In Chapter 3

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LIST OF MAPS

AUTHORS AND CONTRIBUTORS

Janet Nackoney (WRI)
Bancy Mati (ICRISAT)
Greg Mock (consultant)
Linda Cotton (consultant)
Norbert Henninger (WRI)
Florence Landsberg (WRI)
An Notenbaert (ILRI)
Russ Kruska (ILRI)
Eunice Kariuki (ILRI)
Pamela Ochungo (ILRI)
Dan Tunstall (WRI)
Carolina de Rosas (WRI)
Hyacinth Billings (WRI)
Jamie Worms (WRI)

WHAT THIS CHAPTER SHOWS

Water is unique from an ecosystem perspective because water and the associated freshwater systems are linked to all four categories of ecosystem services. This chapter provides an overview of water availability and demand, and describes where in Kenya specific water uses are concentrated. A first set of maps shows the uneven availability of surface water as exemplified by annual and seasonal rainfall, as well as the network of permanent and intermittent rivers. The next map compares water availability to projected demand from households, industry, and agriculture and highlights where demand is projected to exceed local surface and groundwater supplies. The following section presents a series of maps reflecting the main uses and users of water in Kenya: sources of drinking water supply across the country, water transfers to Kenya's two largest urban areas, subdrainage areas important for electricity generation, location of irrigated crop production, and water demand from livestock and wildlife in the rangelands. Two maps showing the occurrence of floods conclude this chapter. They serve as a reminder that impacts from ecosystem processes are not always benign: what constitutes a service for one group or area may be very detrimental to another group or area.

3

Water

Water in sufficient quantity and quality is essential for human well-being. Kenyans use water for drinking, energy generation, livestock production, agriculture, tourism, industry, and many other livelihoods. Lack of adequate, good-quality water is therefore a significant obstacle to development. Exposure to unsafe water, for example, is a major contributor to child mortality and disease in Kenya. Reduced access to water increases collection time—a burden that falls disproportionately on women and children—taking time away from other productive tasks, such as going to school.

Water is also the lifeblood of Kenya's ecosystems. The hydrological cycle sustains life: all organisms need water to survive. Water enters the terrestrial environment as precipitation and then turns into surface flows and groundwater. In the process, aquatic systems such as rivers, lakes, wetlands, and other freshwater habitats are created. Ecological processes such as the cycling of nutrients also depend on water. Unfortunately, water is not always plentiful in Kenya, and the country has been characterized as water scarce. This poses challenges for water management now and in the future.

From an ecosystem standpoint, water is unique in that it is linked to all four categories of ecosystem services (MA 2005):

- *Provisioning services* of freshwater systems include the storage and retention of water (in lakes, rivers, and as groundwater) for domestic, agricultural, and industrial use. Water is a vital input for the production of food (e.g., fish, irrigated crops, and livestock), timber, fiber, and fuel. Of course, freshwater itself is a product for consumption.
- *Regulating services* of freshwater systems and important freshwater habitats such as wetlands include modifying water flows (hydrological flows), recharging and discharging groundwater resources, and diluting or removing pollutants. The ability of freshwater systems to provide these services is strongly linked to the type of vegetation cover and to land cover changes, such as conversion of wetlands or expansion of urban areas.
- *Supporting services* of the hydrological cycle are important for soil formation and soil loss (erosion) and nutrient cycling. Freshwater systems also provide habitat for a great number of species, promoting biodiversity, which underlies the resilience and productivity of ecosystems.
- *Cultural services* include the important recreational benefits provided by lakes and rivers, as well as their spiritual and inspirational roles in different cultures.

Service provision from water often leads to conflicting benefits and costs, depending on the perspective of the different users. A service for one group may be a "disservice" for another. For example, damming rivers for hydroelectric power generation may benefit urban electricity users but harm local fishers. Floods can have both positive and negative impacts depending on the context. While floods can destroy homes, crops, and kill people and animals, they often serve as an important supplier of nutrients to floodplains and are an important factor in maintaining biodiversity and freshwater systems.

This chapter provides an overview of water availability in Kenya as reflected by its annual and seasonal rainfall patterns and networks of permanent and seasonal rivers. It also compares water supply and demand and examines the different uses of water in Kenya's economy. The chapter also highlights floods, one of the potentially hazardous characteristics of water.

The chapter addresses the following questions:

- What is the geographic distribution of water resources in the country?
- How is drinking water obtained in rural and urban areas?
- What is the water demand from livestock and wildlife, and how does it vary across the country?
- How do water and freshwater ecosystems contribute to the economy?

Although this chapter does not specifically examine the topic of wetlands, they deserve a brief note because of their ecological importance. Wetlands cover only 2-3 percent (640,000 ha) of Kenya's surface area (SoK 2003) but play a critical role in Kenya's ecosystems. They provide groundwater recharge and discharge, water storage, filtering of nutrients and pollutants, shoreline stabilization, microclimate stabilization, and habitat for biodiversity. Kenyans raising livestock or growing crops depend on wetlands as a refuge from drought, especially in arid and semi-arid areas (Emerton and Vorhies 1998). Given their high diversity of bird species, wetlands also support tourism activities. It has been a common practice for wetlands in Kenya to be converted to cropland, (e.g., Campbell et al. 2003) undermining their supply of other ecosystem services.

WATER SUPPLY AND DEMAND

Kenya is characterized as having marginal rainfall over most of the country. More than 80 percent of its land area, including much of the northern and eastern regions, is arid or semi-arid and receives very little rain each year (SoK 2003). The area in southwestern Kenya that gets the most rain, known as the highlands, supports 75 percent of the nation's population and generates a significant percentage of Kenya's Gross Domestic Product (SoK 2003).

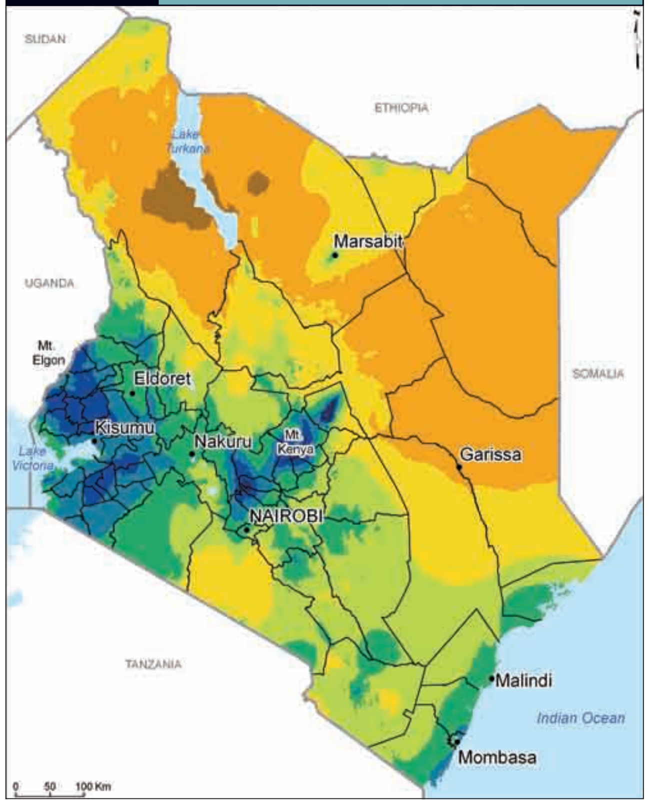
About 32 percent of Kenyan households rely on groundwater for their drinking water supply (CBS et al. 2004). It is also important for industrial use and for crop and livestock production. People living in arid and semi-arid areas rely heavily on groundwater, as it is often the only reliable source of water. Rainfall permeating the soil provides most of Kenya's groundwater resources (Nyaoro 1999).

Rainfall

Rainfall in Kenya is closely linked to the livelihoods of its citizens and the health of the nation's economy. For example, the La Niña drought of 1998-2000 caused damages (loss of hydropower and industrial production, crop and livestock loss, and health impacts) estimated at 16 percent of GDP in each of the following two years (World Bank 2004). Even this number underestimates the full costs of the drought, because it does not reflect costs associated with famine and malnutrition, including loss of lives and livelihoods. The costs of the El Niño floods of 1997-98 are estimated to be of similar magnitude (11 percent of annual GDP).

For a country straddling the equator, Kenya's annual rainfall is relatively low and varies significantly between seasons and from year to year. The average annual rainfall is 630 millimeters per year (FAO 2005), but it is unevenly distributed across

Map 3.1 Average Annual Rainfall



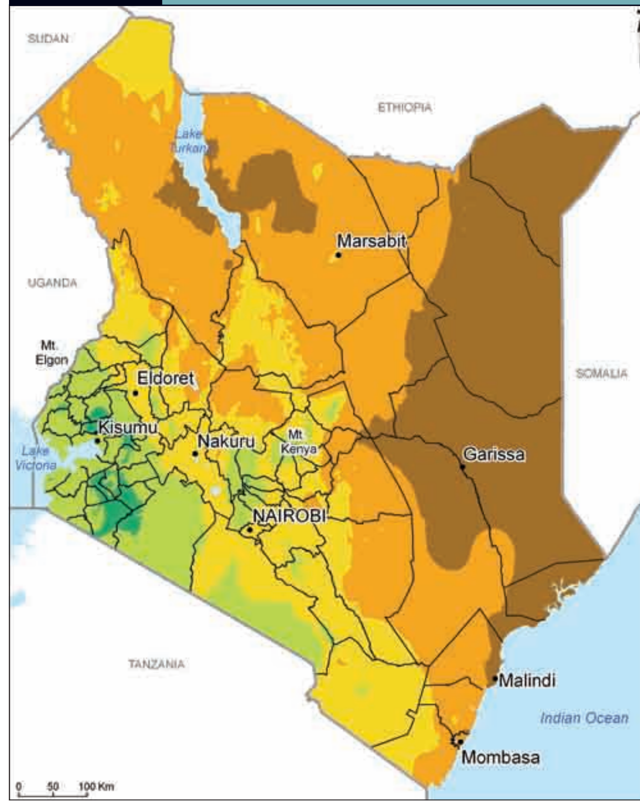
Sources: Administrative boundaries (CBS 2003), cities (SoK and ILRI 2000), water bodies (FAO 2000a), and average annual rainfall (Hijmans et al. 2005).

AVERAGE ANNUAL RAINFALL (millimeters)
- > 2,000
- 1,600 - 2,000
- 1,200 - 1,600
- 800 - 1,200
- 600 - 800
- 400 - 600
- 200 - 400
- <= 200

OTHER FEATURES
- District boundaries
- Water bodies

Areas along the Indian Ocean, in central Kenya close to Nairobi, and in western Kenya bordering Lake Victoria have annual rainfall totals of more than 800 millimeters (a rough benchmark for growing maize). The peaks of high mountain ranges are also associated with elevated rainfall. Rainfall amounts of less than 400 millimeters (which are common in the northern and eastern parts of the country) and of 400–600 millimeters roughly demark Kenya's arid and semi-arid regions.

Map 3.2 Average Monthly Rainfall, February



AVERAGE MONTHLY RAINFALL (millimeters)
- > 400
- 200 - 400
- 150 - 200
- 100 - 150
- 50 - 100
- 25 - 50
- 10 - 25
- <= 10

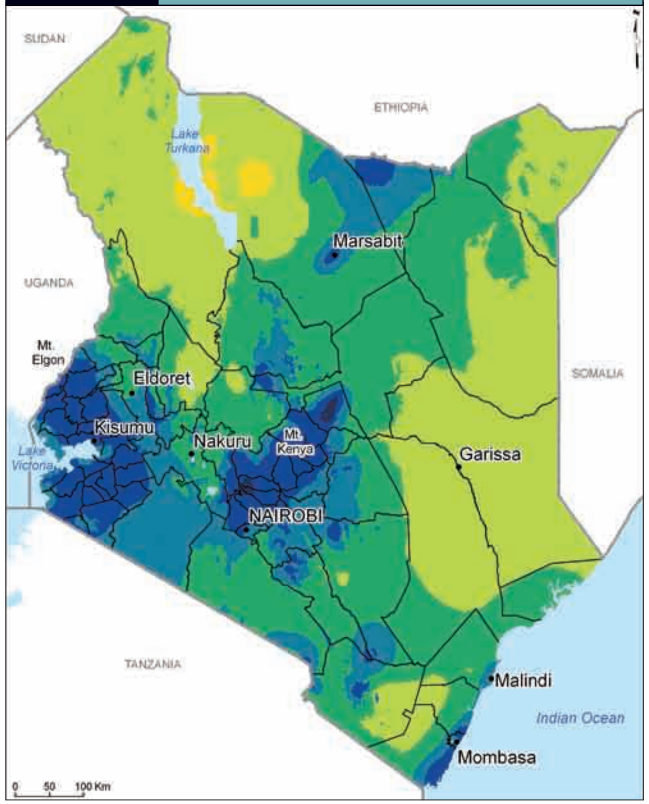
OTHER FEATURES
- District boundaries
- Water bodies

Sources: Administrative boundaries (CBS 2003), cities (SoK and ILRI 2000), water bodies (FAO 2000a), and average monthly rainfall (Hijmans et al. 2005).

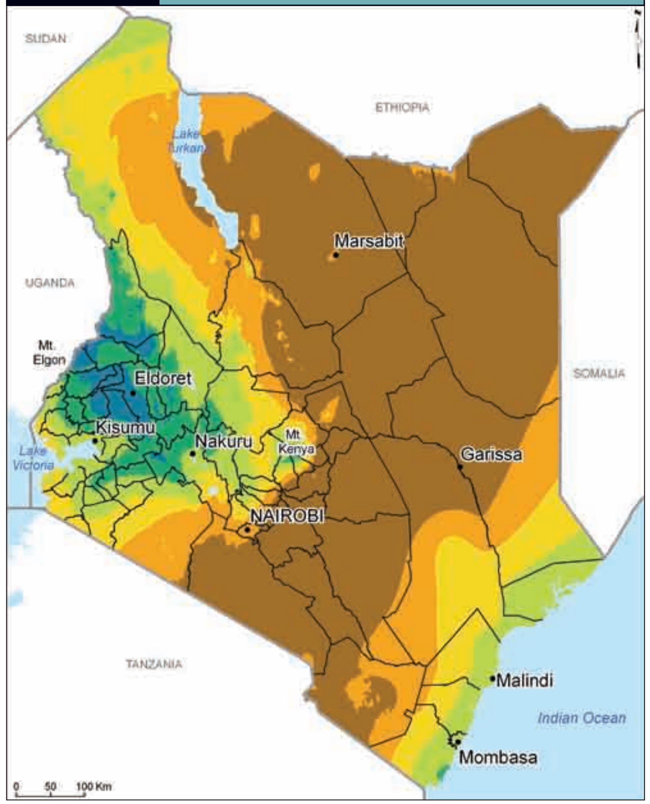
Rainfall in Kenya is highly variable throughout the year. These four maps represent the seasonal variability of the country's rainfall, with average statistics for the months of February, April, July, and November. East of the Rift Valley, two distinct rainy seasons occur. The "long" rains, shown in Map 3.3 (approximated by the monthly rainfall in April), fall from March to May, and the "short" rains (approximated in Map 3.5 with the monthly data in November) fall from October to November. However, the areas in the western part of the country bordering Lake Victoria generally experience one long rainy season from March to September (SoK 2003). During the rest of the year, most of Kenya remains relatively dry (Maps 3.2 and 3.4).

In most parts of the country, the "long" rains account for much of the annual rainfall, but the "short" rains nevertheless play a critical role in many areas. The "short" rains (Map 3.5) are essential for crops to mature in the Districts between Mombasa and Nairobi (Makueni, Kitui, Mwingi, and eastern Machakos), all areas with more marginal annual rainfall amounts of 600–800 millimeters (Map 3.1).

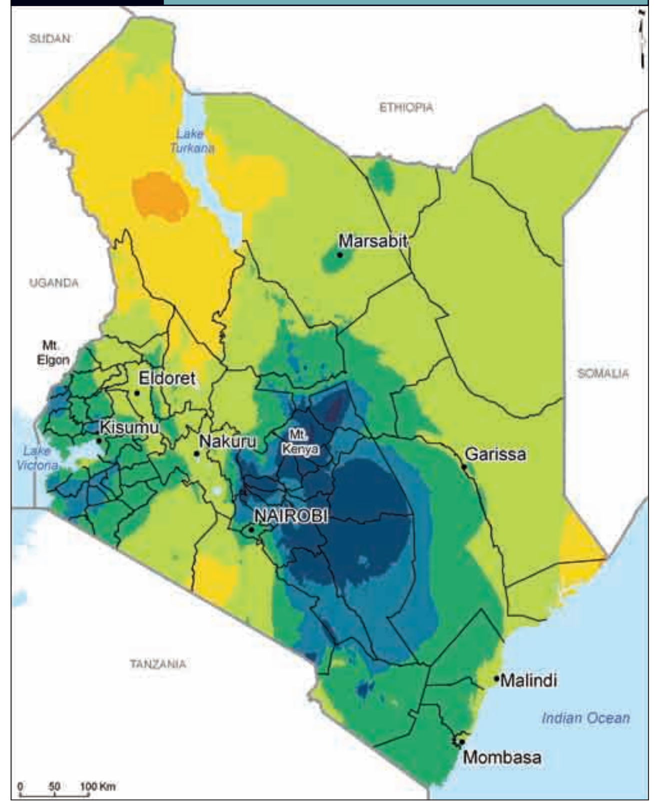
Map 3.3 Average Monthly Rainfall, April



Map 3.4 Average Monthly Rainfall, July



Map 3.5 Average Monthly Rainfall, November



the country (Map 3.1). About 15 percent of Kenya receives sufficient rain to grow maize and other non-drought-resistant crops. Another 13 percent are classified as having more marginal rainfall that is sufficient only to grow selected drought-resistant crops. The remaining 72 percent has no agronomically useful growing season (SoK 2003).

This annual rainfall amount hides the distinct pattern of dry and wet seasons, which vary across Kenya as well (Maps 3.2 – 3.5). In the western and Lake Victoria areas, rainfall is high from March to September, with lower rainfall in January and February (SoK 2003). Areas east of the Rift Valley essentially have two main rainy seasons, referred to as "short" and "long" rains. Kenya is unique in that more of its land area is under two rainy seasons than any other country (Jones and Thornton 1999). This seasonal variation in water availability is reflected in Kenya's great diversity of wild plant and animal communities, which have adapted to these seasonal changes (Oindo and Skidmore 2002). But the unique rainfall pattern also creates a special challenge for growing crops: none of the two rainy seasons is quite long enough to allow very high yields.

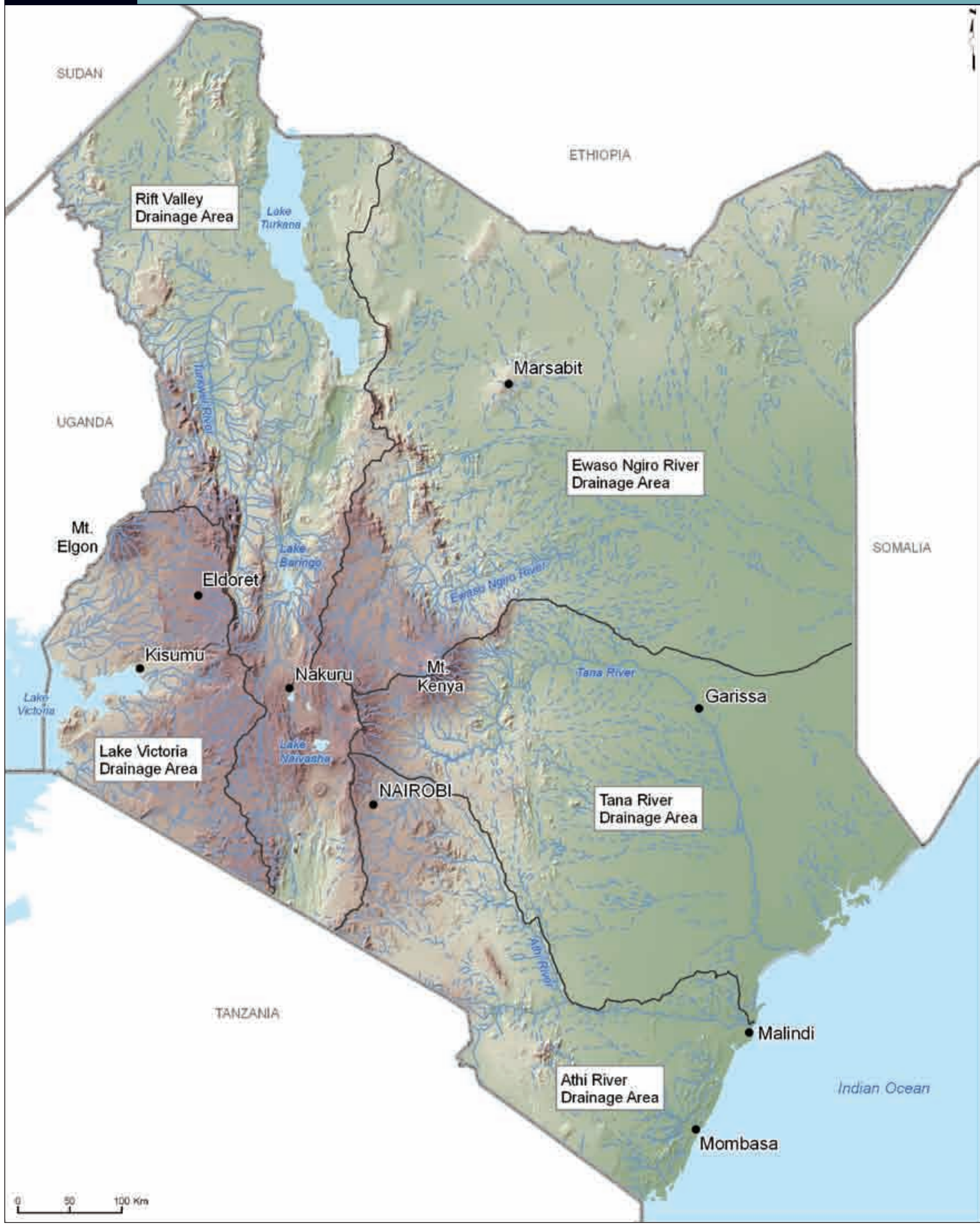
Rainfall amounts and distribution also vary a great deal from year to year. Over the past three decades, eastern Africa has experienced at least one major drought in each decade and floods have occurred frequently (UNEP 2006). Periods of below- and above-average rainfall are somewhat linked (Amissah-Arthur et al. 2002) to sea surface temperature, ocean currents, and atmospheric winds in the southern hemisphere (popularly known as La Niña and El Niño events).

Rivers and Drainage Networks

Surface water from rivers, streams, and lakes provides Kenyans with an important source of water and food. Kenya's major rivers originate in five mountain ranges or 'water towers,' as they are known: Mount Elgon, the Aberdare Range, the Mau Escarpment, Cherangani Hills, and Mount Kenya (See Box 3.1, Map 3.16).

Kenya's network of perennial rivers is most dense in the central and western parts of the country, leading to uneven supplies of surface water. Water resource managers have divided Kenya's surface waters into five large drainage areas: Ewaso Ngiro, Tana River, Rift Valley, Athi River, and Lake Victoria (Map 3.6). A look at the annual renewable water supplies for each of these major drainage areas echoes the patterns shown by a map of Kenya's perennial and intermittent rivers: The Lake Victoria drainage area with its dense network of perennial rivers provides 65 percent of Kenya's internal renewable surface water supply per year. The Athi River drainage area provides the lowest share—7 percent (SoK 2003).

Map 3.6 **Major Drainage Areas and Rivers**



Sources: Cities (SoK and ILRI 2000), water bodies (FAO 2000a), permanent and intermittent rivers (NIMA 1997), 250-meter Digital Elevation Model (SoK, JICA, and ILRI 1996), and major drainage areas (MoWD and JICA 1992a).

This map shows major water bodies and drainage areas, reflecting the spatial distribution of water availability in Kenya. About 1.9 percent of Kenya is covered by water (SoK 2003). Lake Victoria, Lake Turkana, Lake Naivasha, and Lake Baringo are the four largest inland water bodies. Also displayed are the permanent rivers, most of which are found in the highlands, while the intermittent rivers are located in the rangelands. The Tana River (Kenya's longest) and the Athi River flow year-round and travel through significant stretches of dry land. They serve as a vital water and energy resource for people and the surrounding ecosystems.

Major drainage area boundaries

ELEVATION (meters)

High : 4,786

Low : -24

WATER BODIES AND RIVERS

Permanent rivers

Intermittent rivers

Water bodies

Demand Versus Supply of Water

Kenya's total annual renewable water resource is estimated at 30.7 billion cubic meters per year, with 20.2 billion cubic meters coming from internal renewable surface water, and the remainder supplied by groundwater and incoming flows from transboundary rivers (MoWD and JICA 1992b). Using a 2004 population of 32.8 million (CBS 2006), the total renewable water resource available per year is 936 cubic meters per person. Population growth alone will continue to reduce per capita water availability.

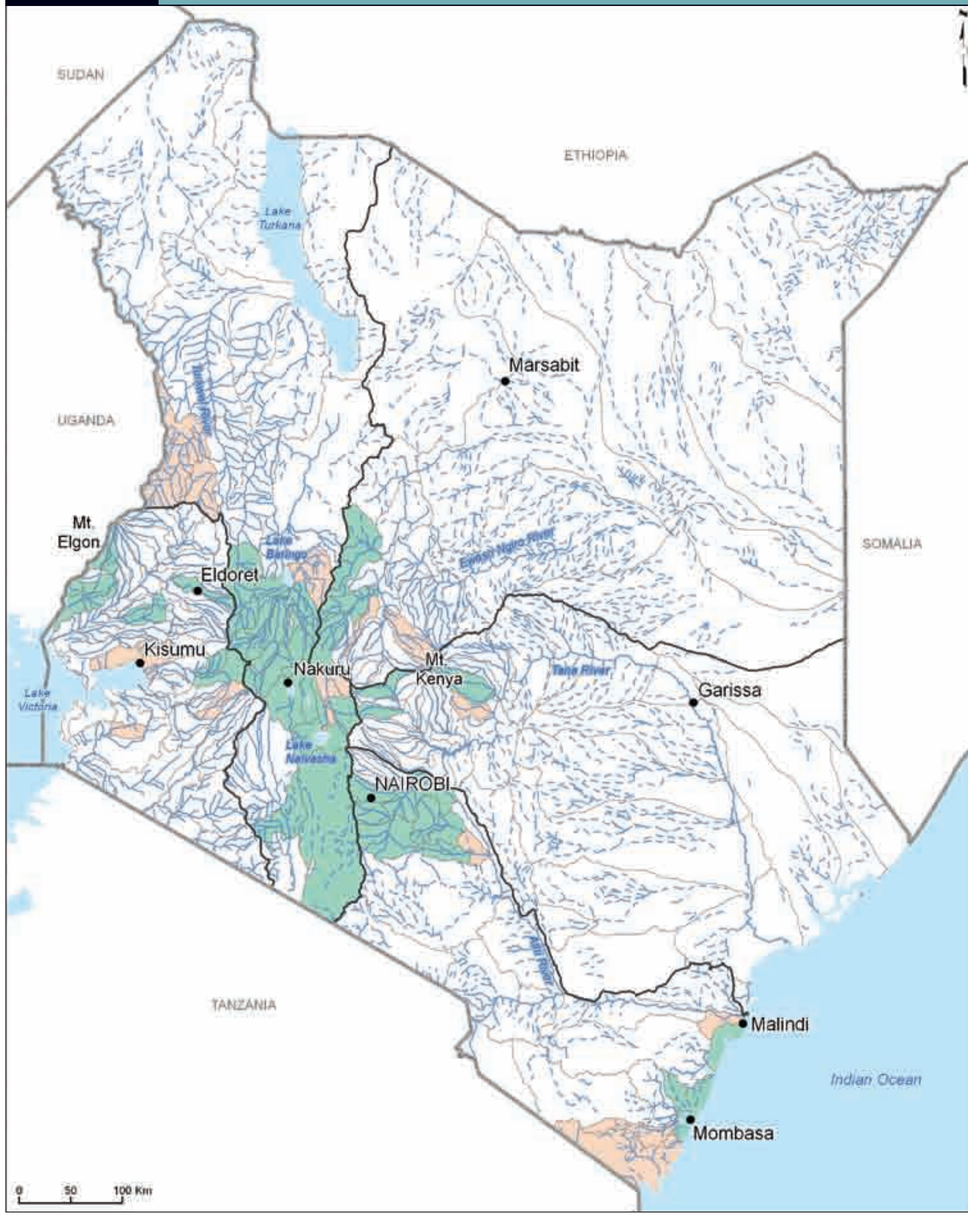
Average water availability of less than 1,000 cubic meters per capita per year designates Kenya as *water scarce*. This signifies that policymakers must pay particular attention to managing water resources so as to avoid hampering food production or impeding economic development. While this national average highlights the challenge posed by water availability to Kenya's development, it masks the great spatial and temporal variability of water supplies. A more detailed analysis of water demand and supply by subdrainage area can reveal where water is scarce and where it is plentiful.

The 1992 *Study on the National Water Master Plan* (MoWD and JICA 1992b) compared potential annual water supply (based on long-term average annual rainfall and maximum exploitable groundwater yield) to annual water demand (for households, agriculture, and industry) for 214 different subdrainage areas, each representing an aggregation of smaller watersheds. Map 3.7 aggregates both average annual surface water and maximum exploitable groundwater resources from the 1992 study and highlights where the projected annual water demand for 2000 and 2010 would exceed supplies. The map shows that subdrainages with densely settled urban populations such as Nairobi and Mombasa cannot cover water needs from their local supplies. In fact both cities have relied on long-distance water transfers for decades (see Maps 3.9 and 3.10). In the Rift Valley subdrainages north and south of Nakuru, local water resources are not sufficient to meet demand. Without continued water transfers from other areas that will keep pace with growing demand, these subdrainages will experience water shortages. Map 3.7 also highlights that even in areas with perennial rivers, demand can outstrip local supplies when a high number of people settle within a subdrainage. For example, some subdrainages in the upper Ewaso Ngiro, Tana River, and in western Kenya are projected to experience a local water deficit.

While such an analysis can pinpoint more location-specific problems, the projections are still based on historic patterns of water use and assumptions about future demographic and economic changes, as well as consumption patterns and investments in water resource development. These assumptions can easily change. For example, the level of rural-urban migration could increase or decrease from the projected rate. Studies show that increased human migration from rural to urban areas multiplies water demand (Thompson et al. 2002; Katui-Katua 2004) and creates a challenge for cities to provide residents and businesses with adequate amounts of clean, piped water for household, commercial, and industrial use. Urban dwellers tend to use about twice as much water as rural residents, and households with piped connections (mostly in urban areas) use, on average, three times more water than those without connections (Katui-Katua 2004).

Moreover, analysis at the scale of a subdrainage still hides issues of water scarcity within smaller watersheds and within communities. Respondents to a 1994 survey (Nakagawa et al. 1994) of Kenyans living in both wet and dry areas found that access to and quality of water was a constant preoccupation. The population living in the wetter areas of Kakamega and Bungoma Districts experienced water shortages only during the three driest months of the year. Residents of the drier areas in Kitui District faced a water shortage almost every month. In the wet areas, each person used on average about 40 liters per day, while in the drier areas it was about half of this amount. Interestingly, individual conceptions of a "severe water shortage" in the wet areas were classified as "average or above average water conditions" in the dry areas.

Map 3.7 **Annual Projected Water Balance by Subdrainage Area, 2000 and 2010**



Sources: Cities (SoK and ILRI 2000), water bodies (FAO 2000a), permanent and intermittent rivers (NIMA 1997), 250-meter Digital Elevation Model (SoK, JICA, and ILRI 1996), subdrainage and major drainage areas (MoWD and JICA 1992a), and annual projected water balance by subdrainage area (MoWD and JICA 1992b).

This map compares potential annual water supply (which includes both surface water based on long-term average annual rainfall, and groundwater based on maximum exploitable groundwater yield) to projected annual water demand from households, agriculture, and industry. Areas with a water deficit in 2000 (in light green) cannot currently meet their annual water needs from supplies within their subdrainage area and the situation is not expected to change by 2010. These areas either require water transfers from other subdrainages to meet growing demand or they experience water shortages. The subdrainage areas marked in light orange do not currently have shortages but are projected to experience water deficits by 2010.

For almost all arid and semi-arid subdrainage areas showing no deficit on this map, current surface water availability alone is not sufficient to meet demand. These areas have to tap into their groundwater supplies to meet current and future demand.

The map tends to overestimate the positive balance between annual water supply and demand for a large number of subdrainage areas, due to the fact that water shortages often occur more locally in smaller watersheds within the subdrainage areas. In addition, the map is limited in that it does not show seasonal or annual variation in water availability. In many of the arid and semi-arid subdrainages, lower-than-average rainfall or droughts are frequent, leading to serious water shortages.

WATER BALANCE
Deficit in both 2000 and 2010
Deficit in 2010
No deficit foreseen
DRAINAGE BOUNDARIES
Major drainage area boundaries
Subdrainage area boundaries
WATER BODIES AND RIVERS
Permanent rivers
Intermittent rivers
Water bodies

Land areas with negative water balances (where water supply is outstripped by demand) will require investment in water resource infrastructure to cover their needs. In addition to increasing water supply, resource managers need to boost the efficiency of water use as well. This includes monitoring water use, especially groundwater uptake. It also requires technologies and policies for regulating water use and for promoting conservation and reuse of water. Such techniques include capturing and storing more of the annual rainfall or runoff (water harvesting), planting crops that are more water efficient, using more efficient technology for irrigation, and using more efficient methods of transporting water (e.g., avoiding leakage).

WATER-BASED ECOSYSTEM SERVICES

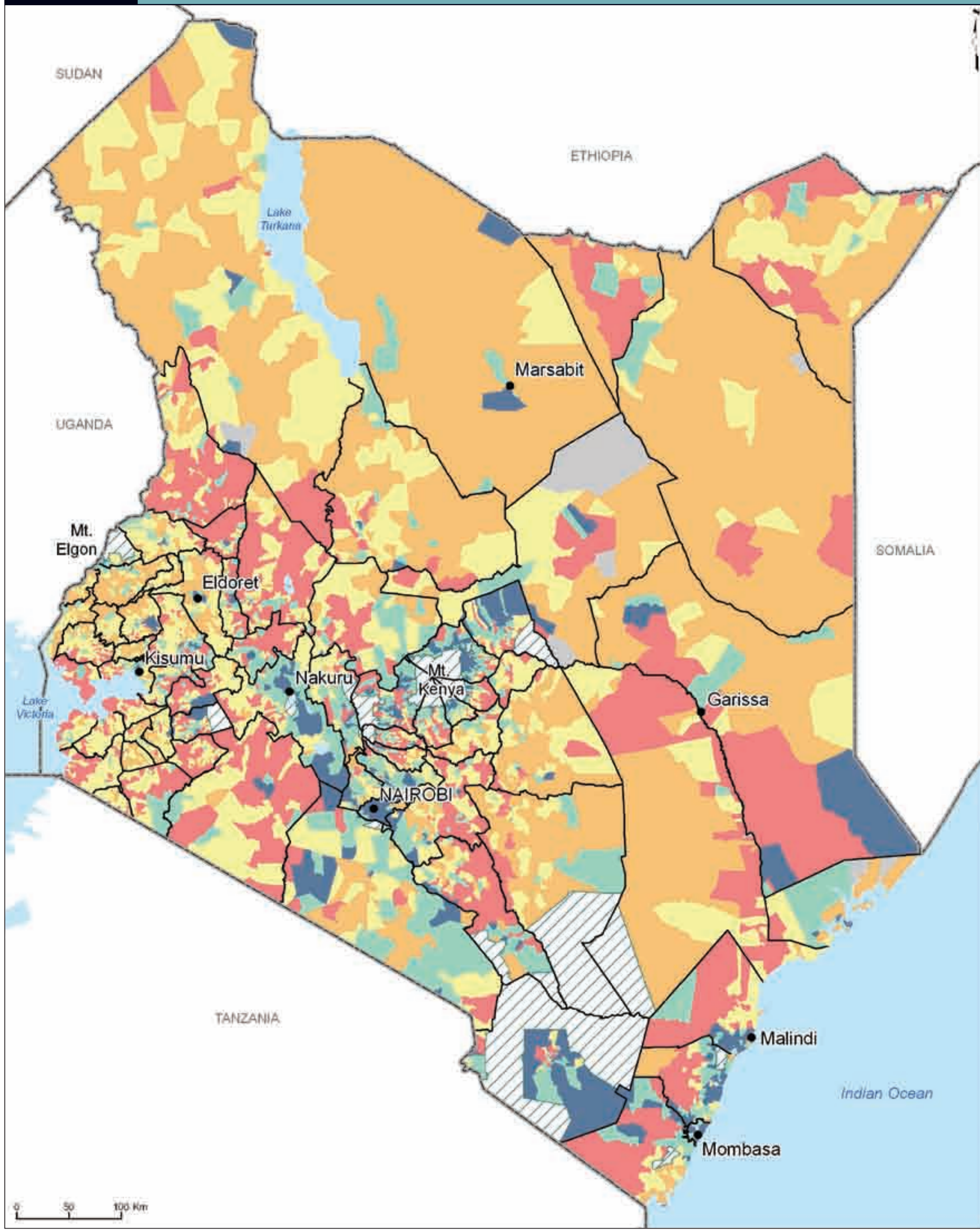
The maps in this section show the main uses and users of water in Kenya: drinking, industrial, and other uses in urban areas; energy generation; crop production; livestock production; and wildlife demand.

Drinking Water

Accessibility to water remains a major problem for rural people in Kenya, as well as for the urban poor. Connection to piped water is often considered a privilege of the more affluent in urban areas. But supply problems can arise with piped water too because of inadequate infrastructure, such as stalled water projects, delays in repairing leaks or damaged equipment at key supply areas, clogged water supplies, or vandalism. It is not uncommon for Kenyans with piped water to experience lengthy water shortages (Njuguna-Githinji 2001; Katui-Katua 2004). Women and girls are generally responsible for collecting water for household use when water is not piped directly to the home—a task requiring heavy physical labor and a great deal of time (Were et al. 2004). Map 3.8 shows the main sources of drinking water for households in Kenya.

In 2003, open surface water (lakes, ponds, rivers, and streams) was the major source of drinking water for 29 percent of Kenyan households, almost all of them in rural areas (CBS et al. 2004). These house-

Map 3.8 **Dependence on Ecosystem for Drinking Water, 1999**



Sources: Administrative boundaries (CBS 2003), cities (SoK and ILRI 2000), water bodies (FAO 2000a), parks and reserves (IUCN and UNEP/WCMC 2006), and 1999 drinking water sources (CBS/ILRI/WRI calculation based on CBS 2002).

In most rural parts of Kenya, people obtain their drinking water from untreated surface water, groundwater, or a combination of surface and groundwater (depicted in red, orange, and yellow, respectively). Dependence on surface water (shown in red areas, where more than 75 percent of households rely on surface water) is most prevalent along permanent streams and other freshwater bodies in the highlands, along Lake Victoria, and close to permanent rivers crossing arid and semi-arid areas (e.g. north of Eldoret and close to Garissa).

Areas in which more than 75 percent of households depend solely on groundwater for drinking water are shown in orange. They are in the arid and semi-arid areas and in a few communities along the Indian Ocean. Here, households obtain their water from wells and boreholes. Groundwater, in this case from springs, is also a dominant source in selected Districts in western Kenya.

Areas where more than 75 percent of households receive piped drinking water are shown in blue. Such areas are clustered around Mombasa, Nairobi, Nakuru, and other more densely populated areas.

SINGLE DOMINANT DRINKING WATER SOURCES
- More than 75% of households rely on surface water
- More than 75% of households rely on groundwater
- More than 75% of households rely on piped water

MIX OF DRINKING WATER SOURCES
- More than 75% of households rely on surface and groundwater
- Mix of piped, surface, and groundwater with no dominant source
- No data

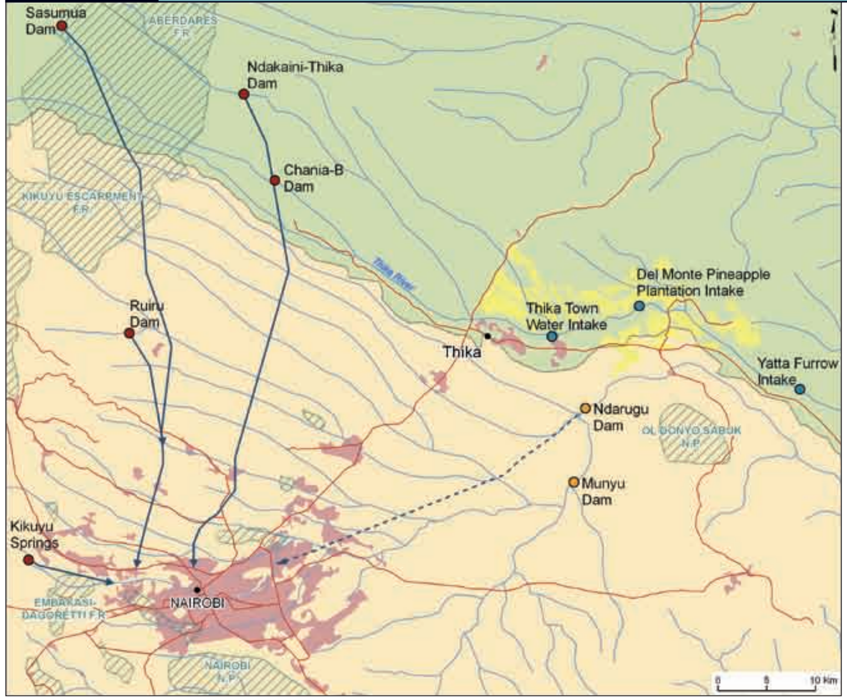
OTHER FEATURES
- District boundaries
- Selected national parks and reserves
- Water bodies

holds are particularly vulnerable since the quantity of water available at any given time depends directly on natural flows of water and the rainfall patterns that generate them. Use of surface waters also implies direct reliance on ecosystems for their natural waste removal capacity, such as filtering by wetlands and the dilution capacity of freshwater systems.

About 32 percent of Kenyan households (CBS et al. 2004) relied on groundwater sources (wells and springs) for their drinking water in 2003. Reliable supplies require sufficient and regular recharge from surface sources. Communities that obtain drinking water from groundwater are generally less vulnerable to water quality issues because of the natural filtering of groundwater supplies. However, high salinity and fluoride levels can make this source of water unsuitable for drinking, especially in coastal areas, as well as some areas in eastern and northeastern Kenya. In these cases, groundwater may still be used for irrigation, livestock, and industrial purposes (Nyaoro 1999).

By 2003, 32 percent of Kenyan households had benefited from piped water—either directly to their homes or through public taps (CBS et al. 2004). However, the differences between urban and rural areas remain great, with 71 percent of urban households and only 19 percent of rural households having piped water. Households with piped water are more indirectly linked to nature. They are relying on water management planning and water delivery systems to ensure adequate supplies and on municipal water treatment to protect them from water contamination.

Map 3.9 **Water Sources: Nairobi**



This map shows the water systems and dams on which Nairobi depends. These are located in the Athi River and Tana River basins. The map also presents water supply points for Thika town and the DelMonte water intake northeast of Nairobi (Nyaoro 1999). The DelMonte plantation extracts water from the Thika River for irrigation of its crops. Many conflicts have arisen between the DelMonte company and the Nairobi City Council, as well as with the Thika Town Council, over the use of this water (Nyaoro 1999). The Yatta Furrow Intake, located further downstream of the DelMonte Intake, supplies water for domestic, livestock, and irrigation use to the North and South Yatta areas of Machakos and Kitui (Wambua 2003). The map also shows the sites of the proposed Ndarugu Dam and Munyu Dam, planned drinking water sources for Nairobi.

WATER PIPELINES
- Existing pipeline
- Proposed pipeline

WATER WITHDRAWAL SITES
- Existing supply sites for Nairobi
- Proposed supply sites for Nairobi
- Other important water withdrawal sites

IMPORTANT LAND COVER FEATURES
- Urban areas
- Pineapple plantations

DRAINAGE AREAS
- Tana River drainage area
- Athi River drainage area

OTHER FEATURES
- Major roads
- Permanent rivers
- National parks and reserves

Sources: Cities (SoK and ILRI 2000), water bodies, urban areas and pineapple plantations (FAO 2000a), parks and reserves (IUCN and UNEP/WCMC 2006), major roads (SoK and ILRI 1997), permanent rivers and Sasumua pipeline (NIMA 1997), Athi and Tana River major drainage areas (MoWD and JICA 1992a), and location of dams, withdrawal points, and other pipelines (approximately placed by WRI based on SoK 1971, and on information from MoWD and JICA 1992c, 1992d, 1992e, and from Nyaoro 1999, Wambua 2003).

Water Supply in Urban Areas

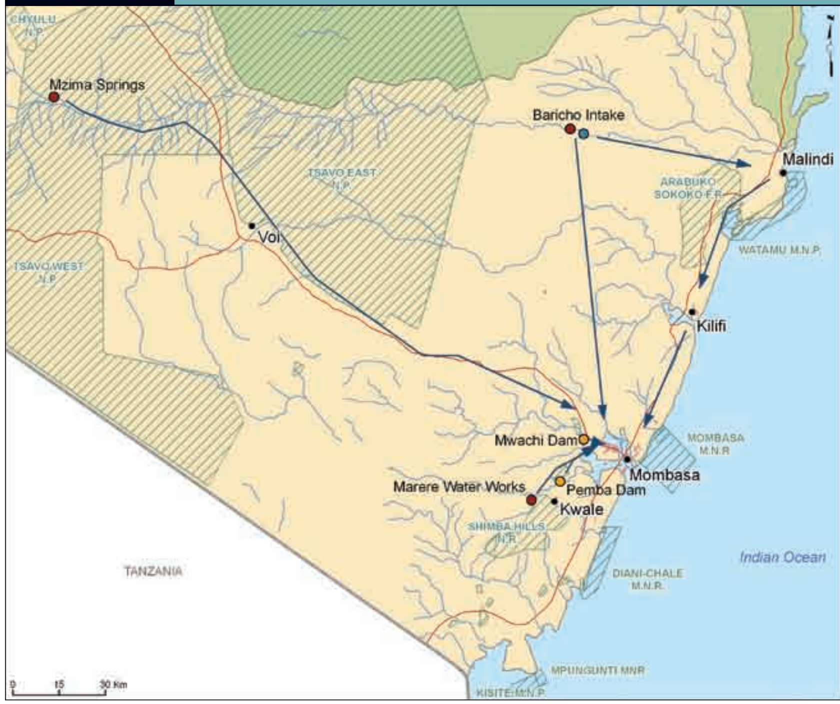
Population and economic activities are highly concentrated in urban areas. Water is used not only for drinking but also for industrial production and urban agricultural activities (see Box 4.1 in Chapter 4). Water for Kenya's two largest cities, Nairobi and Mombasa, is transported over significant distances because supplies in the immediate vicinity are not sufficient.

Industrial use of public water is relatively minor in the country as a whole, consuming only about 4 percent of the total public water supply. In urban areas, the manufacturing industry utilizes a greater percentage of the public water supply, ranging from 13 percent to close to 40 percent (Onjala 2002). However, industrial water use is likely underestimated since it only accounts for withdrawals from public water supply; many companies extract additional water from rivers and private boreholes as well (Onjala 2002).

Nairobi draws its water from five different sources (Map 3.9) with a total capacity of approximately 460,000 cubic meters per day (Owore 2004). Over the past 100 years (Nairobi City Council 2006), Nairobi's sources of water have expanded outwards from nearby springs (Kikuyu Springs) to sources in the Athi River drainage area (Ruiru River Dam) and finally to reservoirs in the Tana River drainage area (Sasumua, Chania-B, and Ndakaini-Thika reservoirs). Despite recent investments in water delivery infrastructure, supplies have difficulty keeping pace with demand. Moreover, uneven distribution, waste through leakage, and illegal connections exacerbate supply shortages in certain areas of Nairobi (Owore 2004).

On the coast, the majority of Kenyans rely heavily on sources further inland for piped-in drinking water. Mombasa District's main sources of water (Munga et al. 2004) are Mzima Springs (through

Map 3.10 Water Sources: Mombasa



This map shows the water supplies serving Mombasa. A pipeline from Mzima Springs in West Tsavo National Park (about 220 kilometers from Mombasa) transports water to the coast. Marere Dam and Baricho Intake are the other two main sources feeding the coastal water supply system close to Mombasa. Baricho Intake serves the cities of Malindi and Kilifi in addition to Mombasa. Two proposed dams that will bring water to Mombasa (Mwachi Dam and Pemba Dam) are also shown.

WATER PIPELINES
Existing pipelines
WATER WITHDRAWAL SITES
Existing supply sites for Mombasa
Proposed supply sites for Mombasa
Other important water withdrawal sites
IMPORTANT LAND COVER FEATURES
Urban areas
DRAINAGE AREAS
Tana River drainage area
Athi River drainage area
OTHER FEATURES
Major roads
National parks and reserves
WATER BODIES AND RIVERS
Permanent rivers
Water bodies

Sources: Cities (SoK and ILRI 2000), water bodies and urban areas (FAO 2000a), parks and reserves (IUCN and UNEP/WCMC 2006), major roads (SoK and ILRI 1997), permanent rivers and Mzima Springs pipeline (NIMA 1997), Athi River and Tana River major drainage areas (MoWD and JICA 1992a), and location of dams, withdrawal points, and pipelines (approximately placed by WRI based on SoK 1971, and on information from MoWD and JICA 1992c, 1992f, 1992g).

a pipeline constructed in 1966, which also serves communities along the corridor) and water works at Baricho and Marere (more recent investments). Mombasa District's demand for water, however, cannot be satisfied entirely by surface water. About 35 percent of the District's demand is met by tapping groundwater sources, and in some areas a majority of households are primarily dependent on groundwater (Munga et al. 2004).

Unfortunately, groundwater supplies in Mombasa District (Map 3.10) are vulnerable to salinity intrusion and pollution from pit latrines and septic tanks as the region currently lacks sufficient sewage treatment to manage the human waste generated in the region. Groundwater from these areas must be treated to be safe for human consumption.

Smaller industrial towns also have trouble providing enough water for industrial activities. According to a report by the Kenya Association of Manufacturers, limited water supply can hamper industrial growth. For example, the report states that Nakuru, home to major industries, is losing business to neighboring towns with more adequate water supplies (Cited in Njuguna-Githinji 1991).

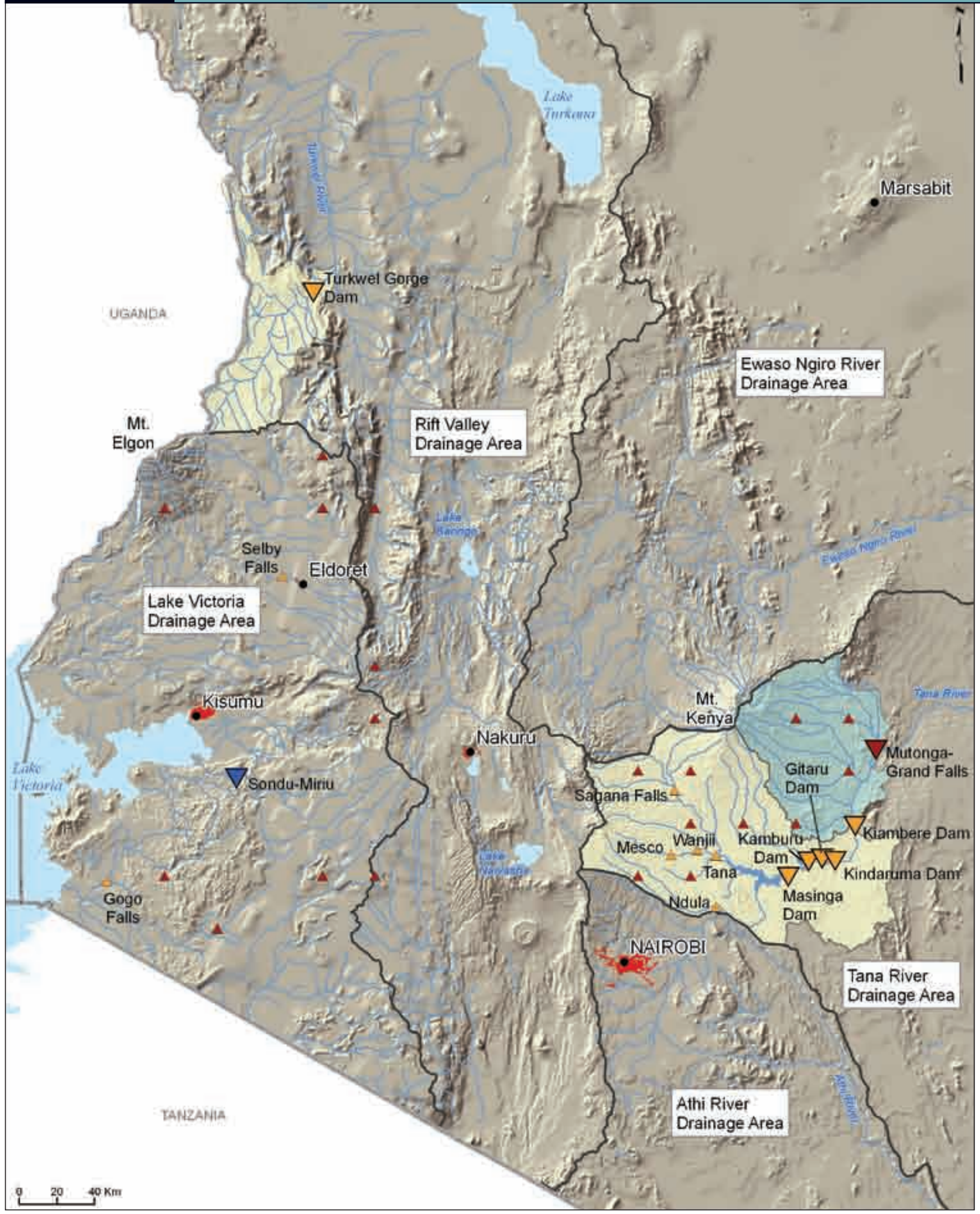
Electricity Generation

Hydropower is the largest source of electricity in Kenya, providing approximately 680 MW or 55 percent of the total installed grid capacity (UNDP et al. 2005). Much of the hydropower comes from large-scale stations and dams on the upper Tana River and the Turkwel River. About 570 MW or 84 percent of Kenya's existing hydropower capacity comes from a succession of dams called the Seven Forks power stations along the upper Tana River (KenGen 2006). Map 3.11 shows the locations of these hydropower dams.

The proposed dams at Mutonga and Grand Falls, just downstream from the existing upper Tana River dams, will likely be the next dams built under Kenya's least cost development plans (UNDP et al. 2005). The Sondu-Miriu hydropower project is currently being constructed to the east of Lake Victoria. Small hydropower systems (generating less than 10 MW each) often provide electricity for off-grid or isolated rural areas. The most important small hydropower sites are in the upper Tana River and a few sites in western Kenya.

Hydropower dams, although contributing significantly to economic development and human well-being, can have negative impacts on populations and ecosystems as well. Dams can affect downstream water supply, displace people, ruin aesthetic and sometimes spiritual landmarks such as waterfalls, and increase threats to fish and other species that depend on rivers for their habitat. Before construction of the Seven Forks dams, the banks of the Tana River flooded naturally during the wet seasons twice a year, helping to sustain the surrounding grasslands, lakes, seasonal streams, and riverine forest and mangrove ecosystems. However, flooding has decreased in volume and frequency since the construction of the five dams (IUCN 2003). An estimated one million farmers, livestock keepers, nomadic and seminomadic pastoralists, and fisherfolk who live along the river and in the Tana Delta depend on the river's remaining seasonal flooding patterns for their livelihoods (IUCN 2003). Investing in appropriate dam design and hydrological management (e.g., timed water releases) could maintain some of these downstream ecosystem benefits but still boost electricity supplies to support Kenya's economic recovery. This could help to achieve a number of development objectives and safeguard the livelihoods of downstream users at the same time (UNEP 2006).

Map 3.11 Water Used for Electricity Generation



Sources: Cities (SoK and ILRI 2000), water bodies and urban areas (FAO 2000a), permanent rivers (NIMA 1997), 250-meter Digital Elevation Model (SoK, JICA, and ILRI 1996), major drainage areas (MoWD and JICA 1992a), hydropower sites (approximately located by WRI based on SoK 1971, and information from KenGen 2006, and from MoWD and JICA 1992c, 1992h, 1992i), existing small hydropower sites (approximately located by WRI based on SoK 1971, and information from KenGen 2006, and Balla 2006), and proposed small hydropower sites (approximately located by WRI based on SoK 1971, and information from ITDG and ESDA 2005).

This map shows the spatial distribution of hydropower sites in Kenya. Areas shaded in beige depict the water catchment areas that feed the five existing power stations (indicated on the map by large orange triangles) and reservoirs on the Tana River, as well as one dam on the Turkwel River. Land use practices in these beige-colored areas (i.e., upstream from these dams) can influence the amount of water and sediment flowing into the reservoirs, affecting water quality and the productive lifespan of the hydropower infrastructure. The Sondu-Miriu hydropower project (under construction) is marked by a large blue triangle.

The catchments that feed the site of the proposed dams for the Mutonga-Grand Falls scheme—also intended to help satisfy Kenya's electricity needs—are indicated by the areas shaded in light green. A large red triangle marks the proposed site. The dams would effectively capture the remaining permanent rivers feeding the Tana River from Mount Kenya and significantly impact ecosystems downstream. These include the seasonally flooded grasslands (important for livestock grazing and wildlife), gallery forests along the river's shores (key primate and bird habitats), and coastal ecosystems (valuable for fisheries) in the Tana estuary.

Small orange and red triangles mark the locations of existing and proposed small hydropower sites. A number of the proposed small hydropower sites are considered economically viable and the impact to freshwater systems and associated species and habitats would be limited.

Note: Existing small hydropower sites are operating schemes that were built between 1919 and 1955. There are a number of additional small hydro schemes associated with tea companies, community groups, and a private hospital (Balla 2006).

HYDROPOWER INFRASTRUCTURE

- Existing hydropower sites
- Hydropower sites under construction
- Proposed hydropower sites
- Existing small hydropower sites
- Proposed small hydropower sites

IMPORTANT DRAINAGE AREAS

- Drainage area important for current dams
- Drainage area important for proposed dams

IMPORTANT LAND COVER FEATURES

- Urban areas

OTHER FEATURES

- Major drainage area boundaries

WATER BODIES AND RIVERS

- Permanent rivers
- Water bodies

Crop Production

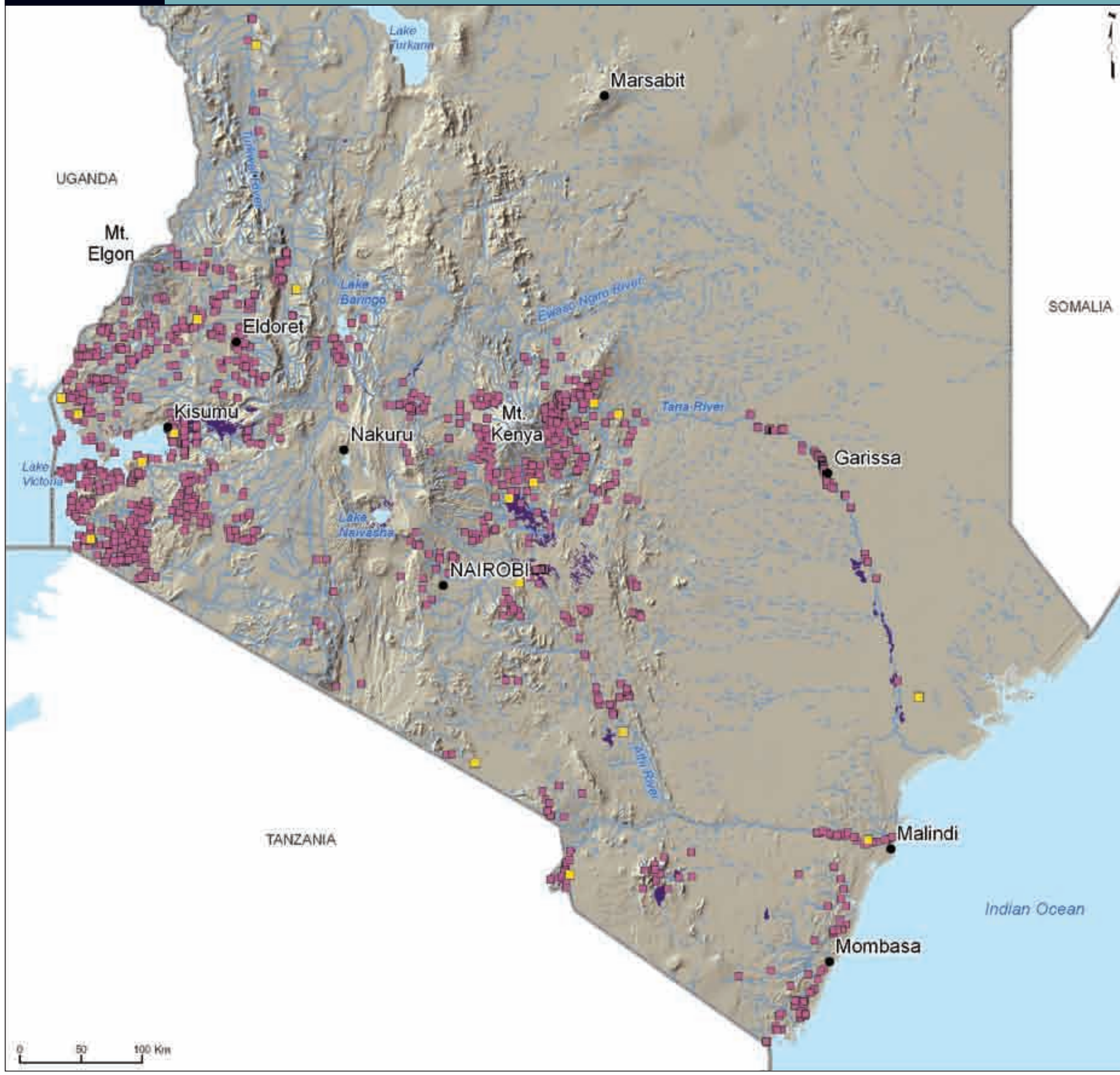
Since 98 percent of Kenya's cropping is rainfed, most farmers are exposed to the high variability of rainfall within and between years. Only 15 percent of Kenya receives more than 762 millimeters of rain per year, in four out of five years. This is the minimum amount required to grow maize and other non-drought-resistant crops. Another 13 percent of Kenya has more marginal rainfall (508–762 millimeters) requiring special dry farming or irrigation practices to cultivate crops (SoK 2003). But even in high-rainfall areas, sufficient water for a successful harvest is not guaranteed every year—both "long" and "short " rains can be ill timed or not fall at all (e.g., FAO 2000b; KFSSG 2006). Investment in water storage and irrigation infrastructure can reduce the risk of insufficient rainfall for farmers.

Irrigation in Kenya is carried out on both a small-scale, local level and in large-scale irrigation schemes (Map 3.12). Smallholders account for 46 percent of Kenya's irrigation, using it for fruit and vegetable production. Larger commercial firms account for another 42 percent. About 12 percent are public schemes under the National Irrigation Board (FAO 2005).

According to FAO (2005), only 19 percent of Kenya's potential area is equipped for irrigation. The proportion of cropped area which is irrigated is well below the average, at 2 percent compared to 3.7 percent in sub-Saharan Africa as a whole (FAO 2005). This low level of irrigation is due to limited water availability, rising costs of supplying water and building irrigation systems, and poor economic performance of existing irrigation schemes (Onjala 2001).

To satisfy Kenya's future water needs and demands from increased agricultural production, the *Study on the National Water Master Plan* has stressed the importance of investing in water resources development. For example, it has proposed 18 major irrigation schemes and 140 small-scale irrigation schemes for 2010.

Map 3.12 **Water Used for Crop Irrigation**



Sources: Cities (SoK and ILRI 2000), water bodies and large-scale irrigation areas (FAO 2000a), permanent and intermittent rivers (NIMA 1997), 250-meter Digital Elevation Model (SoK, JICA, and ILRI 1996), small-scale irrigation and drainage points (IWMI compilation based on MoALD 1995), and proposed large-scale irrigation schemes (MoWD and JICA 1992j and 1992k).

This map shows small-scale irrigation points as well as certain large-scale irrigation schemes in central and southern Kenya. Dark purple shading represents large-scale irrigation systems, with the largest located at the foothills of Mount Kenya. This includes Kenya's largest irrigation investment, the Mwea-Tebere rice irrigation scheme. Covering more than 6,100 hectares, this area produces most of Kenya's rice. Other irrigated areas are located close to Kisumu (where sugar cane is produced) and along the lower Tana River (which produces citrus and rice).

Clusters of small-scale irrigation points, marked by pink squares, are especially prevalent around the shores of Lake Victoria and the base of Mount Kenya. The irrigated areas around the base of Mount Kenya depend mostly on water from the upper Tana and Ewaso Ngiro Rivers, which drain from the top of the mountain.

The map also shows 18 proposed irrigation schemes marked with yellow squares, as outlined by the *Study on the National Water Master Plan*.

IRRIGATION INFRASTRUCTURE

- Existing small-scale irrigation and drainage points
- Proposed large-scale irrigation schemes
- Large-scale irrigation schemes

WATER BODIES AND RIVERS

- Permanent rivers
- Intermittent rivers
- Water bodies

Livestock and Wildlife

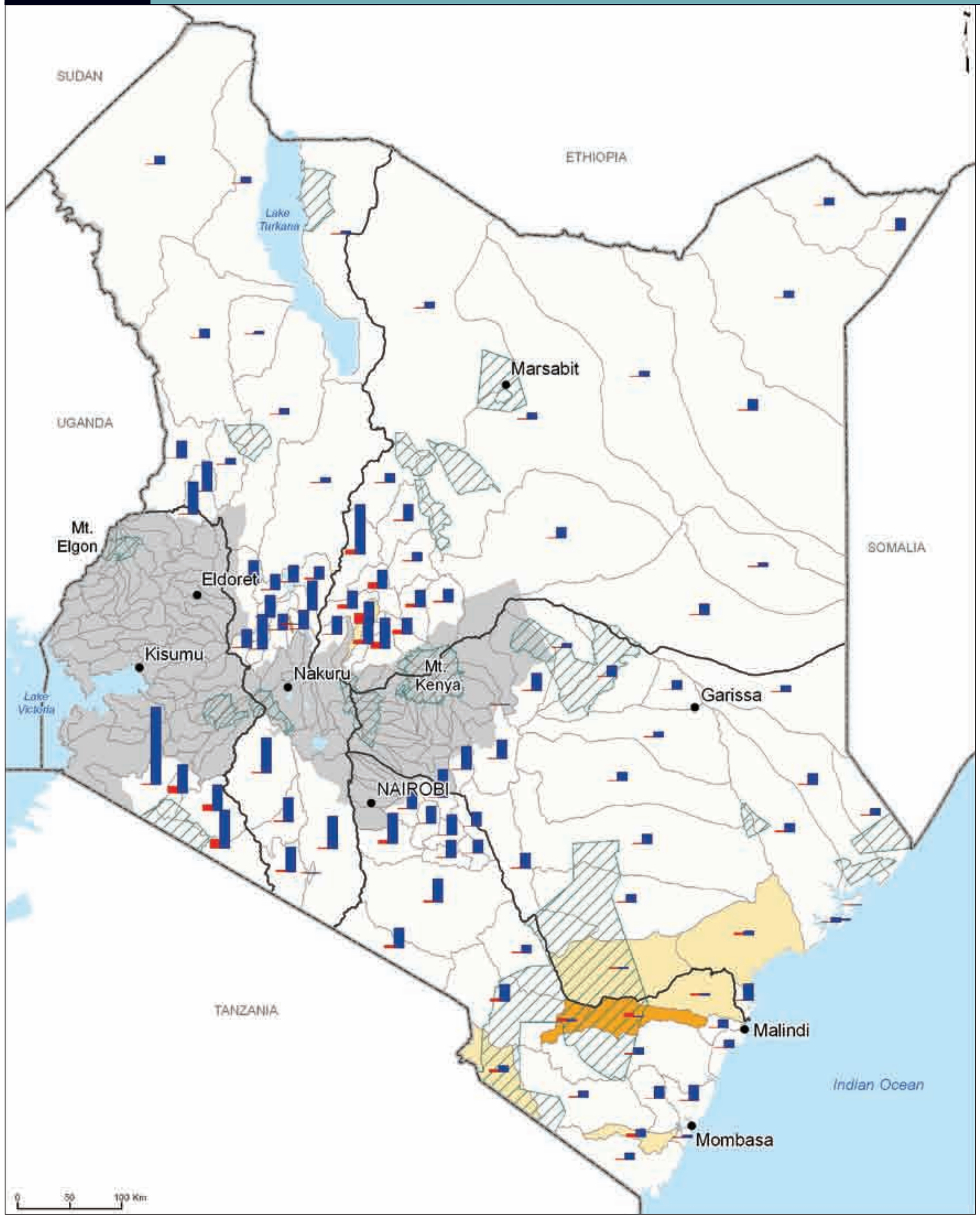
Rivers and lakes must maintain a minimum flow to sustain the aquatic and riparian species that depend on them. Fish—an important part of diets and livelihoods for Kenyans who live close to Lake Victoria—depend on an adequate quantity and quality of water to live and reproduce. Kenya's wild animal species also require water; wildlife viewing is central to the country's tourism industry and in some areas, illegal hunting of wildlife provides meat to rural households (see Chapter 4).

Livestock production is also very dependent on adequate water sources. Herding in the arid and semi-arid areas, where over half of Kenya's livestock are produced, relies heavily upon ground-water sources (SoK 2003). It can be difficult to find enough sources of water for livestock due to competing water demands. A typical cow weighing approximately 250 kilograms drinks 20-50 liters of water a day, depending on whether or not the animal is lactating (Peden et al. 2003). Herders with large quantities of livestock often have to travel to distant sources such as small dams, rivers, water pans, and boreholes.

Problems arise when water is scarce, as livestock may wander in search of additional water sources. Cows can pollute river water and spread helminthes (a type of worm carried by snails) when river levels are low and they are forced to walk into the river for water (Peden 2004). During times of drought, there are occasionally clashes between cattle ranchers and pastoralist herders over land rights. Herders often end up moving their livestock into private ranches in order to avoid areas of significant drought, especially in Narok and Kajiado Districts. There are also conflicts over water use between livestock herders and wildlife in these drier areas (Zecchini 2000).

Map 3.13 shows water consumption of major animal species for Kenya's rangeland Districts. It takes into account the distribution of livestock species and wild grazing animals within each subdrainage area and multiplies each animal's weight by its estimated water consumption. Water consumption,

Map 3.13 Average Water Consumption of Livestock and Wildlife by Subdrainage Area, 1994-96



Sources: Cities (SoK and ILRI 2000), water bodies (FAO 2000a), parks and reserves (IUCN and UNEP/WCMC 2006), subdrainage and major drainage areas (MoWD and JICA 1992a), and average water consumption of livestock and wildlife (WRI/ILRI calculation based on animal data from DRSRS 2003; Grunblatt et al. 1995, 1996; and daily water requirements for selected species from MoWD and JICA 1992l, Peden at al. 2003, 2004).

This map shows water consumption of livestock and wildlife. The greatest water demand from livestock occurs in the surveyed subdrainages of the Lake Victoria drainage area near Tanzania. Wildlife demand for water is also high in this area, mostly because of the number of animals within and close to a large protected area (Masai Mara).

The subdrainages north of Mount Kenya (Ewaso Ngiro North drainage) also have significant water demand because of the high number of wildlife species.

Note: Livestock (cattle, sheep, goats, camels, and donkeys) and wildlife (21 different large grazing animals) numbers came from a rangeland census using low-altitude flights. The blue and red bars, showing average consumption of water per square kilometer per day, are placed within the center of the subdrainage area and not necessarily where most water consumption occurs. See Chapters 4 and 5 for animal distribution maps.

AVERAGE WATER CONSUMPTION BY SUBDRAINAGE AREA
(liters per sq. km per day)
970
0
Wildlife consumption
Livestock consumption
SHARE OF WILDLIFE IN TOTAL WATER CONSUMPTION
(percent of total livestock and wildlife consumption)
> 50
25 - 50
<= 25
Area not sampled
DRAINAGE AREA BOUNDARIES
Major drainage area boundaries
Subdrainage area boundaries
OTHER FEATURES
Major national parks and reserves (over 5,000 ha)
Water bodies

which varies by species, is directly proportional to each animal's body weight (MoWD and JICA 1992l; Peden et al. 2003). Some animals, such as eland and impala, can live without drinking water for long periods; other animals, such as elephants, need more regular access to water.

In almost all of the subdrainages in Kenya's rangeland Districts, water demand for livestock is significantly greater than for wildlife. There are only a few subdrainage areas where wildlife consume a larger share of water than livestock. They are within or close to protected areas, which do not permit livestock grazing.

It should be noted that the analysis in Map 3.13 includes only water requirements for drinking water. The amount of water necessary for the production of fodder—either on natural pasture or grown as crops—is about one hundred times greater than the amount necessary for direct consumption by animals (Peden at al. 2003). Incorporating these numbers into the calculation would increase the total amount of water utilized, but would not change the relative relationship between domesticated and wild animals significantly.

Subdrainage areas with both high wildlife and livestock numbers such as the Ewaso Ngiro subdrainage will require special attention to ensure sufficient water supply. It will be especially important for water managers in this area to monitor activities and water withdrawals taking place upstream from these wildlife-rich areas so as to protect the water supply for these animals. In addition, catchments upstream from livestock (for example, areas important for groundwater recharge) need to be managed so that pastoralists further downstream have adequate amounts of water as well.

Over the long term, integrating the water needs of livestock into future development plans will become more important as Kenya's water supply becomes scarcer and demand for livestock products increase. The projections published in the *Study on the National Water Master Plan* estimated that livestock production will be responsible for 15 percent of national water demand in 2010 (MoWD and JICA 1992m).

Map 3.14 Areas Flooded and Prone to Flooding, 2002–06

Sources: Cities (SoK and ILRI 2000), water bodies, floodplains, and valley bottoms (FAO 2000a), permanent and intermittent rivers (NIMA 1997), 250-meter Digital Elevation Model (SoK, JICA, and ILRI 1996), and 2002–2006 flooded areas (Brakenridge et al. 2006).

This map shows the areas flooded between 2002–06 (in red), as well as floodplains and low-lying areas prone to flooding (in orange). Floodplains consist of land adjacent to a river channel that is seasonally covered by river water. Readers should note that the flooded areas shown in red are most likely an underestimate of actual flooding. Areas that experienced the most flooding are the shores of Lake Victoria in western Kenya, the banks of the Tana River in eastern Kenya, and the Lorian Swamp in central eastern Kenya, all highlighted on the map. Although the flooding near Lake Victoria does not appear to be extensive from this national map, it is important to understand that population density in that area is high and thus flooding is very destructive.

AREAS FLOODED OR PRONE TO FLOODING

Flooded areas, 2002 - 2006

Flood plains and valley bottoms

WATER BODIES AND RIVERS

Permanent rivers

Intermittent rivers

Water bodies

WATER AS A HAZARD: FLOODING

Flooding occurs erratically in Kenya, usually around the season of the "long" rains during the months of March through May. Many floods have affected the western parts of the country in the densely settled Kano Plains, Yala swamp, and other low-lying areas around Lake Victoria. Homes, schools, livestock, and farmlands in other parts of the country have also been destroyed. During the El Niño rains in 1997, for example, flooding affected the city of Nairobi and lower parts of the Tana River, but also the western parts of Kenya, mostly Busia and Nyando Districts (SoK 2003).

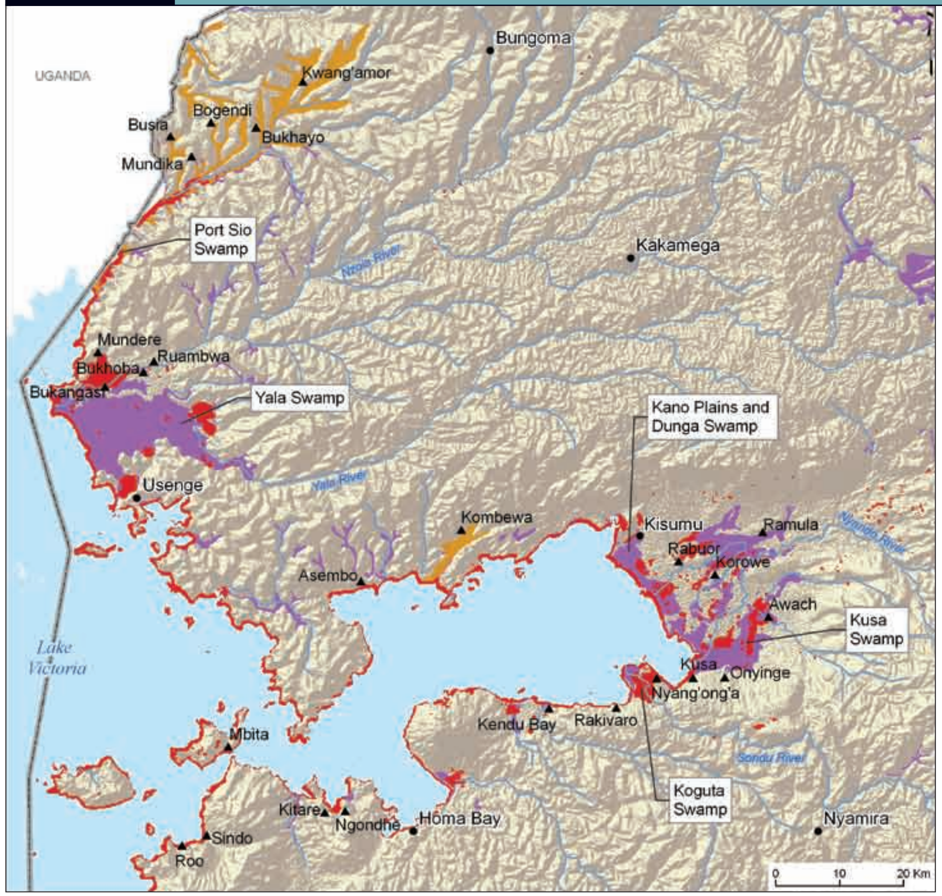
In May 2005, devastating floods displaced ten thousand people, especially along the shores of Lake Victoria, as well as in Tana River and Garissa Districts further east. Residents of affected areas reported the flooding to be the heaviest since 1963. Heavy rains also caused flooding in Isiolo District and in the Dadaab refugee camp in north-eastern Kenya, leaving more than 25,000 Somali refugees homeless. Impassable, waterlogged roads seriously hampered efforts to help the victims (ReliefWeb 2005).

Flooding can reduce access to clean water by destroying or polluting drinking water supplies, increasing the chances of contracting waterborne diseases. Stagnant water that remains after flooding can also increase exposure to mosquito-borne diseases such as malaria by providing a medium for mosquitoes to breed. Washed-away bridges and impassable roads can isolate communities for extended periods, leading to food and other shortages.

On the other hand, flooding can sometimes be helpful to both ecosystems and people. About one million people (IUCN 2003) depend on the Tana River's flooding regime for their livelihoods, including nomadic and seminomadic pastoralists, who rely on floodplain grasslands for dry season pasture. Some seasonal fisherfolk and fish traders also depend on the Tana's flooding pattern, as do some farmers, who count on seasonal floods to irrigate their riverbank farms. In addition, birds and wildlife are dependent on the annual flood cycle of the Tana for habitat and forage. Wetlands are often replenished by the flooding as well.

Studying the hydrological response to different types of land cover and land uses in flood-prone areas, implementing better land use planning, and establishing early flood warning systems are possible interventions that could mitigate some of the worst flood impacts.

Map 3.15 **Floods in Western Kenya, 2002–06**



Sources: Cities and market centers (SoK and ILRI 2000), water bodies, wetlands, floodplains, and valley bottoms (FAO 2000a), permanent rivers (NIMA 1997), 90-meter Digital Elevation Model (USGS 2004), and 2002–2006 flooded areas (Brakenridge et al. 2006).

This map focuses on western Kenya for a closer view of flooding that occurred in 2002–06 around the shores of Lake Victoria. Cities, towns, and market centers near floodplains and flooded areas are marked to illustrate flood impacts in these high-density zones. Major swamps are labeled, as well as major rivers such as the Nzoia River, which often floods on its lower reaches.

▲ Market centers

AREAS FLOODED OR PRONE TO FLOODING

Flooded areas, 2002 - 2006

Flood plains and valley bottoms

IMPORTANT LAND COVER FEATURES

Wetlands

WATER BODIES AND RIVERS

Permanent rivers

Water bodies

Box 3.1 Mapping Water-Related Ecosystem Services: Links to National Decision-Making

Kenya has been characterized as a water-scarce country. Decision-makers need to find innovative ways to supply enough water to accommodate the multitude of demands for agriculture, hydropower, tourism, industry, and drinking water, while still supporting plant and animal life. It will also be increasingly important to address the links between poverty and lack of access to improved water supply and sanitation services.

There is a strong relationship between economic status and access to improved water supply and sanitation in Kenya. About 37 percent of rural households rely on open surface water (streams, rivers, ponds, and lakes) for their drinking water (CBS et al. 2004). Public investment in the rehabilitation and expansion of water supply infrastructure has generally benefited urban populations and more affluent communities. But many of the poor who live in informal settlements in urban areas also have no easy and affordable access to potable drinking water.

Kenya's *Economic Recovery Strategy for Wealth and Employment Creation 2003–07* (GoK 2003) proposes many goals related to water and the achievement of economic growth. These include reducing the role of the Kenyan government in the provisioning of water supply and sanitation in favor of more efficient private companies; improving the physical infrastructure of new and existing water schemes; and narrowing the inequality between rich and poor communities in terms of access to treated water and adequate sanitation. The geospatial information presented in this atlas could help decision-makers meet such goals. Geographic indicators of water supply combined with other maps and indicators on human population density, poverty, and physical infrastructure can inform sound water management approaches that also benefit the poor. Below are examples of how maps can assist in the discussion and planning of certain interventions proposed in the Economic Recovery Strategy. Each item begins with a specific goal (in italics) drawn from the Strategy.

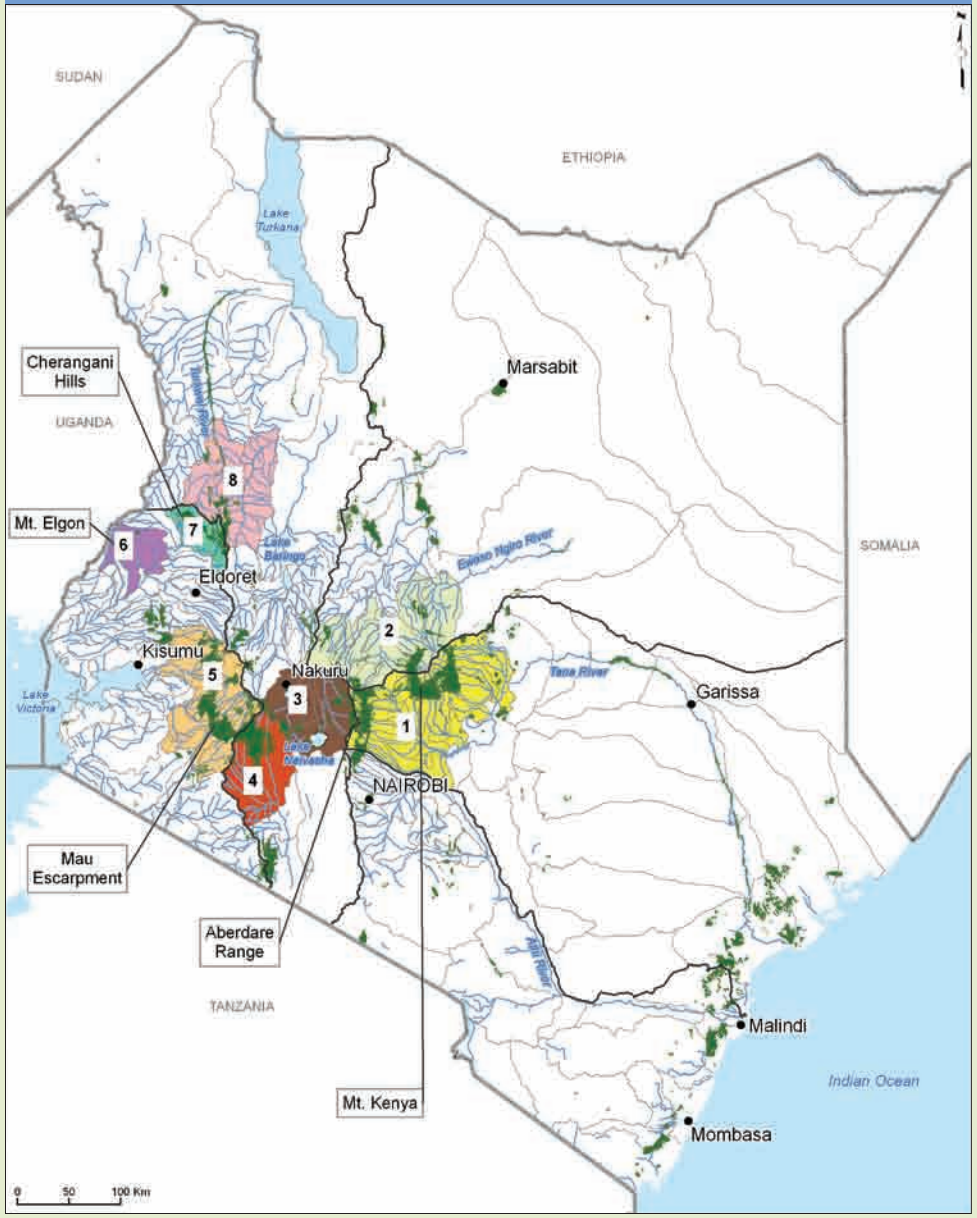
- *Improve the physical infrastructure of current water schemes:* Maps of water lines and their status can be used to identify specific locations that need rehabilitation. Combined with census data, planners can estimate how many people are not receiving proper water services due to damaged water lines or dams in need of repair. Delineating flood-prone areas and combining this information with the location of water lines can pinpoint water lines at risk of flood damage. Water and sanitation agencies can publicly release the location of new water infrastructure investments, thus providing communities an opportunity to hold these agencies accountable for their performance and priorities.
- *Increase the poor's access to treated water and sanitation services:* Using census information on sources of drinking water (as shown in Map 3.8) and combining that with poverty maps and additional household data can help prioritize communities with the greatest or most urgent needs. In addition, by overlaying maps of water infrastructure with detailed poverty maps, the water and sanitation sector can select appropriate technologies for poorer areas that require less capital and human resource investment. Constituencies and communities can use regular reports showing where access has improved to examine distributional equity issues and lobby for changes in resource allocation formulas.
- *Rehabilitate existing community water pans, dams, and boreholes in rangeland, in collaboration with the private sector, NGOs, and other development partners, for livestock development and prevention of poverty in arid and semi-arid lands:* Maps highlighting water supplies (as shown in Map 3.8), information on the location of boreholes, dams, and wells (as shown for northern Kenya in Map 5.12, Chapter 5), and maps of livestock density or livestock water demand (see Map 3.13), can all be combined to understand the relationships between water services and livestock development. With additional information on the water needs for tourism, for wildlife, and for other important ecosystem services, planners can identify areas where future water investments may create synergistic benefits or where multiple demands may require careful examination of tradeoffs.
- *Develop new irrigation schemes to promote year-round agriculture and food security, especially in arid and semi-arid lands:* Maps can be used to examine rainfall and farming patterns outside of the highlands to determine which parts of arid and semi-arid lands might be most suitable for development of new irrigation schemes. Maps such as Map 3.12, which shows locations of small and large-scale irrigation, will be useful to create a comprehensive picture of where irrigation efforts are already taking place.
- *Mitigate flooding by constructing dams across rivers, rehabilitating deforested water catchments, constructing dykes, and preparing an early warning system:* Locations most prone to flooding can be mapped (as shown in Map 3.15). With the help of more detailed elevation information; accurate road, housing and population data; and monitoring of weather patterns, rainfall, and flood levels in rivers, an early warning system could alert communities of approaching storms and rising floodwaters.

Another key issue not specifically mentioned in the *Economic Recovery Strategy* but relevant to its goals is the need to examine the competing demands for water resources between upstream and downstream users. Maps can pinpoint rapid land-use changes, cultivation methods, heavy applications of fertilizer and pesticides, discharge of sewage and industrial effluent, and sources of water withdrawals. With additional models (for example, incorporating the magnitude of water withdrawals) or economic valuation (for example, measuring the costs, benefits, or externalities), planners can examine how upstream interventions are affecting water quantity or quality downstream, thus ensuring that the many investments envisioned under the *Economic Recovery Strategy* are not too detrimental to a specific area or community.

As evidenced by the information and maps presented in this chapter, regular data collection efforts such as the *Population and Housing Census, Demographic Health Surveys*, and meteorological monitoring, all provide useful information on water supply, water use, and water-related health impacts. Moreover, significant information has been compiled for the *Study on the National Water Master Plan* (MoWD and JICA 1992m), albeit not in a format that is easily accessible to all stakeholders involved in water and sanitation issues. To strengthen national and local planning, much better integration of these water-specific data with other sector information is needed.

Box 3.2 Creating a Poverty and Demographic Profile for Kenya's 'Water Towers'

Map 3.16 Five 'Water Towers' and Selected Upper Watersheds



Sources: Cities (SoK and ILRI 2000), water bodies (FAO 2000a), permanent rivers (NIMA 1997), subdrainage and major drainage areas (MoWD and JICA 1992a), upper watersheds for five 'water towers' (WRI delineation based on MoWD and JICA 1992a).

UPPER WATERSHEDS

- Upper Tana River (1)
- Upper Ewaso Ngiro (North) (2)
- Lake Nakuru, Lake Elementaita, and Lake Naivasha tributaries (3)
- Upper Ewaso Ngiro (South) (4)
- Upper western watersheds of the Mau Escarpment (5)
- Upper eastern watersheds of Mount Elgon (6)
- Upper southwestern watersheds of the Cherangani Hills (7)
- Upper northern watersheds of the Cherangani Hills (8)

OTHER FEATURES

- Closed forests

DRAINAGE BOUNDARIES

- Major drainage area boundaries
- Subdrainage area boundaries

WATER BODIES AND RIVERS

- Permanent rivers
- Water bodies

The high rainfall areas in Kenya's mountains are the source of its largest rivers, many of them running year-round. The rivers which drain into the arid and semi-arid lands are an indispensable source of water to grow crops, raise livestock, and support wildlife.

The slopes of these mountains provide a complex bundle of ecosystem services. In general, they are densely settled, particularly the hills below the steeper slopes. Soils are fertile, and the dominant land use is agriculture. The higher elevations include most of Kenya's densest and multilayered tree cover. As of 1995, only 1.7 percent of Kenya's land area had sufficient tree and canopy cover to be classified as closed forest (UNEP 2001). Mount Kenya, the Aberdare Range, the Mau Escarpment, Mount Elgon, and the Cherangani Hills are home to most of these forests, together covering about 1 million hectares (Akotsi and Gachanja 2004). They are sometimes referred to as Kenya's five 'water towers.'

Maps of subdrainages (as shown in Map 3.7) can be used to delineate the upper watersheds (each consisting of various subdrainages) of the major rivers originating from these five mountain ranges. Map 3.16 outlines eight selected upper watersheds. Since all the maps in this volume are available in GIS format, the poverty and population maps in Chapter 2 can be combined with the eight outlined areas to create demographic and poverty profiles. Table 3.1 provides estimates of total population and population density, as well as estimates of the number of poor and the average poverty rate for each of the eight areas. It also shows the distribution of poverty rates among the administrative areas (Locations) falling within each upper watershed. Using this table, the demographic and poverty characteristics for these upper watersheds can be contrasted to understand poverty patterns and target poverty and ecosystem services interventions. For example, downstream users who want to benefit from improved watershed functions need to have sufficient resources to pay for specific land use practices in the uplands, in case planners want to establish a payment-for-ecosystem-services scheme.

What Do the Map and Poverty Profile Show?

- About 7.5 million people live in these eight upper watersheds, which together cover an area of almost 59,000 square kilometers (about 10.1 percent of Kenya's land area). Average population densities range from 19 to 308 persons per square kilometer, with the upper eastern watersheds of Mount Elgon (number 6) and the upper Tana (number 1) being the most densely settled. Limited resource endowments (for example, too little and unreliable rainfall or poor soils, making it difficult to grow crops) and the presence of protected areas (for conserving watersheds or wildlife) are the major reasons for lower population densities in some areas.
- While the eight upper watersheds represent 27.6 percent of Kenya's population, about 23.7 percent of the country's poor live here. The upper eastern watersheds of Mount Elgon, the upper western watersheds of the Mau Escarpment, and the upper northern watersheds of the Cherangani Hills (numbered 6, 5, 8 in the map) have the highest average poverty rates of 55, 51, and 50 percent, respectively.
- The tributaries feeding Lake Nakuru, Lake Elementaita, and Lake Naivasha (number 3) and the upper Ewaso Ngiro (number 2) have low average poverty rates of 36 and 38 percent respectively. These two upper watersheds, plus the upper Tana (number 1) all have clusters of administrative areas with some of Kenya's lowest poverty rates.

Continued

Box 3.2 Creating a Poverty and Demographic Profile for Kenya's 'Water Towers' – *continued*

- Of the eight outlined areas, the greatest number of people live in the upper Tana (3.1 million). Poverty rates for the 222 Locations within this area range from very low to very high covering all four classes in the table. The upper Tana includes a large cluster of the least poor communities but also some very poor administrative areas, most of them in the drier plains below the hills downstream of the Aberdare Range and Mount Kenya.
- This brief comparison shows that poverty and demographic patterns in Kenya's 'water towers' differ. About one quarter of all Kenyans live in the eight selected areas—very close to the total number of people in all of the arid and semi-arid lowlands. The average level of well-being in Kenya's 'water towers,' however, is significantly higher than in the communities further downstream.

Similar profiles could be constructed comparing other water-related maps from this chapter with indicators of human well-being presented in Chapter 2. For example, comparing poverty maps with maps showing high dependence of communities on surface water could help identify areas where poor communities are particularly vulnerable to interruptions in water flows and to water contamination.

Table 3.1 People, Poverty, and Kenya's 'Water Towers'

NAME OF UPPER WATERSHEDS AND MAJOR RIVERS [NUMBER IN MAP]	MOUNTAIN RANGE(S)	AREA	PEOPLE	POVERTY	POVERTY RATE: NUMBER OF LOCATIONS
Upper Tana River [1] Tana River and its tributaries draining Mount Kenya and the Aberdare Range	Mount Kenya, Aberdares	12,474 sq. km 2.1% of Kenya	3.1 million 11.4% of Kenya 250 persons per sq. km	1.3 million 9.2% of Kenya's poor 43% average poverty rate 107 poor individuals per sq. km	< 35% Range: 56 35 - 50% Range: 79 50 - 65% Range: 56 > 65% Range: 31
Upper Ewaso Ngiro (North) [2] Ewaso Ngiro (North) and its tributaries draining the Aberdare Range and Mount Kenya	Mount Kenya, Aberdares	10,541 sq. km 1.8% of Kenya	0.5 million 1.7% of Kenya 44 persons per sq. km	0.2 million 1.2% of Kenya's poor 36% average poverty rate 16 poor individuals per sq. km	< 35% Range: 22 35 - 50% Range: 26 50 - 65% Range: 2 > 65% Range: 1
Lake Nakuru, Lake Elementaita, and Lake Naivasha Tributaries [3] Rivers feeding Lake Nakuru, Lake Elementaita, and Lake Naivasha	Mau Escarpment, Aberdares	5,508 sq. km 0.9% of Kenya	0.8 million 3.1% of Kenya 152 persons per sq. km	0.3 million 2.2% of Kenya's poor 38% average poverty rate 58 poor individuals per sq. km	< 35% Range: 15 35 - 50% Range: 28 50 - 65% Range: 3 > 65% Range: –
Upper Ewaso Ngiro (South) [4] Ewaso Ngiro (South) and its tributaries draining the Mau Forest Complex into the Rift Valley	Mau Escarpment	5,881 sq. km 1.0% of Kenya	0.1 million 0.4% of Kenya 19 persons per sq. km	0.1 million 0.4% of Kenya's poor 49% average poverty rate 10 poor individuals per sq. km	< 35% Range: 1 35 - 50% Range: 7 50 - 65% Range: 12 > 65% Range: –
Upper Western Watersheds of the Mau Escarpment [5] Mara, Sondu Miriu, Nyando, and other rivers draining the Mau Forest Complex	Mau Escarpment	9,826 sq. km 1.7% of Kenya	1.6 million 5.7% of Kenya 160 persons per sq. km	0.8 million 5.5% of Kenya's poor 51% average poverty rate 81 poor individuals per sq. km	< 35% Range: 3 35 - 50% Range: 85 50 - 65% Range: 91 > 65% Range: 7
Upper Eastern Watersheds of Mount Elgon [6] Malakis River and tributaries feeding the Sio and Nzoia Rivers from Mount Elgon	Mount Elgon	2,846 sq. km 0.5% of Kenya	0.9 million 3.2% of Kenya 308 persons per sq. km	0.5 million 3.3% of Kenya's poor[2] 55% average poverty rate 168 poor individuals per sq. km	< 35% Range: 2 35 - 50% Range: 12 50 - 65% Range: 38 > 65% Range: 2
Upper Southwestern Watersheds of the Cherangani Hills [7] Upper tributaries of the Nzoia River flowing from the Cherangani Hills	Cherangani Hills	2,811 sq. km 0.5% of Kenya	0.4 million 1.3% of Kenya 126 persons per sq. km	0.2 million 1.1% of Kenya's poor 46% average poverty rate 57 poor individuals per sq. km	< 35% Range: 1 35 - 50% Range: 35 50 - 65% Range: 7 > 65% Range: –
Upper Northern Watersheds of the Cherangani Hills [8] Tributaries of the Turkwel, Marun, and Kerio Rivers from the Cherangani Hills	Cherangani Hills	8,692 sq. km 1.5% of Kenya	0.2 million 0.8% of Kenya 24 persons per sq. km	0.1 million 0.7% of Kenya's poor 50% average poverty rate 12 poor individuals per sq. km	< 35% Range: – 35 - 50% Range: 24 50 - 65% Range: 21 > 65% Range: 1
Total for Eight Upper Watersheds		**58,579 sq. km 10.1% of Kenya**	**7.5 million 27.6% of Kenya 129 persons per sq. km**	**3.4 million 23.7% of Kenya's poor 45% average poverty rate 58 poor individuals per sq. km**	

Sources: Poverty and demographic estimates (1999) are based on CBS 2002, 2003. Areas for the eight upper watersheds are WRI calculation based on Map 3.16.

Note: All estimates of area, people, and poverty are for the administrative areas (Locations) falling within the upper watersheds outlined on Map 3.16. Data are for 1999 and assume total population of 27.4 million and total number of poor individuals of 14.4 million as estimated by CBS (2003). Kenya's area is 582,650 square kilometers.

SUMMING UP

- From an ecosystem standpoint, water is unique, in that it is linked to all four categories of ecosystem services. *Provisioning services* include: the storage and retention of water in lakes, rivers, and as groundwater; water as an input to grow food, timber, fiber, and fuel; and freshwater for direct consumption. *Regulating services* of freshwater systems and important freshwater habitats (e.g. wetlands) include modifying water flows, recharging and discharging groundwater resources, and diluting or removing pollutants. *Supporting services* include nutrient cycling, soil formation, soil loss, and promoting biodiversity. *Cultural services* include recreational benefits, as well as the spiritual and inspirational roles of water bodies and aquatic habitats.
- Average annual rainfall amounts are distributed very unevenly: about 15 percent of the country receives sufficient rain to grow maize and other non-drought-resistant crops; another 13 percent has more marginal rainfall sufficient only to grow selected drought-resistant crops; and the remaining 72 percent has no agronomically useful growing season.
- Rainfall amounts show distinct seasonal patterns. Areas east of the Rift Valley have two rainy seasons per year. This high variability in seasonal water amounts has contributed to a great diversity of wild plant and animal species. It creates a special challenge for growing crops, however, because none of the two rainy seasons is quite long enough to allow very high yields.
- Rainfall amounts vary greatly from year to year as well. Major droughts and floods have occurred regularly in each decade over the past 30 years.
- Kenya's network of perennial rivers is most dense in the central and western parts of the country, leading to uneven supplies of surface water. The Lake Victoria drainage area supplies the highest share (65 percent) of Kenya's internal renewable surface water per year. The Athi River drainage area provides the lowest share (7 percent).
- The total renewable water resource available per year is 936 cubic meters per person (2004). This designates the country as *water scarce*. Policymakers must pay particular attention to the management of water resources to avoid hindering food production or impeding economic development. Population growth alone will continue to reduce per capita water availability.
- Subdrainages with densely settled urban populations such as Nairobi and Mombasa need to maintain their long distance water transfers to meet growing demand in the future. The same is true for all subdrainage areas in the central part of the Rift Valley north and south of Nakuru. Even in areas with perennial surface water flows, high local demand can outstrip local supply. The *Study on the National Water Master Plan* projects local water deficits for selected subdrainage areas in the upper Ewaso Ngiro, Tana River, and in western Kenya.
- Open surface water is the major source of drinking water for 29 percent of Kenyan households, almost all of them in rural areas. About 32 percent of Kenyan households rely on groundwater for their drinking water. The same proportion of Kenyan households uses piped water (71 percent of urban households and 19 percent of rural households). Families using untreated surface water are relying completely on the regulating services of ecosystems to provide uncontaminated water at sufficient quantities.
- Hydropower is the largest source of electricity providing 55 percent of the total installed grid capacity. About 84 percent of Kenya's existing hydropower capacity is located on the upper Tana River.
- Ninety-eight percent of Kenya's cropping is rainfed. Thus, the high variability of rainfall within and between years poses a significant risk for most farmers. Irrigation, covering the remaining 2 percent of cropland, is carried out by smallholders (46 percent), larger commercial firms (42 percent), and by public schemes (12 percent). Only 19 percent of Kenya's potential area is equipped for irrigation.
- In almost all of the subdrainage areas in Kenya's rangeland Districts, water demand for livestock is significantly greater than for wildlife. Only in a few subdrainage areas within or close to protected areas do wildlife consume a larger share.
- What constitutes an ecosystem service for one group may be a disaster for another. For example, floods can have both negative and positive impacts depending on the context. Floods regularly destroy homes, schools, and crops, and kill people and animals. This is especially true in western Kenya in the densely settled low-lying areas around Lake Victoria. On the other hand, flooding can sometimes be helpful to both ecosystems and people. About one million people in the lower Tana River depend on the river's flooding regime for their livelihoods. In addition, birds and wildlife depend on the annual flood cycle of the Tana for habitat and forage.