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WYSS ACADEMY FOR NATURE

Towards sustainable futures for nature and people

An appraisal report for the Mt. Kenya–Ewaso Ng'iro North landscape, Kenya

WYSS ACADEMY REPORT 2

Boniface Kiteme, Thomas Breu, Joan Bastide, Sandra Eckert, Markus Fischer, Santos J. González-Rojí, Christian Hergarten, Kaspar Hurni, Martina Messmer, Christoph C. Raible, Mark Snethlage, Thomas F. Stocker, Amor Torre-Marin Rando, Urs Wiesmann

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Executive summary

Boniface Kiteme, Thomas Breu, Christian Hergarten

Accelerated development processes in recent decades have led to irreversible biodiversity loss, large-scale land use change and degradation, as well as to an unprecedented climate crisis. Resulting pressures are threatening the most vital resources for humans and nature, which are land, water, and climate. Human wellbeing is a fundamental precondition for sustainable nature conservation, and while the urgency of addressing habitat degradation is widely acknowledged, the pathways to achieve this without denying local communities their rights and livelihoods is a major challenge. The Wyss Academy for Nature at the University of Bern aims to address these challenges by transforming scientific knowledge into action. It runs Regional Hubs in Europe, Southeast Asia, East Africa and South America. The report at hand is an account of relevant developments and trends of the Upper Ewaso Ng'iro basin of Mt. Kenya in East Africa, presenting an overview of processes and stakeholders relevant for nature and people initiatives and identifies challenges, opportunities and research needs for reconciling nature conservation and human well-being in the region.

The Ewaso Ng'iro basin is characterized by steep ecological gradients from the heights of Mt. Kenya to the northern lowlands, adding to the high and diverse values of nature, which in combination with the scenic landscape forms a global bright spot. Land use and population density in the basin vary along the south-north gradient. The foot slopes of Mt. Kenya are dominated by smallholder agriculture, large farms and increasingly also agribusiness, resulting in high population density. Adjacent further north follows the Laikipia / Samburu plateau with large private ranches, focusing on livestock and wildlife conservation, alongside traditional pastoralists roaming the landscape with their herds. In the northern lowlands, pastoralist lifestyles dominate, along wildlife conservation, resulting in the lowest population density. Competing claims for resources along the gradient are creating complex socio-ecological patters, resulting in uneven power dynamics and contentious relationships. Hence, the high values of nature are increasingly threatened. Growing smallholder agriculture, expanding agribusiness, and pastoralists suffering from limited mobility due to conservancies and ranches have led to accelerating degradation of water and vegetation resources. Climate change tend to further aggravate these human induced degradation processes. Human well-being is characterized by significant socio-economic disparities, high poverty rates, varying education levels, and unevenly distributed access to services. The differences of human well-being in the region follows two gradients, one between highlands and lowlands and the second along center-periphery patterns around urban centers.

Increasing pressure on nature’s contributions to people, expansion of commercial agriculture leading to conflicts with pastoralists over access to resources, contested external conservation interests and growing disparities due to unequal economic development are just some of the most important challenges the area is facing. However, there are also opportunities promising entry points for catalyzing local and regional development – linked to the high natural capital endowment and the young and comparatively well educated workforce eager to get involved. Further, the development of transportation infrastructure accelerates the regional integration of markets, and modernized governance frameworks are creating new opportunities to shape nature-people relations more sustainable in the future.

Knowledge gaps and research needs required to strengthen sustainable nature-people relations in the region are linked to a better understanding of the socio-ecological system and its dynamics and triggers enabling systemic change and transformation to a more sustainable and just future.

1 Introduction

Thomas Breu, Boniface Kiteme, Urs Wiesmann

Climate change is accelerating. Social disparities are widening. And biodiversity is decreasing at an alarming rate. These challenges are global, and they are interlinked. The decade we are currently in will show to what extent humanity can – will – cope. We argue that concrete pathways to sustainable development must reconcile nature conservation and human well-being. Focusing on the Upper Ewaso Ng'iro basin north of Mt. Kenya from a sustainable nature conservation perspective, this report provides an sappraisal of key features relevant for development in this particular social and geographic context. Our basic premise is that improved human well-being, prosperity, and self-determination of local communities are a prerequisite for halting and reversing habitat loss and nature degradation. This report offers integrated knowledge needed to design and implement ways of achieving this.

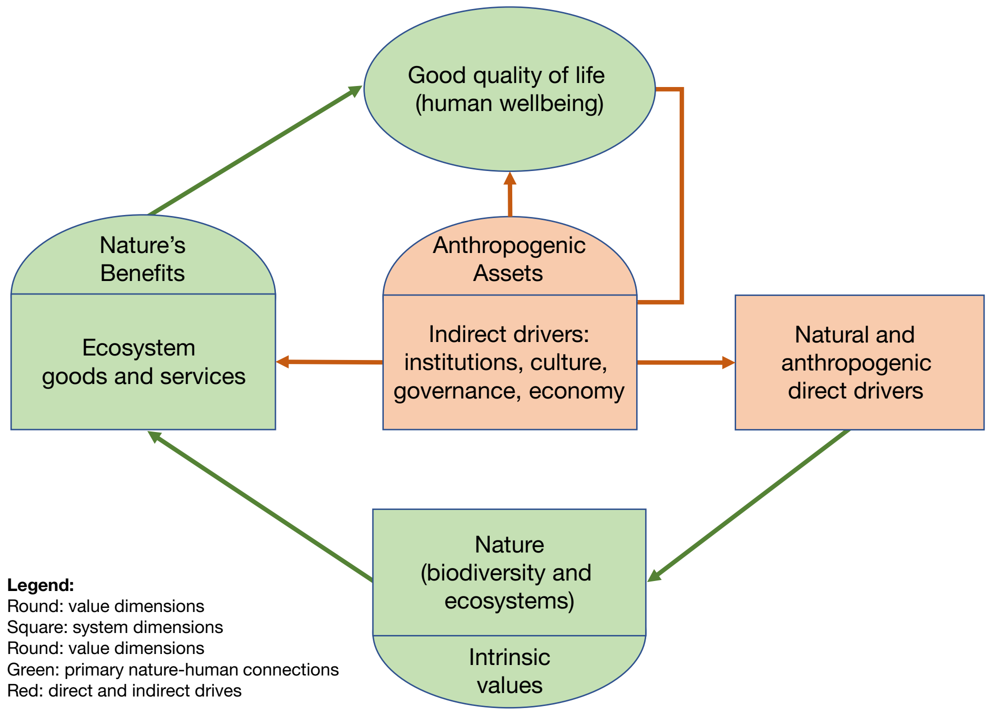
We begin by summarizing the status of the relationships between nature and people as well as relevant trends. To this end, we examine nature's contributions to, and limitations for, livelihoods and human well-being, as well as people's impacts, both positive and negative, on natural resources. In terms of nature, we describe ecosystem services and underlying drivers of change. In terms of people, we provide an overview of different stakeholder interests and power relations as well as existing initiatives, projects, and networks that could be aligned or overlap with the activities of the Wyss Academy. On this basis, the report identifies approaches and opportunities that enable transformations for reconciling objectives of nature conservation and human well-being. In addition, it identifies knowledge gaps and research needs related to the different topics addressed.

The information on biodiversity, ecosystem services, and direct drivers of change – such as land degradation caused by invasive species, climate change, and others – are guided by an adapted IPBES conceptual framework (Figure 1.1). Believing that local populations and communities are pivotal in finding solutions and pathways for improved nature conservation and for respective valuations of nature and human well-being, we also give due attention to *indirect* drivers of change. They occur within the socioeconomic system, reflecting the complex interplay of demography, culture, economy, governance, and technology at different scales. Indirect drivers are directly linked to human use of land – for different purposes and in different contexts.

This report draws on the body of knowledge accumulated over the past 40 years by the Nanyuki-based organization CETRAD, the Centre for

Development and Environment (CDE) at the University of Bern, and CDE's broad partner network. In the biophysical realms, the analysis of land use system dynamics is based on satellite imagery (e.g. MODIS) and publicly available global datasets provided by the International Geosphere-Biosphere Programme (IGBP), Global Biodiversity Information Facility (GBIF), and others. The climate is assessed based on weather stations and reanalysis data, output from regional climate models, as well as from the Coupled Model Intercomparison Project (CMIP5), the latter included in the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2013). The ecosystem and biodiversity assessments are based on a review of peer-reviewed documents, which was complemented with grey literature, such as biodiversity strategies, climate change strategies, and action plans. The analytical work on indirect drivers of change relies on the data from the Kenyan National Population Census and the analytical work presented in the Socio-Economic Atlas of Kenya by the Kenya National Bureau of Statistics (KNBS), CETRAD, and CDE, as well as numerous project reports, master's theses and PhD dissertations, and government documents.

Figure 1.1: Adapted conceptual framework used for the report on the Mt. Kenya–Ewaso Ng'iro North landscape, Kenya (Source: CETRAD derived from Díaz et al. [2015])



One of the limits of mainstream development approaches in the past was to consider the local contexts across the global South as stable, permanent, homogeneous, and comparable. This narrow and linear vision allowed development paradigms based on generic models, blueprint approaches, and a unified vision of development goals to flourish among institutions and professionals. But evidence from decades of development efforts and research have clearly shown that this one-size-fits-all approach was not only ineffective – it was also potentially harmful. Moreover, the recent global shift towards sustainable development – development that combines multiple and sometimes conflicting goals – has highlighted the complexity and context-specificity of development pathways, and hence the need to design context-specific and locally accepted solutions. The Wyss Academy for Nature aims to achieve this through a threefold approach, by 1) understanding the socio-ecological systems targeted by development and policy interventions, 2) negotiating sustainability targets and trade-offs with key local – and sometimes distant – actors to develop a joint vision for the future, and finally 3) identifying the most effective levers to trigger systemic change that addresses both symptoms and root causes of the problems.

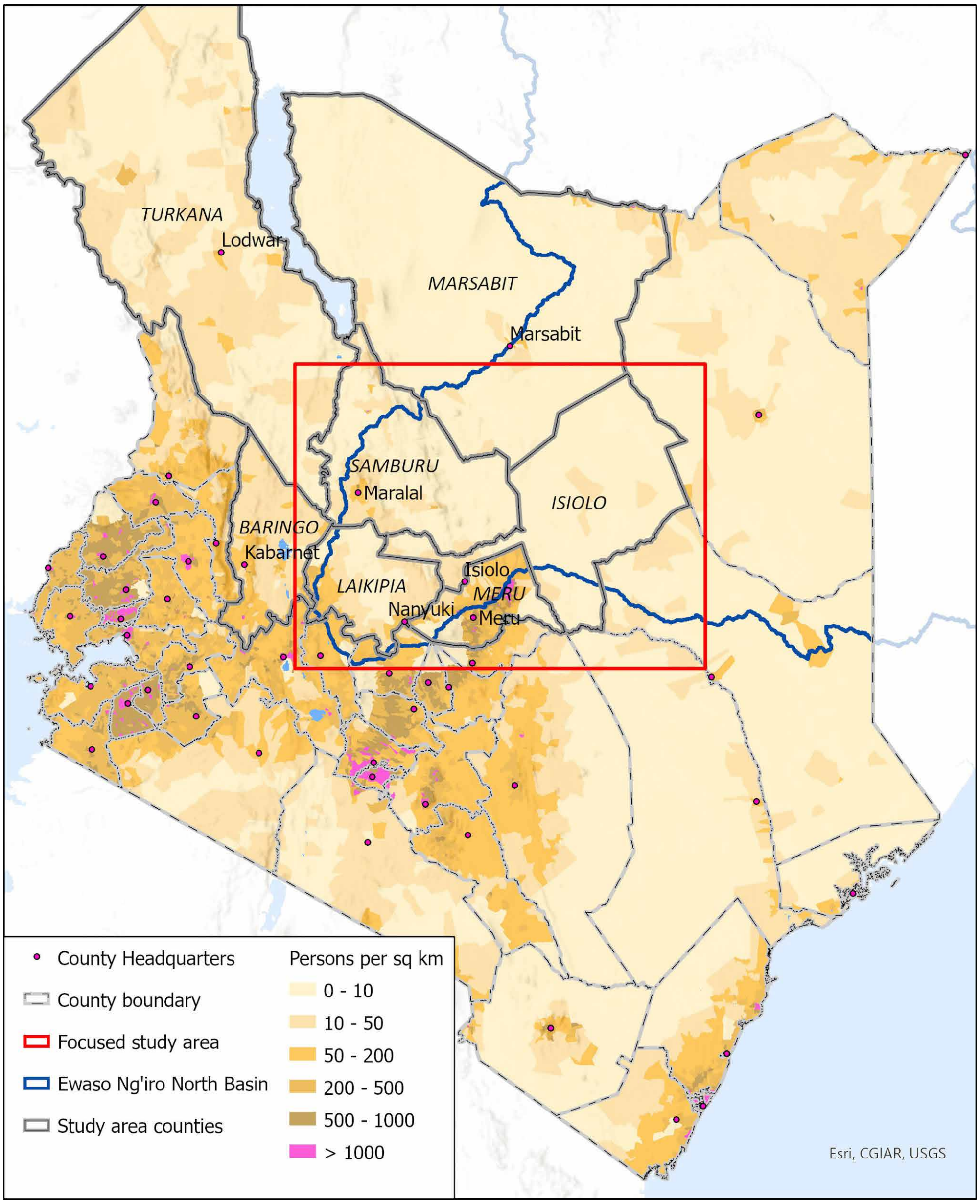


Figure 1.2: Map of Kenya depicting population density, Ewaso Ng'iro catchment, focused study area, and key counties (Source: Wiesmann et al. 2016)

Against this background, we start, in this section, by briefly presenting some of the key features of the Mt. Kenya–Ewaso Ng'iro North landscape that require adaptations in policy and development interventions.

As Figure 1.2 illustrates, our study area borders the densely populated highlands that form the economic and political core of the nation, and extends north to the arid and semiarid lowlands. The humid highlands are well suited for agriculture and have two rainy seasons – the "long rains" from March to May and the "short rains" in October and November, while the arid and semiarid lowlands are characterized by less precipitation and more variability. Located between center and periphery, the region is thus in a context of transition.

At the interface of the Mt. Kenya and the Ewaso N'giro river systems, the landscape presented in this report is characterized by spectacularly steep ecological gradients. From the rather green slopes of the second highest mountain in Africa (5,199 m a.s.l.), to the semiarid plains of the lowland counties of Isiolo and Samburu (at elevations between 1,200 m and under 500 m), precipitation dramatically decreases in amount and increases in variability, to levels that limit the spectrum of livelihood options. At the same time, the steep gradients have enabled the development of a very rich sequence and diversity of ecosystems, spanning mountain forests and savannas to shrub- and grassland ecosystems. These are further enriched by the rivers that originate in the mountains and remain perennial far into the dry environments in the lowlands.

Traditionally, the strategy employed by the local population to cope with resource scarcity and unpredictability of rainfall patterns was pastoralism – an extensive and semi-nomadic livestock raising system. In fact, until the early 20th century, the whole region was under a pastoralist land use system and its vertical sequence of ecosystems was optimally suited to the strategy of mobility to follow the rains. But is became impossible to carry out this strategy during colonial times – particularly from the early 1900s to 1964. Under British rule, pastoralists were cut off territorially from dry-season highland pastures which became known as the "White Highlands". The area was subdivided into huge portions of land that were granted to European settlers and mostly converted into ranches. This structure of land ownership persisted after independence so that in certain counties of the region, privately owned, often fenced-off areas still represent up to 40% of the total land mass. In the process, Maasai from the Laikipia plateau were pushed out of their ancestral lands towards the lowland semiarid plains or even displaced to southern Kenya. After national independence in 1964, some of the former large-scale farms and ranches – especially near the mountain – were sold and subdivided, opening the region to internal migration of smallholder farmers from other parts of the country. This third wave resulted in a very high regional population growth rate comparable to that of Nairobi and other urban centers, making it even more difficult for pastoral groups to move across the landscape. It also put heavy pressure on the water resources originating in Mt. Kenya, turning perennial streams into seasonal rivers in the pastoralist lowlands. Thanks to its rich and diverse wildlife, the region is a global hotspot and showcase for nature conservation and wildlife tourism. National parks and protected areas were designated by the colonial administration and since then, more and more private ranches and local communities have turned their lands into nature conservancies. The landscape currently presents one of the highest shares of land dedicated to nature conservation globally.

As a result of the three phases of historical evolution – colonialization, post-colonial centralism, and new decentralization – the landscape is dominated by five main land use systems with very different patterns of dependencies, livelihood strategies, claims, and valuation of nature. These are:

1. the pastoralist system, characterized by low population density and ethnic diversity; dominance of livestock raising as their main livelihood; a high dependence on mobility to follow water and pasture; and persistence of traditions;
2. large-scale landholdings such as ranches, farms, and conservancies, characterized by very low population densities as well as diversification of income sources through farming, livestock, tourism, and institutional funding for conservation;
3. the smallholder farming system, characterized by medium population densities; small agricultural parcels; and diversification of incomes among agriculture, livestock, and non-farm activities to distribute risks;
4. a system of local and regional urban centers, characterized by high population density and ethnic diversity, a larger share of non-agricultural income, and better access to basic services and safety nets;
5. and protected areas, i.e. national parks and game/forest reserves, which are exclusively government managed (with limited or no involvement of local communities), with some portions therein leased out to private developers targeting the international tourist market.

Until recently, the lower part of the region in particular, was mainly a poor and remote periphery, often neglected by the central government. However, this condition is fast changing with the introduction of county governments, the extension of transportation and communication networks, and the launch of regional integration megaprojects such as the LAPSSET corridor. The region is going through profound socioeconomic transformations, including rapid population growth, expansion of settlement areas, increasing ethnic diversity, diversification of the economy, better access to services, revaluation and commodification of land, intensification of trade and exchanges with neighboring regions and countries, and deep cultural and behavioral changes.

Once ruled mainly by a very distant central government on the one hand and customary institutions on the other, the region is now increasingly under the influence of new governance systems and powerful external actors. From the government perspective, the devolution process initiated by the Constitution of Kenya 2010 has substantially empowered the counties. In parallel, new institutions have been mandated to manage biophysical features such as watersheds, forests, and protected areas. With the very high density of development aid and nature conservation organizations, the region has also become a hotspot of external interventions. Regional integration is attracting internal migration and foreign investment, bringing in actors with much higher economic means and political capital than the local population. The changes are leading to an exponential increase in social and territorial complexity, where the most powerful actors benefit from legal and policy gaps as well as the competing authority between mismatching administrative scales and levels, to fulfil their agenda.

Currently, the main losers of these trends that are reshuffling the region seem to be the pastoralists. Unfairly stigmatized as the main drivers of land degradation and loss of wildlife, they are seeing their ancestral lands encroached upon and their capacity to circulate throughout the landscape in search of water and pasture, dramatically reduced. As economic development increases, so do the tensions over land, water, and other natural resources – between pastoralists, farmers, conservationists, large-scale landowners, and investors. Understanding the power relations – as well as the different perspectives, aims, claims, and nature valuation – between these different actors is a very important step towards achieving greater justice in regional development and nature conservation.

Protecting the Mt. Kenya–Ewaso Ng'iro North landscape is a key challenge and opportunity not only for Kenya, but also for the world. It should not be reduced to just territorially separating nature from people. The region is unique not only because of its stunning wildlife, but more importantly, because of the way in which people and nature have coexisted for centuries before the outside world entered the stage. At the global level, rangelands and savannas play an important role in climate and biodiversity regulation. Mt. Kenya is the landmark and water tank of the region and beyond. The Ewaso Ng'iro North river is the main source of life for millions of people downstream. Biodiversity and wildlife are global commons of prime importance for ecological services and for their intrinsic value. Often neglected by the government, and threatened and demonized by conservationists, pastoralism is a cultural world heritage and one of the most impressive examples of adaptability to natural constraints and resilience to climate change. It is the system of the Mt. Kenya–Ewaso Ng'iro North landscape as a whole that needs to be protected and improved – not only its parts.

The present report provides baseline information and empirical insights for understanding this complex context, in order to practically address the people–nature nexus in the Mt. Kenya–Ewaso Ng'iro North landscape.

2 Status and trends of ecosystems and biodiversity

Kaspar Hurni, Amor Torre-Marin Rando, Mark Snethlage, Markus Fischer

This chapter gives an analytical overview on the current biodiversity status of the main ecosystem trends in the study area. Chapter 2.1 describes the main ecosystem types in the Mt. Kenya–Ewaso Ng'iro North landscape, depict their spatial extent, and appraise their current biophysical health. Taking these ecosystems as analytical units, Chapter 2.2 outlines the status and trends of important biodiversity facets such as species richness and endangered charismatic species. Chapter 2.3 concludes with an appraisal of current biodiversity conditions and trends for different land user categories of the study region's three main agricultural systems.

2.1 Description of main ecosystem types

Elevation gradient and ecosystem types in northwestern Kenya

The area north of Mt. Kenya is characterized by a pronounced elevation gradient which ranges from 5,199 m a.s.l. (peak of Mt. Kenya) to below 500 m a.s.l. on average in Isiolo county. To describe the diverse ecosystems and their changes in this region, we use seven counties (Baringo, Isiolo, Laikipia, Marsabit, Meru, Samburu, and Turkana) as analytical units (Figure 2.2). Laikipia and Meru lie at the foothills of Mt. Kenya and show the highest average elevation followed by Baringo, which is located to the west in an area considered of high potential for agricultural production. From the foothills of Mt. Kenya, a plateau at an elevation of 1,500–2,000 m stretches through Laikipia into Samburu, before descending into the semiarid and arid lowlands. Turkana, Marsabit, and Isiolo are mostly in the lowlands with a few elevated ridges in Marsabit and Turkana. The precipitation regime constitutes the main determinant for the evolution of ecosystems in the study region. The precipitation gradient is highly correlated with elevation, with annual average rainfall increasing from north to south (Figure 2.1).

This precipitation pattern is shaped by orographic monsoon rains resulting in a more pronounced seasonal variability towards the dry lowlands. The study region's main ecosystems are grasslands, savannas, and shrublands, with limited cropland areas in Meru county and around the foothills of Mt. Kenya in Laikipia county. The main ecosystems of Meru and Baringo are grasslands, savannas, and some forests. Laikipia and Samburu counties show grasslands as the main ecosystem type. Isiolo, Marsabit, and Turkana are characterized by large shares of grassland but also substantial shares of shrubland, with bare areas occurring in Marsabit and Turkana.

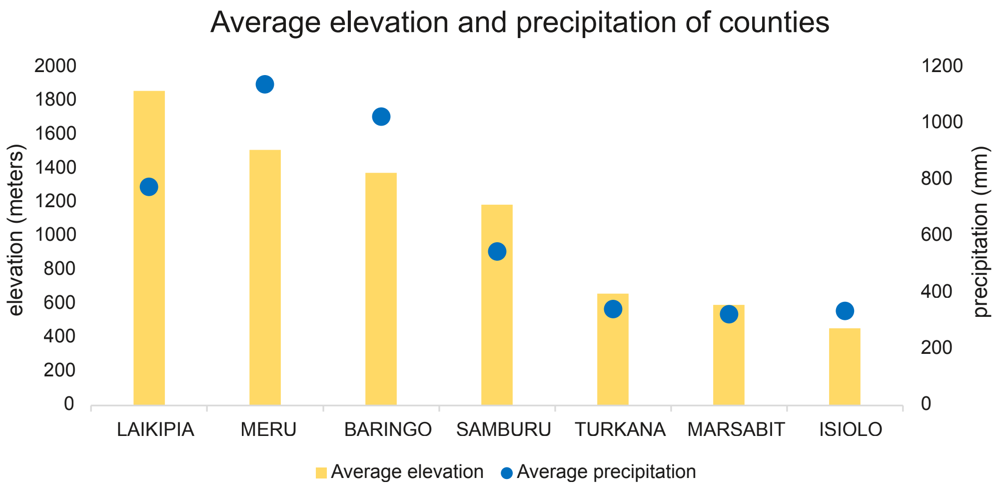


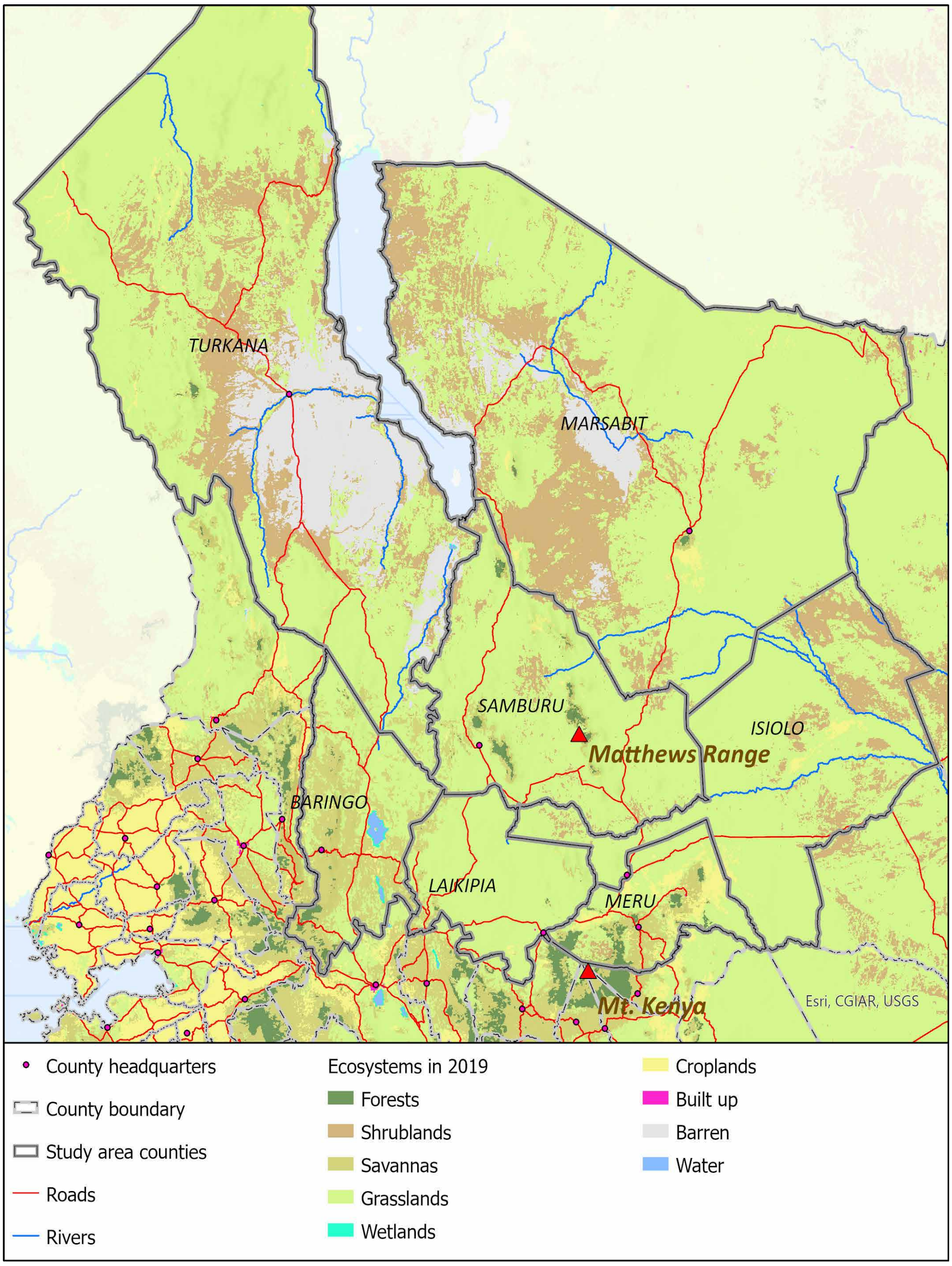
Figure 2.1: Average elevation and precipitation (2001-2020) in study area counties (Source: Farr et al. 2007a; Funk et al. [2015])

Ecosystem change in the northwestern counties of Kenya

We analyzed changes in ecosystem types between 2001 and 2019 using the International Geosphere-Biosphere Programme (IGBP) land cover classification type 1 (Friedl and Sula-Menashe 2019). The data provides consistent and reliable information on ecosystem types (see Figure 2.2) and change, and our analysis focused on forests, shrublands, savannas, grasslands, croplands, and barrens. Given its spatial resolution of 500 m, some areas could not be entirely documented. These include changes in wetlands, built-up areas (urban and peri-urban areas, resort cities), and the expansion of greenhouses around the foothills of Mt. Kenya. Croplands also tend to be underestimated, as smallholder plots cannot always be captured due to their size. The overall dynamics, however, are well represented and correspond with accounts from the field.

Each ecosystem type is home to a distinct composition of flora and fauna, mainly determined by environmental characteristics and use intensity. Located in areas with favorable conditions, forests are biodiversity hotspots, but also savannas tend to show multiple levels with a layer of perennial grasses at the bottom, followed by patches of bushes and shrubs, and at the top, scattered trees (Figure 2.3). Intact shrublands look similar, but do not show trees, while grasslands consist of perennial and annual grasses only. Degradation and rehabilitation of grasslands can occur in all three ecosystem types. While altering the composition of savannas and shrublands, grassland ecosystems may change to bare or shrubland ecosystems. Degradation processes due to increased climate variability and use intensity (e.g. grazing of wildlife and livestock) include change from perennial to annual grasses and an increase in number and size of bare patches, often encroached upon by unpalatable herbs and invasive species, a process which is almost irreversible. Degradation and extraction

Figure 2.2: Ecosystem types north of Mt. Kenya in 2019 and the study area counties outlined in dark grey (Source: Map design by CDE, data from CETRAD and Friedl and Sula-Menashe [2019])



of woody vegetation (e.g. due to an increased number of small ruminants, as well as firewood collection) can change savanna and shrubland ecosystems towards grassland ecosystems or even bare areas (Mureithi et al. 2016; Pas 2018). Multiple processes and feedback loops can thus be at play and, under favorable climatic conditions and with limited use, intensity regeneration also occurs (e.g. denser grasslands, increase in number and size of woody vegetation), but has so far not been observed in the heavily degraded areas. To understand spatial and temporal patterns of ecosystem change, we analyzed the dynamics at county level. As Table 2.1 shows, the main county-level dynamics appear to be occurring along a south–north gradient.

Figure 2.3: Examples of dryland ecosystems and degradation. Savanna landscape with scattered trees, patches of bushes and shrubs, and perennial grasses (top). Degraded landscape with bare ground or annual grasses, unpalatable herbs, and wood extraction (bottom left). Gully formation in a degraded shrubland with scattered trees (bottom right) (K. Hurni [2014]).

Table 2.1: Trends in area covered by ecosystem types between 2001 and 2019. Black arrows represent strong trends, grey arrows moderate trends, and blank arrows no trend (Source: Data analysis by CDE using Friedl and Sula-Menashe [2019])

County	**Ecosystem trends**						**Main from–to changes**
	Forests	Savannas	Shrublands	Grasslands	Barren	Croplands	
Baringo	↘	⬈	⇨	⬊	⇨	↗	grasslands to savannas
Meru	↘	⬈	⇨	⬊	⇨	↗	grasslands to croplands
Laikipia	⇨	⇨	⇨	⇨	⇨	⇨	almost no change
Samburu	⇨	⇨	⇨	⇨	⇨	⇨	small changes only
Isiolo	⇨	⇨	⬊	⬈	⇨	↗	shrublands to grasslands
Marsabit	⇨	⇨	⬊	⬈	⇨	↗	shrublands to grasslands
Turkana	⇨	⇨	↗	↗	⬊	↗	multiple smaller changes

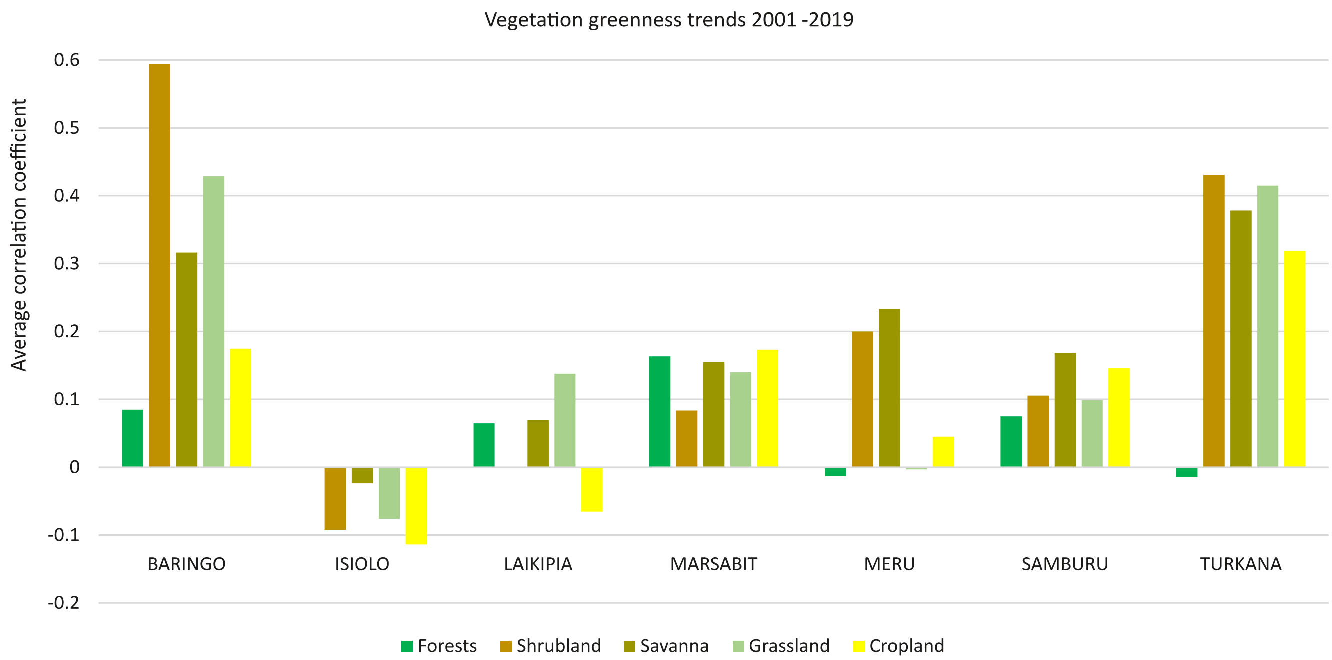
Baringo and Meru both show an increase in woody vegetation, particularly a change from grasslands to savannas, but also increases in croplands and some minor forest losses. In Baringo, savannas expanded in the northeast and along the border with Laikipia, while croplands increased in the area between the lakes. Wildlife habitats in these areas thus seem to improve as grasslands are converted to savannas. In Meru, croplands have expanded along the ridge northeast from Mt. Kenya and further into the lowlands. While supporting a growing population of smallholder farmers and economic growth through agribusinesses, the expansion of cropland comes at the expense of downstream ecosystems used by e.g. wildlife and pastoralists (Otuoma et al. 2009; Eckert et al. 2017). Laikipia and Samburu counties, both located on or around the Laikipia plateau, do not show large changes in ecosystem types, with the main category being grasslands used as wildlife habitats and for livestock farming mainly by private ranches or conservancies. Samburu also shows forest ecosystems along the Matthews Range and Kirisia Hills (west of the Matthews range, see Figure 2.2). These mountain forests remained unchanged and are important for biodiversity and forages for livestock and wildlife during dry spells (Nyingi et al. 2013).

Isiolo and Marsabit, to the southeast, are still characterized by grass- and shrublands. Due to strong losses of woody vegetation, a substantial share of shrublands was converted to grasslands between 2001 and 2019. Shrubland losses occurred mainly in the north of Marsabit and around the Isiolo–Marsabit county border. This change in the ecosystem composition from mostly woody plants, perennial grasses, and some annual grasses, to a mosaic dominated by annual grasses, unpalatable herbaceous species, and bare patches has been associated with e.g. overgrazing and the use of branches as fodder for goats and fuelwood (Kiringe and Okello 2005; Mureithi et al. 2016; Pas 2018). Located in the northwest, Turkana shows a large patch of bare land around Lodwar, a similar amount of shrub around the bare land, and a substantial amount of grasslands (>60%) to the north. Overall, Turkana shows an increase in vegetation, with moderate increases in shrublands and grasslands on formerly bare areas. Croplands are also increasing, mainly in the northwest along roads.

Vegetation greenness trends 2001–2019 in the northwestern counties of Kenya

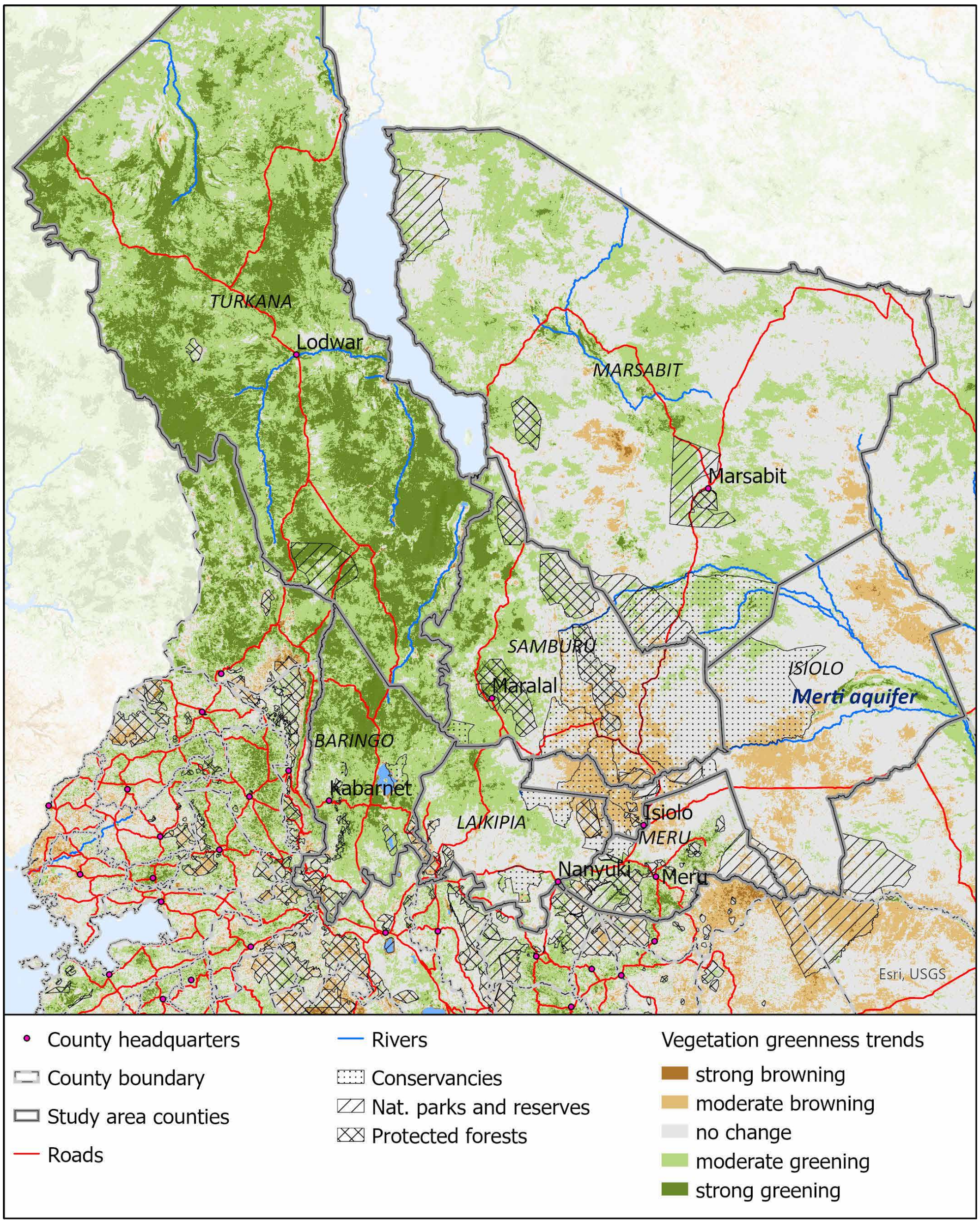
Changes in ecosystem types represent clearly visible dynamics, e.g. in changes in the composition of vegetation. Often, however, these changes are not abrupt; instead, they happen gradually, and are usually triggered by changes in environmental conditions, land management, and land use. To understand these more subtle dynamics, we used remote sensing data to calculate the annual average Normalized Difference Vegetation Index (NDVI). We then applied Kendall's Tau-b rank correlation across all years (2001–2019) to document the greening and browning of vegetation (e.g. increases or decreases in green grasses, leaves, or crops), but not necessarily changes in biomass or amounts of woody vegetation. The correlation coefficient ranges from -1 to 1, with values around 0 representing no or only subtle trends and values towards 1 and -1 strong greening and browning respectively.

Figure 2.4: Vegetation greenness trends for the different ecosystem types. Strong greening (positive correlation coefficients) occurs in Baringo and Turkana, moderate browning (negative values) across all ecosystems in Isiolo (Source: Data analysis by CDE using Didan [2015])



The summary of our analysis (see Figure 2.4) shows that on average, almost all vegetation types are becoming greener in most counties, i.e. we see an increase in photosynthetic active leaves, grasses, or crops. The exception is Isiolo, where over the past 20 years, vegetation has become browner, with fewer photosynthetic active leaves, grasses, or crops. Overgrazing and selective logging, exacerbated by climate variability and shifts in seasonality, have so far been documented as potential causes

Figure 2.5: Trends in vegetation greenness from 2001–2019. Most areas in our study area counties show greening; however, large areas of browning occur around Isiolo town and to the east (Map design by CDE, using data from CETRAD and Didan [2015])



(Kiringe and Okello 2005; Mureithi et al. 2016; Schmocker et al. 2016; Pas 2018). Greenness trends in Laikipia, Marsabit, Meru, and Samburu are similar for most classes and show moderate greening of vegetation; only Laikipia's croplands show slight browning. Forests tend to be greener, because in most cases these are protected ecosystems with little human disturbance apart from moderate tourism. We observed a slight browning of forests only in Meru and Turkana; this is possibly a result of selective illegal logging, which has been reported to occur moderately around Mt. Kenya (Nyingi et al. 2013).

Patterns, however, also vary across space. Figure 2.5, a map of vegetation greenness trends, shows a strong gradient from southwest to northeast. Turkana and Baringo both show strong greening across all ecosystem types. This pattern of greening continues into the western parts of Samburu, Laikipia, and along Mt. Kenya into Meru, but changes into browning in the lowlands around Isiolo. Browning occurs in most of Isiolo; only the Merti aquifer shows greening, which corresponds with accounts of increased springwater. Marsabit shows moderate greening in most areas; only the drylands and shrublands west of Marsabit are becoming browner, possibly due similar processes as in Isiolo. Mt. Kenya's forest shows greening in the north, but moderate browning in southern directions, possibly due to changes in the precipitation regime.

Patterns of ecosystem change and vegetation greening and browning in the study area

Our analysis of land cover change between 2001 and 2019 showed that composition of ecosystem types can vary significantly by county. Ecosystem types are shaped by elevation and precipitation gradient from south to north and interact with man-made factors (land use in particular, but also climate change). Substantial changes were observed in Marsabit and Isiolo, with 20% of Isiolo's area changing from shrublands to grasslands. This is an indication of degradation and a loss of woody vegetation, both of which have been associated with overuse and with more erratic precipitation patterns (Kiringe and Okello 2005; Nyingi et al. 2013; Schmocker et al. 2016). Still, in Marsabit, most ecosystems show greening, while in Isiolo all land cover types show browning. Of the seven counties we analyzed, degradation is strongest in Isiolo.

The patch of vegetation browning around Isiolo stretches into Samburu, which then transitions into greening towards the higher elevated plateau. Samburu, Laikipia, and Meru all show some changes between ecosystem types, but no substantial processes. Most ecosystem types (grasslands, savannas, and shrublands) in these counties also show greening during the period of 2001–2019.

Finally, we documented processes of vegetation improvement in Turkana and Baringo, i.e. increases in woody vegetation and strong trends of vegetation greening. While the two counties host different ecosystem types (from savannas and grasslands in Baringo, to grasslands and bare lands in Turkana), they are both located to the east of the study area. We assume that changes in precipitation patterns and variability from east to west, along with land use intensification around Isiolo, have led to these dynamics.

2.2 Status and trends of important biodiversity facets

Ecosystems

Mt. Kenya is a vital water catchment in Kenya and an ecosystem of global importance for the conservation of biodiversity, with international recognition as a Key Biodiversity Area (KBA) and a World Heritage Site (Key Biodiversity Areas Partnership, 2021, Musila et al. 2019). The Ewaso Ng'iro river basin hosts the largest remaining population in the world of Grevy's zebras and Jackson's hartebeest as well as the largest national populations outside of protected areas of rhinoceros and reticulated giraffe (Silvestri et al. 2013). The vegetation in the basin varies with the precipitation gradient, with natural and plantation forests on the slopes of Mt. Kenya; land under rainfed crops downslope; and, in the lower part of the catchment, grass and shrublands interspersed with riparian wetlands such as the Lorian Swamp (downstream of the Merti aquifer, see Figure 2.5) (Ericksen et al. 2012). The mountain habitats include lower montane wet and dry forests, bamboo, upper montane forests, a heath zone, alpine tussock grasslands (afro-alpine zone), and the nival zone (Zhou et al. 2018). Mt. Kenya's forests represent the largest continuous forest block in Kenya (Bussmann 1996; Kleinschroth et al. 2013).

Montane forests are the most common vegetation type in Mt. Kenya. Species such as *Newtonia buchananii*, *Olea europaea,* and *Juniperus procera* predominate in lower montane areas, while *Hagenia abyssinica* and *Hypericum revolutum* predominate in upper montane zones. Bamboo areas are characterized by the species *Yushania alpina* and *Lobelia bambuseti*. *Alchemilla argyrophylla* and *Erica arborea* are characteristic in the heath zone, while *Carduus keniensis* and *Dendrosenecio keniodendron* are common in the afro-alpine zone. Species such as *Arabis alpina* are present in the nival zone (Rucina et al. 2009; Zhou et al. 2018). Riparian forests are scarce, but have an important biological role. They are often dominated by *Acacia xanthophloea* trees (Butynski and Jong 2014; Kinga et al. 2018), while *Acacia tortilis* is found along seasonal rivers (Pas 2018).

Biodiversity in the Mt. Kenya region is under increasing threat from human activities (Musila et al. 2019). Forests in particular are under extreme threat, with degradation occurring due to uncontrolled use and exploitation including illegal logging, firewood collection, charcoal production, poaching, destructive honey collection, grazing, and forest fires (Rucina et al. 2009; Nyingi et al. 2013; Nyongesa and Vacik 2018; Musila et al. 2019). Some of the species targeted by illegal logging include camphor (*Ocotea usambarensis*), cedar (*Juniperus procera*), wild olive (*Olea europaea*), and East African rosewood (*Hagenia abyssinica*) (Bussmann 1996; Kleinschroth et al. 2013; Nyingi et al. 2013). During drought periods, pastoralists drive their livestock into the forest in search of pasture, adding pressure to forest ecosystems. Goats in particular have an important negative impact on the growth of seedlings and tree recruitment (Nyingi et al. 2013; Pas 2018). Other illegal activities such as growing *Cannabis sativa* also threaten forest areas (Bussmann 1996; Rucina et al. 2009; Musila et al. 2019). The impacts of intense tourism in the alpine zone have led to habitat destruction and overexploitation of some species such as *Dendrosenecio keniodendron* for fuelwood (Kinga et al. 2018; Mureithi et al. 2016; Pas 2018; Young and Peacock 2006).

Grasslands and open woodlands are dominated by *Acacia* and *Commiphora* as a woody vegetation layer. Various grasses and forb species dominate the understory vegetation (Mureithi et al. 2016; Kinga et al. 2018; Pas 2018). Open wooded grasslands are decreasing due to agricultural encroachment and the increase in livestock populations, which subject areas to prolonged heavy grazing, giving woody plant species advantage over grasses (Otuoma et al. 2009; Lalampaa et al. 2016). The reduction in available land in the rangelands, as well as the further increase in rainfall variability, have led to serious land degradation, illustrated by the spread of bare ground patches and soil erosion gullies (Mungai et al. 2004; Kimiti et al. 2017; Pas 2018). The spread of the invasive alien species, erect prickly pear (*Opuntia stricta*), is also contributing to rangeland degradation (Mureithi et al. 2016; Kimiti et al. 2017; Dudenhoeffer and Hodge 2018), which could be further accentuated by the expansion of *Prosopis* sp. (Bekele et al. 2018).

Freshwater ecosystems in the Mt. Kenya–Ewaso Ng'iro North landscape are small and largely seasonal or periodic. They comprise the Ewaso Ng'iro river and its tributaries and natural springs, as well as wetlands such as the Lorian Swamp and seasonal marshes (Nyingi et al. 2013). The dominant vegetation in wetlands is papyrus (Kinga et al. 2018). Freshwater ecosystems are highly vulnerable to disturbance and degradation through overexploitation of natural resources, such as water abstraction and overgrazing by livestock. They are also threatened by habitat loss and drainage for agriculture, settlements, and development of infrastructure (Nyingi et al. 2013). Small wetlands in the region are vanishing at a rapid rate (Mwita et al. 2012). Similarly, large wetland areas such as the Lorian Swamp have been reduced in perennial size from 150 km^2 within the last 100 years to a few km^2 and are now dominated by seasonal swamp vegetation (Mumma et al. 2011; De Leeuw 2012). Water quality has decreased due to pollution from large-scale agriculture (Zaehringer et al. 2018). Climate change is a further threat to freshwater ecosystems, as changes in rainfall patterns alter river flows and can cause unprecedented floods (Mwita et al. 2013; Nyingi et al. 2013). The introduction and spread of invasive species such as the Louisiana crayfish (*Procambarus clarkii*) may have negative effects on fish communities and their productivity in the lower reaches of the Ewaso Ng'iro river (Nyingi et al. 2013) (Figure 2.6).

Figure 2.6: Trends in ecosystems in the Mt. Kenya region from the 1970s to 2019: spatial extent and impact of direct drivers of change on ecosystems (Source: Based on literature review)

			Impact of driver				
Ecosystem	**Indicator**	**Trend**	Land use change	Climate change	Invasive alien species	Pollution	Overexploitation
Forest	Extent	Decrease	Moderate	Moderate	ND	ND	High
Savanna and grassland	Extent	Decrease	High	High	High	ND	High
Freshwater	Extent	Decrease	High	High	Moderate	Moderate	High

Trends in ecosystems:

Decrease | Increase | ND No data

Impact of drivers of change:

High | Moderate | No or marginal | ND No data

Species

Since the late 1970s, there have been extreme declines in wildlife in the Kenyan rangelands (Figure 2.7) (Ihwagi et al. 2015; Ogutu et al. 2016). Causes of these declines include infrastructure development, increasing livestock numbers, rangeland degradation and fragmentation, poaching, disease outbreaks, declining rainfall, and a rise in temperatures and fire linked to exponential human population growth and climate change (Lelenguyah 2012; Ogutu et al. 2016; Svengren et al. 2017). Poaching is the greatest immediate threat to elephant survival (Ihwagi et al. 2018). The annual proportions of poached elephants in the Laikipia–Samburu ecosystem increased between 2002 and 2012, peaking at 70% of all recorded deaths in 2012 (Ihwagi et al. 2015). In the Samburu ecosystem, illegal killing rates were strongly correlated with black market ivory prices (Wittemyer et al. 2014). Human–carnivore conflicts and retaliatory killings for livestock

Figure 2.7: Changes in population of wildlife species in Laikipia, Samburu, and Isiolo Counties between 1977–1980 and 2011–2016. (Source: Based on Ogutu et al. [2016] and O'Brien et al. [2018])

	County		
Species	Laikipia	Samburu	Isiolo
Elephant	↑	↗	↓
Buffalo	↑	↓	↘
Burchell's zebra	↑	↘	↓
Grevy's zebra	↑	↓	↓
Hartebeest	↓	ND	ND
Waterbuck	↘	↓	↓
Eland	↓	↓	↑
Oryx	→	↓	↓
Lesser kudu	ND	↓	↓
Gerenuk	→	↓	↓
Grant's gazelle	→	↓	↓
Thomson's gazelle	↓	↓	ND
Impala	↘	↓	↓
Warthog	↓	↓	↘
Ostrich	↓	↘	↓
Vultures	↓	↓	↓

Population trends:

↓	Strong decrease (>50%)	↑	Strong increase (>50%)	→	Stable (+/-10%)
↘	Decrease (10-50%)	↗	Increase (10-50%)	ND	No data

losses are causing declines in carnivorous species like lions, hyenas, and wild dogs (Campana et al. 2016; Carter et al. 2018; Mitchell et al. 2019; Ndeereh et al. 2019). Primate communities are mainly threatened by habitat fragmentation, loss, and degradation as well as by the decline in perennial water sources (Butynski and Jong 2014). Vulture populations have collapsed due to ingestion of Furadan (O'Brien et al. 2018), a pesticide used as predator poison, which is also affecting other scavenging birds such as bateleurs (*Terathopius ecaudatus*), tawny eagles (*Aquila rapax*), and steppe eagles (*Aquila nipalensis*) (Ogada and Keesing 2010).

Wildlife populations of some species, such as Burchell's and Grevy's zebra, buffalo, and elephant, increased substantially only in Laikipia (Figure 2.7) (Ogutu et al. 2016; Goheen et al. 2018). Laikipia's network of private and community conservancies provides habitats for a wildlife population larger than that of Amboseli, Nairobi, and Tsavo National Parks combined (Bersaglio and Cleaver 2018). Laikipia hosts the second largest population of elephants in Kenya, after Tsavo National Park. In addition, Laikipia is home to one of the world's only increasing populations of African wild dogs, is a key area for the globally endangered Grevy's zebra, and contains four black rhino sanctuaries which host half of Kenya's black rhino population (Bersaglio and Cleaver 2018; Goheen et al. 2018).

2.3 Status and trends of the main agricultural systems

The three main agricultural systems in the area north of Mt. Kenya consist of livestock-keeping by often large ranches (mainly Laikipia); agro-pastoralism and pastoralism in the northern savannas, grasslands, and shrublands; as well as crop cultivation (smallholders, large scale farms, agribusinesses) along the high-potential belt on the foot slopes of Mt. Kenya (Kiringe and Okello 2005; Schmocker et al. 2016; Eckert et al. 2017).

As shown in Chapter 2.1, savanna, grassland, and shrubland ecosystem types showed vegetation browning (i.e. decreases in green grasses and leaves) in pastoralist areas around Samburu and Isiolo as well as conversion of shrublands to grasslands in Isiolo and Marsabit as a result of overgrazing, fuelwood extraction, and climate variability. At the same time, ecosystems are regenerating (e.g. from bare to shrub and grasslands) in Turkana and vegetation is greening in Marsabit and Turkana, both also agro-pastoralist and pastoralist areas. Laikipia, a livestock area dominated by large ranches, shows almost no ecosystem changes. Only moderate vegetation greening with some browning trends towards the lowlands of Isiolo could be observed between 2001 and 2019.

Croplands have also expanded in the study area, but particularly before 2010. Recent years have seen intensification processes, such as the emergence of agribusinesses producing flowers and herbs for the European market (Eckert et al. 2017; Giger et al. 2020). Smallholder croplands form a belt around the northern foot slopes of Mt. Kenya and towards Isiolo town in the lowlands (Figure 2.8). Large-scale farms also cover a substantial share of the foot slopes, mainly in the area between Nanyuki and Meru. In between, and also scattered in the smallholder croplands, lie greenhouses, which have been established in recent years. While they offer economic opportunities for surrounding smallholders to diversify their income (e.g. food security and education benefits), they increase pressure on ecosystems and people through e.g. water use, release of chemicals, and consumption of limited arable land.

Competing land use systems

This intensification of agricultural production in the triangle between Nanyuki, Isiolo, and Meru meets the needs of a growing population and brings economic benefits. However, cropland expansion has reduced the access of wildlife and livestock to grazing grounds. Particularly during drier years, these more humid parts of the landscape were important to bridge fodder needs and reduce pressure in drought-affected areas. At the same time, an increasing number of smallholder farmers, agribusinesses, and large-scale farms compete heavily over irrigation water from rivers, springs,

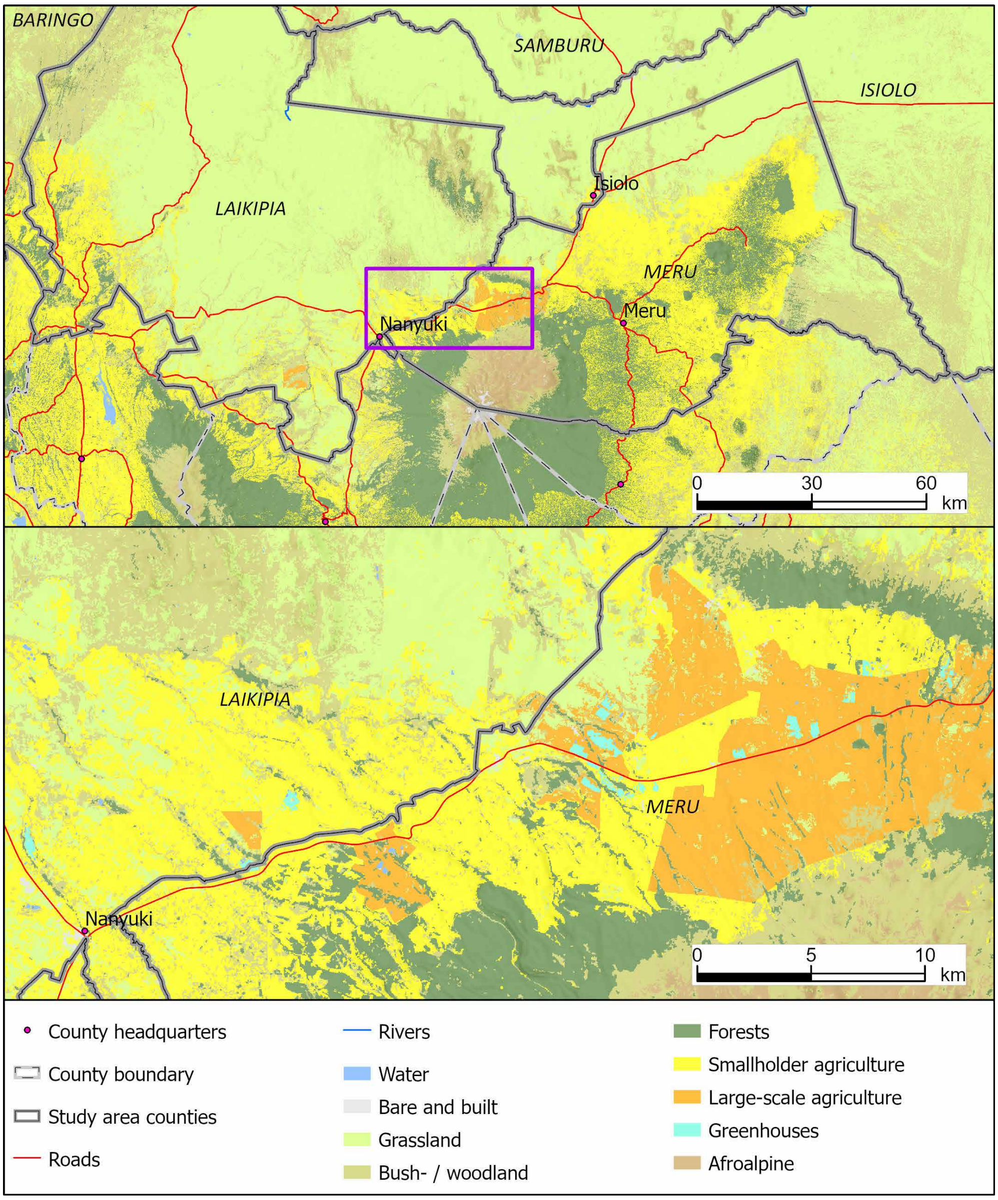


Figure 2.8: Ecosystem types around Mt. Kenya in 2016, with a focus on the northern foot slopes with smallholder croplands, large-scale agriculture, and agribusinesses in the form of greenhouses (Source: CDE and CETRAD)

and boreholes. Such water abstraction for agricultural production reduces dry season river flow that is fed from the uplands and springs, ultimately exacerbating drought years in the lowlands. With increasing population and livestock pressure, not least also triggered by non-agricultural investments, pressure on natural resources are likely to further increase. It will require a balanced set of interventions to reconcile the interests between upstream and downstream communities while protecting nature from further degradation.

3 The value of nature, ecosystem services, and biodiversity

Christian Hergarten, Kaspar Hurni, Amor Torre-Marin Rando, Mark Snethlage, Markus Fischer

To describe the emblematic gradient running along a south–north transect from the top of Mt. Kenya to the northern lowlands, our study area encompasses the counties of Meru, Laikipia, Isiolo, Samburu, Marsabit, and Turkana. Ecosystems which are heavily dependent on rivers originating from Mt. Kenya, however, are discussed in the context of the Upper Ewaso

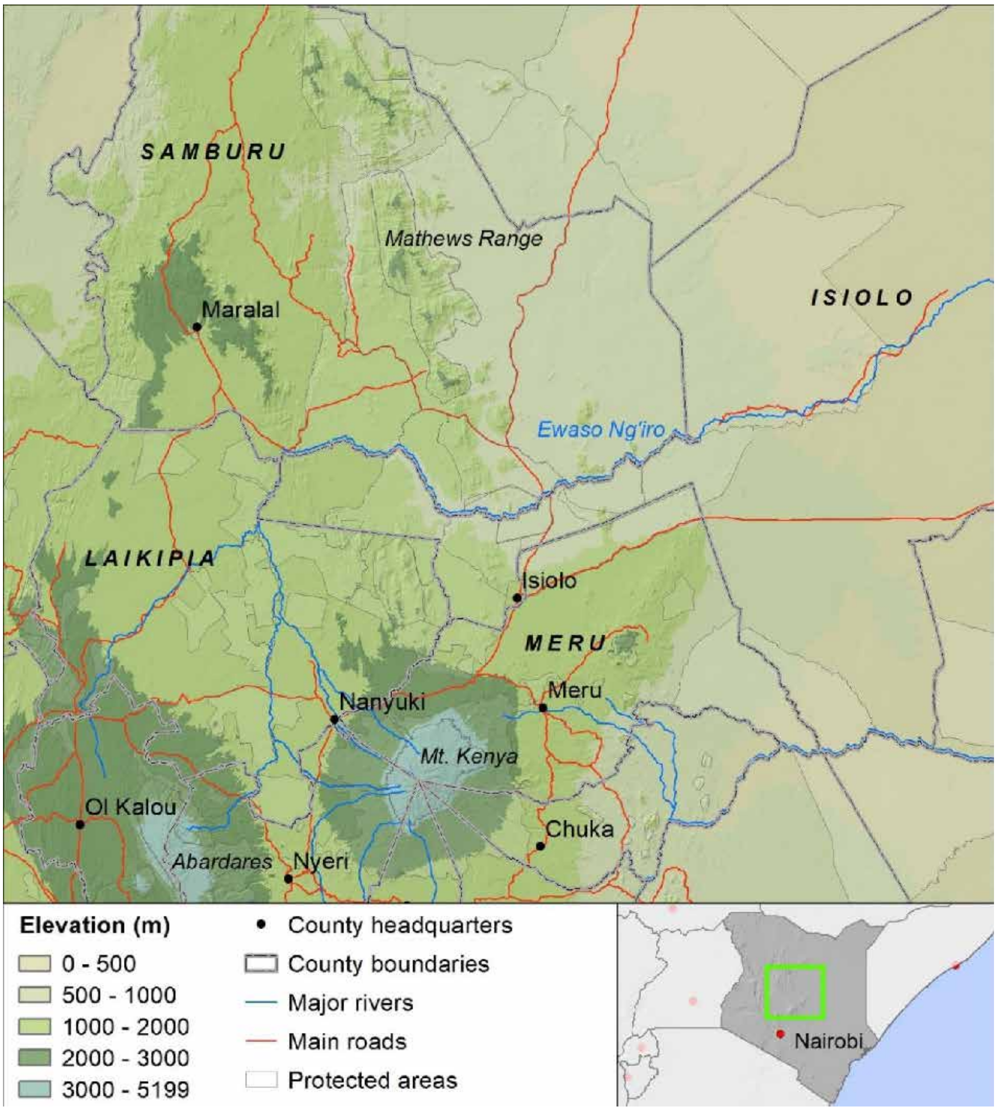


Figure 3.1: Topography map depicting the gradient from Mt. Kenya to the northern lowlands (Source: CDE using data from CETRAD and Farr et al. [2007b])

Ng'iro basin, which does not cover the most northern counties of Turkana and Marsabit (Figure 1.2).

Stretching from the tropical humid Mt. Kenya, the Ewaso Ng'iro basin extends to the sub-humid foot slopes and adjacent semiarid Laikipia plateau, across the northern and eastern arid lowlands of Kenya. The basin epitomizes a tropical highland–lowland system, which is characterized by the flow of water from the precipitation-rich heights of Mt. Kenya to the dry northern plains. The resulting distribution and succession of land cover types along the south–north gradient is shown in Figure 3.1, with endemic forests on the slopes of Mt. Kenya and patches of agriculture on the northern foot slopes (considered agricultural high-potential areas, with their fertile soils, sufficient humidity, and mild temperatures). Adjacent to the foot slopes, vast savanna landscapes follow, transitioning into grass and shrublands further north in the dry lowlands.

3.1 Distribution of major land use categories

The landscape along the transect from the top of Mt. Kenya to the northern lowlands follows a typical sequence of many tropical highland–lowland systems (Figure 2.2 shows the main land cover types derived from satellite imagery for the year 2019). At the humid mountain top (5,199 m a.s.l.), only remnants of the Darwin glacier remain; otherwise, mostly barren land and rocks dominate the landscape down to 4,300 m a.s.l., where alpine vegetation starts to cover the ground. Further down, below the tropical tree line, alpine forests dominate the landscape – nowadays as a protected area (Mt. Kenya Reserve). Below the montane forests, arable lands stretch in a ring shape along the foot slopes before grasslands take over and extend across the Laikipia plateau. This area already belongs to the semiarid zone, and patches of shrubland and savanna occur, although the dominant land cover type is grassland. Here, large conservancies have been created, enabling local communities to control and use natural resources; more recently, we have seen the emergence of private conservancies engaging in wildlife conservation, driven by influential external actors. Towards the end of the plateau, the Samburu hill zone rises with some forests and savanna-type landscape before the dry lowlands of Marsabit extend to the Ethiopian border – a vast area covered mostly with sparse grassland vegetation.

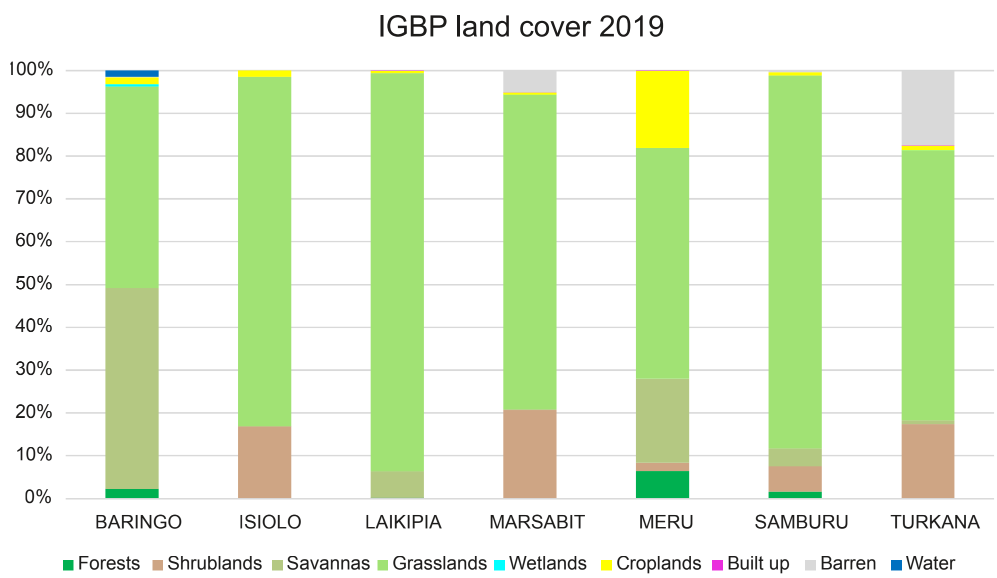
The gradient describing the sequence of land cover types runs almost parallel to the gradient of declining precipitation. While rainfall decreases, evapotranspiration increases dramatically, transforming the northern lowlands into a desert-like landscape. Although rainfall varies distinctively along the gradient, it continuously decreases from ~1,800 mm/a at the top of Mt. Kenya, with Meru town at the foot slopes still receiving 1,602 mm/a, further down Nanyuki 819 mm/a, and Maralal 602 mm/a – further north, it decreases to less than 400 mm/a (Liniger et al. 2005).

The region is characterized by high rainfall variability and by bimodal rainfall. The two rainy seasons account for more than 85% of the annual precipitation, with the second (October to December) accounting for more rain than the first (March to May) (Schmocker et al. 2016) (cf. Chapter 4.2).

The availability of humidity not only defines the spatial distribution of land cover types; it also limits the possible land use for the local population. At the foot slopes mostly small-scale – but increasingly also large-scale – agriculture and intense horticulture dominate, while the Laikipia plateau is mostly used by agro-pastoralists herding livestock. The dry climate here does not allow any rainfed agriculture in this area. The diagram (Figure 3.2) describing the distribution of land cover types per county shows some characteristic features of the landscape. Grassland is predominant on the Laikipia plateau (80% coverage), while in Meru, small-scale agriculture covers almost 20% of the area and is very important for the local economy. Nearly half of the county of Baringo is covered by savanna, while grassland is predominant in the landscapes of Samburu, Isiolo, Marsabit, and Turkana. In the dry lowlands, barren land accounts for 20% of Turkana and 5% of Marsabit county, while agriculture is practiced only on a tiny share of the overall land area.

The distribution of predominant land cover types also hints at the main features of population density patterns. Counties with high amounts of arable land tend to have higher population densities – mostly since the agricultural sector is dominated by labor-intense small-scale structures, as shown for Meru (cf. Figure 3.2 and Figure 3.3). It is important to note that horticulture in greenhouses, which is relevant for the formal employment sector in Laikipia county, might be underestimated, given the limited resolution (250 m) of the land cover data. Similar generalization effects leading to spatial underrepresentation may apply for the "Built Up" land cover category, which is only observable in Laikipia, although urban centers also exist in other counties.

Figure 3.2: Land cover area distribution per county (in %) (Source: own analyses, using Friedl and Sula-Menashe [2019])



The high population density of Meru (193 people/km²) clearly reflects its location in the high-potential zone on the foot slopes of Mt. Kenya (Figure 3.3). This is also the reason for the comparatively higher density in Laikipia (41 people/km^2) – although here the population is concentrated mostly in urban centers such as Nanyuki, while the "hinterland" of the drier Laikipia plateau is rather sparsely populated and supports only extensive uses of land such as livestock rearing and herding. The somewhat higher population numbers in Baringo (50 people/km^2) mostly result from a higher population concentration in the county's western part, connected to the high-potential agricultural areas towards the Lake Victoria basin. Turkana (12 people/km^2), Marsabit (4 people/km^2), Isiolo (6 people/km^2), and Samburu (11 people/km^2) all show very low population densities, reflecting the environmental conditions and lower potential of the ecosystem for supporting agriculture, but also the distance to the high-potential areas around Mt. Kenya.

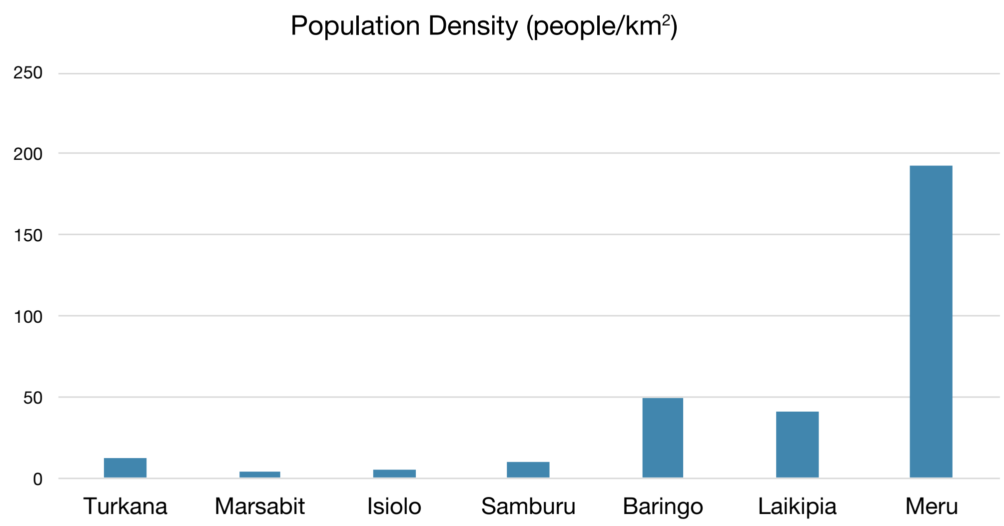


Figure 3.3: Population density per county (expressed in people/ km2) (Source: Based on Wiesmann et al. [2016])

Figure 1.2, which depicts population density at sub-county level within our study area, demonstrates the importance of small-scale agriculture and pastoral activities for household livelihoods (main activities) and goes some way towards explaining the economic transition of the area. Meru has the highest population density of all counties discussed in this report

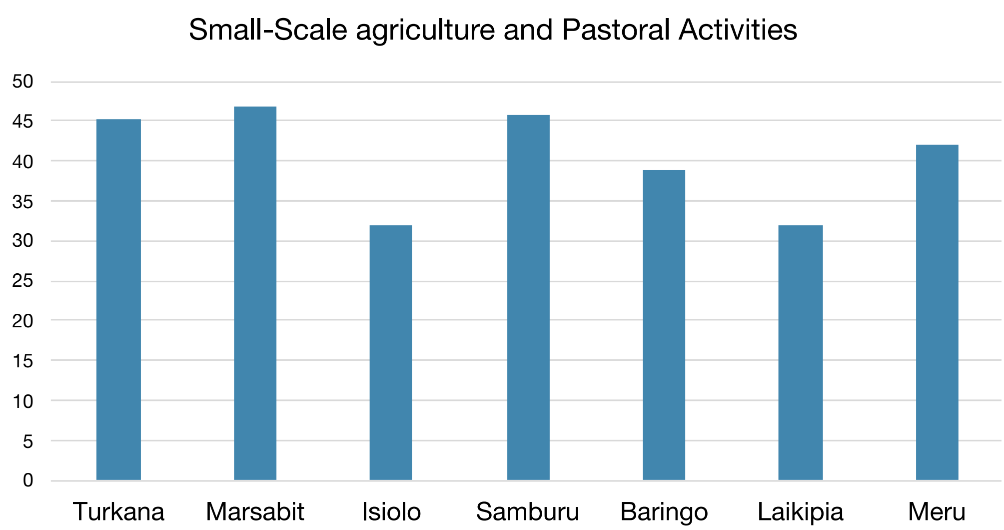


Figure 3.4: Percentage of households engaged primarily in small-scale agriculture and pastoral activities (Source: Based on Wiesmann et al. [2016])

(Figure 3.3), and, at 42%, a lower share of households engaging in small-scale agriculture (and pastoralism) than in Turkana, Marsabit, or Samburu, where pastoral activities dominate (Figure 3.4).

Laikipia and Isiolo show similar distinctive patterns, with a pronounced large-scale agricultural commercial sector absorbing manpower otherwise engaged in traditional small-scale and pastoral activities. Commercial agriculture in Isiolo and particularly Laikipia also explains the high immigration rates to these two counties (Figure 3.5), as it offers employment opportunities for people from other parts of the country. However, the overall percentage of households primarily engaged in small-scale agriculture and pastoral activities (Figure 3.4) is surprisingly low – particularly for the northern counties of Turkana, Marsabit, and Samburu, where pastoralism is traditionally the most important land use form, as it is virtually the only livelihood strategy the marginal lands can offer. However, Figure 3.6 brings the numbers to some extent into perspective – underlining the large percentage of households owning livestock and therefore keeping a strong connection to traditional forms of livelihood. According to Wiesmann et al (2016), the apparent unaccountability can be construed as a shift from a primarily livestock centered livelihood system towards a more diversified income base (Wiesmann et al. 2016).

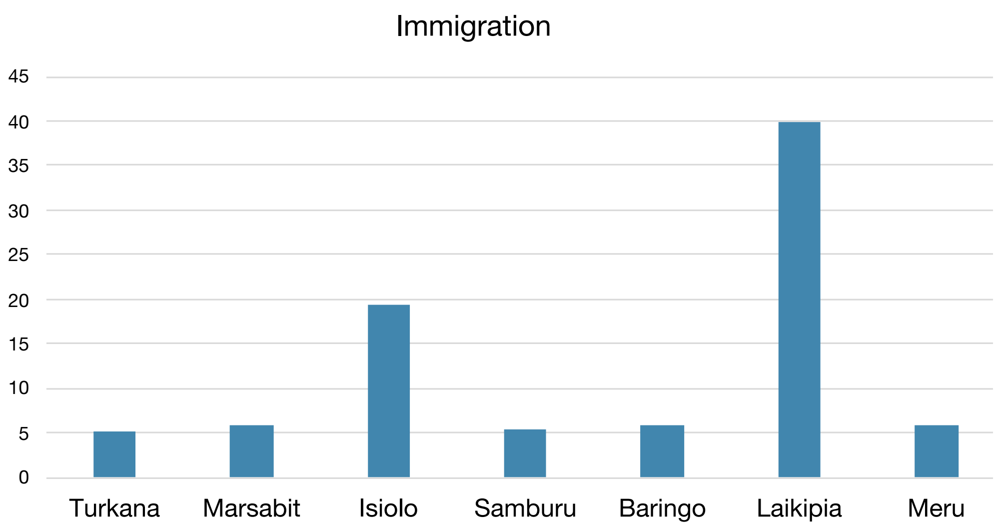


Figure 3.5: Percentage of the population immigrating from other regions. (Source: Based on Wiesmann et al. [2016])

As shown in the bottom panel of Figure 3.6, it is interesting to note that the share of cattle in the “owned livestock mix” category changes in the drier northern plains (Turkana, Marsabit, Samburu, Isiolo) towards small ruminants (goats, sheep), compared to Meru, Laikipia, and Baringo. However, considering the harsh conditions and feed base in the dry north, this may not come as a surprise, because small ruminants, in contrast to cattle, can feed off woody vegetation when grasslands are depleted. Keeping small ruminants is thus an important strategy to secure the livelihood base in arid areas with climate variability.

The economic potential of the agricultural sector in Laikipia and in other high-potential areas along the foot slopes of Mt. Kenya is built on the rich

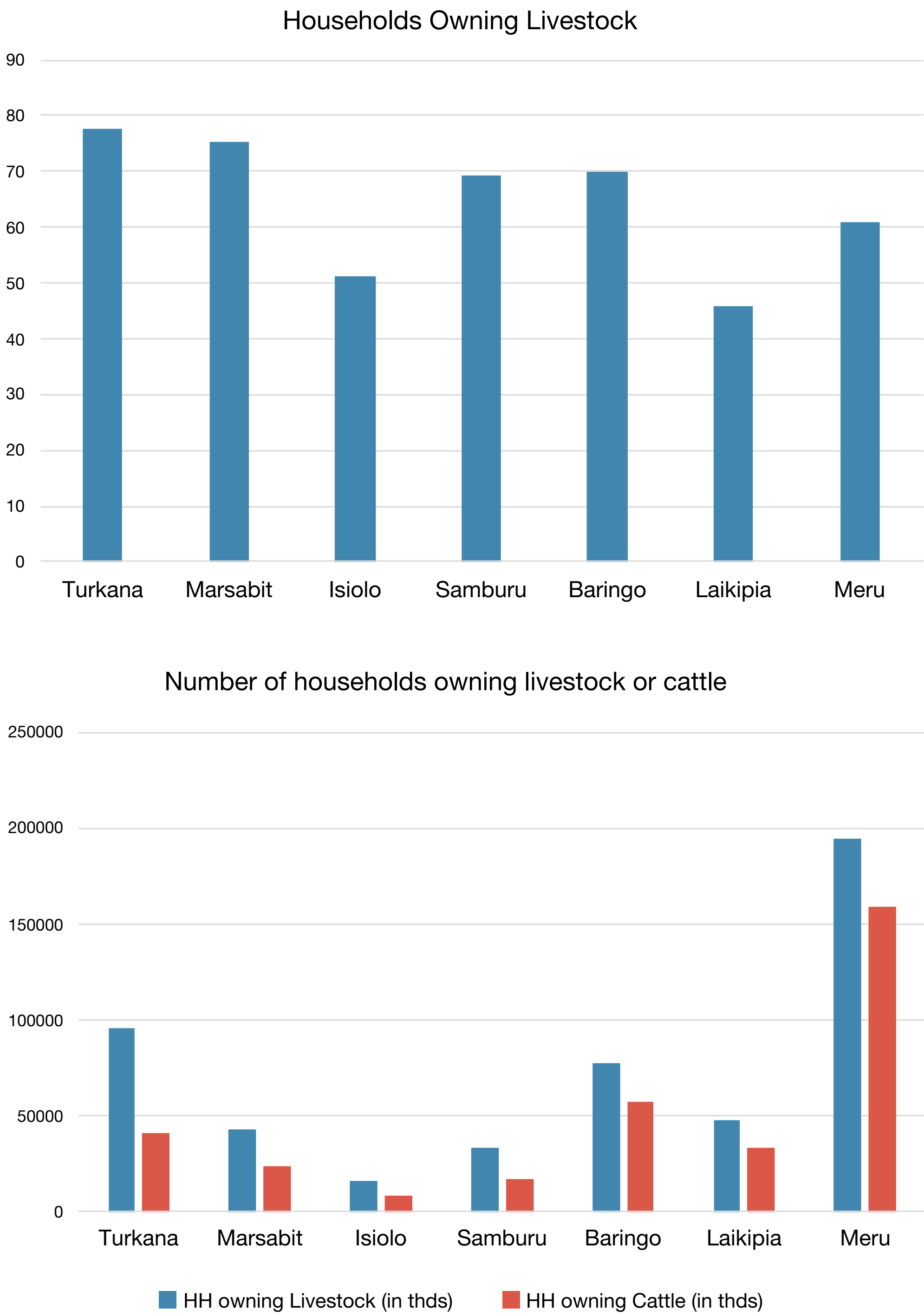


Figure 3.6: Number of households owning livestock – in total numbers (top) as well as in percentages (bottom) (Source: Based on Wiesmann et al. 2016)

natural resource base available. The comparative economic prosperity in this area comes at a cost, as development of the agricultural sector competes for limited water resources with other extensive land uses. As a result, downstream areas in the Ewaso Ng'iro basin suffer from increased water shortages, putting at risk livelihoods of traditional communities engaged mostly in livestock rearing and small-scale agriculture. At the same time, natural habitats for wildlife in the lowlands are increasingly altered.

While along the foot slopes in Laikipia and Meru large-scale agricultural land (export-oriented) is owned by only a few wealthy households, the small-scale mostly subsistence-oriented agricultural land in Turkana, Marsabit, and Samburu is typically clustered along waterways, wetlands, or along isolated hillslopes (cf. Appendix figure 1), mostly coinciding with the conservancies depicted in Figure 2.5.

Appendix figure 2 highlights another important aspect characterizing land cover and land use in the area: cultural and ethnic diversity. Laikipia, Meru, and Isiolo are more ethnically diverse than Turkana, Marsabit, and Samburu. Diversity increases especially along the rural–urban gradient (cf. Kenya Atlas[1], Wiesmann et al. 2016) and rural areas remain ethnically rather monotone. Cultural and ethnic diversity is an important asset for Kenyan society, and a certain cultural mix helps to prevent resource access conflicts from erupting primarily along ethnic lines.

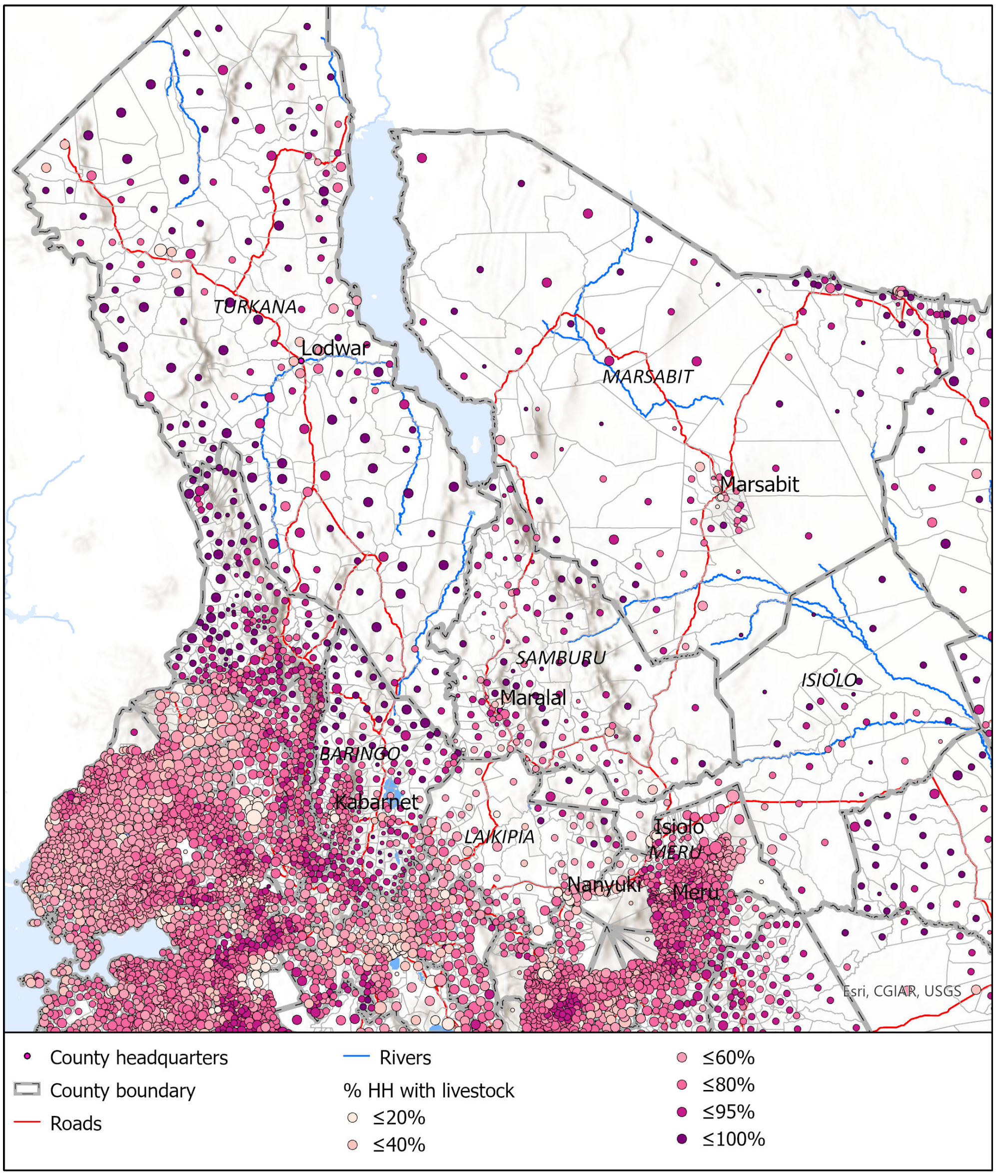


Figure 3.7: Livestock density distribution in northwestern Kenya, point sizes vary by total population (Source: Wiesmann et al. [2016])

1 https://www.kenya-atlas.org/

3.2 Main ecosystem services: estimates of supply and demand

In the Mt. Kenya region, the main ecosystem services mentioned in the literature include water provisioning; climate regulation; energy (firewood, charcoal); food and feed (edible plants and pastures); materials (timber, poles, roofing, tool handles); medicinal resources; and a number of non-material (cultural) services that include aesthetic value of the landscape, tourism, and spiritual experiences and sacred sites. Forests covering the slopes of Mt. Kenya in particular play an important role in regulating and ensuring a continued flow of water to parts of the Ewaso Ng'iro basin and the Tana River basin (Lanari et al. 2018; Musila et al. 2019), providing up to 90% of the dry season flow of the Ewaso Ng'iro river (Nyingi et al. 2013). It is estimated that the area provides more than 40% of the country's water needs (Kleinschroth et al. 2013). The forests on Mt. Kenya provide energy (fuelwood and charcoal); food and feed (fodder, honey, and edible plants); materials (timber, construction materials, utensils, ropes, weaving materials, gum Arabic, and dye); medicines, repellent, and cosmetics; as well as ecotourism opportunities (Bussmann 2006; Wekesa et al. 2010; Kaburi and Medley 2011; Nyingi et al. 2013; M'mboroki et al. 2018; Nyongesa and Vacik 2018). However, agricultural expansion, rising demand for forest products by a growing population, forest fires, and illegal logging are increasing the pressure on the available forest resources (Nyongesa and Vacik 2018; Musila et al. 2019).

Rangelands provide feed for livestock and wildlife as well as the basis for conservation and tourism. The distribution of rangeland-related services is connected more to land tenureship than to the different habitat types (Ericksen et al. 2012), with land tenure arrangements including e.g. communal lands for livestock production, private ranches, and community-based conservancies combining livestock production and wildlife conservation, or areas dedicated entirely to wildlife conservation. Forage availability can vary greatly between years, depending on rainfall and drought patterns. Wildlife and livestock rely on mobility to find water and grazing areas, and their migration varies both seasonally and annually (Ericksen et al. 2012). However, pasture availability is declining due to rangeland degradation, a process that started decades ago in some locations. This is due to increases in livestock numbers, which leads to overgrazing, combined with increases in drought frequency, the spread of invasive alien species, and agricultural encroachment (Otuoma et al. 2009; Lalampaa et al. 2016; Kimiti et al. 2017; Pas 2018). Rangeland fragmentation is leading to the misalignment of pasture availability and seasonal livestock movements (Pas 2018; Unks et al. 2019). Rangeland degradation might lead to conflicts between the different users, including pastoralists, smallholder farmers, large-scale ranches, and wildlife conservancies (Eckert et al. 2017; Kimiti et al. 2017). In addition, the spread of the invasive *Opuntia stricta* species has direct impacts on livestock such as eye punctures in camels and cattle, as well as mortality in goats from ingestion of the plant (Shackleton et al. 2017). It is expected that climate change impacts in rangelands, including increased aridity and water stress, will diminish yields from rain-fed agriculture and increase food insecurity and malnutrition (Kagunyu et al. 2017).

Freshwater systems are key in Kenyan rangelands and serve as sources of water for people, livestock, and wildlife (Nyingi et al. 2013). Local communities highly depend on wetlands, including swamps and seasonal marshes, for their livelihoods. Wetlands provide valuable dry-season grazing areas for livestock and wildlife, fertile areas for agricultural production, clean water, fuelwood, materials, and space for sociocultural activities for local communities. Wetlands are also important carbon sinks (Mwita et al. 2013; Nyingi et al. 2013) and provide habitats for resident and migrant bird species and wild animals (Thenya 2001). Water availability is decreasing due to the growing volume of water abstraction, including for the expansion of horticultural agribusiness, inadequate water resource management, and declining rainfall, affecting ecosystems and downstream users (Mutiga et al. 2010; Ulrich et al. 2012; Nyingi et al. 2013; Ulrich 2014). This leads to conflicts both between upstream and downstream water users and between pastoralists and farmers (Mutiga et al. 2010; Eckert et al. 2017; Lanari et al. 2018). Different stakeholders' diverse uses of the wetlands – such as for crop cultivation, grazing, and harvesting of plants for building materials, fuel, and handicrafts – lead to conflicts over the use of the scarce resources and, together with an increase in nearby settlements, result in land degradation (Mwita et al. 2012).

Figure 3.8: Changes in population of livestock species in Laikipia, Samburu, and Isiolo counties between 1977–1980 and 2011–2016 (Source: Based on Ogutu et al. [2016])

	County		
Species	Laikipia	Samburu	Isiolo
Sheep and goats	↑	↑	↗
Camel	↑	↑	↘
Donkey	↑	↘	↑
Cattle	→	↘	↘

Population trends:

↓	Strong decrease (>50%)	↑	Strong increase (>50%)	→	Stable (+/-10%)
↘	Decrease (10-50%)	↗	Increase (10-50%)	ND	No data

Medicinal and ceremonial plants are widely used by local people in the Mt. Kenya region. Medicinal plants are foremost applied in the treatment of skin infections, malaria, fever, common colds, wounds, stomach problems, parasites, and post-natal care (Nanyingi et al. 2008;

	Ecosystem service	Final service	Stakeholder group
Regulating	Habitat creation and maintenance		Local communities; pastoralists; conservancies; tourists
	Pollination and dispersal of seeds & other propagules		ND
	Regulation of air quality		ND
	Regulation of climate		Smallholder farmers; all
	Regulation of ocean acidification		ND
	Regulation of freshwater quantity, flow, and timing	Water	Local communities; pastoralists; large- scale land users (ranchers, horticultural farms); smallholder farmers; conservancies
	Regulation of freshwater and coastal water quality	Water	Local communities; pastoralists; large-scale land users (ranchers, horticultural farms); smallholder farmers; conservancies
	Formation, protection, and de-contamination of soils and sediments		ND
	Regulation of hazards & extremes		ND
	Regulation of organisms detrimental to humans		ND

Table 3.1: Use of ecosystem services by different stakeholder groups in the Mt. Kenya region. Ecosystem service categories following IPBES nature's contributions to people categories (IPBES, 2017). (Source: Assessment based on literature review)

Gakuya et al. 2013; Muthaura et al. 2015; Bruyere et al. 2016). Medicinal plants are also traditionally used in livestock health management and as biopesticides (Gakuubi and Wanzala 2012; Gakuya et al. 2013). Traditional ecological knowledge for the use of culturally significant and medicinal plants is declining, due to social changes and loss of the perceived value of those species (Gakuya et al. 2013; Bruyere et al. 2016). However, medicinal plants are still threatened by overexploitation, deforestation, drought, and bushfires. Sacred forests and sacred sites in the Mt. Kenya region may be a significant factor in nature conservation and environmental protection. For example, Mt. Kenya is a holy mountain for the Kikuyu community that believes they should preserve the forest (Nyongesa and Vacik 2018; Kendi 2014).

Human–wildlife conflicts, including livestock predation, crop raiding, damage to infrastructure, and physical harm, are also an important aspect of the human–nature relationship, especially affecting local communities (Bond and Mkutu 2018; Carter et al. 2018; Evans and Adams 2018; Green et al. 2018).

	Ecosystem service	Final service	Stakeholder group
Provisioning	Energy	Firewood	Local communities; pastoralists; tourists
		Charcoal	Local communities
	Food and feed	Honey	Local communities
		Livestock	Pastoralists; large-scale land users (ranchers); local communities
		Edible plants	Local communities
		Agricultural products	Local communities; smallholder farmers; large-scale land users (horticultural farms)
	Materials and assistance	Timber	Local communities
		Construction and tool making materials	Local communities; pastoralists
		Ornaments	Local communities; pastoralists
		Gum Arabic	Local communities
	Medicinal, biochemical, and genetic resources	Medicinal plants	Local communities; pastoralists; smallholder farmers
Cultural	Learning and inspiration		Local communities and others – more formally, universities and research for development agencies
	Tourism and cultural values	Tourism	Conservancies; tourists
		Sociocultural activities	Local communities
	Supporting identities	Sacred and natural sites	Local communities
		Ceremonial and sacred plants and animals	Local communities; pastoralists

ND: No data found in the literature

This creates conflicts among stakeholders who benefit from the presence of wildlife, for example through tourism enterprises, and those negatively affected, such as smallholder farmers and pastoralists who suffer from elephants raiding their crops and large carnivores attacking their livestock (Bond and Mkutu 2018; Evans and Adams 2018; Mitchell et al. 2019).

3.3 Ecosystem service supply and demand: appraisal of current and prospective trends

This section analyzes ecosystem service supply and demand considered most relevant to the main uses and user groups in the study area. Key ecosystem services discussed in this report have been selected from Table 3.1 above and mapped into Table 3.2 below, according to their supply capacity under current climate and economic conditions. In a next step,

Table 3.2: Appraisal of ecosystem services supply and demand under current and future conditions. (Source: Based on literature review)

Service	ES supply capacity clearly below demand	ES supply capacity slightly below demand	ES supply capacity equals demand	ES supply capacity above demand	Drivers of change
Regulating					
Pollination and dispersal of seeds		○○	**		Landscape changes, phenology shifts, warming
Regulation of climate		○○	**		Competition for land, warming, saturation
Regulation of freshwater	○○○	***			Increasing need, quality, local droughts & floods
Formation, protection of soils and sediments	○○	**			Increased erosion rates due to increase of torrential rains
Regulation of organisms detrimental to humans		○○	**		Occurrence of new pathogens, reduced ecosystem integrity, warming
Provisioning					
Energy	○○	**			Increasing need for energy for economic transition, warming
Food and feed	○○	**			Increased food need, competition for water, warming
Livestock production	○	**			Rising meat demand, drought, pests, warming
Materials and assistance	○○	**			Competition for land with agriculture & forestry
Medicinal, biochemical and genetic resources	○	*			Overexploitation, warming
Cultural					
Tourism		○○	**		Hazards, increase population, warming
Learning and inspiration		○	*		
Physical and psychological experiences		○○	**		Warming, population increase
Supporting identities		○	*		Environmental degradation, warming

** = estimated current service supply and service demand; number of stars indicate importance*

○ = estimated service capacity under a future global change scenario

based on evidence from literature as well as on expert knowledge, the future provision capacity of these services has been appraised in view of projected climate change scenarios (see also projections discussed in Chapter 4.2 of this report) – considering also most likely socioeconomic development pathways. Black star symbols refer to the current situation (supply vs demand), while red circles assess potential future scenarios (assuming continued but eventually slower population growth and increasing rates of urbanization and socioeconomic development). It is important to note that the appraisal is only partly supported by evidence and may therefore be considered to some extent speculative. Nevertheless, such an appraisal helps to identify and assess potential trends and hotspots of mismatch between service supply and demand – not only now but also in the future. It should also be noted that this appraisal concerns the study area north of Mt. Kenya only. At this stage, due to the lack of disaggregated data and information, it cannot inform on county or landscape-level implications.

At study-site level, some patterns are discernible – relating mostly to the continuing importance of regulating as well as provisioning services. Regulation of freshwater quantity, flow, and timing is in this regard certainly a key service, and in high demand by all major stakeholder groups: local communities depend on water for their livelihoods and survival, pastoralists and large-scale ranches need water for their livestock, and the horticultural industry has to water their produce. In addition, the economically significant tourism sector depends critically on this service.

Under the projected climate change scenario discussed in Chapter 4.2, some areas receiving higher amounts of precipitation are likely to increase their supply of provisioning ecosystem services such as food and feed production (e.g. the western shores of Lake Turkana), while many other areas are likely to lose this capacity. However, the climate models also predict higher overall variabilities as well as an increase in the severity of extreme events (Chapter 4.2), with droughts and flooding predicted to occur at magnitudes hardly seen under current climatic conditions. This will have important ramifications for the region's socioeconomic development – particularly for the agropastoralists who, these days, live in the lowlands of Marsabit, Isiolo, and Samburu – but also for large-scale agricultural production. While ecosystem changes such as the spatial distribution of forests in the area have been mostly neglected in this analysis, it goes without saying that the continuous survival and functioning of these ecosystems will be key to ensuring that the higher intensities of future climate events can be absorbed and moderated to the extent that human life can still prosper in this semiarid area. Otherwise, the increased velocity of river runoff – especially on the steeper slopes of Mt. Kenya, but also across degraded rangelands with bare patches – will have devastating effects and may e.g. lead to massive erosion of fertile lands and seeds, due to the eroded capacity of hazard regulation and mitigation services.

However, more information and data will be necessary to understand the complex interplay of dynamics to allow for a fuller and spatially explicit assessment.

4 Direct drivers of change

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4.1 Nature protection and ecosystem trends

Here, we consider use zonings such as protected forests, national reserves, national parks, and conservancies as direct or external drivers of change. This is under the assumption that the local population had little part in the design of these processes; instead, they are recipients and now face new opportunities and constraints. New features and dynamics are increasingly altering a system that already faces natural resource limitations, e.g. in changing availability of upstream–downstream water resources and conflicting land use claims. Against this background, this section evaluates ecosystem change in relation to use zoning claims for nature protection.

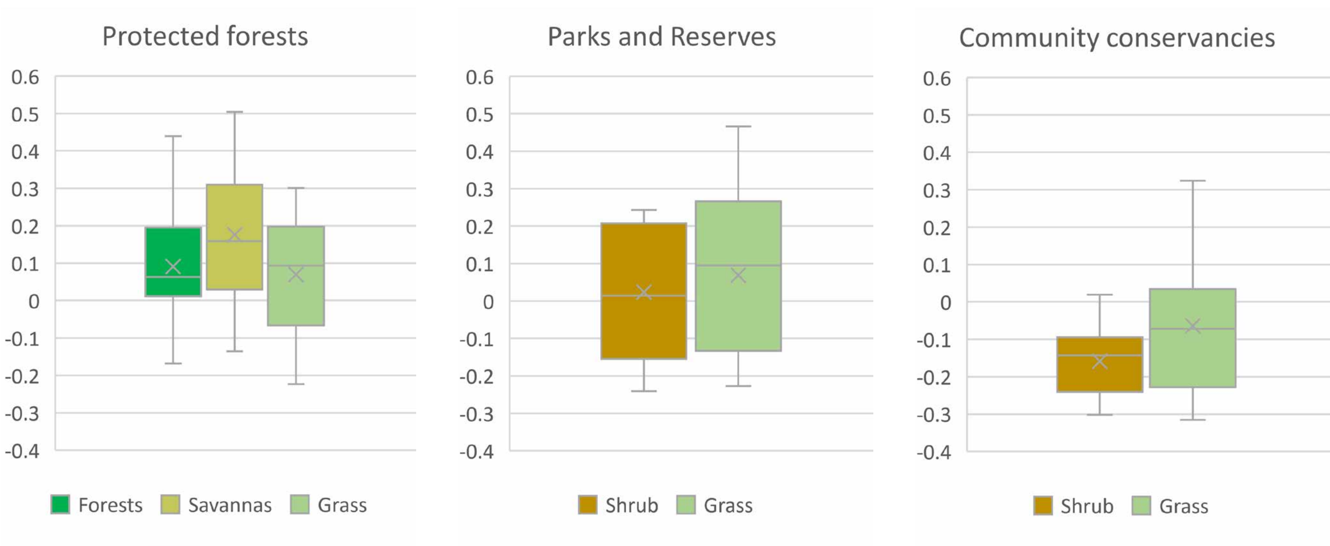
We analyzed ecosystem change and vegetation greenness trends within protected forest areas (biodiversity hotspots and water towers), nature parks and reserves (wildlife and tourism), and conservancies (wildlife, livestock, and tourism). Our analysis reveals that ecosystem processes vary by use zone/protection type, but the trends we observe within specific zones are also the result of a variety of environmental (e.g. south–north precipitation gradient) and socioeconomic conditions and processes in and around these areas. Table 4.1 shows the summary of main ecosystem trends we documented within the different types of protection and conservation areas, and Figure 4.1 displays the vegetation greenness trends for the different ecosystems.

Table 4.1: Trends of ecosystem types between 2001 and 2019 in protected areas and conservancies north of Mt. Kenya. Black arrows represent strong trends, grey arrows moderate trends, and blank arrows no trend (Source: Data analysis by CDE using Friedl and Sula-Menashe [2019])

	Ecosystem trends						
Protection	Forests	Savannas	Shrublands	Grasslands	Barren	Croplands	**Main from–to changes**
Protected Forests	↘ (strong)	↗ (strong)	⇨ (no trend)	↗ (moderate)	⇨ (no trend)	⇨ (no trend)	forests to savannas
Nature Parks and Reserves	⇨ (no trend)	⇨ (no trend)	↘ (moderate)	↗ (moderate)	⇨ (no trend)	↗ (moderate)	shrublands to grasslands
Community Conservancies	⇨ (no trend)	⇨ (no trend)	↘ (strong)	↗ (strong)	⇨ (no trend)	⇨ (no trend)	shrublands to grasslands

From 2001–2019, protected forest zones showed a decline in forest ecosystems from 29% of the protected area to 25%. Savannas increased from 27% to 30%, and grasslands from 39% to 41%. This moderate decline affects almost all forests in our study area, possibly a result of minor processes of selective illegal logging (Kiringe and Okello 2005; Mureithi et al. 2016). At the same time, vegetation greenness trends (i.e. an increase or decrease in photosynthetic active leaves and grasses) suggests a greening of protected forest areas. These trends in forest greenness, however, vary across our study area as shown in Figure 2.4. The Matthews Range (see Figure 2.2) in the center of Samburu as well as south-facing slopes of Mt. Kenya's protected forest area show vegetation browning, while most other protected forest areas are located towards the west of our study region and show vegetation greening. Increased pressure on natural resources in the Samburu–Isiolo lowlands and what seems improved environmental conditions towards the west may have resulted in this pattern.

Figure 4.1: Vegetation greenness trends (2001–2019) of ecosystem types within the different types of protection and conservation areas (Source: Data analysis by CDE, using Didan [2015])



National Parks and Reserves showed a large share of grasslands (77%) followed by 18% of shrublands and small patches of forests, savannas, croplands, and barren in 2001. Nearly two decades on, there is little change: in 2019 we documented a 2% increase in grasslands at the expense of savannas, and a small increase in croplands. We thus see a moderate degradation of ecosystem types, which is also reflected by vegetation greenness trends, although these vary more strongly along the east–west axis. Parks and reserves in the southeast show vegetation browning, while those in the study area's center and north are greening up. Land claims, economic development, traditional land use, and climate variability coalesce in the lowlands of Isiolo, Samburu, and Meru and may be a reason for the more pronounced degradation processes we observe in this region (Mureithi et al. 2016; Kimiti et al. 2017).

We also observe ecosystem degradation in the community conservancies, which are clustered in the lowlands of Isiolo and Samburu and showed large shares of grasslands (84%) and shrublands (14%) in 2001. By 2019, however, more than half the shrublands had disappeared and these areas were replaced by grasslands, which increased from 84% in 2001 to 92% in 2019. Conservancies thus show degradation processes in the form of woody vegetation losses. We also observe vegetation browning, i.e. decreases in green leaves and grasses. Ecosystems in the conservancies seem to be under pressure due to a variety of factors. Reasons for ecosystem degradation in the Samburo and Isiolo lowlands include overgrazing (annual grasses replace perennial grasses), an increase in small ruminants (feeding off woody plants), selective logging, and climate variability (Schmocker et al. 2016; Kimiti et al. 2017; Pas 2018).

4.2 Past and prospective climate trends

Climate change simulation

The climate in East Africa, and in Kenya in particular, is characterized by anomalously dry conditions compared to other equatorial regions (Trewartha 1981; Hastenrath et al. 2011), and shows rather heterogeneous behavior. The climate zones in Kenya range from tropical monsoon climate to hot semiarid and desert climate, according to the Köppen-Geiger climate classification. This heterogeneity is the result of large-scale as well as regional-scale drivers. These drivers include the complex topography, such as the Turkana channel between the Ethiopian and East African highlands; Mt. Kenya and Mt. Kilimanjaro (S. Nicholson 2016); the Indian Ocean (Saji et al. 1999; Hastenrath et al. 2011); large inland water bodies, such as Lake Victoria, and the resulting atmospheric circulation (Camberlin and Philippon 2002; Gichuki 1998); and the rainforest in central Africa. These large-scale controls lead to two rainy seasons: the so-called "long rains" during March–April–May (MAM) and the "short rains" in October–November (ON). Precipitation is scarce in the remaining months. For example, maximum climatological precipitation in Munyaka is recorded in November, with 127 mm per month, followed by April, with 100 mm per month. The weather station shows the typical "long" and "short rains" (Table 4.2). The temperature is relatively stable throughout the year, with a minimum of around 7–8 °C and a maximum of 26 °C.

Table 4.2: Climate overview for the Munyaka weather station, located northwest of Mt. Kenya (mean values are calculated for the period of 1991–2019). (Source: CETRAD)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T min (°C)	7.06	7.06	6.91	7.83	8.44	8.06	7.74	7.67	7.65	7.71	7.63	7.19
T mean (°C)	16.21	16.58	16.41	16	17.2	15.43	15.22	15.35	15.69	15.64	15.07	15.52
T max (°C)	25.17	26.19	26.12	24.85	23.66	23.87	23.78	24.13	24.44	23.83	23.09	24.02
P (mm/month)	54.91	33.04	76.85	100.78	55.04	18.09	20.97	26.86	24.11	73.82	127.37	65.51

While the "short rains" are less important for the total amount of annual precipitation, they account for most of the inter-annual variability (Camberlin and Philippon 2002; Hastenrath et al. 2011). Thus, the "short rains" are responsible for both flooding and drought. The occurrence of floods in Kenya is rather common, particularly after very dry years (Hastenrath et al. 2011; Gichuki 1998). The variability in the "short rains" is influenced by changes in sea surface temperatures (SSTs) in different ocean basins and related changes in atmospheric patterns (Saji et al. 1999; Hastenrath et al. 2011; Nicholson 2016; Gichuki 1998). Changes in the "long rains" are associated mainly with droughts (Williams and Funk 2011; Liebmann et al. 2014; Ayugi et al. 2016) and caused primarily by a faster than normal northward displacement of the tropical rainband (Wainwright et al. 2019).

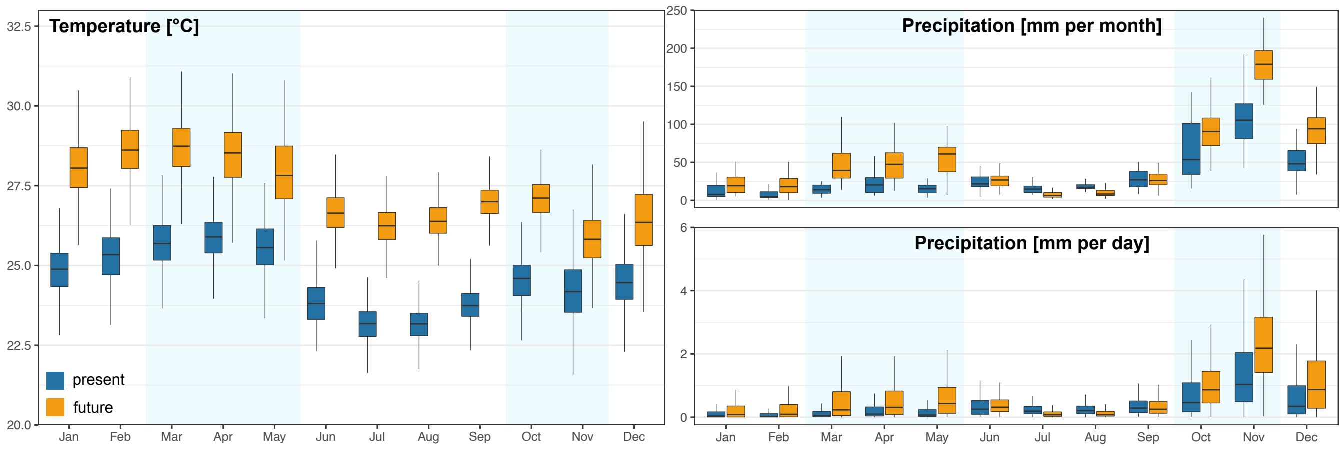


Figure 4.2: Climatology for each month using daily mean 2 m temperature (in °C, left) and precipitation sums (in mm, right) monthly (top) and daily (bottom) over Kenya depicted as boxplots. The blue boxes represent the present climate (1981–2010), while the orange boxes depict the future climate (2071–2100, RCP8.5). The boxes cover the range of the 25th to the 75th quartile, while the whiskers extend a maximum of 1.5 times plus or minus the distance between the first and third quartiles. Outliers are not shown, to simplify the plots. Blue shading indicates the wet months (Source: Author's design)

The strong sensitivity of precipitation to changes in SSTs and shifts in the intertropical convergence zone call for high-resolution simulations to inform projections for the future. Our dynamically downscaled simulations for the past (1981–2010) and the future (2071–2100) indicate an increase in precipitation during the two wet seasons, while a decrease in precipitation is projected for the future (Figure 4.2, right column). By the end of the 21st century, July and August in particular will show a significant reduction in monthly precipitation, with a significant increase during March to May and November. According to our simulations, year-to-year variability in precipitation is projected to increase during the rainy season, causing further uncertainty to farmers growing crops. The higher variability towards larger daily precipitation sums increases the risk of flash floods, because infiltration capacity is quickly reached and excess water flows overland. The increase in precipitation on an annual scale is observed throughout the entire country and is especially pronounced in higher elevated areas in western Kenya (not shown). The underlying mechanisms explaining these changes must be further investigated. One caveat of the climate model simulations is that the intensity of the "long rains" is underestimated. This indicates that the global model may be missing some important processes, such as a realistic SST distribution in the Indian Ocean and the associated atmospheric circulation. A more in-depth analysis is needed to find the underlying mechanism for this mismatch, but the projections depicted in Figure 4.2 are still valid for the climate at the end of the century.

Temperature is expected to increase by the end of the century (Figure 4.2, left panel), by around 2 °C in the wet seasons and more than 3 °C in the dry season. The weakest increase is found in November. The changes in magnitude of the increase in temperature are strongly related to changes in precipitation level. With more water available for evaporation, heating is dominated by latent rather than by sensible heat. If water is further reduced as in the dry reason, more sensible heating is expected.

Under the high-emission scenario RCP8.5, the CMIP5 models analyzed for the IPCC-AR5 (2013) project a maximum increase of up to 7 °C and a median increase of around 4 °C for Eastern Africa at the end of the century. With our simulation we are at the lower limit of this estimate (around 3°C for Kenya in the CESM1 simulation), which might partly be related to the projected changes in precipitation and the horizontal resolution. While the CMIP5 models project a slight trend towards more precipitation by the end of the 21st century from October to March, we find a rather distinct increase. Conversely, from April to September, no clear signal is projected due to the large spread of the IPCC modelling results and the low agreement between them. During these drier months, the regional model results presented here show a reduction in precipitation. The variability of precipitation is projected to increase in both seasons, indicating that extreme events such as remarkably wet seasons and abnormally dry seasons may occur more frequently. The model simulations used for the IPCC-AR5 are generally in line with our simulation and help to increase the robustness of our findings, in particular the interpretation of changes between the two periods.

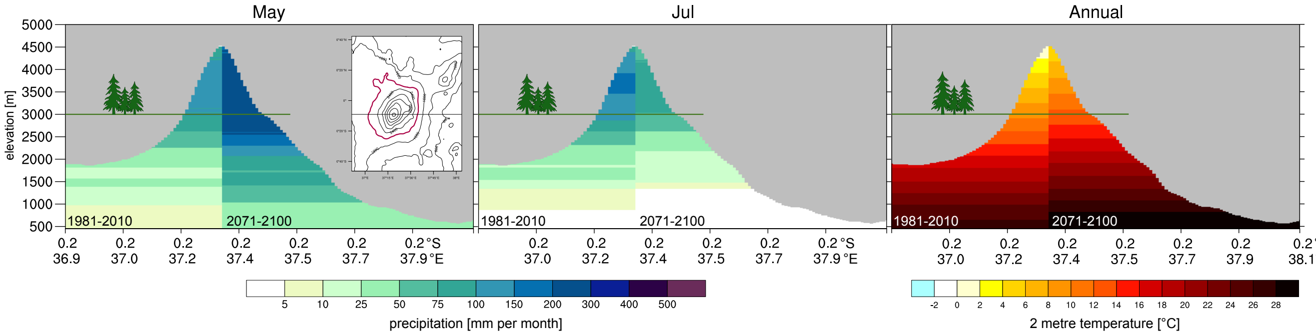


Figure 4.3: Comparison of monthly accumulated precipitation (in mm) for May and July and mean annual temperature (in °C) for the present climate (1981–2010, left part of the topography) and a possible future climate (2071–2100, right part of the topography) for Mt. Kenya. The values are averaged along height contour lines (e.g. along the red contour in the inset) and 10-meter height sections for both periods. This means that all values in one height class are used to calculate the averages shown for both periods. The topography is overlaid to provide information on the model topography along the west–east cross-section (shown in the inset) through the peak of Mt. Kenya. The green line at around 3,000 m a.s.l. indicates the approximate position of the tree line (Source: Author's design)

These changes in precipitation and temperature are also well visible on Mt. Kenya, an example of one of the most important freshwater towers in central Kenya. The projection indicates an increase in precipitation from the foothills all the way up to the peak in the "long" and "short rains", while precipitation is reduced in the dry season (Figure 4.3). As expected, temperature also increases along the slopes of Mt. Kenya. The modelled peak of Mt. Kenya, which is in the range of 4,500 m a.s.l. in the model (around 5,200 m a.s.l in reality), reaches temperatures in the future that are currently measured at an elevation of around 3,200 m a.s.l. This increase can substantially affect the endemic vegetation along the slopes of Mt. Kenya. Assuming that the tree line is limited by temperature and not precipitation, as the latter is abundant, it could move from around 3,000 m a.s.l. up to 3,700 m a.s.l. The strong increase in temperature further affects the remaining glacier, which is currently an important water resource during drier months (Figure 4.3). How this increase in temperature will affect species composition and interactions is not fully clear. Since some occupy a comparably narrow elevation and temperature zone, "moving up" to maintain the temperature also means losing habitat area.

Both precipitation and temperature changes have implications for human and animal well-being, but they also affect plants and land cover. The increase in precipitation in most months leads to a clear reduction in the fire weather index (FWI) in the rainy season (Lawson and Armitage 2008). From June to September, the risk of initiation or uncontrolled distribution of fires is substantially increased in the eastern lower-lying areas of Kenya (Figure 4.4). In western Kenya, precipitation amounts are high enough to keep the fire risk minimal throughout the entire year, both in the present and the future climate. The higher availability of water has a positive effect on fire risk in the future, but it comes at the cost of increased heat stress in combination with expected temperature rises (illustrated by the heat index in Figure 4.5) (Anderson et al. 2013; NOAA 2014). The heat stress is increased in the wet seasons, because of an increase in relative humidity and temperature. The heat stress index considers the fact that the human body requires evaporative cooling, enabled by sweating, to prevent overheating. With increasing temperature and ambient humidity this mechanism is reduced or can even be stopped, which can be fatal. Especially, the lower-lying regions in eastern Kenya change from "extreme caution" to "danger" levels under the RCP8.5 scenario, substantially increasing the risks of heat strokes and exhaustion.

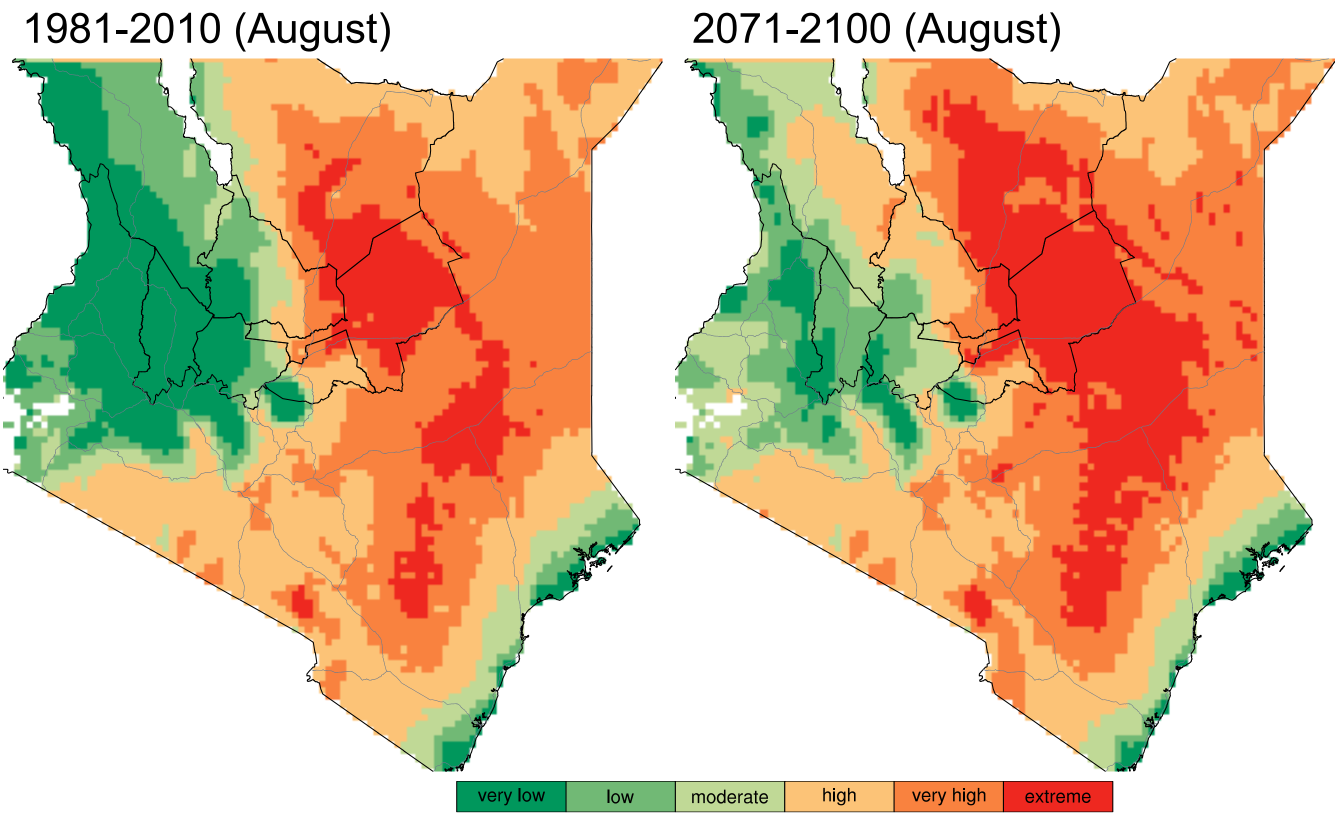


Figure 4.4: The fire weather index (FWI) for Kenya is depicted for the present climate (1981–2010, left) and a possible future climate (2071–2100, right) for August (the month with the highest risks, according to the simulations) (Source: Author's design)

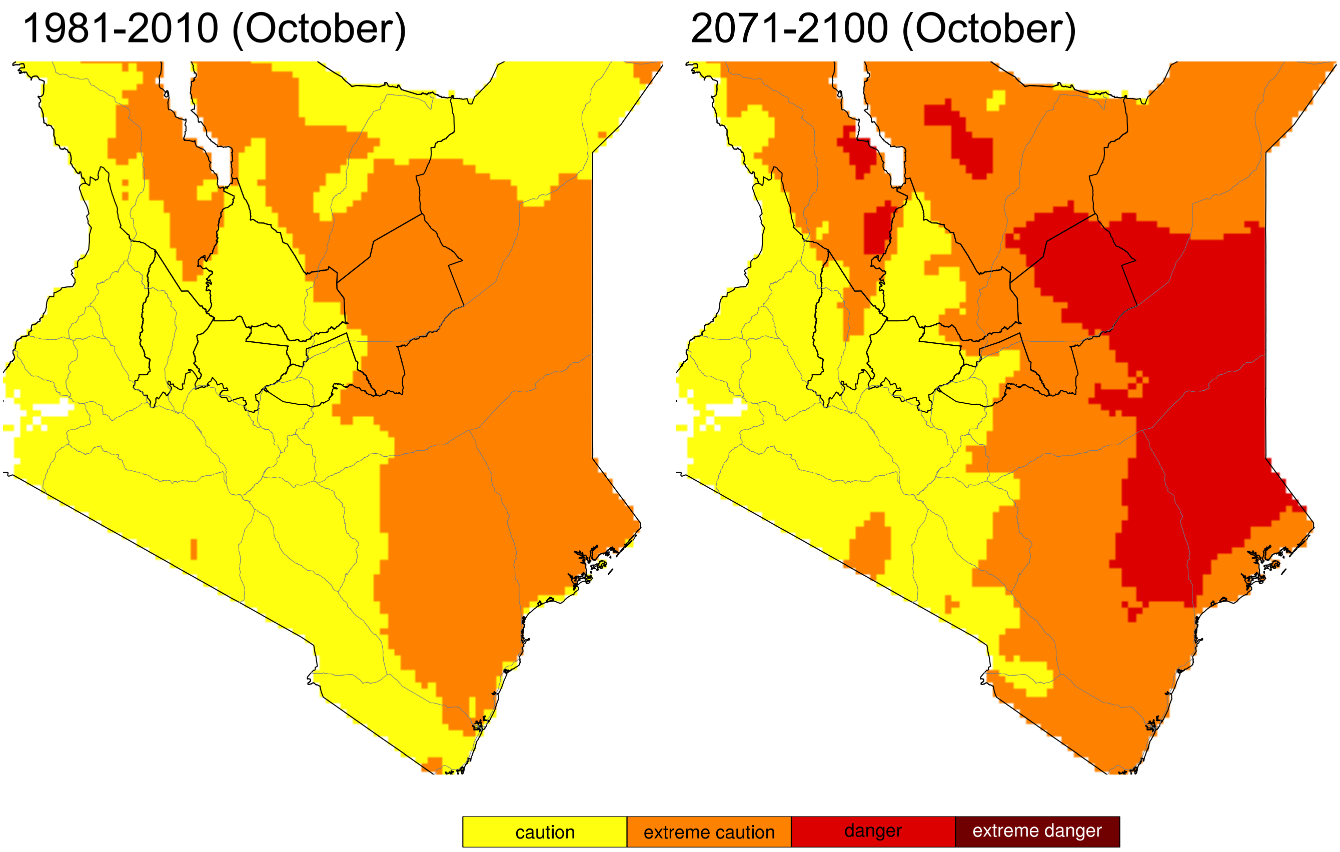


Figure 4.5: The heat index for Kenya is depicted for the present climate (1981–2010, left) and a possible future climate (2071–2100, right). October is chosen to show the increase in risk during the wet season (Source: Author's design)

Prospective climate change and land use

Climate change and particularly changes in precipitation levels as well as seasonal distribution can have pronounced effects on ecosystems and land use in semiarid and arid areas. In this chapter, we consider the results of the climate simulations for the years 1981–2010 and 2071–2100 (Table 4.3) and discuss prospective changes in monthly precipitation averages between the two periods of simulation in relation to land cover and use. Baringo, Laikipia, Samburu, and Turkana all show increases during the "long rains", decreases from July to September, and a lot more precipitation during the "short rains". With these changes, variabilities also increase substantially. While we expect more rain on average during the wet seasons, individual or consecutive years during the period of 2071–2100 may also show less precipitation than we see today, which may strongly affect ecosystems and land use. During the dry period in January and February there is not much change between the simulation periods.

Table 4.3: Increases (strong & moderate) and decreases (strong & moderate) in average monthly precipitation between simulations for 1981–2010 and 2071–2100. The values are calculated as differences between monthly mean precipitation sums normalized by the difference in annual mean precipitation sums of the future and the past. The traditionally wet seasons ("long rains": March–May, "short rains": October–November) are in italics. Bold numbers represent significant trends.

County	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Baringo	1.1	1.6	2.3	3.3	***22.2***	7.5	-10.6	-13.0	2.0	***32.6***	***37.8***	***13.2***
Meru	2.9	***6.2***	10.0	9.3	***15.5***	-0.7	-1.3	-1.7	-3.4	2.2	***43.2***	***17.8***
Laikipia	2.2	2.3	2.4	5.1	***20.6***	1.8	-9.5	-12.6	-8.1	***36.3***	***44.6***	***14.8***
Samburu	0.9	1.5	3.6	5.8	***18.5***	***7.1***	-8.2	-6.1	-0.9	***30.6***	***36.4***	***10.6***
Isiolo	1.3	3.5	***10.8***	***13.3***	***12.9***	1.2	-0.4	-0.4	-0.9	7.7	***39.8***	***11.2***
Marsabit	0.7	1.3	4.9	***8.6***	***19.0***	4.3	-3.6	-2.2	-0.3	***21.7***	***36.0***	***9.5***
Turkana	0.2	0.6	1.4	3.9	***22.7***	***14.2***	-9.2	-7.7	2.5	***31.5***	***30.4***	***9.7***

In Isiolo, Marsabit, and Meru, the "long rains" tend to show little precipitation in the present simulation, while the simulation for the future shows increased amount and variability of rainfall. There is little change during the dry months (June/July to September), but the simulation for the future shows substantial increases in precipitation amounts and variabilities during the period from October to December.

These projected changes in precipitation will strongly affect ecosystem composition and the pace of degradation or regeneration processes. These changes – in levels, seasonality, and variability of precipitation – will be felt within landscapes over time and across space. Traditionally, pastoralists and wildlife, mobile enough to follow the rains, are highly adapted to such variabilities. This also supported ecosystem stability by increasing resource use in temporarily more humid areas while decreasing pressure in drier areas. Over the last decades, however, this mobility has been severely hampered in the area north of Mt. Kenya, due to land zoning, economic developments, urbanization, and expansion of cropland and agribusinesses. Increases in precipitation variability thus become an issue for most land users – be it crop failure when practicing rainfed agriculture; lack of irrigation water; insufficient rains to support the watering needs of green pastures, livestock, and wildlife; or tourism.

Higher precipitation amounts, particularly heavy rains at the onsets of the rainy seasons when pastures tend to show little vegetation and degraded lands and croplands are usually bare, can wash away seeds (crops and grasses), cause soil erosion and gully formation, and even lead to flash floods, ultimately exacerbating ongoing degradation processes that follow a dry period (Pas 2018). On the other hand, there are also potentials if land use strategies manage to cope with variabilities and higher precipitation amounts. Water and land management becomes crucial to maintain crop production. Examples include water reservoirs to collect excessive rains; terraces and agronomic measures to increase infiltration and water retention, while reducing erosion and surface runoff; and adaptations in crop varieties and the cropping calendar.

Pastoralists and wildlife remain dependent on mobility for access to green pastures and water. Current arrangements in the form of community conservancies embed flexible use options and governance mechanisms to support these movement needs in an area where mobility is more and more constrained. At the same time, there are accounts of arrangements between private ranches and pastoralist herders for temporally limited mutual pasture use during dry periods. Such arrangements, whether institutionalized or individual, on mutual use of natural resources seem promising to also address mobility needs in the future. But current trends of ecosystem degradation also suggest that additional governance mechanisms are needed. As processes and changes continue to occur – and to affect each other – the complex interplay between ecosystems, climate, and a variety of land use types and practices needs to be better understood, to support governance and navigation of trade-offs and co-benefits.

4.3 Urbanization and infrastructure development and prospects

LAPSSET accessibility and land cover change

The Lamu Port, South Sudan, Ethiopia Transport Corridor (LAPSSET), initiated in the 1970s and since then interrupted and resumed several times, is an infrastructure and transport megaproject intended to stimulate trade and cross-border market integration. With an estimated cost of ~2.5 trillion Kenya Shillings (~29 billion US Dollars), the project includes the construction of a seaport, major roads, international airports, a crude oil pipeline, resort cities, and other socioeconomic infrastructure such as schools and health centers. Starting at Lamu on the northeast coast, the road enters the Mt. Kenya–North Ewaso Ng'iro region through Garissa. It continues to Isiolo, before forking off on the one hand towards Moyale, on the Ethiopian border, and on the other to Nakodok, on the South Sudan border. The road from Isiolo to Moyale used to be an earth road that took two to three days to travel. Construction of the new asphalt road started in 2008 and the road was opened to the public in 2016. Travel time between Isiolo and Moyale was heavily reduced and now takes only about 6-8 hours. With improved access, market opportunities also increased and diversified, e.g. livestock can now be transported in trucks from the north to the southern markets, and arable land may be converted to cropland for food production. To examine potential effects of the LAPSSET mega-infrastructure project on land cover change and vegetation greenness trends, we modelled accessibility to the LAPSSET stretch from Isiolo to Moyale as real travel time and distinguished five classes with increasing travel time away from the LAPSSET into the hinterlands or along arterial roads, i.e. 0-2h, 2-4h, 4-6h, 6-8h, 8-10h (Appendix figure 4) (Weiss et al. 2018). We then analyzed changes in ecosystem types between 2001 and 2019 within each travel time class. The main dynamics are summarized in Table 4.4.

Table 4.4: Trends in area covered by ecosystem types between 2001 and 2019 for five classes with increasing travel time (or distance) from the LAPSSET. Black arrows represent strong trends, grey arrows moderate trends, and blank arrows no trend (Source: Data analysis by CDE using Weiss et al. [2018]; Friedl and Sula-Menashe [2019])

Travel time from LAPSSET	Ecosystem trends						Main from–to changes
	Forests	Savannas	Shrublands	Grasslands	Barren	Croplands	
0–2h	⇨	⇨	⬊	↗	⇨	⬈	shrublands to grasslands
2–4h	⇨	⇨	⬊	⬈	⇨	⇨	shrublands to grasslands
4–6h	⇨	↗	⬊	⬈	⇨	⇨	shrublands to grasslands
6–8h	⇨	↗	↘	↗	↘	⇨	various dynamics
8–10h	⇨	⇨	⬊	⬈	⬈	⇨	shrublands to grasslands

The LAPSSET stretch we analyzed is located in the semiarid lands with mainly grasslands and shrublands, and the main trends thus show dynamics involving these two classes. Our analysis shows that no matter the distance from the LAPSSET, the main trend in ecosystems is the conversion of shrublands to grasslands. The amount of shrubland converted to grassland and other dynamics (e.g. increase in croplands or savannas), however, vary, and the LAPSSET and associated economic opportunities and population growth may have contributed to these processes.

Within 2 hours' travel time from the LAPSSET, grasslands are the main land cover, while shrublands cover only 11% of the landscape. By 2019 shrublands were reduced to 7% while grasslands and croplands increased. The comparably low share of shrubland within 2h travel time may be a result of earlier processes along the earth road, because we see higher shares and losses of shrubland in all other travel time classes. The increase in croplands, however, only occurs in this class and is most likely an effect of the LAPSSET.

Within 2–4h travel time from the LAPSSET we document a strong loss of shrublands (from 20% to 12%) but an increase in grasslands, as well as other, minor dynamics. The loss in woody vegetation may have been accelerated by the LAPSSET, with e.g. an increase in people and economic opportunities leading to increases in livestock as well as charcoal production. We basically see the same dynamic also happening within 4–6h travel time from the LAPSSET (loss of shrublands to grasslands), but at the same time we also see a moderate increase in savannas. This increase mainly occurs in Baringo county, the high-potential area in the west, and dynamics in Baringo may not be associated with the Isiolo–Moyale stretch. Rather, buying livestock from the Isiolo–Moyale region has become more attractive in Baringo, a sign of economic opportunities offered by the LAPSSET, but maybe also associated with losses in woody vegetation. Within 6–8h and 8–10h travel time from the LAPSSET we also see shrublands converted to grasslands. While at a much more moderate level in total (shrublands decrease by a small percentage to 25% and 20% respectively), in general, shrublands are lost to grasslands to the east of the LAPSSET, and grasslands lost to shrublands to the west. It seems that starting at 4h travel time from the LAPSSET stretch from Isiolo to Moyale, other factors are most likely to be of stronger influence, e.g. accessibility to Nairobi (particularly around Baringo and Laikipia) and the elevation and precipitation gradient. The conversion to croplands and degradation of woody vegetation we observe within 4h travel time may have been accelerated by the LAPSSET.

LAPSSET Growth Areas

We further examined the "LAPSSET growth areas" as indicated in the LAPSSET development plans. We examined all four designated growth areas in the region – Isiolo, Moyale, Lodwar, and Lokichogio (Appendix figure 4). Trends differ strongly (Table 4.5) and some may be associated with LAPSSET developments. The "Isiolo growth area" shows the largest share of croplands of all growth areas, but fairly little change from 2001 to 2019. The largest dynamics are fluctuations between croplands and grasslands. However, the 500 m resolution of the classification has issues with properly representing smallholder croplands and local accounts confirmed that cropland increased around Isiolo during the last two decades.

Table 4.5: Trends in ecosystem types between 2001 and 2019 for the four LAPSSET growth areas. Black arrows represent strong trends, grey arrows moderate trends, and blank arrows no trend (Source: Data analysis by CDE using Friedl and Sula-Menashe [2019])

	Ecosystem trends						
Growth area	Forests	Savannas	Shrublands	Grasslands	Barren	Croplands	**Main from–to changes**
Isiolo	⇨	⇨	⇨	⇨	⇨	↗ (grey)	cropland increase
Moyale	⇨	⇨	↘ (black)	↗ (black)	⇨	⇨	shrublands to grasslands
Lodwar	⇨	↗ (grey)	↗ (black)	↘ (black)	↘ (black)	⇨	shrublands to grasslands
Lokichogio	⇨	⇨	↘ (black)	↗ (grey)	⇨	↗ (black)	various dynamics

The Moyale growth area shows tremendous changes. In 2001 most of the land was still covered by shrubs; by 2019 it was 16%. Since the construction of the asphalt road from Isiolo to Moyale, travel time between the two towns has decreased from 2 to 3 days to under one day. The loss in shrublands may be associated with this reduced travel time, as northern pastoralists gather in Moyale to transport livestock to the southern markets. Increased fodder and fuelwood needs could have led to this strong decline in shrubs. The Lodwar growth area shows increases in woody vegetation – grasslands and barren have been converted to shrubs from 2001 to 2019. This process corresponds with the greening up and increase in woody vegetation we see across most of Turkana and is most likely not associated with LAPSSET developments. In the Lokichogio growth area, moderate conversion of shrublands to grasslands occurred and grasslands were also converted to croplands. This could be a sign that LAPSSET developments have started in Lokichogio.

Large-Scale Agricultural Investments and Urban Expansion

Traditionally, the fertile and resource-rich land on the foot slopes of Mt. Kenya have been used by pastoralists, followed by colonial settlers, and then ranchers and smallholder farmers after independence (cf. Chapter 1). These days, mostly flori- and horticulture investors are pushing into the same high-potential areas, displacing less profitable uses such as small-scale farmers or even ranches, and competing with traditional land users for land and water resources.

This has various consequences. On the one hand, the labor-intensive horticulture industry is creating new livelihood opportunities and could be expected to lead to a rise in formal employment income in the region. However, according to recent research (Ulrich 2014; Mutea et al. 2019), the horticulture sector mostly depends on migrant labor from other counties of Kenya, while the local population seems to benefit less from this opportunity. This is also well reflected in the substantial immigration trends observed for the counties of Meru and Laikipia, and to a lesser extent Isiolo (Wiesmann et al. 2016). On the other hand, this development also deprives local communities in the area and further downstream of their access to fertile land and clean water resources (Zaehringer et al. 2018).

Furthermore, adjacent landholdings previously considered to be of marginal and limited value and quality, have suddenly increased in value and started to attract venture capitalists. Formally such lands may be owned by local marginalized (agro)pastoralist communities, who may be selling their lands under value to speculators and investors and losing their right to have a say in, and shape, future developments in their "front yards" and immediate vicinity.

Although recent studies have revealed a decline close to 30% in dependence on river water of the flori- and horticulture industry (Lanari et al. 2016), this industry is nevertheless a major consumer of water in Isiolo and Laikipia. The chemical fertilizers and pesticides required for such intense systems tend to be very high, increasing the risk of contaminating the environment through leakage or polluted runoff. The potential consequences for local and downstream land users who depend on wells (ground water) for drinking water could be serious – especially if the environmental legislation is not strictly implemented and enforced.

New industries are also contributing to the urban expansion observed in many development hubs or cities in Kenya. The characteristic spatial patterns observed (Figure 2.8, highlighting large-scale agricultural investment areas) suggest processes of peri-urban sprawl, starting typically with the fragmentation of agricultural lands at the urban–rural fringe of existing urban centers. In areas suitable for cropland on the foot slopes north of Mt. Kenya, this intensification affects the capacity of ecosystems to provide services pertaining to food production and clean water or air – leading to rapid ecosystem degradation if not addressed in urban planning. Such encroachment processes are observed particularly in high-potential areas, but also along new infrastructural axes that are enabling agriculture to expand into marginal areas for crop production.

4.4 Invasive alien plant species

Globally, numerous invasive alien plant species are considered a severe threat to agriculture, biodiversity, and delivery of ecosystem services. In eastern Africa, invasive alien plant species are known to negatively affect a biodiversity already under threat, as well as local livelihoods, most of which depend heavily on natural resources (Maundu et al. 2009; Kebede and Coppock 2015; Shackleton et al. 2017). Many species that are now invasive were purposely introduced by aid agencies and governments to amplify existing natural resources. However, they are now causing more negative impacts than benefits (Mwangi and Swallow 2008; Maundu et al. 2009).

In eastern Africa, alien plant invasions have added a new dynamic to landscape management, e.g. by reducing the capacity of rangeland to support livestock. Combined with continued population growth, this is increasing competition over land and natural resources, contributing to further marginalization of rural pastoralist communities (Maundu et al. 2009) and increasing conflicts between different stakeholder groups (Mwangi and Swallow 2008). Additional conflicts arise due to different opinions on how to respond to a particular problem, i.e. whether a) biological control is safe to use as a management option, and b) use of plant biomass from invasive species should be encouraged. These conflicts can only be addressed through development and implementation of appropriate policies and effective management interventions. Such interventions must be informed by scientific evidence, including a good understanding of the biological characteristics that foster the invasion process, and of the negative and positive impacts of the invasion. To inform the development of appropriate responses, we need up-to-date information on the spatial occurrence and distribution of invasive species, to quantify their various negative and positive impacts on the planets' natural resources (Witt et al. 2018; Eckert et al. 2020).

A number of factors contribute to the distribution and spread of invasive alien plant species, with climate being the dominant factor at the continental scale, and topography, land use, and land cover being the most important at the regional scale (Milbau et al. 2009). The various ecosystems and climatic conditions found across eastern Africa makes the entire region particularly prone to plant species invasions. Large parts of the arid and semiarid landscapes of northeastern Kenya have been invaded by trees and shrubs that were introduced for their ability to thrive in low-rainfall areas, e.g. *Prosopis spp* (hereafter referred to as *Prosopis*) and various succulents, including *Opuntia stricta, Opuntia ficus-indica,* as well as various Agave species (Witt et al. 2018).

Land degradation resulting from unsustainable land use and inappropriate land management practices, in particular overgrazing and deforestation, promotes the spread of invasive plant species. Coupled with climate change, land degradation also fosters the spread of such species to other eco-climatically suitable areas, especially to areas that are already highly disturbed (Witt et al. 2018). A recent study (Eckert et al. 2020) modelled the potential future spread of two invasive tree/shrub species, *Prosopis* and *Lantana camara,* at the regional scale in Ethiopia, Kenya, and Tanzania, considering current and future climate scenarios. The study found that while *Lantana camara* is unlikely to invade northern Kenya, an area receiving less than 500 mm of annual rainfall, *Prosopis* is likely to continue spreading across northern Kenya and increase in abundance (Appendix figure 5).

Currently known hotspot areas for invasive species are along the Tana river in Isiolo county; several locations in Turkana county (e.g. along the Turkwei river and Lake Turkana); and around the town of Taveta in the south, bordering Tanzania. In other words, our study area is substantially and increasingly affected by invasive species.

Semiarid Baringo county is also affected. For example, an invasion of *Prosopis* into grasslands has significantly reduced available fodder, because high densities of *Prosopis* have been reported to suppress grass growth and reduce understory species diversity (Muturi et al. 2013; Andersson 2005). Moreover, high-density, thorny *Prosopis* cover hinders accessibility to water points for people and livestock, and limits livestock mobility to grazing areas (Maundu et al. 2009). Further, *Prosopis* is known to consume substantial amounts of groundwater (Dzikiti et al. 2017; Shiferaw et al. 2021). The problems experienced in Baringo are likely to occur also in other regions in the northeast of Kenya, where *Prosopis* is currently still scarce but observed to be increasing in frequency, with *Prosopis* thickets forming. More recently, *Prosopis* has also been identified north of the town Isiolo, spreading along the main roads and crossing creeks and rivers towards the north and east of Kenya.

5 Indirect drivers of change

Boniface Kiteme, Joan Bastide, Urs Wiesmann

Indirect drivers of change comprise the complex interplay of demography, culture, economy, governance, and technology within the socioeconomic system. Indirect drivers are linked to the human use of land. They therefore have to be understood in their contextual specificity and variation – which means that a high spatial and temporal resolution is required to assess both the socioeconomic and ecological system.

Attempting to explain this complexity goes beyond the scope of this report. We therefore limit our deliberations on the context required to understand indirect drivers in this landscape to the bare minimum. We first deal with population, livelihoods, and economic characteristics (Chapter 5.1), briefly touch on the complexity of the governance system (Chapter 5.2), and finally turn to some overarching mega-trends that require attention and monitoring.

5.1 Population, livelihoods, and economic activities

Unevenly distributed population densities

The Ewaso Ng'iro North landscape (Appendix figure 6) is a highland–lowland system stretching from the high-potential core regions of Kenya to the arid and semiarid areas of the country's northeast. It mainly includes the four core counties of Laikipia, Meru, Samburu, Isiolo – and in some cases a fifth, the most northern county of Marsabit. It is one of the country's five major river basins and is unevenly populated, with population densities reaching from below 10 people/km^2 in the lowlands to more than 1,000 people/km^2 in its upper reaches (Appendix figure 6).

A dominantly rural and poor region

The region includes a network of small urban and trading centers but only two larger towns (Nanyuki and Isiolo), which are situated on the border between high- and low-potential areas. With an urban population proportion of only about 20%, the region displays mainly rural characteristics with livelihoods closely linked to nature and natural resources. Within the Kenyan economy, the region was for long marginalized and not a development priority, which has resulted in two out of three of the currently about 2.5 million inhabitants in the Ewaso Ng'iro North landscape living below the national poverty line (Appendix figure 6). However, a small segment of the population – one that is culturally largely disconnected from the rest of the population – has considerable wealth in the form of large portions of land granted during colonial times (see historical abstract in the introductory chapter as well as the governance section 5.2 below).

Young and growing population

In most parts of the region, children and youth under the age of 18 constitute the majority of the population (Appendix figure 7). This proportion increases from 40% near Kenya's central highlands to above 60% in parts of the semiarid lowlands of the Ewaso Ng'iro North landscape. This strong distortion in the age pyramid is a clear indication that the region – and especially its northern parts – are still at a much earlier stage of the demographic transition than large parts of the Kenyan highlands. This means that the population will continue to grow at a high rate for at least two to three decades.

Labor shortage

An important consequence of the current stage of the region's demographic transition is that the proportion of the population in the economically active age group of 18 to 64 years is small (Appendix figure 8). While this proportion reaches 50% or even 60% in high-potential areas around Mt. Kenya, it drops to less than 40% at lower altitude. This means that the economically active population has to produce and provide for more dependents per capita. So, in spite of continued fast population growth, the labor force is a limiting factor. This constitutes a significant competitive disadvantage in economic development compared to large parts of central Kenya, where the demographic transition is approaching its final stages.

Focus 5.1: High-resolution Socio-Economic Atlas of Kenya

Linking indirect drivers to land use and nature entails assessing their characteristics and effects in high spatial resolution, a condition which is rarely met due to lack of high-resolution socioeconomic data. This analysis however has the opportunity to build on the Socio-Economic Atlas of Kenya, which was created by the Kenya National Bureau of Statistics (KNBS) in collaboration with CETRAD and CDE (Wiesmann et al. 2016).

This empirical basis enables us to analyze socioeconomic data at varying levels of spatial resolution. In this report, the following spatial reference levels are used to link indirect drivers with the environment:

- **Wards** are the smallest decision-making units. They are also the basis of County legislation through the County Assembly (comprised of Members of County Assembly elected at Ward level).
- **Counties** are the main administrative units in Kenya. With the new Constitution of Kenya 2010, they are the main areas of decision-making relevant to the people–nature nexus.

- **Constituencies** are the units on which national elections are based. They link local and regional populations with the national policy and legislation level.
- **Watersheds** are biophysical units delineated by hydrological features and administratively recognized as spatial reference in planning processes and decision-making.

The maps in the Annex of this report refer to one of the above spatial reference levels, depending on the issue investigated. For each spatial unit in these maps, the respective population size is represented by the size of circle-signatures, while the color of the signatures represents the populations' attributes.

Female-headed households and migration

Women play an important and often neglected role in the development of the region. Not only do they cater for the large portion of children and youth in the population; they are also taking on a greater role in the household overall. This is expressed by the high proportion of female-headed households, which increases from around 30% in the highlands to 40% or even 50% in the lowlands (Appendix figure 9). This is a result of permanent migration (Appendix figure 10) and, to a greater extent, of temporary or semi-permanent labor migration of men and young women to the regional or national economic hubs. This is resulting in the phenomenon of multi-local households between rural periphery and economic centers and is the backbone of significant remittances to the region. Multi locality of households, however, also implies that local decision-making, e.g. on land use, is co-influenced by distant actors.

High sociocultural diversity

The gradients of socio-demographic characteristics from the highlands to the lowlands of the region are overlaid by a high diversity of sociocultural features. The zone of contact and mix of predominantly Muslim and Christian faiths and cultures runs from northwest to southeast, partly overlaid by pockets of traditional religions. The region is shared by six ethnic groups. The foot zone of the mountain is predominantly populated by Bantu-speaking Meru and Kikuyu, whose culture is rooted in mixed farming and peasantry. To the north and northwest, the Nilotic communities of the Maasai and Samburu continue to be strongly bound into the traditional pastoralist Maa-culture. The Cushitic Borona and Somali communities dominate in the lowlands of the northeastern parts of the region, and are rooted in pastoralist cultures that span large, even international spaces. North of Isiolo, a range of settlements of Nilotic Turkana represent traces of migration that occurred during the colonial period. Typically, these dominant ethnic communities are strongly intermingled in economic core regions and in and around urban centers, which are also home to other ethnic communities from all over Kenya.

Complex mosaic of populations

Together with the varying socio-demographic characteristics, this high sociocultural diversity leads to a complex mosaic of populations in the region with a high variety of synergetic exchange, but also hidden conflicts and resulting sociopolitical disruptions. This complex mix of populations is overlaid by the culture of the national economic and political elites and complemented by the specific culture of – partly colonially rooted – large-scale landowners and entrepreneurs in international tourism.

Spatial gradient of poverty

Poverty is an important indicator of human well-being and also plays a key role in questions of political and social empowerment. As mentioned, a large proportion of the region's population is poor. This is confirmed by the poverty incidences of the four core counties of the region, which – to different degrees and with the exception of Meru – are poorer than the Kenyan average (Appendix figure 11). In more detail, poverty rates are lower in and near larger economic centers, but significantly increase along the gradient from the highlands to the lowlands of the region (Appendix figure 12).

Poverty gap and wealth gap

How poor are the poor? How far above the poverty line are the non-poor? These two questions are crucial for every welfare and development policy. The poverty gap indicates the severity of the poverty of the poor populations. It highlights the comparatively favored situation in the highlands of the region where this gap is narrower than in the lowlands (Appendix figure 13). This implies that greater efforts are needed to lift people out of poverty in the lowlands than in the highlands. The wealth gap indicates how far above the poverty line the non-poor populations live and shows a similar pattern in the region (Appendix figure 14). In the lowlands the gap is narrow, implying that any economic or environmental shock or crisis carries the risk of pushing many people back into poverty, while in the highlands the buffer capacity is higher as the wealth gap is wider.

Connectedness of livelihoods with the environment

To what extent do people's livelihoods depend on the local environment? This question is crucial when dealing with the people–nature nexus. A first simple indicator of the degree of connectedness is the use of biofuels for cooking, especially wood and charcoal. More than two-thirds of all households – and in most sub-regions, more than 90% – rely on this energy source (Appendix figure 15), pointing to a close embedment of livelihoods into the local biosphere. Just over half the population has access to safe water (Appendix figure 16), mainly from local boreholes and protected wells and small springs (except in parts of Meru, where piped water from Mt. Kenya is available). However, this means that the other half has no access to safe household water, highlighting the risks of the close connection between livelihoods and the local environment and natural resources.

Primary production as key in the people–nature nexus

People's livelihoods in the region depend largely on primary production, i.e. processes resulting in the production of food. This has caused two distinctly different production systems to evolve: small-scale mixed farming and pastoralism.

Two basic strategies to deal with environmental uncertainty

Now as in the past, both production systems have to deal with the uncertainties of highly variable environmental conditions, especially precipitation, to balance and secure their livelihoods in the semi-humid to semiarid Ewaso Ng'iro North landscape. The two systems deal with these uncertainties through two different basic strategies or rationales. Pastoralism builds its system on livestock production and applies the basic strategy of *mobility*, balancing the risk of rainfall variability and corresponding biomass production of pastures by moving with their herds to areas with temporarily more favorable conditions. By contrast, small-scale farming is bound to a specific location and responds to the given uncertainties through a *multi-strategy*, by producing a broad range of crop and livestock products to guarantee that even if some parts of the production fail, other parts will compensate for the losses.

Sociocultural importance of the two strategies

Both basic strategies of the two traditional production systems are highly complex and have therefore been inscribed in local cultures and sociocultural rules and regulations. The two distinctly different traditional cultures cannot be discussed here in detail. However, it is important to note that large parts of these cultures persist in today's livelihoods and societies, e.g. in the different perceptions and valuations of nature and natural resources. In other words, how nature is valued can vary significantly between the two different cultures and also contrast with nature valuations by other actors, such as large-scale landowners or external elites or experts. These differences deserve high attention in any approach to the people–nature nexus.

Current state of pastoralism and small-scale farming

How important, then, are pastoralism and small-scale farming in the current economy and economic activities of the populations in the Ewaso Ng'iro North landscape? At the national level, mainstream perception by decision-makers and experts tend to grossly overestimate the proportion of the Kenyan labor force in small-scale farming and pastoralism. In fact, over the past decades this proportion has sunk to 33%. The same trend applies to the Ewaso Ng'iro North landscape, where in most areas less than 50% of the labor force still practice either small-scale farming (Appendix figure 17) or pastoralism (Appendix figure 18). Small-scale farming is concentrated in the highlands, mainly in remote upland areas, and fading out towards the lowlands (Appendix figure 17). Pastoralism displays the opposite pattern, with the highest values found in remote lowland areas and less towards the highlands (Appendix figure 18), which however before colonial times were an integral part of the mobility pattern of pastoralists. The two distribution patterns point to a zone between highlands and lowlands where the two production systems meet, mix, and also conflict with each other. This intermediate or transition zone is especially critical from the perspective of the people–nature nexus.

Importance beyond the labor force

Pastoralism and small-scale farming remain important in the culture and livelihoods of more people in the region than the labor force figures might suggest. One indicator of this is the proportion of households who keep livestock (Appendix figure 19). This proportion is in all sub-regions higher than the proportion of the labor force involved in pastoralism or small-scale farming. This means that primary production is still part of most livelihood strategies – but that it is now *one of several components* of these strategies. At the same time, it also implies that the two traditional cultures are still practically rooted in the vast majority of the population living in the Ewaso Ng'iro North landscape.

Strongly limited formal labor market

The proportion of the population seeking work and livelihoods outside traditional primary production is rapidly increasing. This is due to factors mentioned above: changes in the traditional sectors of pastoralism and small-scale farming, as well as a rapidly growing, still young population. However, the formal labor market – i.e. employment and self-employment in registered enterprises – is very limited, as it is concentrated in the central highlands and especially in the major economic hubs of Kenya (Appendix figure 20). For the Ewaso Ng'iro North landscape, this means that only a few areas, mainly in the highlands and in the two urban centers of Nanyuki and Isiolo, can offer more than 20% of the total occupation in the formal sector. A certain role is also played by formal employment in large-scale farming or ranching, as well as in the tourism sector (Appendix figure 20).

Burgeoning informal sector

The fact that only a part of the growing labor force in the region can be absorbed into traditional agriculture and the formal sector is leading to a burgeoning informal sector, which includes local production, provision, and trade of goods and services in non-regulated markets. Known as "Jua Kali" ("under the hot sun"), the informal sector already occupies 44% of the labor force at the national level and has reached similar levels in most of the Ewaso Ng'iro North landscape (Appendix figure 21). The informal sector is key to the supply of goods and services to the population of the region, but it bears many risks and uncertainties. In any case, its growth indicates the need for economic development beyond traditional agriculture and a formal sector still dominated by the public sector.

Educational levels and development perspectives

Educational levels of the population in the region will be a decisive factor for economic development perspectives but also for approaches and negotiations in addressing the people–nature nexus. Current educational levels of the adult population show a distinct pattern (Appendix figure 22). Whereas adults in the highlands and around central Kenya have on average completed primary school (education index = 1), the adult population in the rest of the region, particularly the pastoralist lowlands, has on average very little formal education. This means that the potentials for economic development are higher in the highlands, especially when also considering factors mentioned above, such as the higher economic buffer capacity and the slower population growth rate in these areas. Marginalization of the lowlands, especially the pastoralist areas, will be further exacerbated by variations in school attendance by children and youth (see striking differences between secondary school attendance between the highlands and lowlands of the Ewaso Ng'iro North landscape, Appendix figure 23).

Population, livelihoods, and economic activities

In sum, the above analyses and considerations reveal a clear gradient of almost all aspects of demography and livelihoods between highlands and lowlands of the predominantly rural Ewaso Ng'iro North landscape. This dominant gradient is overlaid by local center–periphery patterns, especially around the two major towns of Nanyuki and Isiolo. The distortion of the age pyramid with its implications for population growth, dependency rates, labor shortage, and the resulting importance of female-headed and multi-local households, follow this pattern of gradients. The same patterns are revealed for the still-high poverty incidences, severity of poverty, economic buffer capacity at household level, levels of formal education, and resulting labor force capacities for economic development, in which the lowlands are clearly disadvantaged.

The livelihoods of people in the region are still closely linked to nature and the local ecological environment, with small-scale farming in the highlands and pastoralism in the lowlands still forming the basis of household economies for almost half the population. However, large parts of the growing population cannot be absorbed by the primary sector anymore, causing more people to be pushed into the informal sector. This dynamic is especially critical at the lower end of the gradients, in particular, in the marginalized lowlands.

The socioeconomically important highland–lowland gradient is overlaid by a high diversity of sociocultural settings rooted in religion, ethnicity, and pastoralist culture. The resulting complex mosaic of populations is the basis for synergetic exchange, but also for hidden conflicts and political disruptions. The differing worldviews and valuations of nature among such a diverse population will almost certainly clash with the culture of the national economic and political elites, large-scale landowners with their colonial roots, and entrepreneurs in international tourism. Any meaningful approach to the people–nature nexus in the Ewaso Ng'iro North landscape will have to take into careful account the said gradients and the complex mosaic of cultures.

5.2 Governance

Decision-making processes across the landscape

Historically, the larger Ewaso Ng'iro North landscape has been characterized by multiple layers of distinct mosaics of territorial units of governance. The Constitution of Kenya 2010 seemed to regularize/legitimize this by introducing changes in the form of additional constitutional and legislative administrative and political organs with a broad range of different governance functions – authority, privileges, and responsibilities that are shared between the national government and county governments. Administratively, territorial units are distinguished by scale and level of jurisdiction (i.e. national, county, sub-counties/districts, locations, and sub-locations for the national government). Counties are divided into subcounty, ward, and village governance structures. Politically, there are the elective jurisdictions at different levels: county (the governor, senator, and women's representative), constituency (member of parliament), and ward (member of county assembly).

The functions for each line are well documented in Schedule 4 of the Constitution of Kenya 2010. In brief, the most relevant functions of the national government are provision of general principles of land planning and coordination of planning by the counties, protection of the environment and natural resources, security, maintaining law and order, education, and external resource mobilization to support mega investments in transport, water, and energy infrastructure. The functions and powers of the county governments are agriculture (crop and animal husbandry and related infrastructure), trade development and regulation, county planning and development, implementation of specific national government policies on natural resources and environmental conservation, and community mobilization and capacity building for the effective exercise of the functions and powers and participation in governance at the local level.

Our area of interest covers parts of the five counties of Laikipia, Isiolo, Samburu, Meru, and Marsabit. Constitutionally, counties are independent governments and therefore the most important governance structures among all the other represented mosaics in the landscape. The county governance structure comprises both legislative and executive functions. The legislature is composed of the elected members of the county assembly. The executive is composed of the governor (and deputy) and several county executive committee members, the number of which varies from county to county, depending on how elaborate the departments/ministries forming the government are. Other than the county-level elective structure represented by the governor, senate, and women's representatives, there are 12 constituencies and 52 wards within our area of interest. At the lower level, wards are the governance unit where project planning and implementation decisions are negotiated, prioritized, and escalated, through subcounty, to county (assembly and executive) for further debate, adoption, and funding.

At the national level, MPs and the women's representative have a direct influence on county development through the National Government Constituency Development Fund, through which they fund community-based development projects and programs for works and services falling within the functions of the national government under the constitution. Alongside these administrative and political territories are designated governance jurisdictions at landscape scale (i.e. river basins or ecosystem) – fostering integrated regional/basin development; enhancing water-sector sustainability (Water Resources Authority); ensuring environmental integrity (National Environment Management Authority); promoting sustainable wildlife conservation (Kenya Wildlife Service) and forest resource management (Kenya Forest Service); and helping to mitigate the effects of climate variability and drought in the region (National Drought Management Authority). We cannot map in detail here the territories these different state agencies work in; a brief mention of each will illustrate the complexity and overlaps involved.

The Ewaso Ng'iro North Development Authority coordinates regional development initiatives for the entire basin covering just over 210,000 km^2 and has established sub-regional offices in strategic areas. The Water Resources Authority has a regional office split into ten Basin Management Units that share similar water and other natural resource management issues, seven of which are relevant to our area of interest. These include Ewaso Laggas, Lower Ewaso Ng'iro, Middle Ewaso Ng'iro, Ewaso Narok, Nanyuki, and Upper Ewaso Ng'iro. Wildlife conservation and tourist development is governed by the Kenya Wildlife Service (KWS). The Ewaso Ng'iro landscape is under three Conservation Areas, namely the Mountain Conservation Area covering Mt. Kenya, the Aberdares, Laikipia, Samburu, and some parts of Isiolo; Eastern Conservation Area that covers the other parts of Isiolo, and Wajir; and the Northern Conservation Area covering Marsabit and Mandera. Forest resource management in the landscape is the responsibility of the Kenya Forest Service (KFS) whose governance structure is implemented through conservancies and ecosystems conservators. The Ewaso Ng'iro landscape is under the Ewaso North Conservancy that comprises Isiolo, Samburu, and Marsabit Ecosystems Conservators. These regional state agencies that handle such crucial sectors have jurisdictions cutting across all the counties in our landscape.

Though not a state agency, the Frontier Counties Development Council (FCDC), established about six years ago, forms another important governance territory spanning several counties in Kenya's Northern Frontier of Garissa, Isiolo, Lamu, Mandera, Marsabit, Tana River, and Wajir, as well as subsequently co-opted counties of West Pokot, Samburu, and Turkana. This constitutes about 63% of the country and 10% of the national population, giving the block immense political power and strong leverage for external resource mobilization, which allows it to attract funding from some of the leading donor institutions and development agencies in the country. The FCDC is potentially a game changer through their planned interventions in general economic development but most importantly the mega investments in road and water infrastructure, as well as their peace building initiative in the region.

Non-Governmental Organizations

Non-Governmental Organizations – of which there are many – constitute another mosaic of governance in the Ewaso Ng'iro landscape. The region has perhaps the highest density and heavy ground presence of local and international non-governmental organizations, including leading donor agencies and development partners in Kenya. Without listing them and going into detail of what they support, their main areas of intervention can broadly be grouped into water development, conservation, food security, pastoral and non-pastoral livelihoods including livestock production and marketing, and range management, among others. While the majority operate at county level, others implement projects and programs that cut across counties. Although some of these engagements are short-lived, they are nevertheless important to consider, given their weighty financial resource base and, in some instances, strong political capital.

Society-rooted (indigenous) governance organs

Closely related to the customary institutions are resource management organs that are rooted in society, such as the Water Resource Users Associations (WRUAs), Community Forest Associations (CFAs), and the most recently established Charcoal Production Associations (CPAs). The WRUAs and CFAs are embedded within the respective legislations – in the revised Water Act 2016 and the Forest Act 2005 respectively, while the CPAs are governed by the Forest (Charcoal) Rules of 2009. While their respective roles may differ in specific terms, the WRUAs and CFAs are formed to promote participatory management and governance of water/forests in their areas of jurisdiction (i.e. in sub-catchments or forest areas). CFAs also facilitate sustainable production (as well as transportation and marketing) of charcoal and support implementation of the reforestation conservation plans in their areas of jurisdiction. Since their introduction, these society-rooted governance structures have become very helpful in resource mobilization, community participation, reducing resource degradation, reducing conflicts, and enhancing equity, at user level.

5.3 Newly emerging structures

The Community Land Management Governance Structure

The Community Land Act of 2016 has introduced yet another layer of governance structure that has the potential to revolutionize how community land and its varied resources are governed within the pastoralists' landscape. The Act creates two critical governance institutions to regulate management of community land: the Community Land Assembly and the Community Land Management Committee. The Act also vests the absolute ownership of community land, together with all rights and privileges belonging or appurtenant thereto, to the community registered as the proprietor of the land. This serves to protect community land against any prospective "grabber", be it private or public.

Wildlife Conservancies

Wildlife Conservancies is a newly emerging concept and practice of wildlife management for nature and people. Although a recent practice, it has become a very prominent and quite powerful (economically and politically) governance institution whose territorial relevance is rapidly expanding in the region, turning the table on conventional conservation approaches and changing the mindsets of indigenous people to adopt more promising business and nature-oriented conservation practices. In our study area, there are about 28 community conservancies, not less than 20 private ranches, and several county government-managed conservancies. The rapid rise to prominence gives Wildlife Conservancies the potential to transform the management of wildlife – initial resistance (apparently politically motivated) and doubts about their social acceptance notwithstanding. It is noteworthy to state that most of the Wildlife Conservancies in the region are now registered members of Kenya Wildlife Conservancies Alliance.

Traditional/customary governance territories

Many traditional governance structures have all but disappeared or are increasingly disregarded by modern governance structures. However, some have persisted and still exert considerable influence on how community land resources are managed in the Ewaso Ng'iro landscape. The most prominent of these community-based common resource management institutions that are still active in the region are the Njuri Ncheke (Meru Council of Elders) and the Boran, Jarsa Dedha (Dedha Council of Elders). The Njuri-Ncheke plays an important role in enforcing the rules and regulations that govern use and conservation of open grasslands, saltlicks, forests, and other natural resources in their territory. Similarly, the Dedha Council of Elders enforces laws and provisions that, among other things, govern herd mobility and use of dry season pasture areas as determined by the Gada council (the supreme Boran governance structure). An important aspect of Dedha's management of communal resources is negotiation of reciprocal use agreements between neighboring pastoral groups (Tari and Pattison 2014).

Relevant policy framework conditions for decision-making in the people–nature nexus

A raft of laws and policies delimit the mandates and missions – and therefore govern – the operations of the governance structures described in the sections above. This does not however include customary institutions, although there have been attempts by some county governments to legislate them. It is important to note that these laws and policies are very sector specific and rarely foster any vertical or horizontal integration across sectors; and besides, they have inherent conflict prone and contradicting provisions that make their interpretation and application on the ground a great challenge. Therefore, coupled with the ever competing and often conflicting political interests, and compounded by strongly regionalized political ambitions, these laws lead to the creation of the kind of complex governance structures discussed above. Complex governance structures that are characterized by clear territorial and thematic overlaps and which therefore result in pronounced conflicts, as each struggle to occupy their perceived space and compete for prominence among the communities they purport to serve. This is more pronounced considering that the county governance structures are still in their infancy and thus struggling hard to establish themselves and assert their authority, especially against the perceived interference by the national government. The creation of the National and County Government Coordinating Summit, assisted by the Intergovernmental Relations Technical Committee (IGRTC) to help harmonize operations between the two levels of governance, has not helped much in this regard.

Policy frameworks at the national level that are operationalized through state agencies at the regional level need to be well understood and carefully considered. Some of them are more prominent and visible than others, due to inherent power (political, social, and economic) differentials among them. There is a risk of quickly entering into collaboration with institutions on the face of it, and simply because of their perceived prominence. However, it would be beneficial to also consider other institutions that may be less prominent, but that have the potential to make significant contributions. Institutions like the National Environment Management Authority and Water Resources Authority may seem less significant compared to established organizations such as the Kenya Wildlife Service, but they are very crucial to fostering sustainability in the people–nature nexus.

Furthermore, governance of the people–nature nexus must consider all the modern and customary structures described above. There is compelling evidence that the customary institutions have excelled over modern institutions in fostering natural resource management in given contexts, especially involving the management of common pool resources such as dry-season grazing areas. We should therefore aim to support these institutions, to help have them legitimized and nurtured – even if towards a hybrid form of customary/informal institutions for the sustainable governance of people–nature nexus in the landscape.

5.4 Overarching mega-trends

The past decades have seen a rapid acceleration of the pace, scale, and depth of socioecological transformations in the Mt. Kenya–Ewaso Ng'iro North region, under the influence of multiple emerging mega-trends.

Linked to dynamics at national, regional, and global levels – dynamics which are beyond the region's scope of influence – these mega-trends are generating new patterns of opportunities and challenges for nature and people. It is important to consider these patterns when trying to understand systems, select targets, and identify possible transformative pathways and solutions relevant to this specific context.

Large-scale investments in infrastructure and transport for regional and market integration

The massive LAPSSET investment is set to have a tremendous and multidimensional impact on sparsely populated areas of low accessibility. Vastly improved road access will open new opportunities for external investors, land speculators, as well as legal and illegal trade with neighboring countries. As basic infrastructure begins to appear along the roads, new settlements are already emerging, expanding, and attracting populations from more remote areas. Security issues, limited space to move for pastoralists, and promises of economic opportunity provide strong incentives for the local population to converge on these new development hotspots, either joining the new settlements or setting up along the roads. In these processes, new migrants bring new skills, mindsets, and values – adding to the already ethnically and culturally diverse population, and changing existing power, social, and political dynamics. In addition, with international sea and air connections, and if the security situation remains stable, the region is expected to attract more local and international tourism.

Changes in agricultural and labor markets

Two main trends can be observed in the agricultural sector: 1) the persistence of subsistence agriculture, often topped up with non-agricultural activities (such as daily labor or participation in the informal sector), and 2) landholders reorienting their production towards external markets.

Increased economic integration coupled with better access to markets, education, and information are indeed stimulating a trend towards higher professionalization and specialization of the agricultural sector. The subsistence agriculture that predominated in the past, especially among smallholders, is now increasingly shifting towards national and international export-driven production. The resulting evolution of crop patterns, modes of production, and value chains require new skills as well as higher investments for inputs and mechanization – increasing farmers' dependence on the banking and financial sector, extension services, qualified labor, and access to markets. Through these dynamics, the local agricultural sector is becoming more telecoupled – meaning that local decision-making and agricultural strategies are increasingly linked to distant actors, dynamics, and market opportunities. This new emerging agricultural system represents a potentially higher return on investment but also entails higher risks, as dramatically illustrated by the disruptions caused by the COVID crisis.

People moving from the family farm and succeed in a more diversified and skill-intensive labor market need higher education or training. But with a job market expanding at a slower pace than the working-age population, and the reduced need for labor on family farms, unemployment is increasing dramatically, pushing entire segments of the population towards the informal system or internal migration to seek job opportunities.

Changes and persistence in mainstream culture

A few decades ago, Kenya was still a predominantly rural society in terms of livelihood structure, culture, identity, and relations to nature. Even the small urban population maintained their deep traditional roots in their hometown, with frequent visits and strong networks of solidarity and remittances. But new conditions are being created amid a higher penetration rate of telecommunications and social networks, better access to education, and the emergence of a middle class with new consumption habits. And as the urban population continues to grow, Kenyan society as a whole has started a transition from a rural culture – strongly rooted in tribe-centered culture and characterized by strong community links and customary institutions led by elders – to a more urban, liberal, individualist culture. New role models have emerged in society through the media, arts, and politics, and deeply transformed the aspirations, cultural references, and self-perceptions of the new generations. However, it is important to note that these social and cultural trends are not linear, unidirectional, and homogeneous throughout the entire territory and society. Rather, the encounter between traditions and modernity tend to produce hybrid patterns of adoption and rejection that can no longer be interpreted exclusively along ethnic or geographic lines. Finally, as more women are empowered through access to education, jobs, and public life, the traditional gender divide is also slowly evolving towards more equality. The result of these overlapping trends is a more diverse, complex, and dynamic society, with steeper gradients of aspirations, claims, and perspectives between groups and individuals. In this context, the effectiveness and relevance of the traditional toolboxes used in rural development programs and policies over the past decades has become obsolete and should be reinvented to reflect the current and future evolution of society.

Communication, technologies, digitization

Worldwide, the emergence and democratization of new technologies of information and communication has deeply transformed societies and economies. In Kenya, the penetration rate of these technologies is already high (mobile, Internet, and social media respectively reached 50, 22, and 9 million users in 2020), and increasing at a rapid pace (over 10% annually). One of the most groundbreaking aspects is the tremendous success of the mobile payment and branchless banking system M-PESA, developed by Safaricom. The mass adoption of M-PESA has allowed easier transfer of remittances from the diaspora, and between urban and rural areas. It is also considered to have had a significant impact on urban violence and thefts.

Finally, it has allowed the development and structuring of the informal sector. We can observe the multiplication of information channels using mobiles for early warning systems and timely dissemination of critical information such as market prices, attacks, floods, pasture and water availability, and locust invasions. The use of these technologies remain at an early stage and represent tremendous opportunities for improving economic opportunities, information exchanges, evidence-informed decision-making, and awareness-raising in the region.

Security and conflict issues

The development of the region faces the challenge of severe security issues related to political tensions with neighboring countries and long-standing conflicts between some of the ethnic groups residing in or migrating through the landscape. At the moment, the main cross-border tensions are with Somalia, where the participation of the Kenyan national army in the fight against the Islamist militant group, Al Shabab, has made it a target of terrorist attacks and violent propaganda. The ongoing closure of large refugee camps on the Kenyan side is likely to increase tensions and throw thousands of vulnerable people into greater poverty, which may be an incentive for them to join terrorist groups as a last resort.

The landscape is also host to a high ethnic diversity. The increased pressure over natural resources such as land, water, and pasture as well as reduced mobility is blowing on the ashes of pre-existing tensions and conflicts, but also generating new ones. While in the past, these conflicts were addressed with spears and arrows, new affordable assault weapons have turned piecemeal conflicts into possible large-scale massacres with dozens of deaths, leading to an uncontrollable spiral of hatred and revenge.

Finally, tensions are also increasing between pastoralists and large-scale landowners. In counties like Laikipia, over 40% of the land is shared between 40 large-scale private ranches, some of which have been turned into conservancies, mostly owned by white settlers. As more and more of these lands are fenced to prevent encroachment and poaching, the landscape is increasingly fragmented and there is less space for pastoralists to feed cattle and move around the landscape according to their needs and traditions. The feeling of injustice about what is locally perceived as land grabbing generates deep resentment and provides the basis for episodes of violent outbreaks, especially during droughts, when the availability of water and pasture is even more critical than usual.

Shifting paradigms in nature conservation

Home to a high density and diversity of wildlife and biodiversity, the region is the target of many nature conservation interventions and has been showcased globally as one of the greatest success stories of conservation in modern times. On top of the protected area model inherited from the colonial administration, new models have been developed. These include community and private conservancies.

While the protected area model is based on a radical land sparing approach – which aims to separate nature and people – the conservancy model represents a shift towards a more integrated landscape management approach, in which land use is planned to provide for conservation, livestock raising, and settlements in a coordinated and sustainable manner. The conservancy model has gained huge momentum in the region, mainly under the leadership of the Northern Rangeland Trust (NRT), a local NGO that is now supporting over 50 community conservancies in the country. Despite the umbrella term of 'conservancy', it should nonetheless be noted that there are significant differences between the privately and community owned conservancies.

Globally, most green NGOs and international organizations have followed a nature-centric perspective on nature conservation, building on the colonial tradition and the American model. But nowhere more than in Africa have these policies proactively worked towards a total exclusion of the local community from the protected areas, which makes scholars in critical conservation studies highlight the colonial, paternalistic, and even racist approach to nature conservation on the continent, which is guided by an exoticized vision of the African wilderness. But as local communities around the world are contesting these top-down and unjust approaches labelled as 'green grabbing', organizations and administrations seem to have initiated a paradigm shift with timid attempts to further include local communities and design mutually beneficial solutions. However, this shift is still recent and far from solves or even recognizes the full extent of past and present injustices.

The analysis of these trends shows that the Mt. Kenya–Ewaso Ng'iro North landscape is under deep and accelerating transformations affecting nature, people, and their interactions. The overall trend is towards heterogenization, faster transformation, and complexification of the economy, society, and territory. It shows emerging challenges related to increased pressure over land, water, and other natural resources, to fragmentation of the landscape, and increasing tensions among different groups. On the other hand, new opportunities are arising from improved accessibility, better connections to markets, availability of new technologies, and further mobility up the social, gender, and economic ladders. Identifying how these trends affect people and nature is key to developing context-relevant and adaptive approaches, understanding and co-designing just, socially acceptable, and suitable solutions, and identifying promising levers to trigger systemic changes. Assuming a telecoupling perspective is crucial for looking beyond local transformations to understand how they are connected to flows, networks, and power relationships at other scales, or in distant locations. Some of the trends presented here might further materialize, and some might not. But it is important to monitor them closely.

Focus 5.2: Trends in pastoralism

Pastoralism remains an important cultural trait, means of livelihood, coping strategy, and way of life in the study region. This traditional system is not fixed in space and time and continues to evolve along historical, social, environmental, and economic contingencies. The main trends observed in modern pastoralism in Kenya include:

- Reduction in mobility due to an increasingly fragmented landscape and changes in culture and aspirations, resulting in semi-sedentarization along access axes and rivers;
- Diversification of income sources through new activities such as agropastoralism, involvement in the informal sector, access to the labor market – all of which are often made possible through higher education levels;
- Increased importance of cash income for access to education, health, permanent housing, and other services;
- Increased migration to other parts of the country, including urban centers, and hence more multi-local households where members of the same household are located in different places;
- Changing herd composition from cattle to small ruminants;
- Deep cultural changes due to exposure to urban life, increased access to information and education, and diversification of economic opportunities. This trend may also lead to an erosion of some traditions.

Beyond this, the concept and traditional practice of pastoral mobility is currently gaining renewed attention in the context of climate change adaptation and the need to govern natural resources in an adaptive way to ensure sustainable management (Pas 2018).

6 Implications for 'nature and people interventions' in the region

Thomas Breu, Boniface Kiteme

Our analysis of the ecological and socioeconomic systems of the Mt. Kenya–Ewaso Ng'iro North landscape confirms that this region has entered a new transformation phase, after the three main transformations to date – colonialization, post-colonial centralism, and new decentralization. This next era is characterized by an increasing number of interlinked developments, which are likely to lead to profound and unprecedented changes. The emerging trend can be summarized as one of increased pressure and environmental degradation of the region's ecosystems as a result of distinct dynamics in society, economy, and policy. The dynamics of the social-ecological system in the Mt. Kenya–Ewaso Ng'iro North landscape are driven by an increasingly complex interplay of domestic and international development forces and amplified by the effects of climate change. As a result, land use systems are being reconfigured on a vast scale.

In the past 100 years – and in particular in the decades since the independence of Kenya – the Mt. Kenya–Ewaso Ng'iro North landscape has undergone a drastic socioeconomic transition. Once characterized by a pastoralist land use system, the upper part of the landscape has been transformed by large-scale ranching, immigrating small-scale farmers, and more recently, large-scale horticultural enterprises. The pastoralist system is key to sustainably managing the region's vast lowlands but is under increasing threat as land zoning measures, an increase in protected areas, infrastructure development, expansion of cropland, and general land degradation trends all lead to restrictions in pastoralist and wildlife mobility. Today, the livelihoods of people in the region are still closely linked to nature and the local ecological environment, with almost half the population dependent on small-scale farming in the highlands and pastoralism in the lowlands. Large parts of the still growing and generally poor population (poverty incidence clearly above 50%) cannot be absorbed by the primary sector anymore, pushing workers into the informal sector. The highland–lowland gradient is overlaid with a high diversity of sociocultural settings based on religion, ethnicity, and a rooting in peasant and pastoralist cultures. The resulting complex mosaic of populations constitutes an asset for innovation and development, but also for hidden conflicts and political disruptions. When considered in relation to the cultures of the national economic and political elites – as well as of the partly colonially rooted large-scale landowners and domestic and foreign investors in infrastructure and tourism – a clash of worldviews and valuations of nature seem inevitable.

Constructively dealing with the above socioeconomic challenges will entail addressing the environmental degradation processes that undermine a sustainable future for nature and people. Our analysis shows that overgrazing, changing herd characteristics, and overuse of woody biomass have caused the degradation of large tracts of savanna. Land has turned barren or allowed growth of non-perennial grasslands only. Despite being recognized internationally as a Key Biodiversity Area and home to numerous protected areas, biodiversity is in general decline across the region. Since the late 1970s, wildlife populations have decreased strongly in the Kenyan rangelands, owing to rangeland degradation and fragmentation, poaching, disease outbreaks, and invasive species among others. At the same time, this arid region has experienced a reduction in water quantity and quality, due to cropland expansion and poor water management, which includes water abstraction for agriculture but also for non-agricultural purposes associated with emerging mega-infrastructure projects. These developments are likely to be further aggravated by the effects of climate change. Our simulations show that the region can expect more rain and a significant rise in temperatures. Precipitation variability is also projected to increase, indicating that extreme events such as unusually wet seasons and abnormally dry seasons may occur more frequently and will constitute a serious additional risk of reaching an irreversible ecological tipping point for large parts of this sensitive ecosystem. In conclusion, the Mt. Kenya–Ewaso Ng'iro North landscape is facing multifaceted and profound development challenges. If these challenges are not mitigated, the region risks moving away from sustainable development. It will be of pivotal importance to overcome increasing competition over resources and to proactively deal with growing mistrust and deep resentments among populations and interest groups. To this end, it will be crucial to co-design local transformations that build on the region's unique assets and take into account how they connect to flows, networks, and local and international actors.

7 Challenges, assets, and opportunities for people and nature

Boniface Kiteme, Joan Bastide, Urs Wiesmann

7.1 Human well-being and the value of nature

The analyses in Chapter 2 to Chapter 5 revealed a differentiated picture of human well-being and the value of nature in the Mt. Kenya–Ewaso Ng'iro North landscape.

People in this landscape live amid persistently high poverty rates, varying education levels, and uneven access to services. The significant socioeconomic disparities follow two gradients, one between highlands and lowlands and the second along center-periphery patterns around urban centers and infrastructure, especially Nanyuki and Isiolo. In combination with the high sociocultural diversity, this results in a complex pattern of settings with differences in human well-being.

Nature is valuable and diverse, with a highland–lowland system comprised of steep ecological gradients. Bright spots include the high biodiversity, manifold wildlife, scenic beauty, and diversity of vegetation. But human and land use dynamics in the past 100 years, and especially in recent decades, is causing water to decrease in availability, posing a threat to the ecological system that so depends on it. Increasing smallholder agriculture, growing agribusinesses, and pastoralists disrupted in their mobility by huge ranches and conservancies have led to significant degradation of water resources, soils, vegetation cover and diversity, and declines in wildlife. And climate change is making things worse.

The patterns of human well-being and the value of nature can be differentiated for three major zones:

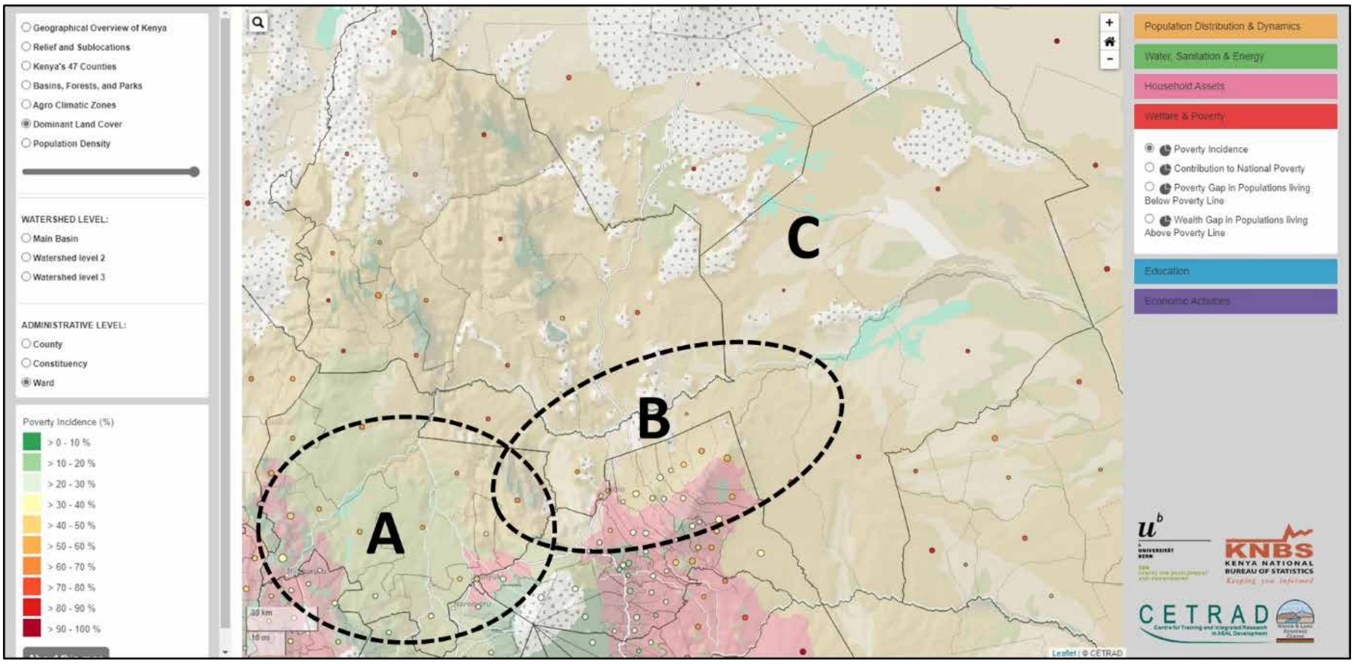


Figure 7.1: Zoning of the Mt. Kenya–Ewaso Ng'iro North landscape. A = Mt. Kenya and the Laikipia Plateau, B = Meru–Isiolo transition zone, C = pastoral lowlands. Background: Dominant land cover and poverty incidences at ward level. (Source: Clip from interactive Socio-Economic Atlas of Kenya 2[Wiesmann et al. 2016])

Zone A. Mt. Kenya and the Laikipia Plateau underwent major land use transitions at the start of the 20th century, when colonial large-scale farming and ranching replaced the original pastoralist use. The second transition started after independence, when parts of former large-scale ranches were subdivided for small-scale farming, attracting smallholder immigrants and leading to large population growth. In the 1990s, large-scale agribusiness started moving into the region and urban growth accelerated, especially around Nanyuki. These developments have led to great differences in human well-being, with people divided into a small rich upper class; a growing market-oriented middle class; and a large group of – still relatively poor – smallholders, urban dwellers, and pastoralists. Increasing degradation and overuse of water resources, especially surface water from Mount Kenya, began to cause conflict between upstream and downstream users. A number of former large-scale ranches have been converted into private conservancies targeting high-class international tourism; this contributes to the preservation of biodiversity but excludes the vast majority of the population from respective monetary gains (Matheka 2008; Chongwa 2012; Cockerill and Hagerman 2020).

Zone B. The Meru–Isiolo transition zone only started transforming significantly in the past two decades, when Isiolo became a major transport hub. It links the Kenyan highlands with the semiarid and arid northeastern lowlands, the new international airport, and the planned LAPSSET corridors

2 www.kenya-atlas.org

and associated infrastructures and investments. Small-scale farming areas have expanded from the Meru highlands towards the semiarid lowlands and along the Ewaso Ng'iro North river on its way to the Lorian swamp. As conservancies were established, pastoralists who had long moved across the land were limited to more marginal areas or became semi sedentary around the new infrastructure. Developments in Zone B have thus divided people into three main groups: a growing, mainly urban, middle-income class; immigrating smallholders; and a decreasing majority of pastoralists with higher poverty rates and lower education levels. Water degradation and overuse are an increasing and conflicting problem in the highland–lowland system between Meru and Isiolo and along the Ewaso Ng'iro North river and related springs. The adjacent pastoral lowlands are heavily degraded due to overgrazing, with vanishing grass canopies, sealed soils, and encroaching invasive species. The natural parks around the river constitute important bright spots for tourism and biodiversity, but it is still too early to establish the impact of the growing number of community conservancies on the value of nature (Sundaresan and Riginos 2010; Boles et al. 2019; Kahumbu 2017).

Zone C. The pastoral lowlands are still mainly under pastoral use and have therefore not transformed in the same way as the other two zones. But the changes in Zones A and B have been instrumental in bringing about the significant changes being experienced in Zone C. This is because developments in Zones A and B have led to the territorial exclusion of pastoral use across important grazing lands, especially during the dry seasons. This has disrupted the pastoralist strategy of linking different ecological zones through herd mobility, leading to further marginalization of pastoralist populations. It has forced them to adapt by changing herd compositions, e.g. from cattle to small ruminants, and by seeking income outside of traditional pastoralism, especially in the informal sector. It has led to multi-local households and triggered processes of semi-sedentarism and the urge to individualize landholdings. As a result, the majority of the population in this area is poor and poorly educated – and it is difficult for them to access services. Changes in livelihood strategies can also lead to a loss of cultural ways of life and community embedment and further contribute to marginalization processes. However, a small portion of the population is able to take advantage of these developments and is busy accumulating resources and connections to political and economic elites. The exclusion of pastoralists from their traditional dry season grazing lands has triggered overgrazing that has led to massive degradation of rangelands with vanishing grass canopies, sealing of soils, and changes in the water balance between runoff and infiltration. These significant devaluations of nature tend to be exacerbated through invasive species, climate change, and further territorial exclusion processes through other uses such as conservancies (Gadd 2005; Graham et al. 2015; Yurco 2017; Ameso et al. 2018; Cruise and Zee 2017).

In sum, human well-being and the value of nature vary significantly between the three zones, but they are linked through ongoing, dynamic transformation processes.

7.2 Core issues and challenges

Based on the analyses of Chapters 2 through 5 and the assessment of megatrends in Chapter 5.3, the participants in two half-day workshops identified twelve core issues and processes that form critical challenges, but may also harbor opportunities. These twelve issues can be grouped into three thematic realms and are anticipated to be relevant beyond the immediate future.

Realm 1: Nature conservation, biodiversity, and conflicts

01 Biodiversity (vegetation, wildlife) remains under pressure. Invasive species remain a growing challenge.

Conservancies and conservation efforts have saved the region's biodiversity from the worst decimation (Ogutu et al 2016). However, beyond conservancy borders, the development trends and transitions mentioned above will trigger further land use changes and intensification, as well as competition over land resources. This will exert further pressure on biodiversity, as will continued population growth, land fragmentation (especially in the pastoral lowlands), and the continued spread of invasive species, exacerbated by the effects of climate change.

02 Nature conservation will remain a major and contested issue, and national and international efforts will increase in this respect.

Increasingly, the region is a hotspot of national and – more so – international conservation interventions. These conservation efforts are in territorial and social conflict with other land uses and their expansion trends. Issues of power, differing valuations of nature, and conflicting perceptions among and between local communities, decision-makers, and conservation stakeholders create a complex and partly explosive sociopolitical constellation.

03 Conflicts between humans and wildlife, as well as communities and conservation stakeholders, will remain problematic.

Human–wildlife conflicts are mainly related to crop and land damage caused by elephants, and increasingly occur near conservancies and along migratory routes of wildlife. Under pressure due to territorial exclusion, pastoralists tend to trespass into conservation areas during the dry season. Since compensation for damage by wildlife is low and trespassing regulations are poorly enforced, this often causes conflicts.

04 Tourism demand is too low for the growing supply of tourism services and for the high local expectations.

Conservancies on former large-scale ranches have developed supply and services targeting mainly high-income international tourists. However, this market is too small, globally contested, and vulnerable to external shocks to serve as model for developing further conservancies. And despite promises to the contrary, this type of tourism has little regional and local economic benefit, making local communities wary of further attempts to get them to participate.

Realm 2: Primary production and resources

05 Pastoralism remains under heavy pressure, with livelihoods and local communities changing and adapting.

The development trend towards mega-infrastructure projects, expanding agricultural and urban settings, and more conservancies will further enhance territorial exclusion processes and marginalization of pastoralists. Persistent pressure will lead to degradation of pastoralist rangelands and, coupled with the effects of climate change, trigger further adaptation processes. Pastoralists are adapting by changing the composition of their herds, seeking economic activities outside of pastoralism (in particular in the informal sector), and becoming semi-sedentary along transport axes and development centers.

06 Agriculture continues to expand as agribusinesses grow and smallholders commercialize.

At the national level, agriculture is undergoing a significant transition. On the one hand, there is an expansion of agribusiness, which is controlled by elites and international companies. On the other, agricultural smallholders and market-oriented livestock producers are being increasingly commercialized and incorporated into the national economy. These agricultural transition trends will be particularly pronounced in areas with favorable ecological conditions, especially access to water, as well as good transport links, access to services, and market integration into the national and international economy.

07 Conventional smallholders continue to struggle with a range of insecurities and risks, such as climate change.

On a generally meagre resource base, conventional smallholders combine subsistence production with some cash crops, some livestock, and off-farm income if opportunities arise. Smallholders apply the resulting multi-strategy to balance the wide range of insecurities and risks they are facing, to deal with shocks, and to avoid falling into deep poverty. Risks include insecurity of landholdings, increasing variability of rainfall and access to water, poor market access and value chains, as well as social and political marginalization. This constellation of multiple insecurities is aggravated by climate change with its unclear trends in precipitation amounts under different emission scenarios, posing additional challenges for multi-strategies and livelihoods.

08 Resource conflicts and degradation (water, soils, vegetation cover) continue to grow.

Changes in agriculture and pastoralism as well as the upcoming mega-infrastructure and growth around urban centers will increase the pressure on natural resources and environmental services. Further territorial exclusion processes are likely and will worsen degradation of vegetation cover and soils in pastoral areas. Water resources will be the most contested of all, with growing demands from agribusiness, commercialized agriculture, and urban and infrastructure settings. This will aggravate highland–lowland conflicts from the local to the regional scale and further marginalize poor populations such as conventional smallholders and pastoralists. Climate change is likely to escalate these developments.

Realm 3: Economy and livelihoods

09 The economy will further develop and diversify – but very unevenly in terms of space and social strata.

The northeastern parts of Kenya were long only marginally integrated into the national economy. Economic growth in this area began to pick up following the new Constitution of 2010 and the devolution of decision-making and financial means to the county level. Now, dramatic changes are expected, due to recent and planned transport infrastructure projects. A railway has been re-established carrying goods, livestock, and passengers between Nairobi and Nanyuki. A highway from Nairobi is currently under construction. The partly implemented LAPSSET corridors to the north and west have their node in Isiolo. And a further LAPSSET corridor is planned between Nanyuki and Rumuruti, the future location of the new capital of Laikipia county. The new infrastructure opens access to national and international markets and is triggering investments in land and enterprises from the economic hubs of Kenya. Urban centers and commercialized agriculture will profit most from these developments, while peripheral areas – if excluded from these integration processes – will be further marginalized.

10 Disparities will continue to grow, leading to persistent poverty as well as social and economic conflicts.

Disparities will increase – but not only because of the difference in prosperity between the growing middle classes in the developing economic centers and the rest of the population. Disparities will also increase due to investments, particularly in land, by external actors near planned infrastructure as well as in large-scale holdings for commercial use or conservation. The resulting speculative land prices will exclude the poorer segments of the population and may even lead to territorial segregation processes. Conventional smallholders, pastoralists, and poor urban dwellers that together still form the majority of the population will be further marginalized. These increasing disparities will – in conjunction with conflicts over resources, such as water – aggravate social and economic tension and conflicts.

11 Traditional primary-production-based livelihood strategies are still under pressure.

Primary production remains at the core of most people's livelihoods, in the form of pastoralism or conventional smallholder agriculture. However, this livelihood basis is under increasing pressure (see core issues 05 and 07), forcing people to find supplementary or even replacement activities to generate an income.

12 Alternative livelihood means are difficult to find or develop and are dominated by the informal sector.

In combination with the still growing population, particularly in the lowlands, the need for alternative income sources outside of primary production will significantly increase the demand for jobs in the secondary and tertiary sectors. Economic development will lead to growth in the formal labor market and increase the need for skilled and highly educated workers. However, this growth will in no way match the large demand for work by unskilled workers with low education levels. The already significant informal sector, where income is low, insecure, and unregulated, will continue to grow. And this huge demand for work will cause a further decline in the quality and security of the informal sector, making it even more difficult to find sustainable alternative livelihoods outside of primary production.

Relevance of the twelve core issues in the three zones of the region

In the workshops, participants assessed the relevance of the above twelve core issues for the three geographical zones (see Figure 7.1). Table 7.1 below displays this assessment with the qualitative scale indicating the degree of significance of each core issue for the three zones.

Our qualitative assessment shows that all twelve core issues are relevant and significant in all three zones, implying that together they form a cluster of important challenges in the whole region. Although each core issue differs in the way it manifests in the different zones (see above), the assessment indicates that all of the issues are involved in overarching processes and show trends relevant to the whole region, and that the issues are interdependent between the zones. This has to be considered when searching for sustainable solutions and development pathways.

Table 7.1: Qualitative assessment of the relevance of twelve core issues in three sub-zones of the Mt. Kenya–Ewaso Ng'iro North landscape (map see Figure 7.1). Legend: * = relevant but less significant, ** = relevant and significant, *** = very relevant and significant

Realm 1: Nature conservation, biodiversity, and conflicts	A	B	C
01 Biodiversity (vegetation, wildlife) remains under pressure. Invasive species remain a growing challenge.	***	***	***
02 Nature conservation will remain a major and contested issue, and national and international efforts will increase in this respect.	***	**	**
03 Conflicts between humans and wildlife, as well as communities and conservation stakeholders, will remain problematic.	***	**	**
04 Tourism demand is too low for the growing supply of tourism services and for the high local expectations.	***	***	**
Realm 2: Primary production and resources	**A**	**B**	**C**
05 Pastoralism remains under heavy pressure, with livelihoods and local communities changing and adapting.	***	***	***
06 Agriculture continues to expand as agribusinesses grow and smallholders commercialize.	***	***	**
07 Conventional smallholders continue to struggle with a range of insecurities and risks, such as climate change.	***	***	**
08 Resource conflicts and degradation (water, soils, vegetation cover) continue to grow.	***	***	***
Realm 3: Economy and livelihoods	**A**	**B**	**C**
09 The economy will further develop and diversify – but very unevenly in terms of space and social strata.	***	***	**
10 Disparities will continue to grow, leading to persistent poverty as well as social and economic conflicts.	***	***	***
11 Traditional primary-production-based livelihood strategies are still under pressure.	***	***	***
12 Alternative livelihood means are difficult to find or develop and are dominated by the informal sector.	**	**	***

7.3 Relevant actors and stakeholders

Chapter 7.2 described the main challenges that impede progress towards just and sustainable interactions between nature and people in the Mt. Kenya–Ewaso Ng'iro North landscape. To design measures that can effectively address these issues requires a good understanding of the main stakeholders relevant to the nature–people nexus. This includes understanding how these actors would affect, or be affected by, the implementation of such measures in the landscape. Chapter 7.3 therefore briefly examines the prevailing stakeholder landscape, building on the results of the stakeholder mapping exercise conducted during the co-design workshop of February 2019.

Approximately 217 diverse stakeholders were captured in the exercise. They were differentiated into four arenas and assessed by broadly defined category, to determine their degree of influence on nature and people, level of interest in conservation, power to influence change, and extent to which they would be affected by change within the nature–people nexus. The results are summarized in Table 7.2 and briefly explained below.

Table 7.2: Qualitative assessment of the degree of stakeholder importance and influence on the nature–people nexus in the Mt. Kenya–Ewaso Ng'iro North landscape. Legend: o = none, * = little importance and influence; ** = moderate importance and influence; *** = high importance and influence

Arena	Main stakeholder categories	Influence on status of N&P	Conser-vation interest	Power to influence change	Affected by change	Important stakeholder sub-categories
Arena of land resources users	Smallholder farmers	***	*	*	***	Smallholder subsistence farmers; smallholder out-growers
	Pastoralists	***	*	*	***	Pastoralists; agropastoralists
	Large-scale farms	***	**	**	**	Large-scale ranches; large-scale horticultural farmers; large-scale food producers
	Conservancies	***	***	**	***	Private conservancies; community conservancies; county conservancies; national parks; protected forests
Arena of non-state actors	Community-based organizations	*	*	*	**	Faith-based organizations; Community self-help groups
	Society-rooted resource governance institutions	**	**	**	**	Traditional governance institutions; Water resource user associations; community forest associations; community water projects
	Conservation and Development NGOs	**	**	*	*	International NGOs; local NGOs
	Local & international commercial companies	**	*	**	**	Local tourism facilities; International tourism facilities; Corporate commercial companies
	International donor agencies and aid organizations	*	*	**	o	Bilateral agencies; multilateral agencies; corporate donor agencies
	Media	*	**	**	o	Print media; electronic media; social media

Arena	Main stakeholder categories	Influence on status of N&P	Conser-vation interest	Power to influence change	Affected by change	Important stakeholder sub-categories
Arena of state actors	National government	***	*	***	*	Line ministries and departments; parastatals
	County governments	***	*	***	*	Line ministries and departments
	Military	**	*	**	**	Kenya Defense Forces; British Army Training Unit in Kenya (BATUK)
	Inter-county agencies	*	**	**	*	
	Elected leadership (national)	*	*	**	*	Members of Parliament; Senate; House Committees; Pastoralists Parliamentary Group
	Elected leadership (regional)	*	**	**	*	Members of County Assembly; House Committees
Arena of re-search and training	National R&T institutions	*	*	*	o	National universities; private universities; governmental research Institutions and projects
	International R&T institutions	*	***	*	***	International institutions (UN); private foreign institutions; multilateral r4d projects and initiatives

Arena of land resource users

The main direct users of the landscape are smallholder mixed farmers, pastoralists and agropastoralists, and large-scale farmers and large-scale ranchers, including conservancies. In our assessment, these stakeholders generally exert very high influence on the status of nature and people, and would also be greatly affected by changes implemented in the nexus because of their heavy reliance on land resources in their respective production systems. But they differ in their levels of interest and power to influence change: the smallholder farmers and pastoralists neither have much interest in, nor the power to influence, conservation endeavors in the landscape. In contrast, large-scale farms, and especially conservancies, constitute a very strong stakeholder group with high interest in conservation and greater economic and political power. The large-scale land users have recently consolidated their power by coalescing into two giant associations, the Laikipia Farmers' Association and the Kenya Wildlife Conservancies Association, through which they secure and foster their interests. These features characterize an arena of stakeholders with very high influence on the status of the people–nature nexus, and would be greatly affected by any changes of it.

Arena of non-state actors

The arena of non-state actors comprises stakeholder categories whose degree of importance and influence fall into the lower portion of the scale – between zero to moderate – depending on their involvement in the landscape. Community-based organizations are assessed to be of little influence and importance and would be moderately affected by change from nature conservation interventions. They nevertheless provide a crucial link to local communities, especially for NGOs or donors that do not deal directly with the communities. Conservation and development NGOs are quite prominent and support a broad variety of conservation and development activities in the region. Consequently, they have influence on the status of nature and people and interest in conservation, although they possess little power to influence change and will be least affected by that change.

Both society-rooted resource governance institutions and local and international commercial companies are assessed to have the same degree of influence on the status of nature and people. They also have equal power to influence change and would be equally affected by change, their different levels of operation notwithstanding. Society-rooted institutions are important and influential by virtue of their composition and functions, which give them the legitimacy and unique capacity to mobilize, integrate, and include all actors across related sectors and stakeholder groups. They will be equally affected by the changes that affect the nature–people nexus. Similarly, commercial enterprises, particularly those from the tourism sector and corporate giants, support local development and conservation work through their corporate social responsibility programs.

Arena of state actors

The arena of state actors comprises stakeholders who are the custodians of policy and legislation, and who have full control of the state machinery at their respective level of governance and administration. They therefore possess greater power to influence change in the nature–people nexus. And because most of these organs are represented at the lowest administrative and political units, these stakeholders further possess great mobilization power and a great deal of influence over local resource users. In this category, albeit with a different function, are the Kenya Defense Forces (KDF) and the British Army Training Unit in Kenya (BATUK), who, despite having little interest in conservation, have considerable influence and power through their exclusive ownership and control over some areas in the region that are used for security installations and training purposes. Furthermore, stakeholders outside this arena are, largely, subordinate to and under the coordination and supervision of actors in this arena. This makes the stakeholders and actors in this category the most decisive in terms of community mobilization, regulation, and policy direction.

Arena of research and training

The research and training arena is represented by strong consortia and networks of local and international research and training institutions that pursue different research agendas relevant to the nature–people nexus. Most of the stakeholders in this arena have a low level of importance and influence – with the exception of the international research and training institutions, which have a high interest in conservation and would be considerably affected by attendant change. The Wyss Academy of Nature belongs to this category.

The validity of these results

It is important to underline two key aspects that may affect the validity of these results. First, that the broad categorization – done to reduce the huge number of stakeholders and simplify the analysis process – conceals important details of who is actually important and has an interest and influence on the nature and people nexus. The process may have yielded different results if the analysis had been done at sub-category level or for a specific intervention. It will therefore be important to consider individual actors or projects when elaborating frameworks and strategies that embrace participation and inclusivity. And second, that all stakeholders in their respective arena are continuously monitored for possible changes in status and periodically reanalyzed to enable adjustments.

In conclusion, these discussions reveal a landscape that depicts a complex set-up of multi-layered stakeholders and actors with overlapping and potentially conflicting expectations, and power differences that will certainly be challenging to mobilize and align to a common agenda in the context of the nature and people nexus. This will require high-level institutional competence and acceptance, as outlined in the conclusion of Chapter 7.4.

7.4 Promising entry points, assets, and opportunities

To address the challenges posed by the above core issues, the two half-day workshops mentioned in Chapter 7.2 concentrated on identifying promising "entry points" to potential solution-oriented pathways. Before presenting these entry points and related opportunities, however, we briefly summarize the main assets that were the focus of Chapters 2 through 5.

Key assets in the Mt. Kenya–Ewaso Ng'iro North landscape

Natural capital: The scenic beauty of the highland–lowland system of Mt. Kenya, the biodiversity of the narrow sequence of altitudinal belts, and the rich diversity of wildlife make the area an asset of global importance. The semiarid conditions in most parts of the region limit options for human use in primary production. But soils are generally good and, if degraded, have significant potential for rehabilitation – and vegetation cover, although partly degraded, holds untapped potential for use as non-timber forest products. Water resources are generally limited, but with proper management and distribution, could serve significantly beyond current use. Groundwater, springs, and increasing rainfall peaks due to climate change could be a way of upgrading the semiarid conditions.

People and knowledge: Although unemployment and low-quality employment in the informal sector are a major development problem in the region, they also indicate that a labor force is available to be engaged in development and conservation activities. The majority of the population is young; comparatively well-educated, especially in the highlands and near towns; and conversant with modern communication technologies, implying a significant openness for change and innovation. The diversity of pastoral populations in the lowlands holds a wealth of contextualized indigenous knowledge on the environment, and the traditional but partly dormant land use regulations build on sustainability and restoration considerations. At the level of scientific knowledge, institutions like the Centre for Training and Integrated Research in ASAL Development (CETRAD) and associated partners and projects have established an exceptional density of contextual data and insights on the socio-ecological systems in the region. CETRAD is also embedded in a network of qualified and experienced experts on the region and its various issues. In relation to nature conservation and grassroots-based natural resource management, the region has much experience with different models on which one can build.

Accessibility and markets: As mentioned in core issue 09, the region is becoming vastly more accessible. The axis to Nairobi is being significantly improved, and the interregional and international axes – east–west and south–north – that intersect in Isiolo are being implemented or planned. This increased supra-regional connectivity opens access to national and international markets and, if carefully managed, can improve related value chains. It is also triggering investments in the region. The asset of increased accessibility will not only improve market conditions for the main products and services of the region, such as livestock, crop products, and tourism, but will also open avenues for specialized and niche products, such as non-timber forest products. In addition, the growing middle and upper classes with their changing lifestyles in Kenya's urban centers can trigger new opportunities such as organically produced crop and livestock products or offers targeting domestic tourism.

Governance and agencies: The Constitution of Kenya 2010 introduced a devolution of power from the national to the county level. This opened the new possibility of contextual decision-making. As counties gained financial means and control over their own budgets, self-driven development increased. A number of laws, e.g. the Community Land Act, are currently seldom enforced, but, if applied, would strengthen the rights of local communities. In addition, the region is a national pioneer in establishing and running officially recognized grassroots-based governance structures, such as Water Resource User Associations (WRUA) and negotiation platforms for water or wildlife fora. The region is also a hub for a broad range of NGOs and initiatives which, if coordinated, can be a significant asset for development and conservation.

Promising entry points and related opportunities

Against this background of assets, our two workshops identified promising entry points to tackle the challenges posed by the twelve core issues (see Chapter 7.2). The entry points build on the vast contextual experience of workshop participants. But they must be treated as *proposals* that require further evaluation in terms of feasibility, stakeholder participation, and already existing initiatives and activities in the respective fields. Entry points are proposed for the following four levels: 1) level of communities and households, 2) level of markets, 3) level of policy and planning, and 4) level of sociopolitical processes. The numbers given in brackets correspond to the core issues from which they were proposed (see twelve core issues in Chapter 7.2)

(1) Entry points at the level of communities and households

Approaches at this level target the people–nature nexus directly. However, these entry points are also crucial for building collaboration and trust with local communities to lay the ground for more complex approaches and processes (see below). At the level of communities and households, we propose further evaluating and testing the following five entry points.

(1.1) Awareness, education, and knowledge (02, 03, 05): Interaction with pastoral communities is key to building on indigenous knowledge and creating awareness of people–nature relations. Developing the skills of pastoral youth can increase their knowledge and competence in conservation and environmental management issues, and will help them face and counter the challenges of the informal sector.

(1.2) ***Rangeland management (01, 03, 05):*** Achieving more sustainable use of the pastoral lowlands will require improvements in community-based rangeland management. One way of doing so is to combine traditional land use regulations with rehabilitation technologies. Another is to address herd composition, livestock–wildlife interactions, and dry season fodder production. All methods require long-term engagement.

(1.3) ***Invasive species (01, 05):*** Control and management of invasive species is increasingly important in rangeland management. There are opportunities to build on community-based experiences and best practices in the region.

(1.4) ***Niche products (02, 05, 07, 12):*** Introduction, promotion, and upscaling of niche products that fit household strategies and supplement the main products of pastoralists and/or conventional smallholders is a promising entry point that can also pave the ground for broader engagement and communication with local communities. Potential niche products include gums, raisins, latex, honey, fish, sand harvesting, and handicrafts. Increased accessibility of the region and adaptation processes among pastoralists are providing increased opportunities for successful niche products.

(1.5) ***Technological innovations (01, 03, 05, 06, 07):*** As with niche products, opportunities to introduce targeted technological innovations among pastoralists and smallholders have increased in recent years. Promising and important potential entry points include climate-smart technologies; technologies for increased water use efficiency, geo-fencing, and predator-proof "bomas"; and community-based technologies to monitor biodiversity, water, and other environmental issues.

(2) Entry points at the level of markets

Improved accessibility, widespread use of modern communication technologies, and devolution of power to county level increase the importance of regional, national, and international markets for the development of the region. Entry points at market level aim at increasing the participation of and benefits for local communities and land users in these accelerated developments. This promises to increase capacities to take risks in innovation, also in the field of environmental sustainability. We propose three entry points for further evaluation.

(2.1) ***Incentives, credits, and benefits (02, 06, 07, 08):*** Local communities, land users, and local youth can be supported in negotiation and business skills, to strengthen their market position vis-a-vis the private sector and state actors. Establishing or supporting favorable credit facilities can help increase the possibility of local innovation.

Initiating or supporting efforts and negotiations for incentives for environmentally relevant services and reproductive activities are complex but could be very rewarding for the people–nature nexus – locally, regionally, but also globally, through novel and innovative compensation schemes (i.e. post-PES [payment for ecosystem services] schemes).

(2.2) Access and value chain (05, 06, 07, 11, 12): The new market conditions open windows of opportunity for improvements in the value chains of most of the regionally relevant production systems. Such improvements would increase benefits and stability for local producers. Initiatives to increase market transparency and information will be crucial and could even open avenues to new opportunities, such as catering to the increasing demand for organic food in the large economic centers of Kenya. In addition, it may be possible to address some state and market regulations that hinder improvement of value chains and development of niche products (see entry point 1.4).

(2.3) Diversification of tourism (02, 04, 12): In connection with nature conservation, the tourist market deserves special attention with the realization that traditional high-income international tourism is reaching its limits and has little regional economic impact. Creatively rethinking tourism, diversifying its products and services, supporting local and regional supply chains, attracting alternative and especially national demand segments, etc. will be crucial for the economic viability of conservation efforts and especially for community conservancies. An important supporting entry point in this respect can be to train local actors in business and tourism-related skills. The context of highly profitable tourism may also provide a key opportunity to conceive innovative benefit sharing mechanisms that enable more just development outcomes.

(3) Entry points at the level of policy and planning

The process of devolution of power and decision-making from the national to the county level that started in 2010 is still ongoing, as policies and planning are adapted at both levels. These adaption processes provide unique windows of opportunity to find new balances of people and nature in policy and planning. There is a role for research institutions committed to helping shape these processes, but two there are two prerequisites to participation. First, such institutions must be recognized by state actors as a valuable partner, and second, such institutions should refrain from lobbying, concentrating instead on providing knowledge-based services and acting as an inclusive moderator. We propose three entry points at the level of policy and planning, with the first (entry point 3.1) showing particular promising.

(3.1) County planning (02, 03, 04, 08, 10, 11, 12): By law, counties are obliged to develop County Integrated Development Plans (CIDPs) and

County Spatial Plans (CSPs). Supporting these planning processes with evidence and knowledge-based planning tools can make a crucial contribution to regional development. Participating in the CSPs may help incorporate conservancies and related land uses into spatial plans, and thus promote exchange and negotiations on the people–nature nexus.

(3.2) ***Land policies (01, 02, 03, 05, 07, 11):*** The very uneven distribution of land ownership (small-scale versus large-scale) and types of ownership (individual ownership with or without titles, state-owned landholdings, or community lands) are a decisive but contested and conflicting factor in any development attempt in the region. Directly addressing the question of land rights would be key but needs to done in a power-sensitive way. However, participating in spatial planning processes or in efforts to strengthen enforcement of the Community Land Act, could to some extent buffer hindrances related to land rights.

(3.3) ***Infrastructure investments (05, 06, 08, 10):*** The increased accessibility to previously very remote communities is leading to processes of market integration and economic development that will continue or even accelerate. This includes investments into infrastructure by private and state actors as well as communities. In cases of water and transport infrastructure in particular, knowledge-based support is crucial from the outset of project planning, in order to minimize negative environmental or social impacts. However, gaining access to these processes requires high institutional recognition. Engaging in pilot infrastructure investments may help to build this recognition.

(4) Entry points at the level of sociopolitical processes

With few exceptions, tackling the challenges at the people–nature nexus in the region requires engaging in sociopolitical processes that bridge different areas and levels of decision-making and link a broad range of actors and stakeholders in novel social configurations. At the basis of such processes lies an exchange of knowledge, experiences, visions, and of what is at stake for the different groups. High institutional recognition, a reputation for reliability and nonpartisan positions, as well as high-quality, contextual, cross-sectoral knowledge are preconditions for successfully initiating and promoting such processes. Meeting these preconditions and triggering processes at a larger scale will require well-thought-out pilot actions, an approach illustrated by the current incubator projects (see boxes). At the level of sociopolitical processes, we propose five important and promising entry points.

(4.1) ***Sociopolitical integration of conservation (01, 02, 03, 04, 08, 11):*** Conservation efforts have significantly contributed to the global recognition of the region as a bright spot of wildlife. However,

the conservancies remain socially and politically isolated. The disconnection of conservation from large parts of the population and from the local economy leads to conflicts and may endanger the high value of nature. At the conceptual level, there is an opportunity to transform the dichotomous conservation–development debate from its current, often narrow and antagonistic angle, to a more synergistic and mutually reinforcing perspective, allowing us to address systemic changes in the people–nature relationship. In concrete terms, knowledge-based creativity is required to trigger improved communication between the relatively poor communities and the comparatively rich conservation actors, to find better ways of benefit sharing, to increase economic multiplication of tourism and conservation in the region, and ultimately to develop shared visions of human well-being and the value of nature. A promising starting point could be to combine a systematic multi-sectoral evaluation of existing conservation models in the region, with creative pilot actions to improve awareness and communication.

(4.2) ***Better integrating wildlife and resource management (01, 02, 03, 04, 07, 08, 11):*** The dominant approach of territorially separating conservation and human land use, e.g. conservancies and pastoral rangelands, has contributed to the high value of nature in the region. In many instances, however, it has also led to the interruption of crucial migratory corridors between ecological zones, affecting wildlife as well as pastoralists and possibly fueling a broad range of conflicts (Cruise and Zee 2017). Introducing flexible zones of inclusive conservation and migration corridors for wildlife and livestock could mitigate the challenges associated with strict territorial separation. A first incubator project, 'Reconnecting the landscape for wildlife and livestock', illustrates how respective sociopolitical processes can be initiated.

Incubator Project: Reconnecting the landscape for wildlife and livestock

The systemic challenges and trade-offs addressed

Traditionally, the landscape was mainly home to pastoralists and abundant wildlife. Mobility through the entire region was vital for livestock to access seasonal pasture and water, and for wild animals to breed and feed. Since the beginning of the 20th century, however, the landscape has gone through successive waves of transformation (see Chapter 1), which have resulted in land degradation, territorial fragmentation, and loss of ecosystem connectivity. Mobility for livestock and wildlife is challenged by the expansion of fences around private properties and conservation areas, human settlements, and large-scale infrastructure. In order to secure the livelihoods and culture of pastoralists on the one hand, and to preserve wildlife on the other, solutions must be found to allow mobility across pastures and habitats, especially along the lowland–highland gradient.

Knowledge for action

Systemic understanding of the landscape is critical to assess connectivity needs and to plan for corridors in the most effective and relevant manner. The Wyss Academy for Nature is therefore working with research organizations and other key actors locally and globally to bring together the sparse fragments of knowledge and to identify and fill knowledge gaps at the larger landscape level. Data, information, and knowledge are then turned into actionable policy products, interactive decision support tools, and awareness-raising materials aimed at various audiences.

Engaging with stakeholders

Establishing corridors requires access to significant amounts of land. As the pressure over this resource is rapidly increasing in the region, land-related issues and human–wildlife conflicts are exacerbated and proliferating at a rapid pace. Engaging with stakeholders at all levels is therefore key to building a common future vision of the landscape as well as increasing the context-relevance and acceptability of the corridor design at the local level. The project partners have therefore established a "corridor champion group" comprised of experts from government, civil society, and research institutions working together towards knowledge generation, advocacy, and policy dialogue. High-level political fora are organized to raise awareness and increase buy-in of political leaders. Finally, intensive local consultation and joint planning is undertaken with local communities for the design and location of the pilot corridor infrastructure.

Piloting solutions

In order to secure the mobility of both livestock and wildlife, the concept of dual-purpose corridors was proposed through a co-design process with key stakeholders. Dual corridors aim at building on the current government momentum for wildlife corridors to secure space for both wild species and pastoralists with their livestock. The process is being piloted in Laikipia county through partnerships with key organizations and through strong community engagement. If promising, solutions will be scaled up through involvement in county-level spatial planning and high-level political processes.

This incubator illustrates the complexity of entry points at the level of sociopolitical processes and corresponds to the proposed entry point of 4.2 (see Chapter 7.4). Although the processes have started well, success is not yet guaranteed, as land ownership and land rights are highly sensitive and may jeopardize implementation.

(4.3) ***Rangeland restoration and water development (01, 05, 07, 08, 11):*** The degradation of rangelands and overuse of scarce water resources are the most severe environmental degradation processes in the region. Land restoration and the protection and optimal use of water resources are therefore key to making improvements in the people–nature nexus. However, both are highly complex and prone to conflicts

and require long-term sociopolitical processes that innovatively combine knowledge, technologies, grassroots institutions, governance structures, economic incentives, and inclusive participation. One of the current incubator projects, "Monitoring and managing springs", illustrates such initiatives.

Incubator Project: Monitoring and managing springs

The systemic challenges addressed

Availability of water is a major development constraint in the lowland areas of the landscape. Current trends such as population growth, expansion of small-scale agriculture, urbanization, and climate change are putting unprecedented levels of pressure on scarce water resources. This is leading to conflicts between users, declines in biodiversity and wildlife, and threats to the livelihoods of already vulnerable populations.

Decades of studies and monitoring in this ecosystem have shown that the key role played by springs and wetlands in the Ewaso Ng'iro North basin's water balance is under increasing threat by rapid land use changes and water extraction upstream. Restoring the flow of the river, which constitutes a lifeline for millions of Kenyans, largely depends on the protection of springs. Context-specific, locally owned solutions are needed to secure this vital resource and ensure the viability of the landscape as a whole.

Knowledge for action

The Wyss Academy for Nature, CETRAD, the Centre for Development and Environment, and the Oeschger Centre for Climate Change Research bring together a dense hydrometeorological monitoring network in the region, cutting-edge high spatial resolution climate projections, and the mapping of all springs in the larger Gare Mara sub-catchment. In addition to an understanding of hydrological dynamics, contextual socioeconomic knowledge is key to ensuring sound and sustainable planning and sharing of resources. Building on three decades of research in the area, project partners are conducting in-depth field surveys to capture the issues, perceptions, and visions of the future of all relevant stakeholders.

Engaging with stakeholders

Managing a scarce and vital resource such as water requires trade-offs and compromises between uses and users. As users can be challenging to reach, the project partners have opened up several avenues for inclusive stakeholder engagement: community mobilization and awareness-raising campaigns, multi-stakeholder platforms, participatory research and planning, and capacity strengthening of grassroots water governance bodies such as the Water Resource User Associations.

Piloting solutions

The Gambella wetland, within the Gare Mara sub-catchment, was jointly selected for piloting comprehensive approaches to spring and wetland restoration.

A pilot project is mobilizing a set of complementary levers, including water infrastructure, physical and legal protection measures, integrated management and planning, stakeholder engagement, use of modern technologies for monitoring and planning, and governance reforms.

This incubator project is a typical and successful example of the entry points at the level of sociopolitical processes, in particular entry point 4.3 (see Chapter 7.4).

(4.4) ***Strengthening grassroots and coordinating non-state actors (02, 05, 07, 08, 10, 11):*** In all approaches that require sociopolitical processes, two issues are critical. First, grassroots institutions, traditional local regulations, and endogenous bodies of knowledge are overshadowed or even suppressed by more powerful actors, institutions, and stakeholders. Second, the region is crowded by a broad range of non-state actors, such as NGOs, development agencies, or conservation actors (see Chapter 7.3), each with their own agenda, strategy, vision, and profile. Way of addressing these two issues include mapping and voicing endogenous knowledge, formalizing local regulations in bylaws, supporting and training local resource user associations, supporting and enabling inclusive fora on contested issues such as water, wildlife, rangelands, etc., or engaging non-state actors in discourses on the relevance of novel scientific knowledge such as climate change projections or socioeconomic trends. Although these efforts do not address the core issues directly, they can pave the way for coordinated and inclusive approaches. They also may be promising entry points for strengthening institutional recognition and reputation.

(4.5) ***Formalizing the informal (10, 11, 12):*** The informal economic sector has developed rapidly in the region and plays an increasing role as a supplement or even substitute in primary-production-based livelihoods, as well as for the large number of youth. It therefore absorbs people from the primary sector, enables transformations in pastoralism, and thus reduces pressure on land and natural resources. However, the informal sector is fraught with high uncertainty and offers low and unreliable incomes. Reducing this uncertainty and making the informal sector more reliable is therefore an important aspect in reconfiguring the people–nature nexus. This can be approached by transforming at least parts of the informal into the formal sector, e.g. when working on improving value chains or by offering business training and by promoting formalized cooperatives in the informal sector. In connection with conservancies and the diversification of tourism (c.f. entry point 2.3), another promising entry point could be to formalize tourism-related products and services at the local level.

This discussion of promising entry points leads to some important conclusions. 1) The entry points will have to be selected and prioritized in line with the vision and theory of change of the Wyss Academy for Nature. 2) There are very few or perhaps even no ‘low-hanging fruits’ for rapid impacts at the people–nature nexus. 3) Some windows of opportunity are currently open but may close soon, the most significant being county-level planning (see entry point 3.1). 4) Success of most entry points will depend on two prerequisites: institutional recognition and a good reputation as a nonpartisan knowledge institution; pilot actions to implement the entry points could serve to build these prerequisites.

8 Knowledge gaps and research needs

Boniface Kiteme, Joan Bastide, Urs Wiesmann

The knowledge needs listed under sections (A) to (F) below are derived from the two workshops, twelve core issues, and promising entry points outlined above. They result from reflections on the people–nature nexus in the concrete context of the Mt. Kenya–Ewaso Ng'iro North landscape and are not yet rooted in generic research concepts. Here, we typologize the knowledge needs, noting that type A ("understanding socio-ecological systems") has received the most attention. It is important to note that we have not carried out a systematic study of whether these knowledge needs have already been addressed by other research institutions. This will be done – and respective collaborations established – when concretely planning research activities in the region.

A. Understanding socio-ecological systems

It is crucial to have contextual baseline data for planning. However such data do not reveal systemic relations, feedbacks, and dynamics in the socio-ecological system. These require in-depth and coordinated disciplinary and interdisciplinary research, which we propose to structure along four socio-ecological systems, or systemic complexes. Each complex is distinguished by its dominant land use system: pastoralism, conservancies, agriculture, and urban development.

This research will be guided by conceptual frameworks on the different socio-ecological systems. Here, we concentrate on listing, for each complex, research questions considered crucial based on the analyses and considerations in this report. Some of the questions specifically take into account interdependencies and links among the four complexes.

A.1 Understanding the 'pastoralist – rangeland complex'

- To what degree are rangelands in pastoral areas degraded (vegetation cover and composition, sealing and erosion of soils), and what are the implications for productivity, runoff and water retention, and biodiversity and habitats?
- What is the ecology of invasive species (including native invasive species such as Acacia reficiens, or *Sansevieria* spp.), to what degree do they depend on rangeland management and degradation, and what are appropriate control measures?

- What are options and conditions for rangeland restoration? Do endogenous knowledge and traditional rehabilitation rules exist, and could they be revoked?
- What options exist or can be negotiated to provide dry season pastures outside the pastoral rangelands (e.g. in large-scale ranches, along corridors, in conservation areas, or in the agricultural highlands)?
- Which niche products from pastoral rangelands (honey, gums, raisins, herbs, etc.) are endogenously known and show promise in terms of upscaling and marketing?
- What are the trends in the livelihood strategies of pastoralists (e.g. diversification, semi-sedentarism, changing herd composition, new livestock marketing options), and what are the consequences for rangeland management and restoration?
- What are the attitudes, expectations, benefits, and losses of pastoralists vis-à-vis conservancies, wildlife, and tourism?

A.2 Understanding the 'conservancies – wildlife – tourism complex'

- How do the different conservancy models compare in terms of wildlife and biodiversity conservation?
- How do the different conservancy models compare in terms of economic viability, and how do they relate to local communities (e.g. pastoralists) in terms of shared responsibilities and shared benefits?
- What is the influence of distant actors (national, international) on conservancy policies and valuations of nature?
- To what degree do conservancies economically depend on tourism, and what is the regional economic impact of different tourism models?
- Which conservation approaches and models can be spatially expanded, e.g. into the pastoral rangelands, without endangering (pastoral) livelihoods?
- Which wildlife species (e.g. elephants) require what type of migratory corridor, and what are the conditions to have corridors established and shared with livestock?
- How and where can human–wildlife conflicts be prevented and mitigated, how effective can novel technologies be in this respect, and how can compensation mechanisms be improved?

A.3 Understanding the 'agriculture – water – land complex'

- What are the trends in agriculture (e.g. shifts between conventional and commercializing smallholders, or the expansion of agribusinesses), and what are the consequences on migration, labor markets, and densities and expansion of rural settlements?
- How is the agrarian transformation reflected in patterns of water use and water pollution, and how do these patterns affect water resources, in particular downstream?
- What conflicts are occurring between the agricultural highlands and the neighboring lowlands in relation to water, land, livestock movements,

and wildlife, and how do the different communities perceive these conflicts?
- What are the trends in the livelihood strategies of smallholders (e.g. diversification, commercialization, off-farm engagement) on reproductive environmental activities and on the quality of soils and biodiversity?
- How do markets for agrarian products change, what are the respective value chains, and how could they be improved?

A.4 Understanding the 'urban – trade – services complex'
- What are the extent, characteristics, and trends of the non-agrarian labor market, and what is its absorption capacity for the population of the region?
- What are the important subsectors of the informal sector, and what potential do they have to be transformed towards the formal sector?
- What quality of services (health, education, security, etc.) are provided and are they accessible for the population of the region?
- What environmental impacts (e.g. on water resources, water and air pollution, wildlife habitats) do the growing urban centers and infrastructures have?

B. Crosscutting valuations

Knowledge needs were not only identified at the levels of baseline data and within processes and dynamics, but also at the level of valuation of key aspects of the people–nature nexus. Putting a value on these aspects should cut across the systemic complexes (see A, above) and cover the whole region and its many contexts. Valuations should be derived at in a transdisciplinary way – based on scientific evidence, they should also include the perspectives and values of the population and stakeholders. We propose four crosscutting valuations as key products to trigger discussions on future development and conservation pathways, e.g. on the engagement platform. These valuations of human well-being and of nature across the region are key to the strategy and approach of the Wyss Academy for Nature (see Chapter 1).

1. The intrinsic vs multidimensional valuation of nature and its contribution to people (NCP)
2. The availability and quality of environmental services and NCPs, e.g. water provision and soil productivity
3. Indications of human well-being in terms of poverty/wealth level and access to basic services
4. A context-specific valuation of the scope of action in choosing future development options and pathways (i.e. within the boundaries of state and local governance rules and regulations and societal value systems)

C. Prospective assessment of megatrends

What has not been captured in the above knowledge needs are the far-reaching impacts and consequences of two externally driven megatrends. These will of course require evidence-based analysis:

1. Prospective assessment of the impacts of climate change. Particularly important are changes in natural hazards, changing productivity of primary production (including changing timing and variability in crop calendars), changes in hydrological balances, and changes for wildlife and biodiversity. Further investigation is needed not only of the impacts of climate change, but also of the complex feedbacks between land use change and climate change.
2. Prospective assessment of the impacts of LAPSSET and related infrastructure on nature and people. Of particular importance are changes for different stakeholder groups in accessibility and respective markets and investments, changes in settlement patterns and in concentration processes of primary production (agriculture and pastoralism), changed pressure on natural resources, especially water, and the impacts on wildlife movements, and not least on the potential impacts on social unrest and conflicts. Of particular interest in this context is also the effect of telecoupled social-ecological systems, and the role of distant actors.

These prospective assessments and scenarios will be crucial when discussing development and conservation pathways and options. They will also form an important basis for supporting formal planning processes, e.g. in County Spatial Plans.

D. Feasibility and transformative capacity assessments

A range of entry points for pilot actions and incubator projects were proposed in Chapter 7.4. To plan the research activities, human resources, and financial means required, feasibility assessments must be performed before implementation. Most importantly, incubator projects should be assessed for their transformative capacity – i.e. for their capacity to contribute to solutions that can transform systems.

E. Monitoring and baseline data

We propose to establish lines of monitoring in order to measure impacts and assess transformation and changes. This includes

1. regular updating of baseline data (frequency of updates depends on the topic);
2. consolidating and expanding monitoring networks established in the past four decades by CETRAD and CDE projects;
3. establishing sites for biodiversity monitoring and rangeland restoration, or joining existing monitoring initiatives (e.g. Mpala Research Centre).

Additional monitoring activities may follow as required, particularly also in view of data-driven early warning systems, and as a basis for strategic foresight activities. We aim to capitalize on CETRAD's and CDE's long-term investments in environmental and socioeconomic data collection in the region, harnessing the wealth of data and making near real-time sensors and data streams accessible online.

Reliable and consistent data on key variables are crucial as a reference for more in-depth research, basic evidence in communication (e.g. on the knowledge and engagement platforms), and as an important basis for entering into planning processes, e.g. supporting County Spatial Plans (see Chapter 7.4). Such data should include high-resolution layers at least on the following topics:

- Topography, geology, and soil properties
- Water resources (rivers, springs, groundwater, and seasonal variability)
- Biodiversity indicators
- Land cover and biomass variability
- Land use types (including protected areas), and land tenure systems (size and type)
- Data on administrative units, infrastructure (accessibility, water supply, etc.), and services (health, education, etc.)
- Up-to-date population and socioeconomic data (e.g. census 2019)

Furthermore, three relevant research needs were identified during the stakeholder workshop and would require respective studies:

- Mapping of the extent of invasive species (including native invasive species)
- Spatial assessment of currently used wildlife corridors and hotspots of human–wildlife conflicts
- Participatory mapping of (traditional) access regulations and management of community lands

Since many of these baseline data may exist, at least in part, e.g. with CETRAD or other institutions, a data harvesting mechanism could be developed, pulling relevant data from individual sources and harmonizing it to ensure database-wide consistency, accessibility, and user-oriented service development. Such a platform could then be upgraded with any layers relevant to the people–nature nexus. Monitoring of climate change and its consequences for people and nature will be of particular importance. Validating climate simulations on a regional scale will require a dense network of weather station data, preferably with long time series and several meteorological variables. While CETRAD has been able to establish and maintain a remarkable network of weather stations in the surroundings of Mt. Kenya for a long period, there is still a lack of stations in sparsely populated areas in the northern part of Kenya. This is to the detriment of the understanding of changes in the climate dynamics related to recent global warming, but also to model validation in the Ewaso Ng'iro North region. Furthermore, the challenging interactions between large-scale circulations, such as the 'Indian Ocean Dipole' or the strong winds occurring in the Turkana Channel (low-level jet) are not well understood yet and further complicate the validation of regional climate models. Also, the complex feedback between the land surface and the atmosphere are not well understood and only very simplified relations are used in climate models, which increases the uncertainty level of such simulations, especially for climate change projection, where also land cover changes must be expected.

9 Conclusion

Thomas Breu, Boniface Kiteme, Christian Hergarten

Our analysis of the interactions between nature and people of the Mt. Kenya–Ewaso Ng'iro North landscape reveals that fundamental transformation processes in the area are already underway. We find a complex and interwoven sociopolitical reality facing a natural environment that is increasingly restricted in its capacity to deliver the contributions we humans take for granted.

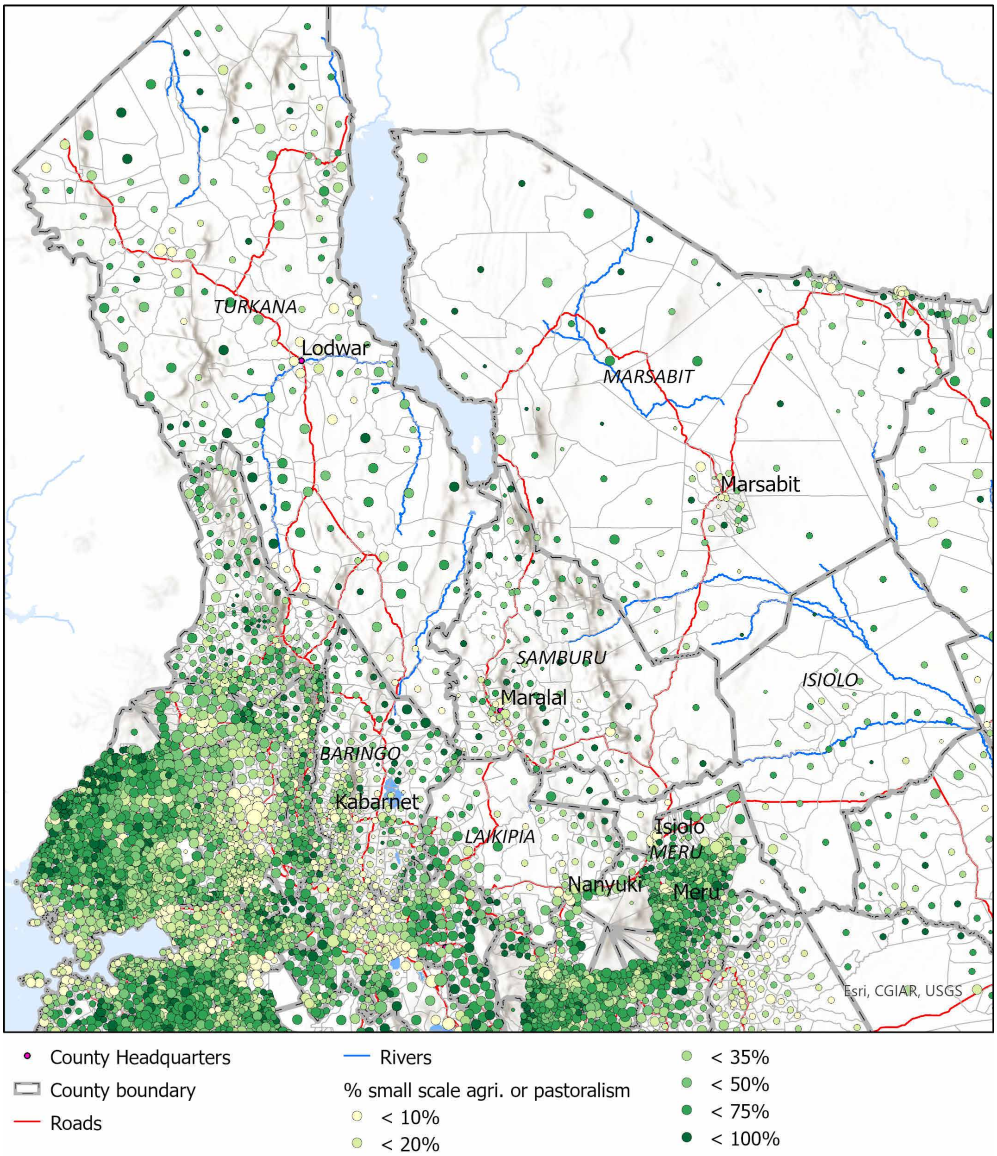
At the top of the landscape towers Mt. Kenya, a majestic sight that is emblematic of the high value of nature. A massive extinct volcano, Mt. Kenya captures humidity from the atmosphere in the form of rainfall and feeds the streams that nurture a highly biodiverse and scenic landscape downstream. The landscape has been recognized as a Key Biodiversity Area of international importance and has always been a regional bright spot, boasting wildlife and favorable ecological conditions. However, this high value of nature is increasingly under pressure from a range of processes linked primarily to intensified human activities. The socioeconomic development of the region has led to diverging changes in land use systems. Small-scale farming and more recently, horticulture farms, have intensified on the slopes of Mt. Kenya. They now compete with traditional semi-sedentary pastoralists over access to limited water resources and land, along with large, colonial-era ranches. This is increasing tensions and stirring up pre-existing conflicts, which in turn are exacerbated by changing patterns and variability of precipitation and temperature as result of climate change. The dynamic economic and political development in the region is altering the social fabric and challenging established power relations. This is leading to the emergence of new beneficiaries, who are enjoying an income from the thriving sectors of tourism, agribusiness, or infrastructure development. But it is also leading to the marginalization of traditional actors and semi-nomadic resource users, i.e. pastoralists. The latter are thus often pushed into more marginal and ecologically sensitive areas and forced to make a living from scarce resources, adding to the increased pressure on nature's capacity to provide irrecoverable ecosystem services.

However, this unique landscape also harbors opportunities. The extraordinary, diverse nature and its natural resource base is an important asset and entry point for engendering local development. Other assets include a well-educated population, a multitude of development actors, the region's attractiveness for domestic and foreign investors, and the existing service infrastructure, all of which in combination constitutes the floor for transformation towards a just relationship between nature and people. The realization of pathways in which nature conservation and human well-being reinforce each other holds the promise of a triple dividend – creating employment opportunities for a young, well-educated workforce, safeguarding biodiversity, and ensuring a sustainable future for traditional land users acting as the custodians of the multiple benefits provided by nature. The ongoing redesign of Kenya's governance system devolving political power to subordinate administration levels provides a window of opportunity to negotiate and test more inclusive decision-making models, ensuring that the benefits from ongoing large-scale infrastructure projects are more equally shared with local communities.

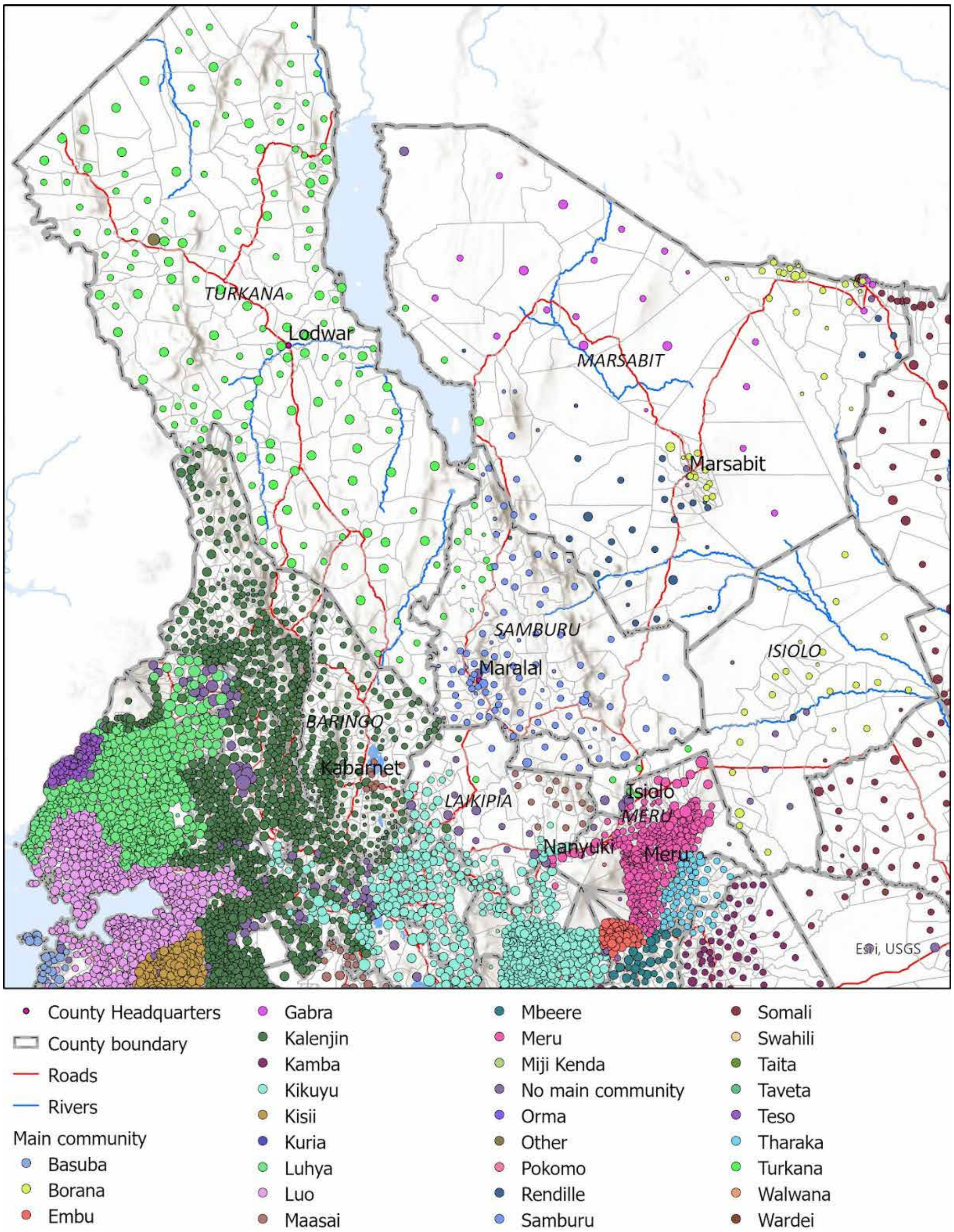
Overcoming such development dilemmas requires knowledge, innovative approaches, and new partnerships. A transformation of the human–nature relationship must ensure just and sustainable gains in human well-being, while allowing nature to thrive and deliver conservation services – in turn supporting all facets of life.

Appendices

Appendix chapter 3



Appendix figure 1: Percentage of the employed labor force working in small-scale agriculture or pastoralism, point size varies by total population (Source: Wiesmann et al. 2016)



Appendix figure 2: Main communities north of Mt. Kenya per ward in 2009, point size varies by total population (Source: Wiesmann et al. 2016)

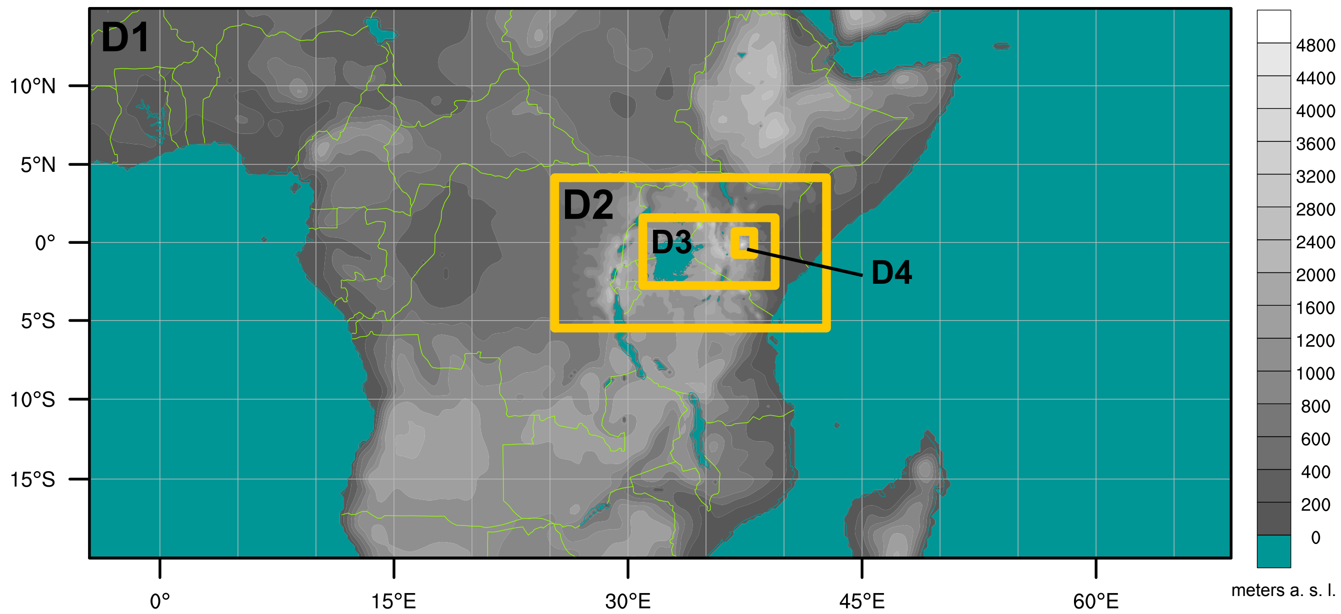
Appendix chapter 4

Climate model methodology

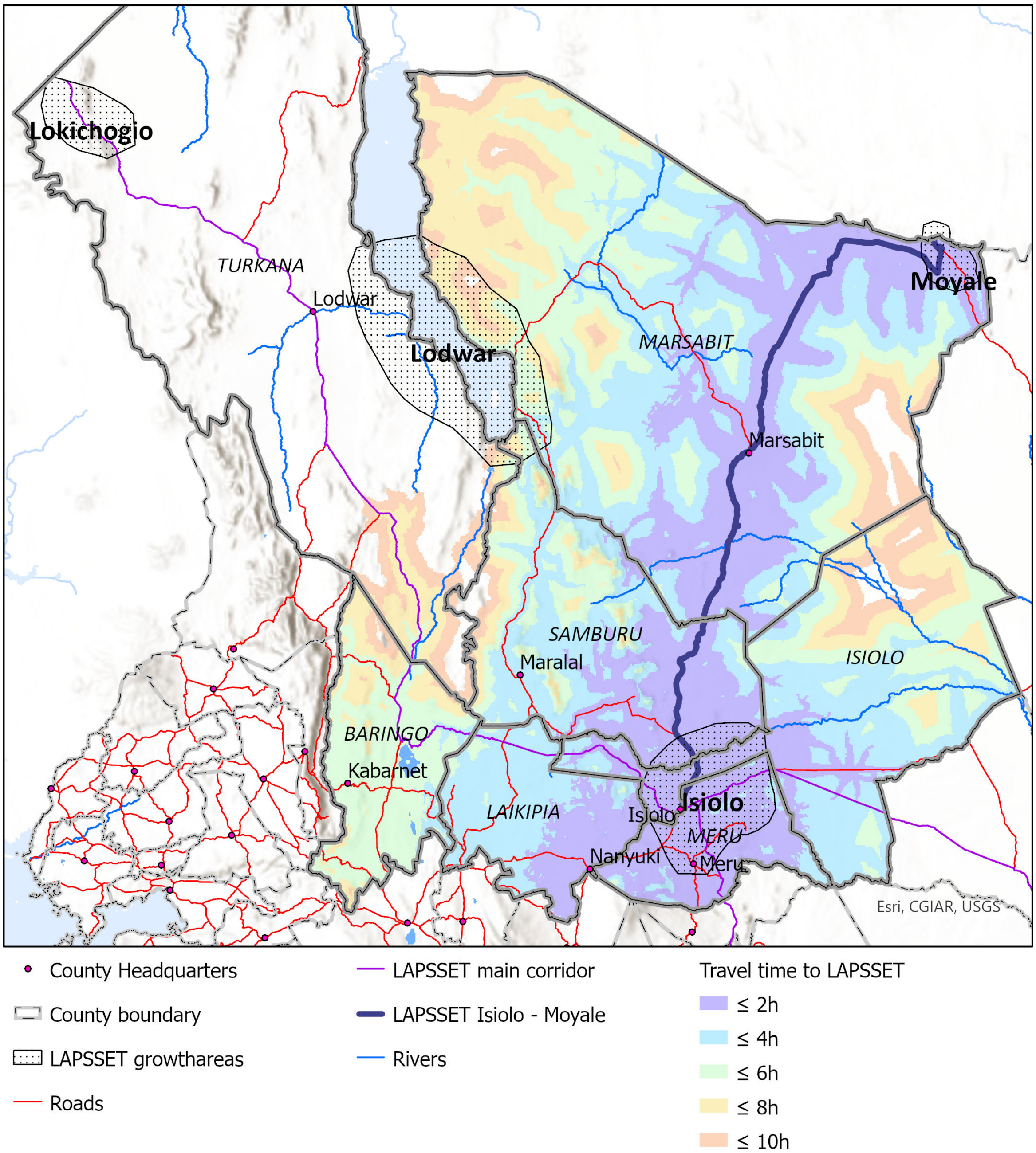
The complex climate in Kenya is simulated using the Weather Research and Forecasting (WRF) model (Skamarock et al. 2008), which dynamically downscales the climate over Kenya to a horizontal resolution of up to 1 km around Mt. Kenya. The simulations are driven by global model outputs of the Community Earth System Model CESM (version 1) (Kay et al. 2015) for two different periods. One period covers the years 1981–2010 and the other period simulates projections for the end of the century, i.e., 2071–2100, using the high-emission scenario RCP8.5. The most extreme scenario and a period far in the future are selected to observe an impact on temperature and precipitation and, hence, to quantify changes in the climate. Note that the simulations are one possible realisation of the chaotic climate system. The relatively high resolution used here, comes at the cost of the number of ensembles and different scenarios. To understand the robustness of our results, we try to put our simulations into the context of other climate simulations run for the Coupled Model Intercomparison Project (CMIP) Phase 5 and used for the IPCC-AR5 (2013).

Before running the climate simulations, extensive tests with different parameterization options have been performed (Messmer et al. 2021). Additionally, a climatology for the years 1999–2018, using the most recent reanalysis data ERA5 as initial and boundary conditions, has also been generated. These tests show that the model is able to capture fine-scale precipitation patterns relatively well, compared to other satellite-based data sets, such as CHIRPS (Funk et al. 2015), IMERG (Huffman et al. 2014) or TRMM (Huffman et al. 2010). In addition, the area around Mt. Kenya is covered by a large number of weather station data with long precipitation measurement series compared to other tropical areas in Africa. Many of these measurements are maintained by farmers. Thanks to the support and involvement of the Universities of Nairobi and Bern, these series are still available today (Liniger et al. 2005; MacMillan and Liniger 2005; Gichuki 1998). In addition to private stations, there are also some that are operated by the government of Kenya, i.e., the Kenya Forest Service or the Kenyan Meteorological Department. These observed precipitation series helped to further validate the regional climate model, in particular along the western slopes of Mt. Kenya. The simulations are run with 4 domains (see Appendix figure 3), whereby the respective inner domain is nested within the outer domain. The first domain has a resolution of 27 km and is followed by three sub-domains, each with a 3 times finer resolution, i.e., 9, 3 and 1 km. The innermost domain focusses on Mt. Kenya, while the second innermost domain extends especially towards Lake Victoria to capture the effect of this inland water body. The second domain (9 km) covers all of Kenya and extends further to the west of Africa. The results in this report are mainly based on the second domain, in order to get an overview of the entire country. One exception is Figure 4.3, which presents results from the innermost domain. The outermost domain covers most of Africa, from the southern Sahara Desert to Madagascar (approximately 15°N-20°S, 5°W-70°E, see Appendix figure 3).

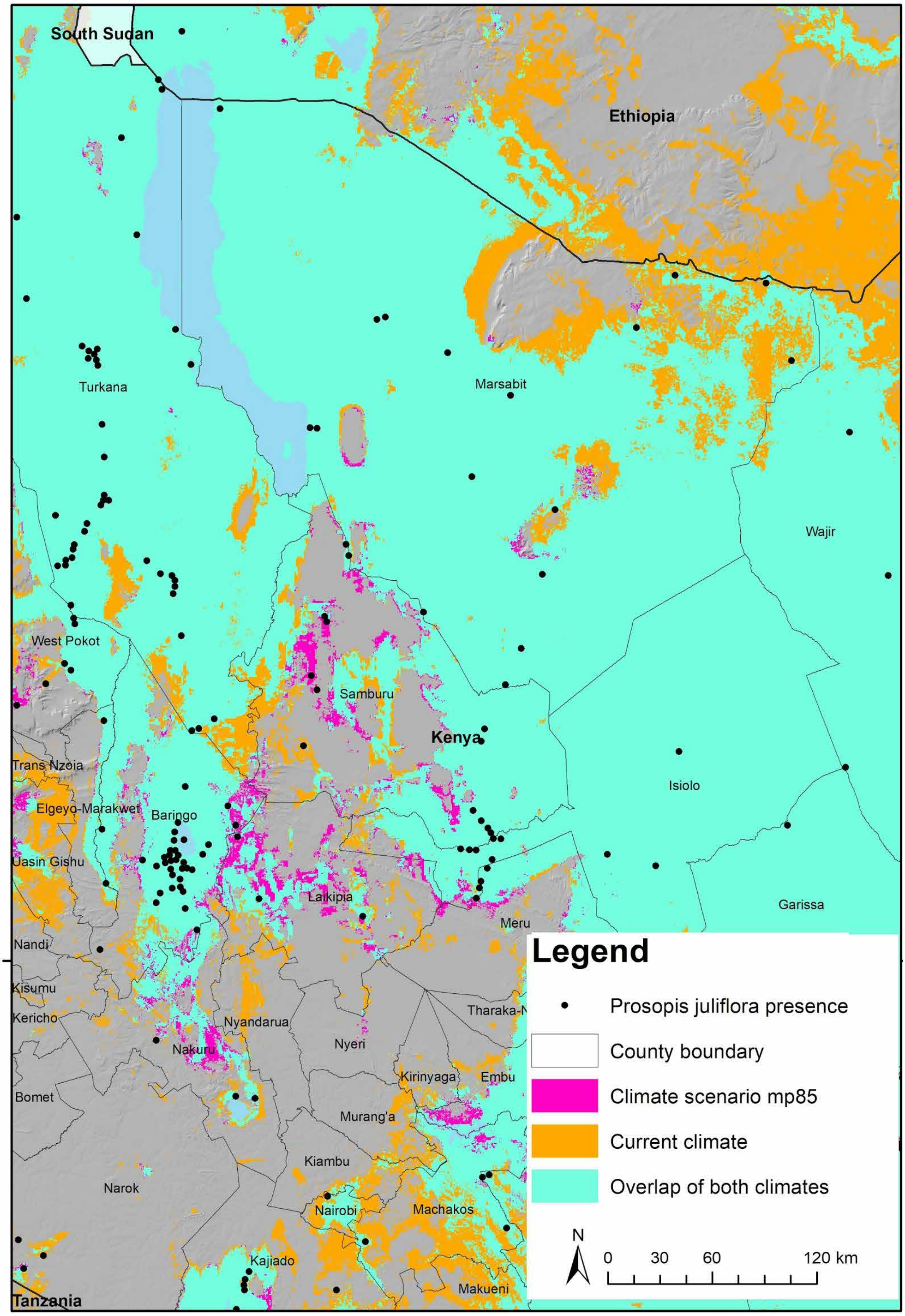
To obtain an estimate of changes in future fire risk, the fire weather index (FWI) is calculated for the regional climate simulations, following the definition in the Weather Guide for the Canadian Forest Fire Danger Rating System (Lawson and Armitage 2008). The FWI considers 2m temperature, relative humidity, wind speed and rain in its definition, but the availability of fire fuel is not included. Still, the FWI provides some indication on the initialization and distribution of fire. The FWI classifies fire danger into six categories from "very low" to "extreme". To evaluate the threat that the changes in temperature, and precipitation can impose on the local society, the heat index was calculated. This index is based on the definition suggested by the National Oceanic and Atmospheric Administration (NOAA). It employs a multiple regression analysis including temperature and relative humidity and assumptions about the human body and clothing. Here, we show maximum values on a daily basis, averaged over months.



Appendix figure 3: The domains of the presented WRF simulations are shown for D1 = 27 km, D2 = 9 km, D3 = 3 km and D4 = 1 km horizontal resolution. The grey shading indicates elevation in meters above sea level. (Source: WRF topography Global Multi-resolution Terrain Elevation Data [GMTED2010] provided by United States Geological Survey [USGS])



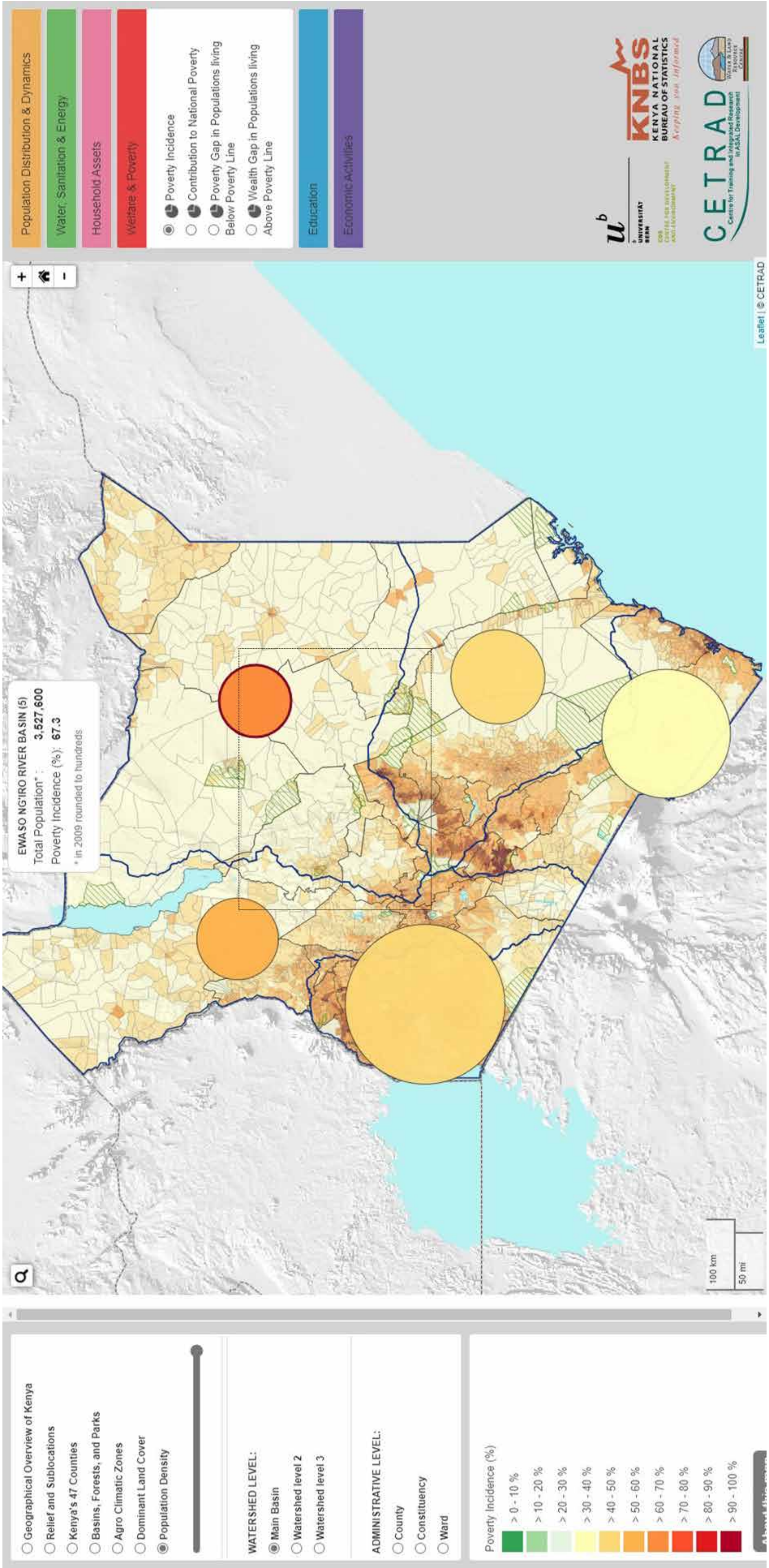
Appendix figure 4: Accessibility in travel time to the LAPSSET stretch Isiolo-Moyale (Source: Map design by CDE using data from CETRAD and Weiss et al. [2018])



Appendix figure 5: Comparison of species habitat models using current climate data and future climate scenario data (mp85) for Prosopis spp. Overlapping areas are shown in cyan, future habitat gains in pink, and future habitat losses in orange (Source: Eckert et al. 2020)

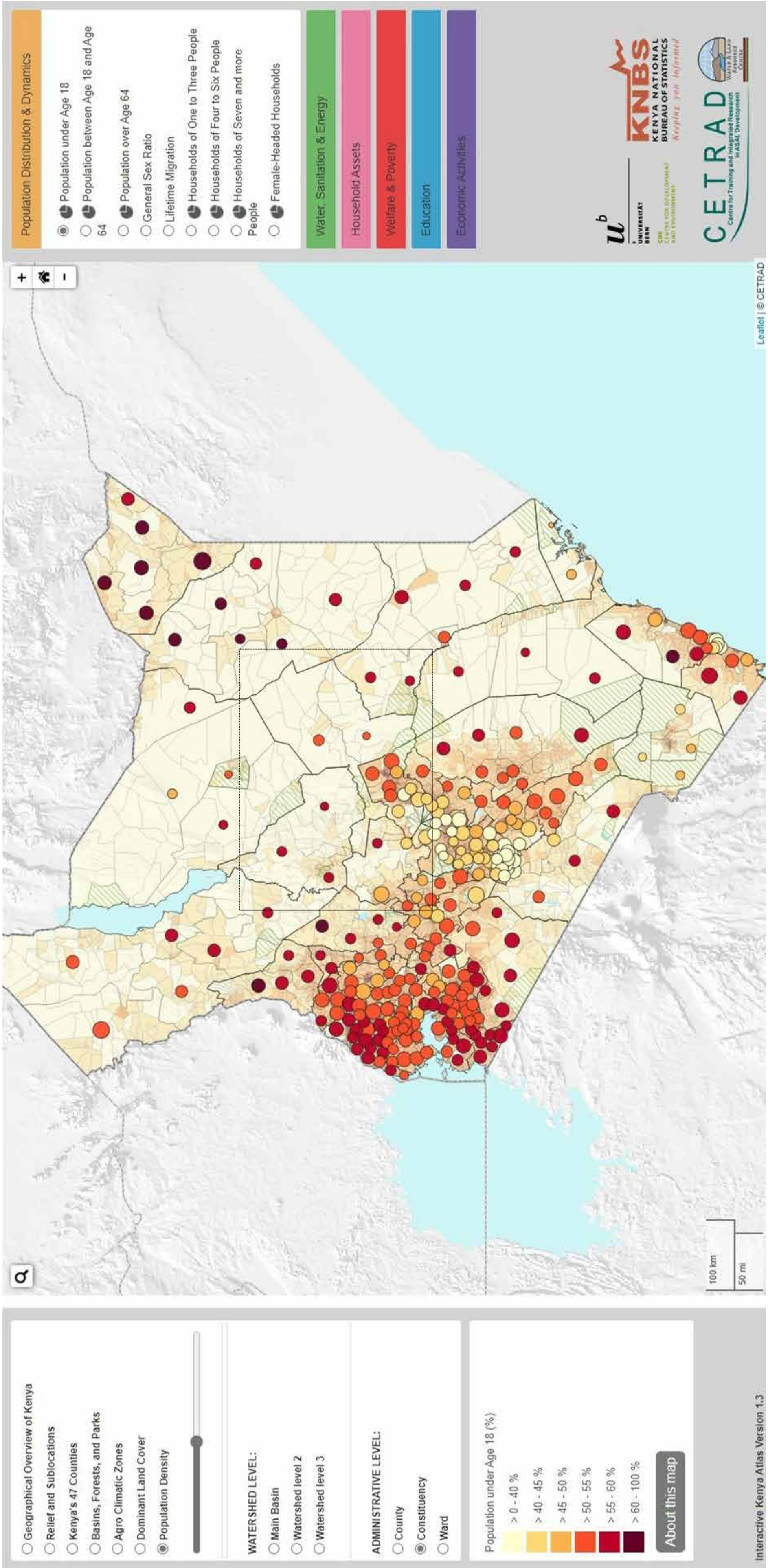
Appendix chapter 5

On the following pages: Figures extracted from Kenya Atlas (www.kenya-atlas.org)

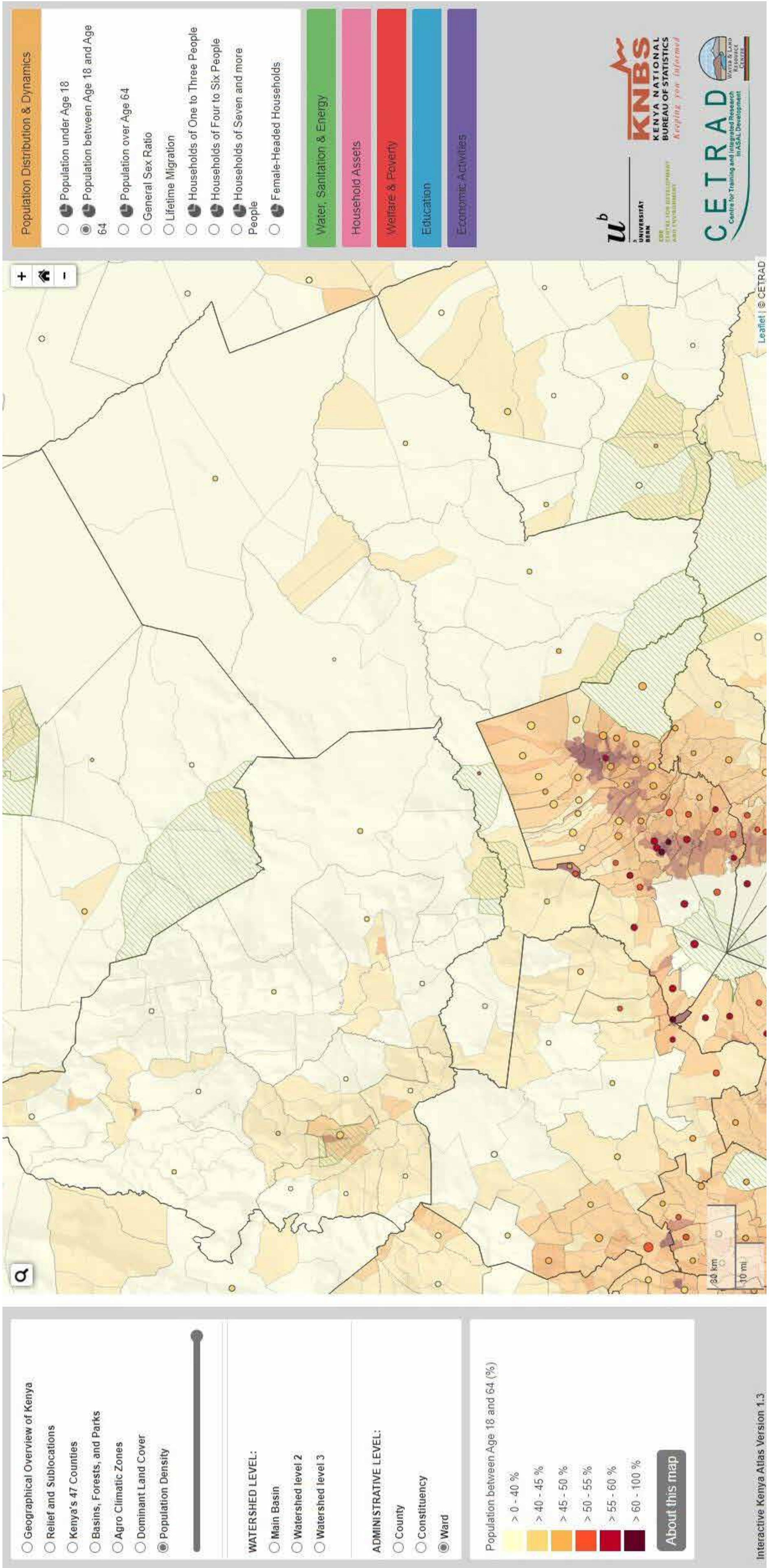


Appendix figure 6: Poverty incidence & population density (Source: Wiesmann et al. 2016)

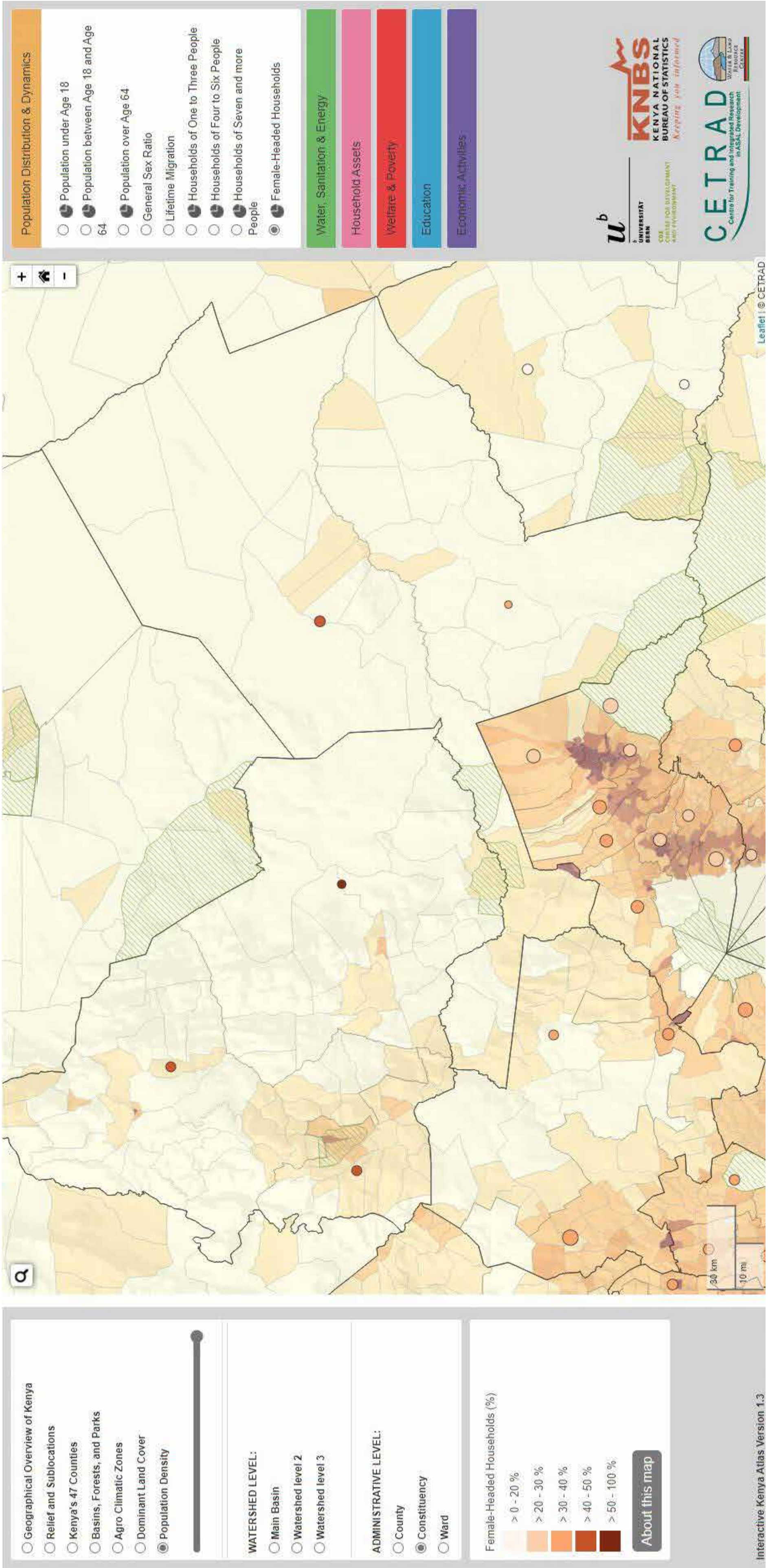
Appendix figure 7: Population under 18 years & population density (Source: Wiesmann et al. 2016)



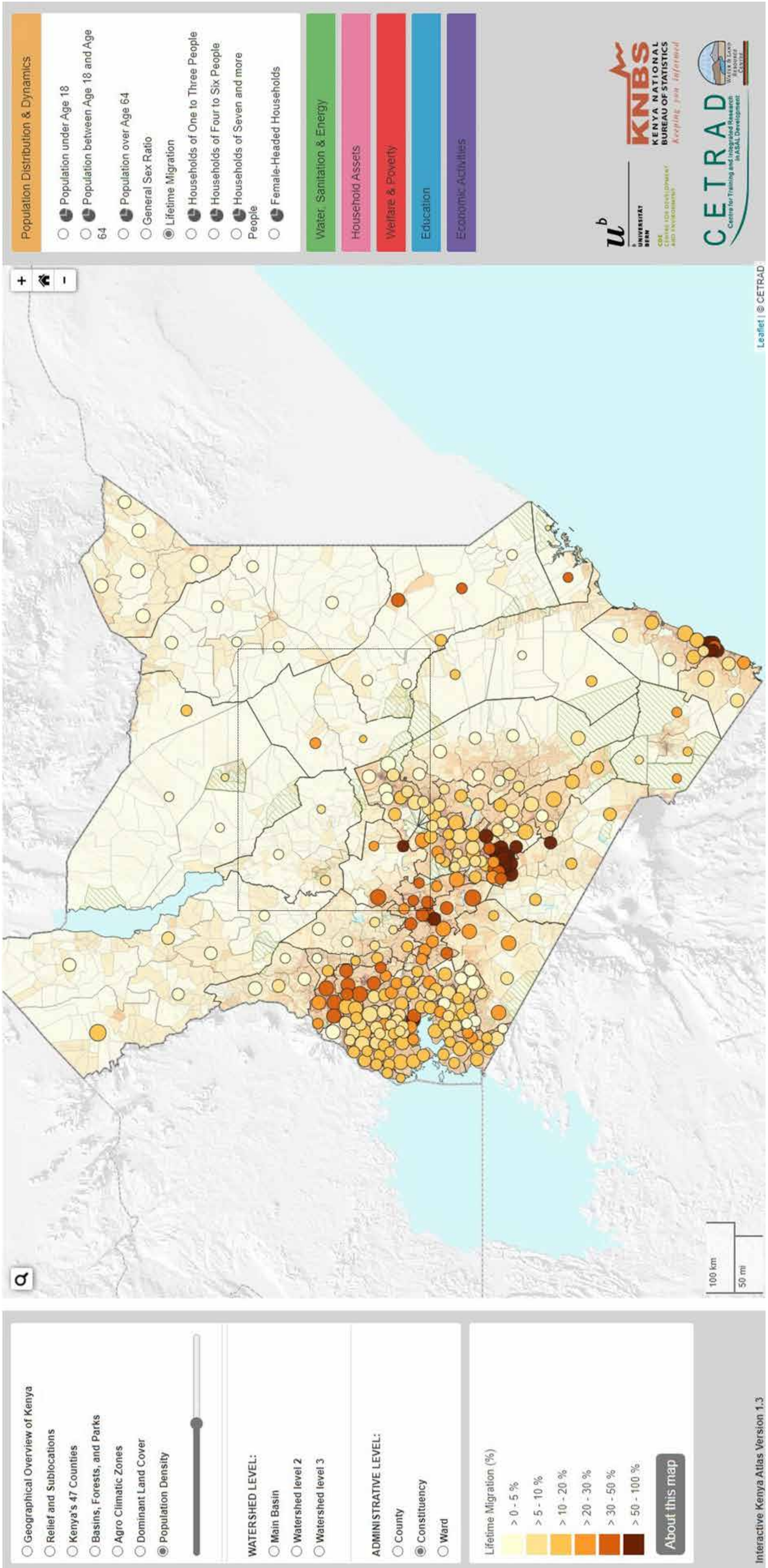
Appendix figure 8: Population between 18 – 64 years & population density (Source: Wiesmann et al. 2016)



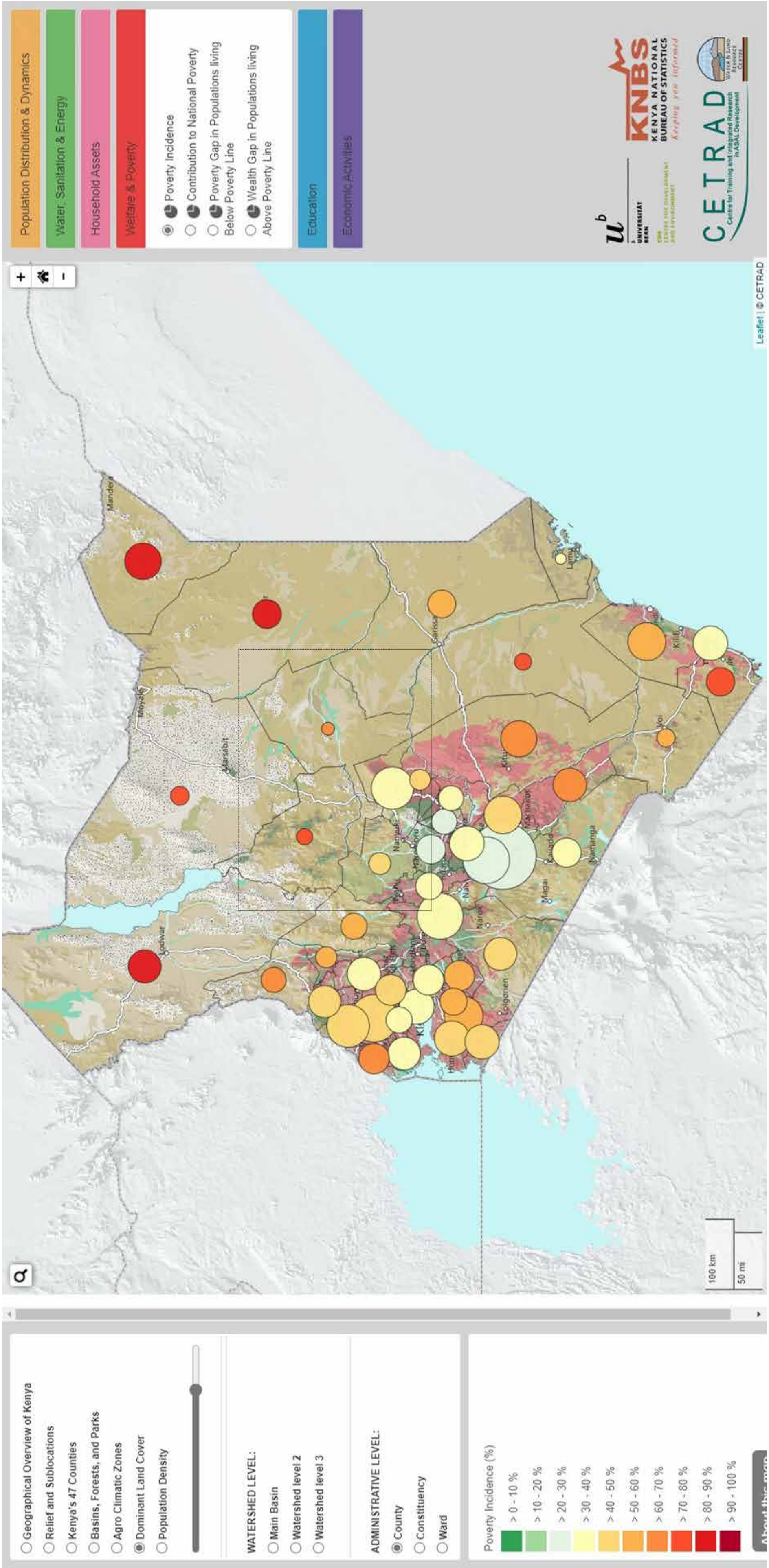
Appendix figure 9: Female-headed households & population density (Source: Wiesmann et al. 2016)



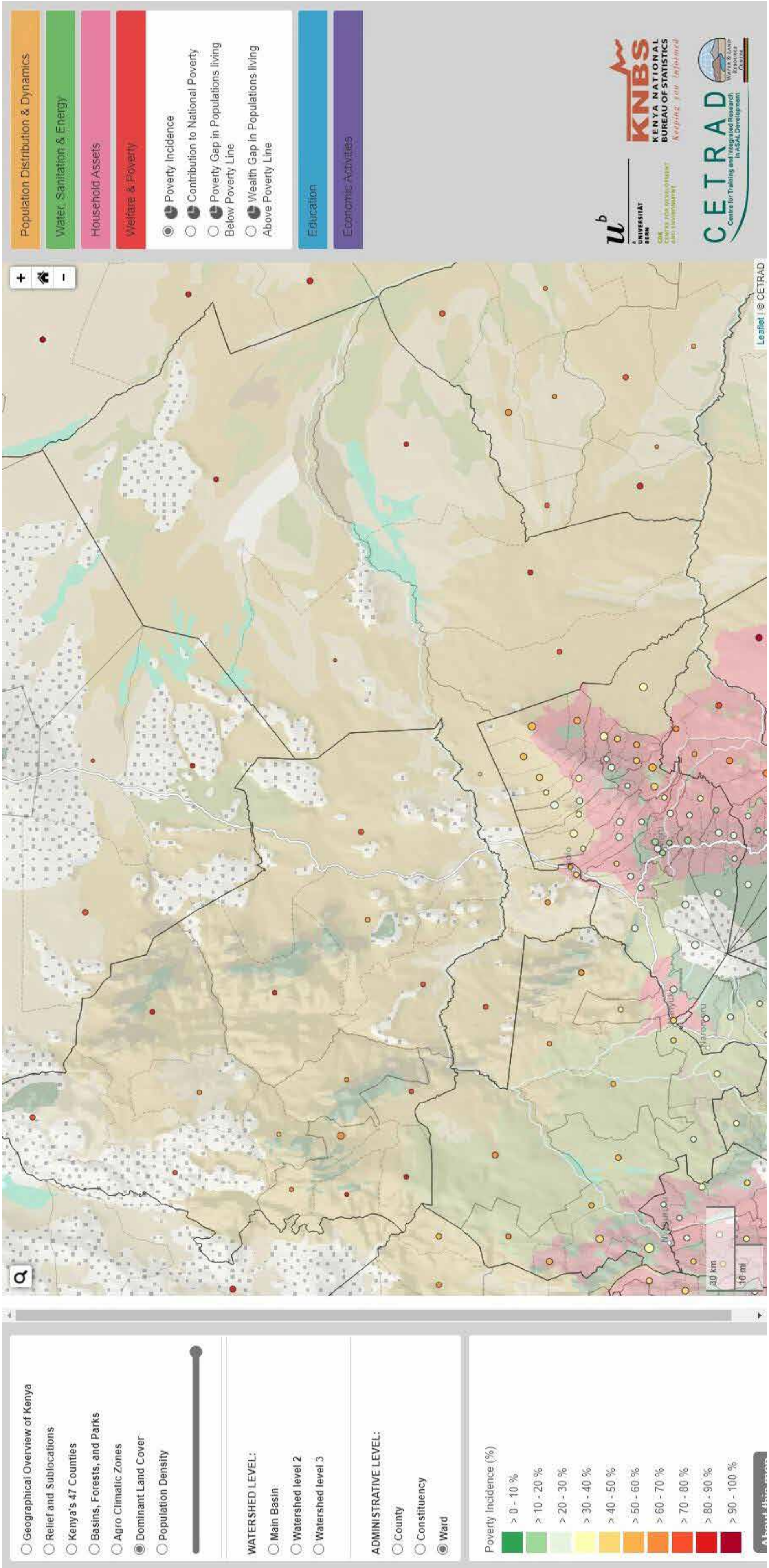
Appendix figure 10: Lifetime migration & population density (Source: Wiesmann et al. 2016)



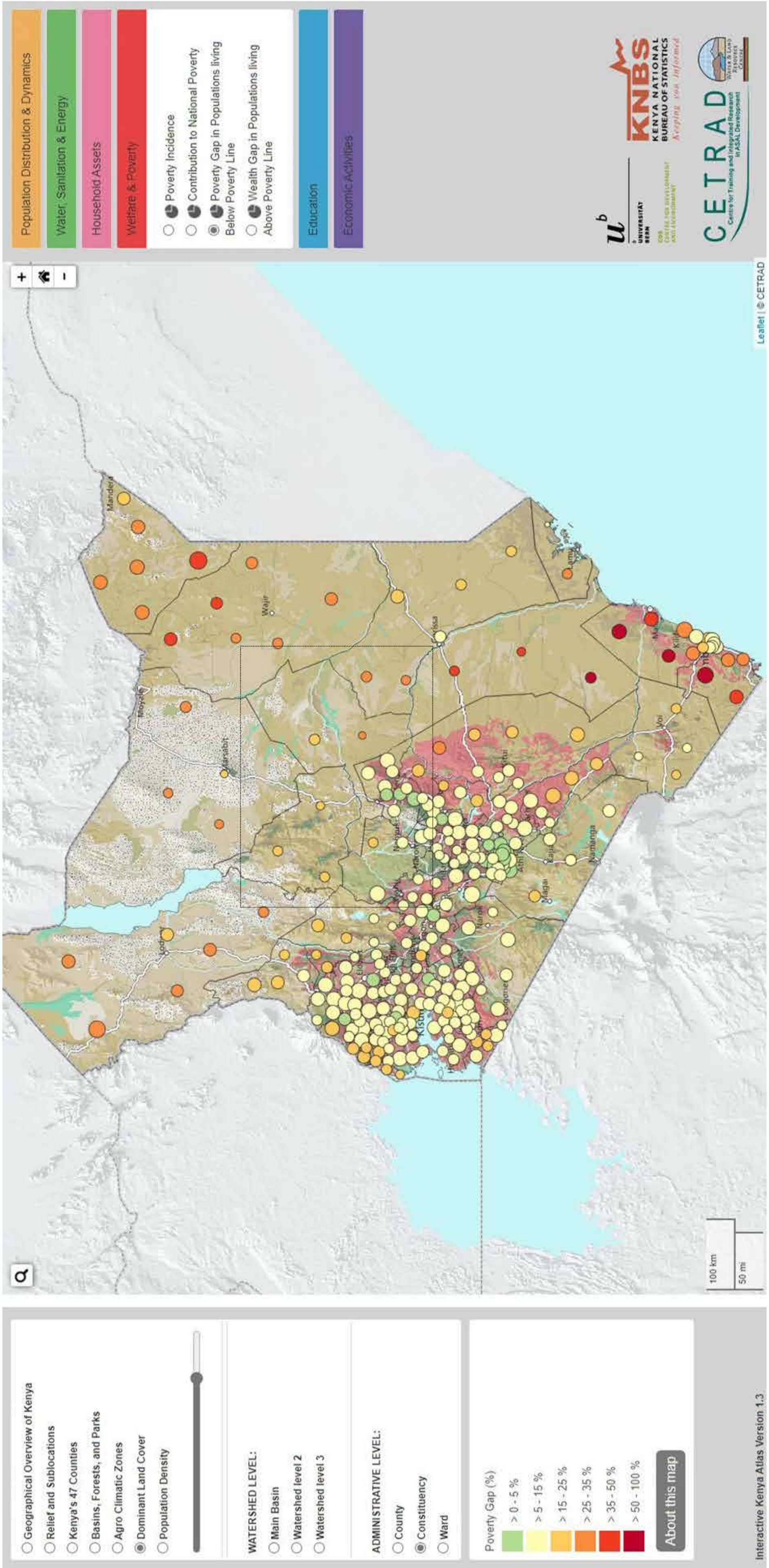
Appendix figure 11: Poverty incidence & dominant land cover (Source: Wiesmann et al. 2016)

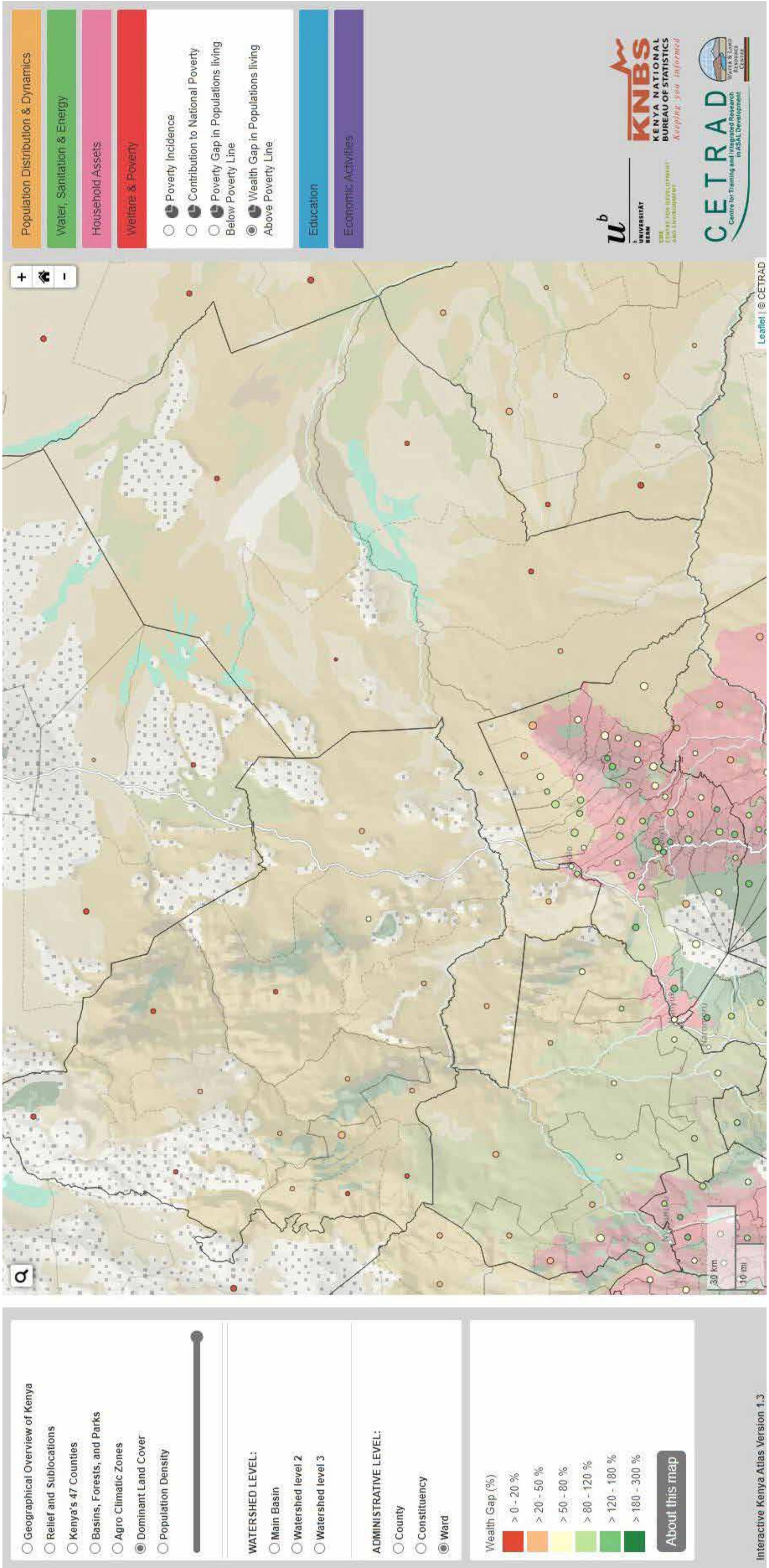


Appendix figure 12: Poverty incidence & dominant land cover – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)

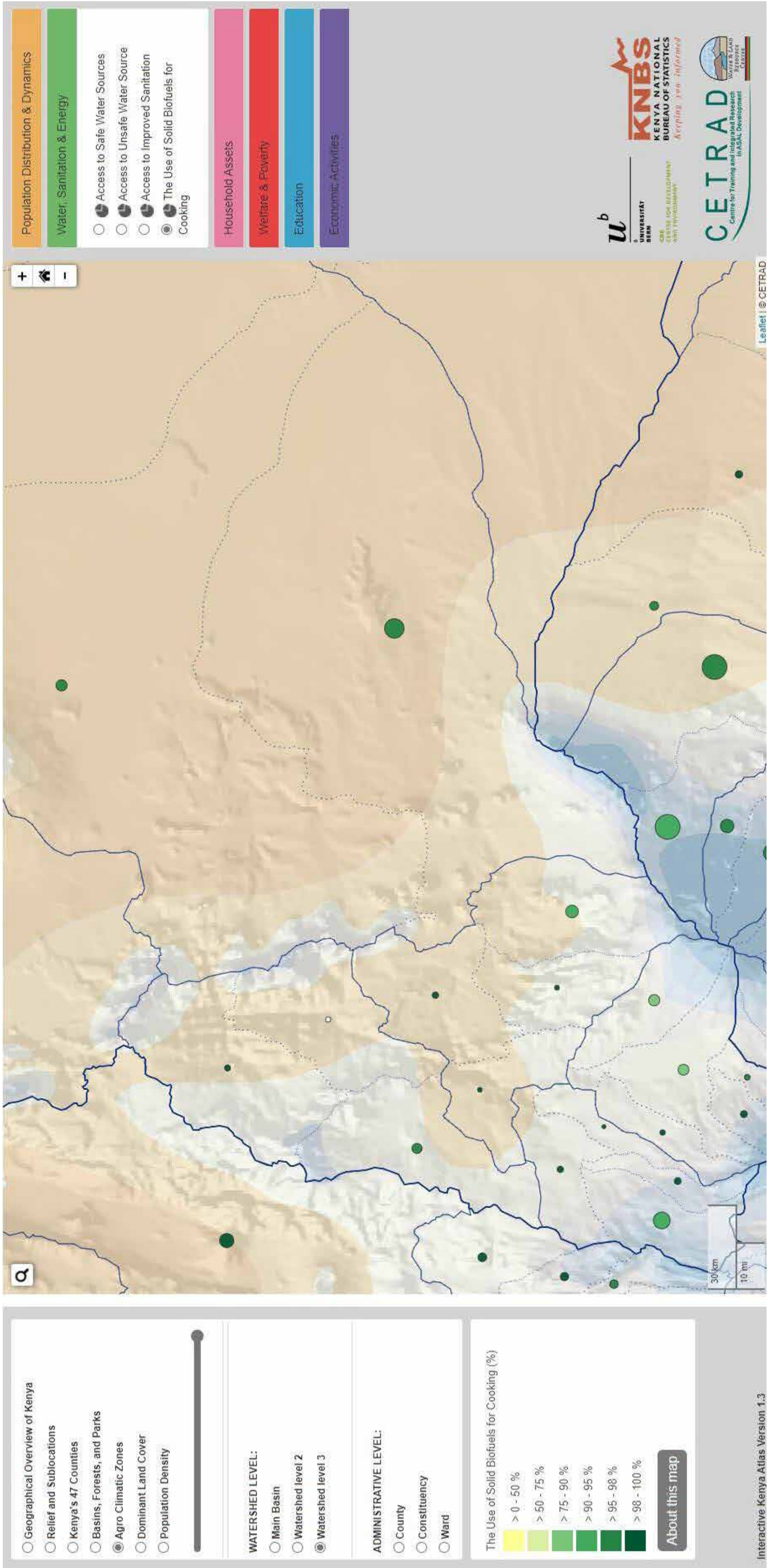


Appendix figure 13: Poverty gap & dominant land cover (Source: Wiesmann et al. 2016)



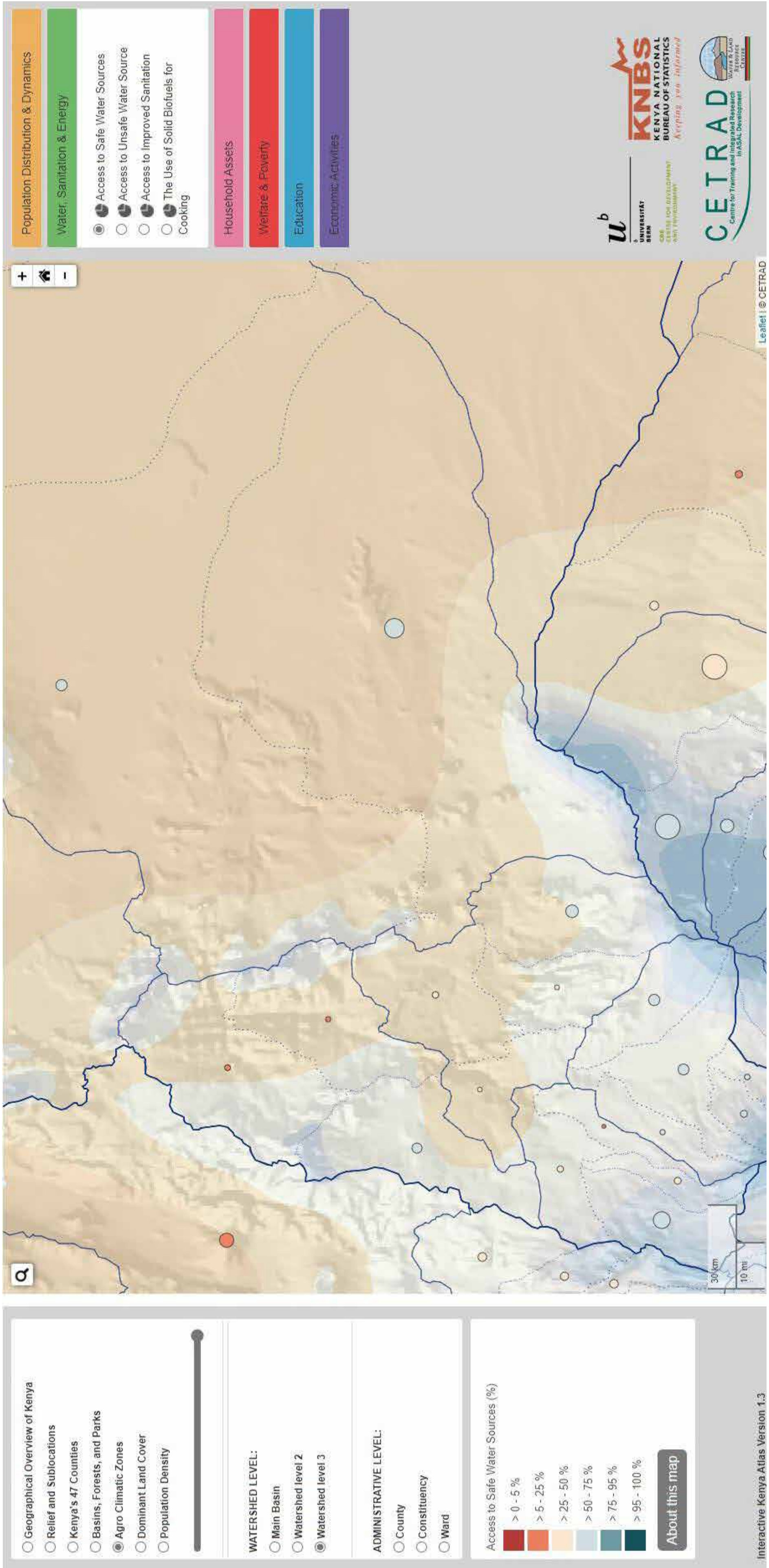


Appendix figure 14: Wealth gap & dominant land cover – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)

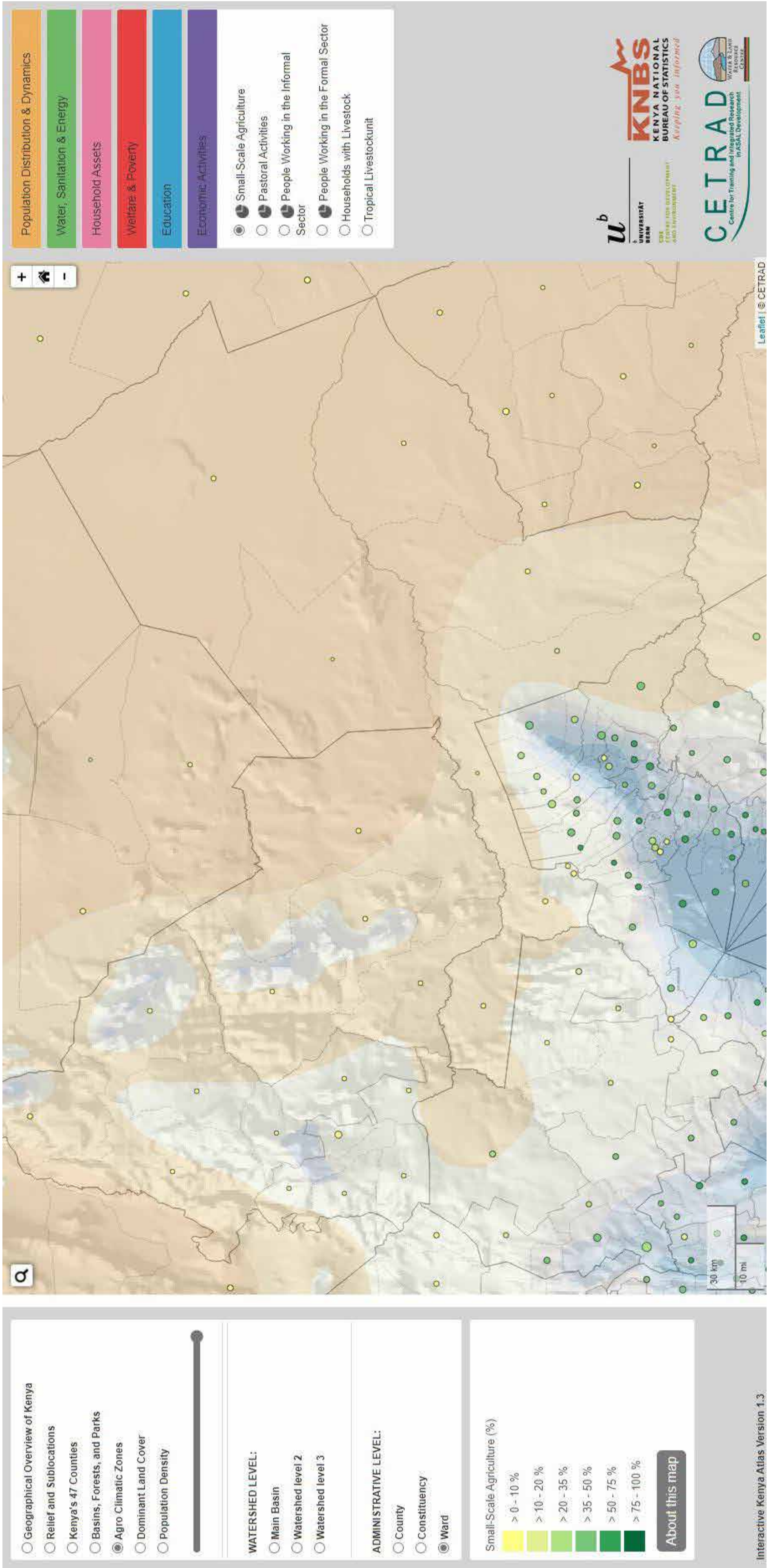


Appendix figure 15: Use of solid biofuels for cooking & agro climatic zones– zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)

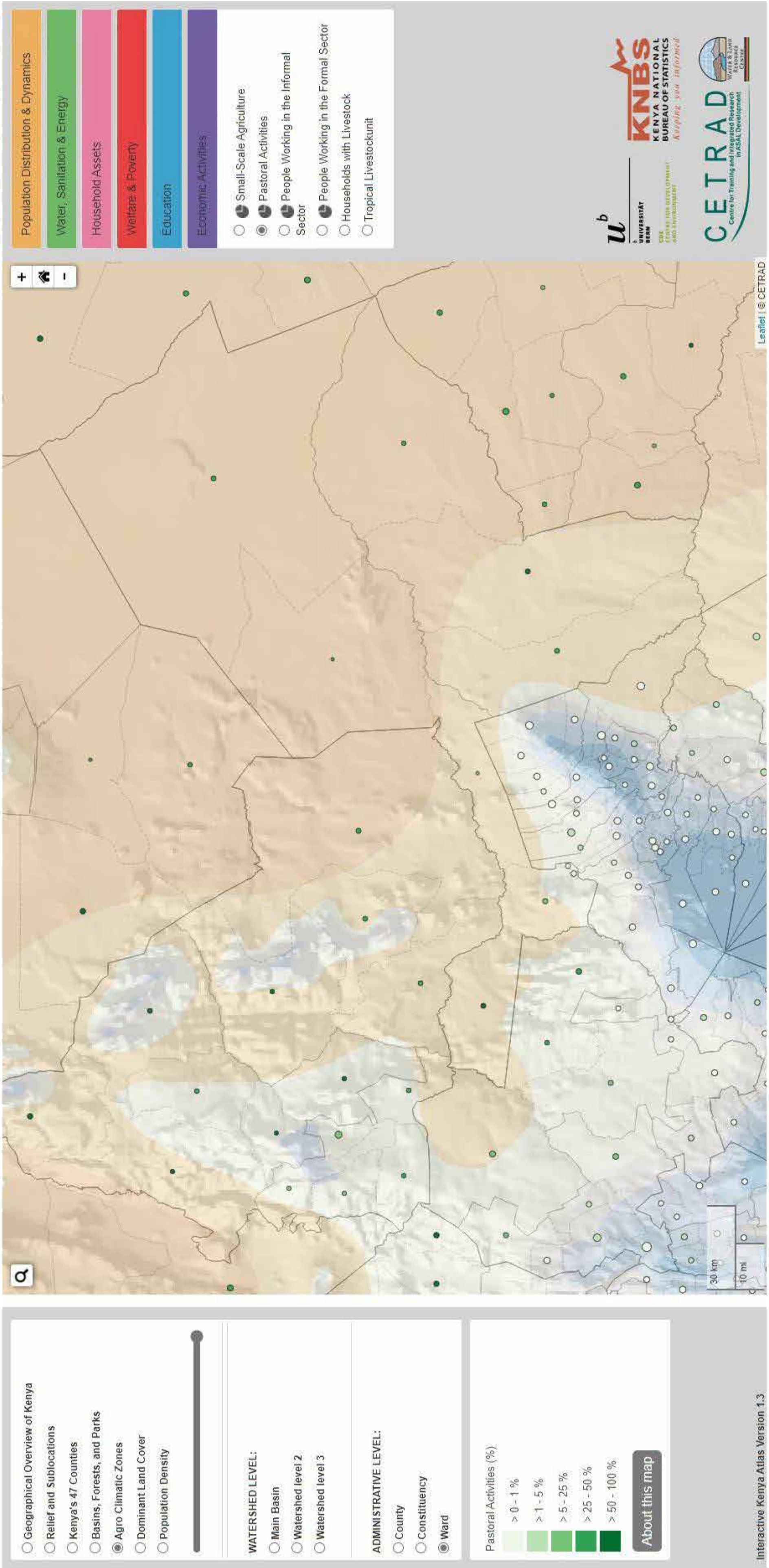
Appendix figure 16: Access to safe water sources & agro climatic zones – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)



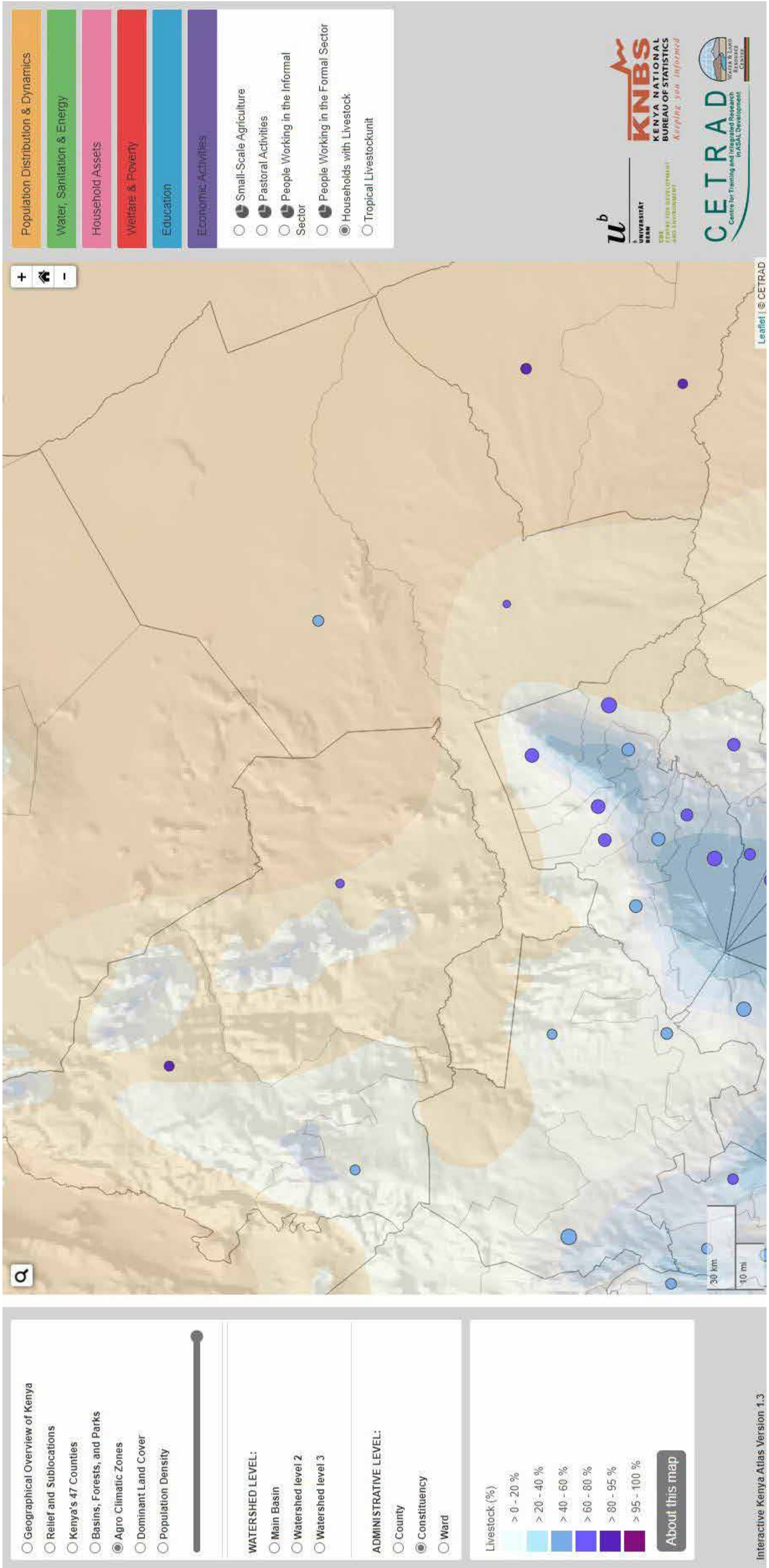
Appendix figure 17: Small-scale agriculture & agro climatic zones – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)

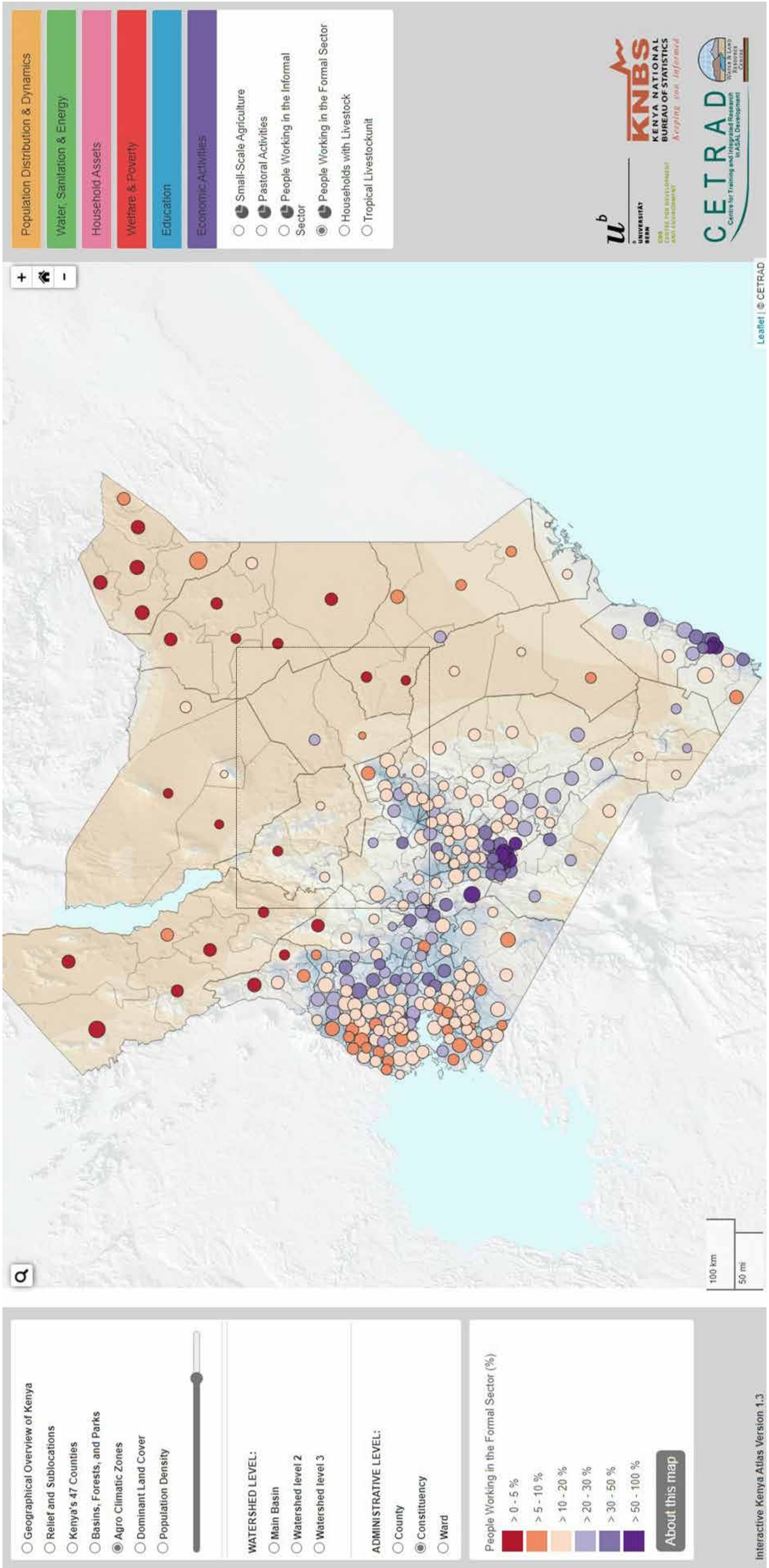


Appendix figure 18: Pastoral activities & agro climatic zones – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)



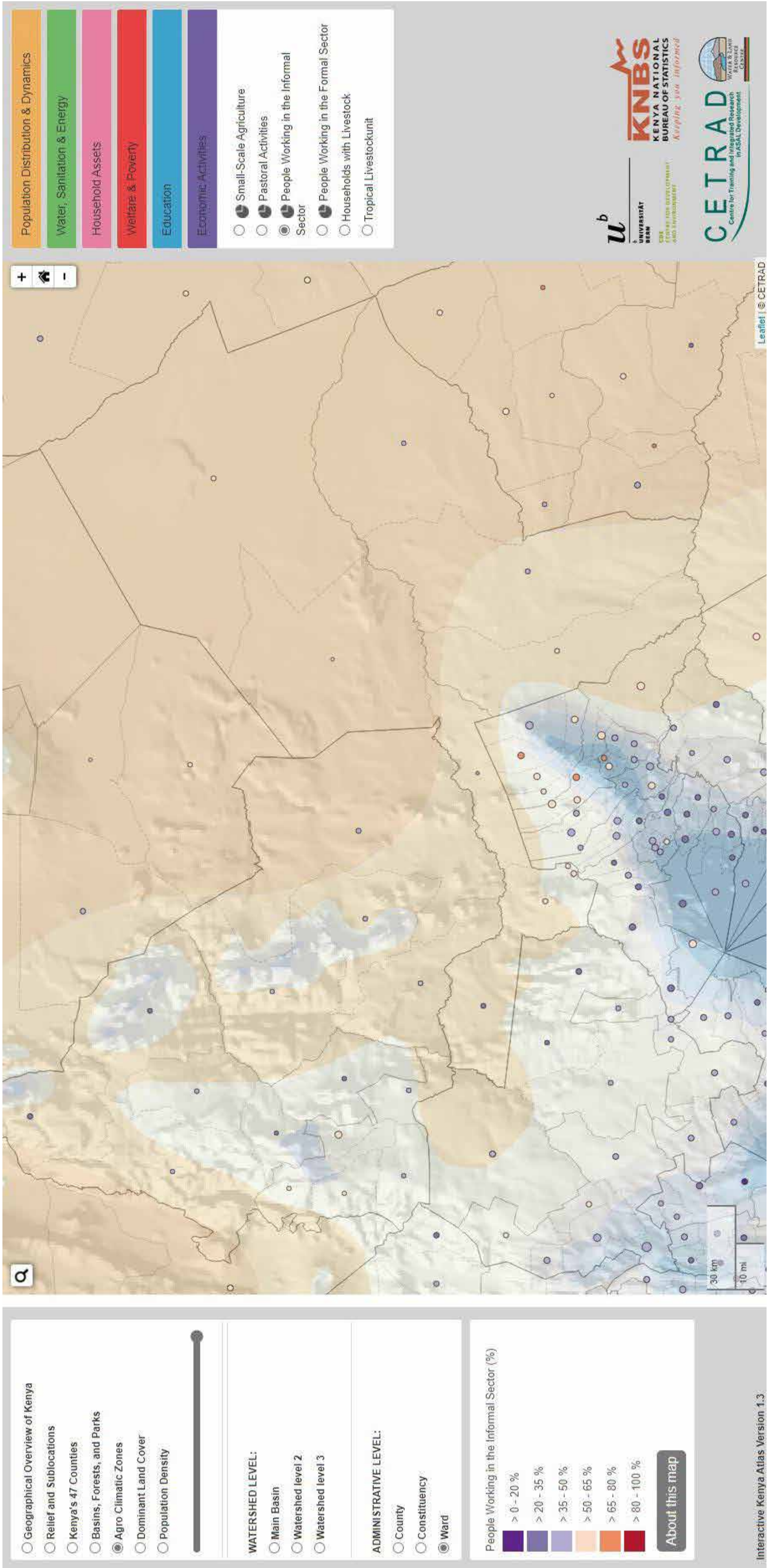
Appendix figure 19: Livestock & agro climatic zones – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)



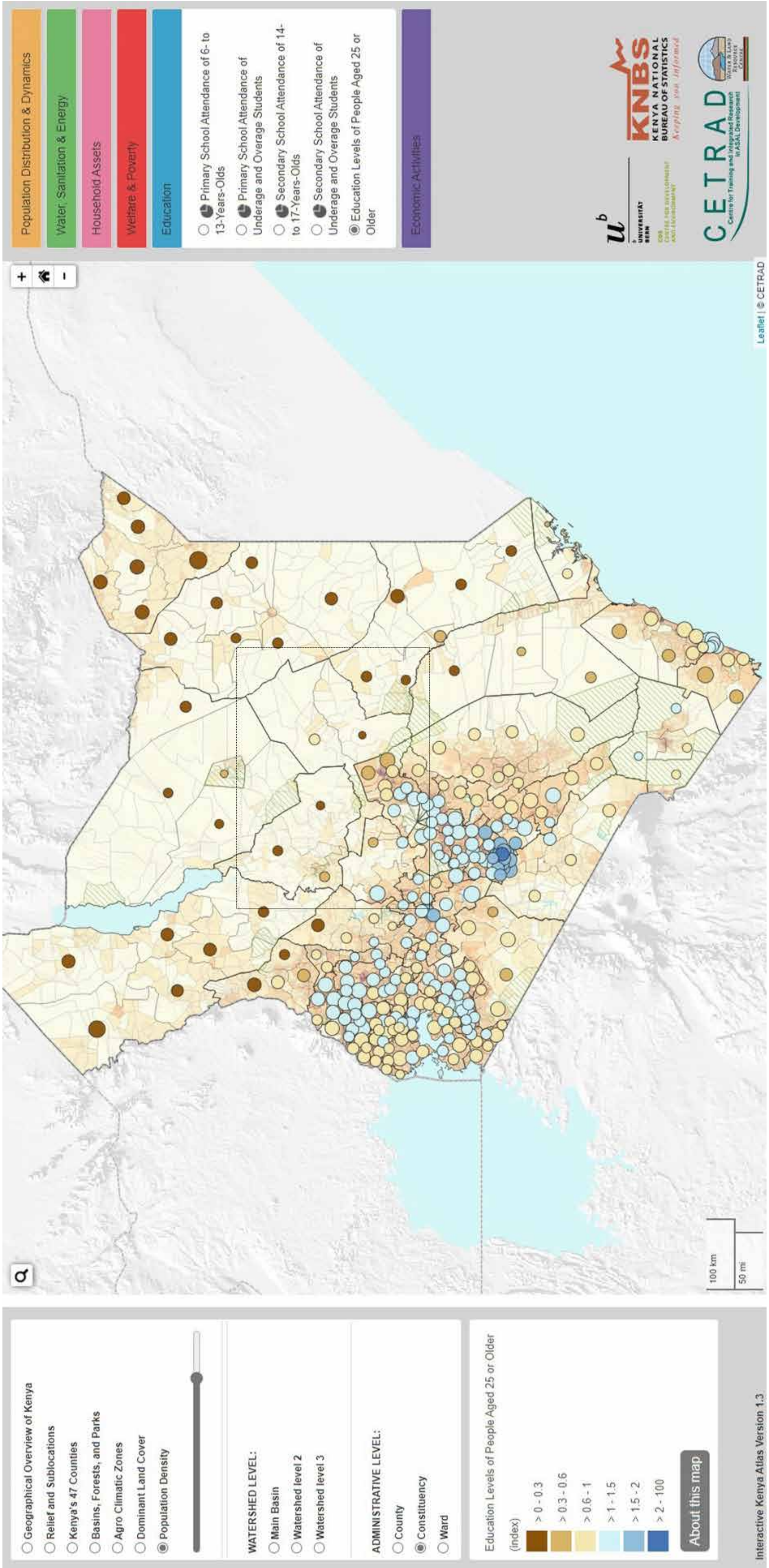


Appendix figure 20: Formal sector employment & agro climatic zones – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)

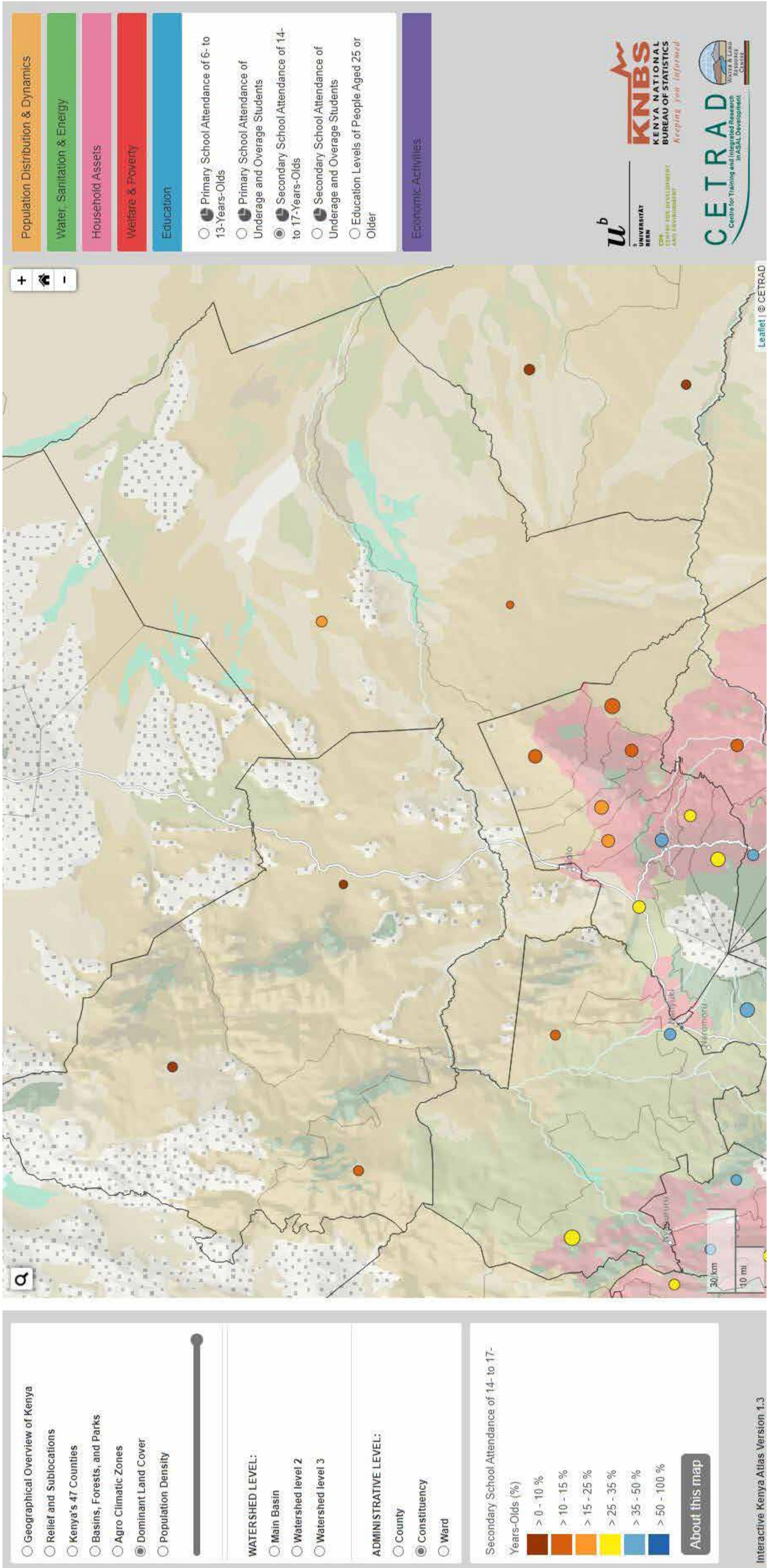
Appendix figure 21: Informal sector employment & agro climatic zones – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)



Appendix figure 22: Education level over age of 25 & agro climatic zones – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)



Appendix figure 23: Secondary school attendance of age 14 - 17 & agro climatic zones – zoom on Mt. Kenya–Ewaso Ng'iro landscape (Source: Wiesmann et al. 2016)



References

Ameso EA, Bukachi SA, Olungah CO, Haller T, Wandibba S, Nangendo S. 2018. Pastoral Resilience among the Maasai Pastoralists of Laikipia County, Kenya. Land. 7(2):78. doi:10.3390/land7020078.

Anderson GB, Bell ML, Peng DR. 2013. Methods to Calculate the Heat Index as an Exposure Metric in Environmental Health Research. Environ Health Perspect. 121(10):1111–1119. doi:10.1289/ehp.1206273.

Andersson S. 2005 Feb 3. Spread of the introduced tree species Prosopis juliflora (Sw.) DC in the Lake Baringo area, Kenya. 5. [accessed 2021 Mar 26]. https://stud.epsilon.slu.se/10961/.

Ayugi BO, Wen W, Chepkemoi D. 2016. Analysis of Spatial and Temporal Patterns of Rainfall Variations over Kenya. :15.

Bekele K, Haji J, Legesse B, Schaffner U. 2018. Economic impacts of Prosopis spp. invasions on dryland ecosystem services in Ethiopia and Kenya: Evidence from choice experimental data. J Arid Environ. 158:9–18. doi:10.1016/j.jaridenv.2018.07.001.

Bersaglio B, Cleaver F. 2018. Green Grab by Bricolage – The Institutional Workings of Community Conservancies in Kenya. Conserv Soc. 16(4):467. doi:10.4103/cs.cs_16_144.

Boles OJC, Shoemaker A, Courtney Mustaphi CJ, Petek N, Ekblom A, Lane PJ. 2019. Historical Ecologies of Pastoralist Overgrazing in Kenya: Long-Term Perspectives on Cause and Effect. Hum Ecol. 47(3):419–434. doi:10.1007/s10745-019-0072-9.

Bond J, Mkutu K. 2018. Exploring the Hidden Costs of Human–Wildlife Conflict in Northern Kenya. Afr Stud Rev. 61(1):33–54. doi:10.1017/asr.2017.134.

Bruyere BL, Trimarco J, Lemungesi S. 2016. A comparison of traditional plant knowledge between students and herders in northern Kenya. J Ethnobiol Ethnomedicine. 12(1):48. doi:10.1186/s13002-016-0121-z.

Bussmann RW. 1996. Destruction and Management of Mount Kenya's Forests. Ambio. 25(5):314–317.

Bussmann RW. 2006. Ethnobotany of the Samburu of Mt. Nyiru, South Turkana, Kenya. J Ethnobiol Ethnomedicine. 2(1):35. doi:10.1186/1746-4269-2-35.

Butynski TM, Jong YA de. 2014. Primate Conservation in the Rangeland Agroecosystem of Laikipia County, Central Kenya. Primate Conserv. 2014(28):117–128. doi:10.1896/052.028.0104.

Camberlin P, Philippon N. 2002. The East African March–May Rainy Season: Associated Atmospheric Dynamics and Predictability over the 1968–97 Period. J Clim. 15(9):1002–1019. doi:10.1175/1520-0442(2002)015<1002:TEAMMR>2.0.CO;2.

Campana MG, Parker LD, Hawkins MTR, Young HS, Helgen KM, Szykman Gunther M, Woodroffe R, Maldonado JE, Fleischer RC. 2016. Genome sequence, population history, and pelage genetics of the endangered African wild dog (Lycaon pictus). BMC Genomics. 17(1):1013. doi:10.1186/s12864-016-3368-9.

Carter NH, Bouley P, Moore S, Poulos M, Bouyer J, Pimm SL. 2018. Climate change, disease range shifts, and the future of the Africa lion. Conserv Biol. 32(5):1207–1210. doi:https://doi.org/10.1111/cobi.13102.

Chongwa MB. 2012. The History and Evolution of National Parks in Kenya. George Wright Forum. 29(1):39–42.

Cockerill K, Hagerman S. 2020. Historical insights for understanding the emergence of community-based conservation in Kenya: international agendas, colonial legacies, and contested worldviews. Ecol Soc. 25(2). doi:10.5751/ES-11409-250215. [accessed 2021 Jul 10]. http://www.ecologyandsociety.org/vol25/iss2/art15/.

Cruise A, Zee B van der. 2017 Feb 2. Armed herders invade Kenya's most important wildlife conservancy. the Guardian. [accessed 2021 Jul 11]. http://www.theguardian.com/environment/2017/feb/02/armed-herders-elephant-kenya-wildlife-laikipia.

Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Báldi A, et al. 2015. The IPBES Conceptual Framework — connecting nature and people. Curr Opin Environ Sustain. 14:1–16. doi:10.1016/j.cosust.2014.11.002.

Didan K. 2015. MOD13Q1 MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V006. [accessed 2021 Apr 16]. https://doi.org/10.5067/MODIS/MOD13Q1.006.

Dudenhoeffer M, Hodge A-MC. 2018. Opposing forces of seed dispersal and seed predation by mammals for an invasive cactus in central Kenya. Afr J Ecol. 56(2):179–184. doi:https://doi.org/10.1111/aje.12504.

Dzikiti S, Ntshidi Z, Le Maitre DC, Bugan RDH, Mazvimavi D, Schachtschneider K, Jovanovic NZ, Pienaar HH. 2017. Assessing water use by Prosopis invasions and Vachellia karroo trees: Implications for groundwater recovery following alien plant removal in an arid catchment in South Africa. For Ecol Manag. 398:153–163. doi:10.1016/j.foreco.2017.05.009.

Eckert S, Hamad A, Kilawe CJ, Linders TEW, Ng W-T, Mbaabu PR, Shiferaw H, Witt A, Schaffner U. 2020. Niche change analysis as a tool to inform management of two invasive species in Eastern Africa. Ecosphere. 11(2):e02987. doi:https://doi.org/10.1002/ecs2.2987.

Eckert S, Kiteme B, Njuguna E, Zaehringer J. 2017. Agricultural Expansion and Intensification in the Foothills of Mount Kenya: A Landscape Perspective. Remote Sens. 9(8):784. doi:10.3390/rs9080784.

Ericksen P, Leeuw J de, Said M, Silvestri S, Zaibet L. 2012. Mapping ecosystem services in the Ewaso Ng'iro catchment. Int J Biodivers Sci Ecosyst Serv Manag. 8(1–2):122–134. doi:10.1080/21513732.2011.651487.

Evans LA, Adams WM. 2018. Elephants as actors in the political ecology

of human–elephant conflict. Trans Inst Br Geogr. 43(4):630–645. doi:https://doi.org/10.1111/tran.12242.
Farr TG, Rosen PA, Caro E, Crippen R, Duren R, Hensley S, Kobrick M, Paller M, Rodriguez E, Roth L, et al. 2007a. The Shuttle Radar Topography Mission. Rev Geophys. 45(2). doi:10.1029/2005RG000183. [accessed 2020 Mar 5]. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2005RG000183.
Farr TG, Rosen PA, Caro E, Crippen R, Duren R, Hensley S, Kobrick M, Paller M, Rodriguez E, Roth L, et al. 2007b. The Shuttle Radar Topography Mission. Rev Geophys. 45(2). doi:10.1029/2005RG000183. [accessed 2020 Mar 5]. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2005RG000183.
Friedl M, Sula-Menashe D. 2019. MCD12Q1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V006. [accessed 2021 Apr 16]. https://doi.org/10.5067/MODIS/MCD12Q1.006.
Funk C, Peterson P, Landsfeld M, Pedreros D, Verdin J, Shukla S, Husak G, Rowland J, Harrison L, Hoell A, et al. 2015. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Sci Data. 2(1):150066. doi:10.1038/sdata.2015.66.
Gadd ME. 2005. Conservation outside of parks: attitudes of local people in Laikipia, Kenya. Environ Conserv. 32(1):50–63. doi:10.1017/S0376892905001918.
Gakuubi MM, Wanzala W. 2012. A survey of plants and plant products traditionally used in livestock health management in Buuri district, Meru County, Kenya. J Ethnobiol Ethnomedicine. 8(1):39. doi:10.1186/1746-4269-8-39.
Gakuya DW, Itonga SM, Mbaria JM, Muthee JK, Musau JK. 2013. Ethnobotanical survey of biopesticides and other medicinal plants traditionally used in Meru central district of Kenya. J Ethnopharmacol. 145(2):547–553. doi:10.1016/j.jep.2012.11.028.
Gichuki F. 1998. Knowledge about highland–lowland interactions: The role of a natural resource information system.
Giger M, Mutea E, Kiteme B, Eckert S, Anseeuw W, Zaehringer JG. 2020. Large agricultural investments in Kenya's Nanyuki Area: Inventory and analysis of business models. Land Use Policy. 99:104833. doi:10.1016/j.landusepol.2020.104833.
Goheen JR, Augustine DJ, Veblen KE, Kimuyu DM, Palmer TM, Porensky LM, Pringle RM, Ratnam J, Riginos C, Sankaran M, et al. 2018. Conservation lessons from large-mammal manipulations in East African savannas: the KLEE, UHURU, and GLADE experiments. Ann N Y Acad Sci. 1429(1):31–49. doi:https://doi.org/10.1111/nyas.13848.
Graham M, Kiteme B, Ehrensperger A, editors. 2015. Biodiversity conservation and wildlife management. In: Eastern and Southern Africa partnership programme: highlights from 15 years of joint action for sustainable development. Bern: Centre for Development and Environment (CDE), University of Bern.

Green SE, Davidson Z, Kaaria T, Doncaster CP. 2018. Do wildlife corridors link or extend habitat? Insights from elephant use of a Kenyan wildlife corridor. Afr J Ecol. 56(4):860–871. doi:10.1111/aje.12541.

Hastenrath S, Polzin D, Mutai C. 2011. Circulation Mechanisms of Kenya Rainfall Anomalies. J Clim. 24(2):404–412. doi:10.1175/2010JCLI3599.1.

Huffman GJ, Adler RF, Bolvin DT, Nelkin EJ. 2010. The TRMM Multi-Satellite Precipitation Analysis (TMPA). In: Gebremichael M, Hossain F, editors. Satellite Rainfall Applications for Surface Hydrology. Dordrecht: Springer Netherlands. p. 3–22. [accessed 2021 Apr 16]. https://doi.org/10.1007/978-90-481-2915-7_1.

Huffman GJ, Bolvin DT, Braithwaite D, Hsu K, Joyce R, Xie P. 2014. Integrated Multi-satellitE Retrievals for GPM (IMERG), version 4.4., NASA's Precipitation Processing Center. [accessed 2021 Apr 16]. https://gpm.nasa.gov/sites/default/files/document_files/IMERG_ATBD_V4.4.pdf.

Ihwagi FW, Thouless C, Wang T, Skidmore AK, Omondi P, Douglas-Hamilton I. 2018. Night-day speed ratio of elephants as indicator of poaching levels. Ecol Indic. 84:38–44. doi:10.1016/j.ecolind.2017.08.039.

Ihwagi FW, Wang T, Wittemyer G, Skidmore AK, Toxopeus AG, Ngene S, King J, Worden J, Omondi P, Douglas-Hamilton I. 2015. Using Poaching Levels and Elephant Distribution to Assess the Conservation Efficacy of Private, Communal and Government Land in Northern Kenya. PLOS ONE. 10(9):e0139079. doi:10.1371/journal.pone.0139079.

Kaburi SM, Medley KE. 2011. Community Perspectives on Fuelwood Resources in East Africa. Mt Res Dev. 31(4):315–324. doi:10.1659/MRD-JOURNAL-D-10-00121.1.

Kagunyu AW, Thuranira EG, Wanjohi JG. 2017. Development agents and their role in cushioning the pastoralists of Isiolo Central Sub-County, Kenya, against negative effects of climate variability. Pastoralism. 7(1):33. doi:10.1186/s13570-017-0103-3.

Kay JE, Deser C, Phillips A, Mai A, Hannay C, Strand G, Arblaster JM, Bates SC, Danabasoglu G, Edwards J, et al. 2015. The Community Earth System Model (CESM) Large Ensemble Project: A Community Resource for Studying Climate Change in the Presence of Internal Climate Variability. Bull Am Meteorol Soc. 96(8):1333–1349. doi:10.1175/BAMS-D-13-00255.1.

Kebede AT, Coppock DL. 2015. Livestock-Mediated Dispersal of Prosopis juliflora Imperils Grasslands and the Endangered Grevy's Zebra in Northeastern Ethiopia. Rangel Ecol Manag. 68(5):402–407. doi:10.1016/j.rama.2015.07.002.

Kendi B. 2014 Oct 10. Exploring the link between forests, traditional custodianship and community livelihoods: The Case of Nyambene forest in Kenya. For Chron. doi:10.5558/tfc2014-121. [accessed 2021 Apr 5]. https://pubs.cif-ifc.org/doi/abs/10.5558/tfc2014-121.

Kimiti DW, Hodge A-MC, Herrick JE, Beh AW, Abbott LE. 2017. Rehabilitation of community-owned, mixed-use rangelands: lessons from the Ewaso ecosystem in Kenya. Plant Ecol. 218(1):23–37. doi:10.1007/s11258-016-0691-9.

Kinga GW, Mironga J, Odadi WO. 2018. Analysis of the Spatial Relationship between Cattle and Wild Ungulates across Different Land-Use Systems in a Tropical Savanna Landscape. Int J Ecol. 2018:e2072617. doi:10.1155/2018/2072617.

Kiringe JW, Okello MM. 2005. Use and availability of tree and shrub resources on Maasai communal rangelands near Amboseli, Kenya. Afr J Range Forage Sci. 22(1):37–45. doi:10.2989/10220110509485860.

Kleinschroth F, Schöning C, Kung'u JB, Kowarik I, Cierjacks A. 2013. Regeneration of the East African timber tree Ocotea usambarensis in relation to historical logging. For Ecol Manag. 291:396–403. doi:10.1016/j.foreco.2012.11.021.

Lalampaa PK, Wasonga OV, Rubenstein DI, Njoka JT. 2016. Effects of holistic grazing management on milk production, weight gain, and visitation to grazing areas by livestock and wildlife in Laikipia County, Kenya. Ecol Process. 5(1):17. doi:10.1186/s13717-016-0061-5.

Lanari N, Liniger H, Kiteme B. 2016. Commercial Horticulture in Kenya: Adapting to Water Scarcity. Bern: Centre for Development and Environment (CDE), University of Bern CDE Policy Brief Report No.: 8.

Lanari N, Schuler R, Kohler T, Liniger H. 2018. The Impact of Commercial Horticulture on River Water Resources in the Upper Ewaso Ng'iro River Basin, Kenya. Mt Res Dev. 38(2):114–124. doi:10.1659/MRD-JOURNAL-D-16-00135.

Lawson BD, Armitage OB. 2008. Weather Guide for the Canadian Forest Fire Danger Rating System. :87.

Lelenguyah GL. 2012. Drought, diseases and Grevy's zebra (Equus grevyi) mortality – the Samburu people perspective. Afr J Ecol. 50(3):371–376. doi:https://doi.org/10.1111/j.1365-2028.2011.01317.x.

Liebmann B, Hoerling MP, Funk C, Bladé I, Dole RM, Allured D, Quan X, Pegion P, Eischeid JK. 2014. Understanding Recent Eastern Horn of Africa Rainfall Variability and Change. J Clim. 27(23):8630–8645. doi:10.1175/JCLI-D-13-00714.1.

Liniger H, Gikonyo J, Kiteme B, Wiesmann U. 2005. Assessing and Managing Scarce Tropical Mountain Water Resources. Mt Res Dev. 25(2):163–173. doi:10.1659/0276-4741(2005)025[0163:AAMSTM]2.0.CO;2.

MacMillan L, Liniger HP. 2005. Monitoring and Modelling for the Sustainable Management of Water Resources in Tropical Mountain Basins: The Mount Kenya Example. In: Huber UM, Bugmann HKM, Reasoner MA, editors. Global Change and Mountain Regions: An Overview of Current Knowledge. Dordrecht: Springer Netherlands. (Advances in Global Change Research). p. 605–616. [accessed 2021 Apr 16]. https://doi.org/10.1007/1-4020-3508-X_60.

Matheka RM. 2008. Decolonisation and Wildlife Conservation in Kenya, 1958–68. J Imp Commonw Hist. 36(4):615–639. doi:10.1080/03086530802561016.

Maundu P, Kibet S, Morimoto Y, Imbumi M, Adeka R. 2009. Impact of Prosopis juliflora on Kenya's semi-arid and arid ecosystems and local livelihoods. Biodiversity. 10(2–3):33–50. doi:10.1080/14888386.2009.9712842.

Messmer M, González-Rojí SJ, Raible CC, Stocker TF. 2021. Sensitivity of precipitation and temperature over the Mount Kenya area to physics parameterization options in a high-resolution model simulation performed with WRFV3.8.1. Geosci Model Dev. 14(5):2691–2711. doi:10.5194/gmd-14-2691-2021.

Milbau A, Graae BJ, Shevtsova A, Nijs I. 2009. Effects of a warmer climate on seed germination in the subarctic. Ann Bot. 104(2):287–296. doi:10.1093/aob/mcp117.

Mitchell AM, Bruyere BL, Otieno TO, Bhalla S, Teel TL. 2019. A comparison between human-carnivore conflicts and local community attitudes toward carnivores in Westgate Community Conservancy, Samburu, Kenya. Hum Dimens Wildl. 24(2):168–179. doi:10.1080/10871209.2018.1548671.

M'mboroki KG, Wandiga S, Oriaso SO. 2018. Climate change impacts detection in dry forested ecosystem as indicated by vegetation cover change in —Laikipia, of Kenya. Environ Monit Assess. 190(4):255. doi:10.1007/s10661-018-6630-6.

Mungai DN, Ong CK, Kiteme B, Elkaduwa W, Sakthivadivel R. 2004. Lessons from two long-term hydrological studies in Kenya and Sri Lanka. Agric Ecosyst Environ. 104(1):135–143. doi:10.1016/j.agee.2004.01.011.

Mureithi SM, Verdoodt A, Njoka JT, Gachene CKK, Ranst EV. 2016. Benefits Derived from Rehabilitating a Degraded Semi-Arid Rangeland in Communal Enclosures, Kenya. Land Degrad Dev. 27(8):1853–1862. doi:https://doi.org/10.1002/ldr.2341.

Musila S, Chen Z-Z, Li Q, Yego R, Zhang B, Onditi K, Muthoni I, He S-W, Omondi S, Mathenge J, et al. 2019. Diversity and distribution patterns of non-volant small mammals along different elevation gradients on Mt. Kenya, Kenya. Zool Res. 40(1):53–60. doi:10.24272/j.issn.2095-8137.2019.004.

Mutea E, Bottazzi P, Jacobi J, Kiteme B, Speranza CI, Rist S. 2019. Livelihoods and Food Security Among Rural Households in the North-Western Mount Kenya Region. Front Sustain Food Syst. 3. doi:10.3389/fsufs.2019.00098. [accessed 2021 Mar 30]. https://www.frontiersin.org/articles/10.3389/fsufs.2019.00098/full.

Muthaura CN, Keriko JM, Mutai C, Yenesew A, Gathirwa JW, Irungu BN, Nyangacha R, Mungai GM, Derese S. 2015. Antiplasmodial potential of traditional phytotherapy of some remedies used in treatment of malaria in Meru–Tharaka Nithi County of Kenya. J Ethnopharmacol. 175:315–323. doi:10.1016/j.jep.2015.09.017.

Mutiga JK, Mavengano ST, Zhongbo S, Woldai T, Becht R. 2010. Water Allocation as a Planning Tool to Minimise Water Use Conflicts in the Upper Ewaso Ng'iro North Basin, Kenya. Water Resour Manag. 24(14):3939–3959. doi:10.1007/s11269-010-9641-9.

Muturi GM, Poorter L, Mohren GMJ, Kigomo BN. 2013. Ecological impact of Prosopis species invasion in Turkwel riverine forest, Kenya. J Arid Environ. 92:89–97. doi:10.1016/j.jaridenv.2013.01.010.

Mwangi E, Swallow B. 2008. Prosopis juliflora Invasion and Rural Livelihoods in the Lake Baringo Area of Kenya. Conserv Soc. 6(2):130. doi:10.4103/0972-4923.49207.

Mwita E, Menz G, Misana S, Becker M, Kisanga D, Boehme B. 2013. Mapping small wetlands of Kenya and Tanzania using remote sensing techniques. Int J Appl Earth Obs Geoinformation. 21:173–183. doi:10.1016/j.jag.2012.08.010.

Nanyingi MO, Mbaria JM, Lanyasunya AL, Wagate CG, Koros KB, Kaburia HF, Munenge RW, Ogara WO. 2008. Ethnopharmacological survey of Samburu district, Kenya. J Ethnobiol Ethnomedicine. 4(1):14. doi:10.1186/1746-4269-4-14.

Ndeereh D, Oloo T, Rono B, Manoa D, Bundotich G. 2019. Towards saving an endangered species: Rehabilitation of hand-raised striped hyaena cubs in Meru National Park, Kenya. Afr J Ecol. 57(1):144–147. doi:https://doi.org/10.1111/aje.12579.

Nicholson S. 2016. The Turkana low-level jet: mean climatology and association with regional aridity. Int J Climatol. 36(6):2598–2614. doi:https://doi.org/10.1002/joc.4515.

Nicholson SE. 2016. An analysis of recent rainfall conditions in eastern Africa. Int J Climatol. 36(1):526–532. doi:10.1002/joc.4358.

NOAA. 2014. NOAA - National Weather Prediction Center. The Heat Index Equation. [accessed 2021 Mar 22]. https://www.wpc.ncep.noaa.gov/html/heatindex_equation.shtml.

Nyingi DW, Gichuki N, Ogada MO. 2013. Chapter 16 - Freshwater Ecology of Kenyan Highlands and Lowlands. In: Paron P, Olago DO, Omuto CT, editors. Developments in Earth Surface Processes. Vol. 16. Elsevier. (Kenya: A Natural Outlook). p. 199–218. [accessed 2021 Apr 5]. https://www.sciencedirect.com/science/article/pii/B9780444595591000165.

Nyongesa KW, Vacik H. 2018. Fire Management in Mount Kenya: A Case Study of Gathiuru Forest Station. Forests. 9(8):481. doi:10.3390/f9080481.

Ogada DL, Keesing F. 2010. Decline of Raptors over a Three-Year Period in Laikipia, Central Kenya. J Raptor Res. 44(2):129–135. doi:10.3356/JRR-09-49.1.

Ogutu JO, Piepho H-P, Said MY, Ojwang GO, Njino LW, Kifugo SC, Wargute PW. 2016. Extreme Wildlife Declines and Concurrent Increase in Livestock Numbers in Kenya: What Are the Causes? PLOS ONE. 11(9):e0163249. doi:10.1371/journal.pone.0163249.

Otuoma J, Kinyamario J, Ekaya W, Kshatriya M, Nyabenge M. 2009. Effects of human–livestock–wildlife interactions on habitat in an eastern Kenya rangeland. Afr J Ecol. 47(4):567–573. doi:https://doi.org/10.1111/j.1365-2028.2008.01009.x.

Pas A. 2018. Governing Grazing and Mobility in the Samburu Lowlands, Kenya. Land. 7(2):41. doi:10.3390/land7020041.

Paula Kahumbu. 2017 Jun 26. Changing the course of history for Kenya’s wildlife. the Guardian. [accessed 2021 Jul 11]. http://www.theguardian.com/environment/africa-wild/2017/jun/26/changing-the-course-of-history-for-kenyas-wildlife.

Rucina SM, Muiruri VM, Kinyanjui RN, McGuiness K, Marchant R. 2009. Late Quaternary vegetation and fire dynamics on Mount Kenya. Palaeogeogr Palaeoclimatol Palaeoecol. 283(1):1–14. doi:10.1016/j.palaeo.2009.08.008.

Saji NH, Goswami BN, Vinayachandran PN, Yamagata T. 1999. A dipole mode in the tropical Indian Ocean. Nature. 401(6751):360–363. doi:10.1038/43854.

Schmocker J, Liniger HP, Ngeru JN, Brugnara Y, Auchmann R, Brönnimann S. 2016. Trends in mean and extreme precipitation in the Mount Kenya region from observations and reanalyses. Int J Climatol. 36(3):1500–1514. doi:10.1002/joc.4438.

Shackleton RT, Witt AB, Aool W, Pratt CF. 2017. Distribution of the invasive alien weed, Lantana camara, and its ecological and livelihood impacts in eastern Africa. Afr J Range Forage Sci. 34(1):1–11. doi:10.2989/10220119.2017.1301551.

Shiferaw H, Alamirew T, Dzikiti S, Bewket W, Zeleke G, Schaffner U. 2021. Water use of Prosopis juliflora and its impacts on catchment water budget and rural livelihoods in Afar Region, Ethiopia. Sci Rep. 11(1):2688. doi:10.1038/s41598-021-81776-6.

Silvestri S, Zaibet L, Said MY, Kifugo SC. 2013. Valuing ecosystem services for conservation and development purposes: A case study from Kenya. Environ Sci Policy. 31:23–33. doi:10.1016/j.envsci.2013.03.008.

Skamarock W, Klemp J, Dudhia J, Gill D, Barker D, Wang W, Huang X-Y, Duda M. 2008. A Description of the Advanced Research WRF Version 3. UCAR/NCAR. [accessed 2021 Apr 16]. http://opensky.ucar.edu/islandora/object/technotes:500.

Sundaresan SR, Riginos C. 2010. LESSONS LEARNED FROM BIODIVERSITY CONSERVATION IN THE PRIVATE LANDS OF LAIKIPIA, KENYA. Gt Plains Res. 20(1):17–27.

Svengren H, Prettejohn M, Bunge D, Fundi P, Björklund M. 2017. Relatedness and genetic variation in wild and captive populations of Mountain Bongo in Kenya obtained from genome-wide single-nucleotide polymorphism (SNP) data. Glob Ecol Conserv. 11:196–206. doi:10.1016/j.gecco.2017.07.001.

Tari D, Pattison J. 2014. Evolving Customary Institutions in the Drylands: An opportunity for devolved natural resource governance in Kenya? Publ Libr. [accessed 2021 Apr 16]. https://pubs.iied.org/10076iied.

Thenya T. 2001. Challenges of conservation of dryland shallow waters, Ewaso Narok swamp, Laikipia District, Kenya. Hydrobiologia. 458(1):107–119. doi:10.1023/A:1013196500456.

Trewartha GT. 1981. The earth's problem climates. By G. T. Trewartha. (University of Wisconsin), Madison, 1961. Pp. vi, 334; 168 Figures; Tables. $7.50. Q J R Meteorol Soc. 87(373):460–461. doi:https://doi.org/10.1002/qj.49708737325.

Ulrich A. 2014. Export-Oriented Horticultural Production in Laikipia, Kenya: Assessing the Implications for Rural Livelihoods. Sustainability. 6(1):336–347. doi:10.3390/su6010336.

Ulrich A, Ifejika Speranza C, Roden P, Kiteme B, Wiesmann U, Nüsser M. 2012. Small-scale farming in semi-arid areas: Livelihood dynamics between 1997 and 2010 in Laikipia, Kenya. J Rural Stud. 28(3):241–251. doi:10.1016/j.jrurstud.2012.02.003.

Unks RR, King EG, German LA, Wachira NP, Nelson DR. 2019. Unevenness in scale mismatches: Institutional change, pastoralist livelihoods, and herding ecology in Laikipia, Kenya. Geoforum. 99:74–87. doi:10.1016/j.geoforum.2018.12.010.

Wainwright CM, Marsham JH, Keane RJ, Rowell DP, Finney DL, Black E, Allan RP. 2019. 'Eastern African Paradox' rainfall decline due to shorter not less intense Long Rains. Npj Clim Atmospheric Sci. 2(1):1–9. doi:10.1038/s41612-019-0091-7.

Weiss DJ, Nelson A, Gibson HS, Temperley W, Peedell S, Lieber A, Hancher M, Poyart E, Belchior S, Fullman N, et al. 2018. A global map of travel time to cities to assess inequalities in accessibility in 2015. Nature. 553(7688):333–336. doi:10.1038/nature25181.

Wekesa C, Makenzi PM, Chikamai BN, Luvanda AM, Muga MO. 2010. Traditional ecological knowledge associated with Acacia senegal (Gum arabic tree) management and gum arabic production in northern Kenya. Int For Rev. 12(3):240–246. doi:10.1505/ifor.12.3.240.

Wiesmann U, Kiteme B, Mwangi Z. 2016. Socio-Economic Atlas of Kenya: Depicting the National Population Census by County and Sub-Location. Second, revised edition. KNBS, Nairobi. CETRAD, Nanyuki. CDE, Bern.

Williams AP, Funk C. 2011. A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa. Clim Dyn. 37(11):2417–2435. doi:10.1007/s00382-010-0984-y.

Witt A, Beale T, Wilgen BW van. 2018. An assessment of the distribution and potential ecological impacts of invasive alien plant species in eastern Africa. Trans R Soc South Afr. 73(3):217–236. doi:10.1080/0035919X.2018.1529003.

Wittemyer G, Northrup JM, Blanc J, Douglas-Hamilton I, Omondi P, Burnham KP. 2014. Illegal killing for ivory drives global decline in African elephants. Proc Natl Acad Sci. 111(36):13117–13121. doi:10.1073/pnas.1403984111.

Yurco K. 2017. Herders and herdsmen: The remaking of pastoral livelihoods in Laikipia, Kenya. Pastoralism. 7(1):15. doi:10.1186/s13570-017-0086-0.

Zaehringer JG, Wambugu G, Kiteme B, Eckert S. 2018. How do large-scale agricultural investments affect land use and the environment on the western slopes of Mount Kenya? Empirical evidence based on small-scale farmers' perceptions and remote sensing. J Environ Manage. 213:79–89. doi:10.1016/j.jenvman.2018.02.019.

Zhou Y, Chen S, Hu G, Mwachala G, Yan X, Wang Q. 2018. Species richness and phylogenetic diversity of seed plants across vegetation zones of Mount Kenya, East Africa. Ecol Evol. 8(17):8930–8939. doi:https://doi.org/10.1002/ece3.4428.

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