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Using Geospatial Information to Connect Ecosystem Services and Human Well-Being in Kenya

The application of geospatial information in the analysis of ecosystem services would help decision-makers to develop programs for poverty reduction in Kenya that would improve the targeting of social expenditures and ecosystem interventions so that they reach areas of greatest need.

Janet Nackoney, Norbert Henninger, Mohammed Said, Paul Okwi, Godfrey Ndeng'e, Florence Landsberg, Patti Kristjanson, Robin Reid, Dan Tunstall and Greg Mock

INTRODUCTION

Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being is the result of a multi-partner effort in Kenya including contributions from the following collaborators: World Resources Institute (WRI); International Livestock Research Institute (ILRI); Department of Resource Surveys and Remote Sensing (DRSRS) at the Ministry of Environment and Natural Resources, Kenya; and the Poverty Analysis and Research Unit at the Central Bureau of Statistics (CBS) at the Ministry of Planning and National Development, Kenya.

The atlas demonstrates the importance of using maps as an analytical tool to analyze the spatial distribution of poverty and ecosystem services in Kenya. Ecosystem services are the benefits people derive from ecosystems and include goods (food and water), services (flood and disease control), and non-material benefits (spiritual and recreational benefits). Using existing data, the atlas provides maps of areas in Kenya important for production of selected ecosystem services such as water (hydropower, access to drinking water, irrigation water), food (crop and livestock), fuel, biodiversity and tourism. The atlas also integrates high-resolution poverty data from Kenya's most recent census and household surveys with these ecosystem services.

A central tenet to *Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being* is that human well-being relies fundamentally on the ability to access a wide variety of ecosystem services. The maps in the atlas show locations of specific ecosystem services in Kenya and demonstrate how they can be combined with spatial metrics of poverty and well-being to analyze where people's lives either depend on, or benefit greatly from, the use of ecosystem services. The authors believe that users of the atlas will gain new insights on the spatial congruence of poverty and ecosystem services, improve targeting of programs addressing poverty and selected environmental services, and provide integrated datasets and methodologies for multi-scale use. Additionally, the atlas should improve environmental reporting in Kenya and contribute to better integration of environmental issues in national poverty reduction strategies.

ECOSYSTEM SERVICES IN KENYA

(Note: the following section is taken from various segments in Chapter 1, pp. 3–12 in the Atlas*.)*

Kenyans – like all people on Earth – depend on nature to sustain their lives and livelihoods. Not only do they obtain the basic goods needed for survival – such as water, food, and fiber – they also rely on nature to purify air and water, produce healthy soils, cycle nutrients, and regulate climate. Collectively, these benefits derived from nature's systems are known as *ecosystem services*. They fuel the Kenyan economy and, if wisely used and invested, build the nation's wealth (*Atlas*, p. 4).

The definition of ecosystem services used in this work comes from the Millennium Ecosystem Assessment. The array of ecosystem services enjoyed by humans can be divided into four main categories (Millennium Ecosystem Assessment, 2003):

- *Provisioning services*, which include the production of basic goods such as crops, livestock, water for drinking and irrigation, fodder, timber, biomass fuels, fibers such as cotton and wool; and wild plants and animals used as sources of foods, hides, building materials, and medicines.

- *Regulating services*, which encompass the benefits obtained as ecosystem processes affect the physical and biological world around them; these include flood protection, coastal protection, regulation of air and water quality, absorption of wastes, control of disease vectors, and regulation of climate.
- *Cultural services*, which are the non-material benefits that people derive from ecosystems through spiritual enrichment, recreation, tourism, education, and aesthetic enjoyment.
- *Supporting services*, such as nutrient cycling, production of atmospheric oxygen, soil formation, and primary production of biomass through plant photosynthesis; these services are necessary for the production and maintenance of the three other categories of ecosystem services.

The dependence of all Kenyans – urban and rural – on ecosystem services demonstrates the importance of managing natural systems wisely. For example, to ensure an adequate and safe supply of drinking water, Kenyans must take care with how they use land located upstream from drinking water reservoirs – whether they build roads, remove vegetation, establish industrial areas, add fertilizer, or spray pesticides – all these are activities that affect water quantity and quality. Similarly, the continued supply of forest, range, and marine resources depends on how sustainably these resources are harvested. To be sustainable, fish, timber, wood fuel, and fodder must be harvested below the rate at which the resources are replenished. Otherwise, the natural capital on which future health and prosperity depends will erode. Likewise, crop yields can rise only if soils are maintained and their fertility increased. Revenues from nature-based tourism will benefit future generations only if wildlife is plentiful and diverse, and oceans and coral reefs are healthy (*Atlas*, p. 4).

The natural resources produced from ecosystem services are vital to Kenya's economy. In 2004, the agriculture sector alone contributed 26 percent of Kenya's gross domestic product (53 percent, if indirect links to other economic sectors are counted), 60 percent of total export earnings, 45 percent of government revenue, and 62 percent of jobs in the formal economy. Accounting for employment in the informal sector, the share of Kenyans depending on agricultural resources for their livelihoods is currently almost 80 percent (Republic of Kenya, 2006; Central Bureau of Statistics, 2004, 2005). Other environmental income contributions to the economy come from tourism based on Kenya's natural endowment of wildlife, mountains, rangelands, beaches, and coral reefs, as well as timber production from forests and fish catches from lakes, rivers, and the Indian Ocean (*Atlas*, p. 4).

USING GEOSPATIAL INFORMATION TO EXAMINE ECOSYSTEM SERVICES IN KENYA

Note: the following section is taken from various segments of Chapter 1 (pp. 3–12), Chapter 3 (p. 34), and Chapter 4 (pp. 45– 47) in the Atlas.

Improving the health and prosperity of Kenya's people, while also safeguarding the natural environment and the many important economic, cultural, and spiritual benefits it provides, are identified as top priorities in national development plans (Government of Kenya, 2003; Ministry of Planning and National Development et al., 2005). Attaining these multiple development goals means that policy-makers, civil society groups, and the private sector need to have access to information and analyses that will make clear the numerous interconnections among environmental resources, human well-being, and economic expansion. Kenya has made substantial investments to map many of its most important natural resources using wildlife and resource survey data. Much of this information is available to the public for use in monitoring, assessing, and managing the ecosystems of the country (*Atlas*, p. 5).

Maps produced from a Geographic Information System (GIS) can show the location of major ecosystem elements such as rivers and lakes, mountains and plains, the clustering of certain plant communities, the home areas of wild and domesticated animals, or the densities of human populations. Moreover, maps can display where people are obtaining certain ecosystem services, for example, important production and harvest areas for food, fiber, or animal products. They can pinpoint locations affected by the construction of roads, canals, pipelines, and dams; by the expansion of settlements and croplands; or by the introduction of new species—each of these activities can influence the availability and flow of multiple ecosystem services. Maps can also highlight important areas that supply other ecosystem services, such as flood protection provided by mangrove forests, or sediment and pollutant removal provided by certain wetlands (*Atlas*, p. 6).

Geospatial data can also assist in understanding spatial patterns of ecosystem services and their drivers,

which are often distributed unevenly across the landscape. For a given ecosystem service, its supply is often concentrated in key resource areas that are characterized by a large number of ecosystem processes. Thus, understanding where key resource areas are located, the ecosystem processes operating to create and maintain these areas, and the services produced and valued by the community is essential for managing resources for improved livelihoods and sustained use (*Atlas*, p. 5, Biggs et al., 2004).

Map 1, *Prominent livelihood strategies pursued by households in Kenya, 2003–05,* shows the spatial distribution of Kenya's predominant livelihood strategies, presenting areas where Kenyans rely most heavily on the environment for such livelihoods as fishing, farming, and pastoralism. Pastoral livelihood strategies dominate in most of the arid and semi-arid areas in northern and eastern Kenya. Pastoralists move their livestock periodically to follow the seasonal supply of water and feed. Areas of cropping combined with pastoral livestock raising (agropastoral strategies) are clustered along the margins where rainfed agriculture is possible and around more permanent water sources. These areas are often close to trading and market centers, which provide some employment and wage opportunities. In most of central and western Kenya, high-potential agricultural lands are dominated by a mix of dairy cattle, food, and cash crops. Mixed farming along the shores of Lake Victoria, in the croplands east and southeast of Nairobi, and in the coastal hinterlands is more marginal. In many of these areas, rainfall is more erratic or soils are less fertile. Here, yields and incomes coming from a mix of livestock and food crops are generally lower (*Atlas*, p. 45).

Map 1 uses data on livelihood zones which are based on questionnaires sent to key food security experts in all of Kenya's 71 Districts (generally about 6–10 persons). In some cases where further clarification was necessary, questionnaires were sent to experts below District level (Division). This group of experts classified each of Kenya's 6,632 Sublocations by their predominant livelihood strategy and other livelihood characteristics (*Atlas*, p. 45).

Map 2, *Intensity of cultivation, 2000*, shows intensity of cultivation in Kenya's farmed areas. The most densely cropped areas are found predominantly in the highlands of central and western Kenya and in small patches of the lowlands. They include intensively produced crops such as wheat, tea, sugar cane, irrigated rice, and high-yielding maize. The majority of Kenya's agroecosystems consist of landscapes with 50 or 60 percent active cropland, mixed with less intensively managed land. The latter can include, for example, forests or woodlands that can support mixed activities such as wood extraction and livestock grazing (*Atlas*, p. 47).

Map 3, *Water used for electricity generation*, illustrates Kenya's dependence on water for the production of hydropower. The map shows the spatial distribution of hydropower sites in Kenya, indicated on the map by triangles. Areas that are shaded depict the water catchments that feed the five existing power stations and reservoirs on the Tana and Turkwel rivers. Land use practices in the catchments upstream from the dams, such as irrigation, for example, can influence the amount of water and sediment flowing into the reservoirs, affecting water quality and the productive lifespan of the hydropower infrastructure (*Atlas*, p. 34).

The proposed hydropower dams shown on the map would effectively capture the remaining permanent rivers feeding the Tana River from Mount Kenya, significantly impacting ecosystems downstream. Potentially affected ecosystems 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. Other proposed micro-hydro sites are indicated on the map by small triangles. A number of these proposed small hydropower sites are considered economically viable and their impact on freshwater systems and associated species and habitats would be limited (*Atlas*, p. 34).

DIMENSIONS OF POVERTY

Note: Certain parts of the following section are taken from Chapter 2 (pp. 13–24) in the Atlas.

Although poverty and human well-being are familiar concepts, these seemingly simple terms tend to defy precise, universally agreed definition. Most modern experts agree that poverty is a multi-dimensional phenomenon, involving not only a lack of financial means, but also various kinds of non-monetary deprivation, such as lack of access to social services and lack of ability to participate in political, social, and cultural institutions and decision-making processes.

There are many ways to show poverty and well-being spatially, as demonstrated in the *Atlas*. Some of the maps show the spatial representation of conventional economic measures of human welfare based on
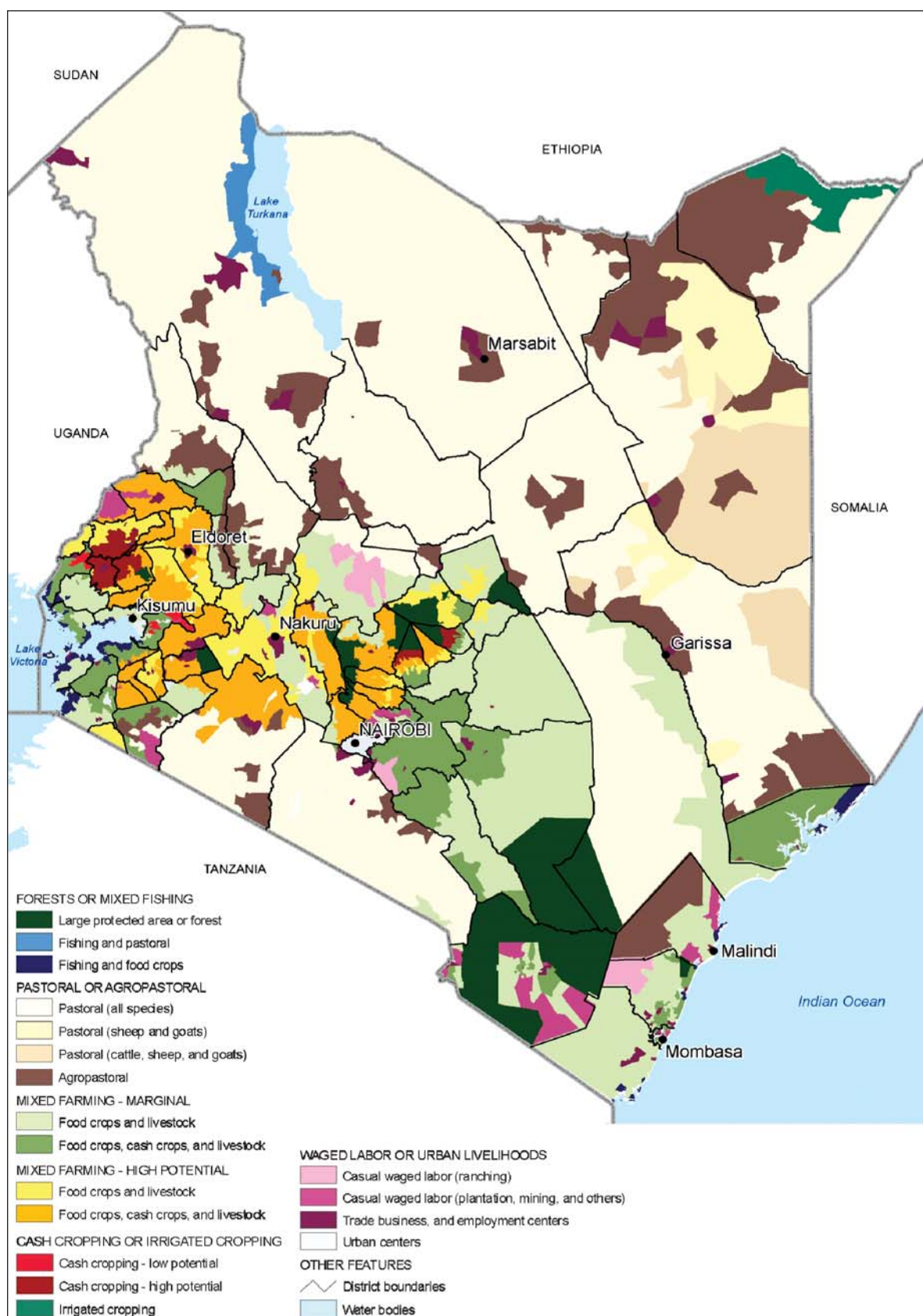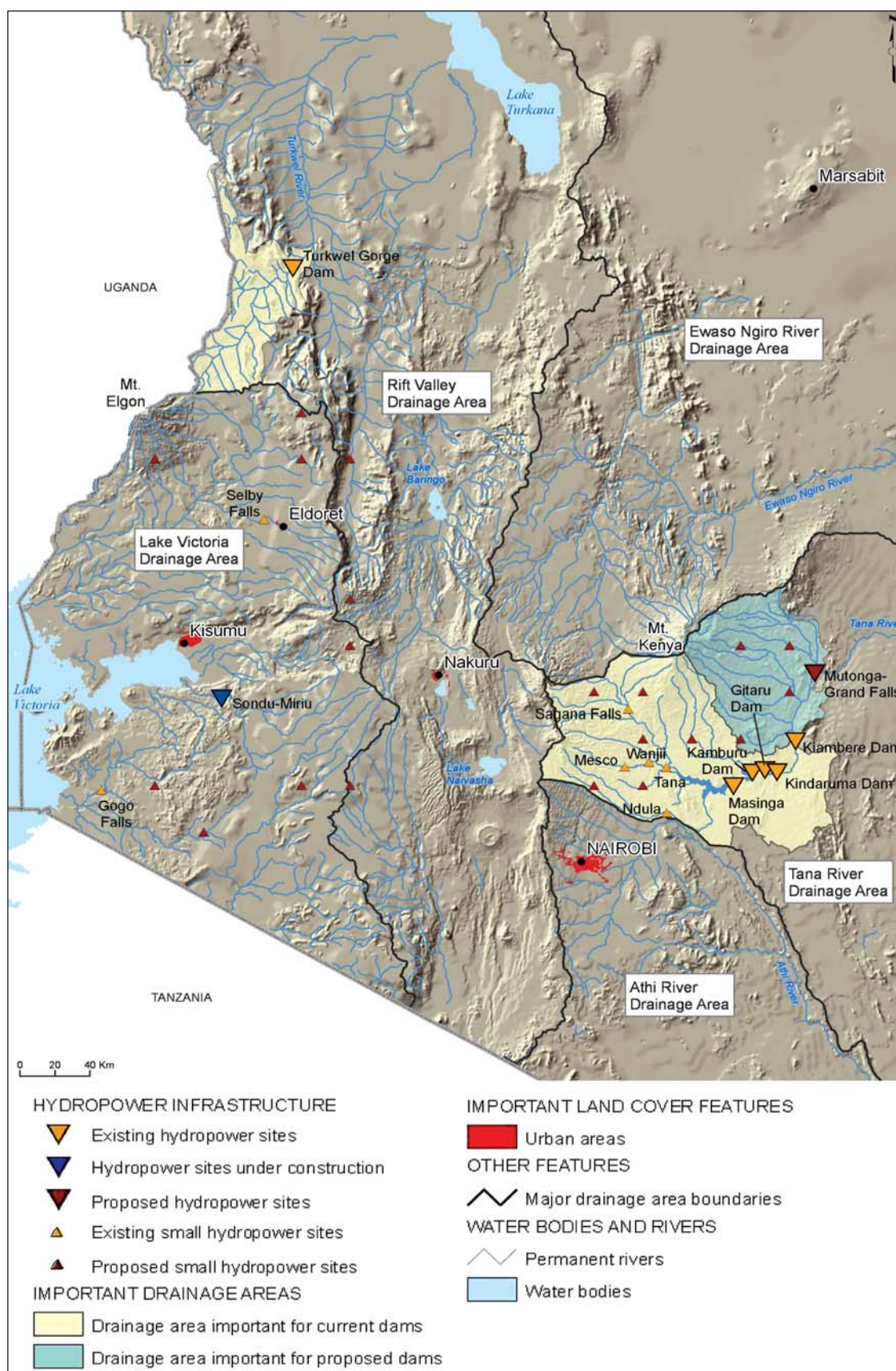
Map 1.   Prominent livelihood strategies pursued by households in Kenya, 2003–05. Colour versions of figures are available in the online version, see Editorial for details.
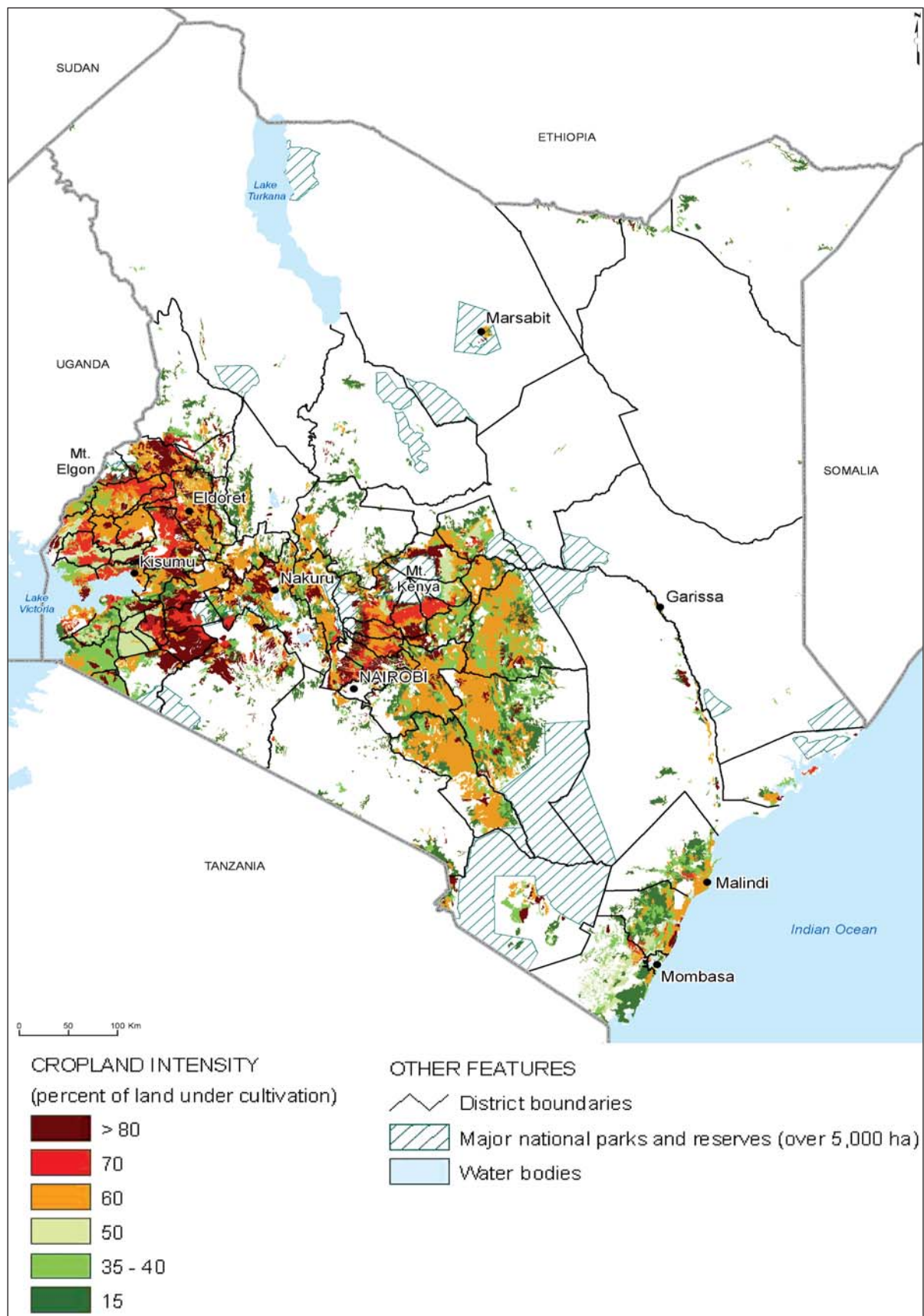
Map 2. Intensity of cultivation, 2000.

Map 3.   Water used for electricity generation.

expenditures (so-called money-metric indicators, such as poverty rate, poverty gap, and poverty density). Other maps show alternative measures of poverty, such as the Gini coefficient, which measures economic inequality; and housing quality, which reflects the overall wealth of a household. Because different geospatial indicators paint different pictures of poverty and human well-being, it is crucially important that analysts choose indicators that are appropriate to illuminate the issue or policy choice under consideration.

Kenya's technical institutions have established a good track record of supplying maps of poverty across the country mapped at various scales. The establishment of the Poverty Analysis and Research Unit in the Ministry of Planning and National Development and its steady release of maps showing the geographic dimensions of well-being is evidence of the country's commitment to map poverty in a timely fashion. *Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being* uses spatial indicators of poverty that build on the results of two poverty mapping analyses conducted by the Kenyan Central Bureau of Statistics with several partner organizations in 2003 and 2005 (Central Bureau of Statistics, 2003, 2005). In addition, the maps used in the atlas rely on detailed information from Kenya's 1999 Population and Housing Census to show the spatial distribution of Kenya's population and to construct an index of housing quality (Central Bureau of Statistics, 2002).

The maps and analyses featured in the atlas examine both rural and urban poverty, two distinctly different phenomena in Kenya. The expenditure-based poverty measures from the Central Bureau of Statistics reflect cost-of-living differences for rural and urban areas. In rural areas, expenditure poverty is defined as spending less than KES 1,239 per month (about USD 0.59 per day), whereas in urban areas, the poverty line is defined as spending less than KES 2,648 per month (about USD 1.26 per day). The poverty maps rely on information that is locally specific—that is, information based on data aggregated separately for each of Kenya's local administrative units. Depending on the chosen indicator, this information may either represent a Constituency area (there are a total of 210 Constituencies in the country), or a Location (the maps show 2,070 rural Locations and 496 urban Locations), or a Sublocation (there are 6,622 Sublocations in the country) (*Atlas*, p. 14).

Readers should note that these maps give only a snapshot for a single period (all well-being indicators are for 1999). Spatial poverty analyses conducted in the future could greatly benefit from regularly updated poverty maps, especially since rapid changes in economic, environmental, and household conditions can throw people into or help people exit from poverty. It is also important to bear in mind that all poverty indicators, including those used here, suffer from certain shortcomings. For instance, data on poverty are often collected and recorded at the level of the household, masking important differences among family members with respect to nutritional status, access to education, and other important dimensions of well-being. In addition, there are inherent limitations in the ability to aggregate locally derived data to give meaningful results at the national level (*Atlas*, p. 15).

A central tenet to our work is that human well-being relies fundamentally on the ability to access a wide variety of ecosystem services. Because many of these services do not flow through markets and do not have a market price attached to their use, they are not accounted for in conventional money-metric measures of welfare, such as income or expenditures. Readers should be continually aware that, for poor people in Kenya, as elsewhere, great gains in well-being can be obtained through more equitable and secure access to local ecosystem services that are central to environmentally sustainable livelihoods (*Atlas*, p. 15).

Maps 4 and 5 show two indicators of poverty in Kenya. Map 4, *Kenya poverty rate, 1999* shows the spatial distribution of Kenya's poverty rate. Map 5, *Kenya poverty density, 1999*, shows Kenya's poverty density. A nation's *poverty rate* is the percentage of the population below the poverty line (this is also known as the 'headcount ratio'). *Poverty density* is the number of poor people living in a given area. Note that these maps show poverty rates for the smallest administrative areas available, combining estimates at three different scales: 2,056 rural Locations (covering most of Kenya), 80 urban Sublocations, and 14 Constituencies (covering the northeastern part of the country). The urban estimates are based on a poverty line of KES 2,648 per month while the rest of the country is based on the rural poverty line of KES 1,239 per month. The poverty estimates for the 14 Constituencies are generally associated with a higher standard error than the other administrative units, a result of the statistical estimation technique (Central Bureau of Statistics, 2005) (*Atlas*, p. 16).

Maps of poverty rates often exhibit spatial patterns that are quite different from those of poverty density. Administrative areas in Kenya's arid and semi-arid
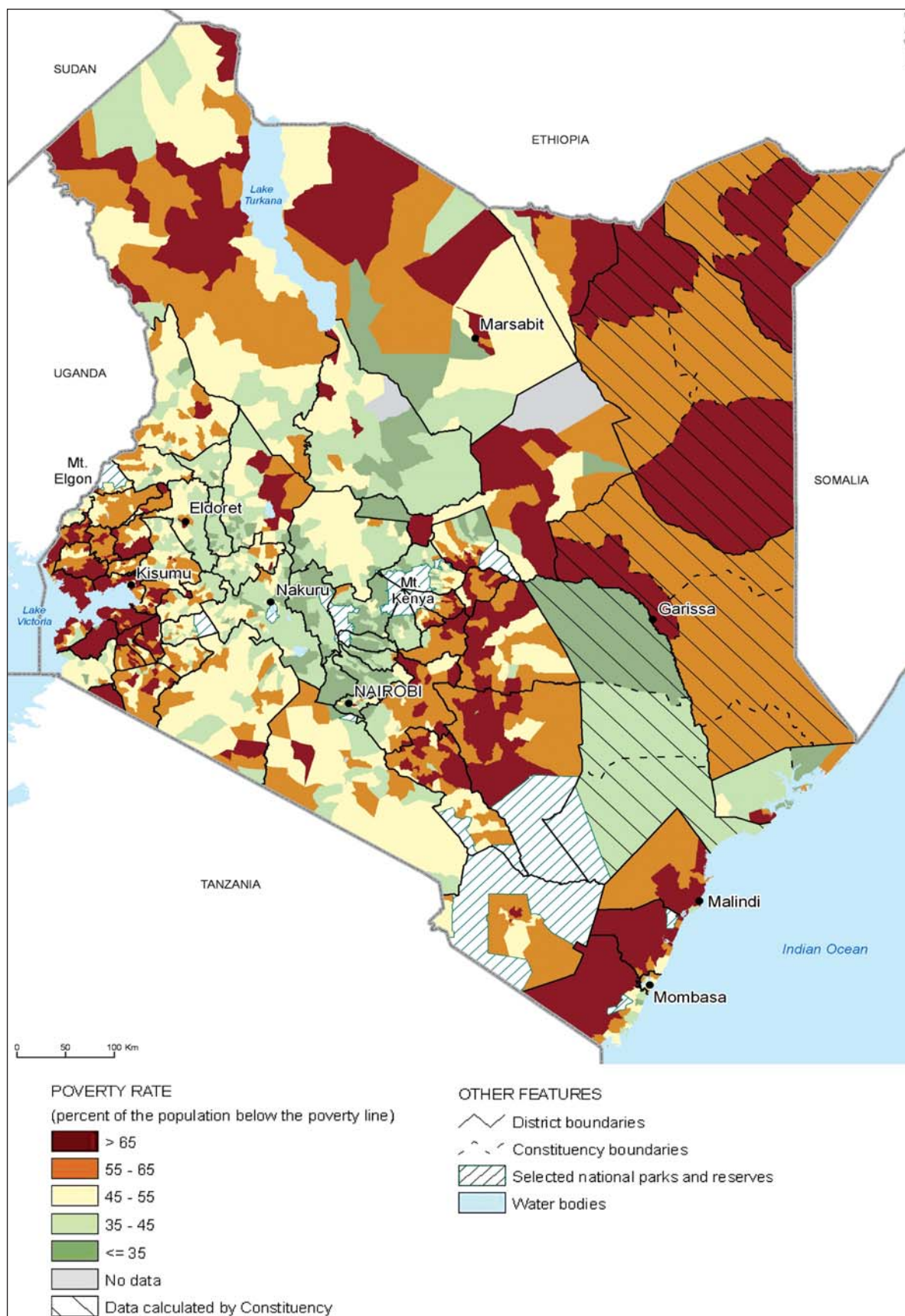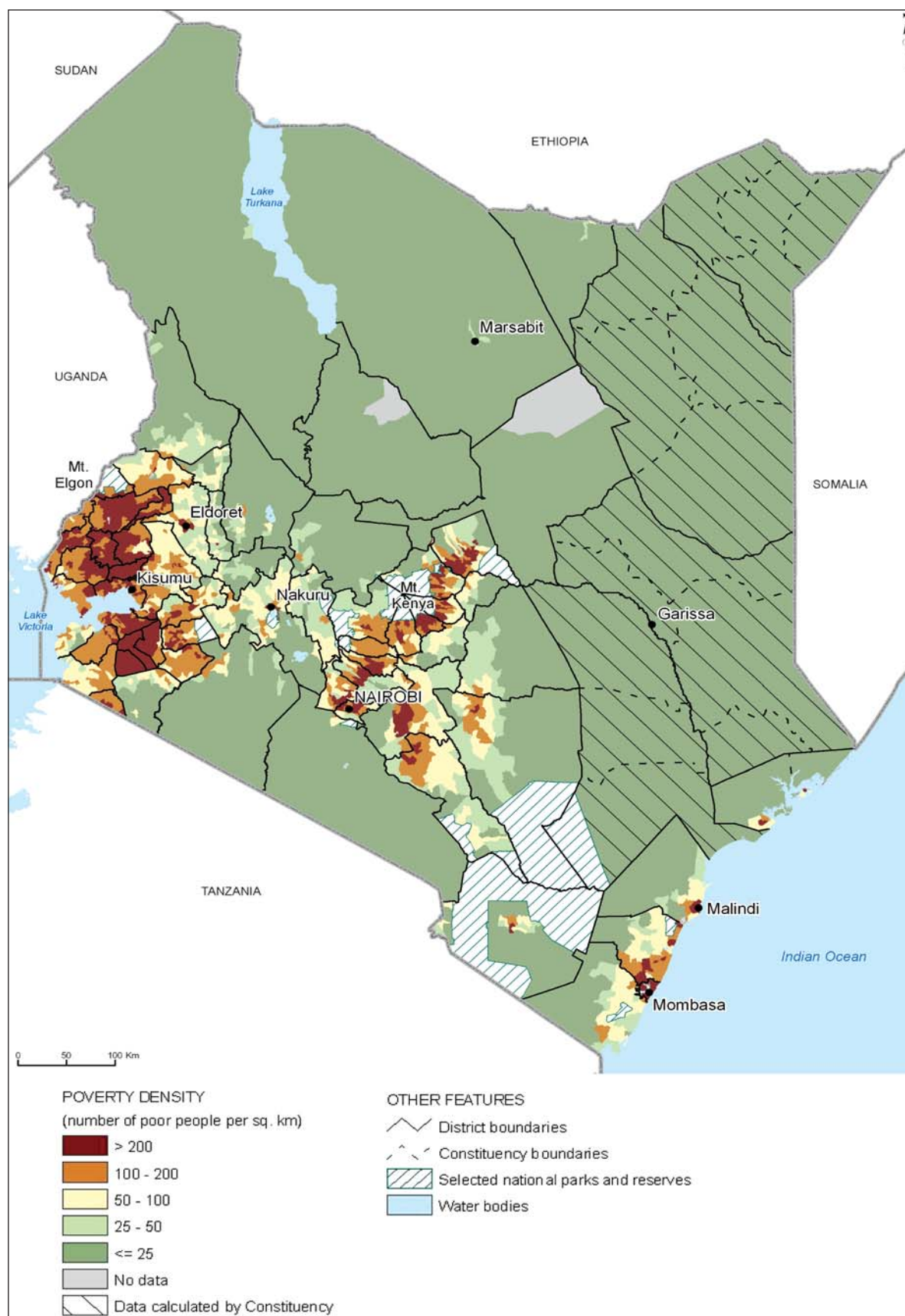
Map 4.   Kenya poverty rate, 1999.

Map 5.   Kenya poverty density, 1999.

regions, for example, generally have high poverty rates but overall very low densities of poor persons per square kilometer. The spatial patterns of these two indicators for large parts of the more densely settled areas are inversely related. For example, highly productive agricultural areas in Central Province have generally low poverty rates but still contain fairly large concentrations of poor people. Exceptions to this inverse relationship occur in western Kenya, some isolated areas in central Kenya, and along the coast, where both poverty rates and poverty densities are high (shown in darker tones on both maps). Understanding the relationships between the poverty rate and the poverty density is important for designing and implementing poverty reduction interventions. Using either the poverty rate or the poverty density alone to identify areas to focus poverty programs will likely be ineffective, either missing many poor people or over-distributing resources to families that are not poor (*Atlas*, p. 16).

For creation of Map 6, *Percentage of households with poor quality housing, 1999,* the authors derived an index of housing quality based on the most recent population and housing census in Kenya. The index was calculated based on the materials used for the roof, floor and walls in people's houses. In most parts of Kenya, the majority of households live in 'poor quality' homes where lower-grade materials are used. Housing quality is higher in the central regions of the country. This reflects the spatial pattern of poverty rates. One exception is in the administrative 'Locations' northwest of the town of Kisumu and slightly inland from the southern shores of Lake Victoria. These Locations show a higher share of better quality housing, but are very poor in terms of per capita expenditure indicators (i.e., poverty rate and poverty density) as shown in Maps 4 and 5 (Note that Map 6 hides high concentrations of very poor housing in small areas such as the informal settlements of Nairobi. It is a result of the scale of administrative areas, the percentage thresholds, and the index components selected for this national view.) (*Atlas*, p. 23).

CONNECTING ECOSYSTEM SERVICES AND POVERTY USING GEOSPATIAL INFORMATION

Note: Certain parts of the following section are taken from Chapter 8 (pp. 109–135) in the Atlas.

Chapter 8 of *Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being* provides an example of how GIS can be used to simultaneously examine relationships between people, ecosystems, and poverty. The chapter focuses on a small area important for people and ecosystems in Kenya, the upper reaches of the Tana River watershed basin. First, the chapter investigates the spatial congruence of different ecosystem services available in the watershed basin. Second, the chapter compares the areas that supply high levels of ecosystem services with geographical patterns of poverty within the watershed basin.

The spatial analyses conducted in this section of the *Atlas* are important because ecosystem services are typically looked at on a sectoral basis (e.g. water, forests, agriculture), which misses the interrelationships among them. Overlapping demand for various ecosystem services may produce conflicts over resource use, requiring tradeoffs among different uses and often between different users. Alternatively, there may be opportunities for synergies between or among different uses of ecosystem services. Mapping and analyzing spatial patterns of the supply and demand of different ecosystem services in the same geographic area can help communities address management decisions in a more integrated and equitable manner (*Atlas*, p. 110).

Comparing the spatial distribution of a range of ecosystem services in a given area with the spatial patterns of poverty in the same area is also important for offering important insights on poverty–environment relationships. For example, such an analysis could help identify areas where natural resource investments could boost environmental income for communities or reduce vulnerability of the poorest households from further resource degradation. It could also help identify communities that might be able to afford to pay for land use practices to ensure a continued supply of ecosystem services for users in the future. The authors believe that such multi-sectoral analyses of ecosystem services and of poverty–environment relationships will inspire more detailed cross-cutting studies in other geographic regions of the country (*Atlas*, p. 110).

Maps 7–10 have been selected from Chapter 8 of *Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being* to provide examples of how geospatial data can be used to create maps and analyses which show the convergence of ecosystem services and human well-being in Kenya. Maps 7 and 8 provide an overview of the population distribution and poverty rates within the watershed. Maps 9 and 10 demonstrate a concrete example of how maps can be used to examine and illustrate one aspect of the economic well-being of
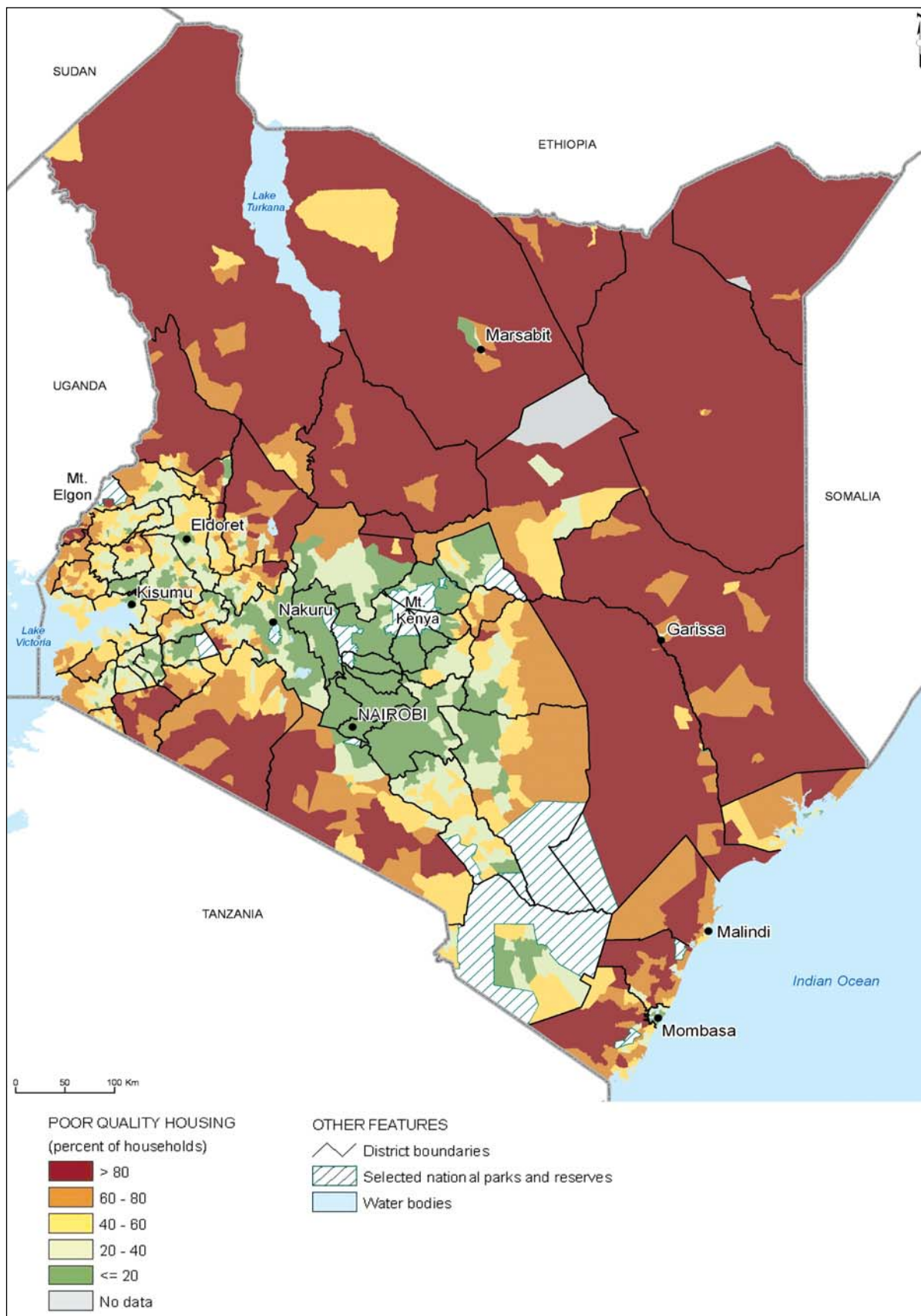
Map 6.   Percentage of households with poor quality housing, 1999.

people who depend highly on milk production for their livelihood. Each map focuses on the geographic region of the upper reaches of the Tana River watershed basin around the base of Mount Kenya. The line in Map 7 and in subsequent maps outlines the upper Tana watershed area. It represents the common watershed boundaries of all the major permanent streams and rivers originating in the Aberdare Ranges and Mount Kenya that flow into the Tana River.

Map 7 shows a three-dimensional view of the Upper Tana River watershed basin and the distribution of population density. About 860,000 households live in the upper Tana region. The average population density is 250 people per square kilometer. The region includes some of the most densely populated rural areas in Kenya, with densities of more than 600 persons per square kilometer in some areas. Population densities in the region's lower elevation sections are generally less than 100 persons per square kilometer (*Atlas*, p. 112).
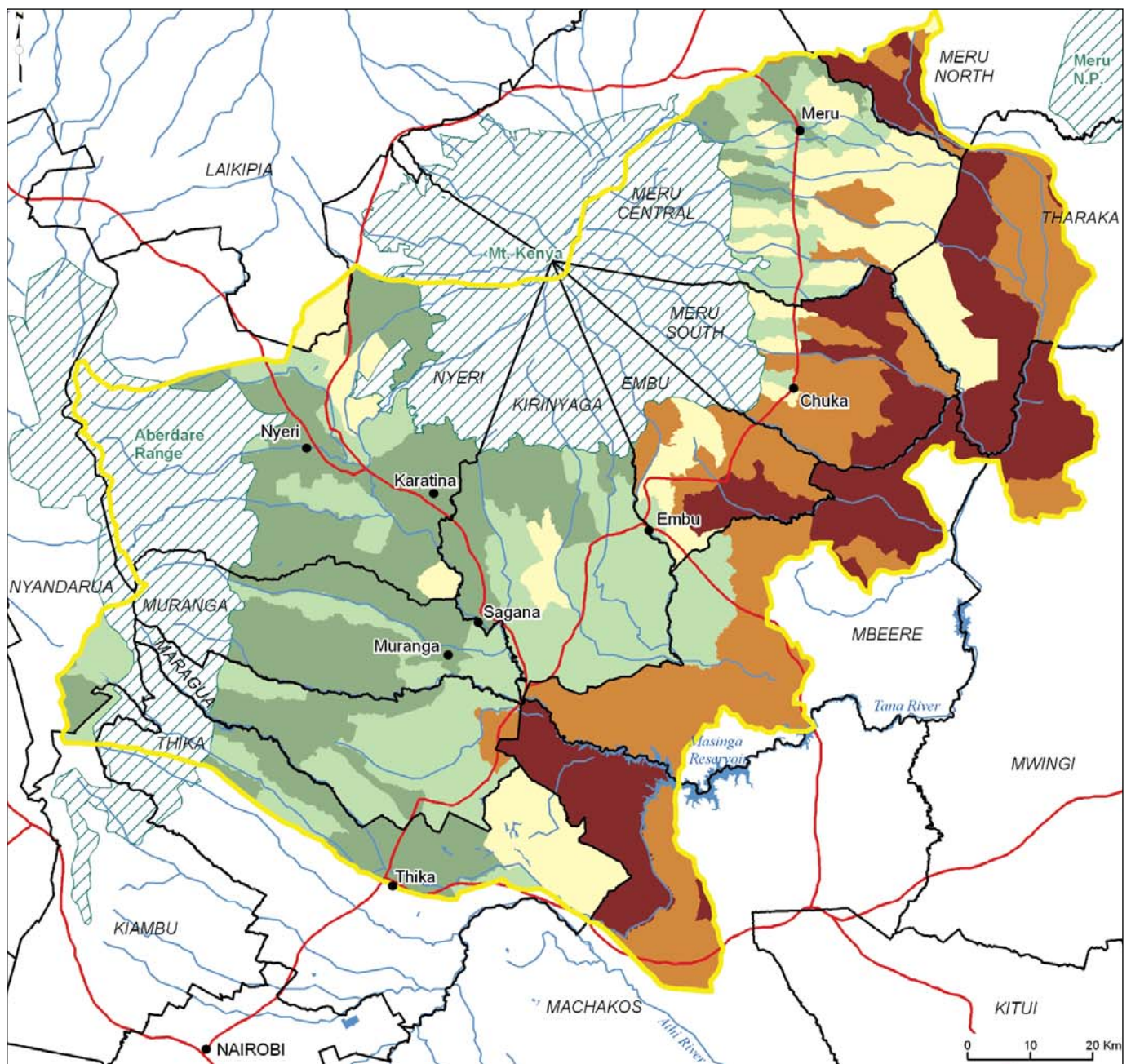
Map 8, *Upper Tana River Watershed Basin – poverty rate, 1999* shows that spatial patterns of poverty in the upper Tana region are quite distinctive. Along the rivers that drain the Aberdare Range or Mount Kenya, administrative Locations at higher elevations generally have lower poverty rates than the Locations further downstream. Communities in the lower plains and the drier parts of the upper Tana have the highest poverty rates, which are above the national rural average of 53 percent. The least poor region, which contains large contiguous areas where the poverty rate is less than 35 percent, is located in the foothills of Thika, Maragua, Muranga, Nyeri, and Kirinyaga Districts. Although not shown in this article, the spatial patterns of poverty *density* – the number of poor people living in the area – are quite different from those of the poverty rates shown here (see Maps 4 and 5) (*Atlas*, p. 113).

Maps 9 and 10 examine the spatial relationship between milk production and poverty in the Upper

POPULATION DENSITY
(number of people per sq. km)

- > 600
- 300 – 600
- 100 – 300
- 50 – 100
- 20 – 50
- <= 20

OTHER FEATURES

- Upper Tana boundary
- District boundaries
- Major national parks and reserves (over 5,000 ha)

WATER BODIES AND RIVERS

- Permanent rivers
- Water bodies
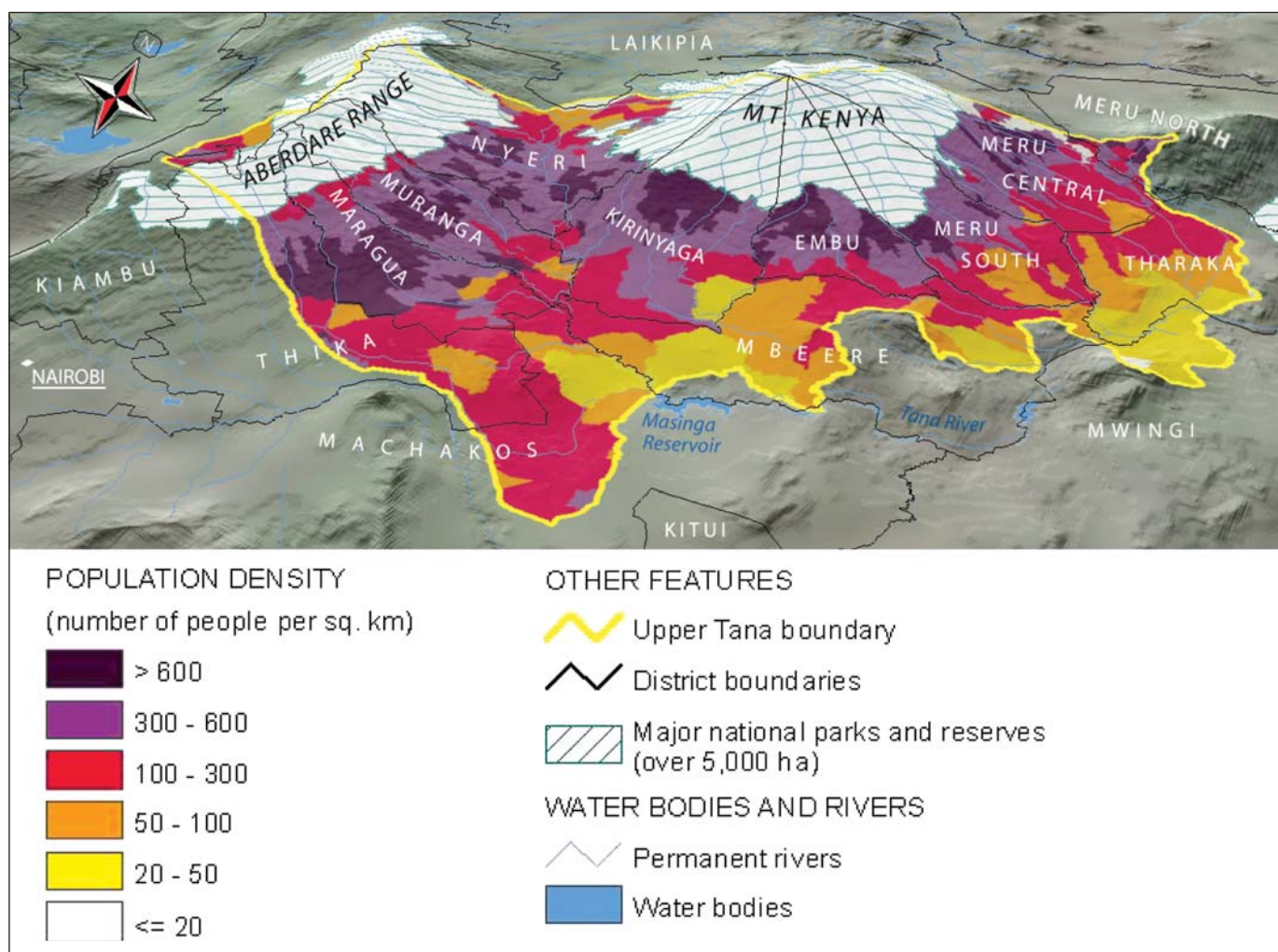
Map 7.   Upper Tana River Watershed Basin – population density, 1999.
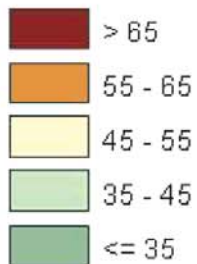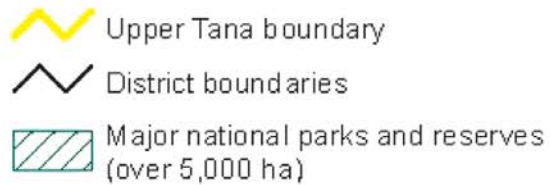
Map 8. Upper Tana River Watershed Basin - poverty rate, 1999.

Tana watershed basin. Map 9 presents the spatial distribution of milk production within the basin. Areas with annual milk production greater than 100,000 liters per square kilometer are mostly at higher elevations in the foothills of the Aberdare Range and Mount Kenya, while areas of low milk production occur at lower elevations (*Atlas,* p. 123).

Dairy provides a source of high-quality protein and micronutrients, which often are lacking in largely cereal-based diets. Thus, areas with relatively high levels of milk production might be expected to be better off economically, with a greater concentration of households that can afford better nutrition. Moreover, livestock provide household savings and supplemental income for farming families. A plausible hypothesis, therefore, would be that areas with higher dairy output correlate with lower poverty rates (*Atlas*, p. 120).

Map 10 shows the spatial coincidence of poverty and locations with high milk production (i.e. production of more than 100,000 liters per square kilometer per year). The map isolates the administrative Locations of highest milk production and displays their corresponding poverty rates. By viewing this particular map, readers can more easily observe the economic well-being of people who depend on milk production for their livelihood. As shown by the map overlay, most areas of high milk production correspond to areas with a low incidence of poverty. Such areas form a large expanse across the eastern foothills of the Aberdares and the southwestern slopes of Mount Kenya, as well as a few areas in Meru Central District. The pattern in these administrative Districts supports the hypothesis that high milk output – most likely associated with a greater number of cross-bred dairy cattle – is more prevalent in communities with lower poverty rates. Further investigation is needed to determine whether households in these communities became less poor once they became high milk producers or whether a certain amount of capital had to be in place to support a high-milk output production system. An examination of areas of high milk production and high poverty rates can provide useful insights into the causes of high poverty rates. It could also help promote appropriate milk production technology in poorer communities in the upper Tana (*Atlas*, p. 123).

Map 10 illustrates an important component of the atlas – to demonstrate that geospatial data and maps can be used to elucidate relationships between ecosystem services and poverty. While the goal of the atlas is not to explain these relationships for particular areas in Kenya, the atlas helps show how analysts and decision-makers in lead Kenyan institutions and elsewhere can begin to assemble similar geospatial tools to examine these relationships more closely. Similar examples of spatial crosscutting analyses involving poverty and other ecosystem services, such as crop production (examination of poverty rates in areas of highest food production), drinking water (examination of poverty rates in areas with piped- and non-piped drinking water access), and irrigation (examination of poverty rates in intensely irrigated areas), are also featured in the atlas.
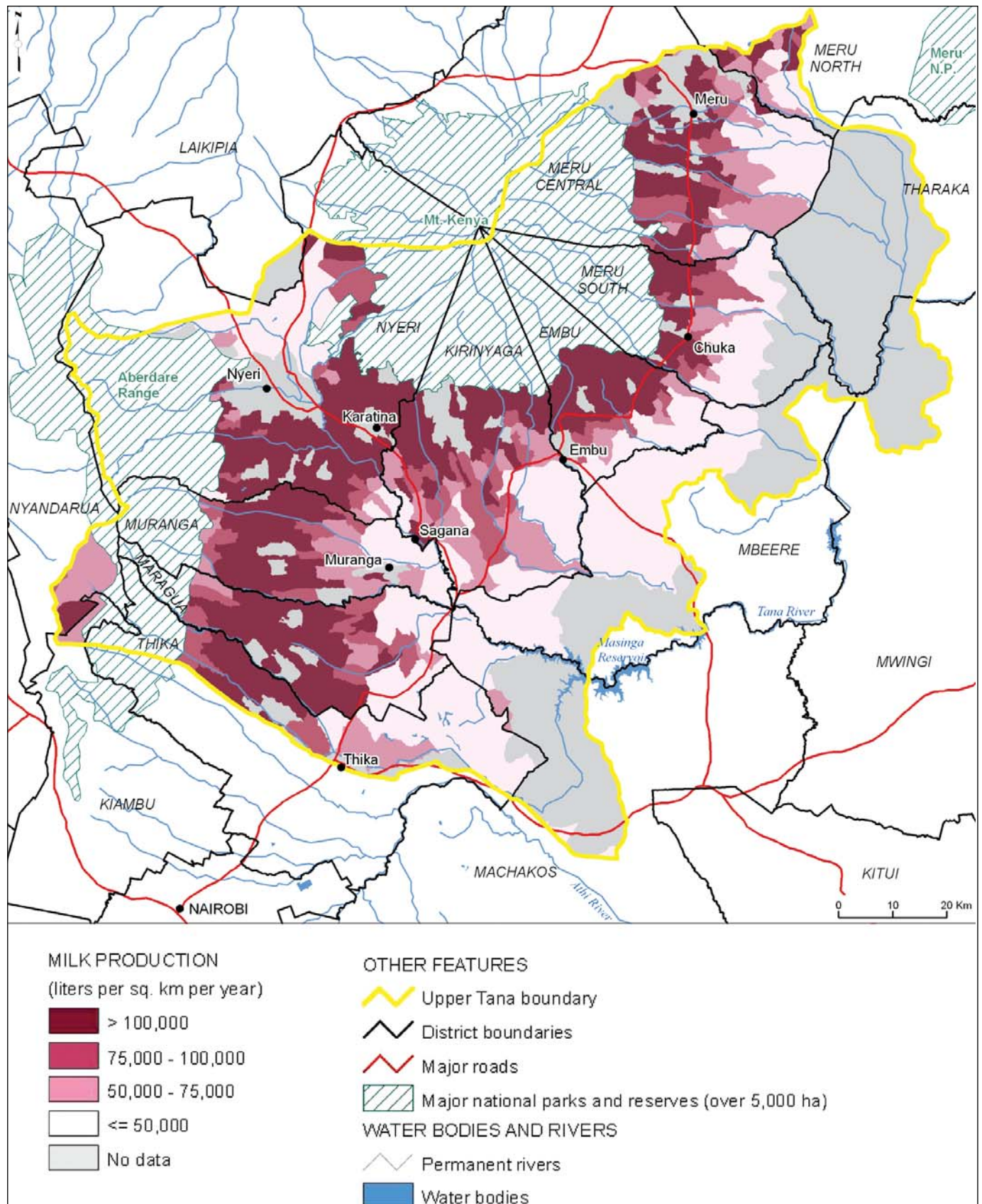
FINDINGS AND CONCLUSIONS

Note: Certain parts of the following section are taken from Chapter 9 (pp. 136–139) in the Atlas.

Maps can serve as useful tools to show patterns of ecosystem service availability and to explore the relationships that these services have with human welfare. It has been demonstrated that Kenya has the capacity and information to map poverty and other dimensions of well-being across the country and at a scale that allows for meaningful examination of the array of ecosystem services that are available at a given location and how they influence the lives of surrounding residents. Kenya has established a solid foundation for analysts to examine the spatial relationships between poverty and selected ecosystem services and for decision-makers to increase their understanding of poverty-environment linkages in specific locations using geospatial information from a GIS.

The following conclusions, beginning with more general findings about the use of maps for socio-geographic analysis, and proceeding to more specific conclusions about ecosystems and poverty in Kenya, have been formulated based on the maps and analyses presented in *Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being*. The atlas also presents a set of recommendations to policy-makers that are not shown here due to space limitations.

1. *By combining existing maps and data on ecosystem services and human well-being, analysts can create new ecosystem-development indicators.* New indicators may capture certain relationships between resources and residents that can shed light on development in these regions. This approach can now be used to analyze many other ecosystem-development relationships such as: communities within a certain

MILK PRODUCTION
(liters per sq. km per year)

- ■ > 100,000
- ■ 75,000 - 100,000
- ■ 50,000 - 75,000
- □ <= 50,000
- ■ No data

OTHER FEATURES

- Upper Tana boundary
- District boundaries
- Major roads
- Major national parks and reserves (over 5,000 ha)

WATER BODIES AND RIVERS

- Permanent rivers
- Water bodies

Map 9. Milk production in the Upper Tana River Watershed Basin.

POVERTY RATE
(percent of population below poverty line)

- > 65
- 55 - 65
- 45 - 55
- 35 - 45
- <= 35

OTHER FEATURES

- Upper Tana boundary
- District boundaries
- Major roads
- Major national parks and reserves (over 5,000 ha)

WATER BODIES AND RIVERS

- Permanent rivers
- Water bodies
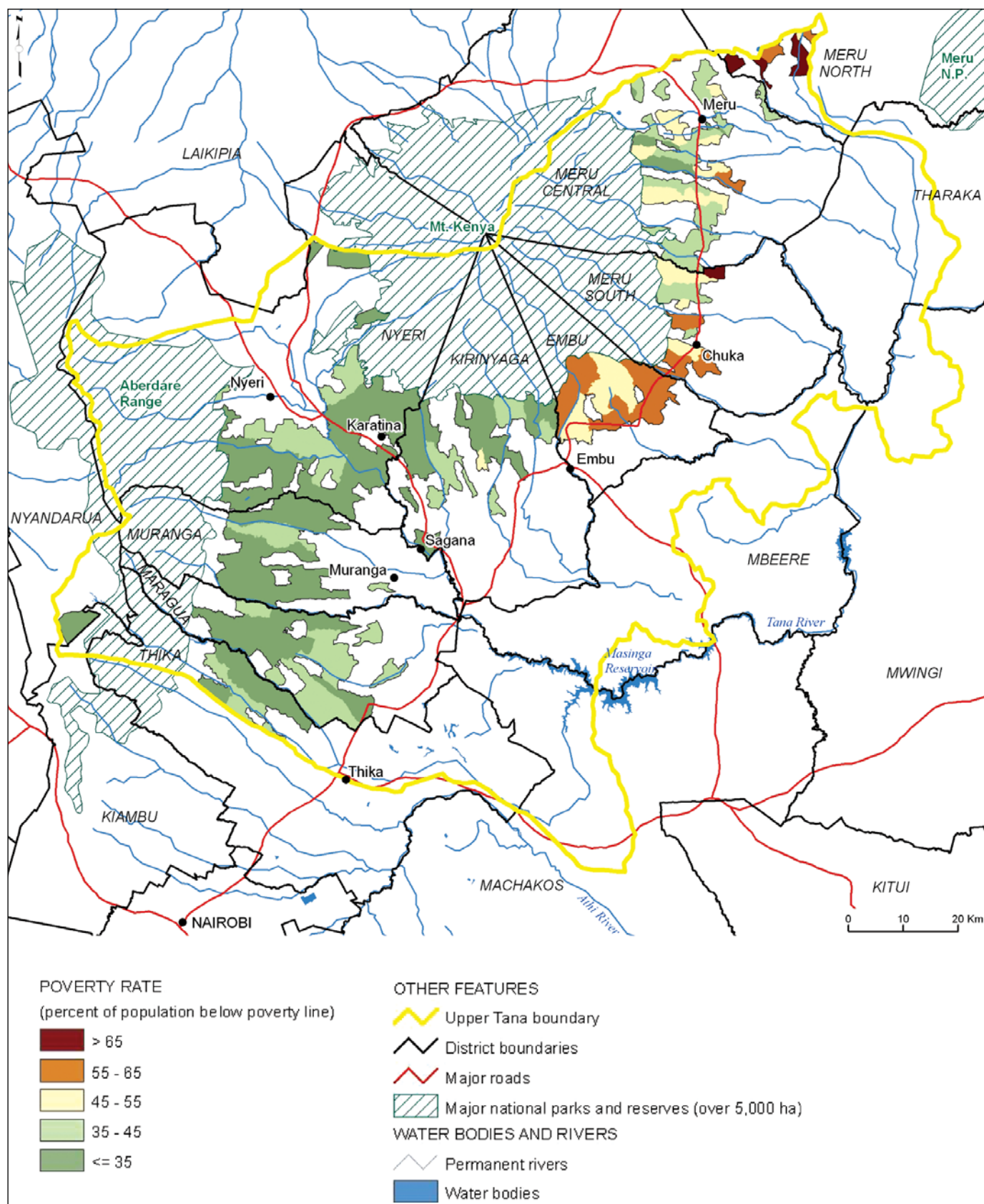
Map 10.   Upper Tana River Watershed Basin – high milk production and poverty rate.

distance of rivers, lakes, and reservoirs; poverty hotspots and access to intensively managed cropland; or physical infrastructure, poverty and major ecosystem services (*Atlas*, p. 136).

2. *Decision-makers can examine the spatial relationships between different ecosystem services to shed light on possible competition (i.e. tradeoffs) and synergies between various ecosystem services.* The maps in the chapter focusing on the upper Tana River watershed basin (Chapter 8) overlay different indicators of ecosystem services such as surface water as a dominant source for drinking water, water used for small and large-scale irrigation, food crop production, milk output, crop diversity, and woodlot densities. These overlays suggest how analysts and policy-makers can compare the spatial patterns of various ecosystem-related indicators. This is the first step to more closely examine potential synergies and tradeoffs between different ecosystem services (*Atlas*, p. 136).

3. *Decision-makers can examine the spatial relationships between poverty and a bundle of ecosystem services.* The overlay of poverty and selected ecosystem services, shown in Chapter 8, highlights whether spatial patterns of selected ecosystem services parallel those of poverty. Decision-makers and analysts can begin to ask important questions such as: 'Do areas with high poverty rates coincide with areas of low food cropping?' 'Where are the exceptions?' For example, in which parts of the upper Tana River watershed are communities who produce a high milk output still relatively poor? (*Atlas*, p. 136)

4. In spite of the usefulness of overlaying maps of ecosystem services and poverty, there are limitations to this approach. These include:

   • *Lack of data to map a comprehensive set of ecosystem services for all of Kenya.* Data collection systems for natural resources generally focus on sectors and commodities with high economic value or important political constituencies. They typically concentrate on the provisioning aspect of ecosystems such as the supply of food and non-food crops, timber, and fish. Data that capture non-timber forest products or reflect the local use of wetlands or mangrove-coral ecosystems, for example, could correct for some of the bias in the available data. Data on regulating services would also be useful, such as spatial data delineating groundwater recharge zones or areas where rapid

changes in vegetation would greatly affect hydrological flows. Another challenge related directly to data acquisition is that geospatial data requires adequate metadata documentation and often requires updates – this demands sufficient capacity which presents certain challenges to many institutions (*Atlas*, p. 137).

   • *Inherent limitations of spatial analyses (i.e. map overlays).* Analysts often lack scientifically valid models with which to link human behavior, ecosystem services, and human welfare. This means that even though analysts may be able to identify spatial correlations between these elements, they may not always be able to pinpoint the cause of poverty or the threats to ecosystem sustainability (*Atlas*, p. 137).

   • *Limitations in the fundamental knowledge of ecosystems and their value.* Some of the shortcomings in mapping ecosystem services are a result of important gaps in basic ecological science and economics. The current understanding of how various ecosystem processes interact with human interventions is still limited, as is a comprehensive estimation of the economic value of ecosystem services in Kenya (*Atlas*, p. 137).

   • *Complexity of measuring and monitoring poverty and livelihoods.* Kenya's poverty maps, which are based on combining household expenditure information with census data, can only capture certain aspects of human well-being and a limited set of poverty dimensions. Similarly, livelihood mapping holds similar constraints. Although this atlas features maps of important livelihood components such as hunting, wood gathering, and charcoal production, it cannot adequately represent the variability and complexity of the livelihoods of poor families (*Atlas*, p. 137).

5. *There are also important institutional barriers to measuring and mapping poverty–ecosystem relationships and using this information to inform national policies and decision-making.* These barriers include:

   • *Lack of awareness about ecosystems and ecosystem processes.* The findings of the Millennium Ecosystem Assessment, a global effort to assess ecosystem conditions and the links to human well-being, were released in 2005 (Millennium Ecosystem Assessment, 2005). The Southern African component of the Millennium Ecosystem Assessment demonstrated that ecosystems can

be examined at various scales (such as a scale covering multiple countries, a large river basin, the area surrounding a protected area, or local communities), and that the resulting information can be linked to national development goals (Scholes and Biggs, 2004; Biggs et al., 2004). In spite of this success, most countries have not fully adopted the ecosystem-oriented approach whose usefulness the Millennium Ecosystem Assessment proved. This is true in Kenya as well, where ecosystem thinking is still contending with a traditional sectoral focus (*Atlas*, p. 138).

- *A sectoral mandate among government institutions that works against cross-cutting analysis involving multiple ecosystem services and poverty.* Mapping a set of ecosystem services and examining the links between these services and poverty requires data and expertise from a number of institutions within and outside government. However, the mandate of many government institutions focuses narrowly on sectors in the economy such as agriculture, fisheries, urban affairs, transportation, water, forests, etc. Central government budgets are designed to support these mandates, generally leaving a relatively small amount of funds and staff support for more integrated cross-sectoral work, such as environmental reporting and ecosystem mapping (*Atlas*, p. 138).

- *Insufficient promotion of interdisciplinary analysis.* Mapping poverty and ecosystem services and analyzing the linkages between them requires an interdisciplinary approach, since no single individual generally has the wide range of expertise needed. Currently, the commitment to such an approach – in training and resources – is often lacking (*Atlas,* p. 138).

It is hoped that by using the data and concepts demonstrated in *Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being*, analysts and decision-makers in lead Kenyan institutions can initiate a comprehensive accounting of ecosystem services for the country. They can continue to develop tools to better integrate poverty–ecosystem relationships in national policies and decision-making. They can foster a better understanding among legislators of these poverty-ecosystem links. And they can apply ecosystem principles and the approach taken in the Millennium Ecosystem Assessment to national and local environmental reporting (*Atlas*, p. 139).

Ideally, accomplishing this would result in programs for poverty reduction in Kenya that take into account where the poor live and what ecosystem services are available to them. It would improve the targeting of social expenditures and ecosystem interventions so that they reach areas of greatest need. And it would make available to decision-makers – both public and private – an array of spatial information that could inform their decisions on a range of resource and social issues in Kenya (*Atlas*, p. 139).

Note

Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being will be released in April 2007 in digital and hard copy formats. The full atlas, data, and maps will be available electronically online and on CD from the World Resources Institute's website at *http://www.wri.org*

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Abstract

Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being is the result of a recent collaborative effort among several institutions in Kenya. The atlas demonstrates how geospatial data and maps can be used to analyze the spatial distribution of poverty and ecosystem services in Kenya. This article introduces concepts of ecosystem services, poverty, and environment–poverty relationships in Kenya and features selected maps from the atlas. It also presents conclusions from the atlas and discusses the ways in which the authors hope the atlas will be used by analysts and decision-makers in lead Kenyan institutions and elsewhere.

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