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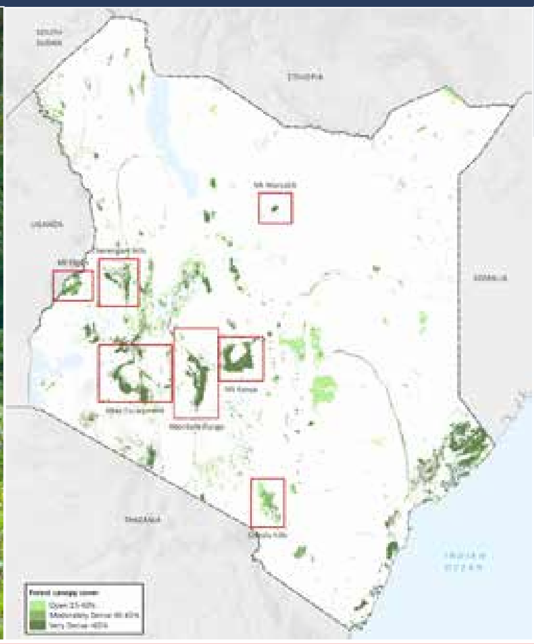
Mapping to support land-use planning for REDD+ in Kenya: securing additional benefits



Ministry of Environment and Natural Resources

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The UN-REDD Programme is the United Nations Collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries. The Programme was launched in September 2008 to assist developing countries to prepare and implement national REDD+ strategies, and builds on the convening power and expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP).

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) is the specialist biodiversity assessment centre of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organisation. The Centre has been in operation for over 30 years, combining scientific research with practical policy advice.

CONTRIBUTORS
Box 1 has been provided by Adam Formica, University of Oxford. Box 2 has been provided by Rudi Drigo and the project "Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and beyond". Box 3 has been produced in collaboration with the project "Mapping Tree-based Landscape Restoration Opportunities in Kenya" of the Kenya Restoration Technical Working Group and World Resources Institute. Aaron Minnick (WRI) and Florence Landsberg (WRI) have contributed text to Box 3 and the Kenya Restoration Technical Working Group, Serah Karuki and Safi Ibrahim (KFS), Nancy Neema (Green Belt Movement), and Florence Landsberg (WRI) have contributed maps.

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Mapping to support land-use planning for REDD+ in Kenya: securing additional benefits

Paulus Maukonen, Lisen Runsten, Julia Thorley, Alfred Gichu, Rose Akombo and Lera Miles

Contents

1. Introduction

Pressure to convert and degrade forests continues to be high in developing nations such as Kenya, resulting in substantial emissions of carbon dioxide. Through the United Nations Framework Convention on Climate Change (UNFCCC), countries are working to address this issue through REDD+, which encompasses five activities: reduction of emissions from deforestation and forest degradation, conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks (Figure 1).

Figure 1 *Definition of the acronym "REDD+".*

REDD+

Reducing emissions from
Deforestation and forest Degradation

+

Conservation of forest carbon stocks
Sustainable management of forests
Enhancement of forest carbon stocks

While deforestation and forest degradation are significant contributors to climate change, they also bring numerous other problems for the future. Removal of forests leads to loss or reduction of many ecosystem services and functions such as soil stabilization, protection of water supply and fisheries, flood control, water retention and filtration, sustainable provision of timber and fibres, medicinal plants, food from the forest, pollination, cultural services and wildlife habitat.

While the focus of REDD+ is climate change mitigation, Parties to the UNFCCC have also agreed that REDD+ actions should take into account the multiple functions of forests and other ecosystems, and enhance other social and environmental benefits (UNFCCC, 2010). REDD+ thus has the potential to achieve important social and environmental benefits through better forest management and governance. However, if implemented inappropriately, REDD+ could instead pose risks to local people's livelihoods, biodiversity and ecosystem services. For example, if some forests are better protected from conversion to agriculture but the drivers of conversion are not addressed, these pressures may be displaced to other forests or ecosystems.

To reduce these risks and instead promote benefits, a set of REDD+ safeguards were defined in the Cancun Agreement at UNFCCC COP 16 in 2010. It was agreed that REDD+ countries should promote and support these safeguards and provide information on how they are being addressed and respected. Guidance on the REDD+ safeguards were further elaborated at COP 17 in Durban, and at COP 19 in Warsaw.

The Government of Kenya's priority is to implement environmentally and socially sustainable land-use and forest policies. Kenya's REDD+ Readiness Proposal (R-PP) states that "even if an international mechanism to provide carbon finance for emissions management activities in forests does not reach the magnitude many are hoping, the Government of Kenya aims to design policies and measures to protect its remaining forest resources from deforestation and degradation and to enhance forest carbon stocks in ways that help improve local livelihoods and biodiversity" (Government of Kenya, 2010b).

The maps presented in this report are designed to inform planning for REDD+ implementation and forest management at the national scale, including through development of a National Strategy or Action Plan for REDD+ and a national approach to safeguards for Kenya. The maps were designed to identify:

- the location of pressures from drivers of deforestation and forest degradation;
- areas important for biodiversity and ecosystem services;
- areas of interest for some of the Cancun safeguards for REDD+;
- potential zones of interest for implementing REDD+ actions, building on the proposed Strategy Options in Kenya's REDD+ Readiness Preparation Proposal (R-PP) (Government of Kenya, 2010b)[1].

[1] This report will refer to the policies or measures that will be developed and implemented to achieve the goals of the national REDD+ process as "strategy options" as per the terminology in Kenya's R-PP document.

Buffalo in Aberdare National Park, Paulus Maukonen

The specific questions to tackle and the mapping methodologies used were discussed during a series of workshops held in 2014 and 2015 involving national and international institutions, including Kenya Forest Service, Kenya Department of Resource Surveys and Remote Sensing (DRSRS), Survey of Kenya, Kenya Forestry Research Institute (KEFRI), African Wildlife Foundation and the UN-REDD Programme.

During the period of developing this report, through the coordination of Kenya Forest Service, the team has collaborated with four parallel initiatives to ensure complementarity: FAO Targeted Support under UN-REDD Programme; the SLEEK project; the Mapping Tree-based Landscape Restoration Opportunities in Kenya project; the Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and beyond project; and with Oxford University-based MSc researcher Adam Formica. These collaborations are reflected in the boxes included in this report and some of the other maps.

The maps presented here can contribute to planning the implementation of REDD+ strategy options in Kenya. They were developed using the best available data, and should be updated when better data become available or if definitions change. Naturally, additional information will be needed or desirable at finer scales for developing land-use plans and/or identifying exact sites for implementation (see Figure 2). This report was developed with Targeted Support funding from the UN-REDD Programme under the coordination of Kenya Forest Service. The data and analytical results developed are held by Kenya Forest Service for future use.

2. Spatial planning for REDD+ objectives: addressing drivers and additional benefits

The fundamental goal of REDD+ is to contribute to climate change mitigation by addressing drivers of deforestation and forest degradation, and by removing barriers to sustainably managing or conserving existing forests and enhancing forest carbon stocks. REDD+ strategy options should be designed to address these drivers and barriers in a sustainable way, in line with the priorities of the country. In addition, a motivation for many governments and stakeholders to become engaged in REDD+ is the potential to achieve additional specific social and environmental benefits. Kenya's R-PP states that all activities will be designed with a focus on additional benefits such as improving biodiversity conservation and livelihoods of forest dependent peoples (Government of Kenya, 2010b). Many different strategy options could help to achieve the goals of REDD+ in Kenya, and these options can be implemented in different ways, in different places, with different results. REDD+ decision makers can take advantage of this flexibility to design strategy options that not only address drivers and lead to emission reductions or removals, but also create desired additional benefits.

Additional benefits may include improved livelihood opportunities, land/resource tenure for local populations, protected/better managed habitat for biodiversity, or retained or enhanced ecosystem services such as water cycling and purification, soil formation and retention, food, fibre and fuel provision, pollination and microclimate regulation. The maps in this report can support the design of strategy options that can yield multiple benefits, by illustrating interactions among drivers, existing land management and different potential benefits.

The design of REDD+ strategy options can be improved by drawing on spatial information on the drivers of deforestation and forest degradation, and spatial analysis of the feasibility, potential benefits and risks of the different options. Kenya is currently in the readiness phase of REDD+, working (amongst other activities) to collect information needed to develop a robust national strategy or action plan. This entails developing strategy options that are in line with national priorities and targeted to address the REDD+ activities[2] that the country has decided on. Developing strategy options for REDD+ is often iterative: candidate REDD+ strategies are proposed and then refined as more information is made available.

Figure 2 outlines some spatial planning steps that countries may wish to take as part of developing a plan for REDD+ implementation. In the readiness phase, this includes identifying the responsible institutions, development of key basic spatial information such as land and forest cover, identifying the impact that various drivers have had on deforestation and forest degradation in the past, and deciding whether and how to model future trends in the absence of REDD+. Kenya has developed an analysis of drivers and underlying causes of forest cover change across its

[2] The term "REDD+ activities" is used here to refer to the five activities agreed under the UNFCCC: Reducing emissions from deforestation; reducing emissions from forest degradation; conservation of forest carbon stocks; sustainable management of forests; and enhancement of forest carbon stocks.

forest types (Ministry of Forestry and Wildlife, 2013), which has been used to inform the spatial analyses presented in Section 5. As a next step, understanding the various functions of forests and the potential benefits of REDD+ activities in relation to these functions can help in prioritizing strategy options and identifying zones where action is most needed, especially in combination with the distribution data on drivers/barriers. The maps in this report contribute to these objectives. In parallel, a benefits and risks analysis of the REDD+ strategy options and identification of measures to mitigate the risks and promote the benefits can help to refine the strategy options and maps of zones where they could be implemented.

In the implementation phase, more detailed data and analysis is needed, and depending on the strategy option in question, and local circumstances, new analyses may be needed to answer new questions.

Figure 1 *Indicative spatial planning steps that can be useful in the readiness and implementation phases of REDD+ as part of developing a plan for REDD+ implementation*
** This report contributes to items marked with a star*

THE READINESS PHASE:
contribute to the development of a national REDD+ Strategy/Action Plan

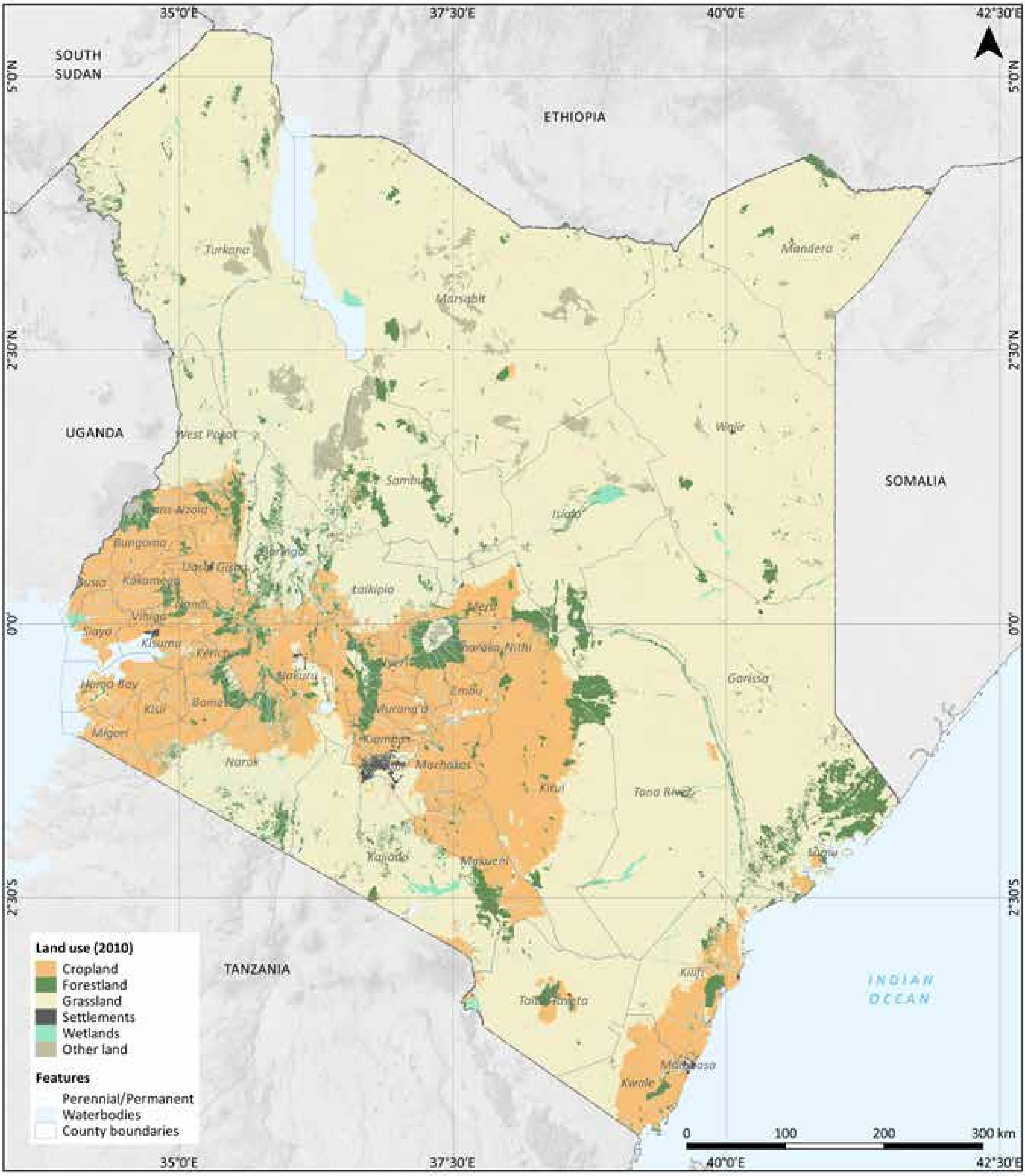
1. **Identify institutional responsibilities for spatial planning and coordinate among these different institutions from an early stage. Consider relevant timings for stakeholder consultations.**
2. **Identify the spatial distribution of forest carbon stocks, forest types and land use/land cover according to categories relevant for planning and management.**
3. **Identify the spatial distribution of drivers of deforestation/degradation; and/or barriers to implementation of sustainable management of forests/conservation or enhancement of forest carbon stocks.**
   Relevant analyses can include, depending on what is needed:
   - *Map areas of past deforestation/degradation and distribution of direct and indirect drivers; **
   - *If relevant, map spatially explicit barriers to implementation of sustainable management of forests, conservation and/or enhancement of forest carbon stocks;*
   - *If resources exist, model potential future deforestation/degradation and/or distribution of direct and indirect drivers.*
4. **If desirable, identify the spatial distribution of additional benefits of REDD+ that have been identified as a priority at national to subnational scale. This can entail mapping the distribution of factors whose improvement are desired benefits of REDD+, including:**
   - *Biodiversity; **
   - *Ecosystem services; **
   - *Rights to land and natural resources; **
   - *Livelihood opportunities, poverty, gender, and other relevant socio-economic issues.*
5. **Identify the biophysical and socioeconomic potential for candidate REDD+ strategy options to address drivers/barriers (and desired additional benefits if applicable).**
   - *Combine the distribution data on drivers/barriers and additional benefits to identify zones where REDD+ strategy options are most needed; **
   - *Assess biophysical and socio-economic potential for candidate REDD+ strategy options. At the national or regional scale this may consider existing development plans, land use, climatic or soil suitability, etc.;*
   - *Map general zones with potential for implementing the various strategy options.*
6. **Conduct a benefits and risks analysis of the REDD+ strategy options, identify measures to mitigate the risks and promote the benefits, and use the results to refine the strategy options.**
   - *Where is there a risk of negative consequences from implementation of strategy options due to factors that vary spatially? For example, where could afforestation cause damage to existing ecosystem services and biodiversity? Where could implementation take place that mitigates such risks and instead achieve intended benefits?;*
   - **If applicable, conduct a spatially explicit analysis of economic factors, including the values of ecosystem services and implementation costs, as a basis for assessing costs and benefits of candidate strategy options;**
   - **Further refine maps of zones where implementation of various strategy options could take place, based on the information above.**

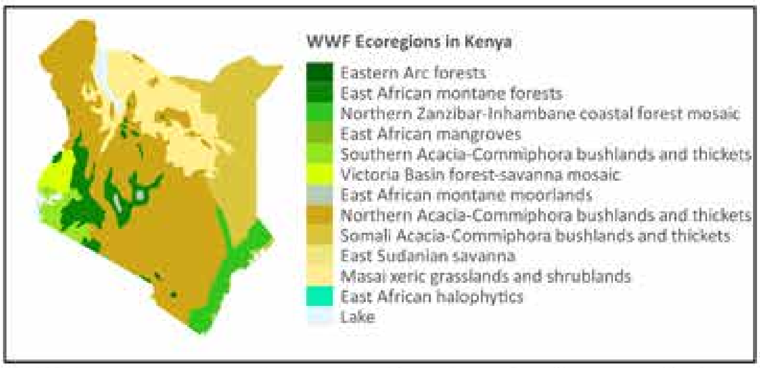
THE IMPLEMENTATION PHASE:
detailed planning for implementation of strategy options

7. **Carry out sub-regional/watershed/local level planning in the potential zones for implementation identified in the readiness phase. Depending on the strategy option that is being considered and the potential local risks and benefits, relevant analyses may include any of those in steps 1-6 using locally relevant data, or other analyses. Socio-economic characterization and participatory approaches will be even more important in this phase to ensure that the needs of relevant stakeholders are considered.**

Map 1: How are land-uses distributed in Kenya?

Accurate, up-to-date land-use or land-cover data is fundamental both to understanding current land use and planning for future management of natural resources. This map was developed by Kenya Forest Service (2013), and may be subject to an update in the near future by Kenya's REDD+ Technical Working Group. The inset ecoregion map is included for further information on ecosystem diversity and distribution.





Methods and data sources:

Land use/Land cover: Kenya Forest Service (2013) Report on National Forest Resource Mapping and Capacity Development for The Republic of Kenya. KFS; Nairobi, Kenya. Data created by the Kenya Forest Service in 2010.

Boundaries: The country and county boundaries were obtained as a shapefile by e-mail from the Kenya Forest Service (KFS) and Surveys of Kenya (SoK), Nairobi.

WWF Ecoregions: Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., Kassem, K. R. (2001). Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938.

* *The boundaries and names shown and the designations used on this map, and all subsequent maps in this publication, do not imply official endorsement or acceptance by the United Nations.*

3. Forests in Kenya

The surface area of the Republic of Kenya is 582 646 km2 and as of 2013 the country had a population of 41.8 million people (Kenya National Bureau of Statistics, 2014), most of whom live in the central and western highlands where also the majority of forests are concentrated. Data from Kenya Forest Service (2013) after a recent accuracy assessment estimate Kenya's forest cover at 3.521 (±0.572) million ha, constituting around 6 percent of the land surface. Most of the forest and cropland are concentrated in the highlands and on the coast (Map 1) and agricultural expansion has been a key driver of deforestation (Ministry of Forestry and Wildlife, 2013). At the same time, loss of tree cover is a key challenge beyond these areas, in the arid and semi-arid lands where over-extraction of trees for charcoal and building materials is contributing to degradation (Republic of Kenya, 2005).

Kenya's Forest Act of 2005 defines "forests" as "any land containing a vegetation association dominated by trees of any size, whether exploitable or not, capable of producing wood or other products, potentially capable of influencing climate, exercising an influence on the soil, water regime, and providing habitat for wildlife, and includes woodlands". The precise forest definition to be used for REDD+ is still being determined. Operational forest definitions are important for several reasons. For spatial planning, it is needed to interpret national policies, laws and regulations as well as international commitments, and to be able to measure progress towards goals.

Kenya's forest resources cover several ecoregions and forest types. A National Forest Resource Mapping study, conducted for the Kenya Forest Service (2013) using remote sensing, differentiated four forest types in Kenya: "natural forest", mangroves, bamboo, and plantations (Map 3a). Other classifications differentiate montane, riverine and coastal ("natural") forests; dry forests (woodlands), and plantations (Peltorinne, 2004).

Although Kenya's forests cover a relatively small proportion of the total land area, they are critical for Kenya's biodiversity. They contain 50% of the nation's tree species, 40% of the larger mammal species and 30% of the bird species. Kenya's forests also host numerous endemic, rare and threatened species. Over 150 internationally recognized threatened woody species occur in the country, and 125 forest areas are known to have threatened plant species (NEMA and UNDP, 2009).

In addition, Kenya's forests provide a range of different goods and services, contributing in numerous ways to local livelihoods and to the wider economy. For example, the Mau Forest complex in Kenya provides goods and services at an estimated worth of US$1.5 billion a year through water for hydroelectricity, agriculture, tourism and urban and industrial use, as well as erosion control and carbon sequestration (UNEP, 2014). About 78% of Kenya's energy comes from biomass (Government of Kenya, 2010a), and out of the 14.9 million kg (dry weight) of fuelwood consumed annually (Drigo et al., 2015), 95 per cent is collected from forests and rangelands.

Developing forest management plans that protect and promote for these and other priority services of forests is greatly facilitated by access to information and analysis on the distribution of the services. The maps and analyses in this report aims to contribute to such an information base.

Great Blue Turaco, Bernard Dupont / Flickr

3.1 Forest carbon stocks

Understanding the spatial distribution of tree cover and carbon stocks is central to decision making for REDD+, forest carbon being the chief value that REDD+ is designed to protect and enhance. When countries are developing a REDD+ strategy, a first step is to consider the distribution of existing carbon stocks and the losses and gains occurring. Understanding where tree cover is high, low and diminishing is useful both for measuring, reporting and verifying (MRV) emissions reductions from REDD+, and for planning the actions that will achieve those reductions, i.e. deciding where implementation of a particular action can be the most beneficial. For example, forests with high carbon stocks that are threatened by deforestation or degradation may be of high priority for actions to reduce emissions from these pressures, especially if the potential for other benefits are also high. Identifying the potential for reduced emissions and other benefits facilitates informed decision making, including by allowing comparison with competing land-uses. Agreeing on criteria for deciding on preferred uses for different areas may be a step in the process for developing and implementing a robust REDD+ national strategy or action plan.

Forest carbon stock distribution data can be collected through field inventories and remote sensing. There are several global carbon stock maps that are based on remote sensing and a relatively small amount of field data (e.g. Ruesch and Gibbs, 2008; Saatchi et al., 2011; Baccini et al., 2012). In a working session at KFS headquarters in late 2014, it was decided that the data that was the most in line with national expert knowledge of carbon stock distribution was a dataset by Baccini et al. (2012). An earlier version of this dataset was validated in Kenya in 2008 (WHRC, 2008). The data of Baccini et al. (2012) represents above-ground biomass. By applying root-to-shoot ratios published by the Intergovernmental Panel on Climate Change (IPCC, 2006), below-ground biomass was calculated and added to this above-ground biomass, and the sum converted to biomass carbon (the carbon in biomass is about half of the total mass) (Map 2a). This is intended as a useful interim dataset for decision making until Kenya has a national map of carbon stocks.

Map 2b shows organic soil carbon stocks, from a regional dataset for Africa developed by Hengl et al. (2015). Globally, the soil carbon pool exceeds the amount of carbon stored in plant biomass and the atmosphere (Scharlemann et al., 2014). Soil carbon is only relevant to consider in REDD+ planning when it is vulnerable to change: soil carbon stocks can decline quickly as a result of land-use change and some forms of management, while other management approaches such as conservation agriculture or agroforestry, may limit such declines (Mäkipää et al., 2012). Recovery of soil carbon stocks that have been depleted is a very slow process. Kenya's National Environment Action Plan Framework 2009-2013 notes that soil degradation and desertification is a major environmental challenge for the country as a result of processes such as deforestation and forest degradation, in turn caused by underlying drivers like poverty (NEMA, 2009).

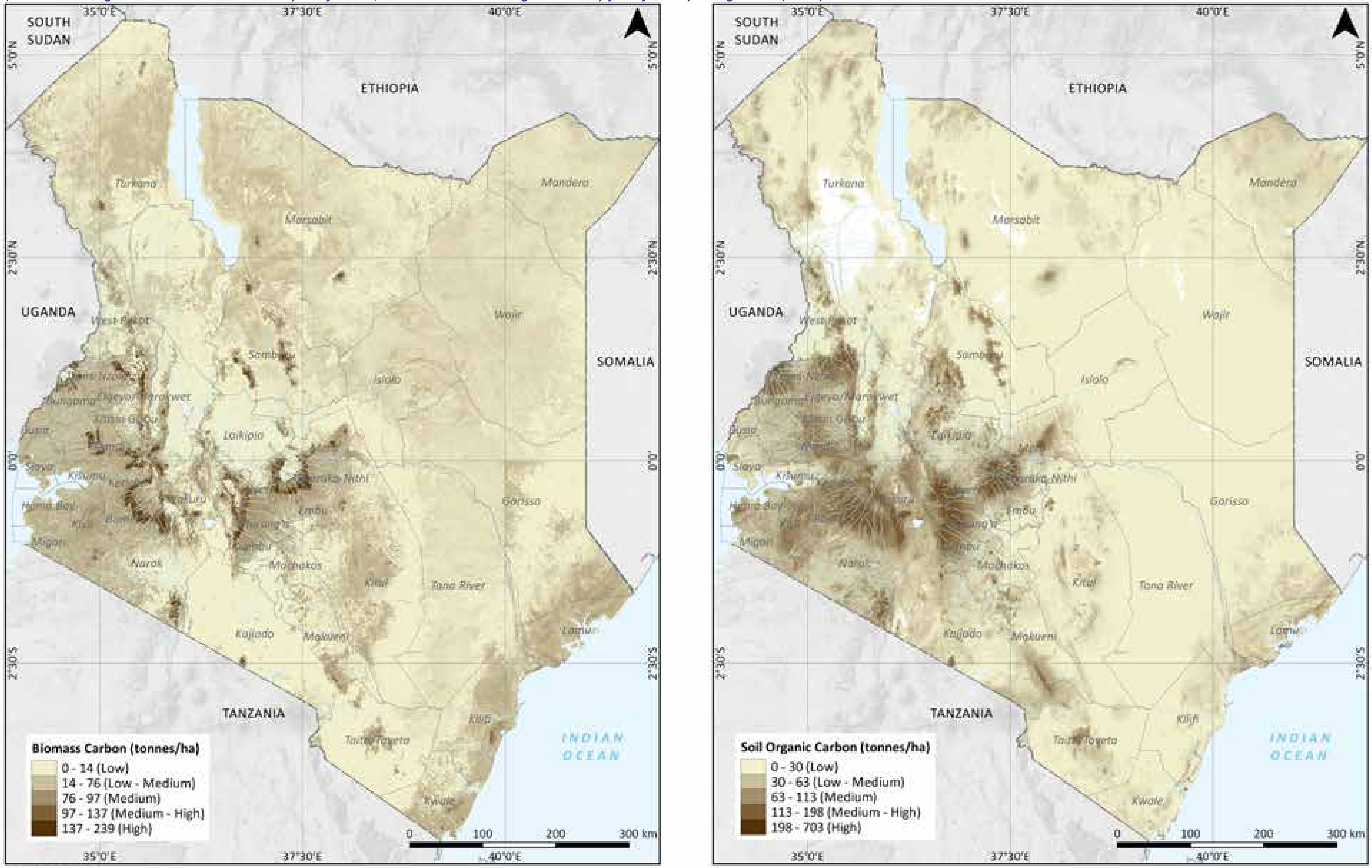
3.2 Identifying natural forest

Establishing a national definition and map of "natural forest" is relevant to REDD+ for multiple reasons. First, to avoid encouraging the conversion of natural forest into plantations, the Cancun safeguards specify that REDD+ actions should be: "consistent with the conservation of natural forests and biological diversity, ensuring that [REDD+] actions (...) are not used for the conversion of natural forests, but are instead used to incentivize the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits" (UNFCCC, 2010).

Furthermore, the "Warsaw Framework for REDD-Plus" established by UNFCCC COP 19 states that national forest monitoring systems for REDD+ should "enable the assessment of different types of forest in the country, including natural forest, as defined by the Party" (UNFCCC, 2013). These decisions illustrate that a definition of natural forest is needed, and leave it to countries to set a national definition. When deciding on a natural forest definition for REDD+, it is relevant to consider that REDD+ actions should not convert natural forest, but rather incentivize their protection and conservation, and that natural forest should be feasible to assess in a national forest monitoring system. Kenya does not yet have an official definition of "natural forest" in the context of REDD+, nor is the concept defined in policies or legislation, though the term is mentioned without definition in Kenya's Forest Policy of 2007 ("...natural forests and plantations...") and the Draft National Forest Policy of 2015 ("...natural and riverine forests..."). If Kenya wishes to set a natural forest definition for REDD+, it may be useful to draw upon existing definitions to ensure historical consistency.

Map 2: What is the distribution of biomass carbon and soil organic carbon?

The left-hand map (2a) shows above- and below-ground biomass carbon, based on a global remote sensing-based study by Baccini et al. (2012) and IPCC-derived estimates of below-ground biomass. The right-hand map (2b) shows soil organic carbon stocks to a depth of 60cm, and is based on a regional study for Africa by Hengl et al. (2015) at 250 m resolution.



Methods and data sources:

Biomass carbon (left): Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P., Dubayah, R., Friedl, M. (2012) Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change 2. 3:182-185. http://dx.doi.org/10.1038/NCLIMATE1354; *Ecosystem-specific conversion factors (IPCC 2006) were used to add below-ground biomass carbon to this map following the method described here: Ravilious, C., Arnell, A. and Bodin, B. (2015) Using spatial information to support decisions on safeguards and multiple benefits for REDD+. Step-by-step tutorial v1.0: Adding below-ground biomass to a dataset of above-ground biomass and converting to carbon using QGIS 1.8. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK.*

Soil organic carbon (Right): Hengl, T., Heuvelink, G.B.M, Kempen, B., Leenaars, JGB, Walsh, M.G., Shepherd K. D. (2015) Mapping Soil Properties of Africa at 250 m Resolution: Random Forests Significantly Improve Current Predictions. PLoS ONE 10(6): e0125814. doi:10.1371/journal.pone.0125814. This map shows soil organic carbon to a depth of 60cm, calculated as the sum of SOC rasters at 4 different depth profiles.

The 2013 National Forest Resource Mapping study (2013) distinguishes "natural forest" from mangroves, bamboo forests and plantations (Map 3a), and also developed a map of canopy density (Map 3b). The forest definition uses a minimum tree crown cover of 15 %; minimum land area of 0.5 ha; and minimum tree height of 2 m.

While "natural forest" is not officially defined, a similar concept, "indigenous forest", has a definition in the Kenya Forest Act of 2005 as "a forest which has come about by natural regeneration of trees primarily native to Kenya, and includes mangrove and bamboo forests". The Draft National Forest Policy (Government of Kenya, 2015) notes that indigenous forests represent some of the most diverse ecosystems found in the country, supplying important economic, environmental, recreational, scientific, social, cultural and spiritual benefits. In the colonial period, large areas of indigenous forest were cleared and replaced with pine, cypress and eucalyptus plantations. During the post-independence period, additional large areas of indigenous forest land were allocated to farmers and communities for subsistence and cash crops such as tea and for livestock grazing, while other areas were cleared illegally.

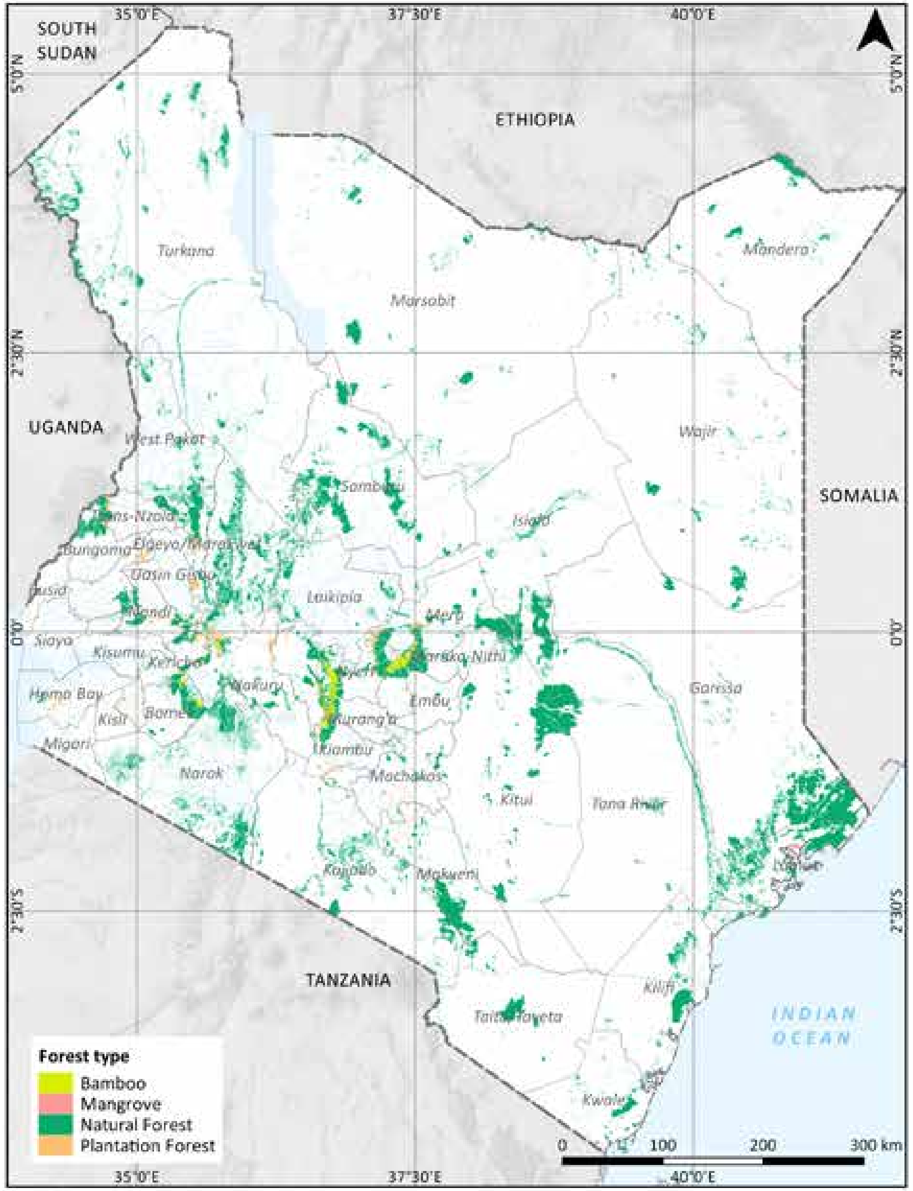
The Draft National Forest Policy (2015) sets out a number of policy statements for indigenous forests, that the Government will: sustainably conserve and manage all reserved forests for multiple use in accordance with approved management plans; promote the rehabilitation and management of water catchment areas; promote participatory management of indigenous forests with communities and other stakeholders; monitor, assess and prepare periodic reports on the integrity of forests including "water towers" ; promote ex-situ and in-situ conservation of forest genetic resources; encourage and support land owners to sustainably manage natural and riverine forests; rehabilitate, restore and protect degraded forest ecosystems, water towers, catchment areas and other ecological fragile areas.

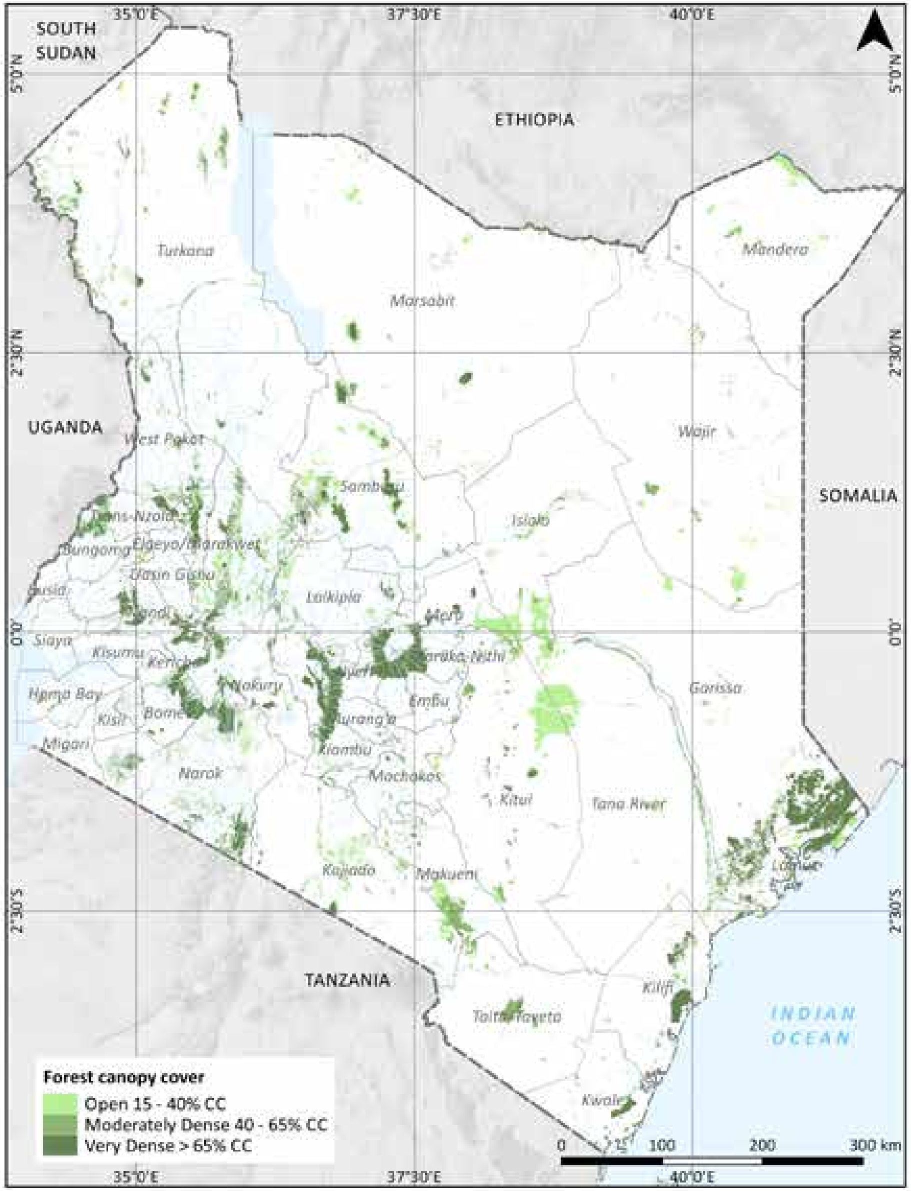
These policy targets align well with the Cancun safeguard (e) for REDD+. When used in combination with one another, many of the maps in this report can be helpful for planning towards these policy targets.

Waterfalls in Aberdare National Park, Paulus Maukonen

Map 3: What is the distribution of natural forest and what is the canopy cover of different forest types?

The left-hand map (3a) shows the distribution of different forest types, including mangroves, bamboo, plantations and "natural forest". The category "natural forest" includes montane, riverine and coastal forests, as well as some woodland forest. The right-hand map (3b) shows the density of forest cover. Montane and coastal forests display high density, whilst woodlands are more open. Both datasets were developed by Kenya Forest Service, using 2010 data.





Methods and data sources:

Forest type and forest canopy cover: Kenya Forest Service (2013) Report on National Forest Resource Mapping and Capacity Development for The Republic of Kenya. KFS; Nairobi, Kenya. Data created by the Kenya Forest Service in 2010.

4. Legal Framework

In the last decade, Kenya has developed or updated a number of laws, policies and strategies to protect remaining forests and increase tree cover. These include:

- The Constitution of Kenya (2010) obligates the state to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure the equitable sharing of the benefits accruing. It also sets an explicit goal of achieving and maintaining a tree cover of at least 10 percent of the land area. Furthermore, it establishes a new system of land classifications comprising public, community and private land. The application of these new categories has been subject to much further debate and the subject of several land related bills and acts.

- The Kenya Vision 2030 is the country's development blueprint for the period 2008 to 2030. Among its Flagship Programmes and Projects for 2013-2017 are three programmes directly targeting forests: Rehabilitation and Protection of the Water Towers (the five major as well as smaller water towers and catchment areas; see Map 10); Forest Conservation and Management (ecosystem and participatory forest management plans will be prepared and nature-based enterprises will be promoted) and Forestry Research and Development (research to develop intervention measures for causes of forest degradation, develop forestry related baseline data, establish a monitoring system for forests and aspects of climate change).

- The National Climate Change Response Strategy (2010) and the National Climate Change Action Plan 2013 -2017 include an overall aim to grow about 7.6 billion trees on 4.1 million hectares of land during the following 20 years.

- The Farm Forestry Rules (2009) require every person who owns or occupies agricultural land to establish and maintain a minimum of 10 percent of the land under "farm forestry", which may include trees on soil conservation structures, on rangeland or on cropland.

- The Forests Act (2005) recognises the importance of forests for greenhouse gas regulation and stabilization of soils and ground water, thereby supporting agricultural activity. The Act established three types of forest management entities: state, private and local authority. It also established the Kenya Forest Service (KFS), including its role in drawing up management plans for all forests, or assisting in doing so. The Act strongly emphasises the involvement of forest communities and other stakeholders in forest conservation and management and enables members of forest communities to enter into partnership with KFS through registered Community Forest Associations (CFAs).

The Forest Policy (2014) has been followed by an updated draft Forest Policy (March 2015), noting that the sector is faced with various challenges that demand review of both the policy and legislative framework. This includes issues of decreasing forest cover and the need for alignment with the new Constitution (2010). The Forest Policy covers government commitments to manage all indigenous forests for water and soil conservation, provision of other forest goods and services and for biodiversity conservation; promote participatory management of indigenous forests with communities and other stakeholders, and rehabilitate, restore and protect degraded forest ecosystems, water towers, catchment areas and other ecologically fragile areas.

View of Shimba Hillls National Reserve, Paulus Maukonen

With support from the UN-REDD Programme, Kenya has developed several legal reviews to inform the REDD+ readiness process (Ministry of Environment Water and Natural Resources, 2013b, c). These reports note some challenges still facing the evolving Kenyan legal and institutional framework, and make recommendations relating to linking land-use law and sustainable development; making harmonized provisions for REDD+ in laws and policies, including the tenure system; institutional mandates; and legal, policy and institutional barriers to REDD+ implementation. Among other things, the reports note the critical importance of clarifying land tenure and use rights with regards to REDD+.

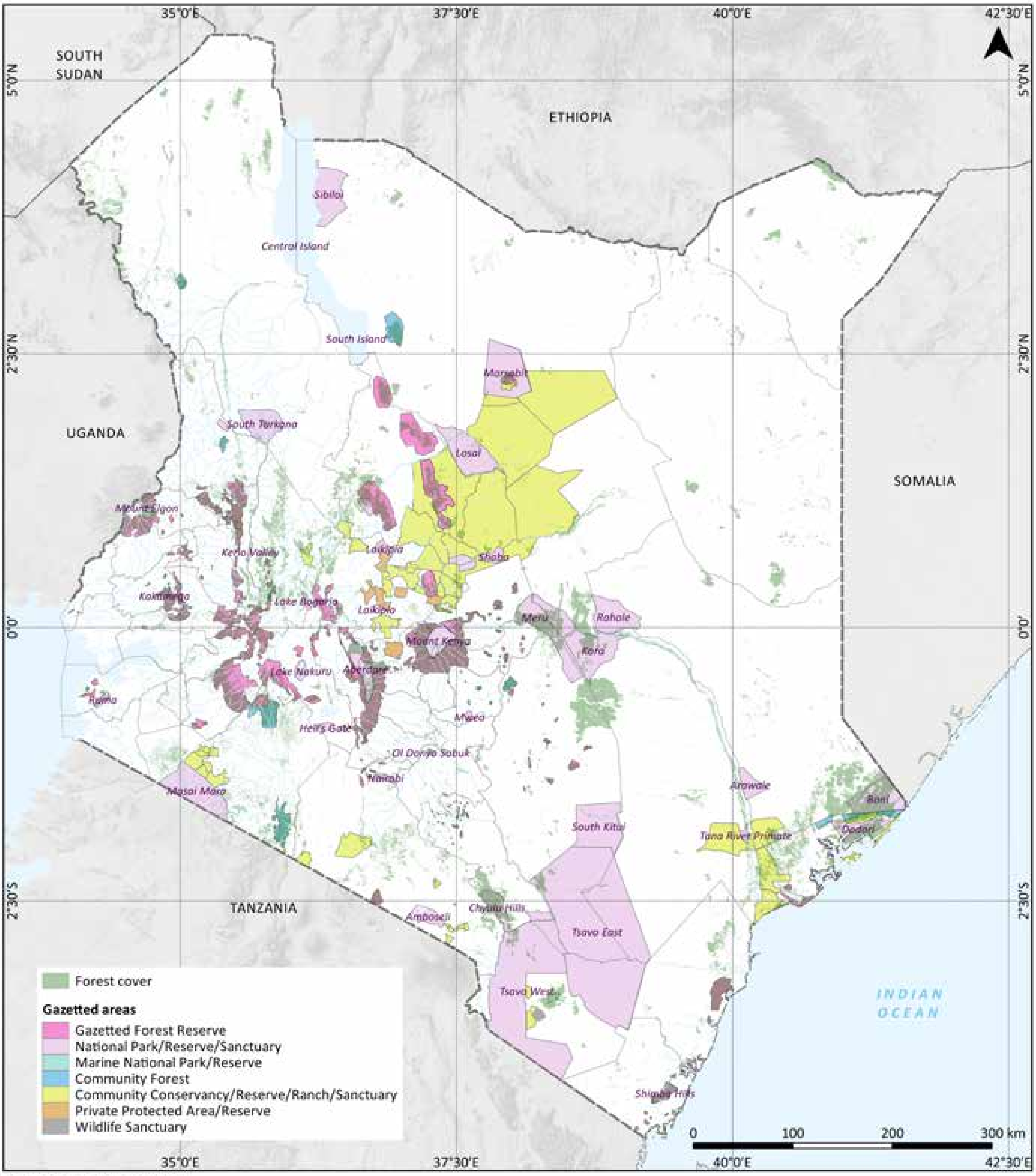
Maps of land management arrangements support spatial planning by helping to identify actions appropriate for the stakeholders responsible for the land. For example, knowing whether a forest is under some form of protection, clarified tenure or has a management plan (e.g. Maps 4, 5 and 16) lends context to information on the functions or values of the forest, such as carbon stocks, biodiversity or ecosystem services (e.g. Maps 2 and 4-10) and drivers of deforestation or degradation in operation there (e.g. Maps 11-15). Currently, about 12 percent of Kenya's land area is under some form of protection (IUCN and UNEP-WCMC, 2015) and approximately 44 percent of Kenya's forests are situated in these areas (Map 4, see also Kenya Forest Service (2013)). Some forests are "gazetted", some are in national parks or reserves and some are community forests or conservancies. Protected areas are critical to conserve sensitive areas for biodiversity, ecosystem services or other values. In fact, most of Kenya's remaining forests with high carbon stocks are under some form of protection (Map 5).

The areas of forest that do fall outside of protected areas, many of which are on community land, may be especially vulnerable to land-use change and require different actions than those already under protection or clarified management arrangements. REDD+ actions that prevent deforestation or forest degradation outside of protected areas can help to conserve forest carbon stocks, biodiversity and ecosystem services in line with the objective of the Constitution of Kenya to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources.

Entrance to Aberdare National Park, Paulus Maukonen

Map 4: Which forest land is under public, community and private management?

This map shows forest inside and outside protected areas, as well as the management classification of Kenya's protected areas: public, community and private land. This map identifies forests lacking protection, and may help to target appropriate interventions to areas under different forms of management.



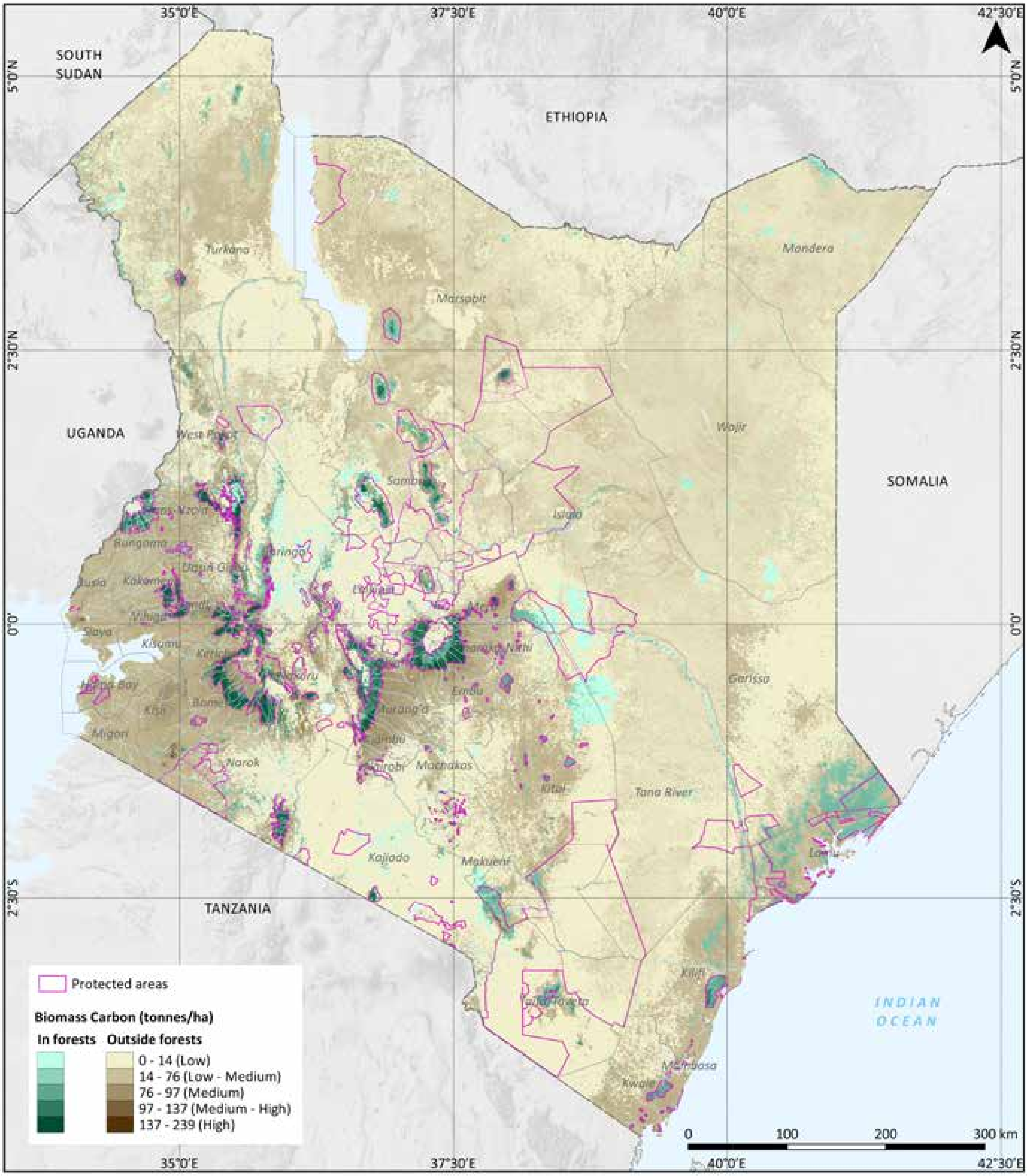
Methods and data sources:

Protected areas: IUCN and UNEP-WCMC (2014), The World Database on Protected Areas (WDPA) [On-line]. Cambridge, UK: UNEP-WCMC. *Available at: www.protectedplanet.net Accessed 12/2014. Additional information from the Kenya Forest Service (KFS) was used to supplement this data. National parks and reserves are labeled on this map.*

Forest: Kenya Forest Service (2013) Report on National Forest Resource Mapping and Capacity Development for The Republic of Kenya. KFS; Nairobi, Kenya. Data created by the Kenya Forest Service in 2010. All forest types are represented in this map.

Map 5: Which high carbon stock forests are outside protected areas?

This map shows the distribution of biomass carbon inside and outside protected areas, for forest and non-forest. Most of the high-carbon forests fall inside protected areas.



Methods and data sources:

Biomass carbon (left): Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P., Dubayah, R., Friedl, M. (2012) Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change 2. 3:182-185. http://dx.doi.org/10.1038/NCLIMATE1354; *Ecosystem-specific conversion factors (IPCC 2006) were used to add below-ground biomass carbon to this map following the method described here: Ravilious, C., Arnell, A. and Bodin, B. (2015) Using spatial information to support decisions on safeguards and multiple benefits for REDD+. Step-by-step tutorial v1.0: Adding below-ground biomass to a dataset of above-ground biomass and converting to carbon using QGIS 1.8. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK.*

Forest: Kenya Forest Service (2013) Report on National Forest Resource Mapping and Capacity Development for The Republic of Kenya. KFS; Nairobi, Kenya. Data created by the Kenya Forest Service in 2010.

5. Mapping the multiple functions of forests - biodiversity and ecosystem services

The maps in this section aim to support planning of strategy options to enhance biodiversity and ecosystem services by identifying some key areas where such values are high. This report will focus on biodiversity and on soil erosion prevention, noting that there are many other forest ecosystem services that contribute significantly to economic development and rural livelihoods in Kenya. Another large set of relevant maps can be found in the Kenya National Biodiversity Atlas launched in 2015 through a collaboration led by the African Conservation Centre.

5.1 Biodiversity

Kenya's wildlife is among the richest and most diverse in Africa, and constitutes a unique natural heritage that is of great conservation importance both nationally and globally. Wildlife conservation areas, which are found in arid, semi-arid and mountain-forest parts of the country, contribute directly and indirectly to the local and national economy through revenue generation and wealth creation, including tourism earnings and formal sector employment.

In addition, wildlife resources provide environmental goods and services for agriculture, fishing, livestock, water, energy, forestry and other industries. A significant proportion of wildlife populations remain outside the protected areas. Furthermore, land fragmentation, unsustainable production systems and habitat destruction have led to loss of biodiversity (NEMA, 2009) and many populations are in decline.

5.1.1 Species Richness

Map 6 shows the distribution of richness of threatened species of mammals, birds, amphibians and reptiles in Kenya, based on the IUCN Red List, together with biomass carbon stocks.

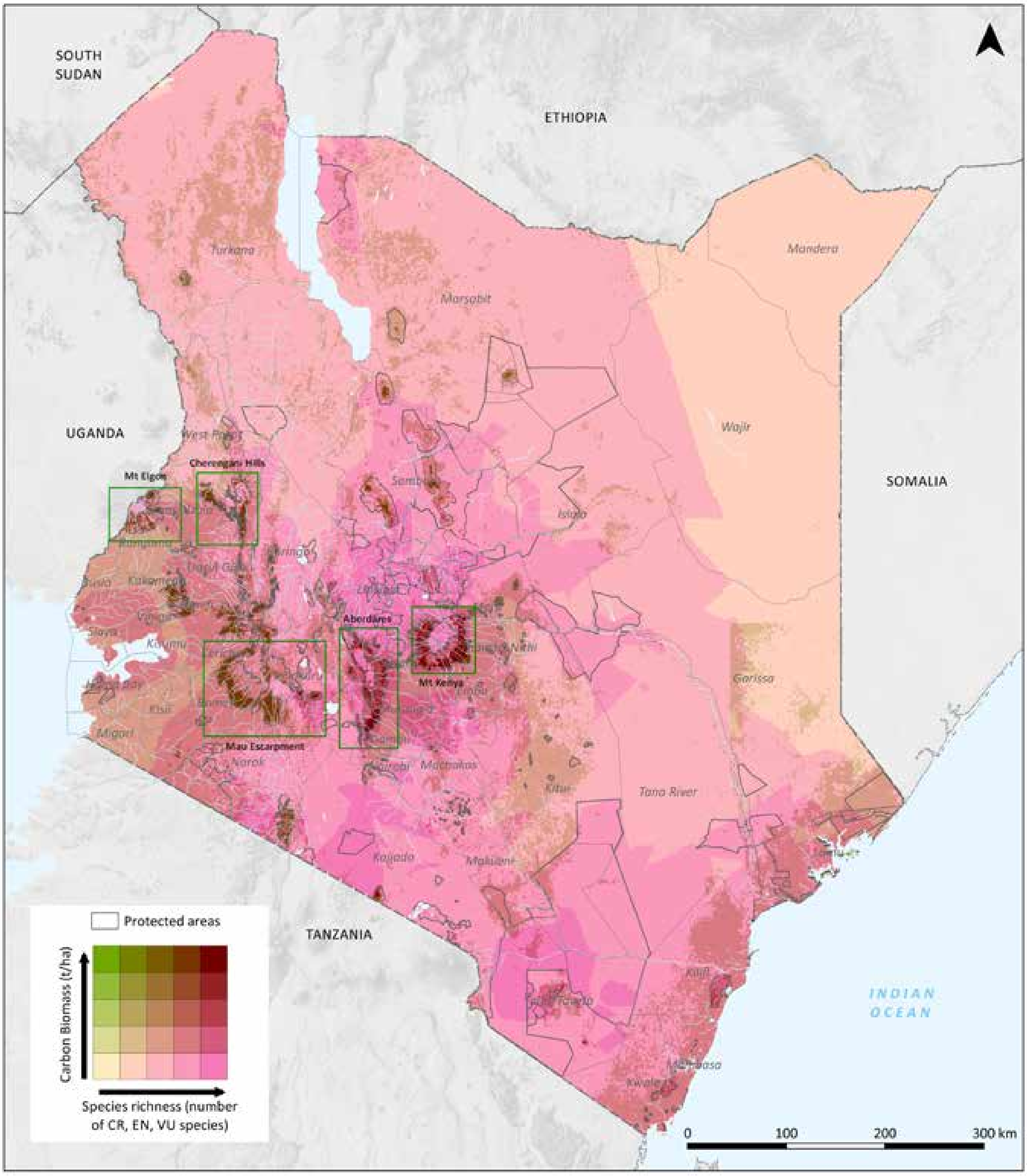
The Kenya Forest Act (2005) declares that forests that are rich in biodiversity and contain rare, threatened or endangered species shall enjoy special consideration. Therefore, areas where both threatened species richness and carbon stocks are high may be of particular interest for efforts to strengthen protection or improve forest management as part of REDD+. Most of the areas that are high in carbon and rich in threatened species (shown in dark red) are already designated as protected areas. In particular, the five forested water towers appear critical for both carbon stocks and biodiversity.

Where a high number of threatened species are found alongside low carbon stocks, it may be useful to identify whether the area has been deforested/degraded, or is naturally a non-forest ecosystem, such as grassland or savanna. If low stocks are a result of deforestation or forest degradation, these areas could be particularly suitable for restoration/reforestation actions. On the other hand, when forests are protected from agricultural pressure or plantations, non-forest/low-carbon ecosystems with high biodiversity values could potentially be at greater risk, which could have negative effects on biodiversity.

White Rhinoceros, Paulus Maukonen

Map 6: How are biomass carbon stocks distributed in relation to the ranges of threatened species and protected areas?

This map shows the distribution of biomass carbon stocks and threatened species richness in Kenya. The dark red areas have the highest density of both biomass carbon and threatened species, notably the five water towers (see Map 10). Pink areas have high threatened species richness and low carbon stocks.



Methods and data sources:

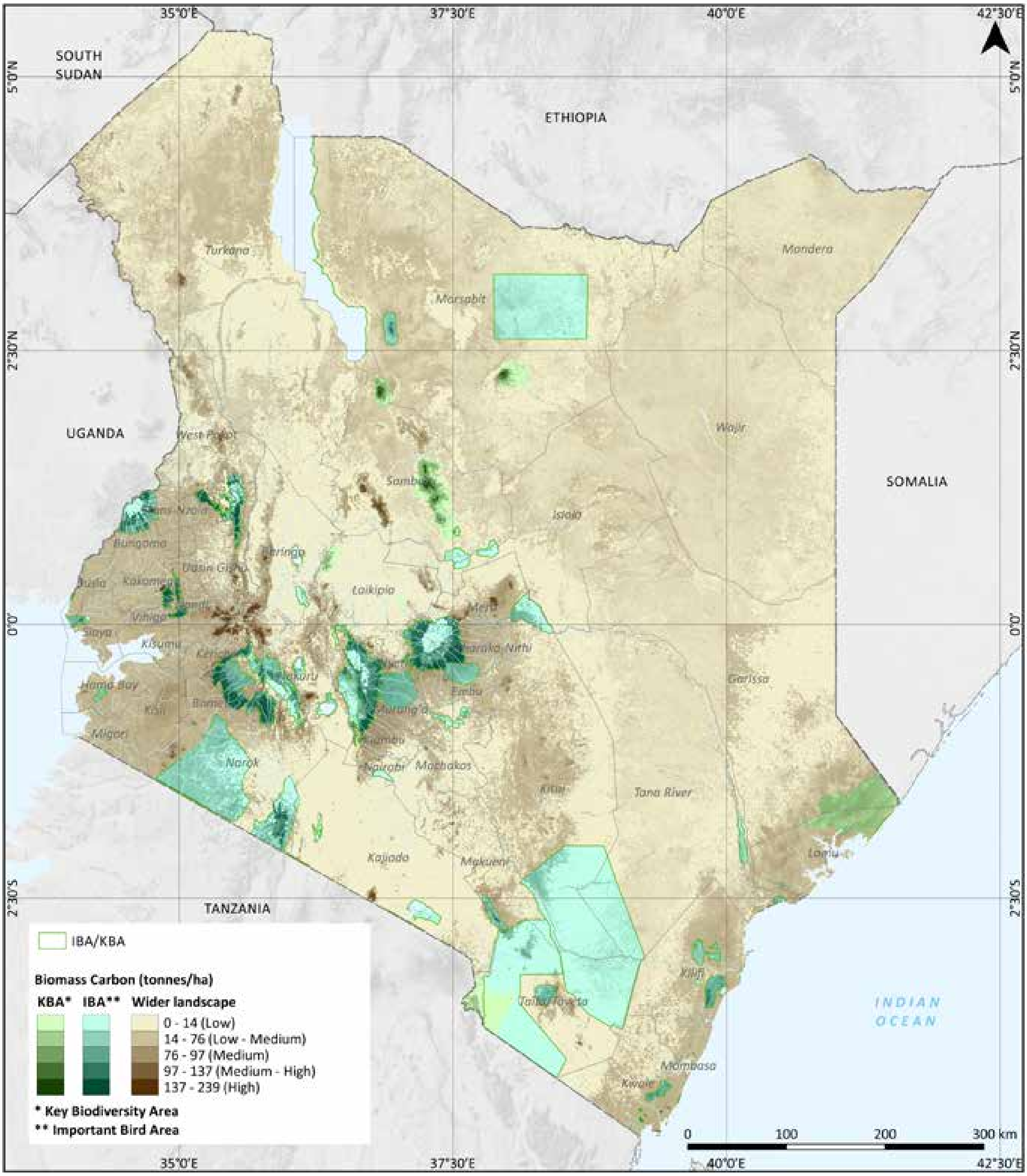
Biomass carbon (left): Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P., Dubayah, R., Friedl, M. (2012) Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change 2. 3:182-185. http://dx.doi.org/10.1038/NCLIMATE1354, The Woods Hole Research Center. National dataset of Aboveground Live Woody Biomass density at spatial resolution of circa 500m derived from field/LiDAR(GLAS)/MODIS. Ecosystem-specific conversion factors (IPCC 2006) were used to add below-ground biomass carbon to this map.

Species richness: Derived from the ranges of mammal, bird, reptile and amphibian species classified as 'Critically Endangered', 'Endangered', and 'Vulnerable' by the IUCN Red List of Threatened Species (2014) Version 2014.2 http://www.iucnredlist.org. Downloaded Nov 2014.

Protected areas: IUCN and UNEP-WCMC (2014), The World Database on Protected Areas (WDPA) [On-line]. Cambridge, UK: UNEP-WCMC. *Available at: www.protectedplanet.net Accessed 12/2014. Additional information from the Kenya Forest Service (KFS) was used to supplement this data. National parks and reserves are labeled on this map.*

Map 7: Which forests have been identified as Key Biodiversity Areas or Important Bird Areas, and what are their carbon stocks?

This map shows the location of Important Bird Areas (IBAs) and other Key Biodiversity Areas (KBAs) and in relation to biomass carbon stocks. These areas have been defined from internationally agreed criteria on the vulnerability of species and the irreplaceability of the site for species conservation purposes.



Methods and data sources:

Biomass carbon (left): Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P., Dubayah, R., Friedl, M. (2012) Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change 2. 3:182-185. http://dx.doi.org/10.1038/NCLIMATE1354; *Ecosystem-specific conversion factors (IPCC 2006) were used to add below-ground biomass carbon to this map following the method described here: Ravilious, C., Arnell, A. and Bodin, B. (2015) Using spatial information to support decisions on safeguards and multiple benefits for REDD+. Step-by-step tutorial v1.0: Adding below-ground biomass to a dataset of above-ground biomass and converting to carbon using QGIS 1.8. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK.*

KBA/IBA: Key Biodiversity Areas (KBAs) of the world including Important Bird Areas (IBAs) and Alliance for Zero Extinction sites (AZEs) compiled by BirdLife International and Conservation International, October 2012. Data as of Oct 2014. For further information please contact mapping@birdlife.org.

5.1.2 Wildlife corridors and movement routes

Whilst many protected areas are critical wildlife refuges, a significant proportion of all wildlife in Kenya is found outside protected areas (NEMA, 2009). Areas of natural vegetation also facilitate the movement of wildlife between protected areas, and such corridors can be vital for the long-term viability of wildlife populations and stability of protected ecosystems (though may not be sufficient if the habitat is highly fragmented).

However, many corridors and dispersal areas (distribution areas) are subject to pressures which limit wildlife movements. A new Wildlife Conservation and Management Act was passed in 2013, calling for a national wildlife conservation and management strategy at least every five years to prescribe, for example, schemes and incentives for securing critical wildlife migratory routes, corridors and dispersal areas for sustainable wildlife conservation and management; and adaptation and mitigation measures to avert adverse impacts of climate change on wildlife and its habitats. Furthermore, Kenya's Vision 2030 has established the flagship project "Secure Wildlife Corridors and Migratory Routes", which involves the formulation of strategies to reclaim wildlife corridors and migratory routes that have been affected by human activities.

Map 8 combines information on protected areas and some important wildlife corridors and movement routes in Kenya. It can support decisions on protection and restoration of natural habitat, including forest as appropriate, to facilitate wildlife movement outside protected areas. Note that not all wildlife corridors and movement routes are displayed on this map. The data were created through a thorough review of two unpublished reports coordinated by DRSRS for the northern and southern rangelands (DRSRS, 2012, 2014), which build on information collected from the 1970s to 2010. The two reports contain many detailed local maps and tables of corridors and migration routes, and the review identified and synthesised the locations of linear corridors that could be shown on a map at the national scale, representing the migration or dispersal paths that run mostly outside protected areas. A new shapefile was created showing each corridor as a line, to illustrate wildlife movements between and dispersal outside protected areas, much of which occurs on land that is not under any form of conservation. Some transboundary routes are included.

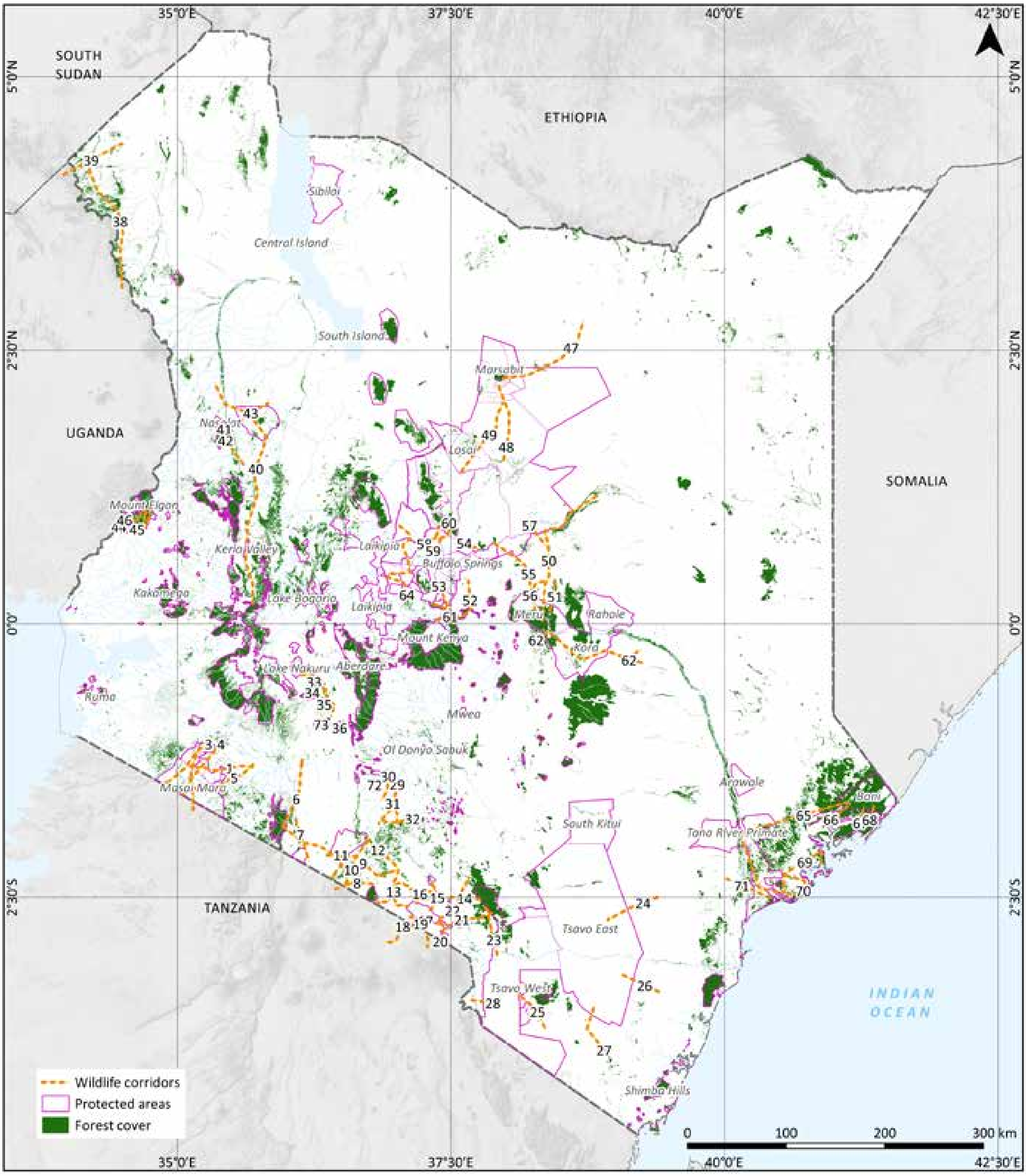
Most of the corridors in the Northern rangelands denote elephant dispersal paths; for example elephant routes occuring between South Turkana NP and Kerio Valley. The Kerio Valley forms a critical linkage between the two conservation areas. Elephant and greater kudu have been recorded there, but settlements have been encroaching and there is illegal livestock grazing. A few smaller routes branching from the main corridor also occur here. (DRSRS, 2014).

In the Southern rangelands there are also critical migration paths for elephant, wildebeest, zebras and other animals. An example comes from the elephant dispersal routes eastwards from Tsavo East NP, including Maktau to Kasigua, the southern park area to Rukinga and Taita, and Tsavo East NP to Kulalu. The Tsavo Ecosystem's large mammal population, especially elephants and large carnivores, depends on wide dispersal areas and corridors extending far beyond protected area boundaries. The Southern park area to Rukinga and Taita is a critical elephant corridor threatened by fencing and small scale farming. Similarly, intensive human activities around the Taita and Rukinga hills limit the elephant movements between the Tsavo East and Tsavo West National Parks. In the latter case, a REDD+ project, the Kasigau Wildlife Corridor project, has been established to secure the vital link between the two parks. Overgrazing is the major threat to the elephant movement corridors between Tsavo East and Galana and Kulalu. (DRSRS, 2012). Table 1 gives an overview of pressures and priority actions of the wildlife corridors presented in Map 8.

Wildebeest migration, Paulus Maukonen

Map 8: Where are some key areas for wildlife movement that are not protected?

This map shows the location of some corridors in Kenya where natural vegetation facilitates the movement of wildlife (elephants, wildebeest and zebra) between protected areas and/or wildlife dispersal areas. Protected areas are marked here in pink, some labelled with name. Corridor numbers shown are referenced in Table 1.



Methods and data sources:

Wildlife migration corridors: Digitised from DRSRS (2014) Kenya's Wildlife Migratory Routes and Corridors: Northern Rangeland Ecosystems, PO Box 47146 Nairobi 00100, Kenya, and DRSRS (2012) Kenya's Wildlife Migratory Routes and Corridors: Southern Rangeland Ecosystems, PO Box 47146 Nairobi 00100, Kenya.

Protected areas: IUCN and UNEP-WCMC (2014), The World Database on Protected Areas (WDPA) [On-line]. Cambridge, UK: UNEP-WCMC. *Available at: www.protectedplanet.net Accessed 12/2014. Additional information from the Kenya Forest Service (KFS) was used to supplement this data. National parks and reserves are labeled on this map.*

Forest: Kenya Forest Service (2013) Report on National Forest Resource Mapping and Capacity Development for The Republic of Kenya. KFS; Nairobi, Kenya. Data created by the Kenya Forest Service in 2010. *All forest types are represented on this map.*

Table 1: *Overviews of pressures and priority actions of the wildlife corridors presented in Map 8. The information in this table is drawn from DRSRS (2012, 2014).*

Corridor	Pressures	Priority actions
SERENGETI-MARA ECOSYSTEM		
1-5	Corridor 5 is highly threatened, requiring work with communities to develop compatible land uses. Most of the other corridors are under relatively low levels of threat depending on the existence of conservancies (a conservancy is land set aside by an individual landowner, body corporate, group of owners or a community for purposes of wildlife conservation). Increasing human population and land tenure insecurity in the Mara have led to an increase in settlements and land-use transition with large-scale mechanized cultivation and intensification of agriculture and livestock production (especially pigs). There has been uncontrolled build-up of tourism facilities. This has all led to wildlife movements outside protected areas being hampered: wildebeest movement to the Loita are curtailed by large-scale agriculture and elephant movement to Transmara and Mau are hindered by agricultural fields and settlements. Over the last 30 years, wildlife density has declined by more than 65%. The wet season grazing/calving land in the Loita/Ngorengore for wildebeest and Lolgorian forest for elephant have been lost. Loss in extent of Mau forest will reduce water to the Mara.	The contiguity of conservancies in this region helps greatly in ensuring connectivity and increasing the freedom of movement for large animals. There is a need to link the conservancies with the Loita wet season range. Creating more conservancies through public-private partnerships in corridor areas could ensure continuity of wildlife habitats. Payments for ecosystem services (PES) for upstream water management and/or wildlife area management could be explored, including REDD+ incentives to rehabilitate the Mau forest, which the wildlife in the Mara and Serengeti depend upon for water. There is also a proposed management plan for the Maasai Mara NR that would zone the park into areas of low, medium and high tourism activities with the aim of optimizing the number of tourists in each zone for better park management and benefits.
SOUTH RIFT ECOSYSTEM – NATRON AND MAGADI		
6-7	Drivers of natural habitat loss include population growth, land tenure and ownership change, land subdivision into smaller land-holdings, changing climate and rainfall patterns. This has led to increased agricultural expansion and livestock populations, dense settlements, water abstraction, charcoal burning and sand harvesting. As a result, habitat has been lost and wildlife numbers are down.	Recommended actions include establishing community conservancies in wildlife dispersal areas and migratory routes, and ensuring that the cross border corridor in the area of Namanga and Longido is not cut off
AMBOSELI-WEST KILIMANJARO ECOSYSTEM		
8-22	Drivers of natural habitat loss include population growth, land tenure and ownership change, land subdivision, changing climate and rainfall patterns, scarcity of water and lack of incentive to conserve wildlife. This has led to changes including expanding agriculture, fencing of swamps, water extraction, charcoal burning and illegal hunting. Some corridors have been blocked or threatened with blockage, while others are not under threat. The connection between Tsavo West NP and the Amboseli Ecosystem as well as the access to Chyulu Hills has been curtailed. The last remaining link between the northern face of Mt. Kilimanjaro to Amboseli NP as well as the corridor between the mountain forest and lowlands is being cut. Swamps critical to wildlife and livestock between Tsavo West, Chyulu Hills and Amboseli NP are diminishing.	Ongoing responses include gazettement of the Amboseli Ecosystem Plan and development of relevant policies and laws. Legal and economic instruments (leases, easements and agreements) are being encouraged in the subdivided group ranches and unsubdivided areas to expand wildlife areas and promote the development of viable conservation ventures. Participatory land-use planning mechanisms in group ranches is being encouraged. High priority actions include establishment of conservancies to: (a) link the following migration routes: Amboseli-Kimana-Kuku-Chyulu-Tsavo West NP, Amboseli-Olgulului North-Imbirikani-Chyulu-Tsavo West, Amboseli-Olgulului south- Loliondo-Longido and Chyulu-Rombo-Tsavo West; (b) draw cross border agreements between Kenya and Tanzania and (c) secure the Amboseli-Kitenden-Kilimanjaro corridor.

Corridor	Pressures	Priority actions
TSAVO-MKOMAZI ECOSYSTEM		
23-28	Drivers of natural habitat loss include population growth, land tenure and ownership change, land subdivision, changing climate and rainfall patterns, scarcity of water and lack of incentives to conserve wildlife. This has led to, among other things, land-use change, encroachment and human-wildlife conflicts. Some corridors are being threatened with blockage or degradation, while others (inside the park) are not under threat.	High priority interventions include establishment of new community wildlife conservancies to increase area accessible to wildlife and maintain contiguous habitats; support the development and gazettement of participatory land-use plans for wildlife conservancies; and strengthen transboundary wildlife management with Kenya.
KITENGELA-ATHI-KAPITI ECOSYSTEM		
29-32 +72	Corridor 30 is the most threatened, followed by 29 and 72. Increasing human population, industrial development, subdivision of land and fencing are restricting wildlife movements. Horticulture is polluting the river, quarrying activities are converting grazing land to wasteland, and sand harvesting along the river is reducing water availability. Climatic changes have been observed leading to unreliable rainfall and loss of dry season refuges. Further threats include illegal hunting, the southern bypass/the Namanga-Nairobi road as a major barrier, and Konza city. The wildlife populations have dwindled and critical corridors cut off – a large population is isolated in Machakos ranches.	A land lease program where landowners are paid for not farming, subdividing land or erecting fences has been established. A master land-use plan has been created. Recommendation for action includes land reclamation and acquisition to link Nairobi NP with other core wildlife areas; establishment of conservancies; improvement of management plans; payments for ecosystem services such as land-lease programmes, easement mechanisms, and upstream water management; REDD+ incentives could be used to rehabilitate the Ngong Hills which provide water to the Athi-Kapiti ecosystem.
NAIVASHA-NAKURU-EBURU AREA		
33-37 +73	Population growth, urbanization, insecure land tenure and subdivision of land parcels have led to encroachment of human settlements, farming, salt mining and fencing, as well as degradation from over-grazing, illegal hunting, illegal water harvesting, logging, charcoal burning and sand harvesting. Wildlife habitats are becoming increasingly isolated, especially the Rift Valley lake system and the Eburu forest reserve.	High priority interventions include developing and implementing land use master plans; securing corridor 73 between Hell's Gate NP and Oserian-Lake Naivasha and corridor 36 from Hell's Gate NP through Kedong to Mt. Longonot; gazetting Lake Naivasha as a national reserve; encourage co-management strategies and purchase private land for the extension of conservation areas.
TURKANA REGION		
38-43	Corridors 40 and 41 are experiencing particularly high threat levels, followed by 38 and 39. Corridors 42 and 43 are noted as having low threat level. Drivers and pressures include expansion of settlements and agriculture; insecure land tenure prompting subdivisions of communal lands to individual parcels with increased fencing; insecurity threats leading to inaccessibility of dry season grazing areas and illegal hunting; construction of hydropower generation facilities; the Kitale-Kapenguria-Lodwar-Lokichogio highway and the LaPSSET transport corridor; oil prospecting and drilling; impacts of climate change on surface water and aquifers; droughts; expansion of irrigation agriculture along the rivers; soft boundaries to protected areas; invasive species such as *Prosopis juliflora*.	Responses and opportunities include public-private-partnerships (PPP) to benefit from conservation areas through land lease, easement programmes, and payment for ecosystem services. Conservancies are being established to allow communities benefit from wildlife. County government authority, community groups and KWS have acquired more land for conservation in the region. Local communities are reconsolidating their lands to create community conservancies to benefit from payments for ecosystem services.

Corridor	Pressures	Priority actions
MT ELGON		
44-46	Over the last two decades, severe human encroachments have occurred in the western section and into the forest and moorland buffer zone around the park (IUCN/UNEP, 1987). A mining concession in Trans Nzoia County has led to fragmentation and loss of wildlife habitats.	High priority interventions include establishment of new community wildlife conservancies to increase area accessible to wildlife and maintain contiguous habitats; support the development and gazettement of participatory land-use plans for wildlife conservancies; and strengthen transboundary wildlife management with Kenya.
MT MARSABIT FOREST AND ADJACENT LOWLANDS		
47-49	Threats include encroachment by human activities; illegal hunting and drought.	No specific recommendations are yet developed for this area.
NAIVASHA-NAKURU-EBURU AREA		
33-37 +73	Population growth, urbanization, insecure land tenure and subdivision of land parcels have led to encroachment of human settlements, farming, salt mining and fencing, as well as degradation from over-grazing, illegal hunting, illegal water harvesting, logging, charcoal burning and sand harvesting. Wildlife habitats are becoming increasingly isolated, especially the Rift Valley lake system and the Eburu forest reserve.	High priority interventions include developing and implementing land-use plans; securing corridor 73 between Hell's Gate NP and Oserian-Lake Naivasha and corridor 36 from Hell's Gate NP through Kedong to Mt. Longonot; gazetting Lake Naivasha as a national reserve; encourage co-management strategies and purchase private land for the extension of conservation areas.
MERU-ISILO-SAMBURU ECOSYSTEM and LAIKIPIA-SAMBURU-MT KENYA LANDSCAPES		
50-64	Threats include insecurity and illegal hunting; livestock incursion into parks; opportunistic crop farming; rapid increase in population driven by need for agricultural land, water and pasture, and urban growth. Elephant route 44 from Shaba NR to Meru NP through Garbatulla is critical for the survival of the species in this region. Corridor 64 is important for Grevy's zebra.	There is enormous eco-tourism potential in the Laikiia-Samburu-Mt. Kenya region, but this comes with trade-offs to traditional pastoralism, forestry and crop cultivation (particularly to wetter highlands). Understanding the trade-offs in pursuing different land uses together is important.
NORTH COAST TERRESTRIAL ECOSYSTEM		
65-71	Many of these corridors are blocked. Encroachment through expansion of agriculture and settlements is a major threat. Land tenure is insecure and some delineation has led to conflicts. Development of the LaPSSET transport corridor will severely restrict wildlife movements unless safe crossings are established, especially for corridor 57 between Boni/Dodori and the Tana River Primate National Reserve. Insecurity and illegal hunting remains a problem, and climate-change-induced droughts cause competition between livestock and wildlife.	Establish Dareem, Kipini and Lamu conservancies, and a conservancy on western bank of Tana River to link Ndera conservancy and Tsavo East NP. Work with communities to develop compatible land-use plans, establish conservancies and develop and implement security strategies against illegal hunting.

Herd of elephants moving through the Maasai Mara, Paulus Maukonen

Soil eorision in the Tana River watershed, Georgina Simth - CIAT / Flickr

5.2 Ecosystem services

5.2.1 Soil erosion prevention and hydrological flows

Forests, especially those on slopes, can provide critical services of soil stabilization and erosion prevention as well as hydrological regulation that supports the capacity of land to deliver stable water flows in streams and rivers. For example, the Mau Forest complex in Kenya provides goods and services worth US$1.5 billion a year through water for hydroelectricity, agriculture, tourism and urban and industrial use, as well as erosion control and carbon sequestration (UNEP, 2014).

After deforestation or forest degradation, surface runoff after heavy rains is often exacerbated, leading to soil erosion and higher risk of floods and water shortages downstream. Soil particles carried by runoff lead to siltation in streams and rivers which can damage downstream infrastructure, such as hydroelectric and other dams. Kenya's National Climate Change Response Strategy (Government of Kenya, 2010a) notes that hydroelectric power generation in the country is indeed affected by this problem. The decline in hydroelectric power production in 2002 was caused by a combination of reduced river flow (volume) due to the 1999-2000 droughts and the siltation of dams by the 1997-1998 El-Niño floods.

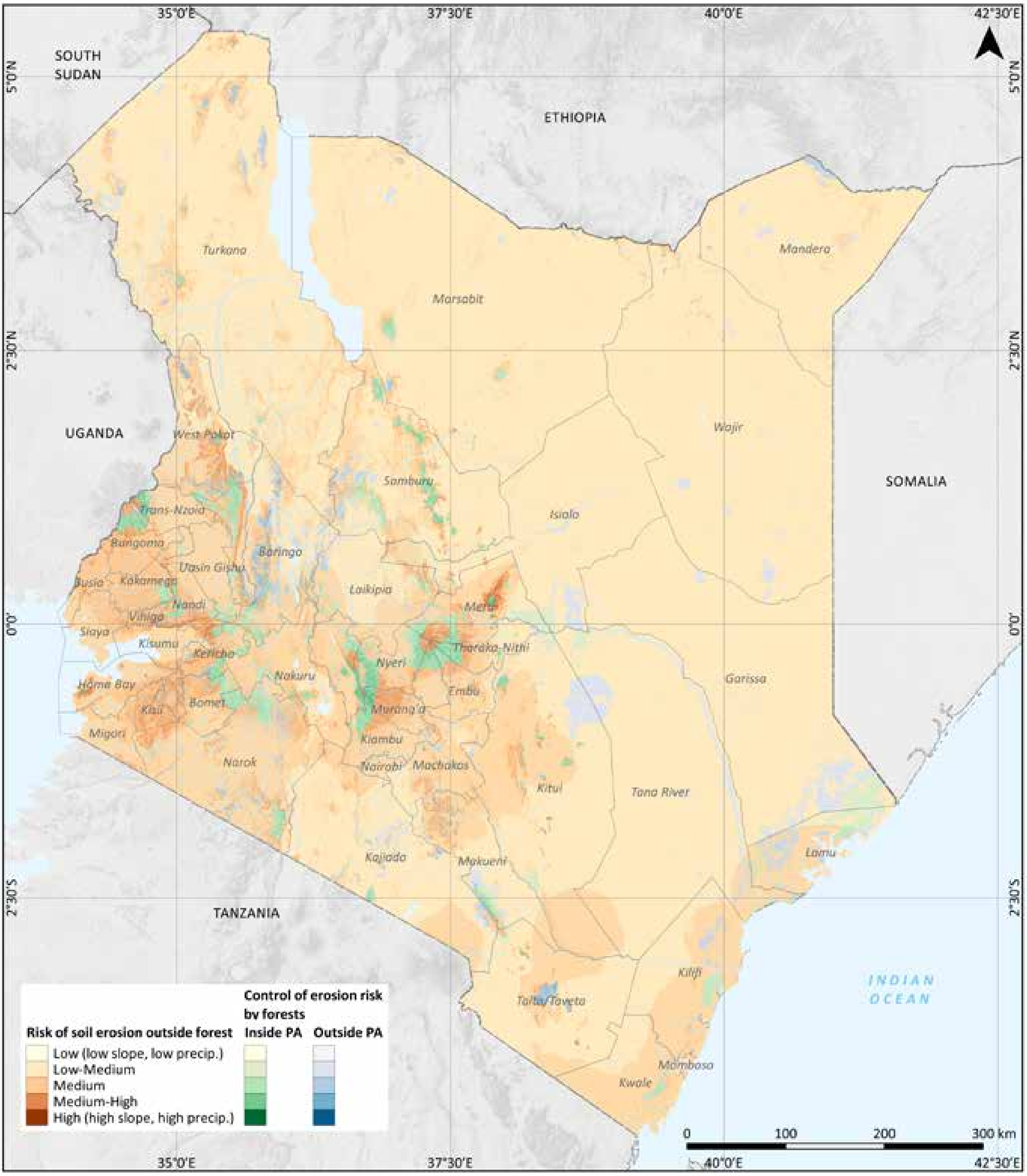
Map 9 shows forests that are likely to be particularly important for preventing water-induced soil erosion, both inside and outside protected areas, as well as non-forested areas at risk of erosion. This map is based on a simple index which combines slope and average annual precipitation; so that areas with high slope and high precipitation have the highest risk rating. Much of the forest area with higher capacity to prevent erosion is protected; some other forests such as those in the Rift Valley have similar qualities.

Map 9 can help direct efforts to protect forests that provide some particularly important soil stabilization services, and also identify areas where reforestation can help to reverse or prevent soil erosion. See Box 3: Restoring forests in Kenya for multiple benefits, for further elaboration.

Map 10 further highlights the critical role for water regulation fulfilled by the five major water towers – Mount Kenya, the Aberdare Range, the Mau Forest Complex, Mount Elgon, and the Cherangani Hills. The water towers are high altitude montane forests, situated in some of the most densely populated areas of Kenya (see map 13). They stand out in Map 9 as areas where the forest is preventing soil erosion. They form the upper catchments of nearly all the main rivers, thereby providing the country with water for irrigation, agriculture, industrial processes, and hydro-power (about 60 per cent of Kenya's electricity production comes from hydropower) (UNEP, 2009). The montane forests that support these critical services have been lost or degraded through a number of drivers, despite being recognized as vital to Kenya's economy and the livelihoods of its citizens. The Kenya Vision 2030 has nominated rehabilitation and protection of the water towers one of its flagship projects both between 2008-2012 and 2013-2017 (Government of Kenya, 2013).

MAP 9: Which existing forests prevent soil erosion caused by rainfall? Which of these forests are protected? Which areas likely to be at high risk of soil erosion are currently lacking forest cover?

Map 9 shows forests that are particularly important for preventing soil erosion by rain. Green areas shows the relative importance of forests for stabilizing soils inside protected areas, while blue areas show the equivalent outside protected areas. Dark orange areas show places where soil erosion risk is high outside of forests.



Methods and data sources:

Erosion risk: Slope was calculated from void-filled hydroSHEDS DEM data at 3 arc second resolution courtesy of the U.S. Geological Survey. Average annual precipitation was calculated using data from WorldClim (Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.) The two layers were reclassified and added together to produce a layer indicating the risk of soil erosion.

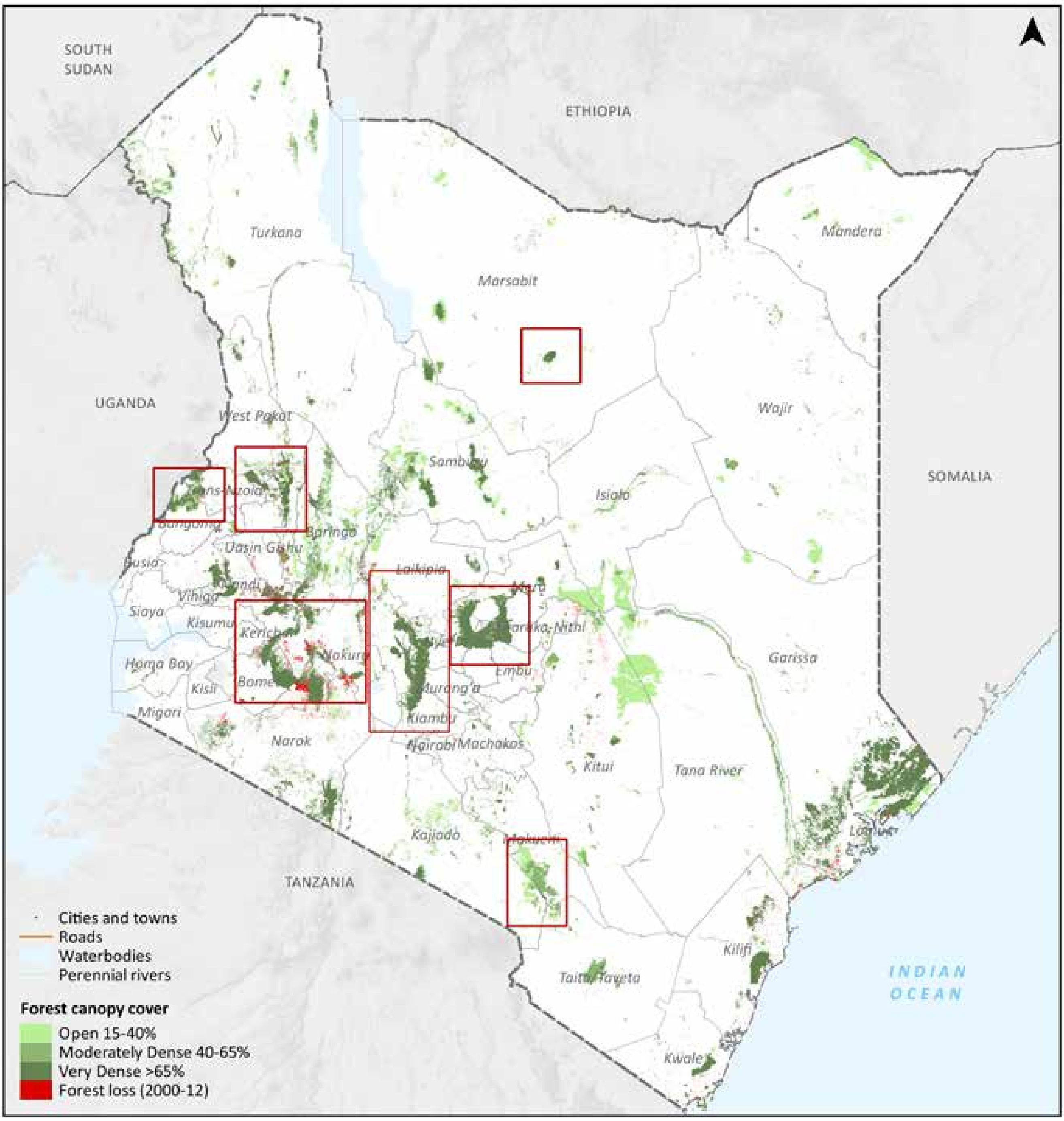
Forest: Kenya Forest Service (KFS) Land Cover 2010. The erosion risk layer was clipped according to two shapefiles representing forests within and outside protected area, created using the protected area boundaries and the forest cover data.

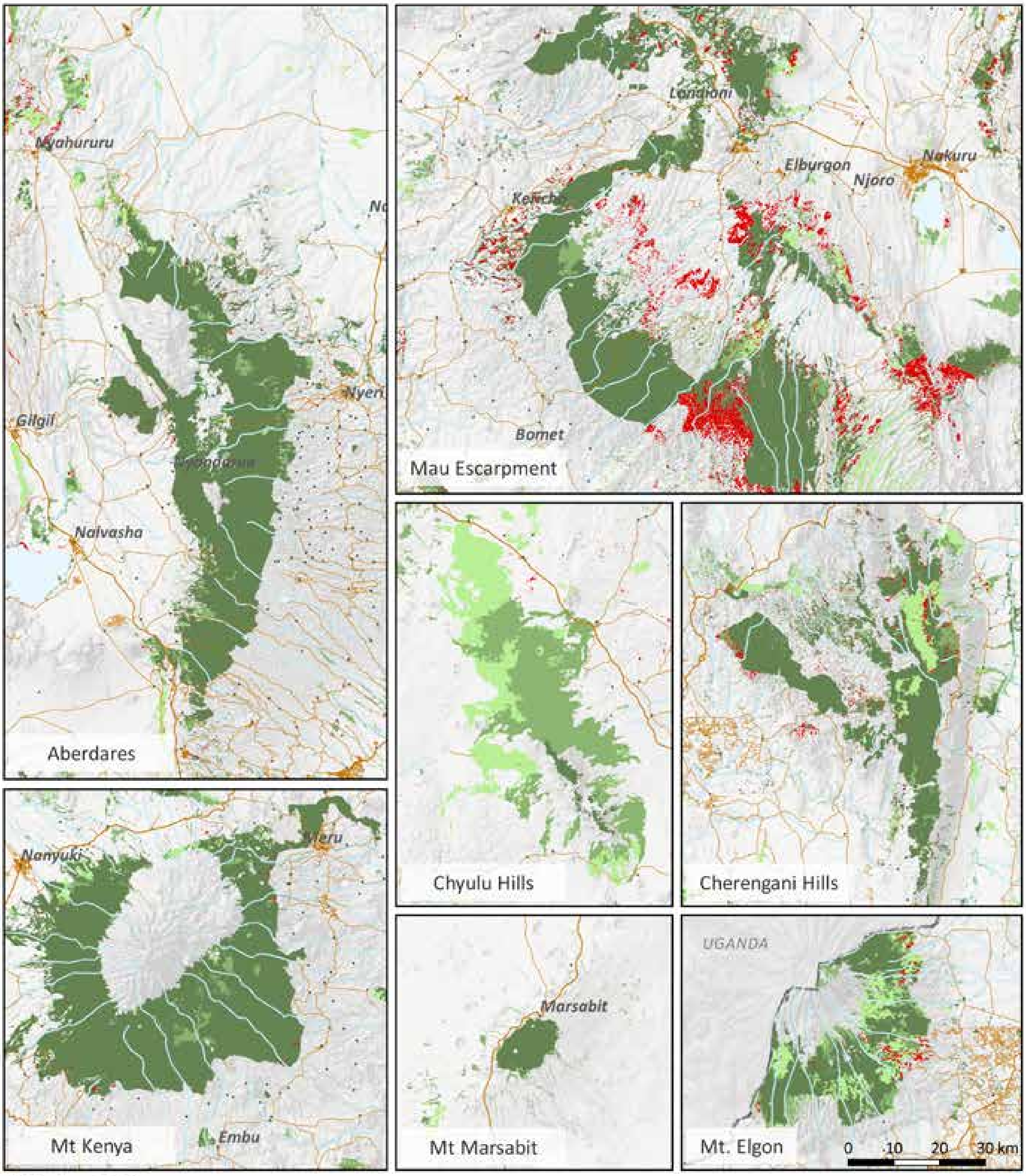
A complete methodology entitled "Open Source GIS Tutorial 7: Evaluating Soil Erosion Risk using QGIS" is available at http://www.unredd.net/index.php?option=com_docman&view=document&alias=14150-open-source-gis-tutorial-7-evaluating-soil-erosion-risk-using-qgis&category_slug=gis-tools-3403&Itemid=134

View of Mount Kenya, Paulus Maukonen

Map 10: Where has recent forest loss occurred on Kenya's major water towers?

Kenya's five major water towers – Mount Kenya, the Aberdare Range, the Mau Forest Complex, Mount Elgon, and the Cherangani Hills – are priority areas for the Government's forest rehabilitation efforts. Understanding where forest loss has occurred recently is helpful for targeting such efforts. Smaller water towers Chyulu Hills and Mt. Marsabit are also shown here.





Methods and data sources:

Towns: Towns and urban centres in Kenya digitized by International Livestock Research Institute, ILRI, GIS group from Kenya topographic sheets scale 1:250,000 for Northern Kenya and 1:50,000 for rest of Kenya from Survey of Kenya (2000). Downloaded from ILRI GIS services December 2014. http://192.156.137.110/gis/

Roads (local scale): Open Street Map (OSM) 2015 Data for Kenya downloaded at http://extract.bbbike.org/ on 01 Feb 2015

Forest: Kenya Forest Service (KFS) Land Cover 2010. All forest types are represented on this map.

Forest loss 2000 - 2013: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest. *Forest loss during the period 2000–2010, defined as a stand-replacement disturbance, or a change from a forest to non-forest state. Loss pixels were resampled to 90m resolution using a majority filter, in order to reflect areas of major forest loss.*

Rivers: World Resources Institute; Department of Resource Surveys and Remote Sensing, Ministry of Environment and Natural Resources, Kenya; Central Bureau of Statistics, Ministry of Planning and National Development, Kenya; and International Livestock Research Institute. (2007) Nature's Benefits in Kenya, An Atlas of Ecosystems and Human Well-Being. Washington, DC and Nairobi: World Resources Institute.

6. The distribution of drivers of deforestation and forest degradation

Understanding the history of forest use and change, including the direct and underlying drivers of deforestation and forest degradation, is necessary for REDD+ strategy formulation and to ensure implementation success. In order to make sure that its REDD+ strategy addresses these drivers, the Government of Kenya has conducted an analysis to identify drivers and underlying causes of forest cover change in the country's different forest types (Ministry of Forestry and Wildlife, 2013). The study collected information through consultative workshops and showed that while the same direct drivers are at work in different areas, the underlying drivers or causes can differ.

The study found that the most dominant direct drivers of forest-cover loss in Kenya have been agricultural expansion and harvesting wood for charcoal and fire wood. Poles for construction for houses and fences are another major forest product that drives forest degradation. There are no commercial concessions for indigenous timber species, but the montane forests in Mau and at Mt Elgon are subjected to illegal logging, particularly for cedar (*Juniperous procera*) and Elgon teak (*Olea welwitschii*). Illegal harvesting of cedar also affects Mt Kulal and Mt Marsabit. Public infrastructure such as roads, railways and dams acts as both a direct and indirect driver of deforestation. Other direct drivers of deforestation and forest degradation are human settlements, mining, damage by wildlife restricted to limited areas, and wild fires.

The consultations also found that the indirect or underlying drivers identified across Kenya were: governance and policies, industrial demand, commodity prices, costs of alternative energy sources, population, rural poverty, infrastructure and weak institutional presence of KFS.The study noted that it would be an important next step to attempt to quantify the effects of the drivers as Kenya designs region-specific forestry and REDD+ strategies. Box 1 on page 32 summarizes a study conducted by Adam Formica, MSc student at University of Oxford, UK, that contributes towards filling this gap.

This section presents some datasets relevant to deforestation and forest degradation that may be helpful for identifying zones for certain policies and measures that Kenya could consider under REDD+.

Maize crop in Narok County, Paulus Maukonen

6.1 Past deforestation, population pressure and infrastructure

The drivers analysis found that development of public infrastructure such as roads, railways and dams directly causes deforestation and also encourages new settlements which put pressure on forest land and resources, though there are no clear records of the extent of these impacts. Roads and railways also transport local wood products to distant markets. Thus infrastructure is both a direct and underlying driver of forest cover change. Further planned infrastructure development, especially development of roads (Isiolo – Merile, Merile-Marsabit and others at different stages of development), is likely to result in increased pressure on dry forests in particular. The LAPSSET project, which will connect the future Lamu Port on Kenya's Coast to the South Sudan oil fields by railway and pipeline, will also most likely cause forest cover loss. Measures to prevent or reduce such impacts may be desirable.

Population growth was found to be a driver of both forest degradation and deforestation, leading to over-harvest of fuelwood and charcoal, which degrades the forest and makes it easier to convert to agriculture. This problem has been felt in particular in the Mau Complex, Kakamega, Gwasi Hills, Aberdares, Mt Elgon, Mt Kenya and Mt Kulal. Map 11 illustrates how population density and road infrastructure relate spatially to forest distribution and patterns of past deforestation.

Past deforestation is a very strong predictor of future deforestation (see Box 1). According to Hansen et al. (2013), some of the Kenya water towers experienced significant deforestation between 2000 and 2013, as did areas around the coast. One of Kenya's candidate strategy options in its R-PP (Government of Kenya, 2010b) targets these areas directly through promotion of sustainable forest management (SFM) in all the water towers.

The impact of human population density on deforestation is indirect, being felt through expansion of agriculture, grazing pressure (livestock density), and woodfuel extraction. While population distribution may not be a straightforward predictor of deforestation in Kenya (see Box 1), the information can help in planning suitable actions to address the needs for forest products (e.g. woodfuels, see Box 2), and targeting enhanced enforcement of forest protection and capacity of forest extension services.

Map 11 shows also how the road network allows access to forests, which can facilitate deforestation and forest degradation.

6.2 Livestock grazing

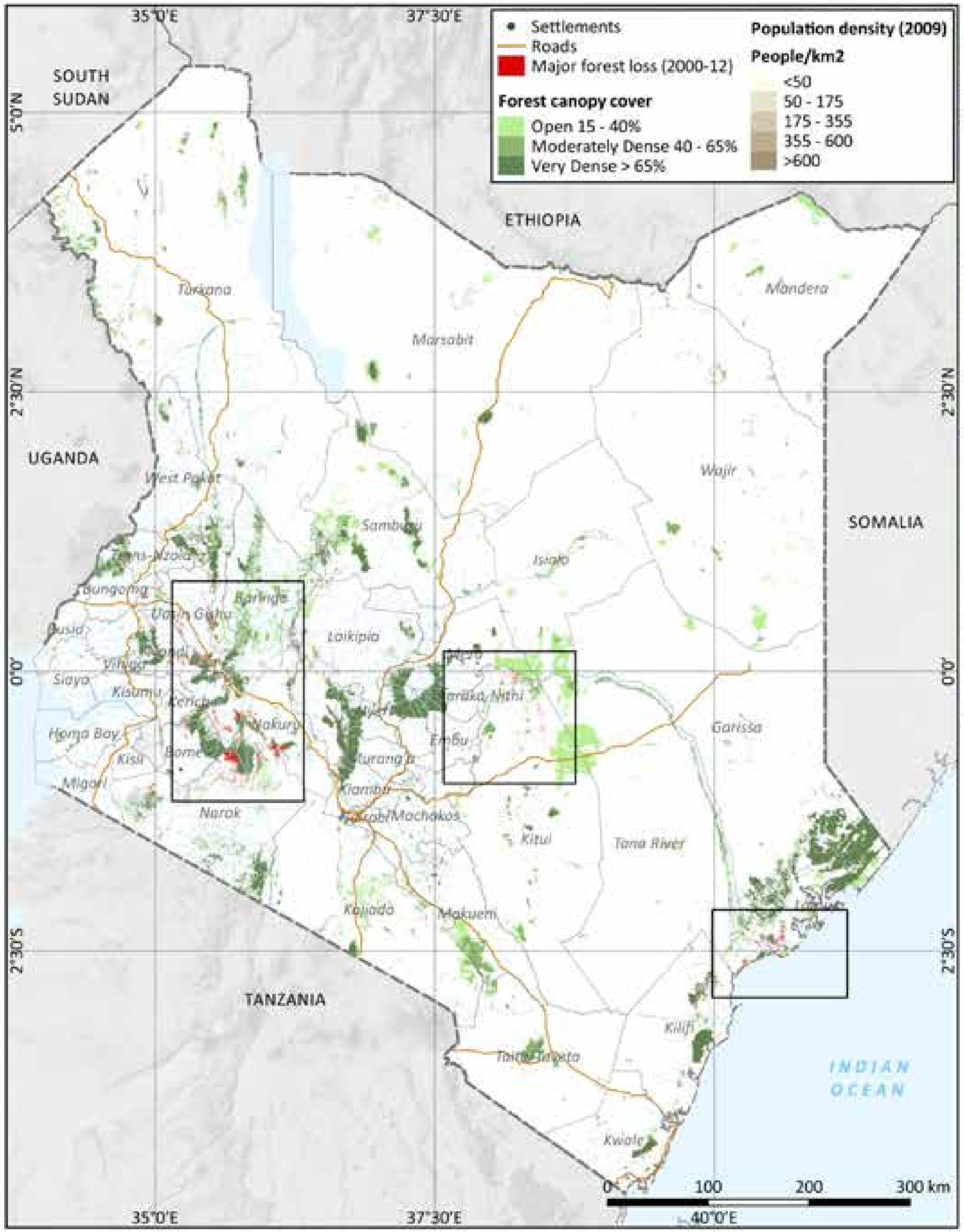
Livestock grazing is a recognized driver of forest degradation in various parts of Kenya and has been estimated to contribute to 7% of forest degradation (Ministry of Forestry and Wildlife, 2013). While livestock keeping is often carried out in a way that respects forests, an increasing population has resulted in increased grazing pressure, particularly in the drylands and also in places such as the Taita and Cheringani Hills (Ministry of Forestry and Wildlife, 2013). Kenya's R-PP includes a strategy option for encouraging livestock keepers to improve the quality of their livestock, reduce numbers and implement improved management of grazing lands.

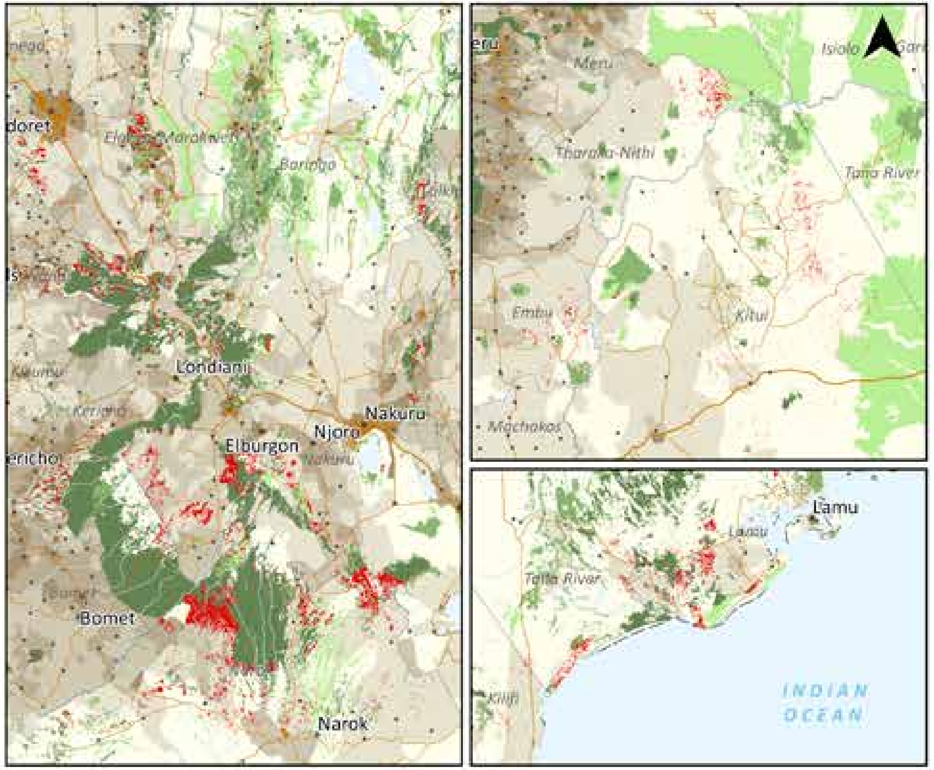
To identify forests or other wooded land where livestock pressure may be particularly high, Map 12 shows overall livestock density together with biomass carbon in the arid and semi-arid lands (ASAL) of Kenya. It also shows known livestock migration routes and specific information about cattle and sheep/goat density. These maps could be usefully complemented with difficult-to-map information, such as reports on grazing impacts on understory vegetation and other forest degradation.

Cows herded through forest, Marich Pass, Paulus Maukonen

Map 11: How do infrastructure and settlements relate spatially to forest extent and recent deforestation?

These maps show forest extent together with three strong predictors of deforestation: recent deforestation, population density and infrastructure. Population density is an indirect driver that exerts pressure in different ways, while infrastructure development can be both a direct and indirect driver. Past deforestation has been shown to be strongly correlated with future deforestation.





Methods and data sources:

Towns: Towns and urban centres in Kenya digitized by International Livestock Research Institute, ILRI, GIS group from Kenya topographic sheets scale 1:250,000 for Northern Kenya and 1:50,000 for rest of Kenya from Survey of Kenya (2000). Downloaded from ILRI GIS services December 2014. http://192.156.137.110/gis/

Roads (national scale): Survey of Kenya. Road network of Kenya derived from topographic map sheets (1978-1997) of scale 1:50.000. Downloaded from ILRI GIS services December 2014. http://192.156.137.110/gis/

Roads (local scale): Open Street Map (OSM) 2015 Data for Kenya downloaded at http://extract.bbbike.org/ on 01 Feb 2015

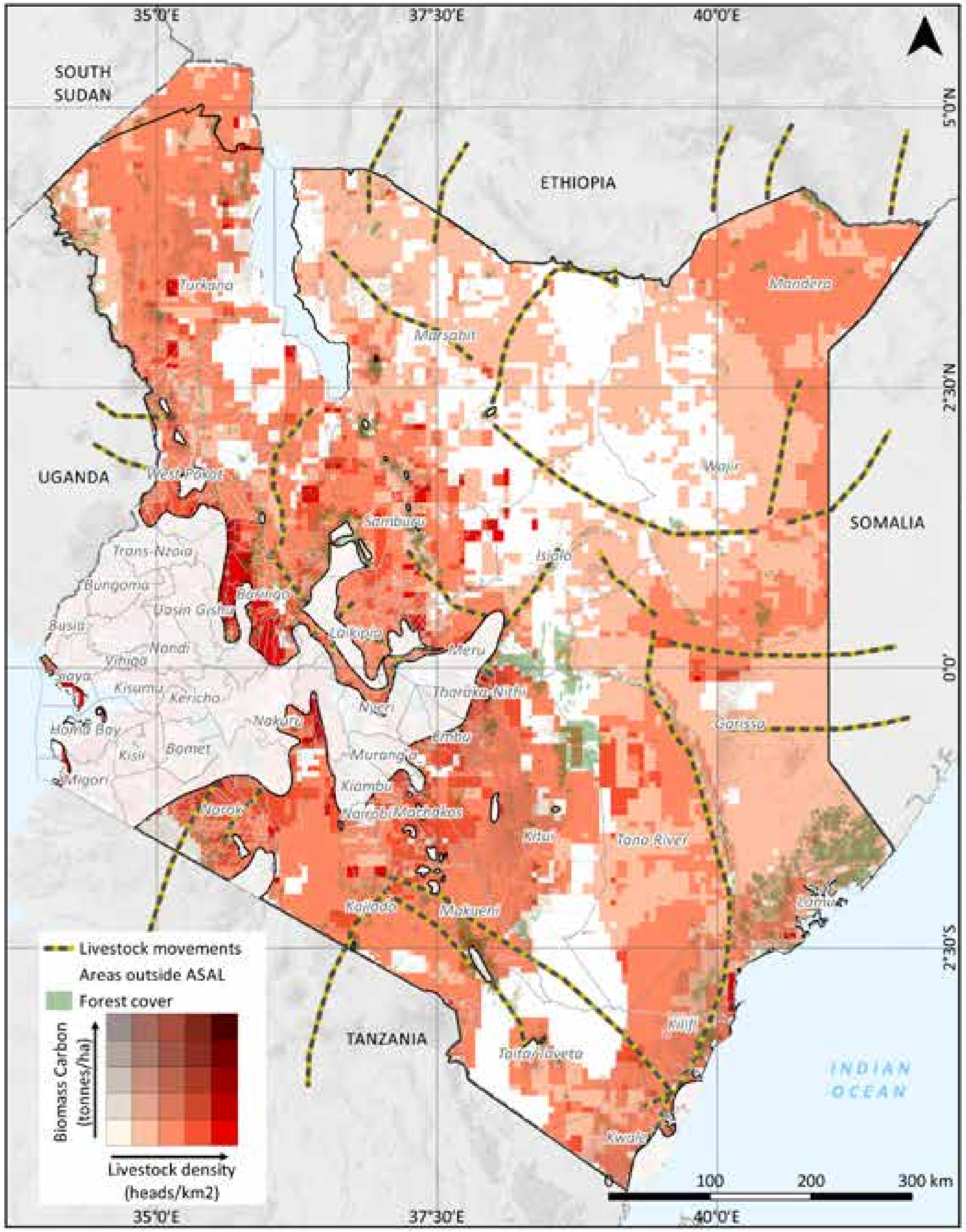
Forest: Kenya Forest Service (KFS) Land Cover 2010. All forest types as defined in Map 3 are presented here.

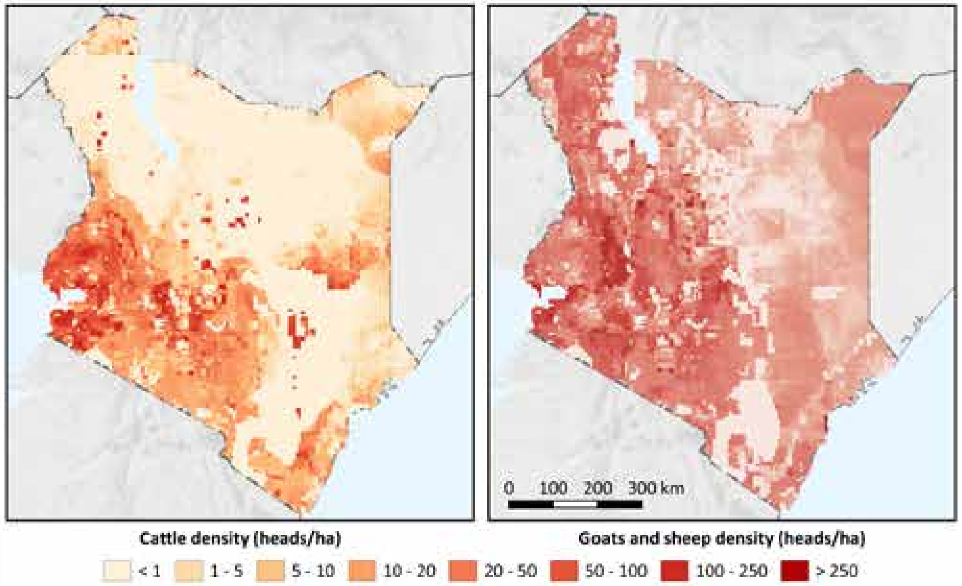
Forest loss 2000 - 2013: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend.(2013)"High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest. *Forest loss during the period 2000–2010, defined as a stand-replacement disturbance, or a change from a forest to non-forest state. Loss pixels were resampled to 90m resolution using a majority filter, in order to reflect areas of major forest loss.*

Population density 2009: Data from the 2009 Census of Kenya (Kenya National Bureau of Statistics) was combined with a shapefile of the Kenya Sublocation boundaries (smallest administrative unit) by the Kenyan-based NGO RuralFocus Ltd., P.O. Box 1011, Nanyuki 10400, Kenya.

Map 12: Where could improved livestock and grazing management protect forests?

These maps show areas of high livestock density in relation to above-ground biomass, to help inform decisions on where it could be important to improve livestock and grazing management to protect forests or other wooded land. In the arid and semi-arid lands of Kenya, livestock is a driver of forest degradation. Inset map shows the diversity and distribution of agro-climatic zones in Kenya.





Methods and data sources:

Biomass carbon (left): Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P., Dubayah, R., Friedl, M. (2012) Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change 2. 3:182-185. http://dx.doi.org/10.1038/NCLIMATE1354; *Ecosystem-specific conversion factors (IPCC 2006) were used to add below-ground biomass carbon to this map following the method described here: Ravilious, C., Arnell, A. and Bodin, B. (2015) Using spatial information to support decisions on safeguards and multiple benefits for REDD+. Step-by-step tutorial v1.0: Adding below-ground biomass to a dataset of above-ground biomass and converting to carbon using QGIS 1.8. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK.*

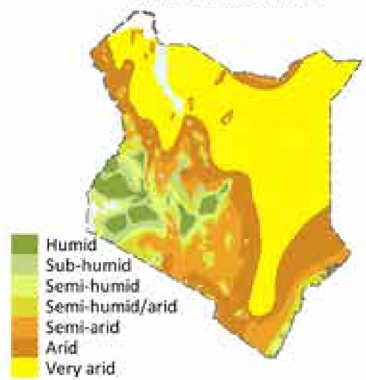
Livestock density (cattle; goats; sheep): Gridded Livestock of the World v2.0. Robinson T.P., Wint, G.R.W., Conchedda, G., Van Boeckel, T.P., Ercoli, V., Palamara, E., Cinardi, G., D'Aietti, L., Hay, S.I and Gilbert, M. (2014) Mapping the global distribution of livestock. PLoS ONE 9(5):e96084. doi:10.1371/journal.pone.0096084. Downloaded March 2015.

Livestock migration routes: Collected by Food Security Steering Group (KFSSG) in 2009 as part of the 2010 short rains season assessment report to the Kenya Government to help in planning purposes. The data was used by ILRI in the year 2011 to compile a GIS database for the Ministry of State for development of Northern Kenya and Other Arid Lands (MDNKOAL) project.

Drylands (ASAL area): Kenya agro-climatic zones based on a combination of both moisture availability zonation and temperature zonation. UNEP/GRID database derived from the Exploratory Soil Survey Report number E1, Kenya Soil survey, Nairobi 1982. Downloaded from ILRI GIS services March 2015 http://192.156.137.110/gis/. Zones catergorised as 40-50-Semi-humid to Semi-arid; Semi-arid; Arid; and Very arid were included here to represent dryland areas.

Forest: Kenya Forest Service (KFS) Land Cover 2010. All forest types are represented in this map, clipped to dryland areas.

Agro-climatic zones



6.3 Fires

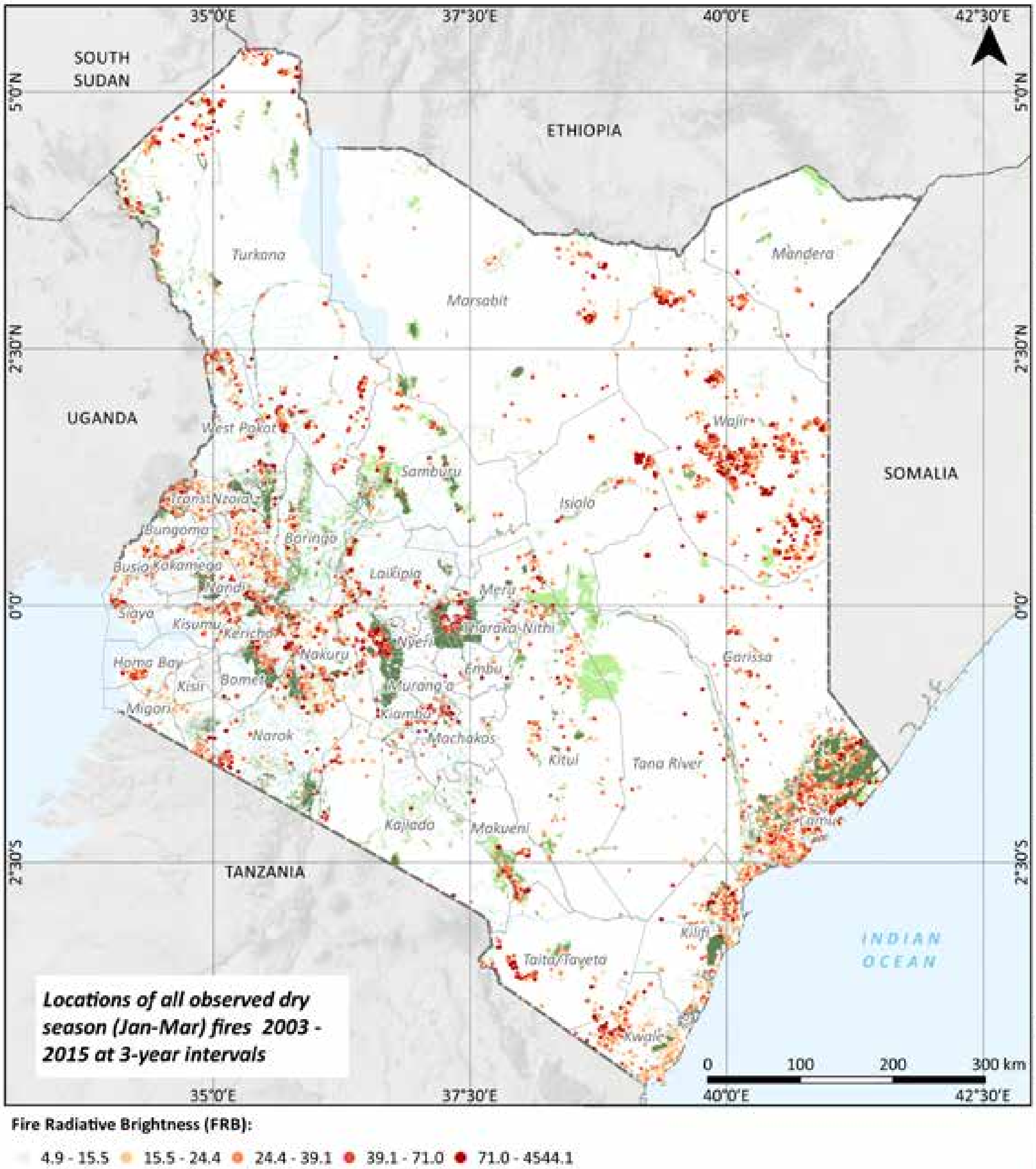
The Ministry of Forestry and Wildlife (2013) also identified fire and poor fire management as a driver of forest degradation in Kenya. Map 13 shows an increase in fire occurrence in Kenya between 2003 and 2015. All major forest areas as well as many ASALs have been affected. In addition to knowing where fires are happening, addressing forest fire requires also understanding its causes.

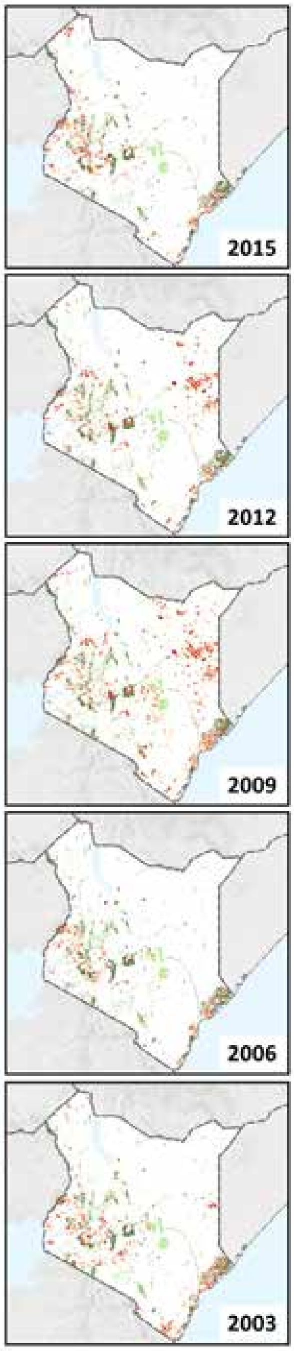
Fire is traditionally used in pasture management, and in land preparation or clearing for cultivation. Annual fires tend to reduce regeneration of natural forests and woodlands, especially when fires spread outside their target area, and create opportunities for agricultural expansion. Extended droughts also lead to dry fuel loads, which increase the risk of heavy burning of standing trees. This is especially pronounced for example in Marania and Ontulili forests on the Western Slopes of Mt Kenya (Ministry of Forestry and Wildlife, 2013).

Kenya's R-PP notes the need to support KFS to address forest fires, including investment in early warning systems, fire preparedness and enhancing firefighting capability.

Map 13: Where is there pressure on the forest from fires?

This map shows the locations of dry season fires in Kenya between the years 2003 and 2015, based on MODIS satellite data. All of the major forest areas, as well ASAL lands are affected by fires.





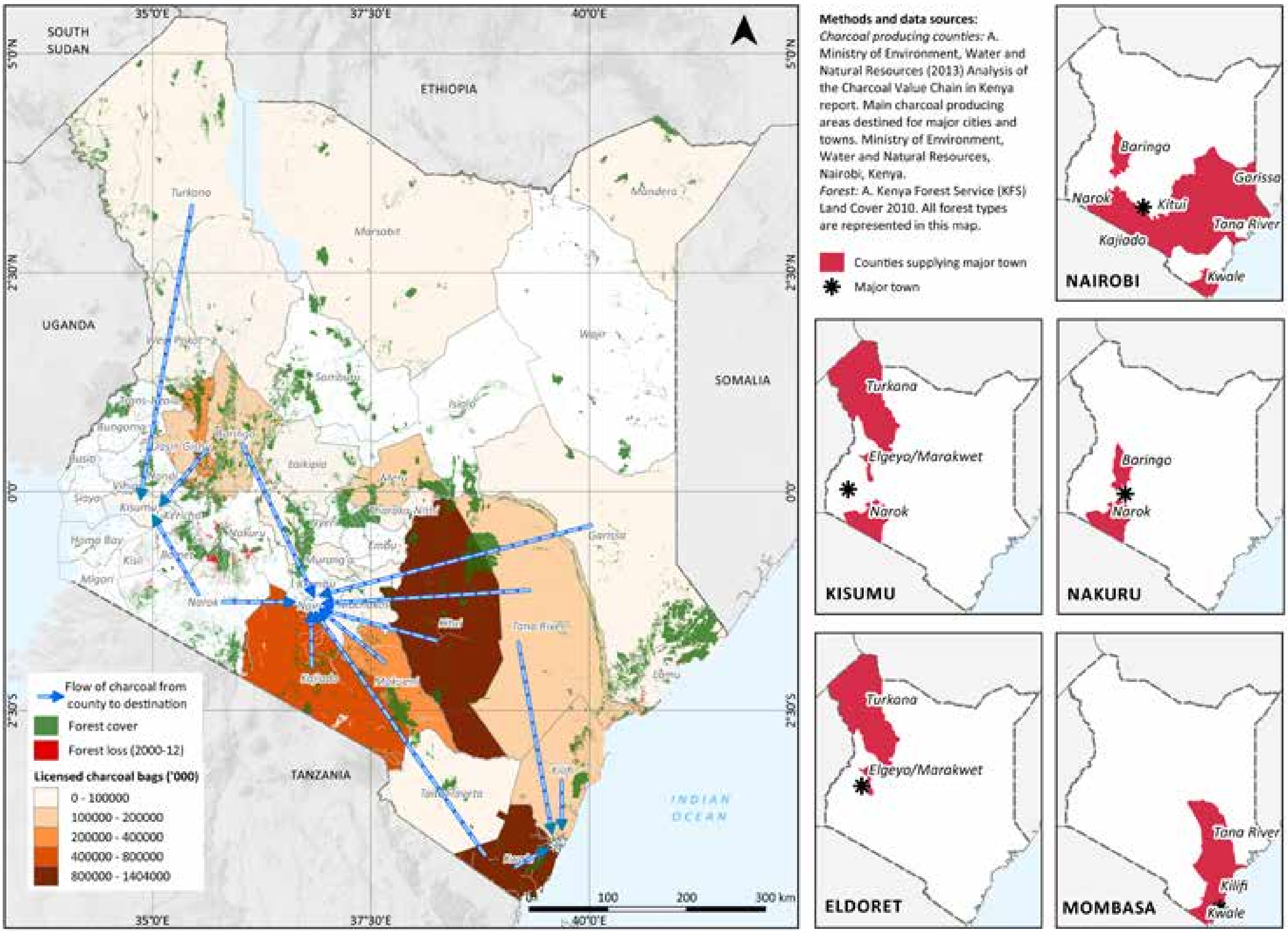
Methods and data sources:

Fires: NASA LANCE - FIRMS (2015) MODIS Active Fire Detections. Data set. Spatial data available on-line: https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data. Accessed Apr 2015.

Forest: Kenya Forest Service (KFS) Land Cover 2010. All forest types are represented in this map.

Map 14: Which counties are charcoal production areas for the major cities and towns?

This map shows flow of charcoal traded across Kenya to serve population centres. County sources for individual cities are shown in insets on the right. Charcoal and fuelwood remain the primary energy sources of the country and a major driver of forest degradation.



6.4 Fuelwood and charcoal production

The Ministry of Forestry and Wildlife (2013) notes that fuelwood and charcoal production are the biggest consumers of wood in Kenya. Currently there is no systematically collected data available on quantity of woodfuels collected, species preference, harvest location or the ratio between conventional and marginal fuelwood. There is also little information on where households source their woodfuel when biomass is scarce locally. Given the importance of wood energy, surveying these aspects of woodfuel collection could support the development of better designed policies (Drigo et al., 2015).

Extraction of wood for fuel is particularly prevalent in the arid and semi-arid woodlands near the coast, and in the Ewaso North and North Rift conservancies, which are the main supply sources of fuelwood and charcoal for urban areas linked to them through road networks.

Map 15 shows major charcoal producing counties in Kenya, and where the production flows to, drawn from a charcoal value chain analysis carried out in 2013 (Ministry of Environment Water and Natural Resources, 2013a). At the coast, charcoal and firewood are harvested in the drier woodlands of Kwale and Taita-Taveta and sold in Mombasa and other coastal urban areas. Nairobi's energy needs are serviced by charcoal transported from locations as distant as Garissa and Kwale.

Complementing this analysis, Box 2 summarizes a study by Drigo et al. (2015), which analyzes in detail the supply and demand balance of woodfuel in Kenya. These analyses combined can be very useful for planning and implementing a number of candidate strategy options in Kenya's R-PP. Some suggestions on this are summarized in Table 3.

Box 1: Modelling drivers of deforestation

Adam Formica, MSc candidate, University of Oxford, UK

A key challenge to addressing the drivers of deforestation and forest degradation lies in predicting which forests are under threat. Information on past deforestation and the spatial distribution of pressures on forest ecosystems can offer clues about how to make such predictions. As data that directly show these historical pressures (such as wood harvest or land conversion) are often not available, modellers often rely on data which can represent the drivers of deforestation as proxies. For example, population density data could indicate higher or lower pressure on forest resources. Statistical models can help to test which datasets are best correlated with past deforestation; and assuming that the drivers of deforestation remain the same in the near future, it is then possible to build a probability model of deforestation risk based on these proxy driver datasets. For the present study, we assessed how well 26 proxy driver datasets, representing the most up-to-date information available, could predict past deforestation in 2007-2012. The 2001-2012 forest cover loss dataset of Hansen et al. (2013) (see Maps 12 and 13) was split into two time periods. 2001-2006 served as one of the 26 proxy datasets, and 2007-2012 was used to test how well the modelled deforestation for 2007-12 matched the observed data.

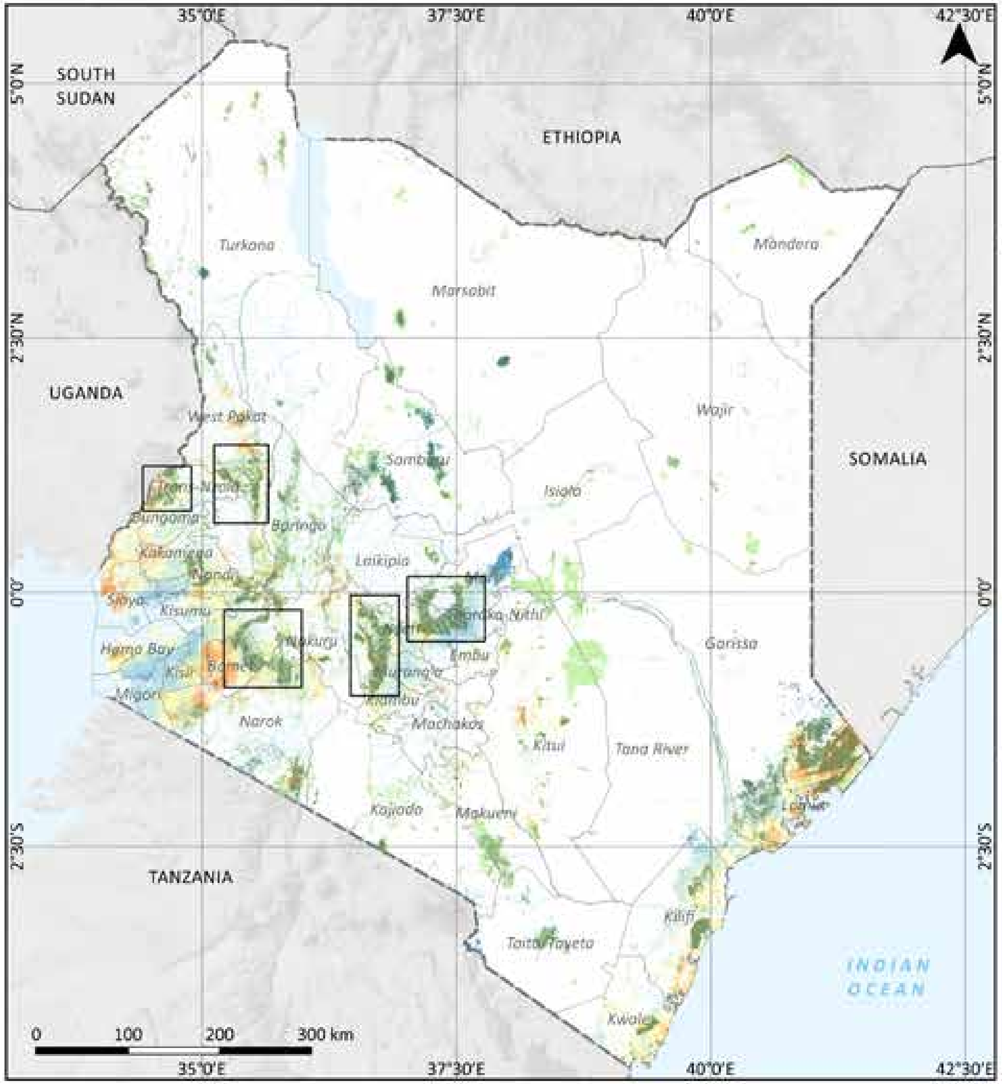
The resulting map of probability of deforestation (Map 15) shows which areas were estimated to be under the greatest threat (with a 95% confidence interval) for 2007-12. The forests in the Mau Complex and Cherangani Hills demonstrated a high probability of deforestation. The forests around Mt. Elgon score lower because there is a high level of uncertainty associated with their high probability of deforestation. Lower risk areas, including the forests in the western Mau Complex have a low probability of deforestation and high uncertainty. Areas with the lowest risk like the southeastern side of Mt. Kenya have a low probability of deforestation and low uncertainty.

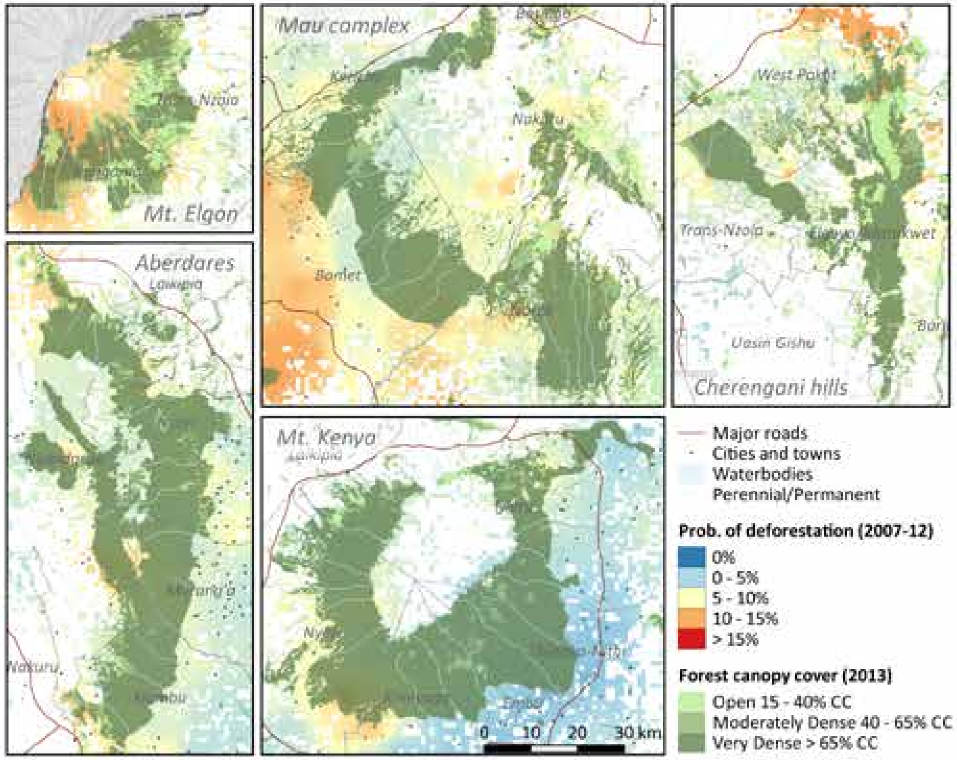
Seven out of the 26 datasets correlated strongly with forest loss, as listed in the inset table in Map 15. The model calculated that the probability of deforestation occurring increases closer to: [1] previous deforestation, [2] major roads and [3] recent fires. These results suggest that access to forests and forest edges is a significant driver of deforestation, and that fires can play a role in facilitating future deforestation, which is also recognized by the Ministry of Forestry and Wildlife (2013). In addition to this, the probability of deforestation increases with [4] higher opportunity costs, presumably as these areas are more desirable for non-forest land uses. On the other hand, the probability of deforestation decreases in areas with [5] higher population density. This may be because the forest in areas with high population density was already cleared before the year 2000 (the base year from which deforestation was measured), because people depend more on local forest products in more sparsely populated (or rural) areas, or that law enforcement is weaker in these areas. The model also suggested that the probability of deforestation decreases at higher [6] slopes, possibly because access to these forest areas is more difficult; and also that it decreases closer to [7] intermittent rivers.

The model does not indicate where deforestation will occur after 2012, nor does the correlation imply a causal relationship between one dataset and deforestation observations; instead it reveals how datasets which have a connection to drivers of deforestation relate to deforestation from 2007-12. We may assume that over the next few years at least, driver levels and their relationship with deforestation could stay relatively stable. As time passes, the map becomes less accurate as driver levels and their relationship with deforestation may change. Scenario data taking anticipated future demographics, infrastructure plans, forest and agriculture policy and land demand into account would be required to better estimate the risk of future deforestation.

Map 15 (next page): Calculated percent chance of deforestation for the period 2007-2012

This map indicates results of a model described in Box 1 that tested how well driver proxy datasets could predict the probability of deforestation in the years 2007-2012, with an overlay of the forest canopy cover mapped by KFS in 2013. Here the effect of the 7 most significant proxy datasets are presented (of a total of 26 tested). Areas shown in red were associated with higher deforestation probability than other areas. By far the strongest predictor was proximity to past deforestation (2001-2006). The table next to the map shows the correlation between the different datasets tested and tree cover loss. Here, "AIC change" indicates explanatory power (a high number indicates a high fit of the model with the proxy driver), while "opt/std" indicates relative effect size (a high number indicates that a small change in the level of the driver results in a large change in predicted deforestation probability).





Driver	Dataset	AIC change	opt/std	Units
Accessibility	Distance to previous deforestation	691.3	-2.71	meters
Population	Population density 2009 (KNBS)	66.1	-1.71	people/km2
Accessibility	Distance to major roads	50.7	-0.03	meters
Land clearing	Distance to active fires	17.6	-0.46	meters
Accessibility	Distance to intermittent rivers	12.1	0.50	meters
Accessibility	Slope	10.1	-0.21	degrees
Agriculture	Opportunity cost	5.2	0.58	$US/km2

Methods and data sources:

Forest loss 2000 - 2013: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest

Population density 2009: Data from the 2009 Census of Kenya (Kenya National Bureau of Statistics) was combined with a shapefile of the Kenya Sublocation boundaries (smallest administrative unit) by the Kenyan-based NGO RuralFocus Ltd., P.O. Box 1011, Nanyuki 10400, Kenya.

Proxy datasets for other drivers: World Resources Institute; Department of Resource Surveys and Remote Sensing, Ministry of Environment and Natural Resources, Kenya; Central Bureau of Statistics, Ministry of Planning and National Development, Kenya; and International Livestock Research Institute. 2007. Nature's Benefits in Kenya, An Atlas of Ecosystems and Human Well-Being. Washington, DC and Nairobi: World Resources Institute.

Forest canopy cover: Kenya Forest Service (KFS) Land Cover 2010.

7. Maps to support planning for proposed strategy options for REDD+

Kenya's R-PP identifies four priority areas to address drivers of deforestation and forest degradation, take action to conserve forest carbon stocks, promote sustainable management of forests and enhance forest carbon stocks:

- **Priority Area 1:** Reducing pressure to clear forests for agriculture and other uses
- **Priority Area 2:** Promoting sustainable utilization of forests
- **Priority Area 3:** Improving forest law enforcement and governance
- **Priority Area 4:** Enhancement of carbon stocks

A number of the strategy options proposed under these priority areas have already been referred to in previous sections of this report. This section looks at some additional strategy options. The analyses build on discussions with stakeholders during a workshop convened by the Kenya Forest Service in November-December 2014.

7.1 Priority Area 1: Reducing pressure to clear forests for agriculture and other uses

Community Forest Associations (CFAs) were introduced as a means to implement the community empowerment and benefit sharing requirements of the Forest Act (2005). This implementation is currently in a pilot phase, and involves allocation of forest areas to CFAs by Kenya Forest Service (KFS). The CFAs then manage the forest under 'Forest Management Agreements' (FMAs) agreed with KFS. CFA members receive training and other forms of capacity building to operate effectively. However, few CFAs have been set up to date, and progress is slow although KFS has plans in place to expand the mechanism (Government of Kenya, 2010b).

Kericho tea plantations, Western Mau, Paulus Maukonen

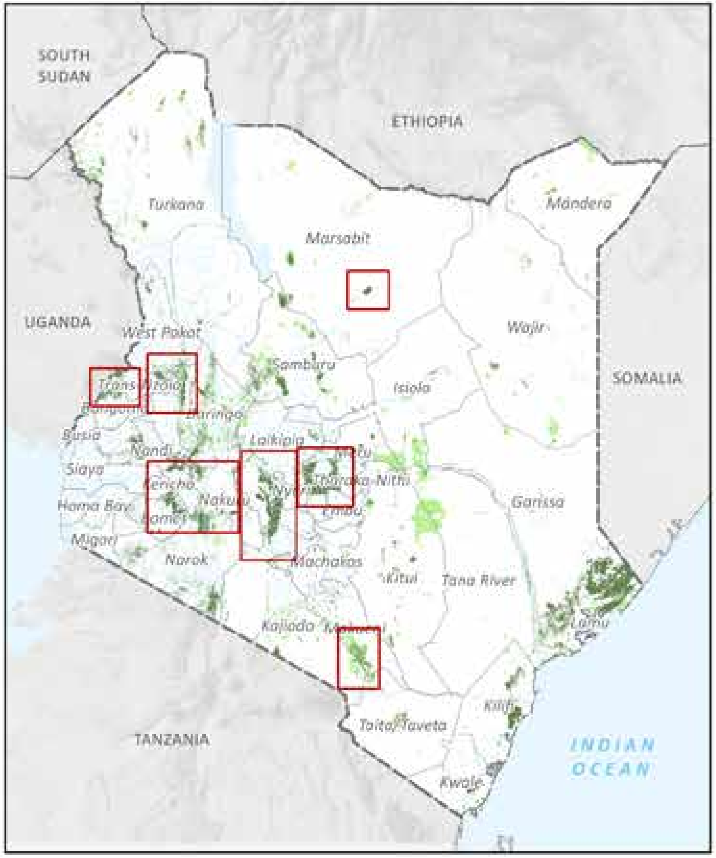
Several strategy options in the R-PP concern Forest management through Community Forest Associations:

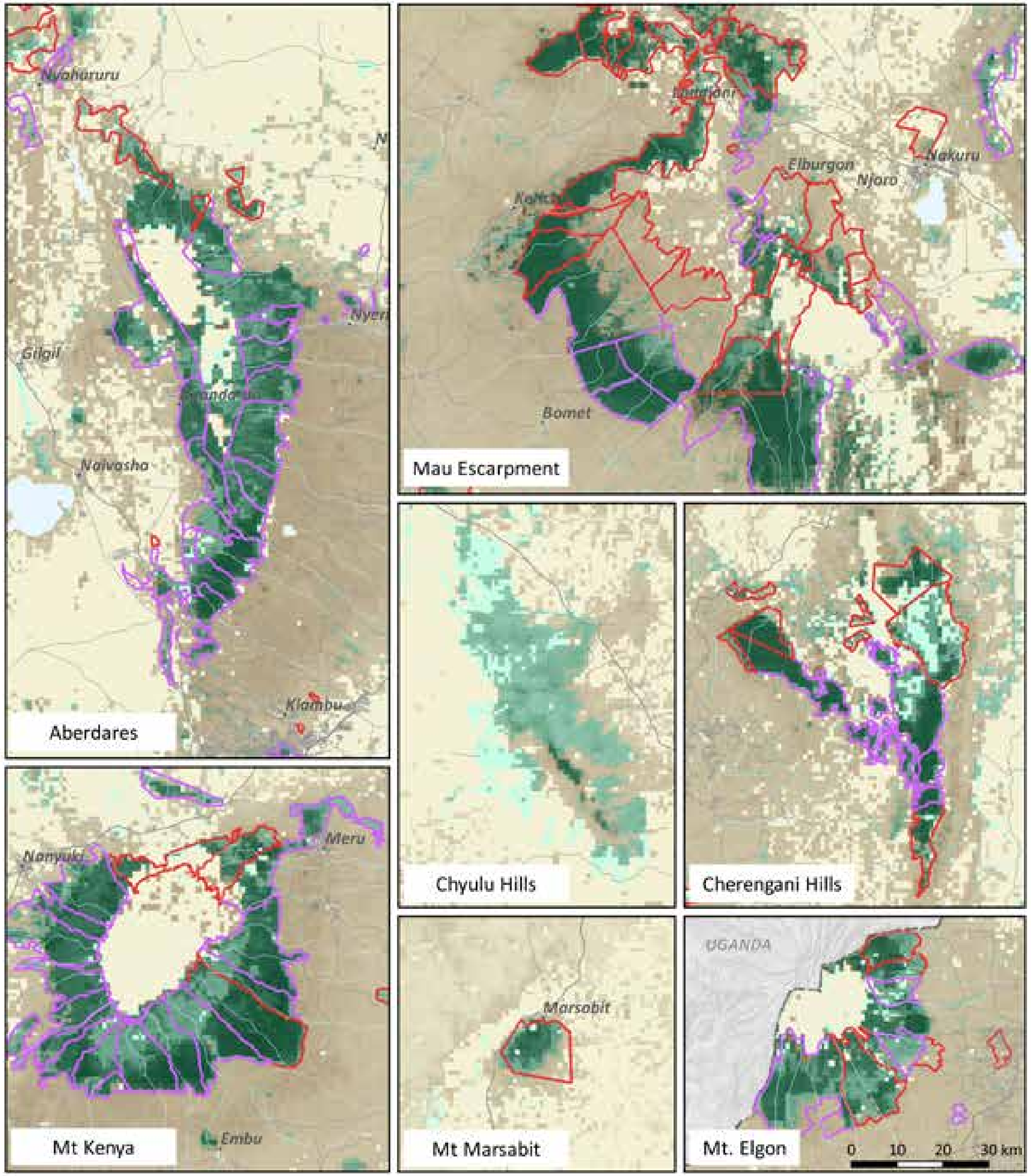
- Pilot management of trustland areas by CFAs (Community Forest Associations) as described in the Forest Act 2005 (this strategy option will also address unsustainable utilization in trustland).
- Assist KFS to pilot community participation arrangements described in the recently elaborated subsidiary legislation to the Forests Act 2005
- Capacity building of CFAs
- Assist KFS to elaborate and pilot benefit-sharing arrangements in the context of the REDD+ task force work, including access to forest resources, with local communities, also elaborated in the recent subsidiary legislation. (Note this activity will also address unsustainable utilization of forest resources – see section 7.2.
- Awareness and advocacy activities among farming communities, and the wider public on the impacts of forest clearance. Strengthen the capacity of Local Authorities to manage the trustland Forests, including technical assistance, guidance in the development of management plans, awareness and advocacy activities

KFS divides the public forests it manages into forest stations, which function as management units. Map 16 highlights which forest stations operated by KFS currently work together with CFAs and where management plans have been developed. The map assumes that forest stations with a signed management plan have also established one or more CFAs. Forest stations without signed FMAs but with high carbon stocks may be of particular priority for this strategy option. For example, the forest stations on the water towers may be a priority. As Map 16 indicates, numerous areas remain without CFAs and management plans, including some of the areas with the most carbon rich forest.

MAP 16: Which forest stations have, and which are lacking, CFAs and management plans?

This map shows which forest stations operated by the Kenya Forest Service that have, and are still lacking management plans in collaboration with Community Forest Associations. A number of priorities may determine which forest stations are next selected for this mechanism, but forest carbon stocks may be a priority to consider under REDD+.





Forest station status

- No management plan
- Under management plan

Forest canopy cover

- Open 15 - 40% CC
- Moderately Dense 40 - 65% CC
- Very Dense > 65% CC

Carbon biomass (tonnes/ha)

In Forest **In wider landscape**

- 0 - 14 (Low)
- 14 - 76 (Low - Medium)
- 76 - 97 (Medium)
- 97 - 137 (Medium - High)
- 137 - 239 (High)

Methods and data sources:

Biomass carbon (left): Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P., Dubayah, R., Friedl, M. (2012) Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change 2. 3:182-185. http://dx.doi.org/10.1038/NCLIMATE1354; *Ecosystem-specific conversion factors (IPCC 2006) were used to add below-ground biomass carbon to this map following the method described here: Ravilious, C., Arnell, A. and Bodin, B. (2015) Using spatial information to support decisions on safeguards and multiple benefits for REDD+. Step-by-step tutorial v1.0: Adding below-ground biomass to a dataset of above-ground biomass and converting to carbon using QGIS 1.8. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK.*

Forest and management stations: Kenya Forest Service (KFS) Land Cover 2010. Forest falling within protected areas has been labelled as "protected forest" and that falling outside as "unprotected forest".

Poverty is a key indirect driver of deforestation and forest degradation in Kenya (Ministry of Forestry and Wildlife, 2013), and the strategies and activities under Priority Area I have an ultimate aim of providing viable and sustainable income sources that could reduce both poverty levels.

When planning how and where to implement such interventions it is helpful to understand spatial indicators of poverty. Poverty distribution varies widely across space, as a result of differences in factors such as agro-climatic conditions, access to markets and public facilities, access to natural resources such as forests or water, as well as political and historical factors. Okwi et al. (2007) investigated the link between poverty incidence and geographical features in Kenyan rural locations. The results showed that different spatial factors contributed to explaining welfare levels in different areas within provinces, so that spatial assessments can help to guide policy implementation.

Table 2 shows results from the study by Okwi et al. (2007). The significance of the relationship between a number of variables and rural poverty is presented for each rural province and the national scale. The results suggest that being far from a public forest is a driver of poverty in Central, Eastern, Nyanza and Western provinces. Limited access to roads could also be an important determinant, associated with higher poverty in the Central, Eastern and Coast provinces. Low agricultural potential, including soil fertility, rainfall and length of growing period was, not surprisingly, found to be related to higher poverty in several provinces. A high percentage of wetlands may reduce poverty in Central, Coast and Eastern provinces. Longer distances to the nearest health facility were associated with higher poverty in North Eastern and Nyanza provinces. A high percentage of land on slopes also showed significant correlation with poverty in several provinces.

Most of the variables found to be correlated with poverty in the study by Okwi et al. (2007) can be quite easily mapped at the local level and included in analyses to inform the selection of priority zones for implementation of REDD+ strategy options. The design of such analyses would consider the ways in which those options might reduce poverty, and the distribution of other factors influencing suitability for those options.

7.2 Priority Area 2: Promoting sustainable utilization of forests

Most strategy options under Priority Area 2 of Kenya's R-PP aim to address woodfuel extraction as a driver of deforestation and degradation (see Section 6.4 and Map 14 on this driver). Box 2 builds on a technical analysis by Drigo et al. (2015) of woodfuel supply, demand and sustainability in Kenya, reviewing the potential of this work to contribute to Priority Area 2.

(Left) *Kenyan ceramic jiko (charcoal stove),* AIDG / Flickr; (Right) *Roadside charcoal trade*, Shutterstock

Table 2: *Variables associated with poverty in the provinces of Kenya, extracted from Okwi et al. (2007).*

Variable	Central	Coast	Eastern	North Eastern	Nyanza	Rift Valley	Western	National
Elevation	*** (+)		*** (–)		*** (+)	NS	NS	**
Distance to forest	*** (+)	NS	*** (+)		** (+)		** (+)	
Percent water		** (–)			** (+)	NS		
Percent built up land				NS		*** (–)		***
Percent grassland		NS	** (–)		NS	NS	** (–)	***
Percent farmland		NS	** (+)		NS	NS	NS	
Percent wooded land			NS	NS				***
Percent wetlands	** (–)	** (–)	** (–)		NS	NS		
Percent protected area			*** (+)				*** (+)	
Percent 0–4% slope	NS							
Percent 4–8% slope		*** (+)	** (+)	**	** (+)	** (+)	NS	***
Percent 8–15% slope		*** (+)	NS		NS	NS	NS	
Percent 15–30% slope			** (+)			NS	** (–)	
Percent ≥30% slope			NS			*** (+)		***
Average travel time to tarmac or murram road	*** (+)	** (+)	*** (+)			NS	NS	**
Flood potential		** (+)						
Mean rain coefficient of variation	*** (+)			** (+)				
Average rainfall					NS			
Percentage of location with length of growing period: <60 days		NS	NS			NS		***
Percentage of location with length of growing period: 180 days (arid)		*** (–)	** (–)			*** (–)		***
Distance to district hospital	** (+)	NS	NS		** (+)	NS		
Distance to dispensary			NS	** (+)				
Rangelands	** (+)				NS		NS	**
Mean distance to town of 10 000		NS		** (+)			** (+)	
Mean distance to town of 50 000		NS		NS				
Mean distance to town of 200 000	NS	NS				NS		
Good soils (Andosols and Nitisols)	NS				NS		** (–)	**

*** = significant at 1%   * = significant at 10%   + = positive effect;
** = significant at 5%   NS = not significant   - = negative effect.

Box 2: Analysis of woodfuel supply, demand and sustainability in Kenya

In collaboration with Rudi Drigo and the project "Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and beyond"

Wood energy currently meets the bulk of Kenya's national energy needs and it is expected to continue as the country's main source of energy for the foreseeable future (Githiomi and Oduor, 2012). Charcoal provides 38 percent of urban and 7 percent of rural household energy, while fuelwood supplies 20 percent of urban and 90 percent of rural household energy (Kenya National Bureau of Statistics, 2010). Demand for charcoal is fast increasing due to population growth, lack of access to energy substitutes, poverty and the development of small industries. In 2009 the Forest (Charcoal) Regulations were gazetted, establishing rules for charcoal production (tree growing and wood conversion to charcoal), transport, trade and use. Policy implementation is led by Kenya Forest Service (KFS) and the Ministry of Energy, in collaboration with other government agencies and stakeholders.

Kenya's REDD+ Readiness Preparation Proposal (Government of Kenya, 2010b) includes a number of strategy options for addressing the unsustainable use of forest for woodfuel harvesting. Drigo et al. (2015) as part of the WISDOM project have recently finalized an analysis of woodfuel supply, demand and sustainability that aims to support KFS and the Ministry of Energy in their policy implementation. The study provides a number of different data compilations and products to support decision making. The results include an estimate of the spatial supply and demand balance of woodfuel, highlighting areas that have a deficit in supply, and areas that have a surplus (map 17a). This map helps understanding of sources and sinks for woodfuel in Kenya (see also to map 14).

Drigo et al. (2015) further maps areas of rural and commercial harvesting sustainability, leading to an estimate of areas experiencing non-renewable harvesting (map 17b). This analysis assumes that the rural (subsistence) supply deficit is partially accommodated by consumption of marginal wood products (e.g. twigs, minor branches, etc), partially by overexploitation of local resources and partially by commercial supply, leading to pressure being shifted to rural farmlands and woodlands throughout Central and Western Kenya. Map 17b is useful for identifying counties that are likely to be experiencing particularly high levels of harvesting beyond renewable levels. These counties (including Kajiado, Baringo, Makueni, Taita Taveta, Nyeri, Kericho and Kiambu) are subject to pressure from commercial harvesting and are more likely to experience progressive forest degradation. Action is particularly needed here to address overharvesting, for example by establishing woodlots or other forms of tree planting, or supporting a shift to more efficient fuel use.

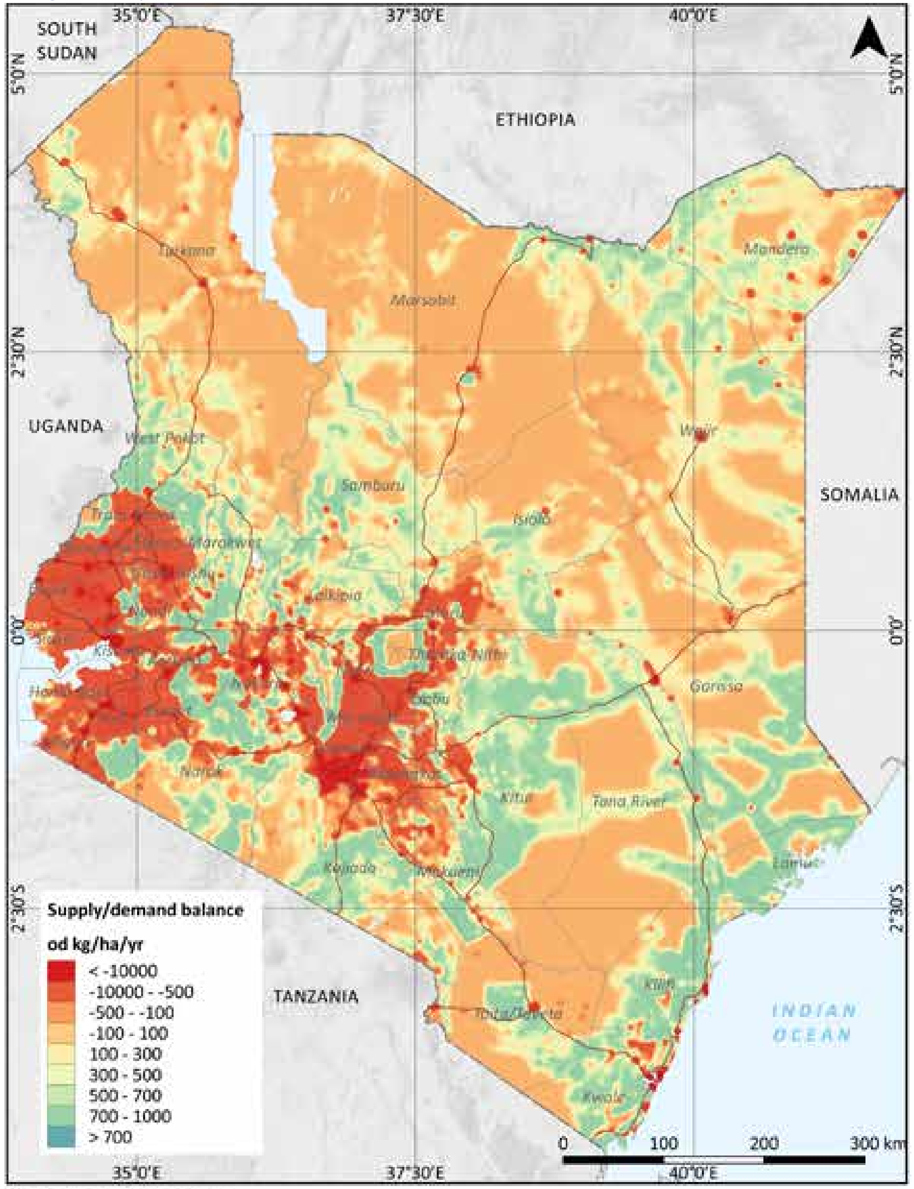
The study maps areas predicted to suffer from degradation of biomass stock from excessive woodfuel harvesting. Map 18a shows annual degradation of biomass resources as percent of stock resulting from unsustainable harvesting. Areas with high annual degradation are generally rural, with very low biomass levels. The maps in 18b show expected degradation in forest areas, with values ranging between 3 and 10 percent degradation per year as a result of unsustainable woodfuel harvesting.

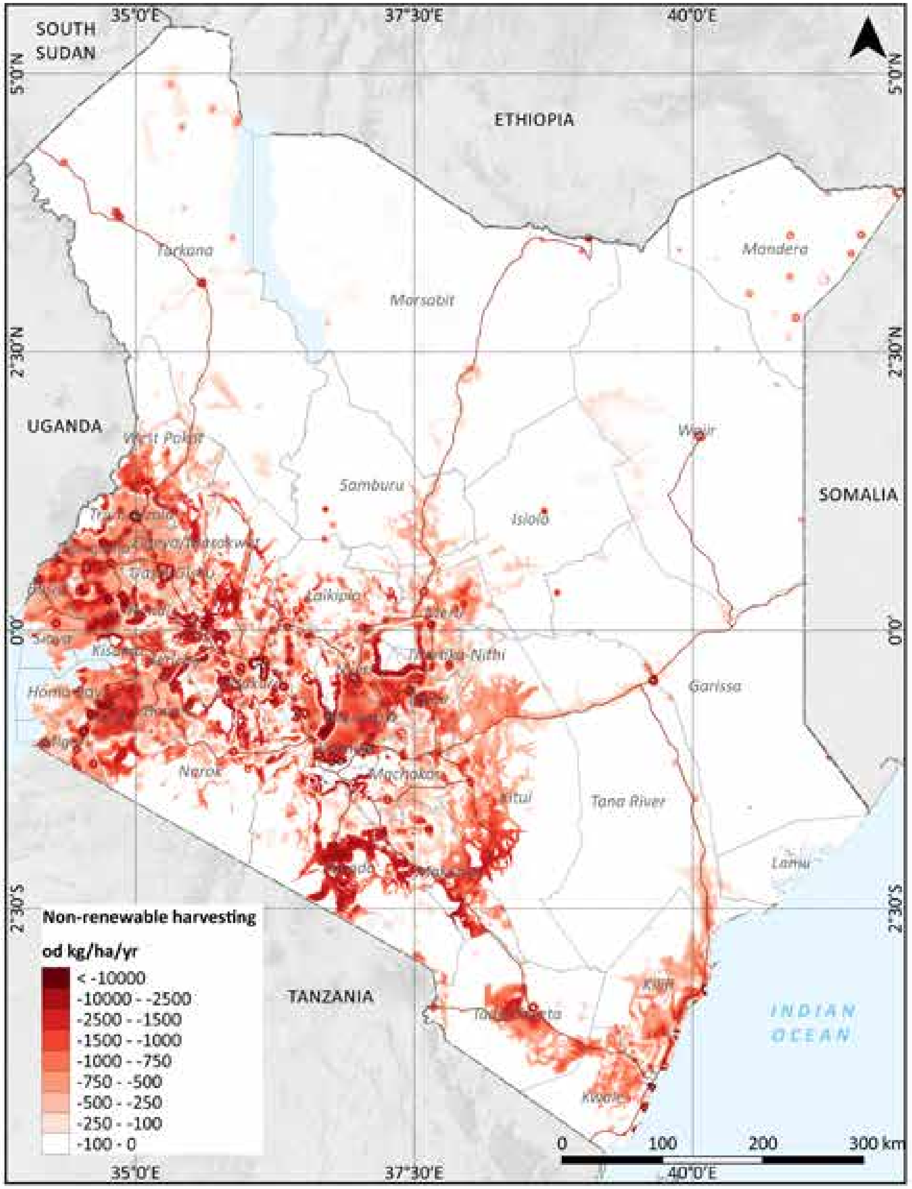
These maps can support REDD+ implementation in several ways, including integration of actions to address woodfuels, protection of natural forest and reforestation. Table 3 shows the strategy options proposed in Kenya's Readiness Preparation Proposal to address unsustainable harvesting for woodfuel, with suggestions for how the study outputs can contribute to spatial planning for these, and the scope for further analyses that can be made to inform plans for these strategy options.

The results presented in this box build on the study "Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and beyond", commissioned by the Global Alliance for Clean Cookstoves (GACC) and supported by UN Foundation, and implemented by the Yale School of Forestry and Environmental Studies (FES) in partnership with the Centro de Investigaciones en Geografía Ambiental (CIGA) and the Centro de Investigaciones en Ecosistemas (CIEco) of the National Autonomous University of Mexico (UNAM). The full study is available here: http://www.wisdomprojects.net/global/csdetail.asp?id=34.

Map 17: What is the supply and demand balance of woodfuel and where are areas experiencing non-renewable harvesting?

Map 17a (left) shows the spatial supply and demand balance of woodfuel, highlighting areas that have a deficit in supply, and areas that have a surplus. Map 17b (right) shows areas experiencing non-renewable harvesting driven by both subsistence and commercial demand.



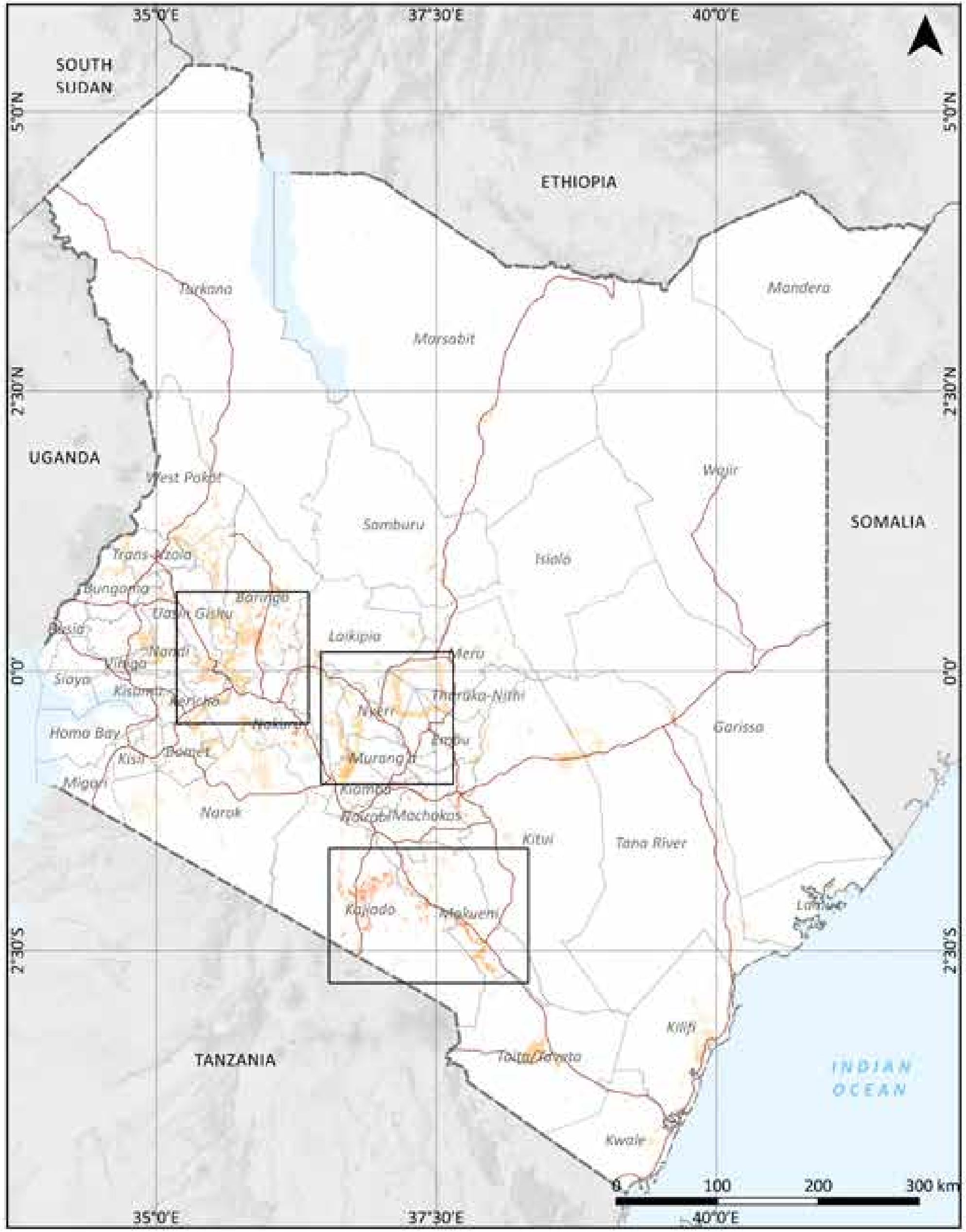


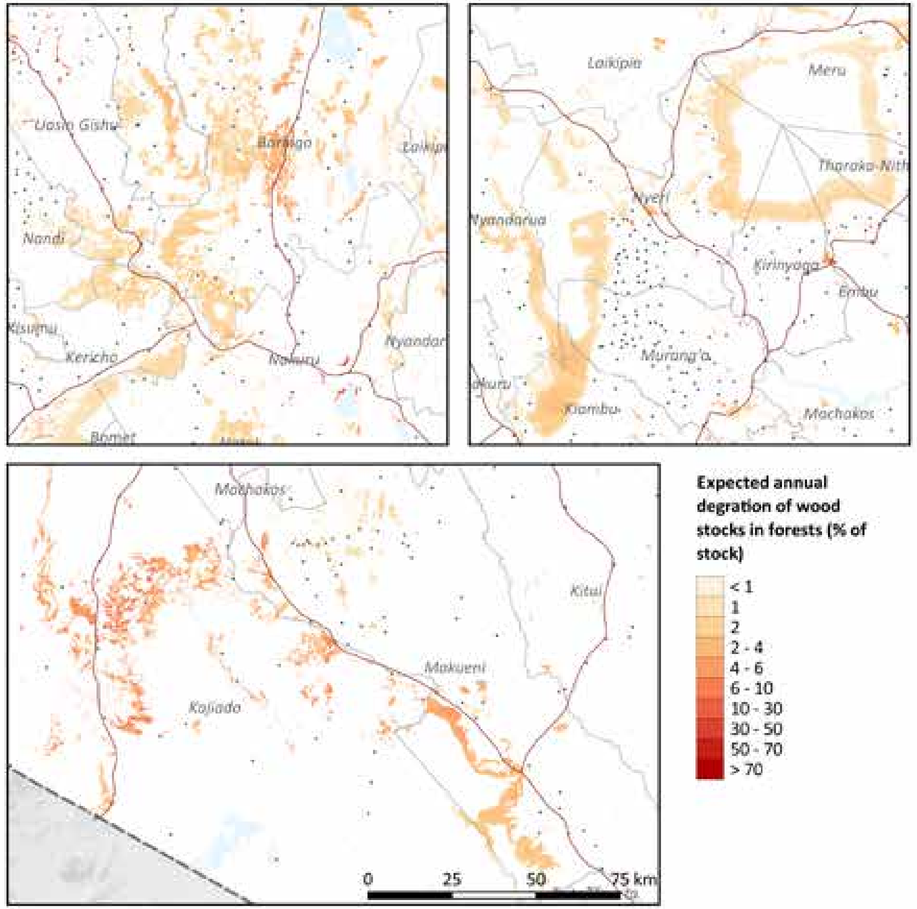
Methods and data sources:

Fuel wood supply/demand and non-renewable harvesting: Drigo, R, Bailis, R, Ghilardi, A, Masera O (2015) WISDOM Kenya. Analysis of woodfuel supply, demand and sustainability in Kenya. Draft 01. Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and beyond. Food and Agricultural Organisation of the United Nations (FAO), Rome, Italy and Kenya Forest Service (KFS), Nairobi, Kenya.

Map 18: Where is degradation of biomass resources taking place as a result of unsustainable woodfuel harvesting?

The large map to the left (a) shows annual degradation of biomass resources as percent of stock resulting from unsustainable woodfuel harvesting. Areas with high annual degradation are generally rural with very low biomass levels. The smaller maps to the right (b) show expected degradation in forest areas, with values ranging between 3 and 10 percent degradation per year as a result of unsustainable woodfuel harvesting.





Methods and data sources:

Expected annual degradation of wood stocks: Drigo, R, Bailis, R, Ghilardi, A, Masera O (2015) WISDOM Kenya. Analysis of woodfuel supply, demand and sustainability in Kenya. Draft 01. Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and beyond. Food and Agricultural Organisation of the United Nations (FAO), Rome.

Table 3: *How the outputs of the study of Drigo et al. (2015) can contribute to spatial planning for Kenya's candidate strategy options for promoting sustainable utilization of forests*

Candidate strategy options for promoting sustainable utilization of forests, in Kenya's R-PP	Suggestions for how the outputs of the study of Drigo et al. (2015) can contribute to spatial planning for these strategy options
Assist KFS to operationalise the recently gazetted subsidiary legislation on charcoal production;	With reference to woodfuel production, the georeferenced WISDOM layers can contribute, among others, to Environmental Impact Assessment studies and can support the formulation of geographically tailored solutions.
Support the Ministry of Energy in the promotion of efficient charcoal-making technology aimed at reducing waste and associated pollution;	WISDOM data can help to identify priority areas of intervention, i.e. where wood resources are adequate to support profitable and sustainable charcoal production. These can become priority targets of efficient charcoal-making projects for the promotion of producers associations and training programmes.
Assist KFS, Ministry of Energy to finalize and operationalize a fuelwood development strategy for the country	Similarly, surplus areas could become target areas for sustainable forest / woodlands management specifically designed for fuelwood production (decisions should take impacts on forest biodiversity and ecosystem services into account).
Promote fuel-efficient institutional and household charcoal stoves through the KFS networks and Energy centres established by the Ministry of Energy;	The demand-module maps and the local-balance map can support the priority ranking of any administrative unit in relation to level of local deficit, woodfuel demand in household, commercial, industrial and public sectors
Promote fast growing fuelwood plantations and development of outgrower schemes to supply fuelwood to tea, tobacco and other industries that currently rely on fuelwood for curing and heating;	The land-cover/land-use layers in combination with slope data can support the identification of areas potentially suitable and available for the establishment of new plantations by County or by District. Again, potential impacts on biodiversity and ecosystem services should be evaluated for individual sites.
Promote agroforestry	The land-cover/land-use layers combined with woodfuel-balance maps can help to identify the areas where an increment of tree cover in farmlands could best contribute to fill in woodfuel gaps. The estimated local gap can be used to inform the quantitative target of the agroforestry program.
Promote community based utilization of other biofuels for lighting and cooking thus reducing demand of fuelwood	The demand module maps and the local balance map can support the priority ranking of any administrative unit in relation to level of local deficit, woodfuel demand in household, commercial, industrial and public sectors. This, in combination with agricultural/livestock data, can contribute to define most promising/appropriate target communities.
Introduce woodlands management guide-lines including establishing and enforcing sustainable harvesting levels in line with the Forests Act, the ASAL development Strategy and land-use policy for the country	Supply layers and surplus maps can contribute to identify target areas for sustainable woodlands management specifically designed for fuelwood production. Areas with high risk of degradation due to excessive harvesting could become priority areas for protection strategies.

7.3 Priority Area 4: Enhancement of carbon stocks

As seen in section 4, Kenya has a number of targets for increasing the tree and forest cover of the country. In addition to promotion of agroforestry and fast growing fuelwood plantations, strategy options in the R-PP to this effect include:

- Tree planting campaigns and support to provision of high quality germplasm to farm holdings. These activities will be jointly implemented between KFS and the Ministry of Agriculture to support implementation of the new Agriculture rules that prescribe that a minimum of 10% should be under forests.
- Suport Government of Kenya to introduce incentives for commercial scale investment in tree planting
- Support to promotion of sustainable forest management (SFM). This support which will be extended to all the water towers will while delivering carbon benefits also enable realization of the objectives of Vision 2030, The National Climate Change Response Strategy, ASAL development Strategy, Land use policy and others.
- Support for forest protection that increases carbon stock, improves biodiversity and livelihood benefits

Map 19 can be useful when addressing several of these activities. Areas where biomass values are high and population pressures are low may be appropriate for measures to protect/ sustainably manage forest in a way that also has biodiversity benefits. Where biomass is low and population density is high, efforts to plant trees on farms for fuel and fibre may be a priority. Where both biomass stocks and population density are low, it could be worth examining the feasibility and impacts of establishing plantations. The legal designation of the land also needs to be considered here. According to the Draft National Forest Policy (Government of Kenya, 2015), expansion of forestry development to arid and semi-arid areas will be necessary. Woody vegetation in the arid and semi-arid areas provides cover to the fragile and highly erodible soils, and can have other benefits such as shelter for people and livestock in the harsh environment. Depending on how forestry activities are carried out, they could be beneficial or detrimental to biodiversity and wildlife. Impact assessments on biodiversity and ecosystem services should be taken into account in decision making.

Tree planting, Alliance of Religions and Conservation / Flickr

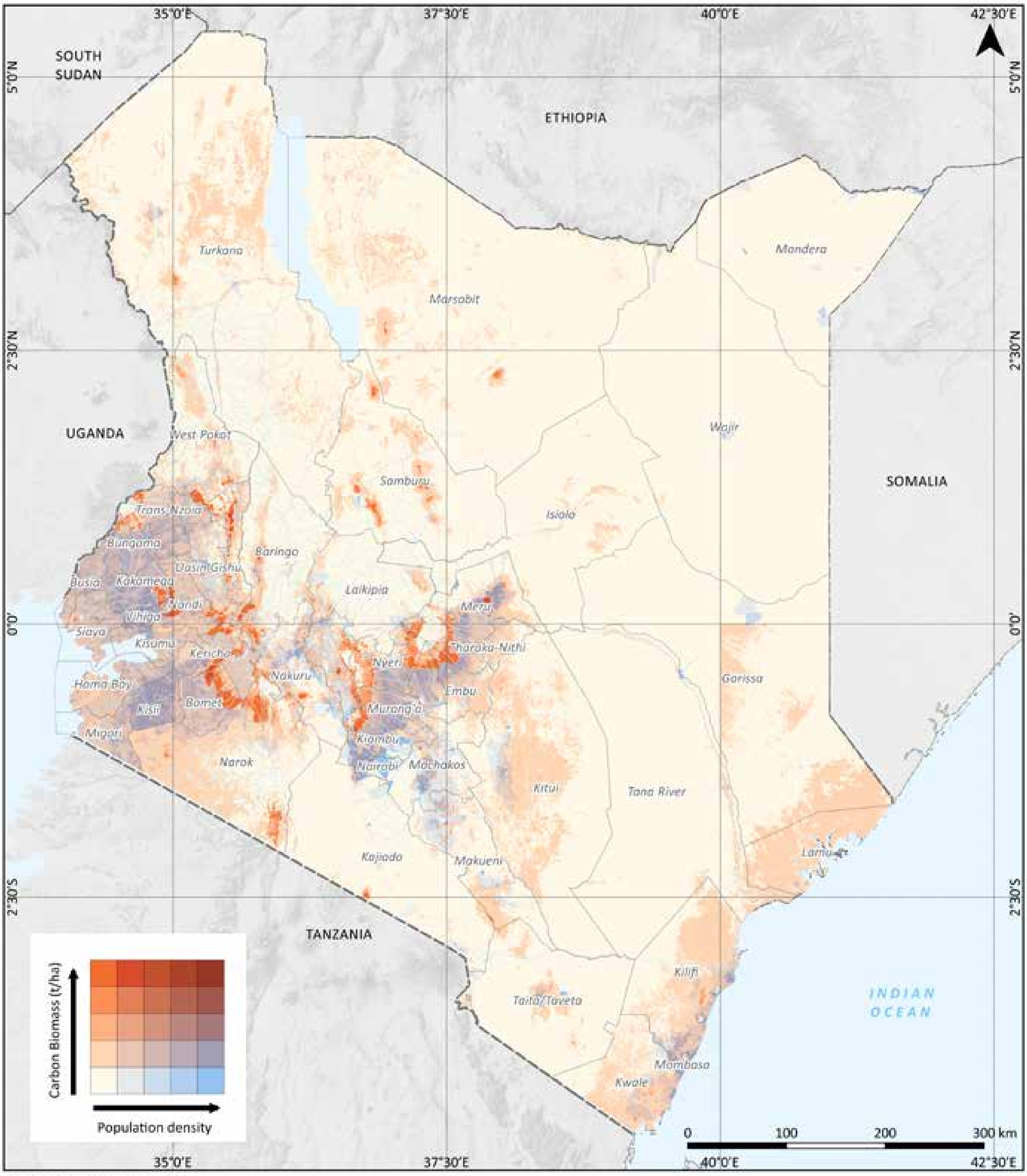
Dryland forests have the potential to supply marketable commodities on a sustainable basis (such as gums and resins, aloe, charcoal, essential oils, silk, edible oil, commercial juices, frankincense, indigenous fruits, honey, thatching materials and timber) (Government of Kenya, 2015). The R-PP proposes provisions that can promote integrated management of dryland natural resources, conservation and management of dryland forests and regulating unsustainable utilization of forests, including charcoal burning (Government of Kenya, 2010b).

Tree planting may also be particularly appropriate on areas of high slope (see section 5.2.1 and Box 3 below). Kenya's Agriculture Rules (2012) determines that any person who cultivates, cuts down or destroys any vegetation, or grazes any livestock on any land of which the slope exceeds 35 percent is guilty of an offence. In addition, slopes exceeding 12 percent need to be protected against erosion by conservation work. Tree planting efforts could be implemented on such land to protect them.

Restoration of indigenous forests is also high on the agenda for Kenya. For this report, the authors have collaborated with the project Mapping Tree-based Landscape Restoration Opportunities in Kenya which works through the Restoration Technical Working Group established by Kenya Forest Service. Box 3 presents four maps that can be used in the context of REDD+ to plan for strategy options to restore natural forests

Map 19: Where do areas of high/low carbon stocks and high/low population coincide?

This map shows how biomass carbon stocks and population density are distributed in relation to one another, which can be helpful for planning a variety of policies and measures, such as enhancement of forest carbon stocks.



Methods and data sources:

Biomass carbon (left): Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P., Dubayah, R., Friedl, M. (2012) Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change 2. 3:182-185. http://dx.doi.org/10.1038/NCLIMATE1354; *Ecosystem-specific conversion factors (IPCC 2006) were used to add below-ground biomass carbon to this map following the method described here: Ravilious, C., Arnell, A. and Bodin, B. (2015) Using spatial information to support decisions on safeguards and multiple benefits for REDD+. Step-by-step tutorial v1.0: Adding below-ground biomass to a dataset of above-ground biomass and converting to carbon using QGIS 1.8. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK.*

Population density 2009: Data from the 2009 Census of Kenya (Kenya National Bureau of Statistics) was combined with a shapefile of the Kenya Sublocation boundaries (smallest administrative unit) by the Kenyan-based NGO RuralFocus Ltd., P.O. Box 1011, Nanyuki 10400, Kenya.

Box 3: Restoring forests in Kenya for multiple benefits

In collaboration with the project Mapping Tree-based Landscape Restoration Opportunities in Kenya : the Kenya Restoration Technical Working Group and World Resources Institute

Forest restoration is a high priority on the agenda of Kenyan legislation and policy. There are several high level initiatives and laws that are strongly linked to restoring lands:

- The Constitution calls for reforesting and maintaining a tree cover of at least 10% of the land area.
- The National Climate Change Response Strategy calls for growing 7.6 billion trees on 4.1 million hectares of land during the next 20 years.
- Kenya also has a Vision 2030, with a flagship project underway for rehabilitation and protection of indigenous forests in the five water towers (Mount Kenya, the Aberdare Range, the Mau Forest Complex, Mount Elgon and the Cherangani Hills), with the goal to increase forest cover and volume of water from the catchment areas.
- Another flagship project intends to plant one billion trees to increase forest cover and at the same time create employment for youth under the Trees-for-Jobs Programme.

In addition to these restoration initiatives, Kenya is also deeply involved with its REDD+ Readiness Preparation Proposal (R-PP) (Government of Kenya, 2010). One of the priority topics included in the R-PP focuses on the enhancement of forest carbon stocks and proposes several strategy options to restore forests, including support to the Government of Kenya (GoK) target to plant 10% of Kenya's land with trees, and promote forest protection that increases carbon stocks, livelihood benefits and improves biodiversity.

As is clear from the above mentioned initiatives, Kenya is working hard on improving their forest cover and the associated ecosystem services. To ensure these initiatives are linked and coordinated, the Kenyan Forest Service (KFS) has established a Restoration Technical Working Group (RTWG), which includes a broad range of stakeholders. The RTWG has identified various landscape restoration options, which include reforestation and rehabilitation of natural forests, farm forestry and woodlots on cropland, commercial tree and bamboo plantations, and tree-based buffers along waterways and wetlands. These restoration options could help restore ecosystem services associated with trees, such as erosion control, regulation of water flows and soil quality, and forest habitat.

Currently, the RTWG is developing a set of national-level maps that identify where tree-based landscape restoration can contribute to the above national targets. The resulting maps will indicate possible zones where each option can be implemented. Some areas may have the potential for multiple restoration options, and the selection of the best option(s) for each area is planned to be determined through stakeholder engagement and cost-benefit analyses for both individuals and society.

An important approach to achieving the above-mentioned policy goals will be reforestation of natural forests. Map 20a on the opposite page is the result of the mapping that is occurring under the auspices of the RTWG, and indicates zones where natural forests could be restored. While not all of this land can, or should, be brought back to natural forest, since there may be other local priorities for land use, the map can be used to set priorities on those areas that provide multiple benefits, such as erosion control and provision of habitat for endangered and vulnerable species.

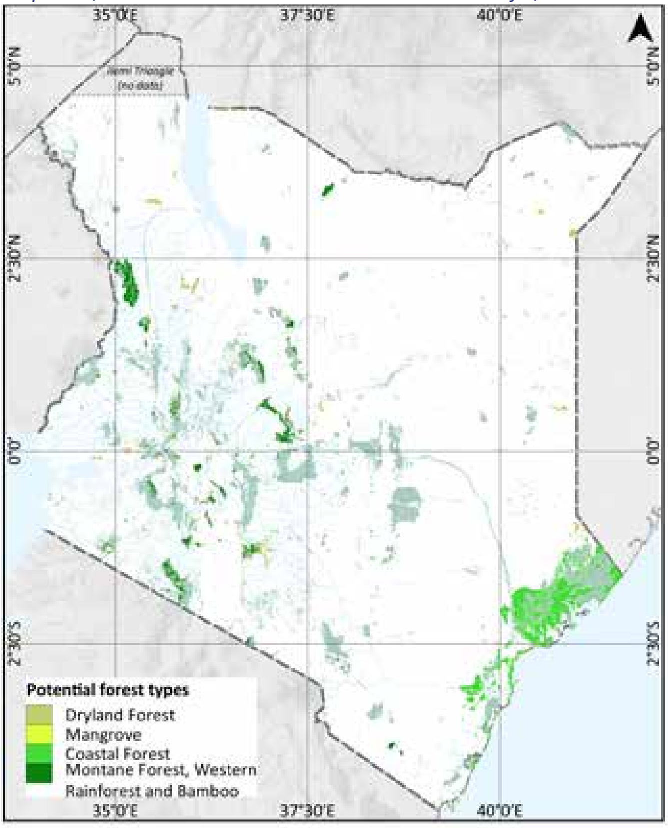
As highlighted in Kenya's National Climate Change Response Strategy, sedimentation from erosion causes a myriad of negative impacts, ranging from the eutrophication of water bodies, reducing the life span of dams, and to the loss of important top soil for agriculture. Trees play an important role in stabilizing soils and reducing runoff, and can greatly reduce the risk of erosion. Map 20b builds on the previous map, identifying where new forests would contribute most to erosion control. The highest risk zones are represented here in dark red.

Tourism plays an important part in Kenya's economy, contributing 10.5% to GDP and 9.2% to total employment in 2014 (World Travel and Tourism Council, 2015). Most tourists visit Kenya to see its abundant wildlife, and many of the critically endangered, endangered, and vulnerable species on the IUCN Red List rely on forest ecosystems to survive. Map 20c identifies zones with reforestation potential that would provide habitat for these important species. The areas with the highest richness of threatened and vulnerable species are primarily found in the center of the country, as well as along the coast in Lamu and Kilifi Counties.

Map 20d on the following page combines maps 20b and 20c to identify zones where reforestation of natural forest vegetation could contribute most to addressing both soil erosion and habitat of endangered and vulnerable species. Some areas within these zones could be good candidates for prioritizing reforestation as a landscape restoration option. For example, this analysis could be helpful for identifying areas to establish forested corridors between biodiversity hotspots. In places where land use does not permit reforestation of natural forests, alternative restoration options should be considered such as farm forestry or commercial plantations.

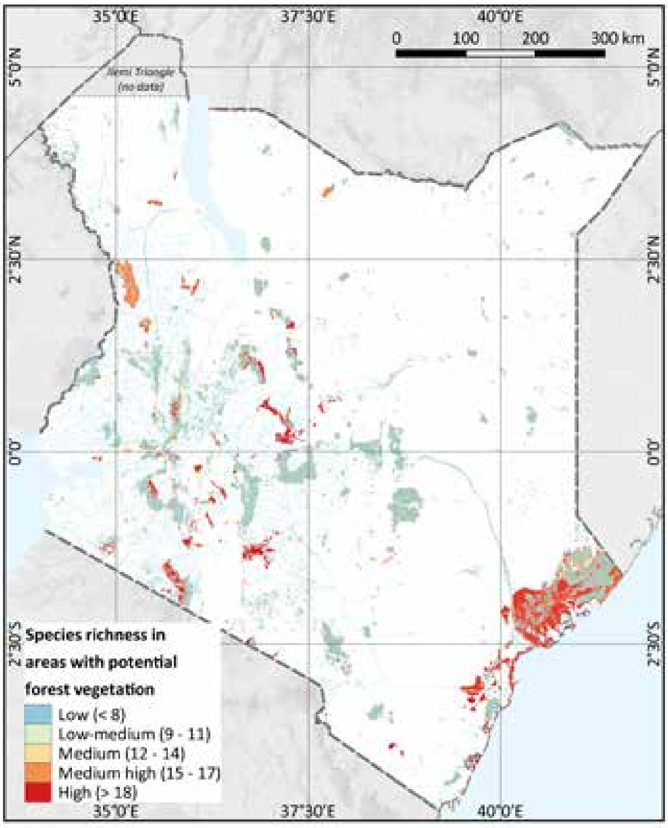
Map 20a: Biophysical potential for natural forest vegetation

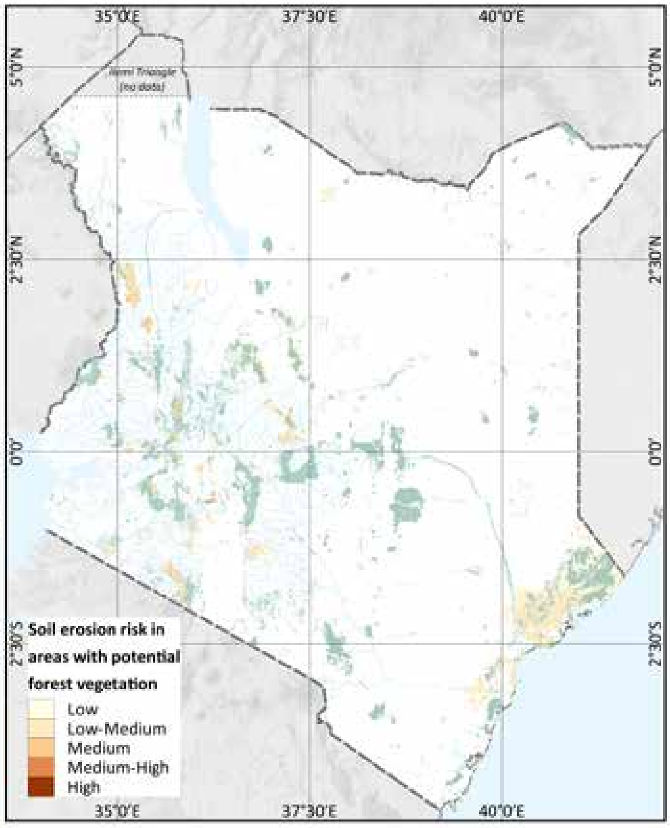
Map of biophysical potential for natural forest vegetation for Kenya based on vegetation maps and surveys from the 1960s through 2003, excluding areas that are already forests (natural forests, bamboo, mangroves, or commercial plantations), wetlands, grasslands, croplands, urban areas and areas above an elevation of 3,800m.



Reforestation potential for soil erosion control and biodiversity conservation

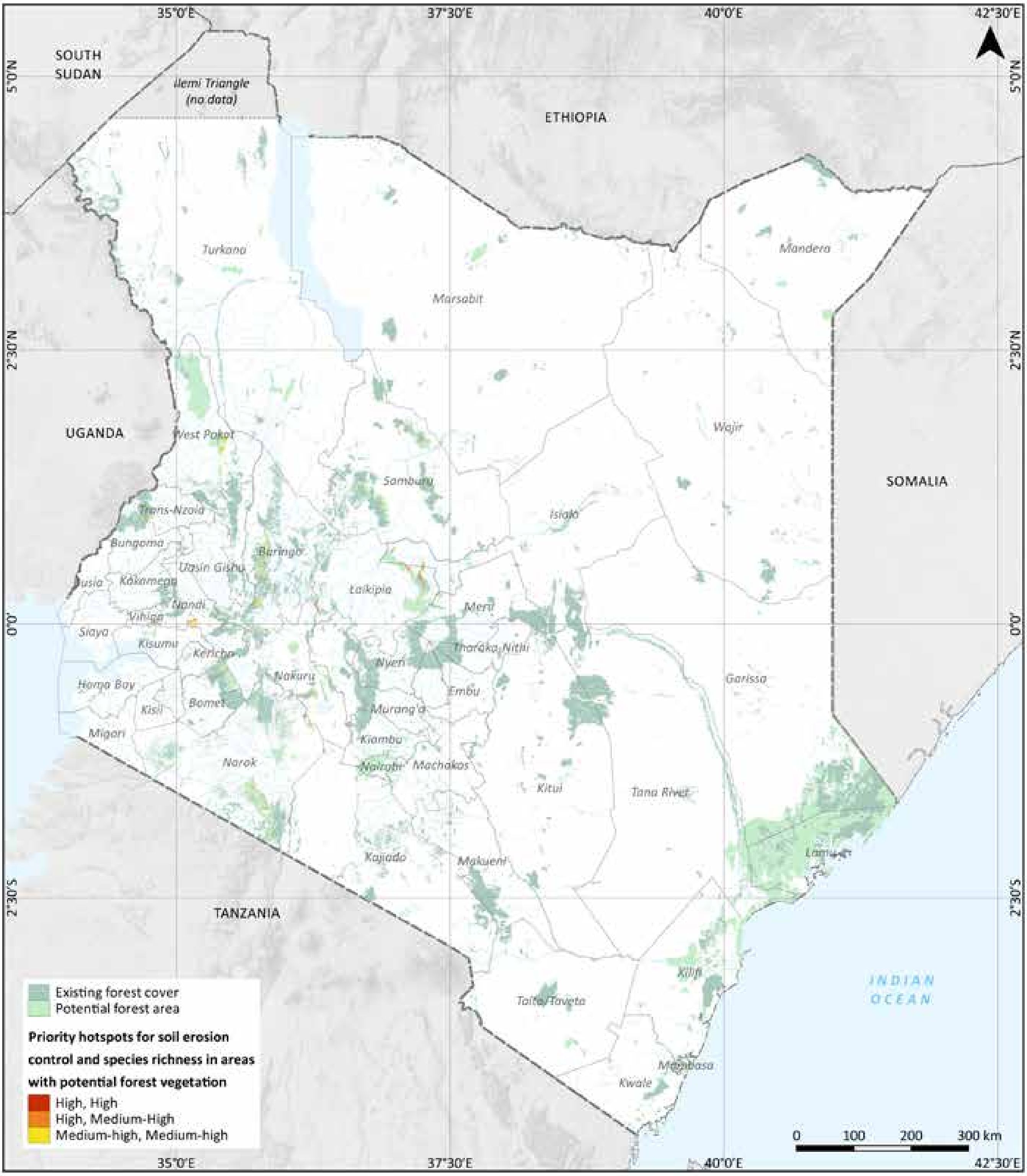
Map 20b (left): *Map of erosion risk for zones where natural forest vegetation is not currently present but has the biophysical potential to be restored. Erosion risk is a product of both slope and precipitation.* ***Map 20c (right):*** *Map of species richness of critically endangered, endangered, and vulnerable species on the IUCN Red List in zones where there is potential for natural forest vegetation.*





MAP 20d: Where do areas with reforestation potential provide the most erosion control and biodiversity habitat?

Map of potential natural forest vegetation for areas with both high risk of erosion and high species richness of critically endangered, endangered, and vulnerable species on the IUCN Red List. Not all of these areas will be suitable for reforestation due to the nature of the current land use. Alternative restoration options could be considered in such areas after consultation with local communities.



Methods and data sources:

Potential Natural Forest Vegetation: van Breugal P, Kindt R, et al (2015) Potential Natural Vegetation Map of Eastern Africa (Burundi, Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia). Version 2.0. Forest & Landscape Denmark and World Agroforestry Centre (ICRAF). URL: http://vegetationmap4africa.org. (additional information about the vegetation map, types and species can be found by following the link.) Documentation specific to Kenya – Kindt, R., van Breugel, P., Lillesø, J-P.B., Gachathi, F., Omondi, W., Jamnadass, R. and Graudal, L. 2014: Potential natural vegetation of eastern Africa. Volume 8. Atlas and tree species composition for Kenya. Department of Geosciences and Natural Resource Management, University of Copenhagen. URL: http://vegetationmap4africa.org/Documentation/Country_docs.html The layer was reclassified to include only the potential vegetation classes that the Restoration Technical Working Group determined corresponded to forest vegetation in Kenya.

Forest: Kenya Forest Service (KFS) Land Cover 2010. The erosion risk layer was clipped according to two shapefiles representing forests within and outside protected area, created using the protected area boundaries and the forest cover data.

Land use/Land cover: see Map 4; *Spceis richnessr:* see Map 6; *Risk of soil erosion:* see Map 9;

8. Conclusions and outlook

Spatial assessments are needed to inform the design and implementation of REDD+ actions. This report has been developed to support Kenya as it prepares for the development of a National REDD+ Strategy. It outlines spatial assessments that can be useful going forward (see Figure 2), discusses a number of topics relevant for designing REDD+ actions based on existing national policies, laws and strategies, and maps some of these using the best available data to date. It covers the distribution, state and types of forest; legal land management arrangements; the spatial distribution of drivers of deforestation and forest degradation; aspects of biodiversity and ecosystem services; and includes maps designed to support planning for some of the draft strategy options in the four priority areas outlined in Kenya's Readiness Preparation Proposal.

This report is intended to support the country in deciding on what additional benefits REDD+ should be designed to achieve; in selecting decision making criteria for the design of strategy options; in assessing the overall potential for various strategy options and in identifying general zones for their potential implementation. They can also be consulted when developing a national approach to REDD+ safeguards, e.g. in clarifying he safeguards and considering the potential risks and benefits of different REDD+ actions. Finally, the maps can help to identify areas for future study, e.g. in identifying areas where forest degradation will be studied more in detail.

This report has aimed to present some of the spatial data needed for initial planning of the strategy options outlined in Kenya's R-PP. Next steps for the country could be to decide on suitability criteria for zoning the various strategy options; select the maps from this report and other sources that provide information on those suitability criteria; combine the spatial data layers to identify zones where such actions could take place; estimate which options have significant potential, and then gather further information as needed to plan for the implementation of those options. Additional data that may be needed could concern costs of REDD+ implementation, existing development plans, and needs of households and communities in different areas. Local information will be necessary for suitability assessments of REDD+ strategy options in different locations; for feasibility studies to understand current land uses as well as the needs and aspirations of stakeholders; and final spatial plans for implementation. For spatial planning to be sustainable, the participatory and collaborative nature of the process is just as important as the underlying data.

View of the Aberdare National Park, Paulus Maukonen

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View of the Cherengani nills from Marich Pass, Paulus Maukonen

REDD+ can contribute to more policy goals than to climate change mitigation alone. The priority of the Government of Kenya is to implement environmentally and socially sustainable land-use and forest policies. All REDD+ activities will be designed with a focus on additional benefits such as improving biodiversity conservation and the livelihoods of forest dependent peoples.

The Government of Kenya has identified a need for better access to comprehensive spatial data and maps on natural vegetation and land use, the biodiversity in relevant ecosystems, the ecosystem services provided by forest, and the geographical patterns of deforestation, forest degradation and their drivers. This information can inform spatial planning and design of REDD+ strategy options.

The purpose of this report is to support REDD+ planning in Kenya through the development of maps on the distribution of drivers of deforestation and forest degradation, potential additional benefits of implementing REDD+ activities, and different implementation possibilities for REDD+ strategy options.

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