-park

Robbins, M., & Williamson, L. (2013). Gorilla beringei, 2013.2. Retrieved February 4, 2014, from IUCN Red List of Threatened Species: http://www.iucnredlist.org/details/39994/0

Rocliffe, S. (2010). Protecting East Africa's marine and coastal biodiversity. Marine conservation agreements in the Western Indian Ocean. York: The University of York.

Roe, E., Hutsinger, L., & Labnow, K. (1998). High reliability pastoralism. Journal of Arid Environments, 39, 39-55.

RRF. (2012). Mount Nimba Strict Nature Reserve, Cote d'Ivoire. Retrieved January 29, 2014, from Rapid Response Facility: http://www.rapid-response.org/?p=1294

Ruiz-Mallen, I., & Corbera, E. (2013). Community-Based Conservation and Traditional Ecological Knowledge: Implications for Social-Ecological Resilience. Ecology and Society, 18(4). doi:10.5751/ES-05867-180412

Sandwith, T., Shine, C., Hamilton, L., & Sheppard, D. (2001). Transboundary Protected Areas for Peace and Cooperation. Gland, Switzerland and Cambridge, UK: IUCN.

Sengalama, T. (2013). Evolution and development of Transboundary Collaboration in the Greater Virunga Landscape: Lessons and Future Prospects. In S. Kanyamibwa, AIbertine Rift Conservation Status Report (pp. 82-86). Kampala and UK: ARCOS Network.

Sheil, D., Ducey, M., Ssali, S., Ngubwagye, J., van Heist, M., & Ezuma, P. (2012). Bamboo for people, Mountain gorillas, and golden monkeys: Evaluating harvest and conservation trade-offs and synergies in the Virunga Volcanoes. Forest Ecology and Management, 267, 163 - 171.

SMNP, & EWCA. (2013). Unique Wildlife on the Roof of Africa. Retrieved February 3, 2014, from Simien Mountains National Park and Ethiopian Wildlife Conservation Authority: http://www.simienmountains.org/the-park/history

Solefack, M. C., Chabrerie, O., Gallet-Moron, E., Nkongmeneck, B.-A., Leumbe, O. N., & Decocq, G. (2012). Analysing deforestation by remote sensing coupled with structural equation models: example of the cloud forest of mount Oku (Cameroon). Acta Botanica Gallica: Botany Letters, 159(4), 451 - 466.

Tafon, R. (2013). The Actor-Interface Case of Development Intervention in the Conservation of Mount Cameroon National Park, Buea, Cameroon. Huddinge: School of Natural Sciences, Technology and Environmental Studies, Södertörn University.

Tagowa, W., & Buba, U. (2013). Emergent strategies for sustainable rural tourism development of Gashaka-Gumti National Park, Nigeria. In M. Schmitz (Ed.), Tourism and Natural Protected Areas (pp. 115-130). Southhampton: WIT Press/Computational Mechanics.

TCS. (2006). Ten Year Transboundary Strategic Plan: Central Albertine Rift Transboundary Protected Area Network. Transboundary Core Secretariat.

UN. (2012). Report of the United Nations Conference on Sustainable Development. New York: United Nations (UN).

UNDP & GEF. (2006). Project Document: Federal Democratic Republic of Ethiopia United Nations Development Program Global Environment Facility, Full Project: Sustainable Development of the Protected Area System of Ethiopia (SDPASE). United Nations Development Programme, Global Environment Facility.

UNDP. (2003). Conservation and sustainable use of globally significant biodiversity in the Tassili and Ahaggar National Parks. Retrieved March 15, 2014, from http://www.undp.org/content/dam/undp/documents/projects/DZA/00033348/prodoc_tassili.pdf

UNDP. (2010). Évaluation Finale du Projet: Préservation et utilisation durable de la diversité biologique d'intérêt mondial dans les Parcs nationaux de l'Ahaggar et du Tassili (Phase 1). Algeria: United Nations Development Programme.

UNECA. (2004). Africa Water Vision 2025. Addis Ababa: United Nations Economic Commission for Africa.

UNEP. (2001). Transboundary collaboration for ecosystem conservation: the mountain forests of Gashaka-Gumti National Park, Nigeria and Tchabal Mbabo, Cameroon. Retrieved January 23, 2014, from Sustainable Societies in Africa: Modules on Education for Sustainable Development: http://www.unep.org/training/programmes/Instructor%20Version/Part_2/Activities/Ecosystems/Mountains/Strategies/Transboundary_collaboration_for_ecosystem_conservation.pdf

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

UNEP. (2009). Kenya: Atlas of Our Changing Environment. Nairobi: United Nations Environment Programme.

UNEP. (2011). 20 Years of Sustainable Mountain Development in Africa: Executive summary & key recommendations. Lucerne World Mountain Conference, 11-12 October. Lucerne, Switzerland: United Nations Environment Programme, Rio+20.

UNEP. (2014). Transboundary Protected Areas. Retrieved from United Nations Environment Programme, World Conservation Monitoring Centre: http://www.unep-wcmc.org/transboundary-protected-areas_469.html

UNEP, KWS, KFWG, & ENSDA. (2008). Mau Complex Under Siege: Values and Threats. United Nations Environment Programme; Kenya Wildlife Service; Kenya Forests Working Group; EWASO NGIRO South Development Authority.

UNEP-WCMC. (1998). Protected Areas and World Heritage. Retrieved March 14, 2014, from United Nations Environment Programme-World Conservation Monitoring Centre: http://web.archive.org/web/20070212211303/http://www.unep-wcmc.org/sites/wh/mt_kenya.html

UNEP-WCMC. (2011). Cape Floral Region Protected Areas: Western Cape & Eastern Cape Provinces South Africa. Cape Town: United Nations Environment Programme World Conservation Monitoring Centre.

UNESCO. (2002). Report on the 25th Session of the World Heritage Committee, 2001. Paris: United Nations Educational, Scientific and Cultural Organization.

UNESCO. (2010). State of Conservation (SOC): Simien National Park (2010). Retrieved February 4, 2014, from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/soc/448

UNESCO. (2014a). Aïr and Téneré Natural Reserves. Retrieved January 30, 2014, from United Nations Educational, Scientific and Cultural Organization World Heritage List: http://whc.unesco.org/en/list/573

UNESCO. (2014b). Maloti-Drakensberg Park. Retrieved January 23, 2014, from United Nations Educational, Scientific and Cultural Organization World Heritage Convention: http://whc.unesco.org/en/list/985

UNESCO. (2014c). Mount Kenya National Park/Natural Forest. Retrieved March 25, 2014, from United Nations Educational, Scientific and Cultural Organization Wolrd Heritage List: http://whc.unesco.org/en/list/800

UNESCO. (2014d). Mount Nimba Strict Nature Reserve. Retrieved February 3, 2014, from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/list/155http://bioval.jrc.ec.europa.eu/APAAT/pa/29067/

UNESCO. (2014e). Rwenzori Mountains National Park. Retrieved January 28, 2014, from United Nations Educational, Scientific and Cultural Organization World Heritage Convention: http://whc.unesco.org/en/list/684

UNESCO. (2014f). Simien National Park. Retrieved February 5, 2014, from United Nations Educational, Scientific and Cultural Organization World Heritage List: http://whc.unesco.org/en/list/9

UNESCO. (2014g). State of Conservation: Virunga National Park. Retrieved May 22, 2014, from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/soc/2941

UNESCO. (2014h). Success Stories. Retrieved February 12, 2014, from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/107/

UNESCO. (2014i). The Criteria for Selection. Retrieved February 12, 2014, from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/criteria/

UNESCO. (2014j). The World Heritage Convention. Retrieved February 12, 2014, from United Nations Educational, Scientific and Cultural Organization World Heritage Convention: http://whc.unesco.org/en/convention/

UNESCO. (2014k). Virunga National Park. Retrieved May 22, 2014, from United Nations Educational, Scientific and Cultural Organization World Heritage List: http://whc.unesco.org/en/list/63

UNESCO. (2014l). World Heritage List. Retrieved March 1, 2014, from United Nations Educational, Scientific and Cultural Organization World Heritage List: http://whc.unesco.org/en/list/

UNGA. (1998). Resolution Adopted by the General Assembly: 53/24 International Year of Mountains 19 November 1998. United Nations General Assembly (UNGA).

UNSD. (1992). United Nations Conference on Environment and Development: Agenda 21. Rio de Janerio: United Nations Sustainable Development.

Uprety, L. (2008). Role of institutions and organizations for the sustainable management of forest and pasture as common property resources in Nepal: an overview of the indigenous and traditional practices. Dhaulagiri Journal of Sociology, 2, 31-64.

USAID. (2014). Contested Claims Over Protected Area Resources in Rwanda. Kigali: United States Agency for International Development (USAID) Rwanda.

UWA, ICCN & ORTPN. (2006). Trilateral Memorandum of Understanding. Goma: Uganda Wildlife Authority (UWA), Institute Congolais Pour La Conservation De La Nature (ICCN), Office Rwandais De Tourism et des Parcs Nationaux (ORTPN).

van Lavieren, E., & Wich, S. (2009). Decline of the Endangered Barbary macaque Macaca sylvanus in the cedar forest of the Middle Atlas Mountains, Morocco. Oryx, 44(1), 133 - 138.

Venema, B. (2002). The vitality of local political institutions in the Middle Atlas, Morocco. Ethnology, 41, 103-117.

Wacher, T., De Smet, K., Belbachir, F., Belbachir-Bazi, A., Fellous, A., Belghoul, M., & Marker, L. (2005). Sahelo - Saharan Interest Group Wildlife Surveys, Part 4: Ahaggar Mountains, Algeria. Sahelo - Saharan Interest Group.

WCS. (2009). Ten Year Transboundary Strategic Plan (2009-2018): Nyungwe – Kibira Landscape. Bronx, New York: Wildlife Conservation Society.

WCS. (2012). Nigeria Program Conservation Strategy 2012 - 2016. Nigeria: Wildlife Conservation Strategy.

Were, K., Dick, O., & Singh, B. (2013). Remotely sensing the spatial and temporal land cover changes in Eastern Mau forest reserve and Lake Nakuru drainage basin, Kenya. Applied Geography, 41, 75 - 86.

Wisborg, P., & Jumbe, C. B. (2010). Mulanje Mountain Biodiversity Conservation Project. Midterm review for the Norwegian Government. Norwegian University of Life Sciences, Department of International Environment and Development Studies, Noragric. Aas: Norwegian Agency for Development Cooperation (NORAD).

Wondie, M., Schneider, W., Melesse, A., & Teketay, D. (2011). Spatial and temporal land cover changes in the Simien Mountains National Park, a World Heritage Site in Northwestern Ethiopia. Remote Sensing, 3, 752-766.

World Bank. (2011). Population density (people per sq. km of land area). Retrieved March 20, 2014, from The World Bank Data: http://data.worldbank.org/indicator/EN.POP.DNST?order=wbapi_data_value_2011+wbapi_data_value&sort=desc

WWF. (2013). Draw the Line: The Economic Value of Virunga National Park. Dalberg Global Development Advisors. World Wildlife Fund.

WWF. (2014a). Habitats: Mountains. Retrieved June 4, 2014, from World Wildlife Fund: http://www.worldwildlife.org/habitats/mountains

WWF. (2014b). Mountain Gorilla. Retrieved February 4, 2014, from World Wildlife Fund: http://worldwildlife.org/species/mountain-gorilla

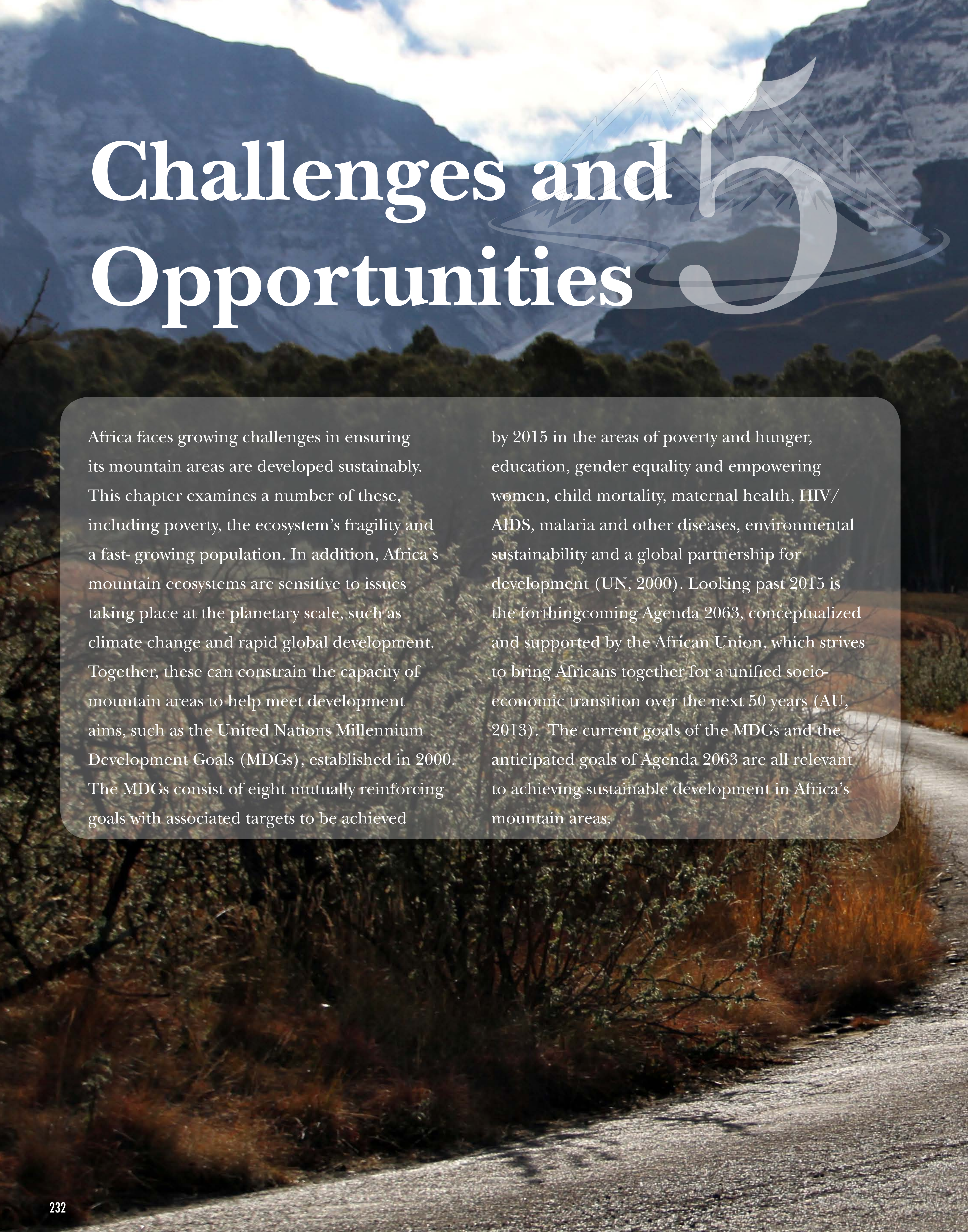
WWF-EARPO. (2007). Proceedings of the regional workshop on the conservation of eastern Africa mountain ecosystems as water towers, 2-5 August 2005. Nairobi: World Wildlife Fund Eastern Africa Regional Programme Office.

Yihune, M., Bekele, A., & Tefera, Z. (2008a). Human-Ethiopian Wolf Conflict in and Around the Simien Mountains National Park, Ethiopia. International Journal of Ecology and Environmental Sciences, 34(2), 149-155.

Yihune, M., Bekele, A., & Tefera, Z. (2008b). Human-Gelada baboon conflict in and around the Simien Mountains National Park, Ethiopia. African Journal of Ecology, 47, 276 - 282.

Zapfack, L., Engwald, S., Sonke, B., Achoundong, G., & Madong, B. A. (2002). The impact of land conversion on plant biodiversity in the forest zone of Cameroon. Biodiversity and Conservation, 11, 2047 - 2061.

Zunckel, K., Mokuku, C., & Stewart, G. (2011). Type of TBPA: A cluster of protected areas and the intervening land. Maseru and Pietermaritz.burg: Maloti Drakensberg Transfrontier Project: South Africa and Lesotho. Retrieved March 13, 2014, from http://www.tbpa.net/page.php?ndx=64



Challenges and Opportunities

5

Africa faces growing challenges in ensuring its mountain areas are developed sustainably. This chapter examines a number of these, including poverty, the ecosystem's fragility and a fast- growing population. In addition, Africa's mountain ecosystems are sensitive to issues taking place at the planetary scale, such as climate change and rapid global development. Together, these can constrain the capacity of mountain areas to help meet development aims, such as the United Nations Millennium Development Goals (MDGs), established in 2000. The MDGs consist of eight mutually reinforcing goals with associated targets to be achieved by 2015 in the areas of poverty and hunger, education, gender equality and empowering women, child mortality, maternal health, HIV/AIDS, malaria and other diseases, environmental sustainability and a global partnership for development (UN, 2000). Looking past 2015 is the forthingcoming Agenda 2063, conceptualized and supported by the African Union, which strives to bring Africans together for a unified socio-economic transition over the next 50 years (AU, 2013). The current goals of the MDGs and the anticipated goals of Agenda 2063 are all relevant to achieving sustainable development in Africa's mountain areas.

A road running through the Drakensberg National Park, South Africa

Barry Tuck / Shutterstock

Chapter Highlights

- ▲ A significant proportion of Africa's mountain people are vulnerable to food insecurity. Population pressures, as well as conflicts in some mountain areas, have led to low per capita arable land availability that constrains agricultural productivity.
- ▲ There is a need for more financing mechanisms to help preserve mountain resources that support human livelihoods.
- ▲ Changes in climate, such as increased temperature and rainfall patterns, are affecting Africa's mountain ecosystems. These changes have already caused, and can lead to further, water stress, pressures on energy generation and food insecurity. National and regional climate adaptation plans are needed to cope with these future changes.
- ▲ Legal frameworks at the national, sub-regional and regional levels need to be developed to guide future mountain development to sustain human livelihoods and protect Africa's mountainous ecosystems, flora and fauna.

Amid these challenges, however, are clear opportunities for African nations individually, regionally and with international cooperation to improve human and environmental conditions in their highland regions. This chapter discusses the following actions that can be taken towards these ends in mountain regions:

- Recognize and address poverty;
- Ensure food security;
- Increase investment, financing and infrastructure
- Provide access to energy security through hydropower;
- Improve water and land use management;
- Empower women and girls; and
- Build capacity for adaption to climate change.

Eragrostis tef **field native to the northern Ethiopian highlands**

Dereje / Shutterstock

Recognize and Address Poverty

The Challenge
Poverty can lead to overexploitation of resources that mountain communities depend upon for livelihoods.

The Situation
Poverty is a major concern in mountain areas, as seen against lowland areas, and the environment can suffer as a result.

The Constraints
Remoteness, natural disasters, erosion and population growth are contributing factors to poverty in mountain areas.

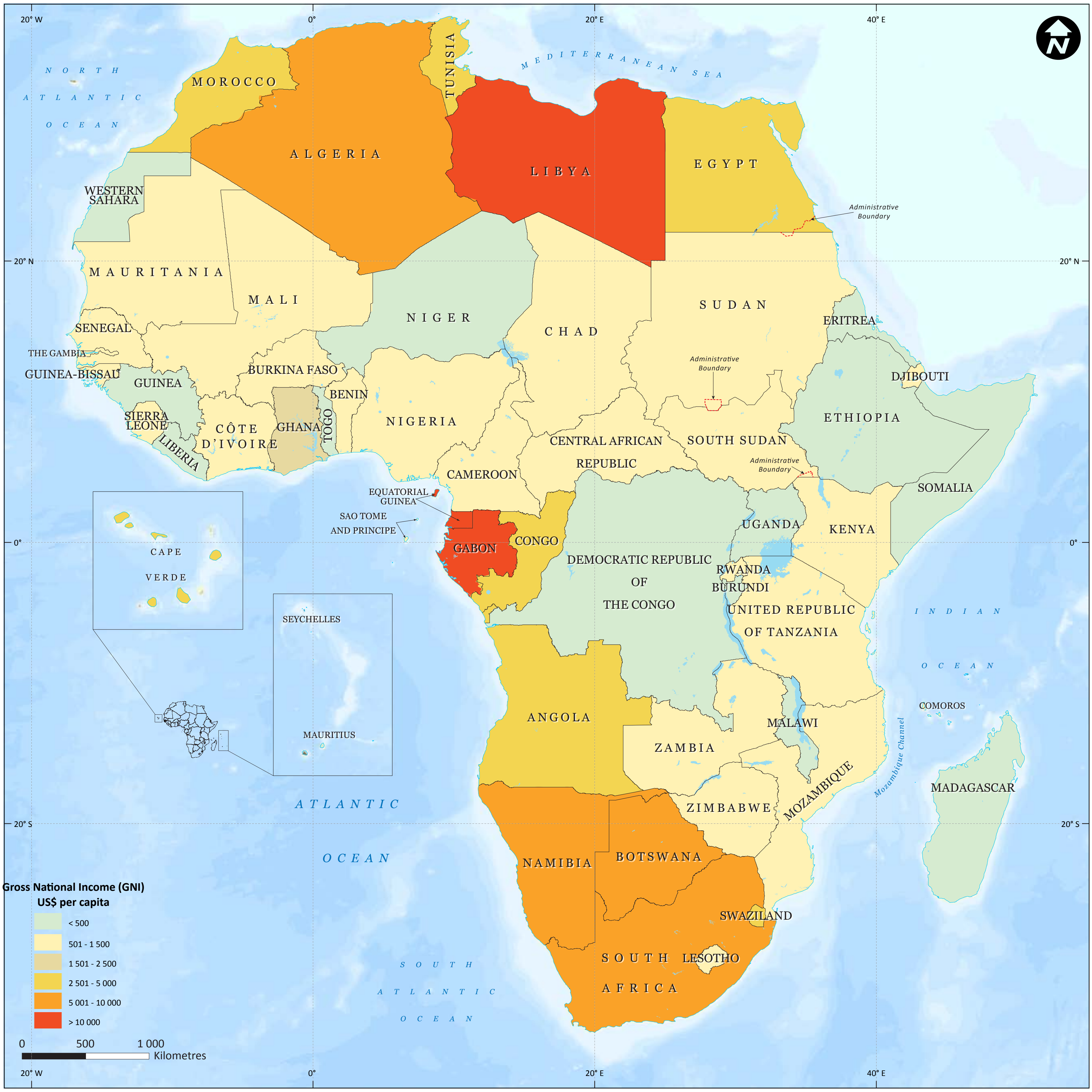
The Opportunities
The multidimensional nature of poverty can be addressed by equitable distribution of mountain resources, supporting the use and integration of indigenous and local knowledge into existing policies and technologies and supporting investments that contribute to a green economy.

The Challenge

As shown in Chapter 2 and reiterated throughout the Atlas, African mountains are important for the functions they serve in providing water, energy and biological diversity; for their key ecosystem resources, such as minerals and forest products; and for the opportunities they provide for industrial development such as tourism and agriculture. Despite these assets, there is widespread poverty among mountain inhabitants in Africa, which is a cause for concern. Faced with a combination of inadequate livelihoods, economic resources and growing populations, poor people are often forced to overexploit the natural resources in their environment.

A young girl plays outside of her parents house in Epwoth, Harare, Zimbabwe

Figure 5.1: Gross National Income (GNI) per capita, (US$)



Source: Compiled from World Bank, 2014; UNEP/DEWA
Note: Data source of all countries is GNI from 2012 with the exception of Djibouti (2005) and Libya (2009)

The Situation

Poverty is prevalent in some of Africa's mountain areas. Overall, the average Gross National Income (GNI) of African countries is rather low (Figure 5.1) and the poverty situation is amplified in some of Africa's mountain areas. There are many reasons that can explain the prevalence of poverty amongst mountain communities. For one, mountainous areas tend to be remote, contributing to the marginalization of people, and they are environmentally fragile since the soils and steep slopes are highly susceptible to erosion (IFAD, 2010). For example, in Lesotho, wage labour opportunities cannot keep up with the number of people that need them to surpass poverty levels. Only 10 per cent of the country is considered arable, resulting in very small plots of land for farmers to cultivate. Approximately 30 per cent of the country's population is considered extremely poor and has less than 0.5 ha of land to farm (IFAD, 2008). Current data show that poverty is increasing and Lesotho is unlikely to meet the MDG to reduce poverty by half by 2015 (KOL, 2013).

The Constraints

Remoteness is a key factor explaining the geographical spread of poverty. It limits access to markets, increases the price of inputs and makes economic and social services such as reproductive health care, less accessible. Limited access to family planning services means that family sizes remain large with heavy demands on already poor people. Poor infrastructure, weak state and market institutions and political isolation combine to create a higher-risk environment for poor rural people (IFAD, 2010). According to estimates by the International Fund for Agricultural Development (IFAD), households in the United Republic of Tanzania within 100 m of a gravel road and a bus service year-round, earned about one-third more per capita than the "rural average" (IFAD, 2010).

> …40 per cent *of the adult population now uses M-PESA…which offers* savings*…benefits are felt especially in remote areas…*

Although roads are still very important, more recent data highlight the benefits that Information and Communication Technologies (ICT), especially mobile phones, are bringing to remote rural areas. In Kenya, for instance, 40 per cent of the adult population now uses M-PESA (a mobile money service), which offers savings and money transfer options and has reduced transaction costs (IFAD, 2010). The benefits are felt especially in remote areas where much of the population has no access to banking services.


A M-PESA agent in Bunda District, Kenya

Torrential rains, cultivation on steep hillsides, overexploitation of forest resources and forest fires all create conditions for erosion and soil loss. This exposure makes highland landscapes even more prone to landslides and floods. Such was the case in the Mulanje Mountains in Malawi during the 1990-91 rainy season and more recently in 2012, when heavy rains led to landslides in the Mount Elgon region in Uganda (See Chapter 3). These catastrophic events have crippling impacts on households and communities as well as on sub-national and national economies. They include reduced mobility due to destroyed public and private infrastructure, limited access to food and water, loss of agricultural crops and/or livestock, increase in diseases and the temporary or permanent displacement of people.

Demographic factors such as population growth combined with extreme poverty limit people's choices and push them into even more marginal areas, compelling them to overuse the fragile resource base. As already noted and emphasized further on, poverty in rural areas frequently leads to overuse of environmental resources; this exacerbates the fragility of the natural resource base making the situation even worse for already poor households (IFAD, 2010), especially in degraded hilly areas. Over-utilization makes the land less productive, affecting household consumption and hence overall poverty and well-being. The environmental outcomes include depleting forest reserves, loss of fertile topsoil, land fragmentation, reduced recharge of groundwater aquifers and possible desertification. For example, population growth and large family sizes in the Bududa district on the slopes of Mount Elgon in eastern Uganda has led to land fragmentation. The average land holding per household has been reduced to about 0.2 ha, with serious impacts on agricultural production, food security and social welfare (NEMA, 2008).

> *Large* family *sizes…have led to land fragmentation,* reducing *the average land holding per* household *to about 0.2 ha…*

While soils in Bududa are highly productive, increased pressure from the population combined with low access to land is already leading to increased encroachment on the Mount Elgon forests, soil loss and reduced volume of water flow in the Manafwa River, with impacts on people's livelihoods (NEMA, 2008). Research has shown that in some mountain areas, such as Kilimanjaro in the United Republic of Tanzania, the smaller the land holding the more intensively it was farmed, which could eventually lead to degradation (Sarris, Savastano, & Christiaensen, 2006).

Migration to mountain areas exacerbates the already fragile areas. Mountains are generally constrained by surrounding steep land, so people—especially those who are poor and have arrived relatively recently—are often forced to settle on steep slopes and marginal land on the periphery, where the risks of floods and landslides are greatest. For example, the High Plateau in the Ethiopian Highlands is the country's most densely populated area, with more than 70 per cent of the total population (FAO, 2011c). So many people live in this area because of the attractive environmental assets, such as fertile soils, fresh water and other natural resources, a cooler climate and the absence of diseases such as malaria, among others (FAO, 2011c). Inhabitants of lowland and mountain settlements depend largely on environmental goods and services such as wood and water from the surrounding highlands. Resulting clearing of forests on steep slopes to meet these resource needs could increase the possibility of floods and landslides. Environmental pollution from mountain towns and cities is also a growing concern. Some mountain areas do not have facilities to treat wastewater or to manage solid waste. In the Atlas Mountains, for example, only about two per cent of solid waste in rural areas is collected and neither the mountains nor the hinterland have any wastewater treatment plants (UOF, 2002).

Alternatively, out-migration from mountainous areas to lowland areas can weaken infrastructure in those communities due to an influx in population. Sometimes the elderly, women and the disabled are those typically left behind, as has been the case in some of Kenya's mountain areas (Njiro, 1998) and currently occurs in other parts of Africa such as the Atlas Mountains (UOF, 2002). In Morocco, it is estimated that annually about 1.2 per cent of the rural population moves to the cities where 56 per cent of the country's population now resides (UOF, 2002).

The Opportunities

Poverty is a multidimensional phenomenon and therefore requires a multidimensional solution. This is the premise behind the Millennium Development Goals (MDGs) and a number of other multilateral agreements that have been signed onto by many African countries. Implementing the MDGs has required a sound understanding of the process of impoverishment, especially in areas such as mountains that are easily left out of the development agenda.

Future strategies to address poverty in its different dimensions in mountain areas need to focus on fostering the sustainable use of local natural resources, strengthening the economy of small-scale farmers in light of existing market conditions, improving environmental management and ensuring that the multiple services provided by mountain ecosystems can continue to enhance food security and human well-being. Multidimensional opportunities have already been recognized in Lesotho (Box 5.1). Realization of these strategies in other mountainous regions of Africa may require the translation of national and international-level documents, such as the poverty reduction strategies and MDGs, respectively, to local conditions and needs. Strategies to encourage small-scale agriculture, such as the Kenya Agriculture Sector Development Strategy 2010-2020 and the Doha Development Agenda that allows differential treatment for developing countries, are examples to consider (von Dach, Ott, Klaey, & Stillhardt, 2006; ROK, 2010). Furthermore, developing economic activities that do not depend soley on agriculture is another option (Box 5.2).

Box 5.1: Opportunities for reducing rural poverty in Lesotho

The International Fund for Agricultural Development (IFAD) operations in Lesotho focus on three opportunities for reducing rural poverty:

(1) Diversifying and intensifying agriculture

(2) Rehabilitating and reclaiming degraded lands

(3) Developing rural financial services to support improved agricultural production and create income generating activities

Source: IFAD, 2008

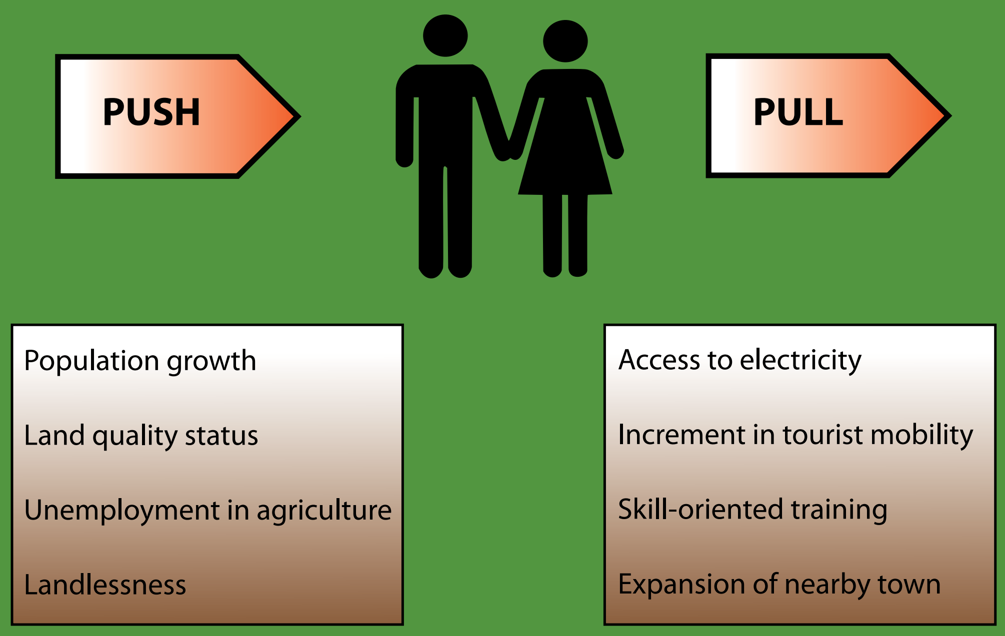
Basotho women in a small village in Lesotho

Michel van den Burg / Flickr / CC BY-NC-SA

Farming in West Usambara Mountains, United Republic of Tanzania

meadhva / Flickr / CC BY-ND

Box 5.2: Alternative livelihood strategies: Tourism a way out of poverty?



In the Simien Mountains of Ethiopia, located in North Gondar of the Amhara National Regional State (ANRS), the majority of the population depends on agriculture. The Mezega watershed, located along the road to Simien National Park (SNP) and partly inside of SNP boundaries, is confronted with several constraints like land degradation and shortage, poor market access and extreme weather conditions (hail storms and frost problems). There has also been a reduction in annual rainfall and a change in the seasonal rainfall distribution, which is affecting the productivity of agriculture. Farmers´ response to these changes, by gradually increasing the production of the faba bean crop in high altitudes, is a manifestation of climate variability. Off-farm activities, such as those in the tourism sector, also contribute to the household income.

Although the economically active population is high, rural unemployment in agriculture is increasing because of decline in land quality and inability to access land. Technology provision to scale- up traditionally practiced non-farm activities is very low and unaffordable for many people. Rural households and experts working in the Mezega water shed were asked to identify and prioritize important drivers for creation of alternative income sources in order to reduce the dependency on agriculture. The responses are categorized as push and pull factors (see diagram above).

Drivers explained as pull factors include access to power (electricity), increment in tourist mobility and skill-oriented trainings. Thus, the vulnerability of people is exacerbated by the dearth of alternatives (e.g. other than subsistence farming), employment opportunities and sources of income, even though there is a huge potential to exploit the tourism sector.

There have been some efforts to establish and strengthen community- based ecotourism associations and partnerships with the private tourism sector from governmental and non-governmental organizations, however not yet inclusive and significantly beneficial for the rural community. To accomplish this kind of collaboration, development of infrastructure, strengthening of community-based ecotourism associations and skill-oriented trainings is required to create favourable conditions for optimizing natural resource endowments.

Sources: Compiled from Hailu, Teshome, Desta, & Wuletaw, 2001; original material from CDR-Centre for Development Research, BOKU-University of Natural Resources and Life Sciences, Vienna, Austria

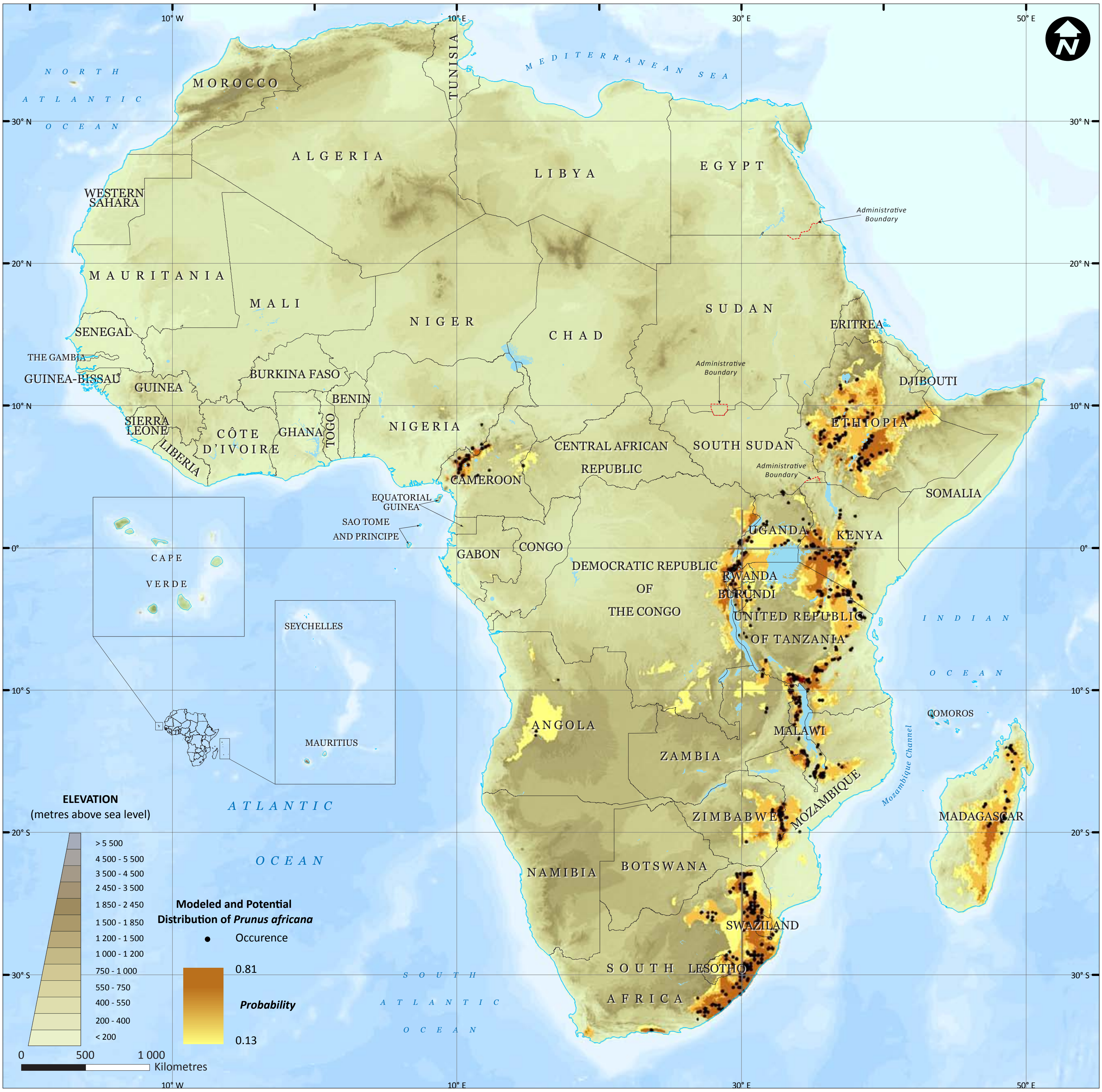
Focus group discussion of rural households in the study area

Farmers ***[on] Mount Cameroon…*** **obtain** ***almost 70 per cent of their annual cash income from*** **harvesting** ***Prunus africana***

Develop policies for the equitable distribution of benefits from mountain resources, and ensure that a percentage of revenue accruing from mountain areas be retained locally for sustainable mountain development and conservation. An example is the regulation of the commercial *Prunus africana* industry in the Mount Cameroon area. The bark of *Prunus africana* is used as a treatment for prostate cancer by both traditional healers and pharmaceutical companies (Tamasang, 2007). The Government of Cameroon has put in place a policy framework consistent with the 1994 Forestry legislation and the 1999/2000 Finance Law that gave communities the right to exploit and commercialize *Prunus*, a valuable medicinal plant. This has translated into benefits at household and community levels for the growers in the Mount Cameroon area, including increased revenues from higher payments per ton collected, training in sustainable management techniques, improved management of the tree species and a reduction in illegal and unsustainable harvesting of *Prunus* bark in most areas. Ndam (2004) estimated that farmers around the Mount Cameroon area obtain almost 70 per cent of their annual cash income from harvesting *Prunus africana*. More recent estimates indicate *Prunus* exports earn the country annual revenues of more than US$2.7 million (Ingram, Awono, Schure, & Ndam, 2009). Figure 5.2 shows that this species is widespread in Africa.

Prunus africana **with stripped bark**

Figure 5.2: Observations of *Prunus africana* and modelled probability of distribution



Source: Adapted from Vinceti et al., 2013; UNEP/DEWA

Integrate indigenous and local knowledge into policies and management practices. Local people have experience in prediction and early warning; knowledge of time-tested coping mechanisms, food production and storage techniques, and soil-improvement technologies; and an impressive plant-based pharmacopoeia for both human and animal health. Indigenous and local knowledge can foster poverty alleviation through sustainable, traditional food production and preservation and traditional medicine practices for health care. For instance, the Matengo people who live on the steep slopes of the Matengo Highlands in the United Republic of Tanzania developed a sophisticated system that enabled them to grow crops on hillsides while at the same time controlling soil erosion and improving soil moisture and fertility (Kato, 2001). Another example is the use of Tughutu, a local shrub, by communities in the Usambara Mountains in the United Republic of Tanzania as an organic fertilizer to increase soil fertility and crop productivity (Wickama & Mwihomeke, 2006).

Implementing the green economy approach may offer new opportunities for investment, especially since mountains are an important source of vital ecosystem services and natural resources on which national, regional and global environments and economies largely depend.

Green economy refers to promoting a low-carbon economy in the framework of sustainable development. UNEP defines a green economy as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities (ten Brink, Mazza, Badura, Kettunen, & Withana, 2012). Mountainous developing

Man picking tea leaves in Kibale, Uganda

Ryan M. Bolton / Shutterstock

countries already have low-carbon economies, but they also have an extremely high incidence of poverty. The challenge in mountain regions is to ensure these economies do not increase their carbon footprint while promoting economic development (ICIMOD, 2011). The 2011 Kathmandu Declaration on Green Economy and Sustainable Mountain Development reinforces the idea that the Green Economy is a tool or a means towards sustainable development (ICIMOD, 2011). Poverty alleviation and resource conservation are two central issues of the green economy. Furthermore, efficient use of resources, such as water and energy, should be a cornerstone of green economy policies. Resource-use efficiency could be incorporated by developing incentive mechanisms such as payments for ecosystem goods (see the section on PES in Chapter 2) to encourage the use of, and build capacity for, efficient practices to lessen the pressure on mountain resources and increase incomes in mountain communities (von Dach, Ott, Klaey, & Stillhardt, 2006).

Green economy *refers to* promoting *a low-carbon economy in the* framework *of sustainable development.*

One of the ways in which the green economy is emerging in mountain areas is through promoting, processing and marketing high-quality products that grow well in these environments and that are in demand on the global market. For example, coffee and tea grown in the cool highlands are increasingly important in improving the livelihoods of many mountain communities (see Chapter 2). As the demand for goods and services from mountains grows steadily, new opportunities for investment are emerging that broaden the scope for economic development (Rasul, 2011). Some other niche products grown in Africa's mountains include specialty coffee, honey and macadamia nuts in Kenya's highlands and specialty coffee in Ethiopia (CABI, 2005).

Ensure Food Security

The Challenge

Agricultural productivity and food production in Africa's mountains is constrained in various ways that affect food security.

The Situation

A significant proportion of Africa's mountain people are vulnerable to food insecurity. Low per capita arable land availability negatively affects agricultural productivity and food production.

The Constraints

Arable land is limited in mountain areas due to population pressure and is leading to land fragmentation and small farm sizes. Land tenure is a major factor contributing to food insecurity in Africa. Conflict across the continent, and in certain mountain areas in particular, constrains food production and can lead to food insecurity.

The Opportunities

Investment in agriculture could support growth in the sector, improve land management and promote food security. More focus is needed on rural areas where the majority of the population lives. Investments in agricultural research and development, including climate-smart agriculture, are required to increase agricultural productivity. There are also opportunities to improve land tenure, which will enhance food security.

The Challenge

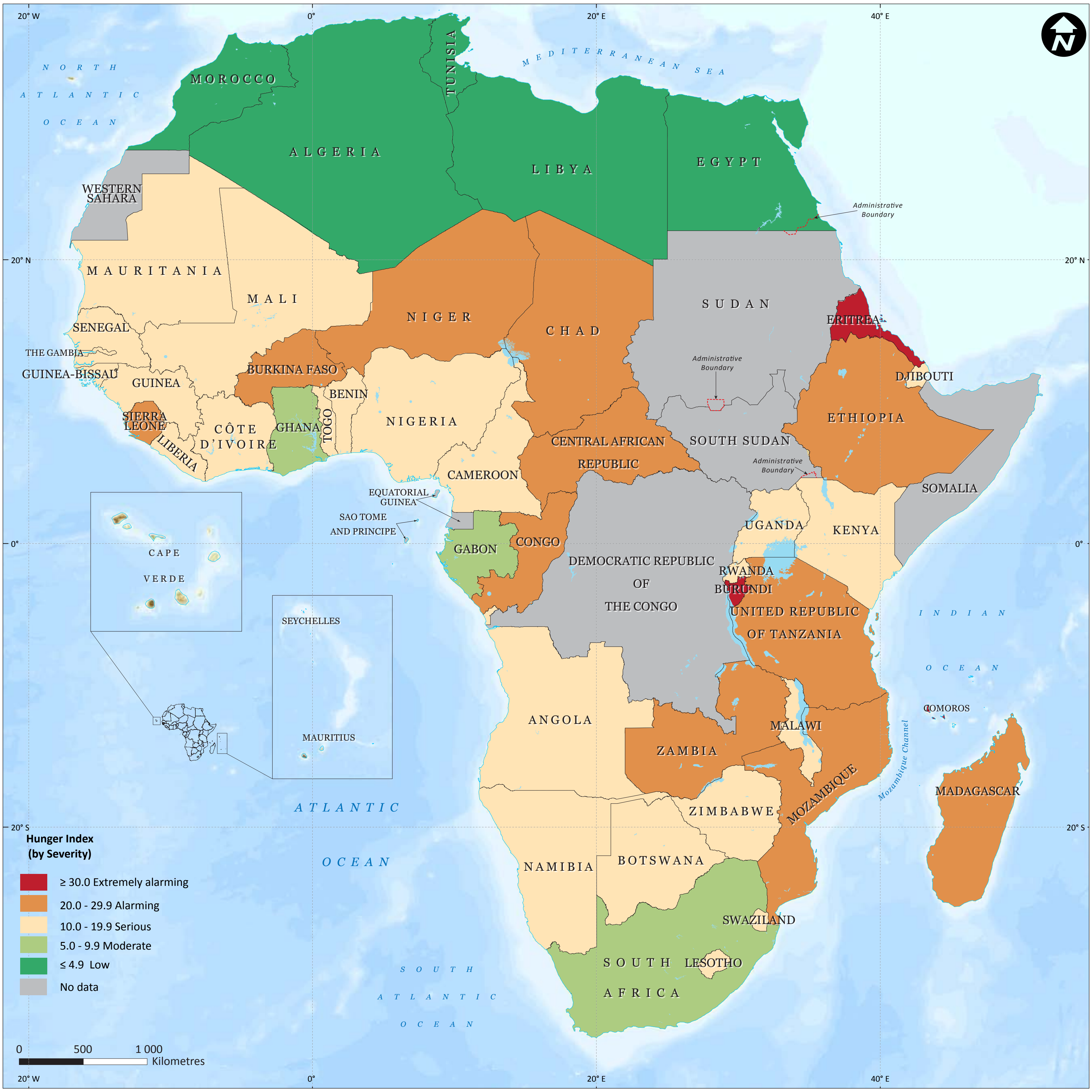
Rice farm in Burundi

Agricultural productivity and food production in Africa's mountains is constrained in various ways that affect food security. Traditional practices that allowed soil to sit fallow and regain its fertility have been generally abandoned due to population increases, forcing farmers to continually plant crops on the same land. This has contributed to soil-nutrient depletion and the decline in per capita food production over the past 30 years in sub-Saharan Africa (IFDC, n.d.). Another factor is the structural adjustment policies of the Bretton Woods Institutions in the 1990s, which put an end to fertilizer subventions. High soil-nutrient deficits, low fertilizer use, over-dependence on rain-fed agriculture and climate variability combine to constrain agriculture and keep productivity low. For instance, fertilizer consumption in sub-Saharan Africa is estimated to be only three per cent of global levels (Druilhe & Barreiro-Hurlé, 2012).

The Situation

Between 40 and 60 per cent of Africa's mountain people are vulnerable to food insecurity; the literature indicates that an average of 50 per cent of those identified as vulnerable are undernourished (FAO, 2002). The 2013 Global Hunger Index, which is calculated from proportions of undernourished populations, underweight children under the age of five and the child mortality for children under five, classifies three mountainous countries: Burundi, Eritrea and Comoros, to be extremely alarming and several others such as Ethiopia, Chad and the United Republic of Tanzania to be alarming (Figure 5.3). The food security and hunger situation in Burundi has not improved since the 1990s, as the country has been struggling with political issues and natural disasters, such as floods and drought, which have resulted in crop losses and increased food insecurity (von Grebmer et al., 2013; WFP, 2013). The population of Burundi, an largely mountainous country, is 46 per cent food insecure, with food insecurity proportions in some regional populations, such as the Plateaux Humides, as much as 64 per cent (WFP, 2013).

Figure 5.3: 2013 Global Hunger Index (GHI) by severity



Source: IFPRI, 2013; UNEP/DEWA

Note: The 2013 GHI could only be calculated for the former Sudan because separate malnourishment rates were not available prior to the independence of South Sudan in 2011.

Low per capita arable land availability negatively affects agricultural productivity and food production. Mountain ecosystems usually have lower per capita arable land availability than non-mountain regions. In addition, many unfavourable agroecological and biophysical factors can negatively affect farmland productivity and labour in mountain regions, thus influencing agricultural potential and food production. In general, only 2 per cent of mountain regions and 22 per cent of non-mountain areas are classified as good-to-very suitable for rain-fed crops (UNEP-WCMC, 2002). For example, in the marginal, hilly area of Oued Sbaihyia in Tunisia, located 50 km south of Tunis, land is farmed so intensively that many farmers are incapable of making a living from agriculture and this has led to seasonal migration of men to coastal towns (Jenny & Egal, 2002).

The Constraints

Arable land is limited in mountain areas due to growing populations and this is leading to land fragmentation and small farm size. Fertile volcanic soils, such as those found on Mounts Cameroon, Elgon, Kenya, Kilimanjaro and the highlands of Ethiopia act as a magnet for people. This puts pressure on agricultural land and has led to land fragmentation through land inheritance practices. For example, in the East African highlands, farm sizes range from 1 ha per household in Ethiopia to 2 ha in the United Republic of Tanzania and 2.5 ha in Kenya and Uganda (Salami, Kamara & Brixiova, 2010). In Rwanda, available arable land per family is 0.6 ha, with 25 per cent of families having land less than 0.2 ha in size (Odhiambo, 2013). This reduction in cropland can affect food security, if the land area is too small to support a family's food needs or to generate income.

In Rwanda, available *arable* land *per family is 0.6 ha, with 25 per cent of* families *having land less than 0.2 ha in size*

Furthermore, some countries could benefit from raising more livestock, which could positively impact agricultural production, increase incomes and provide more food for consumption. However, in countries such as Burundi where this could be beneficial, research showed that more than 30 per cent of households did not have livestock (WFP, 2013).

Conflict across the continent and in particular in certain mountain areas constrains food production leading to food insecurity. Conflict destroys traditional sources of livelihoods, displaces large numbers of people who have to abandon their farms, destroys infrastructure and degrades the environment. This has been a key factor triggering food insecurity in the Nuba Mountains in central Sudan (FAO, 2010) and in Burundi, although there has been some progress towards peace (von Grebmer et al., 2013).

Terraced farmland in Rwanda near Volcanoes National Park

The Opportunities

Investment in agriculture could promote growth in the sector, improve land management and promote food security, but requires a favourable investment climate. In some remote mountain areas, these might include greater investments in agricultural infrastructure, such as roads and irrigation. The 2011 Kampala Principles for Agricultural Finance provide broad policy guidelines that governments can follow to support agricultural investments. They include strategies such as strengthening farmer groups and legislation, implementing the Comprehensive Africa Agriculture Development Programme (CAADP) Principles, improving agricultural productivity and supporting research and development, among others. Additionally, policies regarding land tenure can be developed in areas without existing policies or strengthened in areas where they are already in place. Improving land tenure implies greater equity in terms of access to land and may result in reduced prevalence of undernourishment and a growth in GDP. In addition, it allows for longer term investments in technology and productivity (InterAcademy Council, 2004).

> ...agriculture *contributes 32 per cent of GDP and 65 per cent of* employment *in* Africa...

Increase focus on the rural areas where more than 80 per cent of the low-income population in sub-Saharan Africa live and depend on agriculture; this is vital to addressing food insecurity (Calzadilla, Zhu, Rehdanz, Tol & Ringler, 2009). This focus should aim to increase agricultural productivity as an engine of economic growth. An analysis of the data shows that agriculture contributes 32 per cent of GDP and 65 per cent of employment in Africa (World Bank, 2013c). Dependence on agriculture can be even greater in mountain areas. Agriculture contributes just 17 per cent of the GDP to the mountainous country of Lesotho, but is the primary or supplemental source of income for more than 50 per cent of the population (IFAD, 2008). Furthermore, in Ethiopia, each 10 per cent increase in smallholder agricultural productivity in Africa can move almost 7 million people above the dollar-a-day poverty line (IFPRI, 2000). Strategies can include addressing poverty, supporting improved productivity, developing post-harvest technology, improving transport and marketing infrastructure and initiating sustainable water and land management strategies.

Investments in agricultural research and development, including climate-smart agriculture and organic farming, are required to increase agricultural productivity growth and improve livelihoods. Investments in research to develop risk-reducing and productivity-enhancing technologies are of critical importance. Also, research and capacity building could be undertaken to introduce and support Integrated Soil Fertility Management (ISFM), an approach to farming that encourages adapting to local conditions to increase nutrient and water use efficiency and agricultural productivity. Strategies focus on combining mineral fertilizers and traditional local soil amendments to replenish lost soil nutrients, improving germplasm, agroforestry, crop rotation and intercropping with legumes or other plants that naturally improve soil fertility (IFDC, n.d.). Furthermore, organic farming practices, which omit the use of fertilizers and pesticides, can help to improve productivity, yields and family incomes, leading to better food security and improved livelihoods (Wymann von Dach, Romeo, Vita, Wurzinger, & Kohler, 2013). Box 5.3 describes how organic farming can help to ensure sustainable development and reduce poverty.

> ...organic farming *practices...*can help *to improve productivity,* yields *and* family *incomes...*

Box 5.3: Organic farming

As of 2012, there are approximately 560 000 organic producers in Africa, representing 30 per cent of the world total. Key crops include coffee, oilseeds, cotton, olives and cocoa. In eastern Africa, certified organic agricultural land, where the vast majority of agricultural production is destined for export markets, particularly in Europe, increased significantly between 2007 and 2011. The United Republic of Tanzania had an estimated 115 000 ha of organic farmland in 2011, of which 3 500 ha was used for permanent crops, especially coffee; the number of organic coffee growers in the Kilimanjaro region was estimated to be 1 126 farmers. In Uganda, where the export value of organic products was US$ 42 million in 2010-2011, up from US$4.6 million in 2002-2003, there are nearly 200 000 certified organic farmers. Organic coffee fetches the highest earnings. Promoting organic coffee production in Africa's mountains is a vital business and wealth creation opportunity contributing to poverty reduction and sustainable rural development.

Sources: Compiled from Willer, Lernoud, & Kilcher, 2013; Agro Eco BV & Grolink AB., 2008; Willer & Kilcher, 2012; UNEP-UNCTAD 2010; Willer & Lernoud, 2014

C. arabica coffee

Increase Investment, Financing and Infrastructure in Mountainous Regions

The Challenge

The numerous pressures facing mountain ecosystems means that there are many financial and human resources to manage. However, mobilizing and prioritizing the financial resources to invest in developing mountain areas remains a challenge.

The Constraints

Many mountain communities are isolated and are unable to attract investment for development, except in some cases, such as mountain tourism.

The Situation

There are many competing interests and programmes that encroach on the resource envelope governments have at their disposal.

The Opportunities

Employing a multisectoral or integrated approach to funding sustainable mountain development should be pursued, especially since mountains provide a multitude of ecosystem services in various interlinked sectors such as energy, water and food security.

The Challenge

The numerous pressures that mountain ecosystems face mean they require many financial and human resources to manage their assets. A lack of funding, however, is a key obstacle preventing conservation and development goals from being achieved in mountain areas. Traditionally, governments have provided this required funding through their institutions, but it is never enough, primarily because of the relatively low political support given to mountain systems in Africa. A sectoral approach to funding mountain development means that the limited resources provided cannot be used in an effective and efficient manner (Gichuki, 2002).

Agricultural land on the fertile foothills near Ansi in the High Atlas Mountains, Morocco

Lukasz Janyst22800 / Shutterstock

The Situation

Mountain research requires dedicated funding. The lack of funding for research and programme implementation is a big problem for long-term data acquisition and analysis and building a knowledge base to support the sustainable development of mountain areas. More dedicated funding would mean better planning and focus for the future.

Political leaders *and* policy-makers *should be sensitized and mobilized to appreciate research in mountain regions, to* promote *and* prioritize *investment in mountain research and to use the resulting data and information as appropriate.*

There are also other efforts to improve research on mountains in Africa, such as the IGAD Climate Prediction and Application Centre (ICPAC) to monitor and archive regional glacier volumes and areal extents using both traditional and space-based methods, monitor relevant climate and other related parameters and use the results for regional climate change studies. Political leaders and policy-makers should be sensitized and mobilized to appreciate research in mountain regions, to promote and prioritize investment in mountain research and to use the resulting data and information as appropriate. Furthermore, research institutions should be encouraged and supported, which includes building capacity to actively undertake the needed research according to standardization protocols and to share the research results both within and between African countries and beyond.

Protection and sustainable development in rural and poor mountain areas also requires funding initiatives. Many of Africa's protected areas are found in poor mountain areas, so the lack of funding for sustainable management and development can be clearly demonstrated by using protected areas as a proxy for mountains, as shown in Box 5.4.

Box 5.4: Lack of funding for sustainable development in mountain areas

Currently, financing for conservation priorities are focused on biogeographical units that are flexible, which avoids limiting the budgets to specific objectives. Even though this has been successful, the development community and regional governments find it difficult to allocate these funds appropriately, especially when the money is focused on ecological development. Some local governments lack the capacity and infrastructure to implement specific projects in rural mountain regions and many countries do not prioritize mountain ecology within their funding framework.

It is important to promote the environment as a key priority for funding. At an international level, this can be done by strengthening Africa's capacity to implement multilateral environmental agreements and making sure institutions, policies and regulations are receiving funding support specifically in the area of mountain development. At a national level, strategic environmental assessments (policies that integrate the importance of the environment) can ensure that mountain ecosystems are given priority within national policies and programs. Furthermore, engaging the private sector to provide enabling conditions for investment and to promote development in African mountains is the key to driving economic and ecological development.

Protected areas can be used as a proxy for attracting funding to poor mountain regions. By doing so, it may be possible to create opportunities for poor rural mountain populations and reduce poverty by focusing conservation efforts in these regions and engaging local mountain communities. This could be important in areas like the Simien Mountains in Ethiopia where protected national parkland dominates the region. Finally, at the community level it is imperative to promote the local population's involvement while integrating indigenous culture and local livelihood practices in the process.

Mountain development in Africa should be promoted at a global scale and more funding should be allocated to acknowledge their importance in ecological development, their significance as a base for protected areas and their role in supporting the livelihoods and well-being of poor populations.

Sources: Africare, 2008; Brooks, et al., 2006; Hartley, Nelson, Mayaux & Gregoire, 2007; Mountain Partnership, 2011; WCPA-IUCN, 2000; UNESCO, 2014b

Life in the Simien Mountains, Ethiopia

The Constraints

There are many interests and programmes that compete for the government's resource envelope. For instance, achieving the eight Millennium Development Goals (MDGs) that were agreed upon in September 2000 is now currently dominating the policy agenda in many African countries, especially as the countdown to 2015 draws near. Some observers think the tight timeframe and financial restrictions might force governments to invest in the most productive sectors, thus compromising the quality and sustainability of development efforts and in the long term leading to even greater inequality, especially between geographical regions and social strata (von Dach, Ott, Klaey, &, Stillhardt, 2006). Hence, if this were the case, people living in marginal areas, such as remote mountain regions, risk being disadvantaged by this internationally agreed agenda.

Remoteness limits access to markets, increases the price of inputs and makes both economic and social services less accessible. Poor infrastructure, weak state and market institutions and political isolation all combine to present a higher-risk environment for poor rural people like those in mountainous regions (IFAD, 2010). Limited access to education and health facilities, low levels of infrastructure development and lack of employment opportunities also contribute to high levels of poverty.

The Opportunities

Prioritizing finances for environmental management in mountain areas is increasingly important, especially at community levels. Strategies could include increasing political support, diversifying funding sources, developing sustainable financing plans, implementing efficient financial management and fostering a paradigm shift to a business approach for natural resources management. With political support, some countries such as Ethiopia have managed to place conservation high on the development agenda and thus bridged the funding gap required for protected area management, as described in Box 5.5. This unique approach combines many of the strategies mentioned above.

The growing industry of mountain tourism can be a catalyst for concentrated funding. Where tourism is an option, it can provide an economic base for a region because the cultural, social or environmental resources, such as mountain scenery, sporting opportunities and wildlife, are the only development options (World Bank, 2013d). Indeed, Foreign Direct Investment (FDI) in tourism is growing (Box 5.6 on next page).

Box 5.5: Financing sustainable management in protected areas — the case of Bale Mountains National Park

A 2006 estimate suggests that in developing countries, public national park budgets are between US$1.3 and 2.6 billion a year. As a share of total government spending, these amounts are not large. Many protected areas operate far below the recommended costs per square kilometre reported in the literature. Such is the case of Bale Mountains National Park, a 2 200 km^2 protected area located 400 km southeast of Addis Ababa in Ethiopia. Counting all sources of current funds, there is only US$135 / km^2 available for park management. This is despite the fact that the government has increased allocated funding (by 260 per cent in activity costs between 2009 and 2010) and external financial support. To try to bridge the funding gap, the Bale Mountains National Park Business and Sustainable Finance Plan (2011-2016) was recently launched. Its objective is to increase and improve financial support for the effective management of the Bale Mountain ecosystem.

Sources: Emerton, Bishop, & Thomas, 2006; Kinahan, 2011; UNESCO, 2008

Bale Mountains National Park

Native porters have a rest after hard day in a Shira camp on Mount Kilimanjaro, United Republic of Tanzania

A unique aspect of highland tourism that could be further developed is its draw for sports tourism. High-altitude training centres, such as ones that already exist in Ethiopia, which offer training at altitudes of 2 800 m and higher (Run in Africa, 2014), could continue to be built and supported to entice athlete's worldwide to train as long distance runners in Africa's highland areas. In Lesotho, development of high altitude training has been identified as an ideal tourism investment, as the entire country has an elevation greater than 1 000 m (LTDC, 2007).

Employing a multisectoral or integrated approach to funding sustainable mountain development should be pursued, especially since mountains provide a multitude of ecosystem services in various interlinked sectors such as energy, water and food security. A multidisciplinary approach would allow the integration of sectoral policies and actions and to secure long-term planning and financing. Bringing together scientists, policy makers and communities would also offer the benefit of more informed choices and enhanced links between science and policy at all levels.

More is needed than policy statements, however, including adopting measures to effectively implement policy through improved institutions as well as laws and management tools.

Box 5.6: Investment in mountain tourism

In 2011, the East African countries of Kenya and Uganda attracted US$404 million and US$165 million respectively in tourism FDI. Africa, especially sub-Saharan Africa, has a great potential for expanding tourism due to its abundant assets, including wildlife, cultural attractions and mountain landscapes. Development of mountain tourism on Mount Kilimanjaro has reduced poverty, improved sanitation and management and led to the establishment of trade unions for porters, guides and cooks. Of the average US$50 million in tourism revenues generated annually from the mountain, approximately 28 per cent are pro-poor, providing incomes for about 400 guides, 10 000 porters and 500 cooks. Pro-poor employment opportunities have also been created in the mountain-climbing tourism sector in Kenya.

The regulatory framework is still weak and governments do not have the resources to improve conditions quickly, presenting a high-risk environment for poor local people, but there is opportunity to improve. With the proper framework in place, more opportunities can be created for locals to benefit from tourism income.

Source: World Bank, 2013d

Provide Access to Energy Security Through Hydropower

The Challenge

Insufficient energy generation has led to limited electricity supply and low access levels. The immense amounts of water stored by Africa's mountains are a potential source of clean energy.

The Constraints

Inadequate financing is the main issue hindering the energy sector's development. Other issues include the uneven distribution of potential sites for hydropower development, climate change and other environmental and socio-economic issues associated with building the hydropower industry.

The Situation

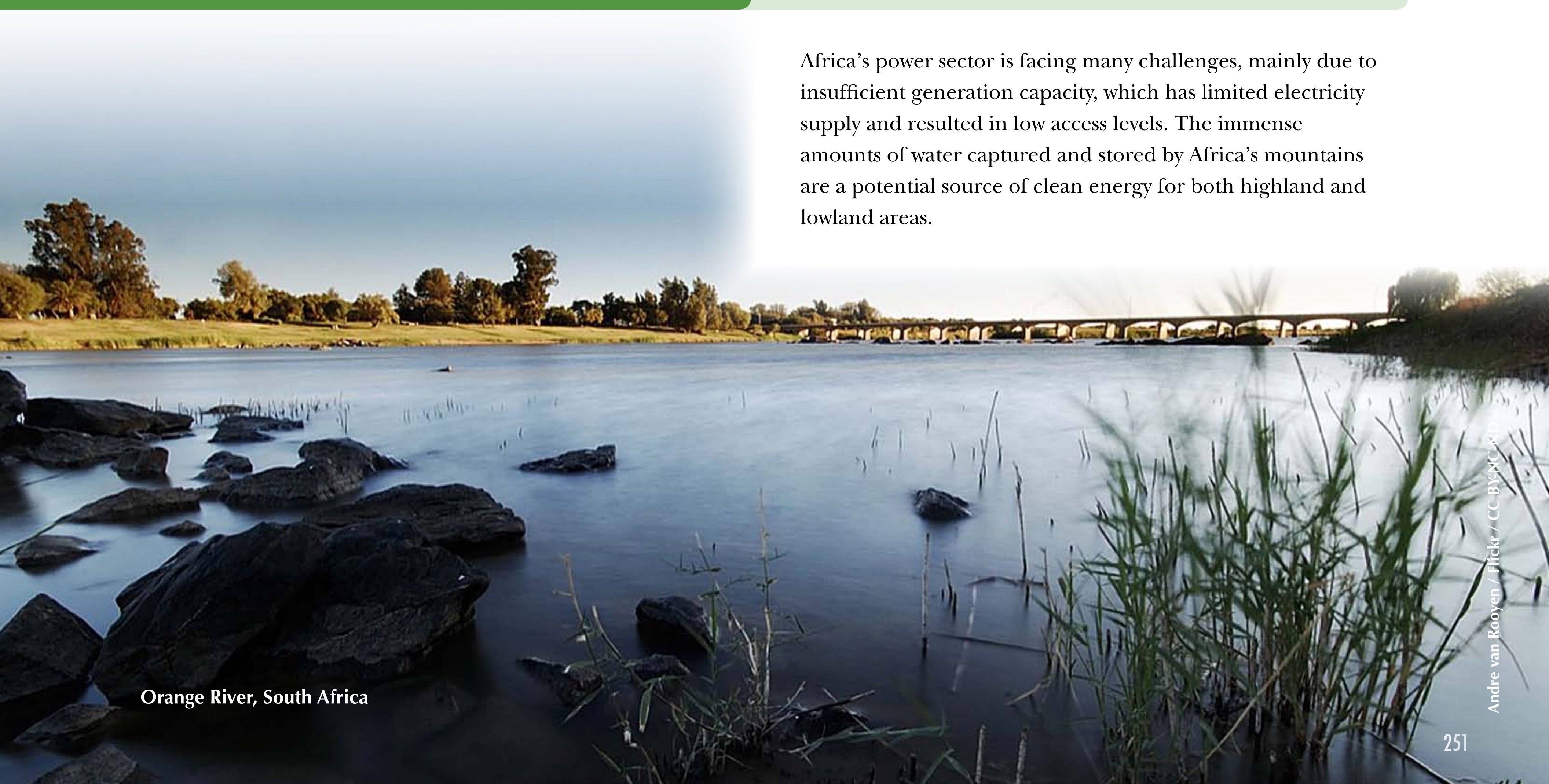
There are significant hydroelectricity resources available for development in mountain areas with a steep slope gradient, but the sources are unevenly distributed and rural areas can have difficulty connecting to a main network.

The Opportunities

Through small-scale and sustainable large hydropower development, mountains can contribute significantly to energy security, which is essential for human well-being.

The Challenge

Africa's power sector is facing many challenges, mainly due to insufficient generation capacity, which has limited electricity supply and resulted in low access levels. The immense amounts of water captured and stored by Africa's mountains are a potential source of clean energy for both highland and lowland areas.



Orange River, South Africa

Access to electricity is difficult to obtain in rural areas and those with low power-generation potential. The region's unexploited energy resources are concentrated in a handful of countries that are geographically removed from the centres of power demand. For instance, the DRC and Ethiopia are far from the main economic centres of southern and northern Africa, and their economies are small relative to the multibillion-dollar investments that would be needed to develop their hydropower potential. These countries do not have the economic resources to invest in developing hydropower and have been forced to adopt inefficient forms of generation like thermal to serve small domestic power markets, even though in many cases the hydro and gas resources of neighbouring countries could support much cheaper forms of generation. These inefficient forms of energy are reflected in their low electricity access proportions (Figure 5.4).

Figure 5.4: Percentage of population with access to electricity

Source: World Bank, 2014; UNEP/DEWA
Note: 2011 data

Electricity supply is generally highly unreliable. In many countries, insufficient generation capacity limits electricity supply, resulting in low levels of access for both households and industries. It also means that electricity is not always available on demand, which limits economic activity at all levels. In sub-Saharan Africa, manufacturing enterprises experience power outages an average of 56 days per year compared to outages in the United States where the average is only one day a decade (Eberhard, et al., 2008). Some of the reasons for the African situation are the low prioritization given to the hydro sector, the aging of power plants and environmental issues such as sedimentation, and flooding or drought-related climate change.

In addition to impacting the industrial sector, low electrification of rural mountainous areas contributes to out-migration from these areas, since it affects overall quality of life. In the Atlas Mountains, the government has undertaken steps to improve electrification in mountainous areas as a strategy to stem the tide of out-migration (UOF, 2002).

In sub-Saharan Africa, manufacturing *enterprises experience* power outages *an average of 56 days per year...*

The Constraints

The pricetag of financing energy development to meet future needs is high. The Africa Energy Outlook 2040 report (NEPAD, AU, & AfDB, 2011) concludes that an estimated US$43.6 billion per year will be needed to meet forecasted energy demand for Africa until 2040 (FAO, 2008). Accessing financing depends on the energy sector's ability to compete for capital against other economic sectors.

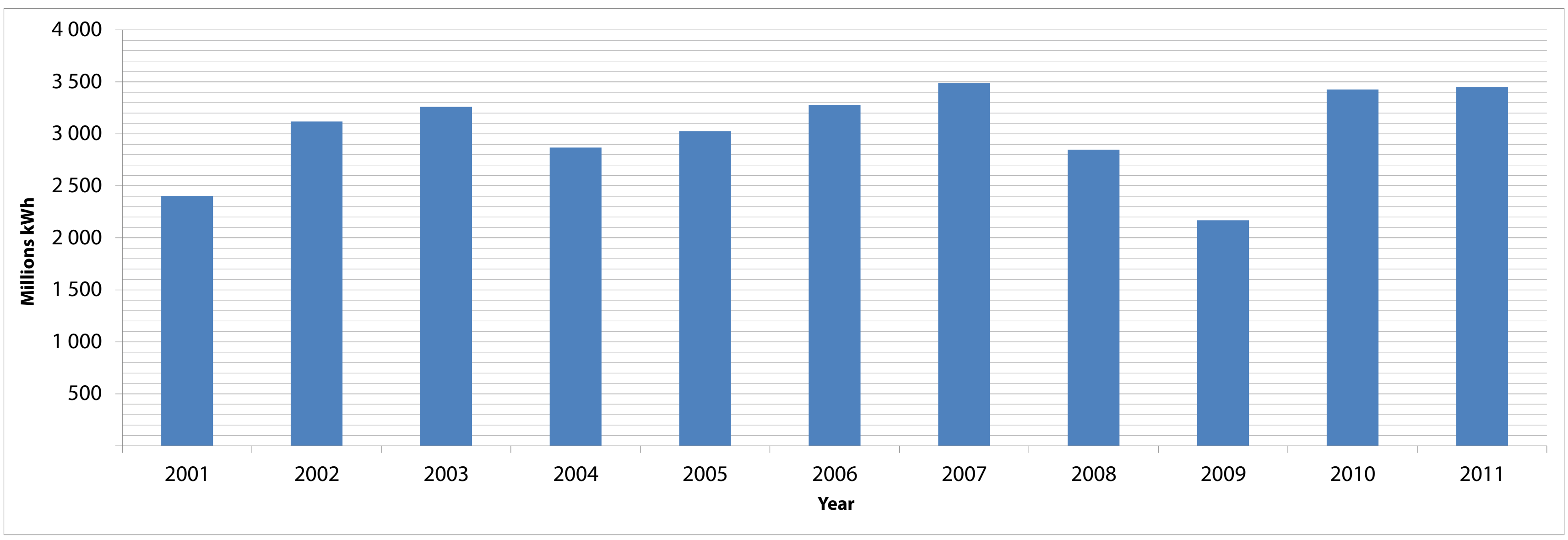
Climate change is likely to affect the hydropower sector across Africa in different ways. In eastern Africa where precipitation is projected to increase, the outlook for hydro development is good; in southern and northern Africa, on the other hand, runoff is projected to decrease, reducing the potential for hydropower generation (Hamududu & Killingtveit, 2012; Arnell, 2012). The sector is already proving vulnerable to the effects of reduced precipitation, increased evaporation levels and droughts. In Uganda, for example, the reduction in Lake Victoria's water levels between 2004 and 2006 led to a decline of 50 MW in hydropower generation, which in turn led to an adjustment in the GDP growth rate from 6.2 to 4.9 per cent (Baanabe, 2008). Already drought years are affecting hydropower in Kenya such as the La Niña-induced droughts in 1999-2000 and in 2009-2010 (Oludhe, 2010). Figure 5.5 shows the decline in hydropower generation in 2009.

There are environmental and social issues associated with developing hydropower. These include endangered livelihoods, displacement of people, damage to cultural sites and impacts on health. Environmental impacts include disturbance to river flow and biodiversity, increased sedimentation and declines in soil and water quality, among others. The large dams on the Zambezi River (with its source in the highlands in northwestern Zambia) have profoundly altered the hydrological conditions most important for maintaining downstream livelihoods and biodiversity. It is estimated that more than 11 per cent of the Zambezi's mean annual flow evaporates from large reservoirs associated with hydropower dams (Beilfuss, 2012). These water losses increase the risk of shortfalls in power generation and significantly impact downstream ecosystem functions. In light of the severity of impacts, best-practice guidelines need to be followed and should include public input before dams are built.

...an estimated *US$43.6 billion per year will be needed to* meet *forecast* energy demand *for Africa until 2040*

New financial mechanisms are needed to reallocate revenue from hydropower sales to directly compensate downstream water uses that are negatively affected by dam operations as well as to restore ecosystem services hampered by development.

Figure 5.5: Total annual hydropower generation in Kenya



Source: World Bank, 2013b

The Opportunities

About 93 per cent of the economically feasible hydropower potential in Africa remains unexploited. The mountains of eastern Africa give rise to some of the rivers with the most hydropower potential. Hydropower potential in the Virunga National Park is estimated to provide US$20 000 worth of electricity and US$10 million in the form of local job opportunities (WWF, 2013). The hydropower potential of rivers flowing through the Mau Forest complex alone is 508 MW, accounting for 50 per cent of the current installed capacity in Kenya (UNEP, KWS, KFWG, & ENSDA, 2008). As a whole, Africa has the potential to develop 10 gigawatts (GW) of energy through small hydropower, but only about 0.5 per cent has actually been developed (WAEA, 2008). Developing these resources is a priority, since deficiencies in the power sector are a serious hindrance to economic growth.

Hydropower potential in the Nile basin exceeds 20 GW (NBI, 2012). The potential is especially high in the Ethiopian highlands where the Blue Nile's 1 300-metre drop between Lake Tana and the border with Sudan could generate about 8 000 MW (NBI, 2012). Figure 5.6 shows the many dams that are located at various elevations and distances from the sea along the Nile River network.

Thus, there are opportunities to develop hydropower to support local and regional environmental, economic and social development. A sustainable electricity supply would help alleviate poverty, improve health, increase productivity, enhance competitiveness and promote economic growth.

The future of hydropower development in support of rural electrification may lie in the development of small hydropower stations in areas with steep mountain streams. Small hydropower (variously called "mini hydro", "micro-hydro" and "pico-hydro" and spanning a very wide range of plants, from 1.5 to 100 MW of capacity (IEA, 2012)) can play a pivotal role in providing energy access to remote areas, either in stand-alone isolated mini-grids or as distributed generation in national grids. In remote mountain areas, the use of micro-hydro schemes could provide communities far from the grid with affordable, easy-to-maintain and long-term solutions to their energy needs, especially if community-based management is utilized (Box 5.7). The availability of electricity generated from micro-hydro schemes

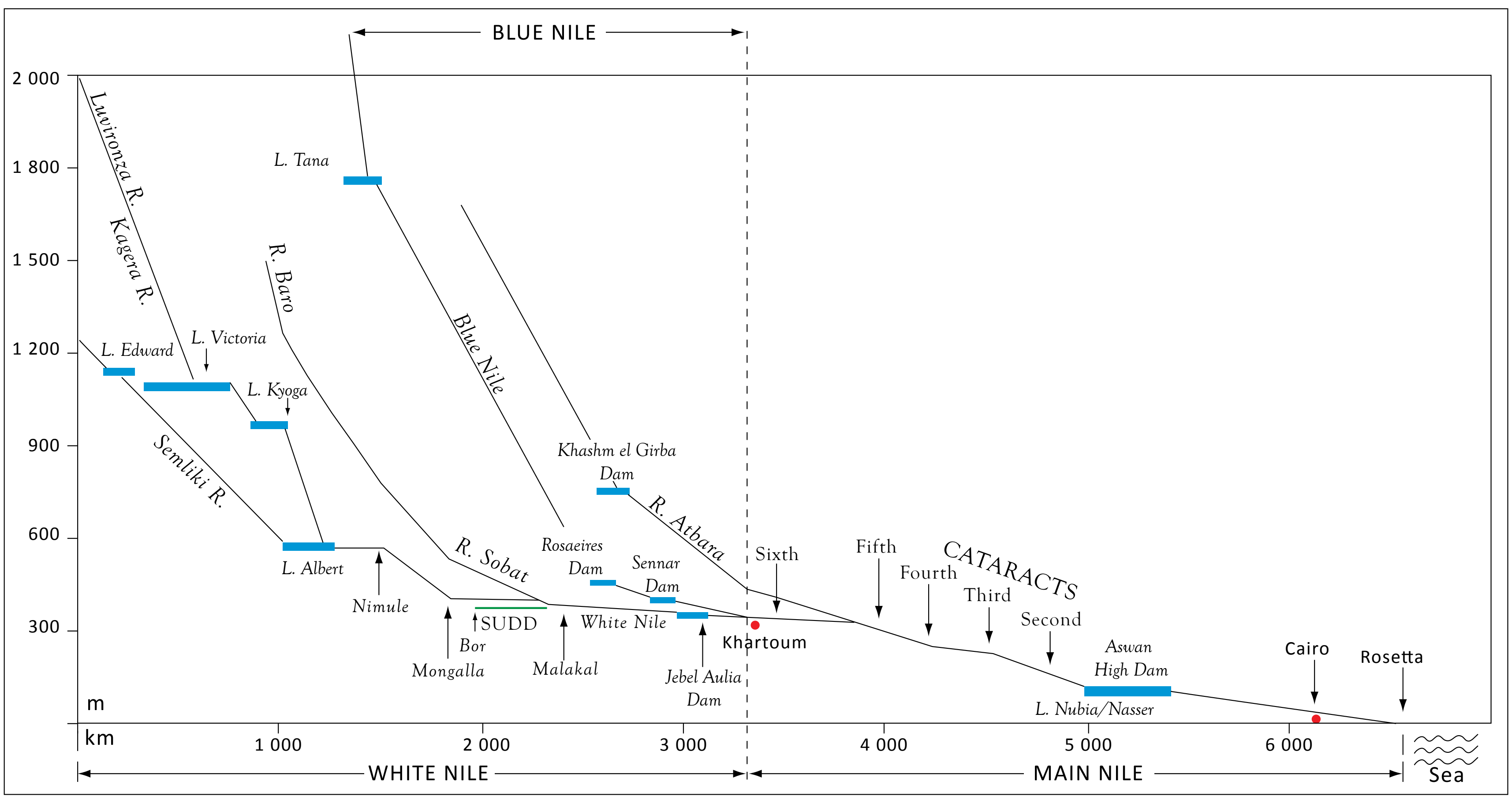
Box 5.7: Use of micro-hydropower schemes in marginal mountainous communities in southern Africa

Existing micro-hydropower schemes were rehabilitated and new ones built in poor marginalized communities in the mountainous regions of Manica, Mozambique, Mulanje, Malawi and Manicaland, Zimbabwe over a five-year period from 2008 to 2012 to help bring electricity to rural populations. Rural electricity access in these three countries is very low: 0.5 per cent in Malawi, 19 per cent in Zimbabwe and 7 per cent in Mozambique.

A total of eight schemes have been completed and an additional five are partially completed. These small-scale schemes are under decentralized, community-level management. Parts, such as turbines, were manufactured locally and community members are engaged in the design, development operation and maintenance of the schemes. An estimated 45 000 people were positively impacted by the health benefits, education opportunities and poverty reduction and at least 200 households, plus schools, clinics and shops became directly connected.

Sources: Compiled from Practical Action, n.d.; Mika, 2011; EuropeAid, 2012

Figure 5.6: Gradient along the Nile offering opportunities for hydropower development



Source: Adapted from World Bank, 2009; UNEP/DEWA

Kinkon dam, a small hydropower dam, in Guinea

Table 5.1: Summary of small hydropower projects in selected countries

Country	Small hydro potential (MW)	No. of identified sites	installed capacity (MW)
Guinea	60.7	136	10.3
Kenya	3 000	-	15 (grid-fed) 31 (off-grid)
Malawi	7.35	22	4.5 (grid-fed) 1.3 (off-grid)
Mozambique	1 000	>60	-
Rwanda	-	333	6.5 (grid-fed)
United Republic of Tanzania	185	85	5.4
Uganda	210	>50	17

- no information

Source: Guinea - N'faly & Barry, 2006; all others as reported in Kaunda, Kimambo, & Nielsen, 2012

will strengthen community activities and enhance their potential to develop livelihood options.

Table 5.1 shows the actual and potential generation from small hydro development in MW for several African countries. In Kenya, areas with considerable pico- and micro-hydro potential include Mount Kenya, the Aberdares, Nyambene, Mount Elgon, the Kisii Highlands, Cherangani Hills, Kerio and Nandi escarpments (Maher, Smith, & Williams, 2002; Meier & Fischer, 2011).

Governments should put in place funding strategies to attract varying sources of financing. Currently, most funding is from development partners or governments and primarily for a particular small hydro project and not necessarily to assess a country's available hydropower potential (Kaunda, Kimambo, & Nielsen, 2012). A number of national governments and bi- and multilateral donors have recognized the potential role of small hydropower in eradicating energy poverty and are implementing programmes to support their development. For instance, the World Bank's new energy strategy highlights small-scale hydropower as an important component of future World Bank activities in Africa (World Bank, 2010). Funding strategies should include plans on how to attract private sources of financing.

Investments in community projects are sometimes facilitated by establishing trust or endowment funds, such as the Mgahinga and Bwindi Impenetrable Forest Conservation Trust (Uganda) and the Eastern Arc Mountains Conservation Endowment Fund (United Republic of Tanzania), which operate as independent entities, and use a "Local Community Steering Committee" structure to vet and screen proposals coming from the local level. A more common channel for dispersing funds in this manner comes from revenue sharing schemes from national parks and other protected areas to front-line communities affected by conservation. In some cases, the lower levels of local governments (parishes or villages) are used as an entry point for planning and supervising these investments (Roe, Nelson, & Sandbrook, 2009).

A number of national governments *and bi- and multi-lateral* donors *have* recognized *the potential role of* small hydropower *in eradicating energy* poverty

Improve Water and Land Use Management

The Challenge

There is high pressure on water and land resources and a notable lack of legislation to guide mountain development and sustainable use of these resources.

The Situation

Human activities (overgrazing, deforestation, etc.) exacerbate soil erosion in mountainous areas and intensification and expansion lead to unsustainable land use.

The Constraints

The amount of suitable land to sustain life that is available per person in Africa's mountains is below average and declining and intense use of the little amount of land available can be devastating. In addition, roads to service settlements can degrade land.

The Opportunities

The development and use of conservation and land management techniques and improved land use will alleviate future management issues. Opportunities should also be created to encourage local communities to engage in protecting and marketing local high-quality mountain products.

The Challenge

Watering seedlings for agroforestry projects in Lushoto, United Republic of Tanzania

P Kimeli / CCAFS / Flickr / CC BY-NC-SA

Mountainous regions have favourable conditions that attract settlement, but it is leading to high pressure on the land and water resources. Fertile soils, better access to water and other natural resources, cooler climates and the absence of tropical diseases such as malaria or trypanasomiasis, combine to act as a magnet to people. However, in some cases, over 50 per cent of the land is too steep to cultivate without risking catastrophic erosion problems. A number of areas host some of the highest rural population densities in the world and this is leading to rapid environmental change.

To cope with this population pressure and need for development, there is essentially inadequate, weak or complete absence of legislation to guide the management of mountain areas, especially at national and lower levels. This may be due to a lack of policy-level recognition of these areas as unique ecosystems that require special attention. Indeed, a quick analysis of the 29 national reports prepared for the Rio+20 meeting (UNCSD, 2011) showed that only three countries — Ethiopia, Madagascar and Nigeria — specifically mentioned hilly or mountainous areas, and the topic was outside the policy or legal context. Despite this, there are strategies that can be employed to improve mountain management.

The Situation

Land use intensification and expansion is unsustainable. Population pressures and the lack of available land to expand farming activities have resulted in intensified use. This can take the form of growing two crops a year, growing new plants such as vegetables and apples and increasing the size of flocks in some places such as the western Atlas Mountains in Morocco. In Kenya, intensifying productive land use both spatially and in time in medium and high potential zones has affected the natural vegetation cover. In many other parts of Africa, small-scale farms are extending their activities onto marginal areas with lower potential that are adjacent to high potential areas. Such extension to less suitable areas changes the land uses inappropriately and leads to environmental degradation (Egziabher & Barakhi, 1996).

Unsustainable use of water resources is lowering supplies for mountain and downstream communities and creating competition within water catchments. For example, on Mount Elgon, people are moving up the mountain due to lowland population pressure and are using mountain streams to water their gardens. This has impacted the supply of water for downstream populations and forced the city of Mbale at the foot of the mountain to ration water supplies for the first time ever in February 2012 (Jacobsen, Webster, & Vairavamoorthy, 2012).

The Constraints

People migrating to hilly terrain often move into marginal, fragile areas that get overused, leading to declining soil fertility and environmental degradation. The results of this land use pressure include deforestation, soil erosion, land fragmentation, desertification and reduced recharge of aquifers. The average area of land holding in Africa is 1.6 ha (Salami, Kamara, & Brixiova, 2010). Since most of the population depends on subsistence agriculture, intense tillage degrades the environment. For instance, between 1970 and 1999, there was a 97.8 per cent loss in Rwanda's mountainous rain forest of Gishwati (REMA, 2009; see Chapter 4). Agriculture practiced on the slopes of hills and mountains, coupled with deforestation has caused extensive land degradation and soil erosion. The FAO classifies about 40 per cent of Rwanda's land as having a very high erosion risk, with about 37 per cent requiring soil retention measures before cultivation (ROR, 2008). Overall, it is estimated that the country is losing 1.4 million tonnes of soil per year. This is equivalent to a decline in the country's capacity to feed 40 000 people per year (REMA, 2009).

Roads constructed to support industries can degrade land. Intervention to support economic growth in rural areas is needed to reduce high migration rates to the cities. The construction of roads, railways and other transport or infrastructure systems, however, are sometimes developed without adequate regard for nature and local cultures. Approaches to planning that integrate economic developments with ecological and socio-cultural aspects are required.

> *...it is* estimated *that [Rwanda] is losing 1.4 million tonnes of* soil *per year. This is equivalent to a* decline *in the country's* capacity *to feed 40 000 people per year.*

The Opportunities

Governments need to introduce improved land use policies and foster awareness among local people. Several management issues arise related to agricultural land uses in Africa's mountains: soil conservation is of utmost urgency; grazing and land tenure need to be improved; better integration between crops and livestock requires further development; alternative livelihood systems that are less taxing on the environment as well as population controls are also needed; and the benefits from natural resources in highland areas need to be more equitably distributed (Egziabher & Barakhi, 1996). Though African countries have generally attempted various management practices, on average their efforts have not yet succeeded in stemming the extent of degradation. Reasons for this include poor coordination amongst government departments; low levels of awareness; and poor land management technologies and high poverty levels in mountain communities, which exacerbate their inability to meet the new challenges of sustainable development in the context of climate change. Creating awareness among local people and making them beneficiaries of the management practices will enable other efforts to avert the degradation more successful.

Some governments are also putting in place policies and legal frameworks to enhance land management in mountain areas. Rwanda, for example, has initiated health, land, agriculture and irrigation policies that are designed to that end (Malesu, Oduor, Chrogony, & Nyolei, 2010).

Practice soil conservation and retention, agroforestry, organic farming and other conservation and land-management techniques. There are numerous examples of technologies applied across Africa to improve land use management. In some cases, they are used to reduce soil erosion and encourage higher yields and in others to pull irrigation water from the mountains. For example, lowland agriculture in Morocco uses rainwater collected in the higher lands of the Atlas Mountains (Montanari, 2013). Other technologies include rainwater harvesting practices in Ethiopia and Zambia to reduce runoff and use the floodwaters to support farming; conservation agriculture in Kenya, Swaziland and the United Republic of Tanzania (Liniger, Mekdaschi Studer, Hauert, & Gurtner, 2011); and cultivating across the slope and planting grass strips in Swaziland (Tfwala, Manyatsi, & Wang, 2012). More sustainable farming practices such as organic farming may be a better way to cultivate the land for both crop production and the health of the land.

Trees and forests in arid lands play an important role in stabilizing land, controlling desertification and protecting watersheds (FAO, MPS, UNCCD, SDC, & CDE, 2011). Activities that encourage reforesting previously deforested lands improve or reduce land degradation and simultaneously have environmental and economic benefits, such as sequestering carbon or diversifying livelihoods. Promoting valuable tree and shrub species such as fruit trees may also provide farmers with incentives to protect land from erosion while providing them with food.

Protect water towers and catchments and promote sustainable use. Water is the most significant limiting factor to life in drylands. According to UNECA (2007), about 66 per cent of Africa is classified as desert or dryland. Dryland mountains alone cover 2.75 million km² or about 11.6 per cent of Africa's land area and about 27.2 per cent of Africa's mountains can be classified as dryland mountains. Through Integrated Water Resources Management (IWRM), a process involving the collaboration of all stakeholders in managing water resources, including the wider catchment area, sustainable use and protection of precious water resources in Africa could be possible. IWRM has proven to be relatively successful where policy interventions have failed. For instance, in Mount Elgon's Ngenge catchment, IWRM has managed to promote sustainable land and water management solutions to address soil erosion and water quality issues while policy interventions have not been effective (Mutekanga, Kessler, Leber, & Visser, 2013). An approach to water management on Mount Kenya using Water Resources Users Associations (WRUAs) is described in Box 5.8.

Dryland **mountains** *alone cover 2.75 million km² or about 11.6 per cent of Africa's* **land area** *and about 27.2 per cent of Africa's mountains can be* **classified** *as dryland mountains.*

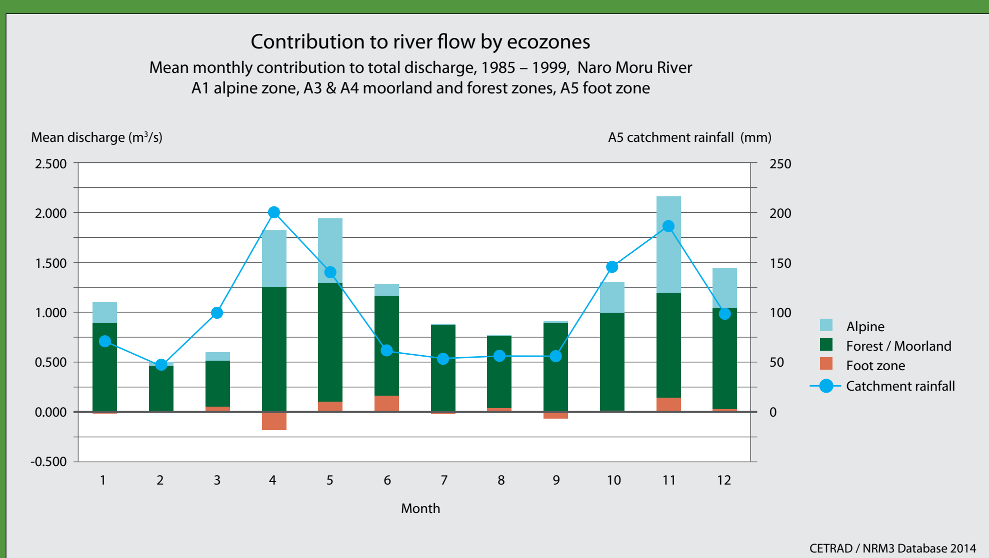
Box 5.8: Mount Kenya: Water tower in a complex regional setting

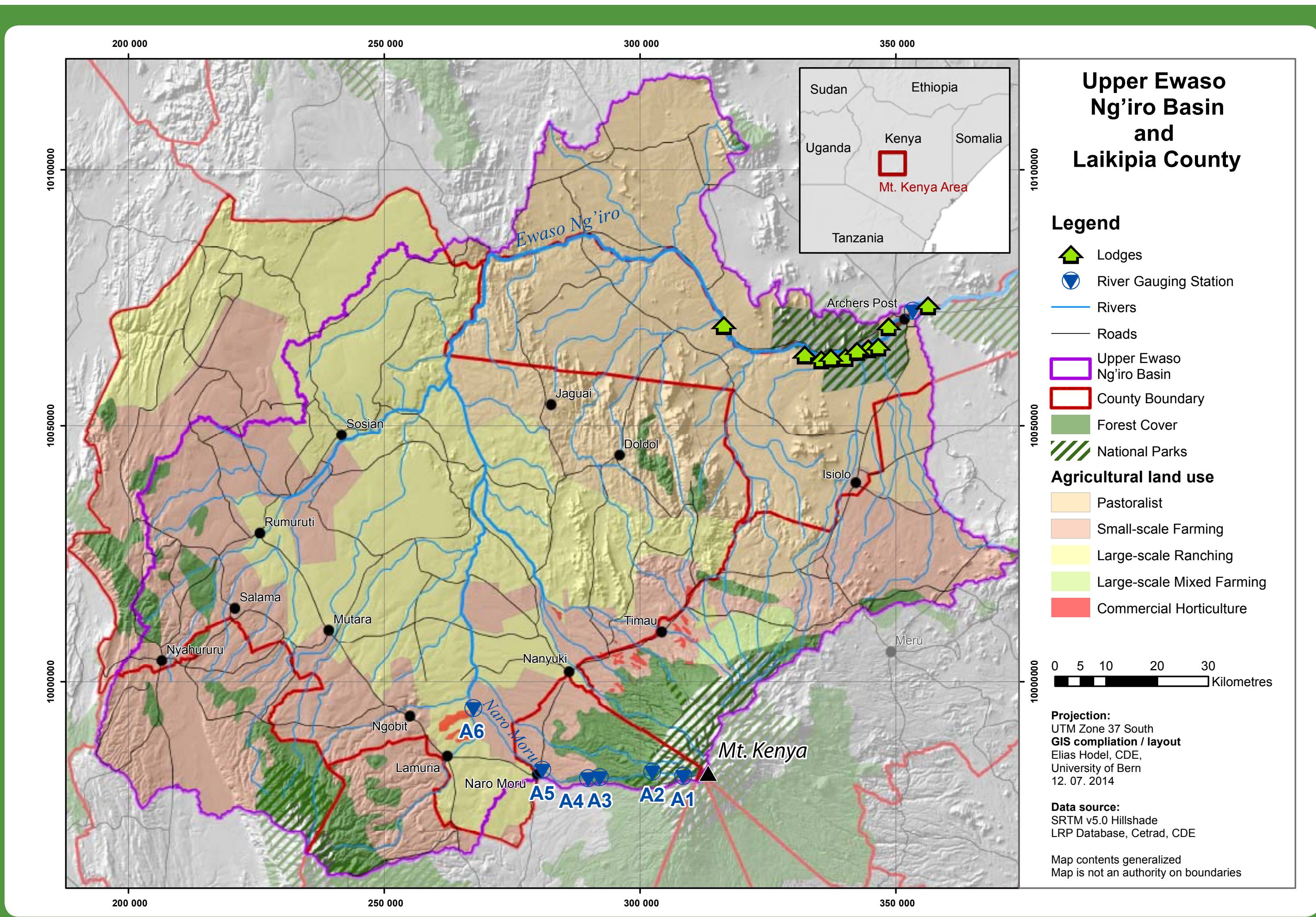
As mentioned in Chapter 2, Mount Kenya is an essential water tower of Kenya. The mountain feeds two of the six major river basins of Kenya: the Tana and Ewaso Ng'iro and provides water to more than 7 million people. Riverflow also contributes to one of the two main irrigation schemes of the country as well as a series of five major dams, which generate about 80 per cent of domestic electricity production. The upper zone of the mountain provides most of the water that is available to the foot zone. This can be shown by the example of the Naro Moru River where forest and moorland contribute 90 per cent of the dry season flow and 69 per cent of the rainy season flow, and the alpine zone an additional 8 per cent and 28 per cent respectively, including a marginal contribution from glaciers (see graph to the right).

Water is a key development issue in all areas around the mountain, but particularly in the rain shadow northwest of Mount Kenya, in the semi-arid areas of Laikipia County and the Upper Ewaso Ng'iro Basin (see map next page). Here, the transition from large-scale ranching to small-scale farming after independence and the growth of urban areas resulted in a sevenfold increase in population between 1962 and 2009, from 58 000 to 400 000. With this growth came an accelerated demand for water, especially for irrigation, resulting in increasing competition and conflict.

Between 1997 and 2004, the amount of water abstracted for irrigation has increased two- to eightfold in the rivers northwest of the mountain. The growing demand for irrigation water by small-scale farmers was aggravated by the additional demand of rapidly growing commercial horticulture introduced in the late 1980s. While irrigation provides a livelihood for small-scale

Typically, river runoff is linked to the seasonality of rainfall, as shown by the example of Naro Moru River west of Mount Kenya. The middle and upper zones of the mountain—forest and moorland (gauging stations A3 and A4)—are crucial for river water supplies, especially in the dry season. The alpine zone including a marginal contribution from glaciers is less important.



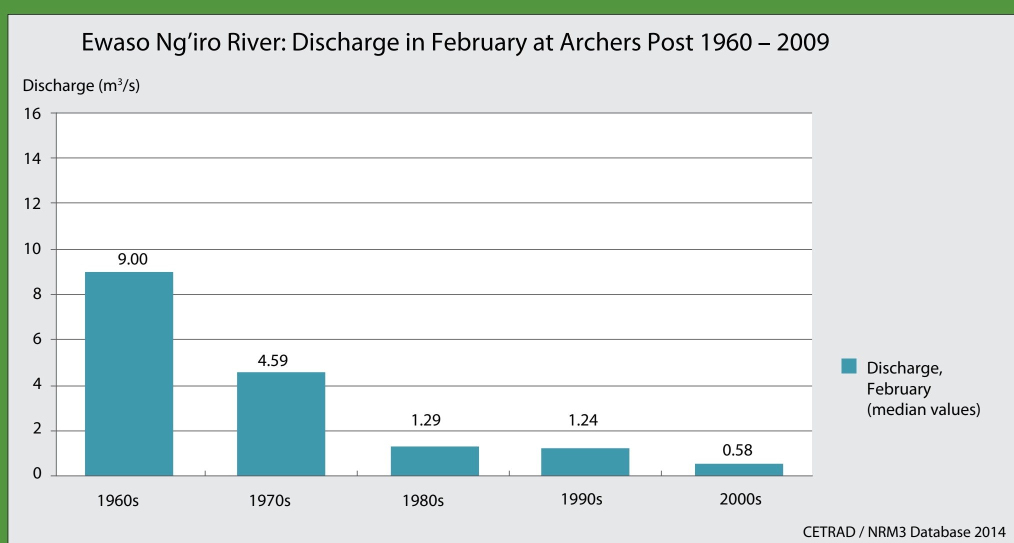


Land use categories refer to the area of the Upper Ewaso Ng'iro Basin and Laikipia County. Note that there is a marked ecological gradient as one moves north and northwest from Mount Kenya, with rainfall decreasing from over 1 200 mm in its forest zone to 300-500 mm at Archers Post.

farmers, large-scale horticulture has grown to become the most important rural job provider, employing over 11 500 people in 2013, mainly for flower production for European markets.

The increasing demand from these upstream users as well as from growing urban areas has virtually cut off supplies of river water to downstream areas in the dry season. Whereas in the 1960s and 1970s the Ewaso Ng'iro River was still flowing all the way down to Archers Post in the lowlands during the dry season, its flow has been reduced to a trickle in the course of the last 3 decades (see graph below). The existence of pastoral communities, the main water users in lowland areas, is threatened by the river drying up. The tourism industry is also affected because tourism in this area depends on rivers to sustain the wildlife that tourists come to see.

In order to address the water issue, local authorities, with the support of external partners, have engaged in multi-stakeholder campaigns promoting sustainable and equitable water use since the late 1980s, relying on long-term hydrological records and continued monitoring provided by research. A number of concrete initiatives resulted from these campaigns, among them the establishment of Water Resources Users Associations (WRUAs). Formed by the users along each river, WRUAs have become effective grassroots institutions to negotiate water sharing and resolve conflicts. The first WRUA in the region was formed in 1997, before governmental water sector reforms commenced, gaining impetus by the legal recognition and external support they received by these reforms. Between 1997 and 2003, the WRUAs resolved 48 out of 52 conflicts over water. In 2013, there were over 80 WRUAs in the region. In addition to conflict resolution, they also engage in resource mobilization for stakeholder participation and ecological sustainability. Some WRUAs have received support from local and foreign funding agencies for improved water management and catchment protection. WRUAs from different rivers have formed a forum to combine efforts in water management. Monitoring of data on water resources and their use, and making these data available to WRUAs, have been key to manage scarce water supplies in a region where the demand for this resource is still on the increase.



Increasing upstream water use over the last 50 years has led to a dramatic reduction of downstream river flow, especially in the dry season, as shown by the flow of the Ewaso Ng'iro River at Archers Post at the lower end of the Basin. February runoff is indicative of change of dry season flows over the years. Decreasing dry season flow heavily affects pastoralism and tourism, the main water uses in that area.

Sources: Compiled from Aeschbacher, Liniger, & Weingartner, 2005; Gichuki, Liniger, MacMillan, Schwilch, & Gikonyo, 1998; Kiteme & Wiesmann, 2008; Kiteme, Liniger, Wiesmann, Notter, Kohler, 2007; Liniger, Gikonyo, Kiteme, & Wiesmann, 2005; MacMillan & Liniger, 2005; Notter, McMillan, Viviroli, Weingartner, & Liniger, 2007; Wiesmann, Gichuki, Kiteme, & Liniger, 2000.

Knowledge about the array of local biological resources, such as animal breeds, local plants and tree species, is invested in the minds of resident communities, especially older members.

Many of the major rivers in Africa are transboundary in nature and managing these together with their transboundary mountain catchments is a major challenge calling for a coordinated approach (see Chapter 4). It is made all the more challenging because water is a major driver of national income growth and thus a potential source of conflict as countries seek to implement their own development programmes. A number of river basin commissions have been established and have adopted an integrated approach to managing resources in the catchment area. These include the Congo River Basin Commission and the Orange-Senqu River Commission, which is highlighted on the next page in Box 5.9 as an example of a management approach to restore and maintain transboundary mountain ecosystems.

Support and enhance ecological restoration activities. Ecological restoration is an approach that aims to restore environments that have suffered some form of degradation. It contributes to achieving a number of multilateral environmental agreements: the Conventions on biological diversity, climate change, combating desertification and wetlands. Some countries have adopted the ecosystems approach, the community-based natural resource management method or other ways to ensure land resources are used sustainably. Examples include the development of community-based restoration conservation action plans in Uganda's Mount Elgon region (Bagoora, 2010) and agroforestry systems to restore soil fertility in many countries in sub-Saharan Africa (Liniger, Mekdaschi Studer, Hauert, & Gurtner, 2011).

Encourage local communities to protect and market local high-quality mountain products. Countless contemporary drugs were developed from plants, many of which were derived from the pool of traditional herbal medicines. Knowledge about the array of local biological resources, such as animal breeds, local plants and tree species, is invested in the minds of resident communities, especially older members (FAO, 2004). They continue to be the stewards of local biodiversity and their knowledge can be used in developing new products that may

Box 5.9: The Orange-Senqu River Commission (ORASECOM)

The Senqu River begins in the Maloti Mountains of Lesotho, and flows west where it becomes the Orange River in South Africa. It continues on through southern Botswana, reaching the Atlantic coast near Alexander Bay in Namibia. The Orange-Senqu River Basin is the largest basin south of the Zambezi and spans four countries (Botwana, Lesotho, Namibia and South Africa), totaling an area of more than 1 million km^2. Approximately 14 million people reside within the Orange-Senqu River Basin and a total of 19 million people rely on it for agriculture, economic growth and industrial production. The river generates half of South Africa's GDP, supplies almost half of all the electricity produced in Africa and plays a large role in regional development. Recently, however, numerous issues have been affecting its long-term sustainability, including large dams and water use, demand for river resources, climate change and pollution.

The Orange-Senqu River Commission (ORASECOM) was established in 2000 to actively develop and protect the river basin. South Africa hosts the Secretariat, which coordinates activities and implements decisions, acts as a knowledge management repository, performs administrative tasks and mobilizes resources, among other responsibilities. It also supports the Council, which is made up of three representatives from each country who are active in their government's water resource sector. Task teams provide technical input, legal advice and financial and communications support to manage projects and ensure that the water resources are managed and developed sustainably.

Between 2004 and 2007, ORASECOM gathered information describing the Orange-Senqu River basin and its water resources. Between 2009 and 2011, it identified and addressed gaps in planning and in the basin's management structure. Examples include identifying climate change impacts, updating and extending the hydrology information, developing an Integrated Water Resource Quality Management Plan (IWRM) and assessing water demand. Presently, ORASECOM is drafting the IWRM Plan and implementing strategic objectives.

As well, there is a UNDP GEF Orange-Senqu Strategy Action Programme to support the IWRM plan. It strengthens institutions in managing knowledge; implements Transboundary Diagnostic Analysis, which will highlight new information to fill knowledge gaps about the basin; provides technical research and demonstration projects regarding those gaps; engages the public's participation; and effectively develops a strategic action programme for national and basin-wide activities. To date, it has helped control encroachment of mountain rangeland invasive species, restore natural grasses and prevent erosion.

Sources: DWAF, 2005; GEF, 2014; ORASECOM, 2014; UNDP-GEF, 2014

Orange-Senqu River

Izbieta Sekowska / Shutterstock

Box 5.10: Agrobiodiversity in Ethiopia

Ninety per cent of Ethiopia's export earnings are based on agro-biodiversity, accounting for 85 per cent of total employment and contributing about 50 per cent of the country's GDP. Agro-ecological conditions are highly influential in the distribution of crop genetic diversity, and the specific conditions in the country's highland areas, making it a centre of origin and genetic diversity for a number of cultivated crops such as chickpea and lentils. The highland areas are also important for other plants such as barley *(Hordeum vulgare*), enset (*Ensete ventricosum*) and yam (*Dioscorea spp*).

Drought generally has a negative impact on ecosystem productivity and increases mortality. In some areas of high crop diversification, repeated drought, degradation of agro-ecological systems and land fragmentation are some of the major factors causing genetic erosion. Species adapted to cold and wet conditions with low reproduction rates and limited mobility seem to be most affected.

The loss of indigenous knowledge systems is worsening the situation. In some cases, farmers are now switching to high yielding crops, which may not be suited to their agro-ecological zones, reducing crop diversity and leading to genetic erosion.

Source: Mkamanga, 2009; van Asten, Fermont & Taulya, 2011

A farmer intercropping cabbage and enset in Sidama, Ethiopia

be a source of income, medicines and food. For instance, local people around Blouberg Mountain in South Africa trade in medicinal plants from the forest habitat as a source of income (Mathibela, 2013). A 2004 study estimated that in South Africa alone, about 20 000 tonnes of medicinal plant material was traded (Mathibela, 2013).

As these species continue to be harvested to fulfill local needs, sustainable use needs to be ensured. Some species may become extinct if they are not harvested with the long term in mind. *Prunus africana*, for example, which is currently being exported from Mounts Kilimanjaro, Meru and Uzungwa in the United Republic of Tanzania, is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, or CITES. Appendix II lists species that are not presently threatened but may become so unless trade is closely controlled (CITES, 2012). Maintaining sacred and cultural forests (see Chapter 2) is one indigenous tool that can be encouraged to enhance the sustainable use and conservation of such species (Msuya & Kideghesho, 2009).

Conserve agrobiodiversity in supporting a green economy. Agricultural biodiversity, or agrobiodiversity, refers to the genetic resources for food and agriculture. They are a source of food, fuel, fibre, medicines and raw materials for industrial purposes and are an important part of the economy (Mkamanga, 2009). One way to conserve agrobiodiveristy is with a green economy approach. At a global level, there are already initiatives to protect agrobiodiversity. The Development Opportunity Crops Network was established in January 2011 to strengthen the role and value of agrobiodiversity in the context of development. It is supported by the secretariats of the Global Forum on Agricultural Research and the International Treaty on Plant Genetic Resources for Food and Agriculture (Looney, et al., 2012). An approach to conserving agrobiodiversity includes empowering mountain communities to take a greater role in decision making for land use management, conservation and implementation of sustainable land use programs. Box 5.10 is an example of the importance of agrobiodiversity to Ethiopia's economy.

The Challenge

Ensure the full participation of both men and women in development activities in mountain areas.

The Constraints

The main barrier to integrating mountain women into development initiatives is their lack of access to education. There are also high levels of inequality in women's access to financial and other productive resources. Lack of access to health services, especially reproductive health and family planning services, is a serious barrier to women's empowerment. Environmental degradation negatively impacts women since it increases the distance they need to travel to collect resources for household use.

The Situation

There is an almost equal proportion of men and women in Africa, yet their contribution to development is not equally recognized. Poverty is higher among women than men. Social indicators are still skewed towards men, but are improving in some instances. Women play a key role in economic sectors such as agriculture.

The Opportunities

There are opportunities to achieve sustainable development through improving gender equality by developing gender equitable laws, policies and programs that facilitate the participation of mountain women.

The Challenge


Martchan / Shutterstock

Women and young girls collect water from a rainwater pool which is purified before use with tablets in Gayo village, Ethiopia

Chapter 13 of Agenda 21, the outcome document from the United Nations Conference on Environment and Development held in Rio in 1992 (discussed in Chapter 4), requests the full participation of women in development activities. Chapter 13 specifies the need for environmental education for farmers, with an emphasis on women, to help understand the ecological issues framing mountain development (UNSD, 1992). In general, women living in mountain areas face similar challenges to women in the developing world, but these challenges are intensified by factors such as elevation, steep topography and isolated locations (Price, 2004). Furthermore, the populations of mountain women across the world, and in Africa, are very diverse. They face unique regional and local challenges and live in differing environmental, cultural, social and political settings (Rudaz & Debarbieux, 2012). The challenge lies in ensuring these requests are fulfilled for Africa's mountain women and girls, while also adhering to environmental, cultural and social needs.

The Situation

There is an almost equal proportion of men and women in Africa, yet women's contribution to development is not equally recognized. According to AfDB (2014), the number of women and men in the population in 2013 was about the same. This is not translated into development policy and practice, however, which perpetuates a situation that trickles into other areas, making access to education and health, financial services, information, legal protection, property and other social services also unequal. Moreover, it hinders women's participation in economic, political and social development. Table 5.2 highlights some gender-specific population indicators in Africa.

Table 5.2: Female population and average population growth rate by gender

	Female population as per cent of the total			Average growth rate 2000-2013 (per cent)		
	1990	2000	2013	Total	Female	Male
Central Africa	50.6	50.4	50.2	2.74	2.72	2.77
East Africa	50.2	50.2	50	2.85	2.83	2.87
North Africa	49.7	49.7	49.9	1.51	1.54	1.48
Southern Africa	50.7	50.8	50.8	2.11	2.10	2.12
West Africa	49.8	49.7	49.5	2.67	2.65	2.69
Africa	50.1	50.1	50	2.44	2.43	2.45

Source: AfDB, 2014

Access to resources for women is less than among their male counterparts. Women hold many responsibilities in the homestead including tending to livestock, planting crops and raising children, but are also responsible for fetching water and firewood (IFAD, 2011). It is estimated that mountain women in eastern Africa expend nearly one-third of their daily caloric intake on gathering and distributing water to their homes and communities (UNEP, 2006). Although responsible for many tasks, women typically have less access to the resources and services necessary to increase their income or improve productivity and fewer opportunities than men to seize development initiatives (IFAD, 2011).

The lack of female participation in decision-making impedes sustainable development and increases women's vulnerability. Women are the main caregivers, tillers of the land and managers of natural resources, but they do not have a major role in decisions regarding these resources. Even when they head the households due to short-term absences of men, they still do not have the same levels of access to resources as men. An example is title deed ownership, the lack of which hampers women's efforts to improve or invest in resource management in a way that would improve livelihoods or reduce vulnerability to climate change and other environmental and social changes. In Ethiopia's Choke Mountains, for example, gender inequality in major household decisions together with the lack of women's participation in climate change adaptive and mitigation projects results in a higher vulnerability of households to the impacts of climate change (Nigussie, 2013).

Mountain women in eastern Africa expend *nearly one-third of their daily caloric intake on* gathering *and* distributing *water to their homes and communities*

The Constraints

The lack of access to education is the main barrier to integrating mountain women into development initiatives. Some of the reasons for this include poverty, distance to school, quality of teachers (especially females, who could act as role models) and sanitary facilities (OECD, 2010). Education can break the cycle of economic struggle. Indeed, studies have shown that women with even a few years of primary education have better economic prospects, have fewer and healthier children and are more likely to ensure that their own children go to school (OECD, 2010). According to UNESCO (2012), only two countries in Africa with available data — São Tomé and Príncipe and Mauritius — had yet achieved gender parity in both primary and secondary education. Development would quicken if girls stayed in school to complete quality secondary education (OECD, 2010).

Furthermore, at the World Education Forum in Dakar in 2000, 164 governments pledged to achieve Education for All. The second goal of the Dakar Framework for Action is to ensure that by 2015, all children, particularly girls, in difficult circumstances and those belonging to ethnic minorities, have access to, and complete, free and compulsory primary education of good quality. The fifth goal is to achieve gender equality in education by 2015, with a focus on ensuring girls' full and equal access to, and achievement in basic education of good quality (UNESCO, n.d.). Likewise, the MDGs set the goal of eliminating gender disparities in primary and secondary education by 2005 and of achieving gender equality by 2015. Such international agreements give countries, including Africa's mountainous nations, specific educational targets to work towards to achieve gender equality. None of the Dakar goals will be achieved, however, and a 2013/14 progress report noted that "In sub-Saharan Africa, the poorest girls will not achieve universal primary completion until 2086" (UNESCO, 2014c).

> ...strengthening *gender equality* **yields** *the highest* **returns** *of all development investments*

Of the 20 countries with available data for education attainment, only 8 countries had higher attainment rates for females than males when considering the population over the age of 25 that had completed primary school (Figure 5.7). Of those 8, 5 countries have land that is 1 500 m in elevation or higher. More data is needed on educational attainment for specific mountain areas.

There are high levels of inequality in women's access to financial and other productive resources such as employment, land and property and yet women play a key role in important sectors such as agriculture. According to the UN (2009), strengthening gender equality yields the highest returns of all development investments. It strengthens women's rights, increases agricultural productivity, reduces hunger and promotes economic growth. Denying women access to land, finances and the right to inherit property also has implications on households (Dejene, n.d.).Women in sub-Saharan Africa are responsible for 75 per cent of household agricultural production and make up about 50 per cent of the agricultural labour force (FAO, 2010), although these figures mask differences at national levels. In the mountainous country of Madagascar, for example, women's participation in the agricultural labour force is 81.1 per cent (World Bank, 2013a). In Malawi, Mozambique, Rwanda and Sierra Leone, the proportion of women who are

Figure 5.7: Educational attainment of the population aged 25 years and older, by gender, for selected countries

Source: UNESCO, 2014a; UNEP/DEWA

Box 5.11: The productivity costs of gender inequality

The costs of gender inequality can best be understood by quantifying the role of women in sectors such as agriculture where they play a big role. When women and men have equal access to agricultural inputs, there are significant increases in productivity at household and community levels. Research shows that yields could increase by 20-30 per cent at the household level, translating into an increase in total agricultural output of 2.5-4 per cent in developing countries.

In Africa, it is estimated that eliminating inequalities in access to agricultural inputs and land would increase yields on women's farms in some mountainous counties by 14 per cent in Malawi and 20 per cent in Kenya.

Source: FAO, 2011a; World Bank, 2013a

economically active is higher than that of men (AfDB, 2014). The constraint is that women are disadvantaged in many land-tenure systems and often have weak property and contractual rights to land, water and other natural resources. There are examples of where the situation is changing, however; in Rwanda, for example, the 1999 Inheritance Law gives women equal inheritance rights with men (OECD, 2011). Box 5.11 explains some of the costs of gender inequality.

Lack of access to health services, especially reproductive health and family planning services, is a serious barrier to women's empowerment. The lack of access to health care has significant social and economic repercussions for women, in particular in relation to health, employment and income generation. Access to health services helps to prevent maternal mortality, allows child spacing and reduces vulnerability to disease that would otherwise lead to a loss in productive time and income through ill health. There are many reasons why health services are often inaccessible to women in isolated mountain areas. Some of these include poor road infrastructure that may be impassable during the rainy season, long distances between communities and health centres, unpredictable transport and lack of availability of medical personnel. For example, maternal mortality rates in Lesotho's rural, mountainous and isolated areas are particularly high at about 620 per 100 000 women in 2013 (AfDB, 2014). In the remote Dabat district, located at the foot of the Simien Mountains in northwest Ethiopia, where over 90 per cent of children live 1.5 or more hours from a health centre, children had a two-fold greater risk of dying compared to those who lived within 1.5 hours of the facility (Okwaraji, et al., 2012).

At the foot of the Simien Mountains... over 90 per cent *of children live 1.5 or more* hours *from a* health *centre...*

Environmental degradation negatively impacts women since they have to go further to collect resources for household use. Women and children, especially girls, are responsible for providing household water, fodder and fuelwood and also play a crucial role in food security. Deforestation or degradation of water resources increases the hardships for women since they have to walk further to collect fuelwood and water, while soil erosion affects food yields and thus food security. The pressures are even greater in female-headed households, which can be high in some mountainous countries. For instance, in 2007, women headed 47.9 per cent of households in Swaziland; in 2011, the proportion was 26.1 per cent in Ethiopia; it was 26.8 per cent in Burundi in 2010; and in 2009, it was 36.3 in Lesotho (World Bank, 2013a).


Women rice farmers in Madagascar

IRRI Photos / Flickr / CC BY-NC-SA

Women in Burundi who have been taught to grow rice

The Opportunities

Gender equality *is at the heart of the MDGs and has been* recognized *at a global level as an* essential *ingredient for* sustainable *mountain development.*

There are opportunities to achieve sustainable development by improving gender equality. UNDP's 2011 Human Development Report highlights the transformative potential that promoting gender equality is likely to have on moving the agenda for environmental sustainability forward (UNDP, 2011). Promoting gender equality can advance environmental outcomes by improving access to clean water and sanitation, combating land degradation and reducing deaths due to disasters and indoor and outdoor air pollution. Gender equality can be achieved by increasing the potential for girls to complete secondary education; improving reproductive health, including access to family planning services; increasing women's control over financial and other productive assets and building up a cadre of women leaders at all levels. Government aid may be needed to help to achieve equality. In Lesotho, the education gender gap began to close in 2000 when free primary education was introduced by the government (IFAD, 2008).

Develop gender-equitable laws, policies and programs that facilitate the participation of mountain women in managing natural resources and that secure equitable access and rights to ecosystem goods and services. Gender equality is at the heart of the MDGs and has been recognized at a global level as an essential ingredient for sustainable mountain development. Examples include the Bishkek Global Mountain summit (2002), the Thimphu Declaration (2002) and the Orem Declaration of Mountain Women (2007). The challenge now is translating these so that women can be made an overt part of all development activities, especially in Africa's mountains. A starting point could be a Gender Needs Assessment, which would assist in identifying issues to include in gender policies or legislation. Additionally, women's rights can be introduced into land tenure rights and policies, like they are in Rwanda through policies and laws such as the Matrimonial Regimes, Liberties and Succession Law of 1999, the 2004 National Land Policy, the Organic Land Law of 2005 and the Land Tenure Regularization Process (Santos, Fletschner, & Daconto, 2012).

Build Capacity for Adaptation to Climate Change

The Challenge

Mountainous regions will be affected by the impacts of a changing climate and will need to learn to adapt to changing conditions. African nations will need to develop and support policies, investments and activities that build the adaptive capacity among human and wildlife mountain populations.

The Constraints

Africa is one of the most vulnerable continents to climate change and climate variability: there is already evidence that climate change is affecting the range of disease vectors, rainfall variability, and temperatures, factors which all have an impact on livelihoods and wildlife.

The Situation

Africa is warmer today than it was 100 years ago. Extreme weather-related events such as drought and flooding are increasingly common with severe impacts on peoples' livelihoods.

The Opportunities

Since mountains can be indicators of climate changes, opportunities exist for implementing climate-adaptation strategies, provided that dedicated funding is made available.

The Challenge

Maize affected by drought

Mountainous regions will be affected by the impacts of a changing climate and will need to learn to adapt to changing conditions. African nations need to support policies, investments and activities that build the adaptive capacity among mountainous human and wildlife populations. However, a lack of regional and small-scale meteorological data from which to draw conclusions is a barrier to proper projections and absolute confidence (Hartmann, et al., 2013).

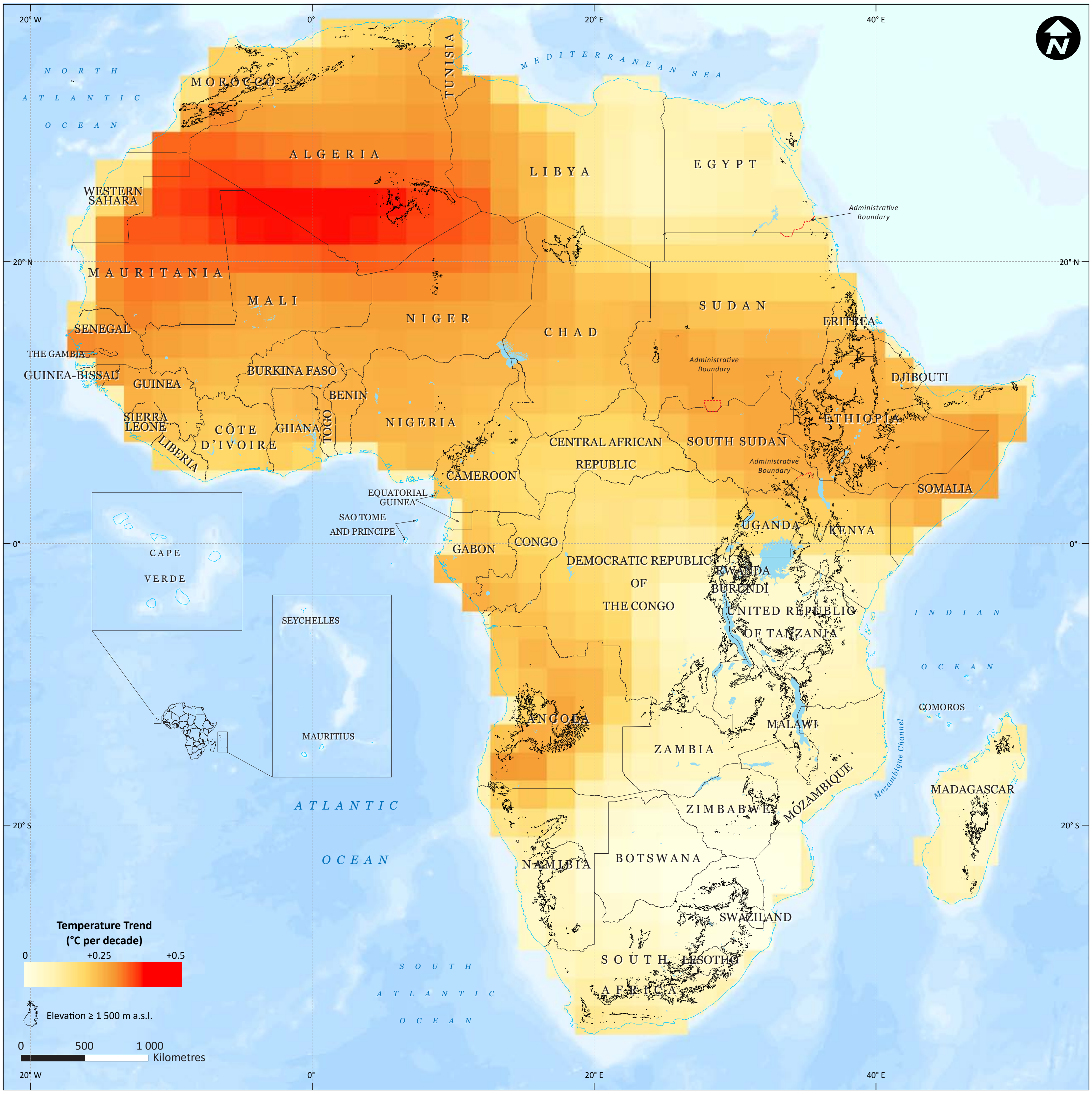
The Situation

Africa is warmer today than it was 100 years ago. According to the IPCC (2007), throughout the 20th century, warming occurred at the rate of 0.7ºC over most of Africa, but not all areas warmed at the same rate. Figure 5.8 shows the distribution of warming across the continent from 1950 to 2013. Specific mountain regions have experienced even greater amounts of warming. For instance, mountainous regions in Morocco have experienced rising temperatures of 1.2ºC (Montanari, 2013). Warming patterns in Africa are similar to global trends, with the most rapid warming having occurred in the 1910s to 1930s and during the post-1970s (Hulme, Doherty, Ngara, New, & Lister, 2001).

Africa will continue to warm during the 21st century (Christensen, et al., 2013), but future temperature changes will continue to vary across the continent, as shown in Figure 5.9a (next page). These changes are similar to those that may occur across Asia, where highland areas are also significant topographic features.

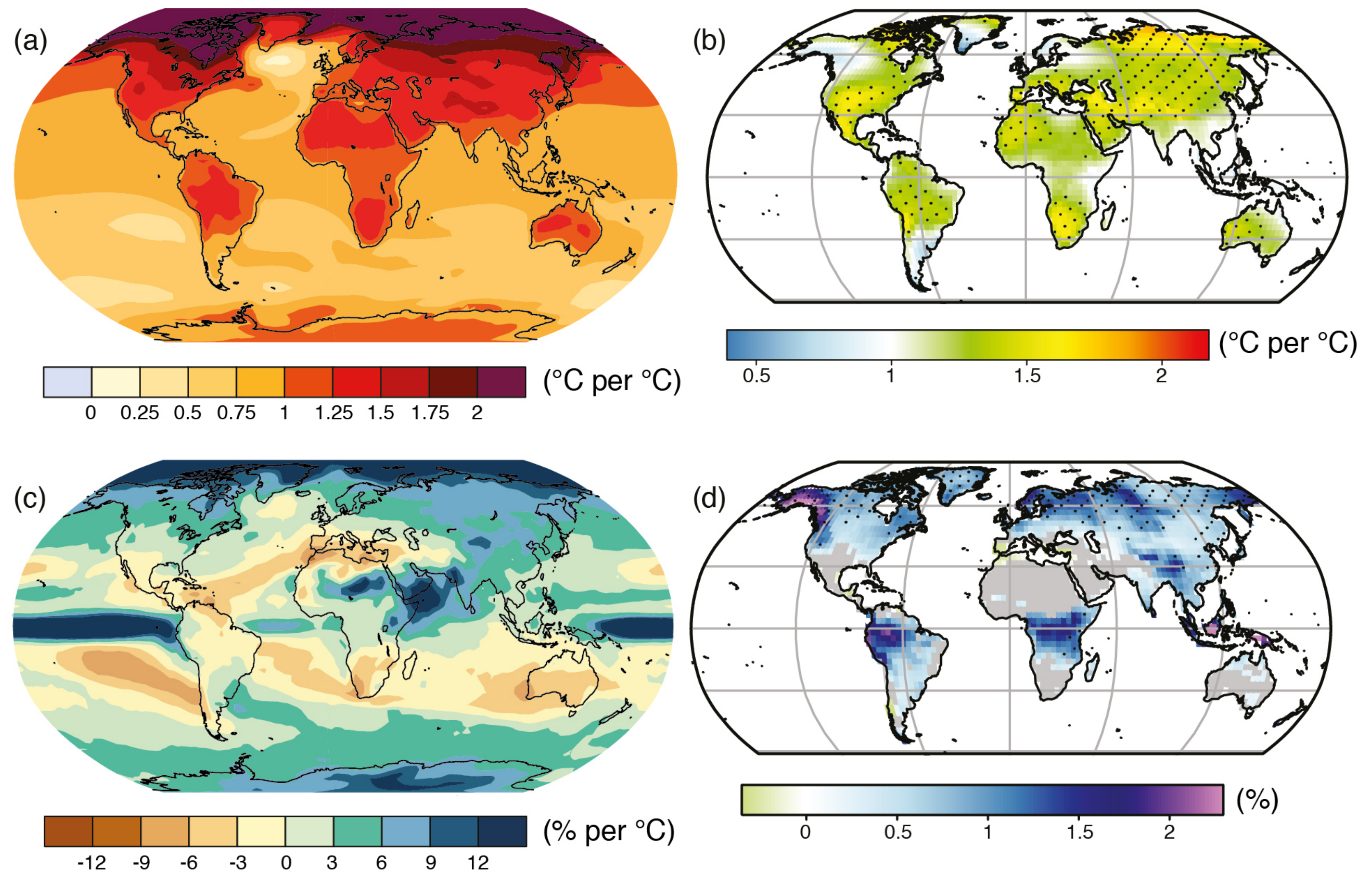
Temperature changes will have implications for evaporation rates, which affect soil moisture. The IPCC projects that southern and northwestern Africa near the Mediterranean Sea will be some of the most affected regions globally regarding increased soil-moisture drying as a result of increased global surface temperatures by the end of the 21st century. This could increase the risk of agricultural drought in southern Africa (Collins, et al., 2013).

Figure 5.8: 1950 – 2013 temperature trends



Source: Adapted from NASA, 2013; UNEP/DEWA

Figure 5.9: Projected 21st century changes in annual mean and annual extremes (over land) of surface air temperature and precipitation: (a) mean surface temperature per °C of global mean change, (b) 90th percentile of daily maximum temperature per °C of global average maximum temperature, (c) mean precipitation (in % per °C of global mean temperature change), and (d) fraction of days with precipitation exceeding the 95th percentile.



Source: Christensen, et al., 2013
Note: Figures 5.9a and 5.9c reflect projected changes in means between 1986–2005 and 2081–2100 from CMIP5 simulations under RCP4.5 scenario; Figure 5.9b and 5.9d reflect projected changes in extremes over land between 1980–1999 and 2081–2100.

Future changes in rainfall patterns will also be unevenly distributed across Africa's mountainous regions. The IPCC states with medium confidence that there will be a small delay in the rainy season, but an increase in precipitation at the end of the season at the continental level. However, some regional variations exist (Figure 5.9c). For example, there may be an increase in rainfall in eastern Africa during the short rainy season, but little change in average precipitation, and possibly a decrease in precipitation in the austral winter in southern Africa (Christensen, et al., 2013). An empirical downscaled model for South Africa indicates increasing summer rainfall (Dec, Jan, Feb) over the central and eastern plateau and the Drakensberg Mountains (Conway, 2009) and under the Representative Concentration Pathway 8.5 (RCP8.5) scenario, the IPCC concludes that in some seasons, it is likely that South Africa will experience decreased precipitation by the end of the 22nd century (Collins, et al., 2013). Water shortages caused by these declines in precipitation are likely to affect many social and economic sectors.

The Constraints

Africa is one of the most vulnerable continents to climate change and climate variability. Many factors limit Africa's capability to address climate change impacts. Socio-economic issues such as poverty and disease, environmental issues such as land degradation and pollution and legal and institutional issues such weak governance structures combine to lower the capacity to manage or survive the impacts of a changing climate (Boko, et al., 2007). Because most African mountain areas are highly dependent on natural resources, climate changes that may damage these assets are likely to have serious consequences for the region's people and economies. Where institutions are weak, communities that are already operating with low-income levels and limited reserves are forced to cope on their own.

Increased rainfall variability contributes to constraining livelihood and economic capacities to adapt to climate-change impacts. Increased aridity in highland areas is likely to affect agricultural production, lead to food insecurity and exacerbate malnutrition; this is likely to occur in northeastern Ethiopia, for example. Other economic impacts will be felt in the transport and power sectors, which are vulnerable to damage from flooding, associated with increased rainfall. Although increased precipitation may be beneficial for agriculture, it could also have economic impacts caused by increased frequencies and intensities of extreme events like floods, affecting the ability of terrestrial ecosystems to recover (Conway, 2009). Floods cause soil erosion, landslides and water contamination and also damage inland water and power infrastructure. Remote mountain areas that may also be poorly resourced are likely to experience a greater impact and recover more slowly (Bird, Hulme, Moore, & Shepherd, 2002). Such mountain-related problems affect roughly 20 per cent or 100 million people in Africa (Mountain Partnership, 2011).

Climate change will affect agrobiodiversity, threatening genetic diversity and the potential for these systems to provide food security. Research in Lesotho, Malawi and Ethiopia, indicate that a variety of factors such as climate change, monoculture, alien invasive species, land fragmentation, a lack of resources for agricultural biodiversity management and replacement of local crop and livestock species by improved breeds, threaten agrobiodiversity, especially from the highlands (Mkamanga, 2009). The effects of climate change, such as drought and floods, are also reducing yields with implications for food security.

There is already evidence that climate change is affecting the range of disease vectors or pathogens in humans, livestock and plants. Climate change (increased temperature, rainfall and drought) are all seen as important drivers for human disease risks in Africa while only drought has been indicated as a driver of risk for animals and only temperature and rainfall for plants (Rweyemamu, Otim-Nape, & Serwadda, 2006). Examples of climate-related diseases include Rift Valley Fever, a human and animal disease associated with above-average rainfall, and water-borne diseases like cholera and diarrhoea, which are associated with both floods and droughts. In addition, Africa has a high diversity of vector-species complexes, which can change their habitat range as a consequence of a changing climate and ecosystems, thus resulting in new disease patterns (Githeko, Lindsay, Confalonieri, & Patz, 2000). For example, temperature,

Floods...*[and their impacts in mountain areas]*...affect *roughly 20 per cent or 100 million* people *in Africa*

Thatched roof huts in the Ethiopian Highlands

Alberto Loyo / Shutterstock

Box 5.12: Climate-related diseases in plants

Climate-related diseases in plants include Sorghum head smut (SHS), Cassava Brown Streak Disease (CBSD) and Cassava Mosaic Disease (CMD). SHS is caused by Sporisorium holci-sorghi, a soil-borne pathogen that is likely to be favoured by hotter and drier conditions. Historically, the first report of CMD came from the Usambara Mountains in the northeastern area of the United Republic of Tanzania in 1894. Rising temperatures are causing an explosion in whiteflies, the insects that carry the viruses causing CMD and CBSD. Cassava is an important food crop, with Africa accounting for more than 50 per cent of global production. It is a resilient plant, growing successfully where cereals and other crops cannot thrive, making it a suitable crop for poor farmers to grow in Africa's marginal areas.

Source: Alabi, Kumar, & Naidu, 2011

A woman using a basket to strain sorghum

Lucian Coman / Shutterstock

rainfall and humidity highly influence the geographical distribution and rate of development of mosquitoes. Indeed, the research indicates an increase in the spread of malaria in highland areas where it was previously unable to survive as it did in eastern Africa's lower-altitude highland areas (Ermert, Fink, Morse, & Paeth, 2012). Modelling the effect of climate change scenarios on malaria distribution in Caminade et al. (2014) also shows an increase in the length of malaria-transmission seasons in the highland areas of eastern Africa as well as those in South Africa, central Angola and Madagascar. However, the models in this research also showed a slight decrease in risk areas in western Africa. Examples of climate-related diseases that can be found in plants are described in Box 5.12.

The Opportunities

There is a need to improve existing data and environmental monitoring networks. Mountains are particularly sensitive indicators of global climate change and are ideal settings for research on the impact of global climate change on species, ecosystems and hydrology (for example, the Rwenzori Mountains in Uganda and DRC) (Bagoora, 2012). However, there is a dearth of observational data available on African mountains. This is because many networks have fallen into disrepair or have not been updated or replaced since they were first installed. There is a general lack of monitoring networks for hydrological, climatological and glaciological conditions, a situation that needs to be rectified (Viviroli, et al., 2011). One recommendation is to include local stakeholders in the monitoring and modelling process, which fosters ownership and knowledge dissemination and at the same time decreases costs and improves quality. To ensure data continuity and effective dissemination, however, it is important to link these lower-level initiatives to networks at sub-national and national levels.

Although global climate change data is available, as shown in Figures 5.9a to 5.9d, regional collaboration is necessary to see how the data truly applies in specific mountain regions. Opportunities to do so are already underway through regional workshops to discuss implications of climate change and adaptation mechanisms, hosted by the Mountain Partnership (FAO, 2014), but these types of workshops could be hosted at a local level as well. A cooperative project among three countries to monitor the impacts of climate change on livelihoods and collect data in mountains is described in Box 5.13.

Box 5.13: Monitoring the impacts of climate change on food security, livelihoods and economic development

The Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) project, funded by the Finnish Ministry of Foreign Affairs, will study the impacts of climate change around Mount Kilimanjaro in the United Republic of Tanzania, the Taita Hills in Kenya and the Jimma Highlands in Ethiopia. It will build up a knowledge base on the impacts of climate change on sensitive mountain ecosystems. Some of these regions, such as the Taita Hills, are home to many rare and endangered species and many communities rely on them for their livelihoods and also for food, water, timber and other natural resources.

The local-level impacts of climate change — on agricultural productivity or outbreaks of insect pests and changes in water resources, for example — are difficult to predict due to the scarcity of monitoring equipment and systems. In the United Republic of Tanzania, the project will collaborate with the Tanzania Meteorological Agency (TMA) to install automatic weather stations on Mount Kilimanjaro, and will work with its lead partners, the University of Dar es Salaam and Sokoine University of Agriculture, to build on-the-ground capacity of Tanzanian institutions to address climate change research and development issues. The CHIESA partners will evaluate the perceptions of farmers and their experiences on how they have been affected by climatic conditions and variability. They will then link this information to scientific data to build the capacity of communities living around Mount Kilimanjaro, and provide them with sustainable and effective options to cope with the impacts of climate change.

Source: CHIESA, 2014

Better forecasting and early warning systems are a prerequisite for adaptation, particularly to predict and prevent the effects of floods and droughts. Such systems provide the opportunity to avoid harm and find alternatives. For instance, information on rainfall and human and livestock health can have economic and well-being implications and so need to be carefully monitored. It is important for local communities to have early warning systems because critical decisions are made at the household level at the onset of adverse environmental changes. Although there is still a need for ground measurements and validation through aerial photographs, maps can still be used in the hydrological modelling of flash floods. In addition, a good data and information support system is necessary for an effective and efficient early warning and disaster management system. Individual countries are advised to prepare mountain-specific disaster-risk management plans that integrate risk assessment, prevention, response and recovery. These plans could contain elements of a green economy, such as sustainable forestry and hazard-resistant road construction. Further, the plans should help restore or establish institutions capable of successfully dealing with hazards and risk management. Some of the challenges that mountain people face when a disaster strikes include delays in receiving information, and in evacuation and humanitarian responses for the displaced, including access to food, safe water and sanitation, recovery and resettlement support and decisions regarding future development.

Traditional knowledge *is* important *in helping ecosystems* adapt *to climate change....*

Expand information and communication technologies (ICT) into remote mountain areas to enhance access to mainstream development. The proposed African Mountain Hub (Ariza, Maselli, & Kohler, 2013) should be operationalized and supported as a specialized platform for building knowledge and capacity, establishing standardized research methods, sharing information and promoting awareness, communication and advocacy.

Protecting the environment and conserving agrobiodiversity is crucial to food security, ecosystem functioning and human well-being. Hence, efforts and practices needed to sustain the environment and preserve biodiversity within Africa's agricultural systems must be encouraged at local and regional levels. Strategies must address poverty issues so they do not further erode agrobiodiversity resources and ecological functions and services. Traditional knowledge is important in helping ecosystems adapt to climate change; in fact, agrobiodiversity is a safeguard against the effects of climate change on the poor (Mkamanga, 2009). Promoting traditional methods that most farmers have relied upon for generations can play a crucial role in maintaining biodiversity in agricultural systems.

A farmer on the slopes of Mount Kenya prepares the land for planting a type of drought-tolerant and insect-resistant maize

Conclusion

The preceding chapters have made evident the lack of enabling institutional, policy and legal frameworks to guide mountain development. This is a major hurdle to achieving sustainable development in mountain areas at national, sub-regional and regional levels. The key message from this chapter supports the conclusion that there is a need for a framework to set and guide the mountain agenda for Africa and create a constituency to buttress it in an efficient, integrated and harmonized manner. Community involvement and knowledge sharing should be foundations for opening up opportunities for improving all the issues discussed in this chapter, since they involve the day-to-day lives of mountain people, especially women — their livelihoods, food security, energy requirements, health care and educational attainment.

References

AfDB. (2014). Gender, Poverty and Inequality Indicators on African Countries 2014. Tunis: African Development Bank (AfDB).

Africare. (2008). The Grand Challenges: Energy, Development, Global Health. Princeton, Woodrow Wilson School of Public and International Affairs: Princeton University.

Agro Eco BV & Grolink AB. (2008). Organic exports –A way to a better life? Export Promotion of Organic Products from Africa. Retrieved June 9, 2014 from, GroLink: www.grolink.se/epopa/Publications/Epopa-end-book

Alabi, O.J., Kumar, P.L., & Naidu, R.A. (2011). Cassava Mosaic Disease: A Curse to Food Security in Sub-Saharan Africa. APSnet Features. doi:10.1094/APSnetFeature-2011-0701.

Ariza, C., Maselli, D. & Kohler, T. (2013). Mountains: Our Life, Our Future. Progress and Perspectives on Sustainable Mountain Development from Rio 1992 to Rio 2012 and Beyond. Bern: Swiss Agency for Development and Cooperation (SDC), Centre for Development and Environment (CDE).

Arnell, N.W. (2012). Climate change and global water resources: SRES emissions and socio-economic scenarios. Global Environmental Change. 14(1), 31-52.

AU. (2013). About Agenda 2063. Retrieved July 14, 2014 from, African Union (AU): http://agenda2063.au.int/en/about

Baanabe, J. (2008). Large Scale Hydropower, Renewable Energy Adaptation & Climate Change & Energy Security in East & Horn of Africa. Kuala Lumpur: Hoso Bunka Foundation (HBF).

Bagoora, F.K. (2010). Challenges of climate change in mountain ecosystems in Africa. An overview presenation at the side event organised by the Mountain Alliance Initiative. Cancun: United Nations Framework Convention on Climate Change.

Bagoora, F.K. (2012). Potential and Climate Change Vulnerability, Impacts and Adaptation Options In African Mountains. A paper presented at the International Conference of Mountain Countries Climate Change in Kathmandu, Nepal 5-6 April 2012. Kathmandu: International Centre for Integrated Mountain Development.

Barr, J. & Mafuta, C. (2007). Chapter 6: Regional Perspectives. Global Environment Outlook 4 (GEO4). Nairobi: United Nations Environment Programme.

Beilfuss, R. (2012). Assessing Hydrological Risks and Consequences for Zambezi River Basin Dams. A Risky Climate for Southern African Hydro. Berkeley: International Rivers.

Bird, K., Hulme, D., Moore, K. & Shepherd, A. (2002). Chronic Poverty and Remote Rural Areas . CPRC Working Paper No 13. Birmingham: Chronic Poverty Research Centre (CPRC).

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., … Hanson, C.E. (Ed). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (p. 433-467). Cambridge: Cambridge University Press.

Brooks, T.M., Mittermeier, R.A., da Fonseca, G.A.B., Gerlach, J., Hoffmann, M., Lamoreux, J.F., Mittermeier, C.G., Pilgrim, J.D. & Rodrigues, A.S.L. (2006). Global Biodiversity Conservation Priorities. Science., 313, 58-61.

CABI. (2005). Report On The Identification Of Income Diversification Options and Development of Small to Medium Enterprise for High Quality Coffee and Macadamia in Kenya. Nairobi: CAB International Africa Regional Centre (CABI-ARC).

Calzadilla, C., Zhu, T., Rehdanz, K., Tol, R.S.J. & Ringler, C., 2009. Economy-wide Impacts of Climate Change on Agriculture in Sub-Saharan Africa. Washington, D.C.: International Food Policy Research Institute.

Caminade, C., Kovats, S., Rocklov, J., Tompkins, A.M., Morse, A.P., Colon-Gonzalez, F.J., Stenlund, H., Martens, P., Lloyd, S.J. (2014). Impact of climate change on global malaria distribution. Proceedings of the National Academy of Sciences of the United States of America 111(9), 3286 – 3291.

Christensen, J., Krishna Kumar, K., Aldrian, E., An, S.-I., Cavalcanti, I., de Castro, M., . . . Zhou, T. (2013). Climate Phenomena and their Relevance for Future Regional Climate Change. In T. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, . . . P. Midgley (Eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1217-1308). Cambridge and New York: Cambridge University Press.

CHIESA. (2014). Welcome to CHIESA. Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA), Nairobi.

CITES. (2012). Convention on International Trade in Species of Wild Fauna and Flora (CITES). Appendices I, II and III. Geneva: United Nations Environment Programme (UNEP).

Collins, M., Knutti, R., Arblaster, J., Dufresne, J.-L., Fichefet, T., Friedlingstein, P., . . . Wehner, M. (2013). Long-term Climate Change: Projections, Commitments and Irreversibility. In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1029-1136). Cambridge and New York: Cambridge University Press.

Conway, G. (2009). The science of climate change in Africa: impacts and adaptation. Discussion paper No 1. October 2009. London: Grantham Institute for Climate Change.

Dejene, Y. (n.d.). Promoting Women's Economic Empowerment in Africa. Addis Ababa: United Nations Economic Commission for Africa (UNECA).

Druilhe, Z. & Barreiro-Hurlé, J. (2012). Fertilizer subsidies in sub-Saharan Africa. ESA Working Paper No.12-04. Rome: Food and Agriculture Organization of the United Nations (FAO).

DWAF. (2005). Introduction to the Orange River Basin. Department of Water Affairs. Retrieved March 11, 2014 from the Republic of South Africa: http://www.dwaf.gov.za/orange/intro.aspx

Eberhard, A., Foster, V., Briceño-Garmendia, C., Ouedraogo, F., Camos, D., & Shkaratan, M., 2008. Africa Infrastructure Country Diagnostic. Underpowered: The State of the Power Sector in Sub-Saharan Africa. World Bank and partners.

Egziabher, T., & Barakhi, O. (1996). Thematic Paper 2: Management of Mountain Resources. Sustainable development in mountain ecosystems of Africa: Proceedings of the African intergovernmental consultation on sustainable mountain development (pp. 42-44). Addis Ababa: African Intergovernmental Consultation on Sustainable Mountain Development.

Emerton, L., Bishop, J., & Thomas, L., 2006. Sustainable Financing of Protected Areas: A global review of challenges and options. Gland and Cambridge: IUCN.

Ermert, V., Fink, A.H., Morse, A.P. & Paeth, H. (2012). The Impact of Regional Climate Change on Malaria Risk due to Greenhouse Forcing and Land-Use Changes in Tropical Africa. Environmental Health Perspectives, 120(1), 77 – 84.

EuropeAid, 2012. Community managed micro hydro power in Southern Africa: Catalyzing modern energy service delivery to marginal communities. Retrieved June 9, 2014, from European Commission: http://ec.europa.eu/europeaid/documents/case-studies/southern-africa_environment_microhydro_en.pdf.

FAO. (2002). State of World Food Insecurity. Rome: Food and Agriculture Organisation of the United Nations (FAO).

FAO. (2004a). Local Knowledge as Part of Agrobiodiversity. Rome: Food and Agriculture Organization of the United Nations (FAO).

FAO. (2004b). What is agrobiodiversity? Retrieved February 27, 2014 from Food and Agriculture Organization of the United Nations (FAO): http://www.fao.org/docrep/007/y5609e/y5609e00.htm#Contents

FAO. (2008). Ministerial Conference on Water for Agriculture and Energy in Africa: the Challenge of Climate Change, 15-17 December, Sirte, Libyan Arab Jamahiriya: Food and Agriculture Organization of the United Nations (FAO).

FAO. (2010). State of Food Insecurity in the World 2010. Rome: Food and Agriculture Organization of the United Nations (FAO).

FAO (2011a). The State of Food and Agriculture, 2010-2011. Women in Agriculture: Closing the gender gap for development. Rome: Food and Agriculture Organization of the United Nations (FAO).

FAO. (2011b). Water for Agriculture and Energy in Africa: the Challenge of Climate Change. Rome: Food and Agriculture Organisation of the United Nations (FAO).

FAO. (2011c). Why invest in sustainable mountain development? Rome: Food and Agriculture Organization of the United Nations (FAO).

FAO. (2014). Strategic Initiative on Mountains and Climate Change: Regional Meetings. Retrieved July 2, 2014 from, FAO and Mountain Partnership: https://mail.google.com/mail/u/0/#inbox?compose=146f84a225d5e5de

FAO, MPS, UNCCD, SDC & CDE (2011). Highlands and Drylands –mountains, a source of resilience in arid regions. Rome: Food and Agriculture Organization of the United Nations (FAO), Mountain Partnership Secretariat (MPS), United Nations Convention to Combat Desertification (UNCCD), Swiss Agency for Development and Cooperation (SDC), & Centre for Development and Environment of the University of Bern (CDE).

GEF. (2014). Did you know Orange-Senqu River Basin largest river basin southern Africa. Retrieved March 12, 2014, from Global Environment Facility (GEF): http://www.thegef.org/gef/content/did-you-know-orange-senqu-river-basin-largest-river-basin-southern-africa

Gichuki, F. N. (2002). Water, environment and development in mountain areas and surrounding lowlands. Nairobi: University of Nairobi.

Githeko, A. K., Lindsay, S. W., Confalonieri, U. E. & Patz, J. A. (2000). Climate change and vector-borne disease: a regional analysis. Bull. World Health Org., 78, 1136-1147.

Hailu, Z., Teshome, E., Desta, G., Wuletaw, Z. (2011). Baseline Study Report Conducted on TRANSACT consortium Micro-Watershed Research Sites. Retrieved July 1, 2014 from, TRANSACT: Strengthening Rural Transformation Competences of Higher Education and Research Institutions in Amhara Region, Ethiopia: http://transact-ethiopia.com/transact/images/Deliverables/TRANSACT%207.pdf

Hamududu, B. & Killingtveit, A. (2012). Assessing climate change impacts on global hydropower. Journal of Energies, 5(2), 305-322.

Hartley, A.J., Nelson, A., Mayaux, P. & Gregoire, J.M. (2007). The Assessment of African Protected areas. JRC Scientific and Technical Reports. Luxembourg: Office for Official Publications of the European Communities.

Hartmann, D., Klein Tank, A., Rusticucci, M., Alexander, L., Bronnimann, S., Charabi, Y., . . . Zhai, P. (2013). Observations: Atmosphere and Surface. In T. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, . . . P. Midgley (Eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 159-254). Cambridge and New York: Cambridge University.

Hulme, M., Doherty, R., Ngara, T., New, M. & Lister, D. (2001). African climate change: 1900–2100. Clim. Res. 17, 145–168.

ICIMOD. (2011). Kathmandu Declaration on Green Economy and Sustainable Mountain Development. Retrieved February 27, 2014 from, International Centre for Integrated Mountain Development: www.icimod.org/resource/4411

IEA. (2012). Access to Electricity Report. Paris: International Energy Agency (IEA).

IFAD. (2008). Enabling poor rural people to overcome poverty in Lesotho. Rome: International Fund for Agricultural Development (IFAD).

IFAD. (2010). Rural Poverty Report 2011: New realities, new challenges: New opportunities for tomorrow's generation. Rome: International Fund for Agricultural Development (IFAD).

IFAD. (2011). Women and rural development. Rome: International Fund for Agricultural Development (IFAD).

IFPRI. (2000). Ending hunger in Africa: Only the small farmer can do it. Washington, DC: International Food Policy Research Institute (IFPRI).

IFPRI. (2013). Global Hunger Index: GHI Data. Retrieved May 16, 2014, from International Food Policy Research Institute (IFPRI): http://www.ifpri.org/book-8018/node/8058

IFDC. (n.d.). Integrated Soil Fertility Management. Retrieved March 18, 2014 from International Fertilizer Development Center: http://www.ifdc.org/Technologies/ISFM/About-ISFM/

Ingram, V., Awono, A., Schure, J. & Ndam, N. (2009). National *Prunus Africana* Management plan for Cameroon, Yaounde: Centre for International Forestry Research (CIFOR).

InterAcademy Council. (2004). Realizing the Promise and Potential of African Agriculture. Amsterdam: InterAcademy Council.

IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (Ed). Cambridge: Cambridge University Press.

Jacobsen, M., Webster, M., & Vairavamoorthy, K. (2012). The Future of Water in African Cities: Why Waste Water?. Washington, D.C.: The World Bank.

Jenny, A. L. & Egal, F. (2002). Household Food and Nutrition in Mountain Areas. An often Forgotten Story. Rome: Food and Agriculture Organisation of the United Nations (FAO).

Kato, M. (2001). Intensive Cultivation and Environment Use Among the Matengo in Tanzania. African Study Monographs, 22(2): 73-91.

Kaunda, C.S., Kimambo, C.Z. & Nielsen, T.K. (2012). Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa. International Scholarly Research Network, 132606.

Kinahan, A. (2011). Bale Mountains National Park Business and Sustainable Finance Plan 2011-2016. Bale, Ethiopia: Frankfurt Zoological Society/Bale Mountains National Park publication.

Kiteme, B., & Wiesmann, U. (2008). Sustainable River Basin Management in Kenya: Balancing Needs and Requirements. In G. Hirsch Hadorn, H. Hoffmann-Riem, S. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Pohl, . . . E. Zemp (Eds.), Handbook of Transdisciplinary Research (pp. 63-78). Heidelberg: Springer.

Kiteme, B., Liniger, H., Wiesmann, U., Notter, B., & Kohler, T. (2007). Land use transformation and global change: The Case of Mount Kenya. roceedings of the Launching Workshop for the Global Change Research Network in African Mountains: Kampala, 23-25 July 2007. Kampala.

KOL. (2013). Millennium Development Goals Status Report 2013 Summary. Maseru: Kingdom of Lesotho (KOL).

Liniger, H., Gikonyo, J., Kiteme, B., & Wiesmann, U.(2005). Assessing and managing scarce tropical mountain water resources - the case of Mount Kenya and the semi-arid Upper Ewaso Ng'iro Basin. Mountain Research and Development. 25(2), 163-173.

Liniger, H.P., Mekdaschi Studer, R., Hauert, C. & Gurtner, M. (2011). Sustainable Land Management in Practice – Guidelines and best Practices for sub-Saharan Africa. Rome: TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO).

Looney, N., Hoogendoorn, J.C., Hughes, J., Kahane, R., Hermann, M., Keatinge, D. & Palmier, H. (2012). Realising the benefits of enhanced agrobiodiversity. Retrieved from New Agriculturist March 13, 2014: http://www.new-ag.info/en/research/innovationItem.php?a=2357

Maher, P., Smith, N.P.A. & Williams, A.A. (2002). Assessment of pico-hydro as an option for off grid electrification in Kenya. Renewable Energy Journal, 28:1357–1369.

MacMillan, L., & Liniger, H.P. (2005). Monitoring and modelling for the sustainable management of water resources in tropical mountain basins – the Mount Kenya example. In Huber, U.M., Reasoner, M.A., & Bugmann, H. (Eds.), Global Change and Mountain Regions: A State of Knowledge Overview (pp. 605-616). Dordrecht: Kluwer Academic Publishers.

Malesu, M. M., Oduor, A. R., Chrogony, K. & Nyolei, D. (2010). Rwanda Irrigation Master Plan. Kigali: World Agroforestry Centre (WAC).

Mathibela, K. M. (2013). An Investigation Into Aspects Of Medicinal Plant Use By Traditional Healers From Blouberg Mountain, Limpopo Province, South Africa. Limpopo: University of Limpopo.

Meier, T. & Fischer, G. (2011). Assessment of the Pico and Micro-Hydropower Market in Rwanda. Nairobi: GVEP International – Africa Regional Office.

Mika, L. (2011). Practical Action Southern Africa: Experiences of setting up of Micro Hydro Power stations for off-grid energy supply to rural communities in Malawi, Zimbabwe and Mozambique. Retrieved June 9, 2014, from Southern African Power Pool: http://www.sapp.co.zw/docs/Harare%20Presentation%20Sept%202011.pdf

Mkamanga, G.Y. (2009). Agro-biodiversity feeds the world. Status report on agro-biodiversity in Africa. Zambia: Community Biodiversity Development and Conservation (CBDC) Africa Network.

Montanari, B. (2013). The Future of Agriculture in the High Atlas Mountains of Morocco: The Need to Integrate Traditional Ecological Knowledge. In: S. Mann (Ed.), The Future of Mountain Agriculture, Berlin: Springer.

Mountain Partnership. (2011). From Rio 1992 to 2012 and Beyond: 20 Years of Sustainable Mountain Development in Africa. Executive Summary and Key Recommendations. Lucerne: UNEPVienna African Mountains for Rio+20.

Msuya, T. S. & Kideghesho, J. R. (2009). The role of traditional management practices in enhancing sustainable use and conservation of medicinal plants in West Usambara Mountains Tanzania. Tropical Conservation Science, 2(1): 88-105.

Mutekanga, F. P., Kessler, A., Leber, K. & Visser, S. (2013). The use of stakeholder analysis in integrated watershed management. Mountain Research and Development, 33(2): 122-131.

N'Faly, Y. & Barry, A. (2006). Rapport sur la situation technique de la petite hydraulique en Guinée. Ministère de l'hydraulique et de l'énergie. Report prepared for training at the International Center for Small Hydropower on 11 October - 22 November 2006.

NASA. (2013). 2013 Continued the Long-Term Warming Trend. Retrieved May 1, 2014 from, National Aeronautics and Space Administration: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=82918

NBI. (2012). State of the River Nile Basin 2012. Entebbe: Nile Basin Initiative (NBI).

Ndam, N. (2004). *Prunus africana*: A traditional medicine finds international fame. In: C. Lopez & P. Shanley. (Ed). Riches of the Forests: For health life and spirit in Africa (p. 33-36). Desa Putera: Center for International Forestry Research (CIFOR).

NEMA. (2008). Pilot Integrated Ecosystem Assessment Report for Uganda: The Lake Kyoga Catchment. Kampala: National Environment Management Authority (NEMA).

NEPAD, AU & AfDB. (2011). Africa Energy Outlook 2040 study. New Partnership for Africa's Development (NEPAD), African Union (AU) and African Development Bank (AfDB).

Nigussie, Y. (2013). Gender inequality: a pro for vulnerability to climate change impacts and a spiral for sustainability of adaptation strategies, evidence from the Choke Mountain Ecosystems, Ethiopia. J. Ecosys. Ecograph., 3(4).

Njiro, E.I. (1998). Human development in the African mountains. Social dynamics, 24(1), 1-33.

Notter, B., McMillan, L., Viviroli, D., Weingartner, R., & Liniger, H.P. (2007). Impacts of environmental change on water resources in the Mt. Kenya region. Journal of Hydrology. 343(3-4), 266-278.

Odhiambo, K. G. (2013). Land consolidation and settlement reorganization: The Rwandan Context. Washington, DC: The World Bank.

OECD. (2010). Investing In Women And Girls - The Breakthrough Strategy for Achieving all the MDGs. Helsinki: Organization for Economic Cooperation and Development (OECD).

OECD. (2011). Women's Economic Empowerment. Paris: DAC Network on Gender Equality (GENDERNET) and Organization for Economic Cooperation and Development (OECD).

Okwaraji, Y.B., Cousens, S., Berhane, Y., Mulholland, K. & Edmond, K. (2012). Effect of Geographical Access to Health Facilities on Child Mortality in Rural Ethiopia: A Community Based Cross Sectional Study. PLoS ONE 7(3): e33564.

ORASECOM. (2014). Orange-Sengu River Commission: One River, Four Nations. Retrieved March 11th, 2014, from Orange-Sengu River Commission (ORASECOM): http://www.orasecom.org/publications.aspx.

Oludhe, C. (2010). Impacts of Climate Variability on Power Generation within the 7 Forks Dams in the Tana River Basin. KME 10th Conference Special Issue: Journal of Meteorology and Related Science (5)2, 13 – 20.

Practical Action. (n.d.). Catalysing modern energy service delivery to marginal communities in Southern Africa (regional hydro). Retrieved June 9, 2014, from Practical Action: http://practicalaction.org/regional-hydro

Price, M. (ed.) (2004). Conservation and Sustainable Development in Mountain Areas. Gland and Cambridge: International Union for Conservation of Nature and Natural Resources.

Rasul, G. (2011). Green Economy for Sustainable Mountain Development 2011. Kathmandu: International Centre for Integrated Mountain Development (ICIMOD).

REMA. (2009). State of the Environment and Outlook Report. Kigali: Rwanda Environment Management Authority (REMA).

Roe, D., Nelson, F. & Sandbrook, C. (2009). Community management of natural resources in Africa: Impacts, experiences and future directions. London: International Institute for Environment and Development (IIED).

ROK. (2010). Agriculture Sector Development Strategy: 2010-2020. Nairobi: Republic of Kenya (ROK).

ROR. (2008). Strategic Plan for the Transformation of Agriculture in Rwanda – Phase II (PSTA II). Kigali: Republic of Rwanda (ROR).

Rudaz, G., & Debarbieux, B. (2012). 'Mountain women': silent contributors to the global agenda for sustainable mountain development. Gender, Place & Culture: A Journal of Feminist Geography (19)5, 615 – 634.

Rweyemamu, M., Otim-Nape, W. & Serwadda, D. (2006). Foresight, Infectious Diseases, preparing for the future. Africa. London: Office of Science and Innovation.

Salami, A., Kamara, A.B. & Brixiova, Z. (2010). Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities. Tunis: African Development Bank (AfDB).

Santos, F., Fletschner, D., & Daconto, G. (2012). Enhancing Inclusiveness of Rwanda's Land Tenure Regularization Program: Initial Impacts of an Awareness Raising Pilot. A paper prepared for the Annual World Bank Conference on Land and Poverty April 2012. Retrieved June 10, 2014 from, Annual World Bank Conference on Land and Poverty: http://www.landandpoverty.com/agenda/pdfs/paper/santos_full_paper.pdf

Sarris, A., Savastano, S. & Christiaensen, L. (2006). The role of agriculture in reducing poverty in Tanzania: A household perspective from rural Kilimanjaro and Ruvuma. Rome: Food and Agricultural Organisation of the United Nations (FAO).

Tamasang, C.F. (2007). Community Forest Management Entities as Effective Tools for Local level Participation under Cameroonian Law: A case study of Kilum-Ijim Mountain Forest, PhD thesis, Faculty of Laws and Political Science, University of Yaounde II. Soa. 91, 93-94.

ten Brink, P., Mazza, L., Badura, T., Kettunen, M. & Withana, S. (2012). Nature and its Role in the Transition to a Green Economy. London and Brussels: The Economics of Ecosystems and Biodiversity (TEEB).

Tfwala, S.S., Manyatsi, A.M. & Wang, Y. (2012). Assessment of Land Degradation at Velezizweni, Swaziland. Res. J. Environ. Earth Sci., 4(10): 878-883.

UN. (2000). Millennium Summit (6 – 8 September 2000). Retrieved June 1, 2014, from the United Nations (UN): http://www.un.org/en/events/pastevents/millennium_summit.shtml

UN. (2009). 2009 World Survey on the Role of Women in Development Women's Control over Economic Resources and Access to Financial Resources, including Microfinance. New York: Department of Economic and Social Affairs, United Nations (UN).

UNCSD. (2011). National Preparations: Synthesis of National Reports for RIO+20, UN DESA/UNDP. Retrieved January 10, 2014 from United Nations Conference on Sustainable Development: http://www.uncsd2012.org/nationalpreparations.html

UNDP. (2011). Human Development Report 2011. Sustainability and Equity: A Better Future for All. New York: United Nations Development Programme (UNDP).

UNDP-GEF. (2014). UNDP-GEF Orange-Sengu Strategy Action. Retrieved on March 11th, 2014 from the United Nations Development Programme - Global Environment Facility (UNDP-GEF): http://undp.orasecom.org.

UNEP. (2006). Africa Environment Outlook 2: Our Environment, Our Wealth. Nairobi: United Nations Environment Programme.

UNECA. (2007). Land Tenure Systems and their Impacts on Food Security and Sustainable Development in Africa. Addis Ababa: United Nations Economic Commission for Africa (UNECA).

UNEP. (2010). State of Africa's Biodiversity. Nairobi: United Nations Environment Programme (UNEP).

UNEP, KWS, KFWG, & ENSDA. (2008). Mau Complex Under Siege: Values and Threats. United Nations Environment Programme; Kenya Wildlife Service; Kenya Forests Working Group; EWASO NGIRO South Development Authority.

UNEP-UNCTAD. (2010). Organic Agriculture: Opportunities for Promoting Trade, Protecting the Environment and Reducing Poverty: Case studies from East Africa. Nairobi: United Nations Environment Programme (UNEP) – United Nations Conference on Trade and Development (UNCTAD).

UNEP-WCMC. (2002). Mountain Watch: Environmental change and sustainable development in mountains. Cambridge: United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC).

UNESCO. (n.d.). Education for All. Retrieved March 18, 2014 from United Nations Educational, Scientific and Cultural Organization http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-all

UNESCO. (2008). Bale Mountains National Park. Retrieved March 18, 2014 from United Nations Educational, Scientific and Cultural Organization: http://whc.unesco.org/en/tentativelists/5315/

UNESCO. (2012). World Atlas of Gender Equality in Education. France: United Nations Educational, Scientific and Cultural Organisation (UNESCO).

UNESCO. (2014a). Data Centre: Education. Retrieved May 16, 2014 from the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics: http://www.uis.unesco.org/DataCentre/Pages/BrowseEducation.aspx

UNESCO. (2014b). Simien National Park. Retrieved March 11, 2014 from United Nations Educational, Scientific and Cultural Organization (UNESCO): http://whc.unesco.org/en/list/9

UNESCO. (2014c). Teaching and Learning: Achieving Quality for All, Summary. Education for All Global Monitoring Report. Paris: United Nations Educational, Scientific and Cultural Organization.

UNSD. (1992). United Nations Conference on Environment and Development: Agenda 21. Rio de Janerio: United Nations Sustainable Development.

UOF. (2002). Mountains and Lowlands: Enemies or Partners? Example of the High Atlas, Morocco. Fribourg: University of Fribourg (UOF).

van Asten, P.J.A., Fermont, A.M. & Taulya, G. (2011). Drought is a major yield loss factor for rain-fed East African highland banana. Agricultural Water Management, 98(4): 541-552.

Vinceti, B., Loo, J., Gaisberger, H., van Zonneveld, M.J., Schueler, S., Konrad, H., Kadu, C.A.C., Geburek, T. (2013). Conservation Priorities for *Prunus africana* Defined with the Aid of Spatial Analysis of Genetic Data and Climatic Variables. PLoS ONE 8(3): e59987. Doi:10.1371/journal.pone.0059987.

Viviroli, D., Archer, D.R., Buytaert, W., Fowler, H.J., Greenwood, G.B., Hamlet, A.F., Huang, Y., Koboltschnig, G., Litaor, M.I., L´opez-Moreno, J.I., Lorentz, S., Schadler, B., Schreier, H., Schwaiger, K., Vuille, M. & Woods, R. (2011). Climate change and mountain water resources: Overview and recommendations for research, management and policy. Hydrol. Earth Syst. Sci., 15:471–504.

von Dach, S. W., Ott, C., Klaey, A., & Stillhardt, B. (2006). Will international pursuit of the Millennium Development Goals alleviate poverty in mountains? Mountain Research and Development, 26(1):4-8.

Von Grebmer, K., Headey, D., Bènè, C., Haddad, L., Olofinbiyi, T., Wiesmann, D., Fritschel, H., Yin, S., Yohannes, Y., Foley, C., von Oppeln, C., & Iseli, B. (2013). 2013 Global Hunger Index: The Challenge of Hunger: Building Resilience to Achieve Food and Nutrition Security. Boon, Washington, D.C., Dublin: Welthungerhilfe, International Food Policy Research Institute and Concern Worldwide.

WCPA-IUCN. (2000). Financing Protected Areas Guidelines for Protected Area Managers. Gland and Cambridge: The International Union for the Conservation of Nature and Natural Resources (IUCN).

WAEA. (2008). Ministerial Conference on Water for Agriculture and Energy, "Hydropower resource assessment of Africa," in Proceedings of the Ministerial Conference on Water for Agriculture and Energy (WAEA) in Africa: The Challenges of Climate Change, Sirte, Libya, December 2008.

WFP. (2013). Burundi: Système de Suivi de la Sécurité Alimentaire – FSMS, Bulletin May 2013. Burundi: World Food Programme (WFP).

Wickama, J.M. & Mwihomeke, S.T. (2006). The Role of Indigenous Knowledge in Combating Soil Infertility and Poverty in the Usambara Mountains, Tanzania. Dar es Salaam: Research on Poverty Alleviation (REPOA).

Wiesmann, U., Gichuki, F., Kiteme, B.P., & Liniger, H.P. (2000). Mitigating Conflicts over Scarce Water Resources in the Highland-Lowland System of Mount Kenya. Mountain Research and Development. 20(1), 2-7.

Willer, H. & Kilcher, L. (eds.). (2012). The World of Organic Agriculture. Statistics and Emerging Trends 2012. FiBL-IFOAM Report. Bonn: Research Institute of Organic Agriculture (FiBL), Frick and International Federation of Organic Agriculture Movements (IFOAM).

Willer, H. & Lernoud, J. (eds.). (2014). The World of Organic Agriculture. Statistics and Emerging Trends 2014. FiBL-IFOAM Report. Bonn: Research Institute of Organic Agriculture (FiBL), Frick and International Federation of Organic Agriculture Movements (IFOAM).

Willer, H., Lernoud, J., & Kilcher, L. (eds.). (2013). The World of Organic Agriculture. Statistics and Emerging Trends 2013. FiBL-IFOAM Report. Bonn: Research Institute of Organic Agriculture (FiBL), Frick and International Federation of Organic Agriculture Movements (IFOAM).

World Bank. (2009). The Nile Basin Initiative. Building a Cooperative Future. Water Week 2009. Washington, D.C.: World Bank.

World Bank. (2010). Towards a Sustainable Energy Future for All. Washington, DC: The World Bank.

World Bank. (2013a). Africa Development Indicators 2012/13. Washington, DC: The World Bank.

World Bank. (2013b). Data. Retrieved May 16, 2014, from the World Bank: http://data.worldbank.org/?display=map

World Bank. (2013c). Fact Sheet: The World Bank and Agriculture in Africa. Retrieved March 13, 2014, from the World Bank: http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/0,,contentMDK:21935583~pagePK:146736~piPK:146830~theSitePK:258644,00.html

World Bank. (2013d). Tourism in Africa: Harnessing for Growth and Improved Livelihoods. Washington D.C.: World Bank.

World Bank (2014). Data: World Development Indicators 2014. Washington, DC: The World Bank. Retrieved April 1, 2014, from http://data.worldbank.org/news/release-of-world-development-indicators-2014

WWF. (2013). The Economic Value of Virunga National Park. World Wildlife Fund. Retrieved January 29, 2014, from http://assets.worldwildlife.org/publications/611/files/original/The_Economic_Value_of_Virunga_National_Park_LR.pdf?1375288396

Wymann von Dach, S., Romeo, R., Vita, A., Wurzinger, M., Kohler, T. (2013). Mountain Farming is Family Farming: A contribution from mountain areas to the International year of Family Farming 2014. Rome: Food and Agriculture Organization of the United Nations (FAO, the University of Bern, Centre for Development and Environment (CDE) and BOKU.

AfDB African Development Bank
AHI African Highlands Initiative
ANP Ahaggar National Park
ARCOS Albertine Rift Conservation Society
ARTA Albertine Rift Transboundary Agreement
AWF African Wildlife Foundation
AMCEN African Ministerial Conference on the Environment
AMD acid mine drainage
AMNP Andringitra Mountain National Park
ANRS Amhara National Regional State
AU African Union
BERSMP Bale Eco-Region Sustainable Management Programme
BLI Bird Life International
BMNP Bale Mountains National Park
BINP Bwindi Impenetrable National Park
CAADP Comprehensive Africa Agriculture Development Programme
CABI-ARC CABI- Africa Regional Centre
CARNPA Central Albertine Rift Network of Protected Areas
CBD Convention on Biological Diversity
CBSD Cassava Brown Streak Disease
CCB Climate, Community and Biodiversity
CDM Clean Development Mechanism
CDE Centre for Development and Environment
CEGENS Centre for the Management of the Environment of Mount Nimba-Simandou
CGIAR Consultative Group on International Agricultural Research
CHIESA Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa
CI Conservation International
CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMD Cassava Mosaic Disease
DAWASCO Dar es Salaam Water Supply and Sewerage Corporation
DEM Digital Elevation Model
DEWA Division of Early Warning and Assessment
DOCNet Development Opportunity Crops Network
DRC Democratic Republic of the Congo
EAC East African Community
EC European Commission
EGS Ecosystems Goods and Services
EIAs Environmental impact assessments
ESRI Environmental Systems Research Institute, Incorporated
EU European Union
EWCA Ethiopian Wildlife Conservation Authority
FAO Food and Agriculture Organisation
FAO-STAT FAO Statistics Division
FDH Fouta Djallon Highlands
FDI Foreign Direct Investment
FEWS Net Famine Early Warning System Network
FFI Fauna & Flora International
GAR Global Assessment Report
GEF Global Environment Facility
GDP Gross Domestic Product
GFAR Global Forum on Agricultural Research
GGNP Gashaka-Gumti National Park
GIS Geographic Information Systems
GNI Gross National Income
GNP Gross National Product and Gombe National Park
GoK Government of Kenya
GPRS Grazing Pressure Reduction Strategy
GRFA Genetic Resources for Food and Agriculture
GRID Global Resource Information Database
IARCs International Agricultural Centers
ICA Infrastructure Consortium for Africa
ICCN Institut Congolais Pour la conservation de la Nature
ICPAC International Climate Prediction and Application Centre
ICRAF International Centre for Research in Agroforestry or World Agroforestry Centre
ICT information and communication technologies
IFA Instream Flow Assessment
IFAD International Fund for Agricultural Development
IGCP International Gorilla Conservation Programme
INECN Institut National pour l'Environnement et la Conservation and de la Nature
IPCC Intergovernmental Panel on Climate Change
ISFM Integrated Soil Fertility Management
ITPGRFA International Treaty on Plant Genetic Resources for Food and Agriculture
IUCN International Union for Conservation of Nature
IWRM Integrated Water Resources Management
KFS Kenya Forest Service
KNP Kibira National Park
KRC Karisoke Research Center
KTDA Kenya Tea Development Agency
KWS Kenya Wildlife Service
KZN KwaZulu-Natalin
LCA Leadership for Conservation in Africa
LHDA Lesotho Highlands Development Authority
LHWP Lesotho Highlands Water Project
MDG Millenium Develepment Goals
MENP Mount Elgon National Park
MGNP Mgahinga Gorilla National Park
MoE Kenyan Ministry of Energy
Mt Mountain
MNP Madagascar National Parks
NARI National Agricultural Research Institute
NASA National Aeronautics and Space Administration
NASA/MSFC NASA/Marshall Space Flight Center
NEMA National Environment Management Authority (Uganda)
NEPAD New Partnership for Africa's Development
NGO Non-Governmental Organization
NNP Nyungwe National Park
NOAA National Oceanic and Atmospheric Administration
ORASECOM Orange-Senqu River Commission
PA Protected Area
PES Payment for Ecosystem Goods and Services
PGA Peak ground Acceleration

PNV Parc National des Volcans
PNVi Parc National des Virunga
PRESA Pro-poor Rewards for Environmental Services in Africa
PWS programmes for watershed services
QENP Queen Elizabeth National Park
RAMSAR The Ramsar Convention on Wetlands
RDB Rwanda Development Board
REDD Reducing Emissions from Deforestation and forest Degradation
REMA Rwanda Environment Management Authority
RMNP Rwenzori Mountains National Park
SADC Southern African Development Corporation
SANP South African National Parks
SBSTTA Subsidiary Body on Scientific Technical and Technological Advice
SDC Swiss Agency for Development and Cooperation
SHS Sorghum head smut
SMNP Simien Mountain National Park
SNP Semuliki National Park
SRTM Shuttle Radar Topography Mission
Tanga UWASA Tanga Urban Water Supply and Sewerage Authority
TBPA Transboundary Protected Area
TCS Transboundary Core Secretariat
TDA Transboundary Diagnostic Analysis
TMA Tanzania Meteorological Agency
TPWS Tasmania Parks & Wildlife Service
TSP Transboundary Strategic Plan
UN United Nations
UNCCD UN Combat to Convention Desertification
UNCED UN Conference on Environment and Development
UNCSD UN Conference on Sustainable Development
UNCTAD United Nations Conference on Trade and Development
UNDP United Nations Development Programme
UNDESA UN Department of Economic and Social Affairs
UNECA UN Economic Commissions of Africa
UNESCO UN Educational, Scientific and Cultural Organization
UNEP United Nations Environment Programme
UNFCCC UN Framework Convention on Climate Change
UNHCR UN High Commissioner for Refugees
UNICEF United Nations International Children's Emergency Fund
UNOCHA UN Office for the Coordination of Humanitarian Affairs
UNOPS UN Office for Project Services
UNSD UN Statistics Division
UN REDD UN Reducing Emissions from Deforestation and forest Degradation
USAID United States Agency for International Development
USDA United States Department of Agriculture
USDA-FAS USDA Foreign Agricultural Service
USFR Uzungwa Scarp Forest Reserve
USGS United States Geological Survey
USGS-GNC USGS Geological Names Committee
USGS-VHP USGS Volcano Hazards Program
UWA Uganda Wildlife Authority
ViNP Virunga National Park
VNP Volcanoes National Park
WCMC World Conservation Monitoring Centre
WCPA IUCN-World Commission on Protected Areas
WDPA World Database on Protected Areas
WFP World Food Programme
WHC World Heritage Centre
WHF World Heritage Fund
WISP IUCN-World Initiative for Sustainable Pastoralism
WRUAs Water Resources Users Associations
WWF World Wildlife Fund

Units
°C degree Centigrade
°N degree North
°S degree South
% per cent
C carbon
cm centimetres
Gt gigatonnes
GW gigawatts
GWh gigawatt hour
KSh Kenyan Shilling
ka thousand years ago
kg kilograms
km kilometres
km² square kilometre
km³ cubic kilometre
kWh kilowatt hour
ha hectare
lat/long latitude/longitude
m metres
m³/s cubic metre per second
m.a.s.l. metres above sea level
Ma million years ago
mm millimetres
m³ cubic metre
m³/yr cubic metres per year
MgC megagram of carbon
MW megawatts
pp/km² people per square kilometre
TSh Tanzanian Shilling
US$ United States Dollar
ZAR South Africa Rand

Strategic Support Team
Ibrahim Thiaw
Mounkaila Goumandakoye
Peter Gilruth
Keith Alverson
Desta Mebratu
Frank Turyatunga
Anna Stabrawa

Technical Coordination
Charles Sebukeera
Musonda Mumba
Robert Wabunoha
Mohamed A.S Abdel-Moneem
Richard Munang
David Ombisi
Ashbindu Singh
Tejaswi Giri
Arshia Chander

Production and Editorial Team

Coordinating Lead Authors
Lindsey Harriman
Ashbindu Singh

Contributing Authors
Boniface Peter Kiteme
Charles Sebukeera
Christopher Tamasang Funwie
Clever Mafuta
Egline Tawuya
Elizabeth Kironde Gowa
Evans Kabue Mwangi
Festus Bagora
Hanspeter Liniger
Joselyne Mutegeki
Kumela Gudeta
Maria Wurzinger
Mohamed Abdel-Moneem
Nilmi Senaratna
Robert Wabunoha
Theuri Mwangi
Thomas Kohler
Urs Wiesmann

Principal Editor
Jane Barr

Technical Editor
Elizabeth Kironde Gowa

Technical Peer Reviewers
Angele Luh, UNEP/ROA
Anna Tengnas, IUCN Eastern and Southern Africa Regional Office, Kenya
Bob Nakileza, Makerere University, Uganda
Callixte Kambanda, ICA, AfDB, Tunisia
Caroline Theka, Environment Affairs Department, Malawi
Cecile Duclaux-Monteil, Gabon
Christopher Tamasang Funwie, University of Yaounde, Cameroon
Damaris Mungai, UNEP/ROA IUCN Eastern and Southern Africa Regional Office, Kenya
Faustin Gashakamba, ARCOS
Festus Bagoora, NEMA, Uganda
Gabriel Senay, USGS/EROS
Guleid Artan, INUTEQ
Gyde H. Lund, Consultant
Janet Macharia, UNEP/EO
John Owino, IUCN Eastern and Southern Africa Regional Office, Kenya
Jourda Jean Patrice Roger, Cote d'Ivoire
Kamwenje Nyalugwe, Enviroplan, Zambia
Kitutu Kimono Mary Goretti, NEMA, Uganda
Maria Wurzinger, CDR, BOKU, Austria
Margaret Afoma Chukwu, Nigeria
Matthias Jurek, Austria
Mohamed A.S. Abdel-Monem, UNEP/ROA
Mookho Monnapula, Lesotho Meteorological Services, Lesotho
Moses H. Duku, Ghana Council for Scientific and Industrial Research
Patrick L. M'mayi. UNEP/DEWA
Paul Mafabi, Directorate of Environment, Ministry of Water and Environment, Uganda
Paul Nteza, UNDP-GEF, Uganda
Philbert Nsengiyumva, ARCOS
Rapule Pule, ORASECOM
Robert Wild, IUCN Eastern and Southern Africa Regional Office, Kenya
Salome Alweny, ARCOS
Sam Kanyamibwa, ARCOS
Soetz Elisabeth, Austrian Development Cooperation
Sophie Kutegeka, IUCN, Uganda
Sunday Leonard, UNEP/DEWA
Thomas Kohler, CDE, University of Bern
Tom Okurut, NEMA, Uganda

Production Support Team
Johannes Akiwumi
Christopher O. Ambala
Jane Muriithi
Elijah Munyao
Onesmus Thiongo
Elizabeth Masibo
Joy Kagoda
Caroline Mureithi
Pauline Mugo

Illustrations and Satellite Image Analysis
Lindsey Harriman
Eugene Apindi Ochieng

Design and Layout
Kim Giese

French Translation
Confiance Lumiku Mfuka
Kouassigan Tovivo

APPENDIX I: IMAGERY SOURCES

(Date: Satellite/Sensor, Bands R, G, B)

Chapter 3

Box 3.2: Landslides on Mount Elgon
11 Mar 2010: EO-1-ALI, Bands 3, 2, 1

Figure 3.4: Extent of ice fields on Mount Kilimanjaro in 1962 and 2000
30 Oct 2013: Landsat 8 OLI, Bands 4, 3, 2

Hotspot: Mount Kilimanjaro, United Republic of Tanzania
24 Jan 1976: Landsat 2 MSS, Bands 2, 4, 1
24 Feb 2013: Landsat 7 ETM+, Bands 3, 4, 2

Hotspot: Rwenzori Mountains, Uganda and the DRC
17 Jan 1995: Landsat 5 TM; Bands 3, 4, 2
09 Feb 2012: Landsat 7 ETM+, Bands 3, 4, 2

Hotspot: Mount Kenya, Kenya
21 Feb 2000: Landsat 7 ETM+, Bands 3, 2, 1
07 Mar 2014: Landsat 8 OLI, Bands 4, 3, 2

Box 3.3: Dust storms over Cape Verde
28 Feb 2014: MODIS Terra, Bands 1, 4, 3

Hotspot: Tibesti Massif and Ennedi Mountains, Chad and Libya
09 Jan 2014: MODIS Aqua, Bands 1, 4, 3

Hotspot: Mount Cameroon, Cameroon
12 Dec 1986: Landsat 5 TM, Bands 7, 4, 2
10 Dec 2000: Landsat 7 ETM+, Bands 7, 4, 2
26 Jan 2012: Landsat 7 ETM+, Bands 7, 4, 2
27 Dec 2012: Landsat 7 ETM+, Bands 7, 4, 2

Hotspot: Nyamuragira, Nyiragongo and the impact on Goma, DRC
07 Aug 1987: Landsat 5 TM, Bands 7, 4, 2
29 Jan 2014: Landsat 7 ETM+, Bands 7, 4, 2
08 Mar 2002: IKONOS, Bands 1, 2, 3
27 Aug 2013: Quickbird, Bands 3, 2, 1

Hotspot: Nabro Volcano, Eritrea
04 Jun 2011: Landsat 7 ETM+, Bands 7, 5, 3
13 Jun 2011: MODIS Aqua, Bands 1, 4, 3
29 Jun 2011: EO-1-ALI, Bands 5, 4p, 2
31 Aug 2011: Landsat 5 TM, Bands 7, 5, 3
02 Jun 2013: Landsat 8 OLI, Bands 7, 6, 4

Hotspot: Cape Town and Table Mountain, Boland Mountain and the Matroosberg Mountains, South Africa
09 Jan 1987: Landsat 5 TM, Bands 7, 5, 3
03 Nov 2013: Worldview, Bands 3, 2, 1
18 Dec 2013: Landsat 8 OLI, Bands 7, 6, 4

Hotspot: Addis Ababa, Ethiopian Highlands, Ethiopia
18 Dec 1984: Landsat 5 TM, Bands 7, 4, 2
01 Dec 2013: Landsat 8 OLI, Bands 7, 5, 3

Hotspot: Dar es Salaam, Uluguru Mountains, United Republic of Tanzania
06 Oct 1986: Landsat 5 TM, Bands 7, 4, 2
17 Jun 2013: Quickbird, Bands 1, 2, 3
12 Jul 2013: Landsat 8 OLI, Bands 7, 5, 3

Hotspot: Marrakech, Atlas Mountains, Morocco
10 Sep 1984: Landsat 5 TM, Bands 7, 4, 2
10 Sep 2013: Landsat 8 OLI, Bands 7, 5, 3
13 Nov 2013: Quickbird, Bands 1, 2, 3

Hotspot: Mount Elgon, Uganda
31 Dec 1984: Landsat 5 TM, Bands 7, 5, 3
29 Nov 2013: Landsat 8 OLI, Bands 7, 6, 4

Hotspot: Lake Alemaya, Ethiopian Highlands, Ethiopia
20 Jan 1985: Landsat 5 TM, Bands 3, 4, 2
01 Feb 1995: Landsat 5 TM, Bands 3, 4, 2
28 Dec 2005: ASTER, Bands 2, 3, 1
04 Jan 2014: Landsat 8 OLI, Bands 4, 5, 3

Box 3.4: Mining volcanic sand from the Karthala volcano
25 Nov 2005: MODIS Terra, Bands 1, 4,3

Box 3.5: Mining near Mount Nimba
26 Dec 2013: Landsat 8 OLI, Bands 4, 3, 2

Hotspot: Witwatersrand, South Africa
07 Jun 1975: Landsat 2 MSS, Bands 2, 4, 1
12 Dec 1986 – 06 Jan 1987: Landsat 5 TM, Bands 7, 5, 3
22 Dec 2013: Landsat 8 OLI, 4, 5, 3
22 Dec 2013 – 31 Dec 2013: Landsat 8 OLI, Bands 7, 6, 4

Hotspot: Letseng Diamond Mine, Lesotho
18 Aug 1984: Landsat 5 TM, Bands 3, 2, 1
15 Jun 2013: Landsat 8 OLI, Bands 4, 3, 2

Figure 3.10: Dark red patches of land indicate recent fire activity in the southern Ethiopian Highlands
25 Jan 2014: Landsat 8 OLI, Bands 7, 5, 3

Hotspot: Mount Moco, Angola
30 Jul 1972: Landsat 1 MSS, Bands 2, 4, 1
21 Jul 2013: Landsat 8 OLI, Bands 4, 5, 3

Hotspot: Aberdare Mountain Range, Kenya
25 Feb 1987: Landsat 5 TM, Bands 7, 5, 3
07 Mar 2014: Landsat 8 OLI, Bands 7, 6, 4

Hotspot: Lesotho Highlands Water Project, Lesotho
07 Jul 1995: Landsat 5 TM, Bands 5, 4, 3
22 Jun 2013: Landsat 8 OLI, Bands 6, 5, 4

Hotspot: Taskourt Dam, Atlas Mountains, Morocco
10 Sep 1984: Landsat 5 TM, Bands 3, 4, 2
10 Sep 2013: Landsat 8 OLI, Bands 4, 5, 3

Hotspot: Tekeze Dam, Ethiopia
22 Nov 1984: Landsat 5 TM, Bands 3, 2, 1
06 Nov 2013: Landsat 8 OLI, Bands 4, 3, 2

Chapter 4

Hotspot: Nyungwe and Kibira National Parks, Rwanda and Burundi
19 Jul 1986: Landsat 5 TM, Bands 7, 5, 3
08 Jul 2011: Landsat 5 TM, Bands 7, 5, 3

Box 4.8: Protecting cultural and natural heritage in Ahaggar National Park, Algeria
16 April 2014: Landsat 8 OLI, Bands 4, 3, 2

Hotspot: Simien Mountains National Park, Ethiopia
22 Nov 1984: Landsat 5 TM, Bands 5, 4, 3
06 Nov 2013: Landsat 8 OLI, Bands 6, 5, 4

Hotspot: Gishwati Forest, Rwanda
06 Feb 1978: Landsat 2 MSS, Bands 2, 4, 1
13 Jul 2013: Landsat 8 OLI, Bands 4, 5, 3

Hotspot: Mau Forest Complex, Kenya
09 Jan 1985: Landsat 5 TM, Bands 7, 5, 3
25 Jan 2014: Landsat 8 OLI, Bands 7, 6, 4

Hotspot: Kilum-Ijim Mountain Forest, Cameroon
09 Dec 1979: Landsat 3 MSS, Bands 2, 4, 1
22 Jan 1987: Landsat 5 TM, Bands, 3, 4, 2
05 Feb 2001: Landsat 7 ETM+, Bands, 3, 4, 2
05 Jan 2013: Landsat 7 ETM+, Bands, 3, 4, 2

Appendix II: About Remote Sensing Images Used in this Publication

The Landsat satellite program, jointly managed by NASA and the U.S. Geological Survey, has collected and archived images of the Earth's surface for over 40 years. This historical record provides a unique opportunity for identifying and documenting areas of environmental change anywhere on the planet. The majority of the remote sensing images used in this atlas are Landsat images. The sensors used in the Landsat series are referred to as "multispectral" sensors. They collect reflected electromagnetic energy from the visible range (0.40 to 0.70 micrometres (µm) as well as wavelengths that the human eye cannot see (0.70-2.35 µm) and thermal energy. Multi-spectral sensors divide the electromagnetic spectrum into a small number of "bands" or ranges of wavelength. For example, Landsat 8 collects electromagnetic radiation in 11 different bands or ranges of wavelength (see table). Each of these ranges of "light" can tell us something different about the Earth's surface.

To create viewable images from multi-spectral sensors, three of the available bands are selected and displayed, each through one of the three colours of standard monitor displays—red, green and blue. This can sometimes yield an image that is not intuitive for a lay-person to interpret (left image). By selecting certain bands and adjusting the distribution of brightness, the overall brightness and the contrast, a more intuitive looking image can be achieved (right image). The images in this Atlas have been adjusted so that non-expert readers can interpret these images more easily. The specific sensors and band combinations used to create the satellite image composites that appear in Chapters 3 and 4 can be found in Appendix I.

Most often, the images are displayed so that growing vegetation shows as various shades of green. Conifer forests will generally show as darker shades of green, as will mangroves to a lesser degree. Broadleaf forests are typically a slightly brighter shade of green. Agricultural fields with actively growing crops can show as a still brighter shade of green; however this is dependent on the crop and its state of growth. The patterns of brightness are often important clues as to the nature of the vegetation as well. Senescent or inactive vegetation generally appears as shades of gray and brown.

Water bodies will generally be blue to black in appearance, but when sediment is present, or the water is shallow, it will appear lighter, even taking on a pink caste at times. Areas of bare ground will show as bright, usually almost white, while urban areas and roads generally appear as a shade of pale purple. Clouds, when they cannot be avoided, will appear as bright white.

In addition to Landsat images, data from other sensors and satellites such as ASTER and MODIS have been used, as well as the high resolution commercial satellites QuickBird , WorldView and IKONOS .

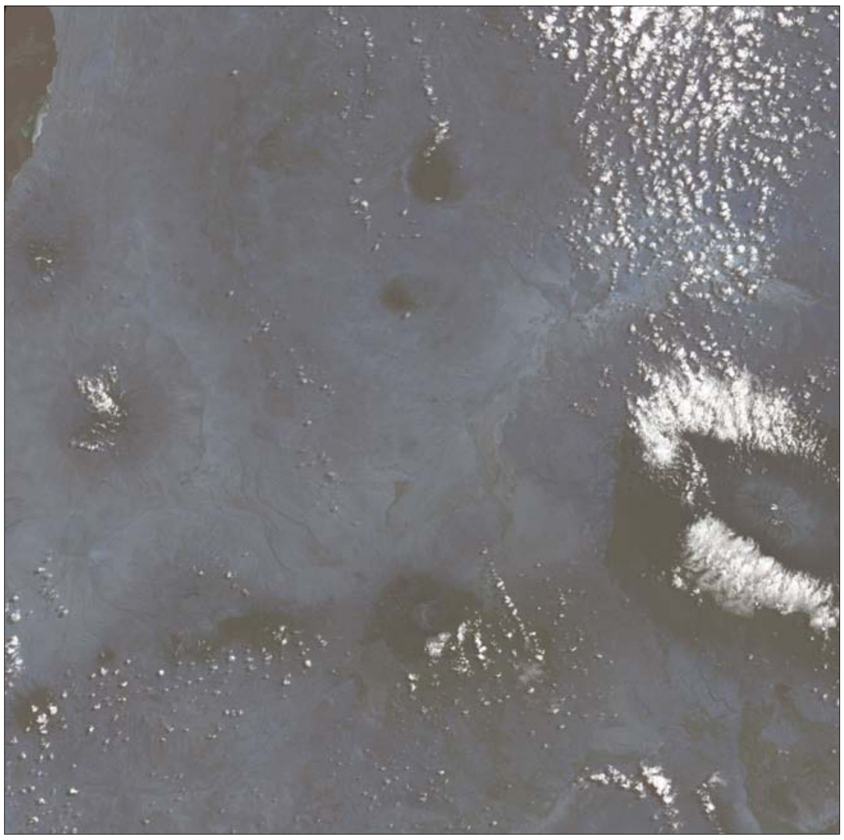
Landsat 8 OLI TIRS Bands

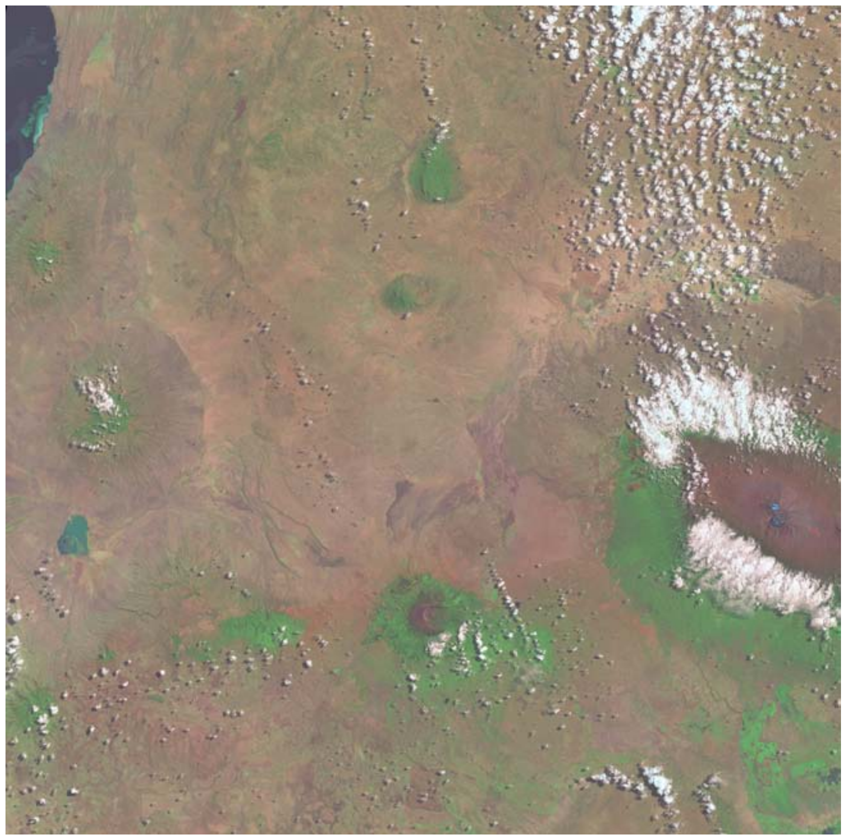
Band	Spectral Range (µm)	Description	Resolution (m)	Mapping Applications
1	0.43 - 0.45	coastal aerosol	30	Coastal and aerosol studies
2	0.45 - 0.51	blue light	30	Bathymetry, distinguishing soil from vegetation and deciduous from coniferous vegetation
3	0.53 - 0.59	green light	30	Emphasizing peak vegetation, which is useful for assessing plant vigor
4	0.64 - 0.67	red light	30	Discrimination of vegetation slopes
5	0.85 - 0.88	Near-infrared radiation (NIR)	30	Emphasizing biomass content and shorelines
6	1.57 - 1.65	Short-wave infrared radiation (SWIR) 1	30	Discrimination of moisture content of soil and vegetation; thin cloud penetration
7	2.11 - 2.29	Short-wave Infrared radiation (SWIR) 2	30	Improved soil and vegetation moisture content; thin cloud penetration
8	0.50 - 0.68	Panchromatic	15	Sharper image definition
9	1.36 - 1.38	Cirrus	30	Improved detection of cirrus cloud contamination
10	10.60 - 11.19	Thermal Infrared Sensor (TIRS) 1	100 (resampled to 30)	Thermal mapping and estimated soil moisture
11	11.50 - 12.51	Thermal Infrared Sensor (TIRS) 2	100 (resampled to 30)	Improved thermal mapping and estimated soil moisture

ASTER (The Advanced Spaceborne Thermal Emission and Reflection Radiometer) is a sensor aboard the National Aeronautics and Space Administration's (NASA) Terra satellite and is a joint effort between NASA, Japan's Ministry of Economy, Trade and Industry (METI) and Japan Space Systems (J-spacesystems).

MODIS (Moderate Resolution Imaging Spectroradiometer) is a sensor carried on NASA's Terra and Aqua satellites.

Both of these images are from the same Landsat 8 image acquired on 27 August 2013 west of Mount Kilimanjaro over Mount Meru in the United Republic of Tanzania. On the left, bands 2, 3, and 4 are shows as red, green and blue, respectively, with the contrast and brightness determined by the default settings of a standard Geographic Information Systems (GIS) software programme. On the right, bands 7, 5, and 3 are displayed as red, green and blue, respectively, and the contrast, brightness and spectral histogram have been adjusted.

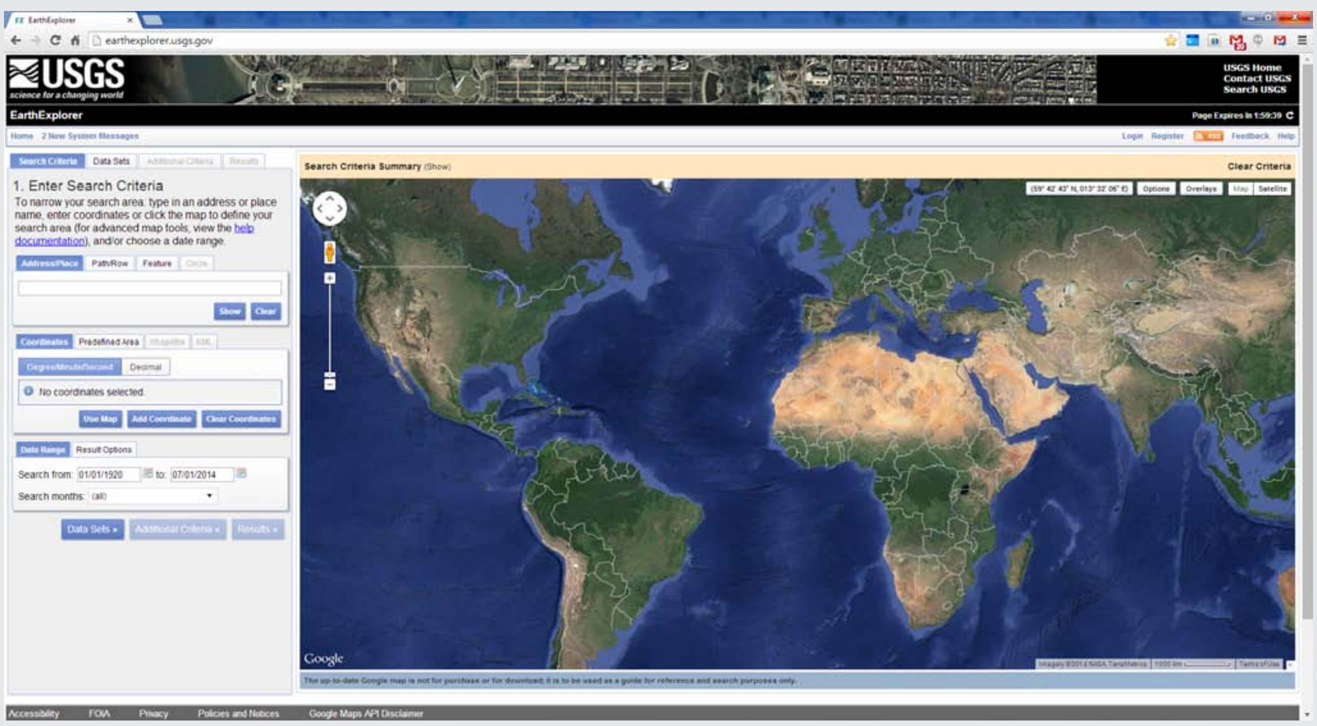




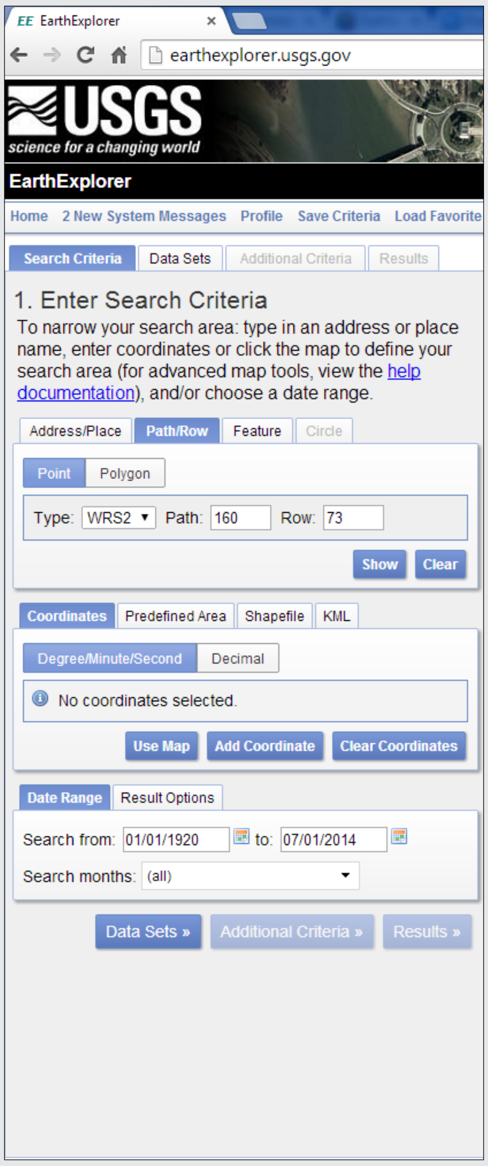
Appendix III: How to Download Landsat Satellite Imagery

1

The extensive 40+ year archive of Landsat satellite images can be downloaded for free from the United States Geological Survey (USGS) from several different platforms including the EarthExplorer site (http://earthexplorer.usgs.gov/) . The user must register and log-in to download images.

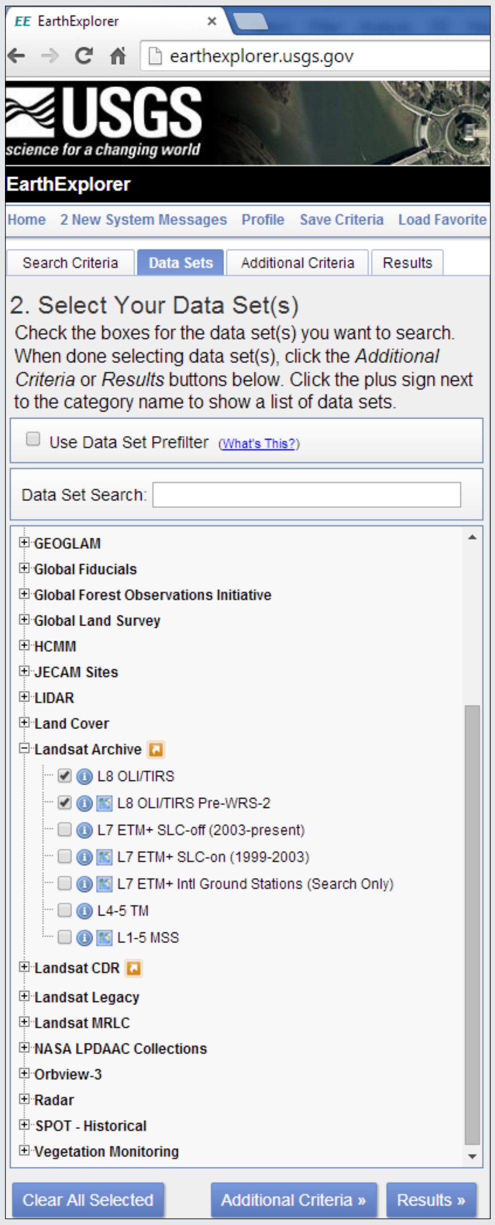


2



Once the user is logged-in, search criteria (address, path/row, coordinates, shapefile etc.) and date range can be entered. The selected example shows a search for path 160, row 73 images acquired during 2014.

3



Then select the Landsat Archive from the Data Sets menu and check in the relevant boxes.

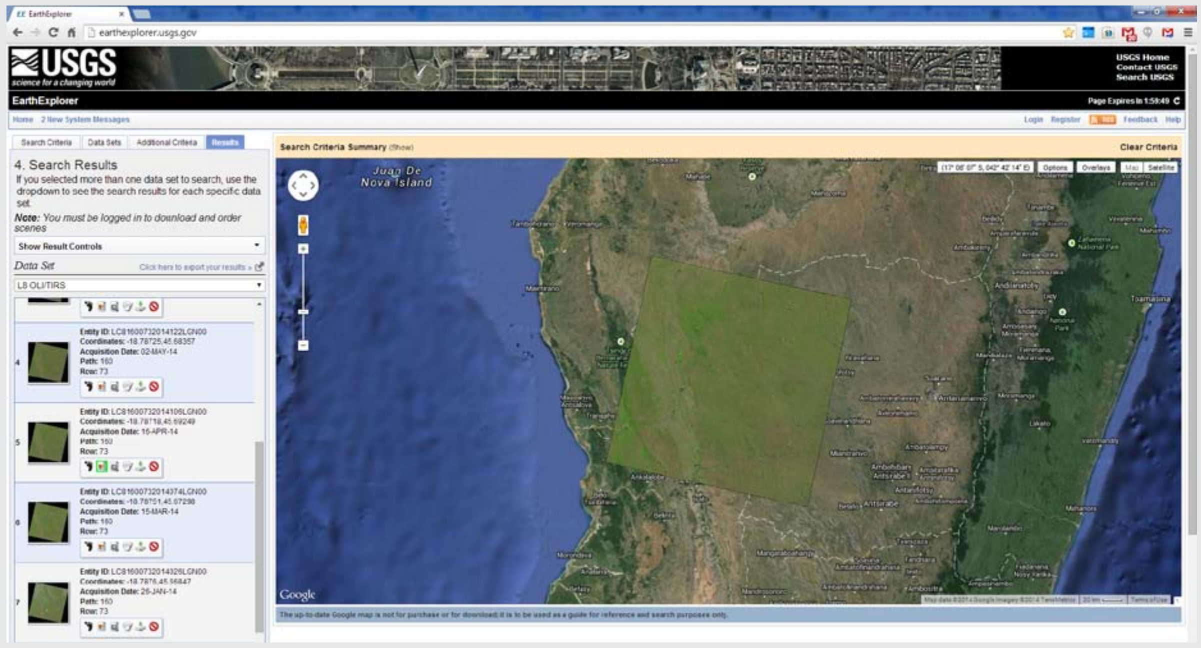
4

Select the appropriate options under the Additional Criteria menu. Make sure that the same criteria are selected for all the data sets under the drop down options of the Data Set. Generally, one should prefer to use the “less than 10% cloud cover” for the Cloud Cover criteria.

5

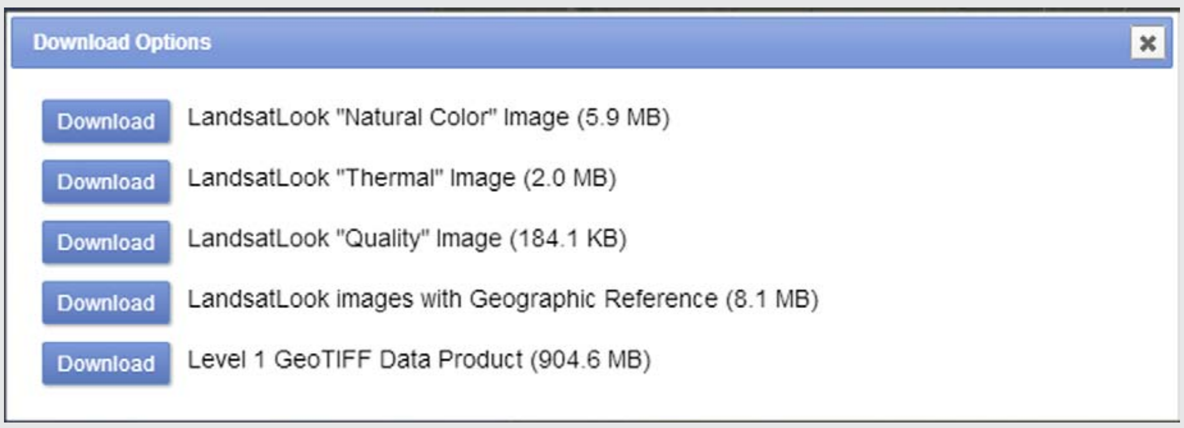
Selecting the Results menu shows all the available images for that particular path/row and acquisition dates.

User can explore different options (footprint, browse, download etc.) under each image. Selecting download option will display the following window.



6

Select "**Download**" next to the "**Level 1 GEOTIFF Data Product**" option. For Landsat 8 images, download is available immediately. For other types of Landsat imagery, depending upon data availability, data may be not be immediately able to be download and rather an order must be placed with USGS. If an order is placed, then the user will receive an email whenever the data becomes available for download.



The image files will download as a zipped folder. The folder must be unzipped in order to process the data.

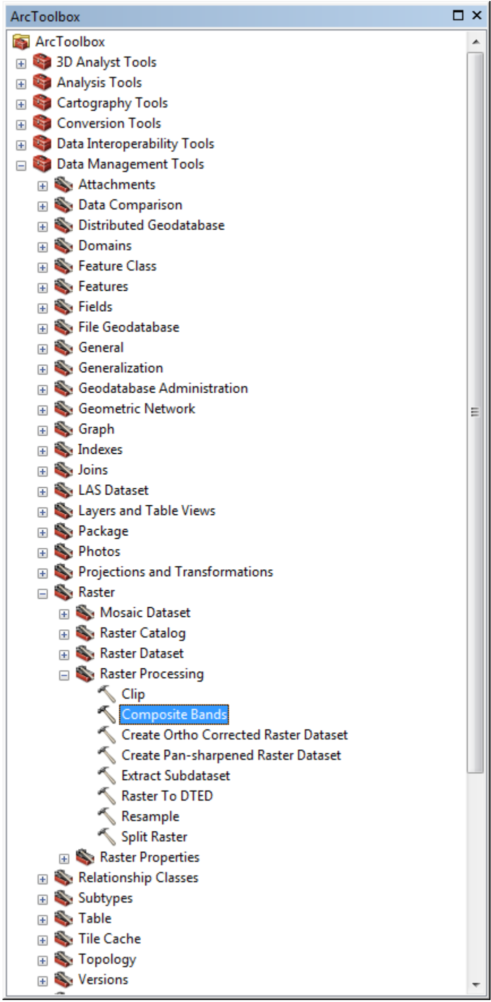
APPENDIX IV: COMPOSITING (STACKING) LAYERS OF IMAGE FILES

1

The user can use any remote sensing and GIS software to process Landsat images. The example shown here is based on the application of ArcMap 10.0 from ESRI.

2

Open ArcMap and then open Arc Toolbox. Select **Data Management Tools – Raster – Raster Processing – Composite Bands**.

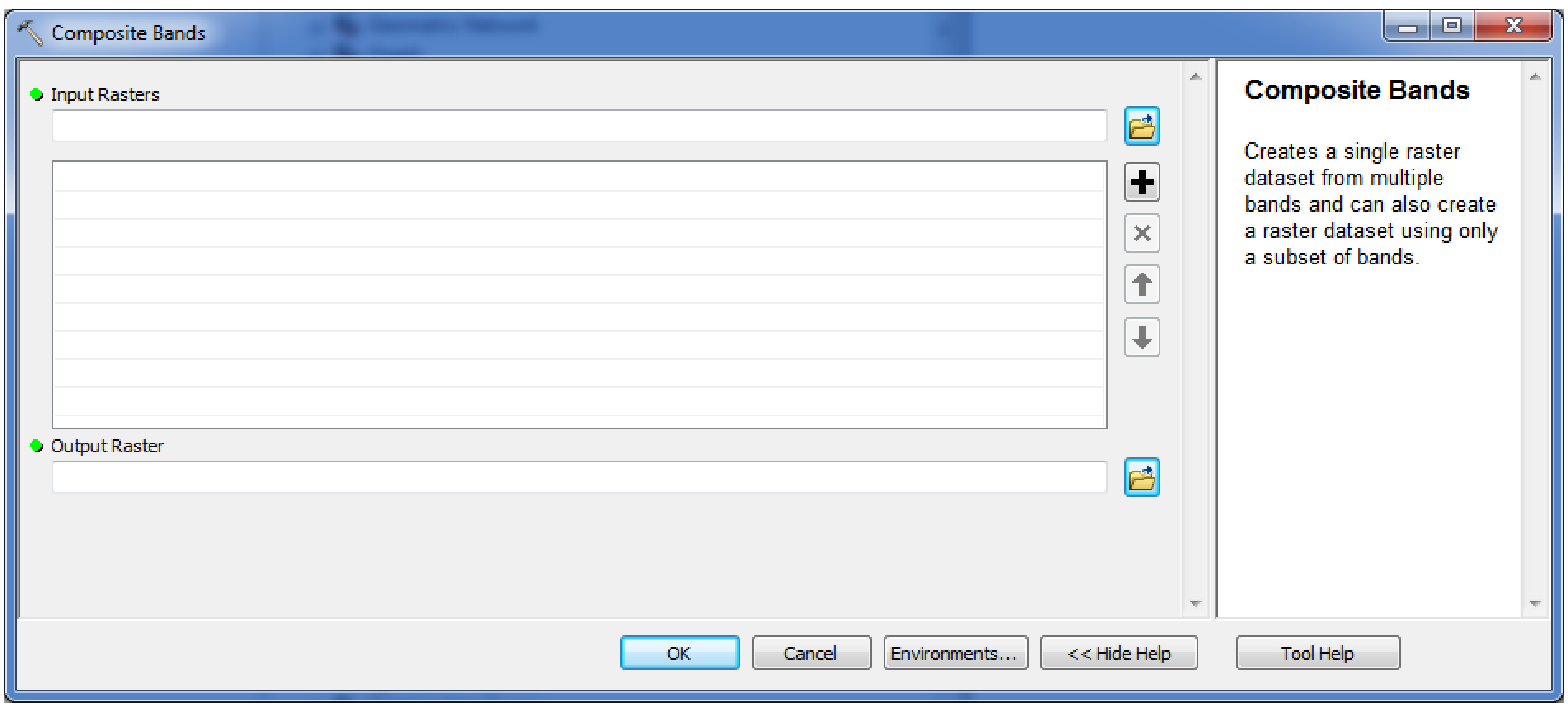


Common composite combinations:

Common RGB Comparisions			
	Composite Type	Landsat 7 & Landsat 5 Combination	Landsat 8 Combination
	Color infrared	4, 3, 2	5, 4, 3
	Natural color	3, 2, 1	4, 3, 2
	False color	5, 4, 3	6, 5, 4
	False color	7, 5, 3	7, 6, 4
	False color	7, 4, 2	7, 5, 3

3

When the Composite Bands window opens, select the file folder and then all the bands necessary to create the composite (typically bands 1 – 7). Select a location for the output raster and rename with the extension .TIF. Select OK. The band combinations can now be altered to get the desire result (e.g. assigning 7, 4, 2 combinations, etc.).



Source: USGS, 2013. How do Landsat 8 band combinations differ from Landsat 7 or Landsat 5 satellite data. Retrieved from U.S. Geological Survey: http://landsat.usgs.gov/L8_band_combos.php

APPENDIX V: ABOUT OUR OTHER DATA SOURCES

Elevation data

For this publication, the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) 7.5 arc second maximum digital elevation model (DEM) product was used to derive and display elevation values of Africa's mountainous areas. In total, there are 21 raster products that comprise the GMTED2010 suite of products, with seven products for three different spatial resolutions: 30, 15 and 7.5 arc seconds. The suite of GMTED2010 elevation products are the result of collaboration between the USGS and the U.S. National Geospatial – Intelligence Agency (NGA). The GMTED2010 products are regarded as the elevation dataset of choice for global and continental scale applications. More information and free download of the products is available here: https://lta.cr.usgs.gov/GMTED2010.

Population data

AfriPop, part of the WorldPop project, population count data was used to calculate population density of Africa. WorldPop produces open source data products using a variety of sources and a distinct methodology to relay demographic information about the world. WorldPop data is available for free under the Creative Commons Attribution 4.0 International License. Methodology information and data download are available here: http://www.worldpop.org.uk/.

To obtain population density data, GIS techniques were used to divide AfriPop population count data by a square kilometre grid.

A

B

C

D

E

F

G

H

N

O

P

Q

R

www.unep.org

United Nations Environment Programme
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
e-mail: uneppub@unep.org
www.unep.org

UNEP

Africa is endowed with dramatic landscapes. The most vivid are its vast plains teaming with wildlife, but rising above them in stark contrast are its impressive mountains. From the iconic snow-capped Mount Kilimanjaro, Africa's highest point, to the massive blocks of highlands that define the vast East African Rift Valley, to the unique Atlas Mountains in northern part of the continent, Africa's mountains represent a variety of ecosystems. Admired and protected for their wild character and beautiful scenery, these mountains are also vital to at least 10 per cent of Africa's 1.1 billion people because of the ecosystem goods and services they provide. The Africa Mountains Atlas uses over 50 compelling satellite images, maps and descriptive text to describe the changes these mountain ecosystems have undergone or are currently experiencing.

The mountains of Africa provide water and food, rich biodiversity, recreational areas and serve as important centres of cultural integrity and heritage. However, Africa faces growing challenges in ensuring the sustainable development of her mountain areas, such as poverty and climate change and addressing the feat of transboundary co-operation. Through use and integration of local and indigenous knowledge, supporting green investments and addressing the multidimensional nature of poverty and food security, these challenges can be surmounted. The Africa Mountains Atlas defines these challenges and presents the associated opportunities that can be seized to prevent unsustainable development of Africa's mountain ecosystems.