MOUNT KENYA
ECOSYSTEM SERVICES ASSESSMENT
REPORT

BY NATURE KENYA

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August 2019

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EXECUTIVE SUMMARY

1. Kenya's highest mountain provides essential ecosystem services, economic services, and cultural services to the community, the nation and the world. Some of these services may not yet be known or measurable. However, we have attempted to measure the current value of Mount Kenya's ecosystem services in order to compare the mountain's ability to provide ecosystem services under two future scenarios. We assessed the quantity, and where possible the value, of ecosystem services (water services, harvested goods, carbon stocks, recreation and other cultural services) provided by the Mount Kenya Ecosystem in 2018 and in two plausible future scenarios – a Business As Usual scenario (BAU), where current trends continue, and a Restoration Scenario, where degraded forest sections are restored.
2. All households living adjacent to Mount Kenya forest use firewood and charcoal as main sources of cooking energy, illustrating the large contribution of forest biomass energy to livelihoods.
3. Most of the local community members residing in the Mount Kenya area had access to piped water. About 78% of the residents experience water shortages during the dry season. Only 35% of households harvested rainwater. We also found that rivers flowing from Mount Kenya Forest have a high sediment load, indicating high levels of habitat degradation. This has to be addressed.
4. We estimated that visitors to the Mount Kenya ecosystem spent US$15.6million annually at the site and in the rest of the country. Continued degradation of the ecosystem will decrease this value to US$9.66million. The travel cost method used here only captures direct payments by visitors to a site and fails to include many indirect contributions to the economy and other associated contributions including job creation and tax payments.
5. Wild goods harvested from the ecosystem in 2018 were valued at about KSh.10.2 billion (US$102 million). Those that had the highest value included livestock fodder and firewood. Others included honey, charcoal, fish, wild fruits, herbal medicine, game meat and skins. Use of most of these goods is expected to increase in a BAU Scenario but this increase would be short-lived due to reduced availability of the goods as habitat degradation increase. The implementation of a forest restoration strategy will lead to a reduction in the amount of wild goods harvested.
6. Goods cultivated in Mount Kenya Forest in 2018 were valued at about 3.0 billion Kenya shillings (about US$ 29.7 million). These comprised of food crops produced under the PELIS program (US$ 15.5 million), timber (US$ 8.8million), and tea (US$ 5.5 million). The amount of cultivated goods will increase in both BAU and restoration scenarios because of ongoing tree planting activities in forest plantations. In the Restoration Scenario, forest plantations in ecologically sensitive areas will be converted into indigenous forest. This will reduce the area available for both crop production under PELIS production. However, in both scenarios, the area under tea production is expected to remain constant.
7. Total carbon stocks in the Mount Kenya ecosystem in 2018 were estimated at about 73 million tonnes. If the current trends continue there will be a 4% reduction in the carbon stocks within the ecosystem; but restoring forests will lead to an 8% increase in carbon stocks.
8. Residents living in the area adjacent to Mount Kenya Forest are aware of many cultural ecosystem services that accrue from the forest. These include religious or spiritual; aesthetic or beauty; leisure, recreation and ecotourism; cultural heritage; education and ecological knowledge; existence and bequest values; social relations and community benefits; health benefits; and inspiration, creative or artistic values. Most of the residents said that the value of these ecosystem services has been decreasing and that this trend will continue unless the restoration of Mount Kenya Forest takes place.
9. Overall, the value of water, cultural, climate regulation, and soil erosion protection will decrease in the BAU scenario but the value of harvested goods will increase. Forest restoration would lead to a decline in the amount of goods harvested from the forest, apart from water. However, it would increase water storage and purification, climate regulation, carbon storage, cultural services including recreation, and other long-term benefits including biodiversity conservation, prevention of soil erosion and pollination services.

1. INTRODUCTION

1.1 Site Location

The Mount Kenya ecosystem is found in Central Kenya and covers parts of Meru, Tharaka Nithi, Embu, Kirinyaga, and Nyeri counties (Figure 1). The forest is surrounded by a largely agricultural community that cultivate coffee, tea, Irish potatoes, maize, beans, cabbage, wheat, carrots and barley, among other crops.

1.2 Vegetation of Mount Kenya Forest

The vegetation on the lower slopes of Mount Kenya is montane forest (indigenous closed canopy and indigenous open canopy forest), transitioning into bamboo, scrub and moorland and giving way to bare rock, ice and snow at the highest altitude. Characteristic tree species in the indigenous forest include *Podocarpus latifolia, Nuxia congesta, Newtonia buchananii, Calodendrum capense, Croton megalocarpus, Juniperus procera, Ocotea usambarensis* and *Olea europaea* spp *africana*. Endemic or near-endemic plants found in this zone include the rare shrubs *Ixora scheffleri keniensis, Pavetta hymenophylla, Maytenus keniensis* and *Embelia keniensis;* and the climber *Rubus keniensis*. Part of the forest adjacent to the local community settlement areas was converted to forest plantations of cypress, pines, eucalyptus, *Vitex keniensis* and *Juniperus procera* for commercial timber production. Above the montane forest zone is the bamboo zone which extends from 2,550m asl. Pure bamboo stands are found in the wetter eastern and southern side while in drier western and northern parts, bamboo is mixed with trees like *Podocarpus latifolia*. The moorland zone is found from 3,000 to 3,500m asl. Characteristic species in this zone include *Hagenia abyssinica* and *Hypericum* spp in open glades. The moorland gives way to Afro-Alpine vegetation characterised by endemic or near endemic plants like giant rosette – *Lobelia telekii* and *L. keniensis* – and *Senecio keniodendron*.

1.3 Conservation Importance of Mount Kenya Ecosystem

The Mount Kenya ecosystem is recognized as an Important Bird Area (IBA) and is the main water catchment area for the Tana and Ewaso Nyiro North rivers– two key rivers that are important to the conservation of many Key Biodiversity Areas found within the Tana and Ewaso Nyiro basins. The Mount Kenya Forest Reserve and the National Park were declared a World Heritage site in 1997 and the status extended to cover Lewa Conservancy and Ngare Ndare Forest in 2013.

The ecosystem is home to many globally threatened mammals, including Bongo (*Tragelaphus eurycerus*), African Elephant (*Loxodonta Africana*), Giant Forest Hog (*Hylochoerus meinertzhageni*), Black-fronted Duiker (*Cephalophus nigrifrons*) and the endangered King African mole rat (*Tachyoryctes rex*). Carnivores found in Mount Kenya are leopard (*Panthera pardus*), spotted hyena (*Crocuta crocuta*), striped hyena (*Hyena hyena*), lion (*Panthera leo*), cheetah (*Acinonyx jubatus*), wild cat (*Felis lybica*), serval cat (*Felis serval*), genet (*Genetta tigrina*) and several mongoose species. Two reptiles, *Atheris desaixi* and *Chameleo schubotzi*, and a butterfly *Capys meruensis*, are endemic to the forest. The snake *Vipera hindii* is found only on Mount Kenya and the Aberdare mountains. Mt. Kenya is important for the following bird species of conservation concern: Abbott's Staling *Pholia femoralis* (Vulnerable and edemic to a few montane forest localities in Kenya and northern Tanzania); Sharpe's Longclaw *Macronex sharpei* (Endangered and Kenyan endemic); African Crowned Eagle *Stephanoaetus coronatus* (Near Threatened)); Martial Eagle *Polemaetus bellicosus* (Vulnerable); and Pallid Harrier *Circus macrourus* (Near Threatened palaearctic migrant).

1.4 Site Management

The Forest Reserves around Mount Kenya are managed by Kenya Forest Service in partnership with Kenya Wildlife Service while the National Park is managed by Kenya Wildlife Service. However, other state agencies have important roles in the management of the ecosystem. These organizations include Kenya Water Towers Agency (KWTA), Water Resource Authority (WRA) and the National Environment Management Authority (NEMA). Sometimes institutional conflict is a challenge in the management of this ecosystem. Ngare Ndare reserve is managed by Ngare Ndare Forest Trust in collaboration with KFS. Nyayo Tea Zone Authority manages approximately 1,000ha of Mount Kenya ecosystem for tea production. This area comprises a 100m strip separating the forest from settlement areas in tea growing areas. This tea belt was intended to create a barrier between the forest and human settlements in order to check on encroachment.

1.5 Ecosystem Services from Mount Kenya Ecosystem

Ecosystem Services are the benefits that man gets from nature. These services can be categorized into provisioning, regulating, cultural and supporting services (MEA, 2005). Provisioning services include food from plants and from animals, fresh water, fuel, medicines, fodder for livestock, herbal medicine, animal skins, food additives among others. A functional ecosystem regulates air quality, climate, water, erosion, pest and diseases and natural hazards (MEA, 2005). Cultural ecosystem benefits are those that people derive from ecosystems, including spiritual enrichment, recreation, aesthetic experiences, and cultural heritage values. Supporting services are those that are necessary for the production of provisioning, regulating and cultural services. These include soil formation, photosynthesis, primary production, nutrient cycling, and water cycling. Functioning ecosystems are intricately

linked with human wellbeing that manifests in secure human societies, with basic material for a good life, healthy populations with good social relations (MEA, 2005).

1.6 Stakeholders relevant for Mount Kenya Ecosystem

Many stakeholders, including the national and county governments, government agencies, Community Forests Associations (CFAs) and other Community Based Organizations (CBOs), national and international conservation NGOs and private sector players have a role to play in the restoration of Mount Kenya Forest (Table 1).

1.7 Rationale for Ecosystem Service Assessment

Mount Kenya is one of Kenya's five water towers. The others are Aberdare Mountains, Cherengany, Mau, and Mount Elgon. Mount Kenya is the main water source for Tana River, from which Kenya generates most of its hydroelectric power. The river also supplies water to millions of Kenyans within and outside Tana River basin. Waters from Mount Kenya sustain biodiversity within the whole Tana River and Ewaso Nyiro River Basins. The Mount Kenya ecosystem is also a biodiversity hotspot and serves as a key carbon sink. The ecosystem and the mountain have high cultural significance to the adjacent community. It is a source of many goods that are necessary for human welfare and sustain businesses in the Mount Kenya region and other areas in Kenya. The ecosystem's ability to sustain these ecosystem services is compromised by habitat degradation, driven by illegal human activities, forest fires, soil erosion, unregulated abstraction of water, human-wildlife conflicts, climate change, illegal grazing, and pollution. There is an urgent need to restore degraded areas. However, this will require resources, political goodwill, and commitment by all stakeholders. An assessment of the value of ecosystem services provided by Mount Kenya is necessary to provide robust evidence that can be used to advocate for the restoration of the ecosystem and therefore of the ecosystem services.

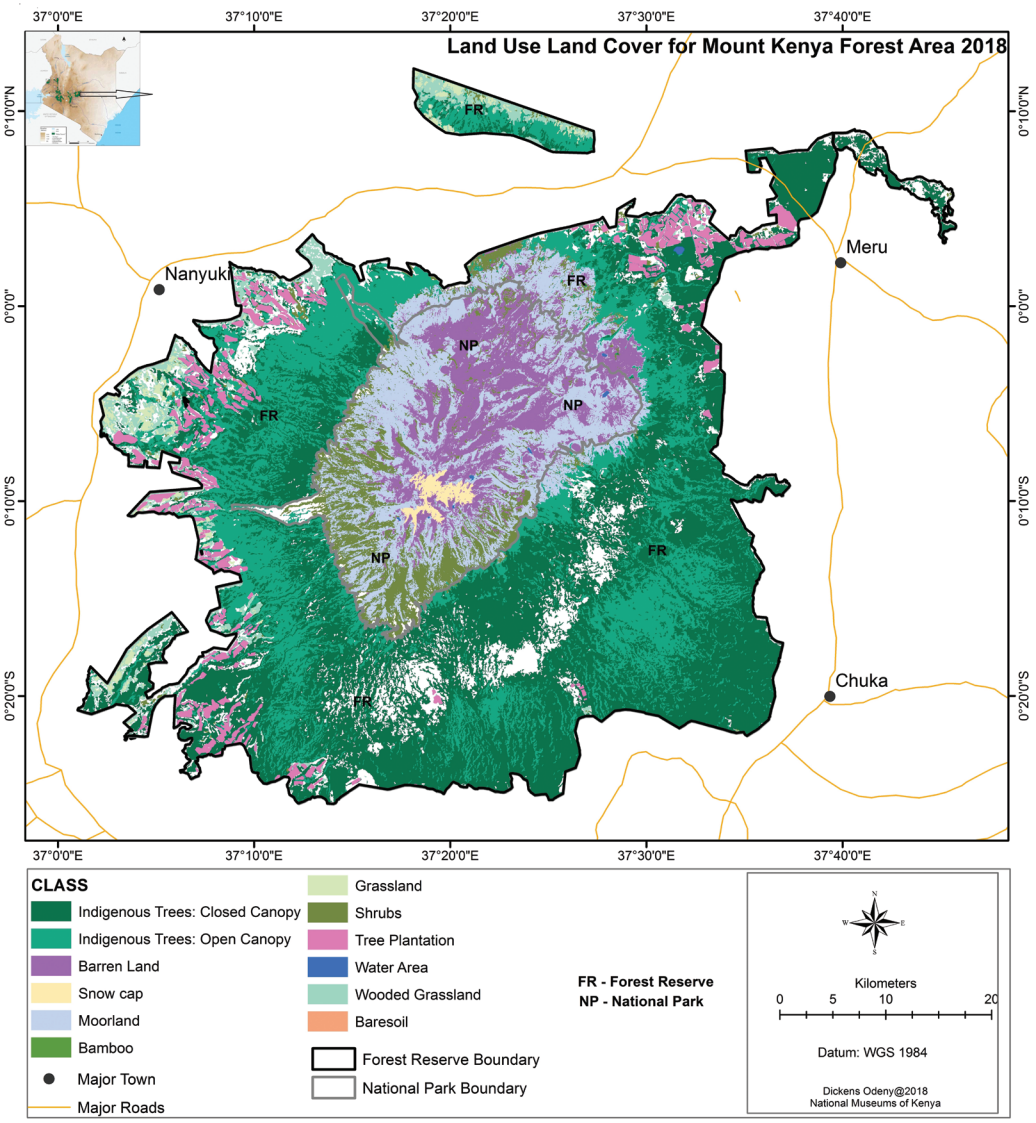


Figure 1.1 Mount Kenya Ecosystem

Table 1.1 Stakeholders in Mount Kenya

Stakeholder	Status	Interests
Kenya Forest Service (KFS)	State Agency	Income generating forestry, plantation forestry, biodiversity conservation, tourism, human wildlife conflicts
Kenya Wildlife Service	State Agency	Biodiversity Conservation, Tourism, human wildlife conflicts
National Environment Management Authority (NEMA)	State Agency	Management and coordination of environmental matters
Water Resource Authority (WRA)	State Agency	Conservation, management and development of water resources Licensing of water abstraction
Nyayo Tea Zone Development Corporation	State Agency	Tea production
Kenya Water Towers Agency (KWTA)	State Agency	Protection, rehabilitation, conservation, and sustainable management of Mount Kenya water tower
Kenya Electricity Generating Company (KENGEN) and Kenya Power and Lighting Company (KPLC)	State Agencies	Forest conservation for sustainable Hydroelectric Power generation
Community Forest Associations (CFAs)	CBOs	Forest Conservation, Livelihood improvement, Human Wildlife conflicts, PELIS programme
Conservation Non-Governmental Organisations (NGOs) e.g. Nature Kenya, Mount Kenya Trust	Civil society	Sustainable forest management, biodiversity conservation
Private sector companies • water service providers • water bottling enterprises • tour operators • tourism sector • hotel operators • saw millers and others • aviation industry	Private	Sustainable supply of ecosystem services e.g. water, tourism, timber, charcoal, carbon credits
Academic, Research Institutions and independent researchers	State, private	Research
Donors	Various	Funding for sustainable resource use
County Governments	Government	• Environment, natural resources and tourism • Water and soil conservation and management • Agriculture
Other resource users including mountain climbers, tourists, Herbalists, etc.	Various	Sustainable use of ecosystem

1.8 General Methods

We used the Toolkit for Ecosystem Service Site-based Assessment (TESSA) (Peh *et al.*, 2017) for this exercise. The process started with a participatory ecosystem service scoping exercise, carried out on 23rd and 24th August 2018. This helped to identify ecosystem services to be included in the detailed assessment, as well as in the formulation of plausible alternative states. We then conducted a detailed assessment of water services, recreation services, harvested goods, climate regulation, and cultural services. A socio-economic survey using a detailed interview schedule adapted from Peh et al., (2017) was the main source of data on cultivated crops, harvested wild goods, and water services. We interviewed 404 members of local communities adjacent to Mount Kenya Forest. All interviews complied with the ethical standards required for human research, following the code developed by the British Psychological Society (BPS, 2014), as implemented by the RSPB (Royal Society for the Protection of Birds) Human Ethics Committee. Kenya Forest Service provided data on revenue from licensed activities within Mount Kenya Forest Reserve. Detailed methods for estimating the quantity of each service in the current and future scenarios are presented in the relevant sections.

A note on units of measurements

Area/extent

Area is presented in both acres and hectares (ha). Hectares are the SI unit of measurement for area and used in GIS systems and the international literature. However, the common local unit of area in Kenya is the acre, and this is used also, especially where quoting responses from residents. 1 acre = 0.405 hectares.

Financial

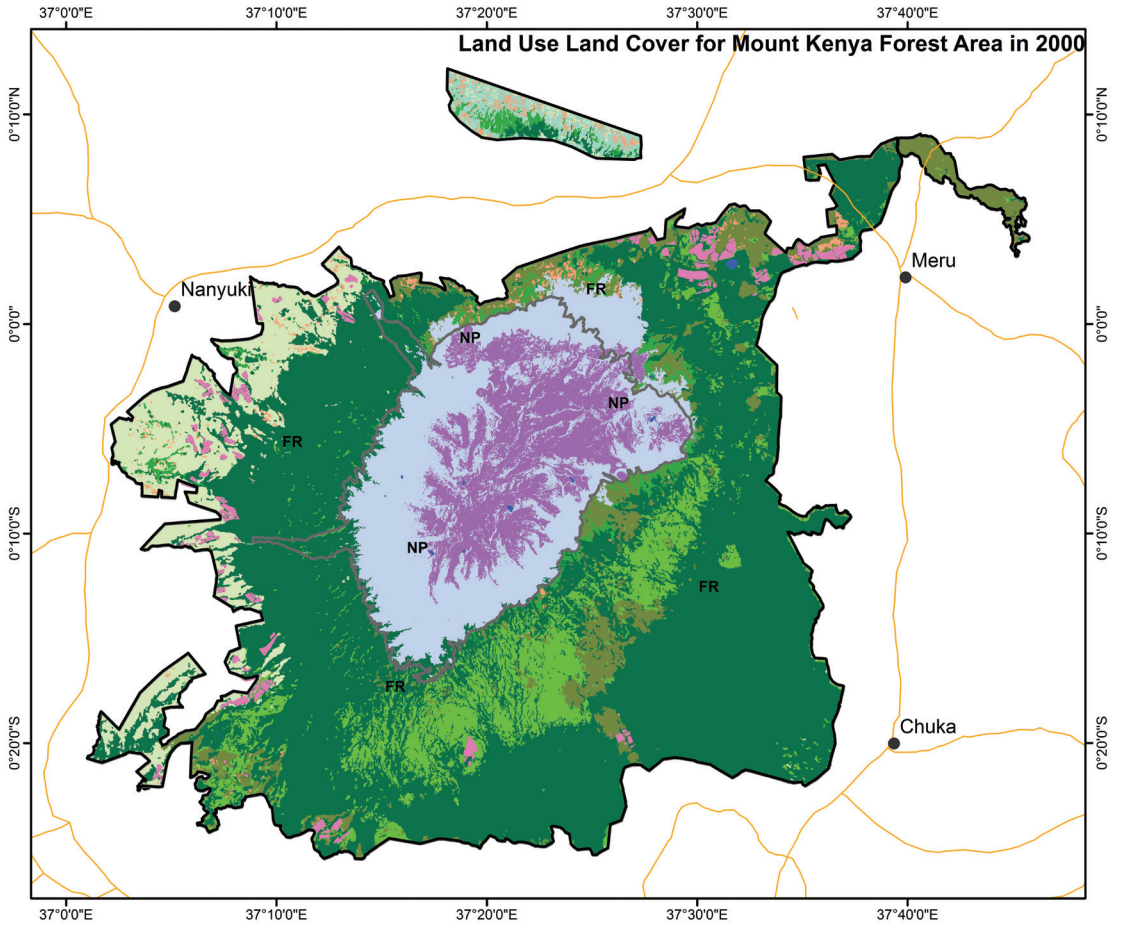
Similarly, the commonest unit of international finance is the US dollar ($) and this has been used for comparing values of commodities and services across service types (food produced, GHG emissions etc.) to aid comparisons, and the sensitivity of estimates of values across service types to international markets for carbon dioxide. However, most values obtained during the assessments were in Kenyan shillings, and so values have also been reported in this currency. In 2018, US$1 = KSh.100.3 (https://www.poundsterlinglive.com/best-exchange-rates/best-us-dollar-to-kenyan-shilling-history).

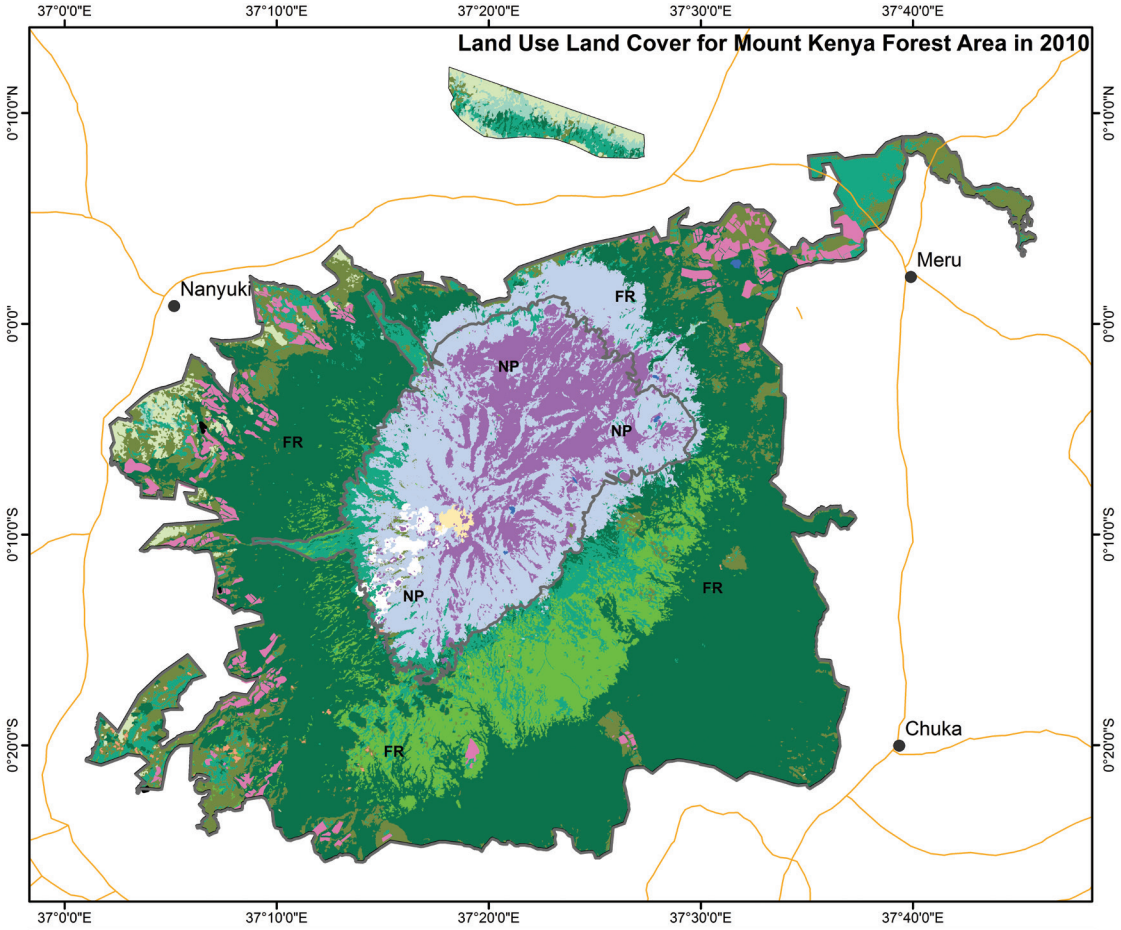
1.9 Describing Scenarios used in Mount Kenya Ecosystem Service Assessment

We based future scenarios on the government and stakeholder aspirations for Mount Kenya Ecosystem. During the stakeholders meeting held as part of scoping exercise (see Section 2), stakeholders were aware that the Mount Kenya ecosystem is being degraded rapidly and that needs to be reversed. A review of action plans for 15 CFAs that operate within the ecosystem highlight the importance of forest restoration. In addition, a review of Mount Kenya Ecosystem Management Plan (KWS 2010), Mount Kenya Forest Reserve Management Plan (KFS) and Vision 2030 (GOK, 2007) also demonstrate stakeholders and Kenyan Government's intention to restore and protect Mount Kenya Ecosystem. Despite these planning documents, Mount Kenya Ecosystem continues to be degraded as shown by the land use/land cover (LULC) changes from 2000 to 2018 (Figure 1.2). There is a need to provide evidence for the advantages of restoring and protecting Mount Kenya Ecosystem. As such, we chose two future scenarios, namely a Business as Usual (BAU) scenario and Restoration scenario.

Business as Usual Scenario: In this scenario, the current drivers of change continue operating leading to the continued decline in ecosystem condition. Land Use Land Cover changes as projected from changes observed from analysis of 2000, 2010 and 2018 satellite images (Figure 1.2). In the Mount Kenya Forest Reserve and National Park, the most significant change is an increase in conversion of indigenous closed-canopy forest to open canopy forest. Under these circumstances, the LULC classes change as shown in Table 1.2. At Ngare Ndare Forest Reserve, the current trend is loss of shrub and grassland vegetation and an increase in the wooded grassland and indigenous forest categories.

Restored Scenario: This is a scenario premised on the implementation of the Mount Kenya Restoration Strategy (KFS, 2019). Emphasis will be on restoring degraded areas of Mount Kenya Forest and mitigating the drivers of negative change including illegal logging, forest fires, and over-harvesting of forest products among other measures. Any forest plantation established in an ecologically sensitive area will be replaced by indigenous forest. The area under tea cultivation by Nyayo Tea Zone Corporation will remain at the current levels. According to the strategy, private sector players who benefit from Mount Kenya ecosystem services will contribute to restoring the ecosystem. The strategy also lays emphasis on improving the economic status of the forest-adjacent communities, to reduce their reliance on forest products. As a result, we project that the ecosystem's LULC will change as shown in Table 1.2.


Land Use Land Cover for Mount Kenya Forest Area in 2000
37°0'0"E
37°10'0"E
37°20'0"E
37°30'0"E
37°40'0"E
0°10'0"N
0°0'0"
0°10'0"S
0°20'0"S
Nanyuki
Meru
Chuka
FR
NP
NP
FR
NP
FR
FR


Land Use Land Cover for Mount Kenya Forest Area in 2010
37°0'0"E
37°10'0"E
37°20'0"E
37°30'0"E
37°40'0"E
0°10'0"N
0°0'0"
0°10'0"S
0°20'0"S
Nanyuki
Meru
Chuka
FR
NP
NP
FR
NP
FR
FR

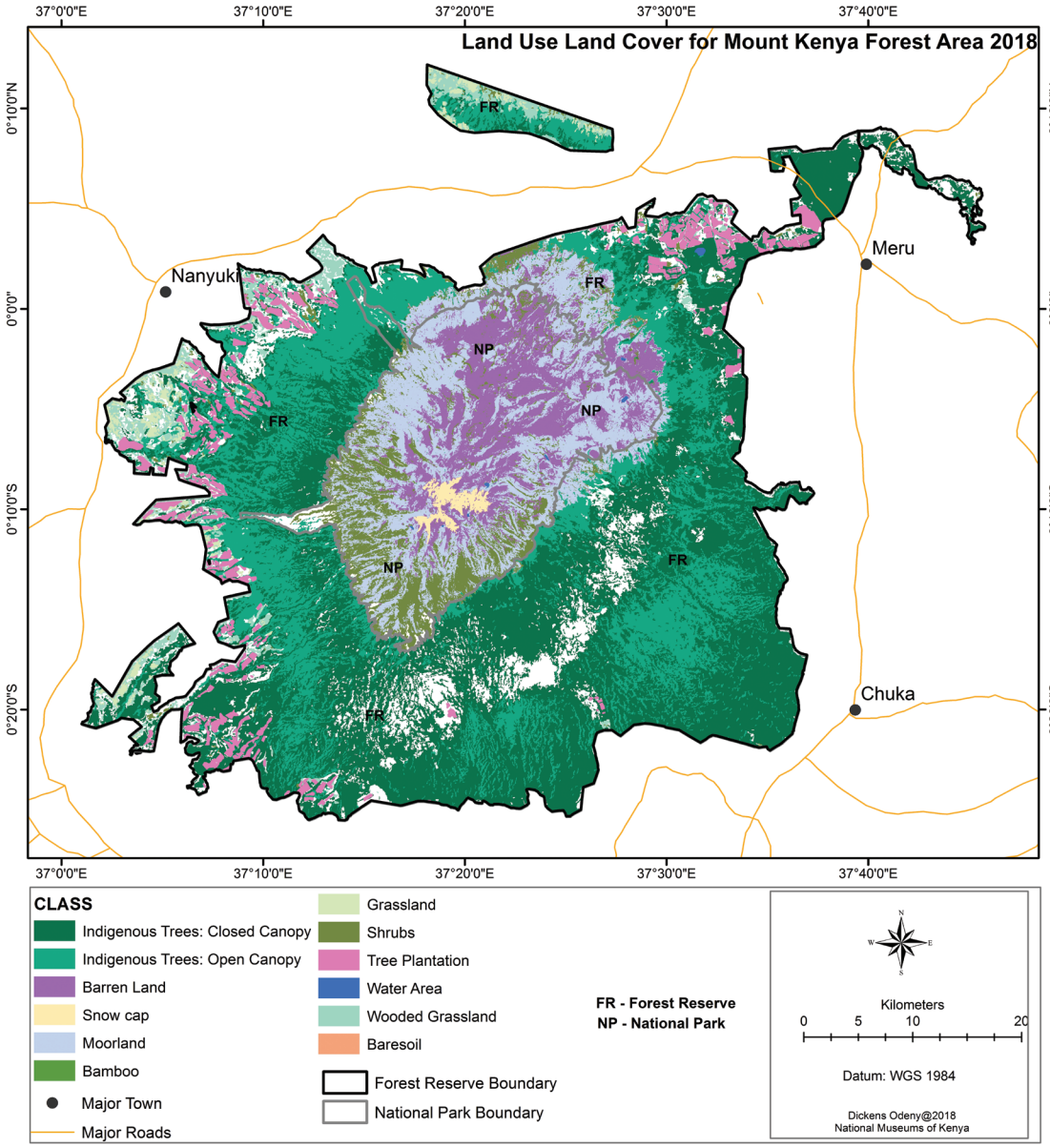


Figure 1.2 Changes in LULC Classes in Mount Kenya Ecosystem Comparing Years 2000-2010-2018

Table 1.2 Land Use Land Cover Classes in 2018 and Two Future Scenarios

Habitat/land Use land cover class	Area (ha)		
	2018	2038	
	Current	BAU	Restored
Mount Kenya Forest Reserve			
Indigenous Trees: Closed Canopy	102,962	80,962	142,588
Indigenous Trees: Open Canopy	56,450	79,841	16,000
Bamboo	20,395	18,300	18,300
Wooded Grassland	5,682	6,213	10,799
Scrub	2,424	-	-
Barren land	2,074	2,000	1,500
Water Area	67	68	68
Moorland	7,380	6,000	4,796
Bare soil	595	2,000	-
Grassland	1,793	500	-
Tree plantation	11,062	15,000	16,833
Tea plantation	787	787	787
Total	**211,671**	**211,671**	**211,671**
			Mount Kenya National Park
Moorland	25,221	20,516	27,221
Barren Land	19,967	17,804	18,195
Shrubs	11,821	9,999	11,821
Snow cap	52	50	50
Indigenous Trees - Open Canopy	917	9,676	226
Indigenous Trees - Closed Canopy	309	228	1,000
Water Area	75	82	75
Wooded Grassland	4	11	4
Total	**58,366**	**58,366**	**58,366**
			Ngare Ndare Forest Reserve
Grassland	677	0	700
Indigenous Trees - Closed Canopy	836	830	2,000
Indigenous Trees - Open Canopy	2,498	3441	2,000
Shrubs	159	0	500
Wooded Grassland	1,921	1822	892
Total	**6,092**	**6,092**	**6,092**
Grand Total	**276,129**	**276,129**	**276,129**

2. LOCAL STAKEHOLDERS' PERCEPTIONS OF ECOSYSTEM SERVICES PROVIDED BY MOUNT KENYA

2.1 Introduction

Most ecosystems are under pressure arising from land use change, climate change, invasive species, overexploitation, and pollution. Many of these problems are associated with the need to produce more food, expand human settlements and other services to a rapidly expanding human population. The ever-increasing pressure on ecosystems compromises their ability to provide the goods and services that are vital to human survival. Each ecosystem has multiple stakeholders whose interests in the ecosystem services vary in type of service needed, space and time. In many instances, different stakeholders are only aware and interested in the protection of the ecosystem services that they perceive as important to them. Unsustainable use of one ecosystem service can jeopardize the ecosystem's ability to provide other types of ecosystem service to other stakeholders.

When different stakeholders appraise the importance of different ecosystem services in a participatory manner, they are able to appreciate the whole range of ecosystem services provided by a site and the consequences of unsustainable exploitation of the same. This paper reports the findings of a workshop in which diverse stakeholders assessed the relative importance of different ecosystem services that accrue to communities living around Mount Kenya Forest in Central Kenya (see Figure1.1). Specifically, the stakeholders' forum aimed at identifying the current drivers of change in Mount Kenya Ecosystem and the ecosystem services provided by the site in the current and future alternative states. The findings of the stakeholders' forum were also meant to inform a further detailed assessment of ecosystem services provided by the site.

2.2 Methods

The work reported here was carried out through an ecosystem scoping exercise conducted on 23rd and 24th August 2018 using methods adopted from The Toolkit for Ecosystem Service Site-based Assessment (TESSA) developed by Peh *et al.,* (2013; 2017). The exercise involved participants representing diverse interest groups including community-based organizations, state conservation agencies (KFS, NEMA and KWS), farmers, private conservancies, and representatives from Meru County Government.

They worked in groups using the Ecosystem Service Scoping Protocol described in details by Peh *et al.,* (2013; 2017) to:

1. Identify current drivers of change and their impact
2. Formulate an alternative state (plausible future state) for Mount Kenya ecosystem
3. Compare ecosystem services provided by the current and alternative states

2.3 Results and Discussion

2.3.1 Drivers of Change

According to the stakeholders, the Mount Kenya forest ecosystem faces many challenges. These include soil erosion, water management, illegal water abstraction, human-wildlife conflict, climate change and severe weather, illegal grazing, pollution, resin harvesting, honey harvesting, among others (Table 2.1). However, there are efforts to improve ecosystem service delivery including implementation of water management initiatives and forest restoration. In addition, on-farm forestry reduces the dependence of the local community on forest products.

Drivers of change that impact negatively on Mount Kenya ecosystem

Stakeholders ranked soil erosion as one of the most serious threats to Mount Kenya Ecosystem. This problem is associated with unplanned and unsustainable practices linked to tourism, agriculture and rapid population growth. This is blamed on cultivation and overgrazing, illegal logging and road construction works where unplanned drainage channels cause severe erosion. Other issues that are linked to soil erosion include forest fires and diseases and pests that reduce forest vegetation cover leading to accelerated erosion (Elias & Thomas, 2015). If unchecked, soil erosion can interfere with plant community development and vegetation succession through its negative impacts on seed availability, dispersal, germination, and establishment, leading to changes in plant community structure and spatial distribution (Jiao *et al.,* 2009).

Stakeholders ranked water management and use issues as the second most important driver of change in the ecosystem. This challenge was also identified by stakeholders during the formulation of Mount Kenya Ecosystem management plan (KWS, 2010). Unregulated water use for both commercial and subsistence agricultural activities has reduced the reliability of downstream water supply, impacted riparian environments and decreased water quality. It was noted that if this issue is not addressed this can significantly harm the wildlife, ecosystem health, and downstream human communities.

Human-wildlife conflicts are another driver of change in the ecosystem. This finding is supported by many previous studies (e.g. Muoria, 1995; Kamweya *et al.,* 2012). Wild animals, particularly elephants, various primate species and also buffaloes and wild pigs, destroy crops, thus impacting negatively on the food security of the local residents. There have also been reports of carnivores killing and/or injuring livestock. Buffaloes, elephants, and snakes are a danger to local communities due to their potential to injure

Table 2.1 Drivers of Change in Mount Kenya Ecosystem (STDEV=Standard Deviation)

Activity	Mean score	STDEV
Soil erosion	9.0	0.00
Water management & use	8.5	0.58
Illegal water abstraction	8.3	1.50
Human Wildlife Conflict	8.0	0.00
Climate change & severe weather	7.8	1.89
Illegal Grazing	7.5	1.00
On farm forestry	7.5	1.00
Pollution	7.3	0.96
Forest restoration	7.3	0.96
Resin Harvesting	7.0	0.00
Honey harvesting	7.0	0.00
Creeper cutting	7.0	0.00
Tree planting (poly tubes)	7.0	0.00
Visitor impacts	6.8	0.50
Logging/wood-harvesting	6.7	1.15
Fuel wood collection and charcoal production	6.5	1.29
Licenced Grazing	6.5	1.29
Deforestation	6.0	0.00
Agriculture & aquaculture	5.8	1.50
Human disturbance	5.8	1.71
Problematic native species	5.5	0.71
Pests and diseases	5.5	1.29
Marijuana cultivation	5.5	1.29
Mining	5.3	1.53
Invasive alien species	5.3	1.53
Fire	5.3	0.96
Geological events	5.3	1.50
Gathering terrestrial plants	5.0	1.00
Residential & commercial development	4.8	1.71
Transportation & access corridors	4.8	0.96
Hunting & trapping	4.8	0.96
Fishing & harvesting other aquatic resources	4.8	0.96

or to cause loss of human life. Wild animals also damage forest plantations by uprooting and trampling of seedlings and debarking of trees (KWS, 2010). Human-wildlife conflicts lead to the local community developing negative attitudes towards wild animals resulting in retaliatory killing of wild animals and withdrawal of support to conservation initiatives.

Livestock grazing is another challenge facing Mount Kenya ecosystem. Livestock grazing takes place both legally where residents pay a fee to Kenya Forest Service (Emerton, 1997) and also illegally. Mount Kenya ecosystem is also an important dry season grazing refuge for lowland pastoral communities. Pastoralists from as far as northern Kenya invade the mountain ecosystem to escape recurrent droughts. Lack of grazing regulation has over the years resulted in overgrazing and conflicts with agricultural communities. Overgrazing in the montane forest has been shown to interfere with vegetation community composition (Kikoti & Mlingo, 2015). Overgrazing can also lead to other problems including soil erosion and spread of invasive plants.

Pollution is also a threat to Mount Kenya Ecosystem. This problem was highlighted in both KFS (2010) and KWS (2010) and arises from poor disposal of sewage and litter especially in the remote, cold and alpine zone of the ecosystem (KWS, 2010). Other potential sources of pollution are the development of tourism and management infrastructure in high-density tourist areas, including hotels, camps, walking trails, offices, and roads. In addition, human activities, especially cultivation, within the fast-increasing population in the slopes of Mount Kenya and surrounding rangelands could be contributing offsite air pollutants that degrade Mt. Kenya ecosystem (Gichuru & Mutahi, 2017). Pollution is likely to have negative impacts on man and biodiversity.

Unsustainable harvesting of forest products including wood, resin, and honey is a conservation challenge (Table 2.1). Resin harvesting was reported by the stakeholders, but the literature search did not reveal previous documentation of this product. Honey harvesting has been blamed for causing forest fires. Logging/wood-harvesting and creeper cutting reduces the ecosystem's climate regulation potential and destroys habitat for many globally threatened species. Tree species targeted by this illegal practice include African Pencil Cedar (*Juniperus procera*), Wild Olive (*Olea europaea* ssp *africana*), East African Rosewood (*Hagenia abyssinica*), East African Camphor (*Ocotea usambarensis*), *Newtonia buchananii*, East African Yellow-wood (*Podocarpus* spp), *Olea capensis* and Meru Oak (*Vitex keniensis*) (KFS, 2010). Communities living adjacent to the lower parts of Mount Kenya Forest Reserve are sometimes involved in illegal charcoal production. This is supported by KFS (2010) which documents that this illegal practice was prevalent particularly in Thegu, Imenti, Burguret, Naro Moru, Ragati and Chehe areas.

Stakeholders mentioned that the site has experienced impacts of climate change including prolonged droughts and severe weather events. Climate change is likely to impact on the site and is expected to cause the disappearance of the glaciers within a few decades (Mission Report, 2008), and result in a general shift in vegetation zones to higher elevations, reducing the area of the unique Afro-alpine communities.

Forest fires are a problem in Mount Kenya ecosystem. These fires are mainly caused by arson and honey gathering (KFS, 2010). Other causes that have been recorded are lightning, grazers, shamba clearing, cigarette butts, and charcoal production. Forest fires alter structural and species diversity and promote the proliferation of invasive species. Forest fires also negatively impact on aesthetics (landscape beauty) and water catchment ability.

Other conservation challenges in Mount Kenya ecosystem include invasive alien species, pests and diseases and wildlife poaching. Some of the invasive species recorded on Mount Kenya include *Caesalpinia decapetala* (Mauritius thorn), *Datura stramonium* (Jimsonweed), *Solanum incanum* (Sodom apple), Curse of India (*Lantana camara*) and *Ricinus communis* (castor oil plant) (KWS, 2010). Insect pests such as pine woolly aphid and the cypress aphid (*Cinera cupressi*), have been a major problem to *Pinus patula* and *Cupresus lusitanica* plantations, respectively. Other pests include rats which are a menace to tree seedlings, feeding on the roots and causing ring debarking in abandoned shamba areas.

Bush-meat poaching is a threat to wildlife species of Mount Kenya ecosystem. Poachers mainly target buffalo, eland, zebra, Bongo (which is now almost wiped out), small antelopes (duiker, bushbuck, and waterbuck) and ground birds (francolin and guineafowl). There are, however, a few isolated cases of "trophy poaching" of elephant, rhino, and leopard in the ecosystem and illegal trade in live reptiles (Mt. Kenya forest viper and chameleons) (KWS, 2010).

On-going conservation activities (Positive drivers of change)

Stakeholders were aware that diverse conservation stakeholders including state agencies like Kenya Wildlife Service, Kenya Forest Service, Kenya Water Towers Agency and a multitude of community-based groups are engaged in conservation activities that are driving changes in the ecosystem. Community-based conservation organizations, particularly Community Forest Associations (CFAs) and also Water Resource Users Associations (WRUAs) are involved in conservation activities including forest restoration. Many local community members were also practicing on-farm forestry which reduces dependence on the forest products. All these activities were aimed at enhancing the status of Mount Kenya Forest and hence its ability to continue providing ecosystem services.

The high stakes placed on ecosystem management by stakeholders is aptly captured in the Ecological Management program of the ecosystem's Management Plan (KWS, 2010), whose objectives revolve around the conservation of threatened mammal species and their habitats, control of wildfires and research and monitoring. A review of Kenya Forest Service's management plan (KFS, 2010) for the same period also lays emphasis on conservation activities that might enhance the condition of the ecosystem. In the natural forests, the emphasis was in the protection of the ecological integrity of the protected areas, preservation of the water catchment function and ecological research. The Forest Management Plan (KFS, 2010) implementation was anchored in the Participatory Forest Management in which stakeholders partner with KFS to manage the forest resources. The plan focuses on enhancing tree planting in the surrounding community land to reduce pressure on forest products. Changes in the policy and legal environment can at times hamper the conservation efforts of some of the stakeholders. For example, tree nurseries have been dependent on plastic polytubes in their tree nursery preparation. Since the implementation of the ban on plastic bags (Gazette Notice No. 2334), there is a scarcity of polytubes for use in tree nurseries.

2.3.2 Ecosystem Services Provided by Mount Kenya

The stakeholders were aware that the ecosystem provides many goods that they need for their welfare. Water was ranked as the most important good that the ecosystem provides. The mean score for the current state is 4.5 out of 5.0 (Table 2.2). Stakeholders thought that restoring the forest will lead to an increased value of the water provision service. The local people value the crops cultivated in the forest under the Plantation Establishment and Livelihood Implementation Scheme (PELIS) program highly and they think the forests will continue being important for cultivated food production in the future. Other goods obtained from the forest include firewood and charcoal, timber and other construction material, livestock fodder, and herbal medicine. According to the stakeholders, the firewood, charcoal, and harvesting of timber, and other construction material from natural forests will decline due to strict monitoring of these illegal activities in the ecosystem. Restoring the forest ecosystem will lead to an increase in the services provided by the forest. Better managed forest plantations will also continue providing timber and fuel-wood, particularly for the many tea factories that dot the tea growing areas in the forest buffer areas.

According to the stakeholders, Mount Kenya ecosystem is important for various regulating services including Local climate and air quality regulation, water flow regulation, global climate regulation, local rainfall regulation, water quality regulation, and erosion control. The stakeholders were in agreement that if the restoration takes place, the ability of the ecosystem to continue providing these services will increase (Figure 2.1). The ecosystem provides the stakeholders with aesthetic, natural heritage, spiritual and religious values and is also important for recreation. The value of these services is expected to increase with the implementation of restoration activities. The ecosystem is a biodiversity hotspot that is home to many species of conservation importance. In addition, the biodiversity present supports other services including provision, regulation, and cultural services. The ecosystem is important in other supporting services including nutrient cycling and biological control.

Table 2.2 Stakeholder Perception of Ecosystem Service Provision in the Current and Future State

Ecosystem Service Category	Ecosystem Service	Mean Value		
		Current	Future	Change
Provisioning	Water for human use	4.5	5.0	0.5
	Cultivated food	3.8	4.0	0.3
	Harvested wild energy sources e.g. firewood, charcoal	3.8	3.3	-0.5
	Harvested wood and wild fibre (timber, and other construction material)	3.5	3.3	-0.3
	Harvested wild livestock fodder	3.3	3.8	0.5
	Harvested wild food	2.8	3.3	0.5
	Cultivated fibre	2.8	3.3	0.5
	Harvested wild natural medicines	2.5	2.5	0.0
	Cultivated energy sources	2.3	3.0	0.8
Regulating services	Local climate and air quality regulation	3.5	4.8	1.3
	Water flow regulation	3.5	3.8	0.3
	Global climate regulation	3.3	4.8	1.5
	Local rainfall moderation	3.0	5.0	2.0
	Water quality regulation	2.8	4.5	1.8
	Erosion control	2.8	4.0	1.3
Cultural	Aesthetic benefits / inspiration	3.3	4.3	1.0
	National heritage	3.3	4.3	1.0
	Spiritual/religious experience	2.8	3.3	0.5
	Recreation/tourism	2.5	4.3	1.8
Supporting	Biodiversity	3.0	4.0	1.0
	Nutrient cycling	3.0	4.0	1.0
	Biological control	2.3	3.3	1.0

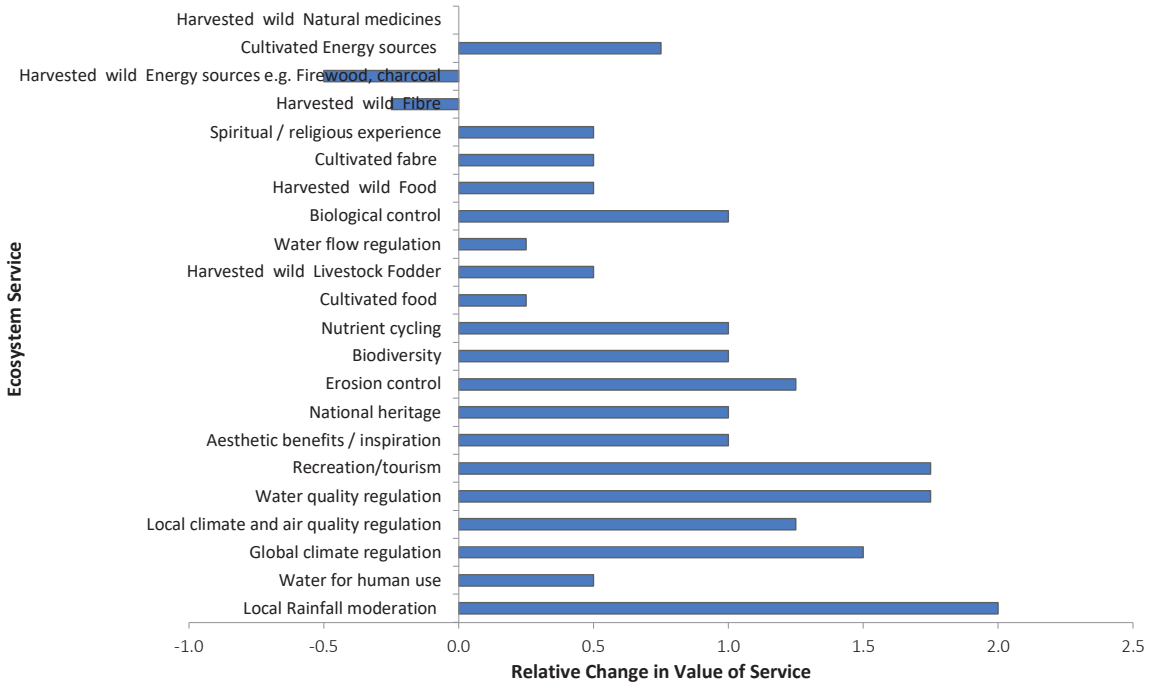


Figure 2.1 Perceptions on Ecosystem Services Provided by Mount Kenya if the Forest is Restored

3. THE SOCIO-ECONOMIC CHARACTERISTICS OF THE LOCAL COMMUNITY

3.1 Introduction

Mount Kenya Forest is surrounded by a largely agricultural community that relies on the forest for various goods and services. The region is one of the most densely populated areas of Kenya. This high human population has been exerting pressure on the forest resources, but it also bears some costs in the form of human-wildlife conflicts. Data on the demographic characteristics and the economic status of this community would enable us to understand current and future trends in the use of various ecosystem services provided by Mount Kenya Ecosystem.

3.2 Methods

A socio-economic survey using a detailed questionnaire developed from templates in Peh et al. (2013) was the primary data source for assessing the value harvested wild goods, cultivated goods (including honey production) and water services. This questionnaire was administered in 28 locations defined using the Community Forest Association operational areas. These 26 locations provided a representation of 6 counties which border Mt. Kenya forest – Nyeri County 7 locations; Meru County 11 locations; Tharaka-Nthi County 3 locations; Embu County 2 locations; Kirinyaga County 5 locations and Laikipia County 1 location. One enumerator was recruited from each of these locations with an additional 2 enumerators recruited to reinforce 2 locations in Meru County that had a larger area to ensure good representation. Before the enumerators commenced the exercise, they were trained in the required methodologies. Each enumerator was tasked to sample a total minimum of 15 household respondents per location. A standardized method of household selection was agreed where the main path, track or road in each location was used as a sampling transect. Each enumerator then estimated the number of households along the transect and divided that number by 15 (sample size) to select target households.

3.4 Results

Demographic Characteristics of the Respondents

A total of 404 households were reached from 6 counties (Embu, Kirinyaga, Nyeri, Laikipia, Meru, Tharaka-Nithi) surrounding Mt. Kenya National Forest Reserve. 73% of the respondents were Household Heads who were mainly male (66%), while 27% (Daughter, Son, and Wife) were household members over the age of 18years, who had the authority to provide feedback to the survey. The level of literacy was high with 93% of the respondent having completed different levels of education (38% - Secondary school, 36% - Primary school, 19% - Tertiary education). The average size of a household was 4.8 people/household (Table 3.1). Comparing the household sizes across the sampled counties, Kirinyaga County had the largest household size of 6.8 people.

Sources of Income

The main occupation of the sampled households is small-scale farmers. About 80% of residents had a monthly income that ranged from 0–15,000 Kenya Shillings (Table 3.2). Only one percent of the respondents reported that their monthly income was more than 50,000 Kenya Shillings. The main source of income for most residents was the sale of farm produce and sale of milk (Figure 3.1) while wages, livestock sales, salaries, and small-scale businesses enterprises also contributed.

Table 3.1 Mean Household Size in Mount Kenya Area

County	Average Household Size (No of people)
Embu	6.4
Kirinyaga	6.8
Laikipia	4.3
Meru	5.8
Nyeri	6.3
Tharaka-Nithi	4.0
All	4.8

Sixty-three per cent (63%) of respondents indicated that monthly income was decreasing compared to previous years. Major expenditure items for local residents were food, clothes, school fees, medical expenses and purchase of farm inputs (Table 3.3).

Table 3.2 Monthly Income of the Residents of Mount Kenya Area

Monthly Income Level	Number of Respondents	Percent (%)	Cumulative Percent (%)
Less than Ksh 2,500	40	10	10
Ksh 2,500-5,000	92	23	33
Ksh 5,000–7,500	63	15	48
Ksh 7,500-10,000	63	15	63
Ksh 10,000-12,500	36	9	72
Ksh 12,500-15, 000	29	7	79
Ksh 15,000 – 20,0000	34	9	88
Ksh 20,000 – 50,000	36	9	97
More than 50,000	3	1	98
No Response	17	2	100
Total	404	100	

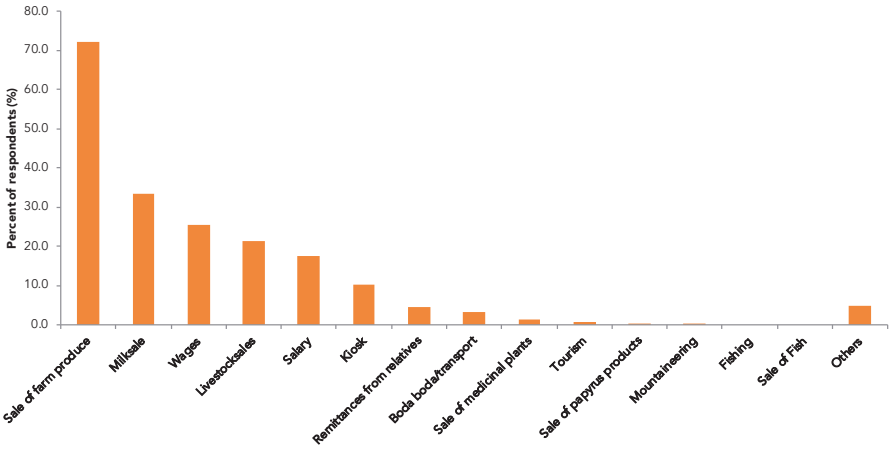


Figure 3.1 Sources of Income for Residents in Mount Kenya Area

Table 3.3 Rank of Expenditure at Household Level

Income Expenditure	Number of Respondents	Importance Rank
Food	342	1
Clothes	232	2
School fees	113	3
Medical expenses	104	4
Farm inputs	102	5

Within each homestead, there were mainly two house structures: The main house and a separate kitchen area. Each of these structures was constructed using different materials. The main houses were mainly roofed with corrugated iron sheets (96%), walls constructed with timber (69%) and the floors made of concrete (55%) and 39% of earth. The second structures which were mainly kitchens had similar construction materials as the main house. The difference was 72% of the kitchen had earth floors.

Sources of Energy

We sampled sources of energy used for cooking in households. Firewood and then charcoal were the main sources of cooking energy (Figure 3.2a). 53% of households did not have any form of energy-saving cooking technology while 42% had adopted energy-saving cooking stoves and 2% had biogas technology. Respondents indicated that energy-saving cook stoves saved between 47%-50% of fuelwood compared to the traditional cook stoves. The main reason provided for the low uptake of the energy technology was costs associated with procurement and lack of local artisans that can fabricate these devices. The majority (54%) of households use electricity for lighting; the rest Kerosene (25%) and solar (18%) (Figure 3.2 b). Only 2 % of the residents used firewood for lighting

Perception on Forest Conservation

65% of respondents were active members of community-based conservation groups – Community Forest Associations, Water Resource Users Associations. 64% stated that the forest condition was improving while 36% had a contrary view.

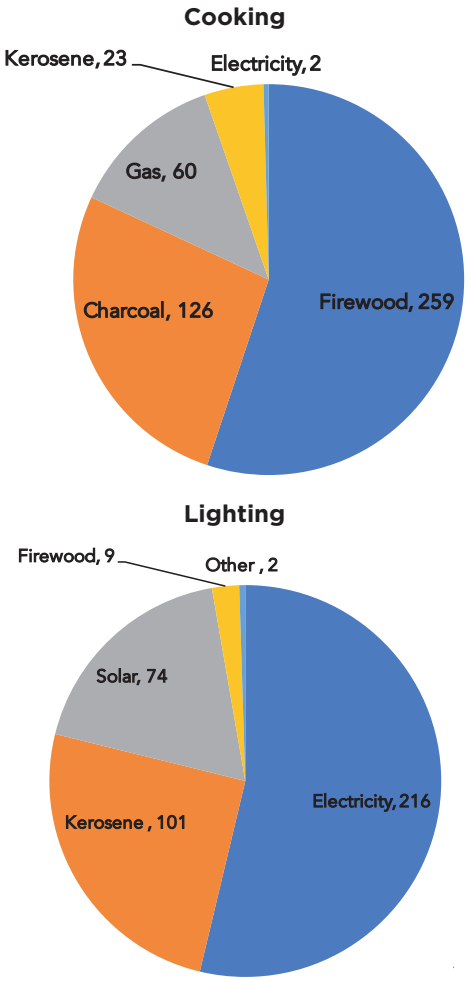


Figure 3.2 Sources Cooking and Lighting Energy

3.5 Discussion

This survey was carried out within the Mt Kenya forest-adjacent community which falls between 0-5km buffers from the forest boundary. The average household size recorded is comparable with that recorded by KNBS and SID (2013). Community monthly income ranged between US$25-USD50 (23% of respondents) and USD50-USD100 (30%). Main income was earned from the sale of farm produce. This includes milk, vegetables and cash crops (coffee and tea).

Timber products were observed to be a preferred material for house construction. This was observed in at least 69% of the household surveyed where walls of houses were made up of timber. Almost 100% of the second building in the homesteads had timber walls. This shows the high dependency of forest adjacent communities on forest products. Even though the sources of timber were not ascertained, whether forest or from on-farm plantation, there is a high probability that the forest contributed most of the construction material.

Majority of forest adjacent community members reported that firewood is their main source of cooking, followed by charcoal. This shows that biomass energy is still highly preferred for households, mainly because it is available, easily accessible and cheaper than alternatives like Kerosene, LPG (cooking gas) and Electricity. Similar results were recorded by KNBS (2009); KNBS & SID (2013) where over 70% of households the counties adjacent to Mount Kenya Forest use firewood as the main source of cooking energy. This puts more pressure on the production of firewood and charcoal from Mount Kenya Forest and can have serious consequences on other ecosystem services like water provision, biodiversity, tourism, and climate regulation. There is a need for increased investment in alternative energy sources and energy-saving cooking stoves. In addition, it is necessary to enhance agroforestry among the local residents to reduce dependence on the forest for firewood and charcoal production.

4. WATER PROVISION ECOSYSTEM SERVICE

4.1 Summary

Most local community members in the Mount Kenya area had access to piped water. About 78% of residents experience water shortages during the dry season but only 35% of them harvested rainwater. We also found out that rivers flowing from Mount Kenya Forest have high sediment load indicating high levels of habitat degradation. There is minimal regulation of water use from the forest. 78% of residents do not know how much water they consume; mainly piped water is not metered. Furthermore, many community water projects have been licensed by WRA to abstract water from independent water intakes which reduces water quantity downstream.

4.2 Introduction

Mount Kenya is one of the five (Figure 4.1) most important water towers. The other water towers are Aberdare Mountain Ranges, Cherangani Hills, Mau Forest Complex and Mount Elgon. Mount Kenya and Aberdares are the main sources of water for both Ewaso Nyiro North and Tana Rivers. These two rivers are very important for Kenya's socio-economic development. For example, most of Kenya's hydroelectric power is generated from the Tana River. The river supplies water to millions of Kenyans both within the Tana River Basin and through interbasin transfers, outside Tana River basin. Water from the Tana River supports both large and small scale irrigation enterprises that contribute to national food security. Tana River is also the main water source for wildlife in many conservation areas with the basin (Figure 4.2). These include Kora, Meru, and Tsavo East national parks; Bisinadi, Mwingi and Arawale national reserves; and the Tana River Primate National Reserve. Ewaso Nyiro River is the main lifeline for thousands of residents in Laikipia, Samburu and Isiolo counties, supplying water for domestic, livestock and irrigation needs. It supports a rich biodiversity heritage found in private and community wildlife conservancies and national reserves within the Ewaso Nyiro Basin.

Increasing water demand in both Tana and Ewaso Nyiro River basins has led to unsustainable water abstraction leading to conflicts between communities. Wiesmann et al. (2000) reported that during the dry season Ewaso Nyiro river downstream flow is curtailed (Figure 4.3) leading to a dire situation for people, livestock and wild animals downstream. The situation has become even worse over the years and even rivers that rarely used to dry up on the Eastern side of Mount Kenya are at times having no flow during the dry season. Other factors contributing to this worsening situation include the impacts of climate change and forest degradation within Mount Kenya Forest. We investigated the current levels of water use in in Mount Kenya Ecosystem and assessed the possible implications of restoring or not restoring Mount Kenya Forest.

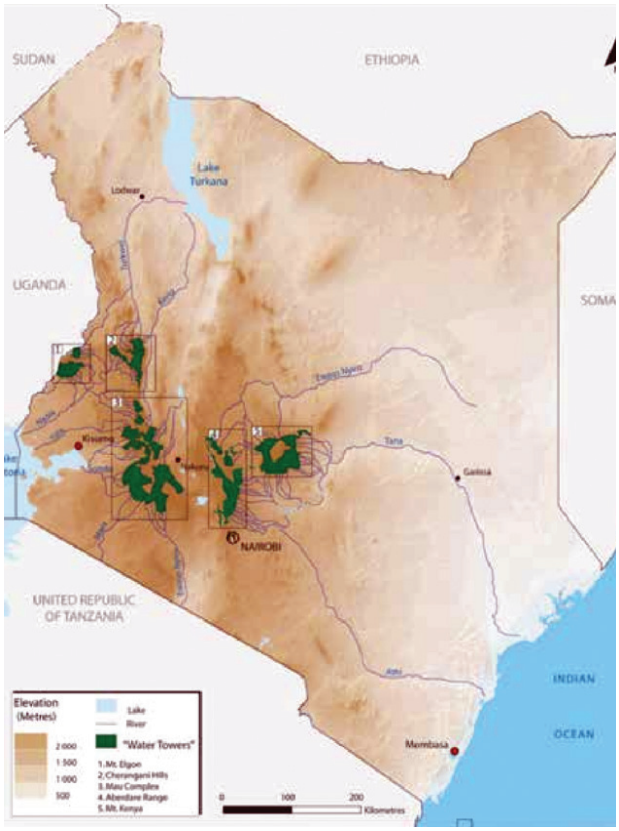


Figure 4.1 Kenya Water Towers

Figure 4.2 Map of Kenya Showing Conservation Areas and Main Rivers

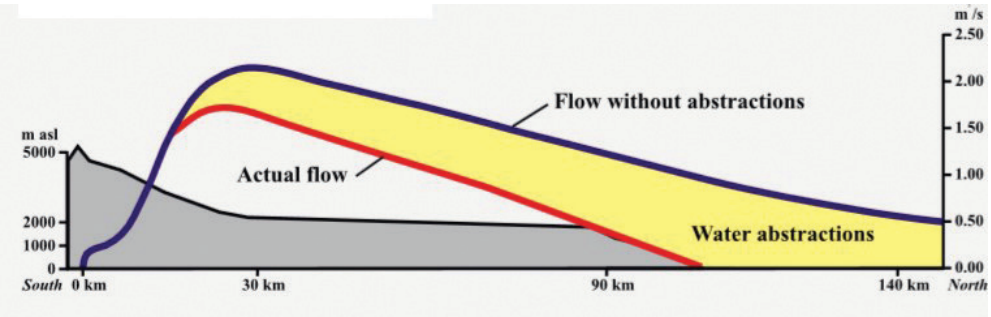


Figure 4.3 Ewaso Nyiro River Dry Season Flow

(Adopted from Wiesmann, 2000)

Elephants search for water in an almost dry Ewaso Nyiro Riverbed in Samburu National Reserve.
© Paul Muoria, February 2009

4.3 Methods

We assessed water services using various approaches including household surveys, Key Informant Interviews and field measurement of stream flow and discharge sediment load.

4.3.1 Household Surveys

A socio-economic survey using an interview schedule described in sections 1.8 and 3.4 was administered to 404 local residents. The focus of the interview was to identify the sources of water used by local residents, water quality and whether these has been changing over the years.

4.3.2 Stream Flow and Discharge and Sediment Load

The study was undertaken in Mt Kenya East in the Eastern part of Kenya (Figure 4.4). The rivers of interest were Tungu, Maara and Thuci, all arising from Mt. Kenya and joining together at the lower end of the county and later joining the main Tana River. These rivers go through the same landscape with similar land use practices and thus may be expected to carry similar sediment load. The rivers were subdivided depending on the predominant land use and sampled for sediment load and physicochemical parameters as well as river channel morphology. All the rivers were first sampled at the forest where human activities are minimal. The second sampling was at the end of tea zone while the other sampling sites were at the end of coffee zone and at the Arid and Semi-Arid Zone (ASAL zone).

River discharge was estimated as described by Rantz (1982). The average suspended sediment load was estimated by quantifying the amount of sediment in one litre of water sampled and multiplying it by discharge. A one litre sample of water that had been collected was filtered using Whatman filter papers (11 µm), dried and weighed. The weight of soil in this sample was extrapolated into the whole river discharge using the following equations.

Sediment load was calculated using the following equations:

$$\text{Sediment Load} = SSC \times Q \quad (1)$$

Where SSC: Suspended Sediment Concentration (mg.L-1) Q: discharge derived from the rating curve or any other means (m3.s-1) (USGS, 2006).

$$SSC = \frac{[(A-B)\times 100]}{C} \quad (2)$$

Where A: weight of filter + residue in mg; B: weight of filter paper in mg; C: water sample filtered in ml.

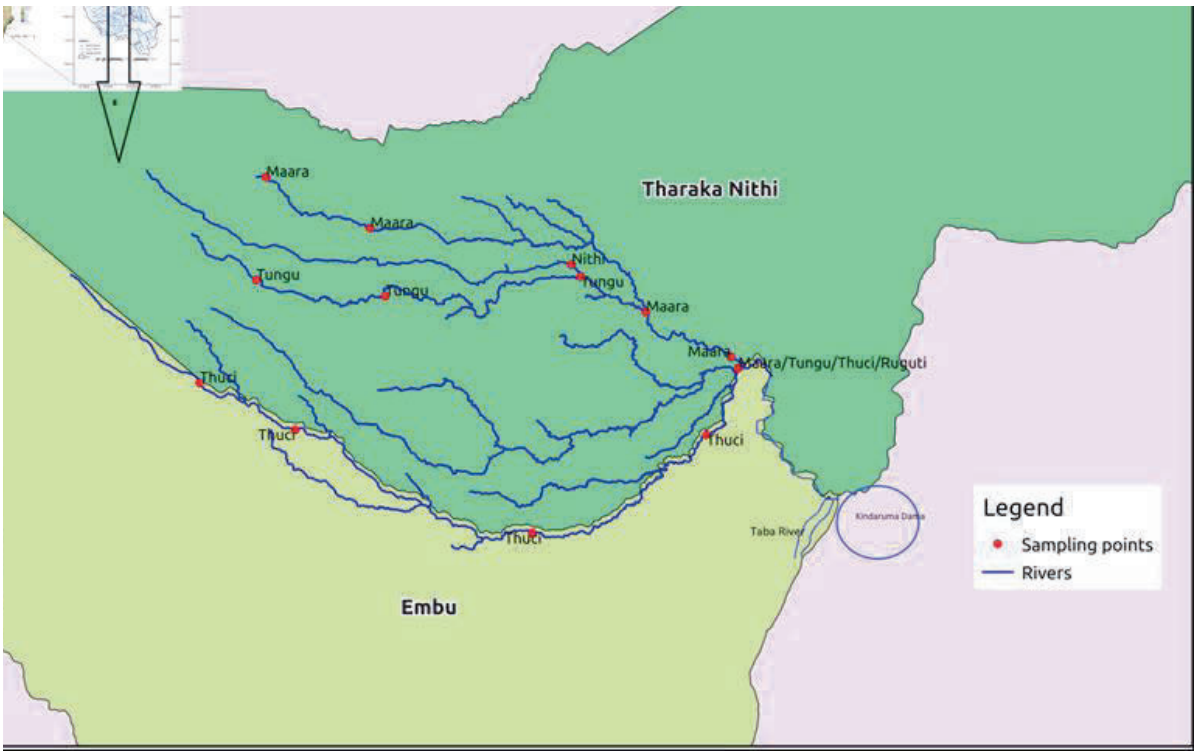


Figure 4.4 Water Sampling Sites

4.3.3. Key Informant Interviews

Key Informant interviews were used to obtain information from Water Resource Authority (WRA) officers, Water Service providers, and Water Resource Users associations.

4.3.4 Data Analysis from Meru Water and Sewerage Services

We analyzed data shared by Meru Water and Sewerage Services (MEWASS) on the water quality recorded in the company's treatment plant before any treatment is carried out. The aim was to assess the quality of water that is tapped from the Mt. Kenya forest as a proxy of assessing the general forest quality. MEWASS abstract water from Kathita River and Gatobora Spring, both originating from Mount Kenya. In both cases, water is abstracted using mass concrete weir and steel pipes conveyed to a water treatment plant. The data analyzed was from the years 2010 to 2019 with data gaps 2014 and 2015. The objective was to assess the relationship between change in forest cover, sediment load and the cost of treatment using Aluminum Sulphate commonly known as Alum.

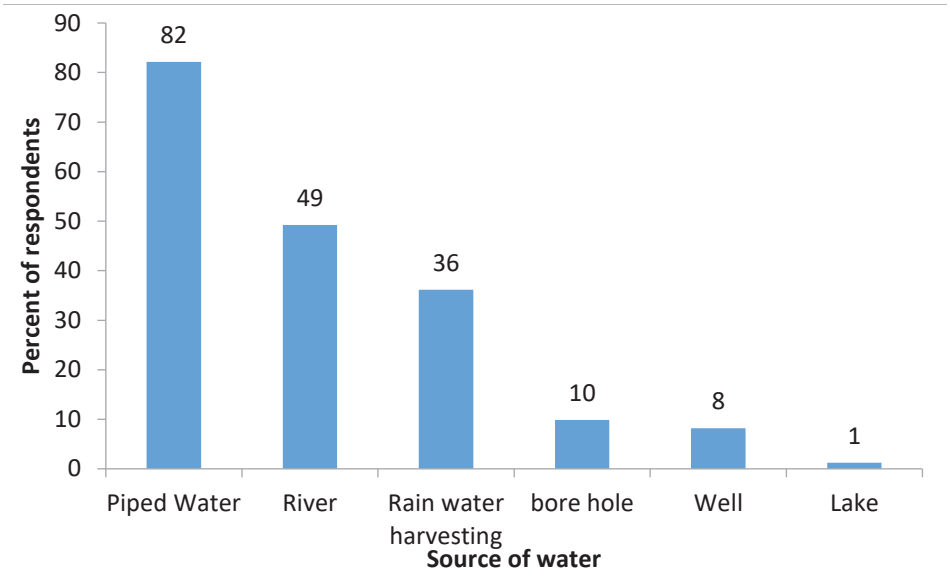


Figure 4.5 Sources of Water for Residents in Mount Kenya Area

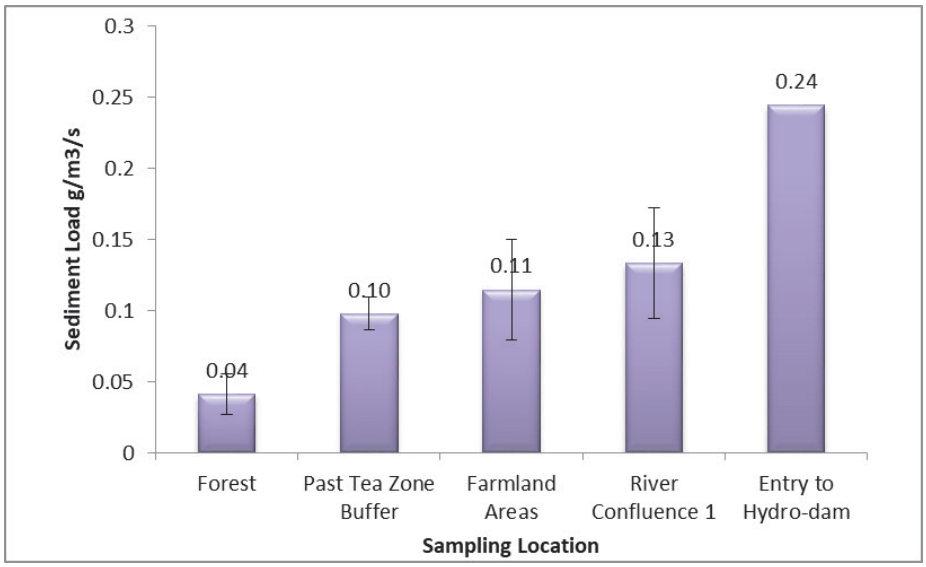


Figure 4.6 Changes in Sediment in Rivers Flowing through Different Ecological Zones in the Eastern Side of Mount Kenya

4.4 Results and Discussion

Results of Household Surveys

Eighty-two percent (82%) of the residents had access to piped water their homes (Figure 4.5). However, 49% of the residents obtained water from rivers, mainly for livestock watering. Only 36% of residents harvest rain water. A few residents also relied on boreholes and wells. During the wet season, most water is used for small scale irrigation and domestic use but during the wet season, rain-fed agriculture is practiced and most water is used domestically. 78% of residents do not know how much water they consume, mainly because the majority of piped water is not metered. However, 80% of households pay for water usage. Seventy-eight percent of the local community members indicated that they have faced water shortages, particularly during the dry season. This was more pronounced in 2000 and 2017.

Water Flows and Sediment Loads

Figure 4.6 illustrates changes in sedimentation load as water flows from forest through tea zone, farmlands and into Tana River and Kindaruma Dam. The mean sediment load increases from 0.04g/m^3/s in the forest to almost 0.1 g/m^3/s as the water leaves the tea zone. The load increases gradually as the water flows to the dam where the load increases to 0.24 g/m^3/s. At this point the flow river discharge is 13.83 m^3/s. This translates to 106.7 tonnes of soil sediments entering Kindaruma each year.

The increase in sediment load reported in this study as the rivers flow to the lower zone may be related to land use. In the forest, the dense vegetation cover provides protection against erosion and overland transport, and sediment yields are low. Low sediment yields also prevail in the upper cultivated zone roughly down to the limit of tea production (Bunyasi, Kigomo, & Onywere, 2013). This may be due in part to the protection given by the dense perennial tea crop. Perennial coffee offers a much greater bare soil surface to rain impact than tea, and cultivation is on steep slopes where only limited protection is provided by terracing. In addition, there is a significant area of horticulture in tributary valley bottoms, leaving soil exposed adjacent to the channels (Archer, 1996). The high sediment loads in the lower areas, ASAL area, could be due to low vegetation cover, overgrazing, and unsustainable agricultural practices. The findings are similar to earlier studies within the larger Tana River Basin. For example, data in UTaNRMP/IFAD (2014) indicate that the forest ecosystem generates the least amount of sediment per unit area (Table 4.1). Forest restoration can decrease this further (Ouyang, 2013). Whereas the forest zone generates about 10 tonnes of sediments per Km2, the other zones generate between 75 – 220 tonnes/ Km^2 (Table 4.1). Conservation measures also need to be instigated in all these ecological zones to reduce the amount of sediment that is deposited in the Dams.

Results of Key Informant Interviews

There are many Water Service providers within the Mount Kenya Region concentrating on large urban centers. Details on some of the Water User Providers are provided in Table 4.2. Data on total water abstracted either was lacking or could not be traced because some abstractions are not metered. Most forest adjacent communities organize their own water at the household level. It was noted that they have formed water projects which are registered at the county level by the Water Resource Authority. From field assessment, there are numerous registered water projects under Water Resource Users Associations. For example, records at Meru WRA office indicate that there are 11 and 17 registered Water Resource Users Associations (WRUAs) in Tharaka Nithi and Meru Counties, respectively.

Table 4.1 Contribution of Sediments in Dams within Tana River Basin by Various Ecological Regions ***(WRMA, 2010 - Physiographic baseline survey Report)***

Ecological zone	Size of catchment (km^2)	Sediment load (tonnes/yr)				Sediment load contribution (Tonnes/ km^2)
		Aberdares	Mt. Kenya	ASAL	Total	
Forest zone	1,925	10,431	8,303	515	19,248	10.0
Tea Zone	1,367	65,194	37,361	-	102,555	75.0
Coffee Zone	2,545	194,712	212,544	-	407,256	160.0
Lower zone	1,012	62,586	119,556	-	182,142	170.0
ASAL zone	2,574	-	-	566,280	566,280	220.0
Total	**9,423**	**332,923**	**377,764**	**566,795**	**1,277,481**	**135.6**

Table 4.2 Selected Water Providers in Mt. Kenya East and West

Name of Company/Project	Number of Intakes	Area of Coverage (km^2)	Installation of master meter
Nithi Water and Sewerage Company (NIWASCO)	5	2,500	Yes
Meru Water and Sewerage (MEWAS)	2	80	Yes
Embu Water and Sewerage (EWAS)	2	972	Yes
Chuka University	1	10	No
Ndagani KK water project	2	40	Yes
Kamiri Water Project	1	15	No
Nanyuki Water and Sewerage Company	1		
Ndigia Water Project	1	15	No
Mathira Water and Sewerage Company	1		Yes
Naro Moru Water and Sewerage Company	1		Yes

Results of Data Analysis from MEWASS

Between 2010 and 2016, the sediment load of the water arriving at the water treatment plant ranged from 423 to 453 mg/pt/l (Figure 4.7) but rose sharply to over 800 mg/pt/l from 2017 and 2018. The sediment load remained unchanged between 2018 and 2019.

There has been increased trend in use of Alum from 2010 and 2019 in water treatment (Figure 4.8). The mean amount of Alum used by MEWASS between 2010 and 2019 varied from 2,216Kg/month and 7,041 Kg/month - a threefold increase in overall treatment cost *(Alum costs vary significantly. For this analysis, an average cost of USD180/T has been used to calculate costs).* In 2010, annual Alum cost was estimated to be KSh.478,000 while in 2019 it is estimated to be KSh.1.5million. Between 2010 and 2019, MEWASS has spent KSh.6.8million in Alum purchases. There is a strong positive correlation between water sedimentation load and the use of Alum ($R2= 0.97$; $P = < 0.05$).

Results from forest cover change in Mt. Kenya shows decline in area of closed canopy forest area and increase in open canopy forest between 2000 and 2018 (Figure 4.9). There is observable correlation between reduction of closed canopy forest area and increase in water sedimentation load. However this cannot be statistically analyzed because of few data replicates.

The results provide a compelling evidence that increase sediment load of water, is correlated with changes in forest cover. This translates to increased operational costs incurred by water services providers through purchase of water treatment chemicals. In the case of MEWASS Company, between 2010 and 2019, a total cost exceeding KSh.6 million has been used in purchase of Alum. Dealing with sedimentation can be dealt with by reducing soil erosion through runoff. This can be done by planting trees and other native vegetation along the riparian zone that provides water filtration services. Similar evidence is available from a study carried out in Sasumua dam for Nairobi Water and Sewerage Company by World Agroforestry Center (Namirembe *et al.*, 2017). Forest landscape

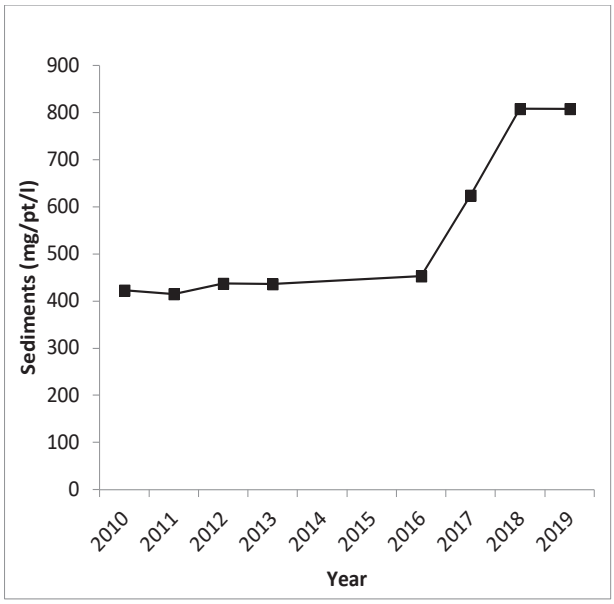


Figure 4.7 Trend of Annual Mean Sedimentation (mg/pt/L) Level Collected in the MEWASS Water Treatment Plant from 2010 to 2019

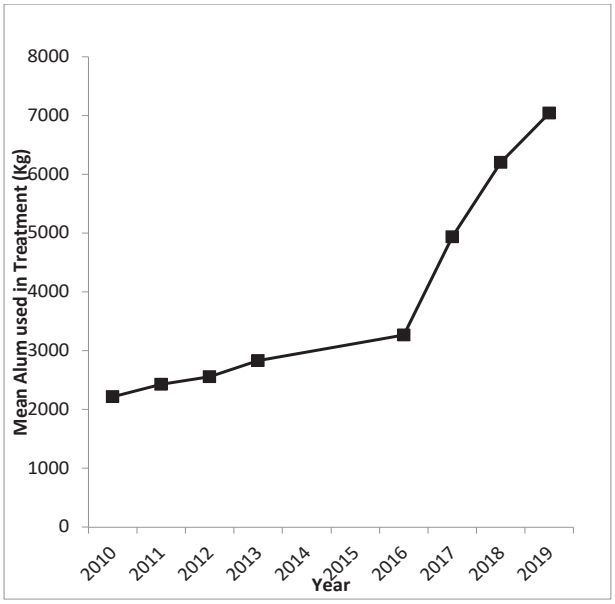


Figure 4.8 Mean Annual Amount in Kilograms of Alum (Aluminum Sulphate) Used in Treatment of Water by MEWASS from 2010 to 2019

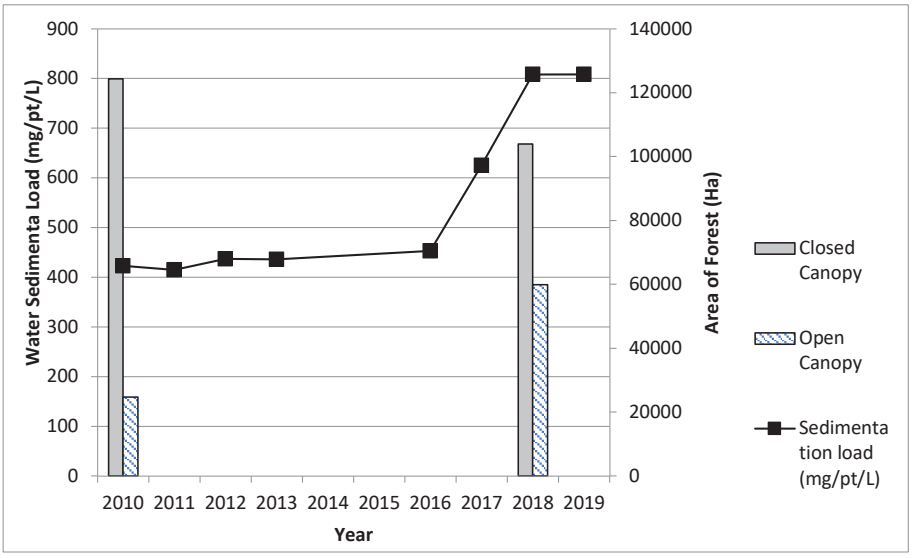


Figure 4.9 Mean Annual Sediment Load in Water Entering MEWASS Treatment Plant from 2010 to 2019 and Changes in Mt. Kenya Forest Cover Change

restoration initiative should be carried out in the forest with an aim to reducing soil erosion by water services providers. This will overall reduce the company's operational costs. In the case of MEWASS, an average of KSh.1.2milion incurred annually in purchase of Alum can be reinvested in forest restoration actions that will lead to will see vital forest ecosystem services restored and maintained. A site targeted restoration strategy can be put in place to achieve desired results.

Comparison of Water Service Provision in 2018 and in Future Scenarios

In the coming years, the demand for domestic, industrial and irrigation water is expected to rise due to the increase in the human population. With minimal regulation of water use from the forest, whereby 78% of residents do not know how much water they consume; mainly piped water is not metered. Furthermore, many community water projects have been licensed by WRA to abstract water from independent water intakes which reduce water quantity downstream. The lack of proper water planning, regulations, and enforcement bring in risks to downstream programs like irrigation projects planned in both Tana and Ewaso Nyiro River Basins. In addition, treatment of water as a commodity of

sale by water suppliers without consideration of water production and recharge from the forests jeopardizes sustaining required water quantity and quality to meet the demands.

The ability of the forest to contribute to water recharge to rivers diminishes with the decrease in tree cover. For example, Zwartendijk *et al.,* (2017) reported that natural forest contributes the highest soil water recharge capability, followed by areas under restoration. In addition, degraded areas record high water run-off, minimizing the ability to recharge groundwater. In a study carried out by Coca Cola (2014), depending on forest type, rainfall patterns and soil type, 1ha of indigenous forest has the ability to recharge up to 1million litres annually of water into the rivers. However, this recharge capability will be reduced through environmental degradation in the forest and the surrounding farmland. This will lead to reduced water quality and quantity with negative consequences for people, domestic animals, irrigated agriculture and industrial production.

KENGEN has planned to expand electricity generation within Tana River Basin by 500MW at High Grand Falls Dam and 40-50MW at Karura. However, if the current trend in habitat degradation continues, electricity production will be curtailed by the silting of dams (Walling, 2008; Bunyasi, 2012). HEP production is also vulnerable to climate change impacts including weather variability (Bunyasi 2012, Oludhe, 2011).

Many recent studies have shown that the rate of sedimentation at Masinga Dam is alarming. Whereas the rate was estimated at 0.6 - 0.9 million tonnes/year by Brown *et al.,* (1996), more recent studies have reported higher figures. For example, Kitheka *et al*., (2005), reported a rate of 6.8 million tonnes/ year and similar figures have been reported by Hunink et al 2011 and 2013; Omengo et al 2016 and more recently by Njogu (2019). Bunyasi (2012) reported that Masinga dam annual water levels are declining at a rate of 0.58m annually. In the report, it is stated that by the year 2029, Masinga dam would attain its minimum water level height which would disrupt power generation capacity. This means that although new dams will produce more electricity, the benefits will be canceled by losses incurred due to silting. The only option left will be to restore the ecosystem starting with the forest but also the farmlands that surround Mount Kenya Forest.

5. THE RECREATION VALUE OF MOUNT KENYA FOREST ECOSYSTEM

5.1 Summary

Snow-capped peaks, rich biodiversity, cultural significance to the local community, and presence of numerous scenic sites and landscape make Mount Kenya ecosystem one of the key tourist attractions in Kenya. However, the recreation potential of this site is threatened by environmental degradation, biodiversity loss, climate change and inadequate resources for restoration and protection of the ecosystem. Data were collected using questionnaires supplied to 104 local and international visitors during the months of November and December 2018, and January 2019. We estimated that visitors to Mount Kenya ecosystem spent US$15.6 million annually at the site and in the rest of the country. Continued degradation of the ecosystem will decrease this value to US$9.6 million. The travel cost method only captures direct payments by visitors to a site but fails to include many indirect contributions to the economy and other associated contributions including job creation and tax payments.

5.2 Introduction

Mount Kenya Forest Ecosystem has a very high tourism potential whose foundation is its scenic appeal, high biodiversity, and cultural value. The ecosystem's scenic appeal is attributable to wilderness quality, snow-capped peaks, lakes, tarns and glacial features. The ecosystem has a high biodiversity value. Mammals of conservation concern include the Mountain Bongo (*Tragelaphus eurycerus isaaci*), elephant (*Loxodonta africana*), lion (*Panthera leo*), and leopard (*Panthera pardus*). Bongo is listed as Critically Endangered and the others mammals as Vulnerable by the IUCN red list (https://www.iucnredlist.org). The ecosystem is home to several primate species: Black and white Colobus (*Colobus guereza*), Sykes' monkey (*Cercopithecus mitis*), olive baboon (*Papio anubis*), the lesser bushbaby (*Galago senegalensis*) and greater bushbaby (*Galago crassicaudatus*). Mount Kenya ecosystem is home to diverse bird species. The ecosystem's high cultural value and numerous historical sites attract many domestic and international visitors. The connection with Lewa Conservancy and Ngare Ndare Forest through a corridor enhances the area's biodiversity and touristic value. In addition, the site has well-established tourism infrastructure, including numerous public campsites, two operational tourist class lodges, tented camps and fishing camps (KWS, 2010; http://www.kenyaforestservice.org). Other facilities include established mountain climbing routes. The neighbouring towns including Nanyuki, Nyeri, Meru, and Embu, have additional tourist class hotels and other tourism facilities.

Despite its high tourism potential, the Mount Kenya ecosystem is threatened by various anthropogenic activities including poaching of wild animals, human-induced forest fires, pollution, habitat degradation, illegal encroachment, and over-abstraction of water primarily for irrigation in adjacent areas. Other issues of concern include climate change that has led to a decline in the glaciers of Mount Kenya and the reduction in the touristic appeal of the mountain's snow-capped peaks. Climate change might also be the reason for the rapid change in vegetation that has been documented in this study (see Figure 1.2). Quantification of the ecosystem's recreation value can provide stakeholders with evidence-based advocacy and awareness creation tools that can facilitate the implementation of strategies to mitigate habitat degradation and promote habitat restoration.

5.3 Methods

We used the travel cost method (Limaei et al., 2014) to quantify the recreation value of Mount Kenya Ecosystem. This was accomplished by administering a questionnaire (Appendix 1) adopted from Peh *et al.,* (2013, 2017) to 104 respondents comprising of local and international visitors during the months of November and December 2018 and January 2019. The resulting data was used to estimate the mean amount of money spent by local and international visitors while visiting the site. The mean annual number of visitors to Mount Kenya National Park from 2012 to 2017 was obtained from KNBS (2018). The annual revenue from entry fee charged by KFS in the financial years 2016/2017 and 2017/2018 was obtained from unpublished records held at Embu, Nyeri and Meru offices. It was assumed that the composition of visitors who filled out questionnaires is representative of the visitors to forest reserve areas. This relationship was used to proportionately assign local and foreign visitors and estimate the number of visitors, based on the entry fees of KSh 200 for locals and KSh 600 for foreigners as per KFS regulations (KFS, 2016). An exchange rate of KSh.100.345 for US$1 was used for monetary conversions. https://www.poundsterlinglive.com/best-exchange-rates/best-us-dollar-to-kenyan-shilling-history

5.4 Results

5.4.1 Characteristics of Visitors to Mount Kenya Ecosystem

The 104 visitors (30 foreign and 74 local visitors) completed the questionnaire (Table 5.1). The foreign visitors were from Norway (6), Italy (5), France (4), Israel (3), Canada (2), Germany (2), Poland (2), Slovakia (2), Switzerland and Tanzania (1). One visitor did not specify the country of origin. The international sample comprised of 11 female and 17 male respondents. Two (2) visitors did not indicate their gender. The representation of females was higher among local visitors than among foreign visitors. All international visitors

Table 5.1 Nationality and Gender of Respondents

Nationality	Female		Male		No Response		Total	
	N°	Percent (%)	N°	Percent (%)	N°	Percent (%)	N°	Percent (%)
International	11	36.7	17	56.7	2	6.7	30	100.0
National	32	43.2	39	52.7	3	4.1	74	100.0
Total	43	41.3	56	53.8	5	4.8	104	100.0

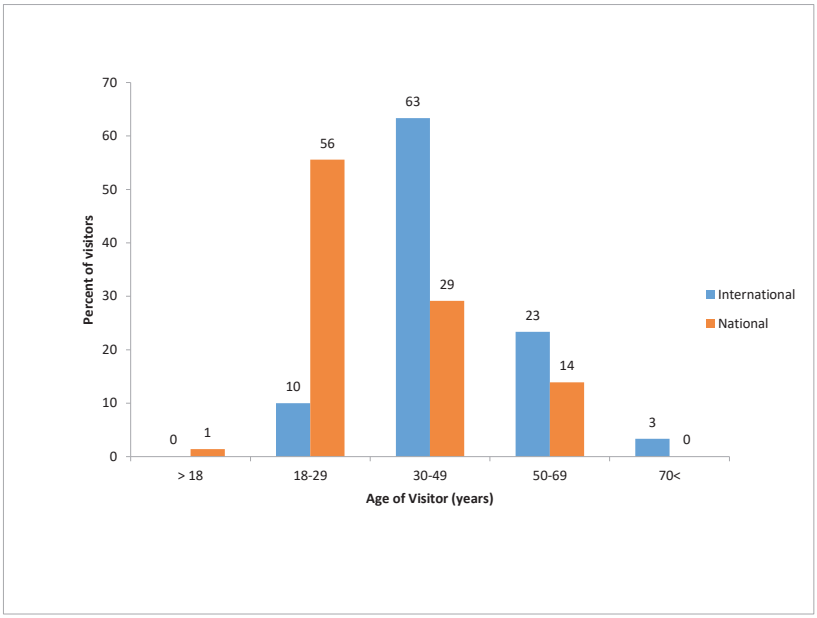


Figure 5.1 Age of Visitors to Mount Kenya Ecosystem

had at least tertiary level of education. However, among the locals, only 69% of the respondents had tertiary level education. Majority of the local visitors were in the 18-29 age bracket whereas most foreign visitors were in the 30-49 age bracket (Figure 5.1).

5.4.2 Purpose of Visit to Mount Kenya

Kenyans mainly visited Mount Kenya either to spend time with family and friends (76% of the respondents) or to view the mountain, nature and its wildlife (62%) (Table 5.2). Viewing the mountain, nature, and biodiversity was the most important attraction for foreign tourists. However, visiting the ecosystem as a place to spend time with family and friends was also mentioned by many of the foreign tourists. Other reasons given by both local and foreign visitors were mountain climbing, exercise and sports, and due to the ecosystem's cultural and spiritual importance.

5.4.3 Travel Cost for Local and International Visitors

Foreign visitors were traveling in groups of (4.28 ± 0.52) implying those interviewed represented 129 visitors. They were to spend a mean of 4.3 (± 0.27) days in Mount Kenya ecosystem and spend an average of about US$2,051.6 (±285.35) and another US$2050.0 (±163.5) in other areas of the country. Our sample size had 74 local/national visitors who travelled in groups of 13.42 (± 1.90) individuals implying that our sample represented some 993 visitors. Each visitor spent an average of 3.14 (± 0.32) days in the ecosystem and spent Ksh 22,040.3 (± 5,774) at the site and for their travels to and from the site.

According to KNBS (2018), Mount Kenya National Park received a mean of 21,683 visitors (±1455.4 SE) from 2012 – 2017 (Table 5.3). The number of visitors was highest (24,500) in 2012 and consistently declined to 18,500 in 2015. The number of visitors

Table 5.2 Activities that Attracted Visitors to Mount Kenya Ecosystem

Activity	Local Residents		International	
	No	%	No	%
Spend time with family or friends	56	75.7	18	60.0
Viewing/appreciating Mount Kenya, nature or wildlife	46	62.2	28	93.3
Mountain climbing	23	31.1	9	30.0
Exercise or sports	22	29.7	8	26.7
Other (please specify) (e.g. picnic, education)	20	27.0	5	16.7
Cultural, spiritual (e.g. visiting religious or spiritual sites, etc.)	20	27.0	5	16.7
No response	4	5.4	2	6.7
Work	2	2.7	0	0.0

Table 5.3 Number of Visitors to Mount Kenya National Park (2012 - 2017)

Year	Total Number of Visitors (KNBS 2008)	Estimated no of Local Visitors	Estimated no of Foreign Visitors
2012	27,500	24,338	3,162
2013	24,600	21,772	2,828
2014	20,200	17,878	2,322
2015	18,500	16,373	2,127
2016	19,100	16,904	2,196
2017	20,200	17,878	2,322
Mean	**21,683**	**19,190**	**2,493**
SE	**1,593**		

increased slightly up to 20,200 in 2017. Assuming that the composition of visitors remains constant through the year and the area receives an estimated 19,190 local and about 2,493 foreign visitors annually, this translates to annual spending of US$ 4,215,007 and US$ 10,225,278 for national and international visitors, respectively.

According to KFS records from Embu, Nyeri, and Meru Ecosystem conservator offices, Kenya Forest Service collected KSh.530,923 from visitors to Mount Kenya Forest Reserve in the financial year 2016/2017 and KSh.322,075 in the 2017/2018 financial year (Appendix 2). Assuming that the proportion of local and foreign visitors to Mount Kenya Forest Reserve is equal to that recorded in the National Park (This Study), then the forest reserve received an estimated 1734 visitors comprising of 199 foreign and 1535 local visitors. This translates into a local and national spend of US$ 1,154,653/year.

5.4.4 Changes in the Recreation Value in Future Scenarios

Assuming that the probability for those who were not sure that they would come back was 0.5, those who said they will definitely not come if there is degradation is 0, and that for those who will come back is 1, the mean the probability will be 0.36 (±0.079 SE) for international visitors and 0.447 (±0.057 SE) for national visitors (Table 5.4). This translates into a perceived decrease in total spending from US$15,595,568 to US$9,585,089. Although restoration is expected to lead to increased visitation to the ecosystem, we could not estimate the increase in monetary terms.

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2017	20,200	17,878	2,322
Mean	21,683	19,190	2,493
SE	1,593		

*The response is based on the question whether the visitor would come back to Mount Kenya if it is not restored.

Table 5.4 Estimated Proportional Decrease in Spending if Forest is not Restored

Response*	Probability of Repeat Visit	Frequency	
		Foreign	Local
Maybe/not sure	0.5	11	2
No	0	12	35
Yes	1	5	29
Total		28	66
Mean probability		0.36 (±0.079 SE)	0.447 (±0.057SE)

Table 5.5 Changes in Spending in Future Scenarios

	Local Visitors	Foreign Visitors
Annual spending by visitors to National Park (US $)	4,215,007	10,225,278
Annual spending by visitors to Forest Reserve (US $)	337,583	817,700
Total spending (US$)	4,552,590	11,042,978
Probability that they will return	0.447	0.36
Reduction in total spending (US $)	2,035,008	3,975,472
Net Spending (US $)	2,517,582	7,067,506
Total if Forest restoration does not take place (US $)		9,585,089
Total if restored (US $)		>15,595,568

5.5 Discussion

We estimated that local and foreign visitors to Mount Kenya spend about US$ 15.6 million annually into the economy. However, we only used the direct contribution to the economy, as an index of the recreation value of Mount Kenya. According to the World Travel & Tourism Council (2018), there many other ways in which tourism contributes to local and national economies. This includes indirect expenses on outside goods and services such as marketing and public relations, cleaning and maintenance, energy providers, catering and food production, design and print, among others. The direct and indirect spending creates employment opportunities and contributes to the national economy through taxes on employee and tourism-related companies and service providers. Revenue from tourism supports the growth of other economic sectors including infrastructure, agriculture, technology, real estate, communications, education, banks, and healthcare.

We estimated that visitor spending would decrease to about US $10 million if the forest is not restored. This implies that according to the respondents, the recreation value of Mount Kenya ecosystem will decrease by about 39 % if forest restoration does not take place. Restoration will increase the recreation value of Mount Kenya ecosystem, but we could not estimate the percentage change from the visitor response.

We used the 2012-2017 mean numbers of visitors to estimate Mount Kenya tourist spending in 2018. However, the tourism sector registered an

improved performance in 2018 compared to 2017 (KNBS 2019) nationally. The number of international visitor arrivals in Kenya increased by 14.0% from 1,778,400in 2017 to 2,027,700 in 2018 while tourism earning increased by 31.3%. It is reasonable to assume that similar trends could have occurred in Mount Kenya ecosystem during the same period. This does not affect our conclusions because our interest is on the relative difference in the 2017 recreation value of Mount Kenya compared to that of future scenario – The Restored and the Business as Usual.

Our index of the value of recreation was computed from data only collected during the months of November 2018, December 2018 and January 2019. December is a holiday season and a tourist peak in Kenya. An examination of bed occupancy figures for Kenya in KNBS (2009) for the years 2016 and 2017 shows that mean bed occupancy rate for 2016 and 2017 was 30.3% and 31.3 %, respectively (Figure 5.2). Although December rates were higher than annual mean occupancy rates, this is by far compensated by the low occupancy rates for January in both years. The rates for November were very close to the annual mean. Therefore, if bed occupancy rates are used as an index of visitor spending, then visor spending during the study period was similar to the annual spending. However, it will be necessary to carry out an annual survey to confirm this.

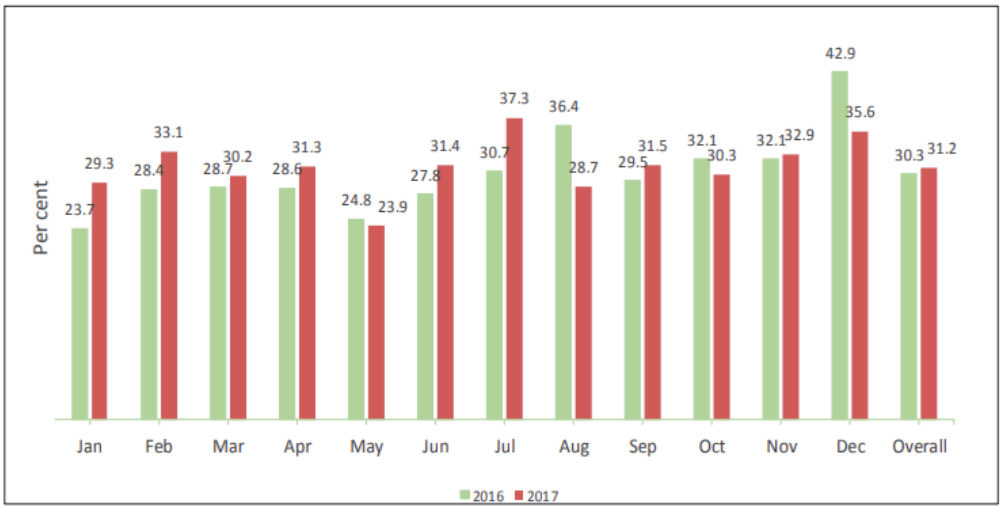

Figure 5.2 Monthly Bed Occupancy Rates, 2016-2017 ***(Source KNBS 2018)***

6. MOUNT KENYA ECOSYSTEM SERVICE ASSESSMENT: THE VALUE OF HARVESTED GOODS

6.1 Summary

Wild goods harvested from Mount Kenya Ecosystem in 2018 were valued at about KSh.12.4 billion (US$124 million). Harvested wild goods that had the highest value included livestock fodder (and grazing) and firewood collection. Other wild goods harvested included honey, charcoal, fish, wild fruits, herbal medicine, game meat and skins. Harvesting of most of these goods is expected to increase in a BAU scenario due increased demand for resources from the forest without checks and balances. However, the increase in amount harvested will not be sustainable due to habitat degradation and possible collapse of ecological processes leading to reduction of the amount of harvested goods by 2038. Restoration of Mount Kenya ecosystem will lead to a reduction in the amount of wild goods harvested following better forest protection and implementation of strategies to reduce the need to rely on forest resources in the human settlement areas (KFS, 2019).

Goods cultivated in Mount Kenya Forest in 2018 were valued at about KSh.3.0 billion (about US$ 30 million). These comprised of food crops produced under the PELIS program (1.54 billion), timber (0.88 billion), and tea (0.55 billion). The value of crops cultivated will not change in the BAU scenario because forest plantation management policies are not expected to change and therefore land available for PELIS program will remain constant. In the Restoration scenario, forest plantations in ecologically sensitive areas will be converted into indigenous forest. This will lead to a reduction in the area available for crop production under PELIS. Forest plantation tree cover has been steadily increasing since 2000 due to vigorous tree planting campaigns. This is expected to to continue in the BAU scenario but some of the areas reserved for forest restoration will not have been restored by 2038 based on the current trend. In the Restoration Scenario, all areas reserved for forest restoration will have been restored. This will lead to increased timber production. In both future scenarios, the area under tea production is expected to be constant hence no change in the value of tea production.

6.2 Introduction

Forests provide many harvestable products, including timber (and other building materials including poles and thatching grass), fuelwood (including charcoal), food, livestock fodder, herbal medicine, resins, hides and skin from wild animals, among others. Food items supplied by forests include bush meat, edible plants, honey, mushrooms, berries and other fruits. Emerton (1997) reported that communities living adjacent to Mount Kenya forest grazed livestock in the forest and also extracted herbal medicine, fuelwood and charcoal, house construction material, timber, honey, wild fruits and game meat from the ecosystem. In addition, commercial timber production takes place within the forest plantations. Through PELIS, local communities produce crops in partnership with KFS, while taking care of tree seedlings in forest plantations. In some sections of the forest, a 100m tea plantation was established in the forest land adjacent to human settlements by the government in the 1980s. This study was designed to quantify the amount of goods harvested from Mount Kenya ecosystem in 2018; and in the Business as Usual and in the Restoration scenario as described in Section 1.9.

6.3 Methods

Data for estimating the amount and value of wild-harvested goods (firewood, harvested fodder, livestock grazing, charcoal, herbal medicine, honey, game meat, wild animal skins, fish, wild fruits) were obtained by interviewing 404 residents who reside in areas adjacent to Mount Kenya forest. Information sought from the respondents included whether the respondents harvest the good, the quantity harvested, units of measurement, whether the product was harvested for domestic consumption or for sale, the price of the commodity (per unit) and production cost (the cost of labor and inputs). Although the method was largely developed following Peh *et al.,* (2013, 2017) a few modifications were necessary for the estimation of the value of some of the harvested goods.

6.3.1 Value of Crops Produced under PELIS Programme

Data obtained from the interviews were also used to estimate the number residents who cultivate crops in the forest plantations area under the PELIS program. Working in Gathiuru and Hombe forest plantations, Ngatia *et al.,* (2017)) reported that the mean vale of crops produced at Gathiuru and Hombe Forest Plantations in the years 2012, 2013 and 2014 was KSh.164,680, which translates to KSh.278,138/ha in 2018 (using Equation 1). The area under cultivation in different stations was obtained from CFA records.

$$FV=PV*(1+r)^t \qquad \text{Equation 1}$$

Where FV is the value of crops produced under PELIS programme in 2018; PV is the value of tea in 2014; *r* is the interest rate (assumed to be 0.14) and t is time in years.

Table 6.1 The Value of Tea Production in Mount Kenya Forest

Parameter	Quantity	Reference
Area under tea production (Ha)	787	KFS 2010
Tea production per hectare (Kg/ha)	2,834-3,412 (mean 3.123)	KIPPRA 2017
Tea production cost (KSh /ha) – 2018 figures	183,034	Recalculated from KIPPRA, 2017
Quantity produced (Kg)	2,460,612	
Production cost (KSh)	97,339,227	
Gross value of sales KSh	646,899,737	
Net value	549,560,510	

6.3.2 Value of Tea Produced in Mount Kenya Forest

Nyayo Tea Zone Agency produces tea in 787 hectares within Mount Kenya Forest (KFS, 2010; Table 6 1). It is estimated that tea production in large scale farms is 2834-3412 kg/hectare or a mean of 3123 Kg/ha (KIPPRA, 2017). In 2015, it was estimated that tea production cost was KSh.49,996/Ac/yr (KIPPRA 2017) or KSh.123,996/Ha/yr. We used the future money value formulae (equation 1), to translate this to 2018 figures. The mean tea price in 2018 at Mombasa Tea Auction was US$2.58 per Kg (Kenya Food Authority, 2019) or KSh.262.90/Kg. These figures were used to estimate the net value of tea produced in Mount Kenya Forest by Nyayo Tea Zone agency.

6.3.3 Value of Livestock Grazing

The number of various livestock species owned by each household and the duration that the animals relied on fodder and/or grazing from Mount Kenya Ecosystem was obtained by interviewing 404 residents using interview schedules adopted from Peh et al. (2013, 2017). The mean number of each livestock species was then calculated and extrapolated to the households in the sub-locations surrounding Mount Kenya Forest Reserve. The figures for the number of households were estimated as described in section 6.3.6. A daily dry matter requirement of 2.5 % per Kg of animal body weight (Government of South Australia, undated) was used to estimate dry matter daily food requirements for cattle, sheep, and goats. It was estimated that an average cow, sheep, and goat weigh 206 kg, 30 kg and 18 kg (Wilson, 1991), respectively. Further, we assumed that if the livestock do not obtain fodder from Mount Kenya, the owners would have to use commercially available fodder that cost KSh.220 per 20kg bale (de Haan, 2014). Residents are supposed to pay KFS a monthly fee of KSh.100 per cow and 40 per sheep to access the forest. This figure was used to estimate the conservation fee due to KFS.

6.3.4 Value of Timber in Plantation Forests

Data on the acreage of different species in the forest plantations (Table 6.2) was obtained from KFS and Ecos consultants (2014). According to KFS (undated), it costs up to KSh.132,076 and KSh.126,500 to manage an acre of cypress and pine respectively for commercial timber production. The gross revenue for timber produced is KSh.1,266,084 and KSh.1,172,267 per acre for cypress and pine respectively. For each of these species, the trees replacement period is 28 years. This translates to an annual profit of KSh.40,500 and KSh.37,349/Ac/yr or 100,076 and 92,300/Ha for cypress and pine respectively. The mean of these two figures (KSh.96,183/Ha) was assumed to be the annual value for other plantation species. These figures were used to estimate the annual value of timber in each type of forest plantation in the current and future scenarios (Table 6.2).

6.3.5 Extrapolating Amount of Goods Harvested to the Whole Ecosystem

We assumed that people who harvest goods from Mount Kenya Forest are within 5km from the forest boundary. Using 2009 national census population density data available from KNBS (2010), and GIS techniques, we estimated the forest dependent population at 665,805 individuals. Kenyan human population growth has been about 3% per year. Assuming a population growth rate for the forest area and using the exponential population growth model (Equation 2), the forest dependent population was estimated at 882,180 individuals at 2018. The mean household size in the area was 5.56 (± 0.18SE) implying that the area had 156,955 households. This was the figure used to extrapolate the value of harvested goods to the local community.

$$P=P_o+e^{rt} \qquad \text{Equation 2}$$

where P = population in 2018, P_o the population in 1989, e = 2.71828, r = population growth rate and time is time in years.

Table 6.2 Value of Commercial Timber Production from Forest Plantation

Tree Species	Area (ha)*	Profit per Acre	Profit per Ha	Net annual Value of Timber	Additional Value if all the Area is Planted	Value in Future State
Cypress	7,774	40,500	100,076	777,992,425	180,716,933	958,709,359
Eucalyptus	1,849	38,925	96,183	177,841,575	41,310,150	219,151,726
Meru Oak	1,331	38,925	96,183	128,019,003	29,737,053	157,756,056
Pine	874	37,349	92,289	80,660,532	18,736,331	99,396,863
Cedar	591	38,925	96,183	56,843,900	13,204,056	70,047,956
Others	1,779	38,925	96,183	171,108,795	39,746,218	210,855,014
Unplanted	3,298					-
Total	**17,496**			**1,392,466,231**	**323,450,742**	**1,715,916,973**

*Based on KFS and Ecos Consultants 2014

6.4 Results

6.4.1 The Value of Wild Goods Harvested from Mount Kenya Forest

Wild harvested goods from Mount Kenya were estimated at about 10.2 billion Kenya shillings annually in 2018 (Table 6.3). The most valuable goods are firewood and livestock fodder (Tables 6.3 and 6.4). Firewood is harvested by members of 61 % of the households. Most (81%) of the firewood collected is used at the household level but the rest is sold. Other items harvested include fodder for their livestock, honey, and charcoal that were harvested by 28 %, 20 % and 5 % of the residents, respectively. Other goods harvested by a few people included timber, wild fruits, herbal medicines, game meat and wild animal skins (Table 6.4; Figure 6.1). For timber production, we assumed that the only source of timber is a forest plantation. This is likely to be an under-estimate because illegal timber harvesting in the natural forest still occurs. In addition, it only considers timber harvesting and ignores other by-products that might be sold including firewood. There is also a need to factor in the annual fee (mean = KSh.207.7 million) paid as a fee to KFS for timber (see Appendix 2 for details). Measures put in place in a restoration scenario will ensure that illegal activities like poaching and logging are reduced or eliminated. As such the value of game meat, skins, charcoal will decrease. We expect that reliance on fuelwood in areas around Mount Kenya Forest will decrease due to the promotion of the use of alternative sources of energy including biogas and solar, the establishment of woodlots on farms and agroforestry. In the BAU scenario, the value of harvested wild goods would be expected to increase following increased demand by the expanding human population reaching 22.56 billion KSh. Continued unregulated harvesting of goods including charcoal, firewood, and livestock fodder among others would lead to extensive habitat degradation. It is expected that the value of some of the products would be too expensive to harvest because of their scarcity and the ability of the ecosystem to replenish them would also reduce. This implies that the value harvested wild goods might even be lower than 12.4 billion Kenya shillings by 2018 in the BAU scenario.

Table 6.3 Estimated Quantity and Value of Goods Harvested from Mount Kenya Ecosystem

Product	Number of Respondents who Harvest		Percent (%) for own use	Quantity Harvested	Units	Mean price in Kenya Shillings	Value for Respondents in Kenya Shillings			Value for Mount Kenya Ecosystem in Kenya shillings
	No	Percent (%)		Quantity			Gross Value	Production Cost	Net Value	
Firewood	248	61.4	81.2	31,491	bundles	260	8,197,141	741,558	7,455,583	2,897,165,321
Livestock fodder (harvested)	79	19.6	92	28,212	bundles	214	6,030,418	209,771	5,820,647	2,266,601,753
Honey	114	28.2	21.4	13,693	Litres	530	7,251,666	1,492,786	5,758,880	2,235,925,168
Livestock grazing										2,075,088,309
Charcoal	21	5.2	61.7	364	Sacks	1850	607,670	76,570	531,100	206,412,184
Fish	3	0.7	32.5	1,035	Kg	547.5	566,662.50	1,000	565,662.50	207,161,550
Wild fruits	7	1.7		*	Kg or crates	600 per crate or 46.25 per kg	582,750	7,000	575,750	219,462,239
Herbal medicine	7	1.7	38.9		mixed units		465360	55800	409560	156,114,555
Game meat	4	1	100	93	Kg	275	25,666	1,200	24,466	9,600,149
Skins	1	0.2	100	50	Pieces	100	5,000	1,000	4,000	1,255,639
Total										**10,274,786,86**

Table 6.4 The Value of Livestock Grazing and Fodder Harvesting

Livestock		Cattle	Goats	Sheep
No who Keep	No	103	30	66
	%	25.5	7.4	16.3
Number Kept per Household	Mean	5.42	11.00	8.64
	SE	0.503	1.000	0.798
Total Number in 404 Households		558	330	570
Number for all Residents		271,214	160,392	277,091
Mean Weight Kg		206	18	30
Duration Livestock depend on Feed (months)	Mean	9.94	11.00	10.56
	SE	0.424	1.000	0.479
Dry Matter Requirement Kg		5.15	0.45	0.75
Feed Cost per Day per Animal		56.65	4.95	8.25
Annual Feed Cost		17,130	1,656	2,649
Annual Feed Cost for all Animals		4,645,808,452	265,639,644	733,955,581
Fee Payable to KFS if Grazing		2,350,003	1,537,782	2,549,312
Net		4,046,950,735	229,994,537	637,168,599
				4,506,616,989
Less Amount Value of Amount Harvested (from Table 6.3)				2,266,601,753
Value of Grazing				**2,075,088,309**

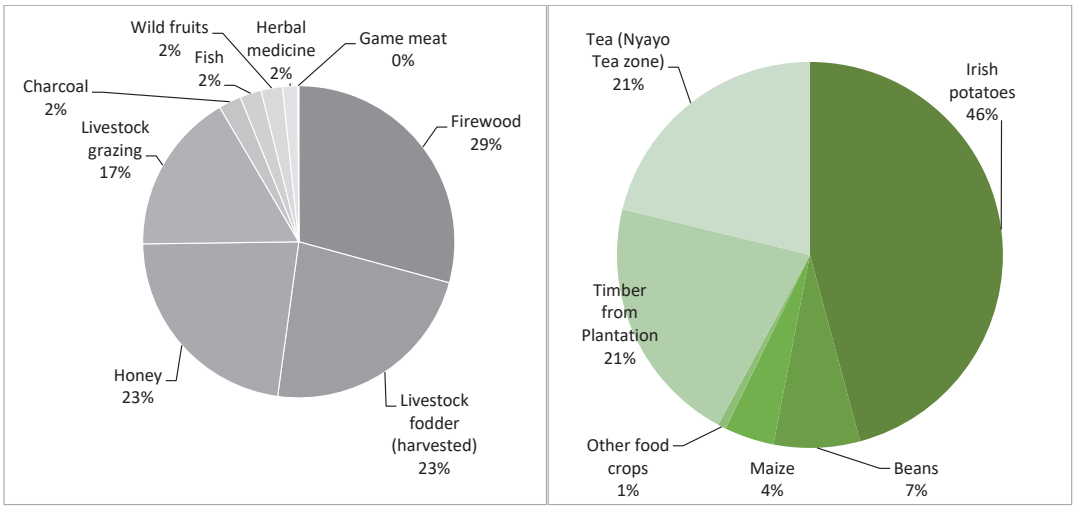

Figure 6.1 The Value of Various Wild (a) and Cultivated Goods Harvested from Mount Kenya Forest. ***Note that some of the harvested goods are not included***

Table 6.5 Current and Future Value of Wild Harvested Goods

Harvested Good	Value (Kenya Shillings)		
	2018	Future Scenario	
		BAU	Restored
Firewood	3,619,899,248	6,595,887,890	Decrease
Livestock Fodder (harvested)	2,839,025,562	5,173,042,961	Decrease
Honey	2,799,993,438	5,101,921,778	More than 5,101,921,778
Livestock grazing	2,075,088,309	3,781,058,231	Decrease
Charcoal	290,192,047	528,764,498	0
Fish	274,932,993	500,960,683	500,960,683
Wild Fruits	274,558,972	500,279,172	500,279,172
Herbal Medicine	195,307,638	355,873,795	195,307,638
Game Meat	11,965,627	21,802,799	0.0
Skins	1,570,872	2,862,316	0.0
Total	**12,382,536,724**	**22,562,454,123***	**>6,298,469,271**

* The value harvested wild goods might be lower than 12.4 billion Kenya shillings due to overexploitation, scarcity of goods and habitat degrdation

6.4.2 The Value of Goods Cultivated in Mount Kenya Forest

A total of 121 (30%) respondents were involved in the PELIS program. Irish potatoes were cultivated by about 26% of the respondents. Other crops cultivated included beans (16%), maize (10%), peas (3%), cabbages (3) and assorted vegetables (1.5%) (Table 6.6; Figure 6.1). Sweet potatoes, green peas, French beans, and carrots were cultivated by less than 1 % of the residents and are listed in Table 6.6. It is estimated that in 2018, crops cultivated in the forest plantation were worth about 1.5 billion Kenya Shillings. Tea cultivated by the Nyayo Tea Zone was estimated to be worth about KSh.1.4 billion in addition to creating employment to members of the local community. We estimated that if the forest plantation is managed commercially for timber production and that plantation species remain unchanged, then the annual value of timber that can be produced in the forest plantations is about 0.9 billion Kenya shillings.

6.4.3 Value of Cultivated Goods in Future Scenarios

The area of forest plantations has been increasing during the last 18 years driven by intensive tree planting campaigns led by KFS in collaboration with CFAs and other stakeholders. This trend is expected to continue even under the BAU scenario following the same rate of increase in area. This increase will result in the value of Timber buy 2038 rising from 0.9 to 1.2 billion Kenya shillings (Table 6.7). In the Restoration Scenario all forest planation areas will have been be replanted leading to an increase in the amount of harvestable timber (Table 6.7). Food production under the PELIS programme will be expected to remain constant in the BAU scenario. Forest plantations in ecologically sensitive areas will have been replaced by indigenous forests by 2038. This will lead to a slight decrease in area available for PELLIS programme and therefore a slight decrease in food production. However, tea will remain unchanged or increase very slightly due to improved micro-climate conditions created by restored forest (Table .6.7).

Table 6.6 Crops Cultivated in Mount Kenya Forest under the PELIS Programme

Crop	Number who Cultivate	
	Number	Percentage (%)
Irish potatoes	104	25.7
Beans	63	15.6
Maize	40	9.9
Green Peas	12	3.0
Cabbages	12	3.0
Vegetables/Kales	6	1.5
Sweet potatoes	1	0.2
French beans	1	0.2
Carrots	3	0.7

Table 6.7 The Value of Cultivated Goods in the Current and Future Scenario

Cultivated Good	Value (Kenya Shillings)		
	2018	Future Scenario	
		BAU	Restored
Total from PELIS Cultivated Crops	1,539,782,867	1,539,782,867	<1,539,782,867
Timber from Plantation	880,399,031	1,193,815,356	1,339,699,592
Tea (Nyayo Tea Zone)	549,560,510	549,560,510	549,560,510
Total Cultivated	2,969,744,426	3,283,158,733	<3,429,042,969

6.5 Discussion

Firewood and livestock fodder were the most valuable harvested goods obtained by members of the local community from Mount Kenya Forest. If the current trend continues, i.e. in a Business As Usual (BAU) scenario, consumption of these goods is expected to increase at a rate equal to or greater than the human population growth rate. Both fuel wood collection and livestock grazing are among the key drivers of forest degradation (Hosonuma *et al.*, 2012, Specht *et al.*, 2015). Impacts of firewood collection on biodiversity conservation are poorly understood. In addition, harvesting by individual residents might appear to be harmless but the cumulative impact might be a disaster. Another emerging problem which has not been documented is the commercialization of firewood collection. In Kenya forest reserves, firewood collection and livestock grazing are legally allowed upon payment of the prescribed fee. However, monitoring compliance is hampered by limited personnel. If restoration measures are carried out following the implementation of the restoration strategy under review (KFS, 2019), then we expect fuel-wood harvesting from the forest to decrease. This is because the strategy recommends measures such as the use of energy-saving stoves, alternative energy sources, on-farm tree planting and use of solar energy. In the case of livestock grazing, the strategy recommends measures that will lead to a reduction in livestock grazing in the forest.

It should be noted that the projected high value of harvested goods in the BAU is not realistic. This is because if the current challenges facing the ecosystem including forest fires, illegal logging, high levels of firewood extraction, unregulated livestock grazing, climate change and poaching will lead rapid decline in the capacity of the ecosystem to provide these services. Biodiversity loss associated with poaching, pollution and other habitat destruction processes might lead to loss of pollination and seed dispersal and other ecological processes. Therefore it is expected that these services will become increasingly difficult to access and with time their value will decrease.

It was difficult to estimate the value of wild goods that were only harvested by a small proportion of the population. Such goods included unlicensed timber, wild fruits, herbal medicine, game meat and skins. The difficulty was mainly due to the problem of sample size. However, the value of such goods might be very high. For example, Emerton (1997) estimated that the value of unlicensed timber production in Mount Kenya forest was twice the value of licensed timber production. Studies focusing on these products need to be conducted using another sampling like purposeful or snowball techniques.

Food production under the Plantation Establishment and Livelihood Improvement Scheme (PELIS) was the most important direct benefit that the local community gets from the forest. It was valued at about KSh.4 billion (US$40 million). The program was introduced after enactment of the Forest Act, 2005, replacing a similar program called the Shamba system under the old Forest Act, and has been embraced by most forest adjacent communities. In this program, local residents pay a small fee and are allocated plots in which they plant tree seedlings but cultivate food crops around the seedlings until the canopy closes. However, researchers and conservationists have been debating the contribution of this practice in forest conservation. Humphrey et al (2016) reported that this practice resulted in increased forest cover at Malava Forest in Western Kenya. In a review of the program, Kagombe (2014) reported that the program benefits both the local community members and Kenya Forest Service. Ngatia et al (2017) found that food production under this program in the Mount Kenya region is now largely commercial but not used for the production of subsistence crops. This commercialization needs to be carefully monitored to avoid abuse of PELIS program.

7. THE CLIMATE REGULATION VALUE OF MOUNT KENYA ECOSYSTEM

7.1 Summary

We assessed the carbon stocks in 2018 and two likely future Scenarios, a restored Mount Kenya ecosystem and a Business as Usual (BAU) where forest degradation continues. Total carbon stocks in the Mount Kenya ecosystem in 2018 were estimated at about 73 million tonnes. If the current trends continue there will be a 4% reduction in the carbon stocks in the ecosystem, but restoring forests within the ecosystem will lead to an 8% increase in carbon stocks.

7.2 Introduction

Forests play a significant role in the global carbon cycle and in global and local climate regulation. They store carbon as living plant biomass; dead material including litter, woody debris, and other organic matter; and as soil carbon derived from dead plant materials and microorganisms. Photosynthesis increases the forest carbon stocks in vegetation while respiration and decay release carbon to the atmosphere. Forest loss through deforestation releases the carbon stored in the forest thus depleting the carbon stocks and contributing to the global warming problem. Mount Kenya has been under increasing pressure from a rapidly growing human population that demands an increased supply of forest goods. Other challenges include climate change, increased incidents of forest fires, encroachment and increased use of the forest for livestock grazing. These challenges have led to forest degradation – a trend that needs to be reversed through restoration. We set out to estimate the quantity of carbon stored by Mount Kenya Ecosystem in 2018 and in two future scenarios: a Restoration scenario and a Business as Usual Scenario.

7.3 Methods

7.3.1 Assessing Carbon Stocks

We assessed the carbon stocks in 2018 and two likely future scenarios: A future in which Mount Kenya Forest is fully restored and sustainably managed and a future in which the current trends of land use continue. These future scenarios are hereafter referred to as the Restored and the Business as Usual (BAU) scenarios. Carbon stock estimates of all the major landcover/land-uses within the Mt. Kenya area were compiled from published estimates. For the majority of habitats, we used the estimates from Willcock *et al.,* (2012), figures for carbon stock within similar habitat types derived from a meta-analysis of appropriate literature values (Table 7.2), and applied these values to the estimated Land Use Land Cover classes estimated for Mount Kenya Forest in 2018 and in 2038 (Table 1.2). Willcock *et al.,* (2012) do not give estimates for bamboo. We used a mean of the above and below ground carbon figures for bamboo in the Ethiopian highlands (Embaye *et al.,* 2005) and global estimates (Embaye *et al.,* 2005) and estimated soil organic carbon stocks from the Harmonised World Soil Database (Nachtergaele *et al.,* 2009).

7.3.2 Results and Discussion

Total carbon stocks in the Mount Kenya ecosystem in 2018 were estimated at about 73 million tonnes (Figure 7.1). Most of the carbon was in the indigenous forest which contributed about 63 million tonnes of carbon translating into 86% of the carbon stocks (see Appendix 1 for details). Bamboo forest, tree plantations and wooded grasslands were estimated to store a total of 9.4 million tonnes of carbon (Appendix 3). If the current trends continue, i.e. in the Business as Usual Scenario, forest degradation will lead to a loss of about 4 % of the carbon stocks by 2038. This will be mainly driven by the conversion of closed-canopy indigenous forest to open canopy indigenous forest. Management changes to the forest could reverse this trend and even lead to an increase in the carbon stocks in the region of 8%. It is expected by 2038, forest restoration efforts will have led to tangible results, with large areas of degraded area being restored. If most of the open canopy indigenous forest is converted to closed-canopy due to restoration and protection efforts (including afforestation of degraded sites, enrichment planting of reduction of other threats including forest fires, overgrazing, and illegal logging), then substantial carbon storage benefits could be realized. In addition, forest plantations established in ecologically sensitive areas will have been converted to indigenous forest.

Table 7.1 Carbon Storage Factors Applied to Land-cover Areas for each Scenario

Land Cover	tC ha^{-1}	Upper 95% C.I.	References	Notes
Barren Land/Bare soil	99.4	110.1	1	
Scrub	212.1	301.8	1	
Grassland, Moorland	153.4	162.7	1	
Wooded Grassland	196.1	219.9	1	
Woodland	490.2	559.9	1	
Indigenous Forest (closed and open canopy*)	428.5	517.4	1	* 0.67 x closed canopy value applied to value for open canopy indigenous forest, based on difference between closed v open categories #4 & #12 in Reference [1], applied to Montane woodland values.
Tree Plantation	234.3	297.4	1	
Tea plantation	163.8	201.2	1	
Bamboo	295.65	-	2, 3,4	

References: 1=Embaye *et al.* (2005), 2= Nachtergaele *et al.* (2009); 3 = Willcock *et al.* (2012) and 4 = Doody (2012)

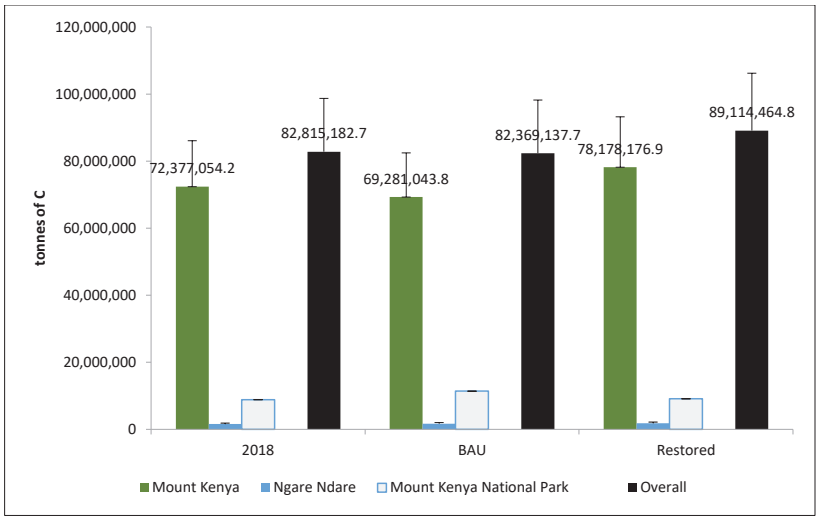

Figure 7.1 Total Carbon stored in Vegetation and Soil in Mount Kenya Ecosystems under Three Land-use Scenarios between 2018 and 2038. ***Error bars reflect the upper 95% confidence limit of estimates***

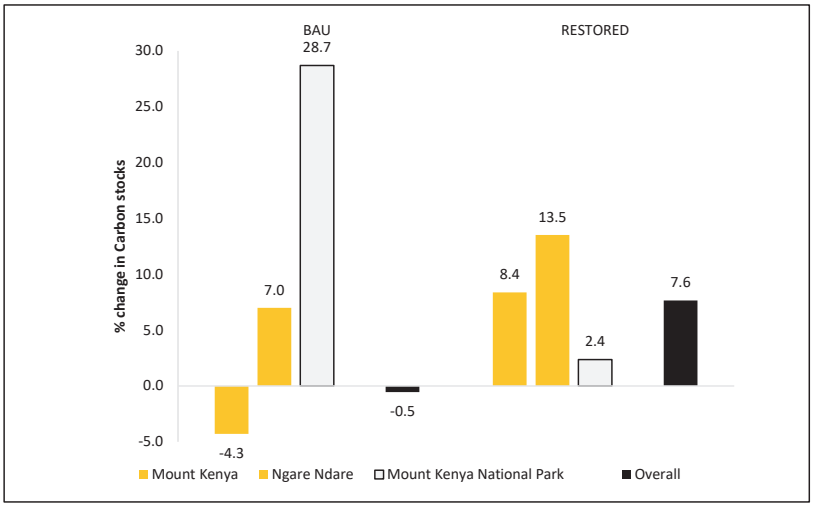

Figure 7.2 Relative Change in the Carbon Stocks in Future Scenarios

8. CULTURAL VALUE OF MOUNT KENYA ECOSYSTEM

8.1 Summary

Mount Kenya ecosystem has a high but undocumented cultural value to the local community members. In this study, we used the Toolkit for Ecosystem Service Site-based Assessment (TESSA) to assess the local community perception on the value of cultural ecosystem services associated with Mount Kenya ecosystem. Our results indicate that the residents were aware of many cultural ecosystem services that they accrue from Mount Kenya ecosystem. These included religious or spiritual; aesthetic or beauty; leisure, recreation, and ecotourism; cultural heritage; education and ecological knowledge; existence and bequest values; social relations and community benefits; health benefits; and inspiration, creative or artistic values. Most of the residents said that the value of these ecosystem services has been decreasing and that this trend will continue unless restoration of Mount Kenya Forest takes place.

8.2 Introduction

Understanding the cultural values of an ecosystem can help in advocating for its conservation and also help attract visitors to the ecosystem. Mount Kenya Ecosystem is very important to the culture of all the ethnic communities that reside around it, including Kikuyu, Embu, Tharaka and Meru. In addition, the mountain ecosystem is important to communities that reside away from the Mountain but can see it and occasionally access it, including the Maasai and Samburu pastoralists who sometimes have to use the mountain ecosystem as a dry season grazing refuge in times of extreme droughts. In spite of the importance of Mount Kenya Ecosystem to the cultural wellbeing of the local communities, the ecosystem condition is deteriorating due to human activities including deforestation, illegal logging, charcoal burning, encroachment and overgrazing (KWS, 2010; KFS, 2010), among other challenges.

There is a need to document the various cultural uses of the ecosystem and assess what is likely to happen to these services in case there is continued degradation. The resulting information can inform policy formulation, awareness creation, and advocacy for forest restoration; and also help in marketing the site for tourism. This study aimed at assessing the cultural ecosystem services currently provided by Mount Kenya Ecosystem and to evaluate the impact of current drivers of change on these services in the future.

The specific objectives of the study were:

- To identify and describe cultural ecosystem services and benefits provided by the assessment site
- To assess cultural ecosystem benefits provided by the assessment site
- To identify and assess potential changes in cultural ecosystem services and benefits due to changes between current and an alternative state of the site
- To provide a qualitative and non-monetary quantitative valuation of cultural ecosystem services and benefits to influence decision-makers

8.3 Methods

We interviewed 404 respondents around Mount Kenya Forest concerning the cultural ecosystem services that accrue from Mount Kenya Ecosystem. The interview schedule (Appendix 1) used was adopted from the questionnaire template M1(Cultural M1) in Peh *et al.* (2017). The respondents were selected as described in Section 2. The focus of the interviews was to find out if Mount Kenya Ecosystem provides the following cultural ecosystem services as described in Peh *et al.* (2017) (Table 8.1).
Scenario.

8.4 Results

8.4.1 Religious and Spiritual Value of Mount Kenya Forest Ecosystem

The local community members resident in areas adjacent to Mount Kenya Forest attach very high religious significance to the mountain and some of its associated features. Indeed the majority (58%) of the respondents reported that Mount Kenya Ecosystem has religious or spiritual values (Table 8.2). Features and sites to which these residents attach high religious and spiritual vale are listed in Table 8.3 and include Mugumo trees (Ficus tree), Mt Kenya itself, Shrines – including Njuri Ncheke shrines, caves, King Muuru tree, Gakeu, Lake Nkunga, Kathethero, Karandi, Kanisene, Kawe, Kiamentha.

Mugumo Tree *(Ficus thonningii)*: To 17 % of the residents living next to Mount Kenya, Ficus thonningii is a sacred tree that has over the generations been used for traditional prayers, sacrifices, rituals, and ceremonies. This tree is still used for these purposes even today by some members of the community.

Mount Kenya and associated forests: The whole mountain and its associated forests were recognized as a religious/spiritual site by 9.4 % of the residents. Indeed traditionally, local people pray facing Mount Kenya and believe the mountain is God's dwelling place. There are still some members of the local community who still carry on with this tradition.

Shrines were mentioned by about 7.2 % of the residents. Some of the notable shrines includes the Njuri Ncheke shrines used by the Meru Council of Elders.

Table 8.1 Categories of Cultural Ecosystem Services as Described by Peh el al., (2017)

Cultural Service	Description
Religious or spiritual	Places where particular ceremonies take place, sacred grove, a tree, mountains, caves, ponds or lake, a species, or just a particular place in the landscape where ancestors used to live or conduct ceremonies, important to you or members of your community
Cultural heritage	Important landscapes, sites or features that provide reminders of historic times and 'memories' tied to the landscape or physical objects, practices, traditions, or languages passed on from generations that are important for your way of life, or of benefit for you and/or your community
Aesthetic/ beauty	This includes sites or species that are appreciated/ liked because of their beauty, sound or smell
Inspiration, creative or artistic	Included are sites, animals, plants or landscape features that act as a source of inspiration for arts and crafts, such as paintings, music, weaving, architecture, stories for individuals or community
Social relations/ community benefits	This refers to natural spaces that allow social and community interactions, places where social groups can gather for picnics or festivities
Education and ecological knowledge	These are places/sites that provides materials or sites for teaching or education purposes
Health - mental and physical	These are natural places that people spend time in or go to when they are stressed
Leisure, recreation and ecotourism	Used in reference to sites that are used for either leisure, recreation or eco-tourism activities
Existence/ bequest values	This refers to particular species, special natural features, or locations in an area that that a person thinks are important to protect just to know they exist and/ or for future generations

Table 8.2 Cultural Values of Mount Kenya Ecosystem According to Respondents

Cultural Ecosystem Service Category	Respondents who Think the Service is Provided by the Site n= 404	
	No.	Per cent (%)
Religious or spiritual	235	58.2
Aesthetic/beauty	223	55.2
Leisure, recreation and ecotourism	197	48.8
Cultural heritage	188	46.5
Education and ecological knowledge	159	39.4
Existence/bequest values	141	34.9
Social relations/community benefits	127	31.4
Health - mental and physical	125	30.9
Inspiration, creative or artistic	120	29.7

Hills: Hills within and around Mount Kenya ecosystem were traditionally used for prayers. Some of the hills are still used. Some of the hills mentioned included Maiti Hill that was mentioned by 13 respondents. Others are Nyambene Hills, Kiamithuri, Karu, Muugi and Kungu Hills.

Caves: There are many caves found within Mount Kenya Ecosystem some of which were used for prayers or worship.

King Muuru: "King Muuru" is a giant Meru oak (*Vitex keniensis*) tree, found in lower Imenti forest, which is part of Mt. Kenya forest. The tree stands about 300m from Imenti Forest Station office and is estimated to be about 300 years old. The height of the tree is about 48 metres tall and its girth at its base is 7.2 metres. The tree's stem has a huge hollow inside. The entrance is big enough to allow an average adult human to go inside and about 5 can be accommodated inside comfortably. It has also another small natural opening about 5 meters from the base of the tree that resembles a window.

Gakeu: This is a lake that has drinking water of medicinal value. The site is used for offerings.

Lake Nkunga: This is a lake that is considered sacred. The site is popular for prayers.
Kathethero: A place with indigenous trees used for prayers.

Karandi: A site used for traditional meetings and for circumcision.

Table 8.3 Features and Sites of Religious Significance among the Local People around Mount Kenya Forest

Site/Feature	Respondents	
	Number	Per cent
Mugumo tree	68	16.8
Mt Kenya	38	9.4
Hills	38	9.4
Shrines	29	7.2
Caves	20	5.0
King Muuru tree	18	4.5
Gakeu	11	2.7
Lake Nkunga	9	2.2
Kathethero	7	1.7
Karandi	6	1.5
Kanisene	5	1.2
Kawe	5	1.2
Kiamentha	5	1.2
Others	88	

Kanisene: This is a place with stones looking like tables and forms; a site for prayers – located in Timau area of Meru County.

Kawe: This is a site in Chogoria Ward of Tharaka Nithi County where there is a Ficus tree around which people used to hold prayers before entering into Mount Kenya Forest. Mineral drinking water is available at the site.

Kiamentha: This is a worship site that has a large stone that resembles a table. It is located in Timau area of Meru County

8.4.2 Cultural Heritage

About forty-six percent of the respondents agreed that Mount Kenya Ecosystem has high cultural heritage value. Numerous caves within the forest ecosystem led among the features that were cited by about 20 % of the residents (Table 8.4). Other features and sites that have cultural significance are listed and described in Table 8.4.

8.4.3 Inspiration Value of Mount Kenya Ecosystem

Thirty percent (30%) of the residents living around Mount Kenya think that the mountain and the associated ecosystem is inspirational. Wild animals/ wildlife was the most frequently mentioned (7.2% of the residents) inspirational aspect/feature of Mount Kenya Ecosystem. The residents thought that some of the animals are very beautiful and attractive, have very interesting behaviour and attract tourists. The animal species mentioned included elephants, buffaloes, monkeys, antelopes, birds, and even squirrels. According to the respondents, elephants and buffaloes have inspired various arts and craft products.

According to 5.2 % of the residents, Mount Kenya itself is inspirational. The scenery, its peaks, the lakes, and associated landscape have inspired many artists, visitors, and mountaineers. The mountain and the forest provided concealment for the locals during the struggle for independence. The many caves found in the ecosystem provided shelter and hiding places for the freedom fighters, and also provide temporary shelter to honey gatherers.

Lewa Wildlife conservancy, despite the fact that it is outside the greater Mount Kenya Ecosystem, was considered inspirational, especially to residents of Meru County, probably due to the high diversity and abundance of wild animals on the property and the ease of sighting them compared to Mount Kenya ecosystem. Many other features and landscapes are also inspiring. The valleys, different vegetation types, waterfalls, swamps (Table 8.5) were also mentioned.

Table 8.4 Sites and Features of Cultural Significance to Local Communities around Mount Kenya

Feature/Site	Description	Respondents	
		No.	Percentage
Caves	Caves were used as hide out places during the Mau Mau War of independence. Some were used as stores and armouries. Some like Mwarania were even named after famous Mau Mau war veterans. In some cases, caves were used by elders as meeting places. For example, Meru Council of Elders sometimes held their meetings in caves. In the past, some of the caves were used for traditional ceremonies.	82	20.3
Mt. Kenya	A Cultural heritage site	28	6.9
Diara along Thiba River	A natural bridge on River Thiba was also cited as a place of cultural importance. It was believed that the bridge can only be used by righteous people.	14	3.5
Mugumo (Fig trees) and other sacred trees	Used for cultural ceremonies and for religious rites. Most communities around Mount Kenya held – and some members of the society still hold – their traditional prayers under the specific fig trees	12	3.0
Kiria		9	2.2
King Muru	A large Meru Oak tree around which some traditional ceremonies are held.	8	2.0
Kathandeini	Cultural ceremonies including weddings were held.	7	1.7
Njuri Ncheke and other shrines	Meru Council of Elders operate from Njuri Ncheke Shrines located in the forest.	7	1.7
Lakes Ellis, Nkungu Ntukurume, Tai		5	1.2
Katakame Spring	A Site where many Mau Mau warriors were killed	5	1.2
Nyumba ya Mburi	Mau Mau fighters offered sacrifices and operated from here	4	1.0
Lewa Conservancy	Important for wild animal viewing	4	1.0
Mau Mau Trench	This was a trench dug by the colonial government in sections of the forest boundary to prevent Mau Mau Fighters from leaving the forest.	3	0.7
Waterfalls		3	0.7

Table 8.5 Features/Attributes of Mount Kenya Ecosystem that have Inspiration Value

Inspiration Feature/Attribute	Residents who Think Ecosystem has Inspiration Value	
	No.	%
Wildlife/Wild animals	29	7.2
Mt. Kenya	21	5.2
Caves	16	4.0
King Muru tree	10	2.5
Forest vegetation	10	2.5
Lewa Conservancy	8	2.0
Diara along Thiba river	5	1.2
Shipton and Austin's tourist facilities	5	1.2
Gachomo Swamp	2	0.5
Kajogu	2	0.5
Karimi Falls	2	0.5
Mpingiro	2	0.5
Mwano	2	0.5
Mwaralesho	2	0.5
Mwirigo	2	0.5
Ruguti	2	0.5
Tatha	2	0.5
Ruongo Rutune	2	0.5
Valleys	2	0.5

8.4.4 Existence Values/Bequest Values

Forty percent (40%) of the residents interviewed thought the ecosystem has species, special natural features or locations that are important to protect just to know they exist and/ or for future generations. Wild animals were the most frequently mentioned attribute in this respect (Table 8.6). At (18.3%), Elephants were the wild animals most cited. Others included buffaloes, monkeys, baboons, antelopes, snakes, and birds. Other features included indigenous forest, specific trees (including Ficus due to their high cultural and religious value, and extra large trees). Other features were sites with trees growing in a peculiar manner like in Miyugo 17 where a group of 17 trees of similar species has formed a circle. Other features of interest include

- Historical sites including caves used by Mau Mau fighters, or trenches made during the Mau Mau War.
- Endangered/threatened wild animals and plants including rhino, sandalwood
- Sites with unique wild animals or plants.

8.4.5 Leisure/Recreation

Local residents and visitors are attracted to the ecosystem by Mount Kenya itself, its natural vegetation, and the natural physical features associated with the ecosystem. The mountain itself is an imposing physical feature with snow-capped peaks, scenic valleys and water falls. The ecosystem is dotted with scenic lakes (including Lakes Nkungu and Ellis) and swamps. Mount Kenya's scenic appeal is enhanced by the diversity in vegetation types and stratification by altitude. The mountain is a key site for professional and non-professional mountaineers. The ecosystem has diverse wildlife that also acts as a pull to visitors, including elephants, lions, buffaloes, primates, birds, among others. Other features include:

- **Caves:** Many of these caves have historical significance especially because they were used by freedom fighters in the 1950s during the struggle for independence. Some of the caves include Sagana, Ndungi, nawe.
- **Tourist facilities:** There are various tourist facilities both in the ecosystem and in adjacent areas. These include:
  - Austin's hut, Shipton hut; and Buimungi camp that are used by mountaineers.
  - Tourist hotels including Mountain Lodge located in Mount Kenya Forest Reserve, Bantu Lodge, Naro Moru River Lodge, among others
  - Canopy walk in Ngare Ndare Forest
- **Waterfalls:** Kirimi, Mirugi
- **Unique trees:** this includes extraordinarily large tress like King Muuru, and various *mugumo* trees used for traditional religious ceremonies.

Table 8.6 Features/Attributes of Mount Kenya Ecosystem that have Existence/Bequest Value

Feature/Attribute	Number of Respondents	
	No.	%
Wild animals	122	30.2
Elephants	25	6.2
Buffaloes	7	1.7
Indigenous forest	12	3.0
Mugumo tree	8	2.0
Karandi	6	1.5
Miyoga 17	5	1.2
Tatha	4	1.0
Devils Kitchen	4	1.0
Mau Mau Trench	3	0.7
Kathengera	3	0.7
Snow	2	0.5
Sandalwood	2	0.5
Rivers in forest	2	0.5
Nkungu forest	2	0.5
Ngurunga caves	2	0.5
Mwariama caves	2	0.5
Mt. Kenya	2	0.5
King Muuru tree	2	0.5
Ciongai	2	0.5
Caves	2	0.5
Others features cited by only 1 resident	28	6.9

- **Lewa Conservancy:** This was mentioned although it is not ecologically part of the larger Mount Kenya ecosystem.
- **Other scenic sites:** Ruguti stones - natural architectural stones; Tutha; Scenic valleys – Nthi valleys.

The main activities carried out by visitors to this ecosystem include mountain climbing and wildlife viewing, nature walks and forest canopy walks (in Ngare Ndare Forest)

8.4.6 Social Relations/Community Benefits

There are many natural spaces in Mount Kenya that allow social and community interactions, places where social groups can gather for picnic, festivities, and sports. These include scenic sites such as waterfalls, caves (like Uramdi caves, Njukiri caves) and landscapes that serve as ideal picnic sites. Other scenic sites include places with unique trees like King Muuru and sites with old structures like the PCEA Retreat Centre. There are also many sites where people traditionally met for ceremonies and rituals, including for circumcision ceremonies (for example Karandi site). Currently, there are football fields located inside the forest reserves that serve as public utilities. These include a football field at Chogoria Gate and at Kawe Gate. Among the Ameru people, the Njuri Ncheke (Meru Council of Elders) hold their meetings at Ruthumbi within the ecosystem. There are also various hotels (for example Mountain Lodge, Bantu Lodge) and tourism facilities within the ecosystem that serves as social facilities. Meru Showground where an annual trade and agricultural exhibition takes place is located within the forest.

8.4.7 Health - Mental and Physical

According to 125 (31%) of the respondents, there are natural places in Mount Kenya that have health benefits to people (Table 8.2). Nineteen respondents mentioned that nature walks in the forest have health benefits. Others (13) mentioned specific sites including "Devils Kitchen" in Murinduko Hill where unique features have been formed through erosion. Other areas mentioned by four or more residents included Hombe Dam, waterfalls and lakes. In addition, eight people mentioned that they rely on the forest for herbal medicines.

8.4.8 Education and Ecological Knowledge

According to 39.5 % of the residents, Mount Kenya Ecosystem provides education and ecological knowledge to diverse stakeholders. According to 31 of the respondents, the mountain and forest ecosystem is used for educational purposes. In addition, many local and foreign students have conducted their academic research in this ecosystem. Table 8.7 shows some of the sites that are of particular educational interest. Sites and/or facilities that were mentioned by over 10 residents

Table 8.7 Educational Features and Sites in Mount Kenya Ecosystem

Educational Feature/Asset	No. of Respondents
Mt. Kenya and the forest	35
Sagana Fishery	22
King Muru Tree	19
Soge School of Adventure	13
Lakes Nkunga	9
Tree nursery	9
View point at Murinduko Hill	8
Wiliam Holden Educational Centre	6
Biodiversity	6
Caves	5
Lewa Conservancy	4
Water intake	3
Devils Kitchen	3
Eco Resource Centre	3
Sabaa	3
Kangaita Forest Station	3
Cultural house	3
Camping site	2
Gachomo swamp	2
Hatcheries	2
Kajogu	2
King Muthuity Tree	2
Meru Showground	2

include Sagana Fishery (where students learn about fisheries production), extraordinary large trees including "King Muru" and King Muthaity, and Soge School of Adventure. Other educational facilities and sites included lakes, scenic landscapes, tree nurseries, caves (particularly those used by Mau Mau war veterans). Sites and features with educational significance reported by at least 2 respondents are listed in Table 8.7. There were other sites and /or features reported to be of educational value by only one respondent.

Table 8.8 Feature and Sites of Aesthetic Value in Mount Kenya Ecosystem

Aesthetic feature	Respondents	
	No	%
Forest/Trees	61	15.1
Wild Animals (mammals, birds, butterflies)	47	11.6
Mt. Kenya	43	10.6
Waterfalls	15	3.7
Urumandi bridge	12	3.0
Lake Nkunga	8	2.0
Kiria (with natural mineral lick)	6	1.5
Caves	5	1.2
Lewa Conservancy	4	1.0
Tatha (an open glade in the forest)	4	1.0
Swamps	4	1.0
Kathethero	3	0.7
Rutunda Park	3	0.7
Salt Lick	3	0.7
View point	3	0.7
Kiigeni	2	0.5
Mathatha	2	0.5
Mutunga	2	0.5
Ngurunga shrines	2	0.5
Nyambene hills	2	0.5
Rivers	2	0.5

8.4.9 Aesthetic/Beauty

Over half (55.2%) of the residents were aware of the aesthetic value of Mount Kenya Ecosystem and associated areas. The most cited aesthetic features included the forest and its trees, wild animals found in the ecosystem, and the mountain itself. These were cited by 51,12, and 11 percent of the residents respectively. Specific forest features that the residents mentioned included the presence of different vegetation types including bamboo and the presence of specific large trees. Wild animals perceived to have high aesthetic value included mammals (particularly elephants, baboons and other primates, rhinos, and the rare bongo); birds and butterflies. Mount Kenya itself was perceived as an important aesthetic value due to the scenic appeal of its snow-capped peaks, valleys. Other key scenic sites included waterfalls, lakes, Urumandi bridge (a natural bridge and River Nyamindi), Kiria (a site with natural mineral lick) and caves. Sites and features reported by at least two respondents are presented in Table 8.8.

8.4.10 Perception on the Changes in Cultural Ecosystem Services

The majority of respondents (Figure 8.1) thought that the value of ecosystem services was better in the past compared to the current status. They also indicated that the value was going to increase if the forest is restored. The majority of the residents thought that the ecosystem's ability to provide services in the future will be curtailed unless the forest is restored.

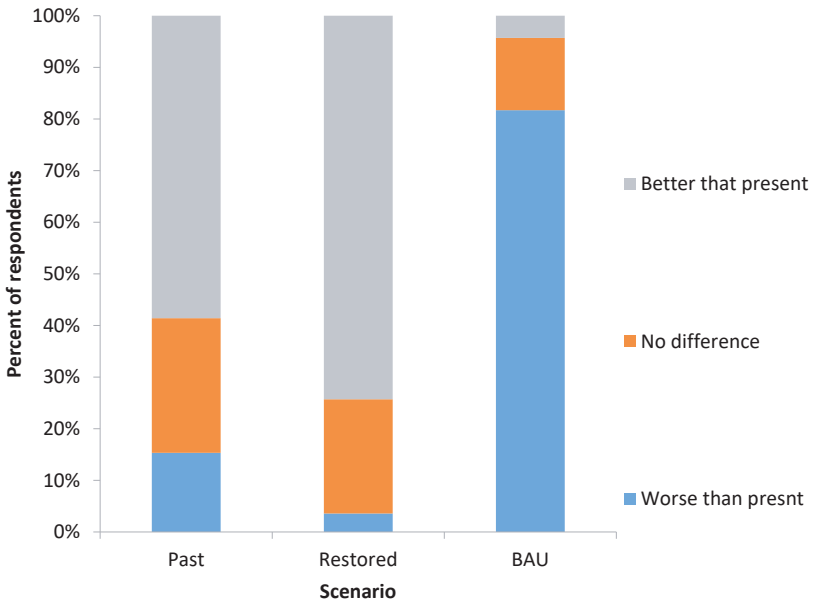

Figure 8.1 Perceived Changes in the State of Cultural Services

9. THE TOTAL VALUE OF MOUNT KENYA ECOSYSTEM SERVICES

9.1 Methods

We summed up the values of quantifiable ecosystem services that were assessed in order to estimate the total value of ecosystem services provided by the Mount Kenya ecosystem. Where applicable, we also used published estimates for values that we did we did not assess.

Qualitative analysis was used to compare the value of ecosystem services in 2018 and in future scenarios. The 2018 values were assigned a score of 1. Based on our results for values of the ecosystem in 2038, an ecosystem service was assigned a score of 1 if it remained constant, a value of 1.5 if it increased and a value of 0.5 if it decreased.

9.2 Results and Discussion

The services which we could quantify in monetary terms were worth about KSh.22 billion (US$220) in 2018 (Table 9.1). The value of these goods and services rise to 32 billion Kenya Shillings in the BAU scenario mainly due to high-value goods harvested from the forest as a result of the increased human population. As pointed out in section 6.4.1, unregulated harvesting of goods would be lead to lower availability of the same goods and therefore lower value in the BAU scenario. However, increased harvesting of goods from the forest will result in decreased quality and quantity of other critical ecosystem services including climate regulation, water services, soil erosion control, cultural services, recreation services, and biodiversity conservation services. Figure 9.1 shows that in the BAU scenario, only the value of harvested goods increases while the others decrease.

Forest restoration leads to a decline in the amount of goods harvested from the forest apart from water. If the forest is restored, all the value of most services increase but the value of harvested goods would decrease. Demand for harvested goods in the forest including timber, firewood, fodder, charcoal is driven by the rapid increase in human population in rural and urban centres around the ecosystem. The demand for forest products can be addressed through enhancing the livelihoods of the local communities through various measures including promoting value addition of agricultural products, promoting zero-grazing, promoting the use of alternative energy sources including biogas and promoting agroforestry, among other measures.

It is important to emphasize that our evaluation of the ecosystem services provided by Mount Kenya is an understatement and should only be used to demonstrate the minimum values of the services assessed. Indeed the value of the services provided by Mount Kenya is infinite and there are probably many values that we are not aware of today. Additionally, it is difficult to attach monetary values to many ecosystem services. For example in this assessment, we assessed the perception of the local community members on different categories of cultural ecosystem services including religious or spiritual; cultural heritage; aesthetic/ beauty; inspiration, creative or artistic; social relations/ community benefits; education and ecological knowledge; health - mental and physical; leisure, recreation and ecotourism; and existence/ bequest values. However, the only cultural service that is quantifiable in monetary terms is recreation and tourism. Other key ecosystem services that we did not assess are regulating services including air quality, disturbance moderation, water flows, waste treatment, erosion prevention, nutrient cycling, pollination and biological control.

In a review of studies on the value of various ecosystem services in different biomes, Groot et al (2012) reported that a tropical forest could provide services worth about 5264 US$ per hectare per year. Indigenous Forest cover in Mount Kenya ecosystem (indigenous closed canopy, indigenous open canopy and bamboo) comprise 184,367 hectares (Table 1.2). This part of Mount Kenya ecosystem services could therefore be worth some 971 million US$ (Ksh 97.1 billion) per year. Other non-forested parts of Mount Kenya Ecosystem also provide various ecosystem services implying that the annual output of ecosystem services from Mount Kenya could be worth over 100 billion Kenya shillings per year. It is also important to note that the review by Groot et al (2012) did not fact in most cultural services (apart from recreation and ecotourism) for which data were not available.

Further work on the valuation of ecosystem services provided by Mount Kenya is required particularly in relation to resource mobilisation. For example valuation of climate regulation including details on carbon stocks for different habitats, and consequences of forest degradation and/or restoration, global warming potential, carbon market trends and related studies would be useful in mobilising resources from the carbon market. Other important studies include the pollination services; mapping and marketing of cultural services and links with the tourism sector and marketing; and water services particularly quantification of amounts used and its value.

Table 9.1 The Value of Various Ecosystem Services Provided by Mount Kenya in 2018 and in Two Future Scenarios

Service	Value of Service		
	2018	Future scenarios	
		BAU	Restored
Avoided Degradation (carbon credits)	0	- 0.05	0.69
Water services -HEP Generation**	3	3	6
Water supply	0.75	<0.75	>0.75
PELIS cultivated crops	1.5	1.5	<1.5
Timber from Plantation	1.4	1.4	<1.4
Tea (Nyayo Tea zone)	0.5	0.5	0.5
Total from PELIS cultivated crops	1.5	1.5	<1.5
Harvested Wild	12.4	<12.4	< 12.4
Recreation	1.6	1	>1.5
Culture/religious/ educational /inspiration/etc		Lower	Higher
Total*	22.65	<22.05	>24.40

In the Table

1. ¶ a value of 22US $ per tonne of carbon (World Bank 2019) was used to estimate the value of carbon stocks lost or gained in the BAU and Restoration Scenarios respectively.
2. * Mreans that some of the values were not estimated.
3. ** The value of hydroelectricity generated by KENGEN in the financial year 2017/2018 was KSh.8,392,000,000 (KENGEN, 2018). 70% of Kenya's Hydro power is from Tana River. Assuming that half of the waters in Tana River is from Mount Kenya, it means that the annual value of hydroelectric power from Mount Kenya could be in the region of US$.293.72 million or approximately KSh.3 billion.
4. Dark red means decline in service; Green means increase in service

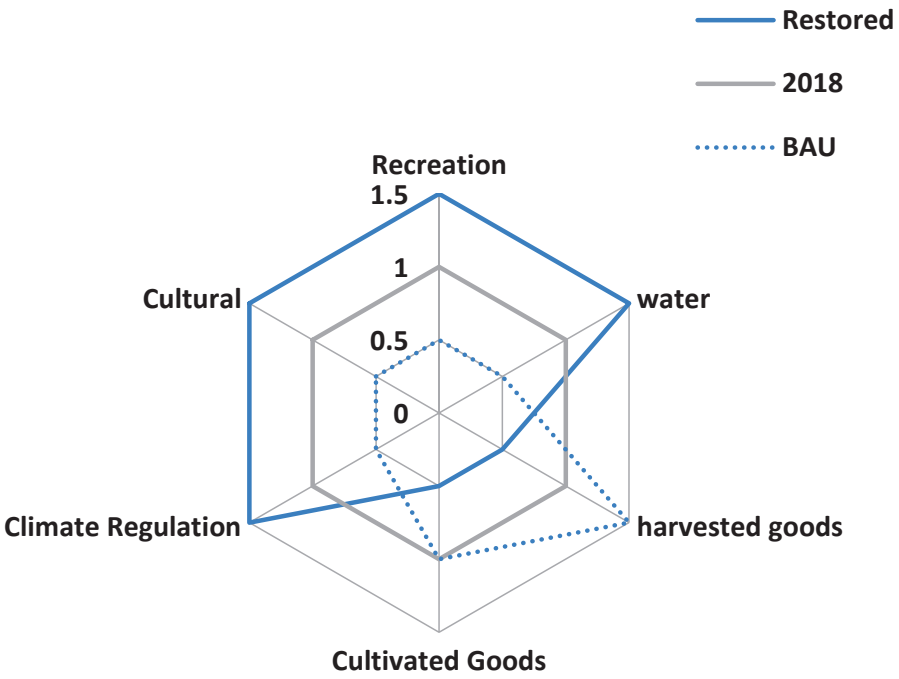

Figure 9.1 Illustration of the Value of Various Ecosystem Services in 2018 and in Two Future Scenarios, the Restored Scenario and Business as Usual (BAU) Scenario

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APPENDIX

Appendix 1: Stakeholders who Participated in the Ecosystem Scoping Exercise Conducted on 23rd - 24th August 2018

Name	Gender	Organization/ Sector Represented
Sebastian Kiogora	M	Lowe Imenti CFA
David Kaberia Muriungi	M	Kiamiriri's Coffee Factory
Francis Muriungi	M	Chairman NEFE CAP CFA
Justace Muriithi	M	E.O B WRWUA
Martin Njogu Kiama	M	Nature Kenya
Patricia Mumbi	F	CFA Kahurura
Ayub K. Rutere	M	Chief FRU Forestry
Joseph Njilu	M	Ngacofa Chairman
Paul Gacheru	M	Nature Kenya
James Mugu	M	Njukiiri Muhano CFA
Isaac Kinoti	M	Church
Kagwiria Joyce	F	Meru County Government Environment
David Kimathi	M	Ontulili CFA
Japheth Kithuchi	M	Chogoria CFA
Kenneth M. Kamanda	M	Chukka CFA
Stellacate Nyaga	F	Irangi CFA
Linus M. Amos	M	CFA
Joshua Kinyua Mbigiru	M	NNF Ngarendare Froest
Margaret Kawira	F	Mweru/Biakuz CFA
Kiama Charles	M	Nature Kenya
Martin Muriithi	M	MZEGIA
Silas Kirianki	M	Chief Ntima
Paul Muona	M	Kenyatta University
John Magaju	M	Meru Gardeners
Nathan Nteere	M	Director Githongo

Name	Gender	Organization/ Sector Represented
David Nduhiu	M	Ragati CFA
Benson M. Mwai	M	Chehe CFA
Sophia W. Muonia	M	Farmer
Siele Joel	M	Nature Kenya
Joseph Kangonga	M	Nyacofa Chairman
John Gitimu	M	Naromoru CFA
Mbaya Kirigia	M	Ntimaka CFA
Gerald Waita	M	Mt. Kebio
Ephraim Muriuki	M	Kabaru CFA
Wilson Thige	M	CFA
Mark Angwenyi	M	NEMA
Simon Maina	M	Disability
Charles Muteithia	M	Ministry of Interior
Mr Kirimi Mbaka	M	KWS
Milka K. Musyoki	F	Nature Kenya
Racheal Nyaguthii Githinji	F	Gathiuru CFA
Ann Macharia	F	WRUA
Gladys C. Godfrey	F	Kiera CFA
Gacheri Mutungi	F	Kuumiria
Zipporah Matumbi	F	MECCFA – CFA
Susan Kagwiria	F	Tree Growers
Ann Gaiteng'a	F	Farm Forestry
Naomi Njoroge	F	KFS
Gloria K. Gitonga	F	MCK
Rose Gitobu	F	Mpuri Ass. Chief
Mary W. Kihungi	F	Githima Group
Christine K. Murianki	F	Ministry of Energy
Zippy G. Maranga	F	Ministry of Energy
Lena Muthoni	F	Chuka CBO
Faith Makena K.	F	Farmer
Edith W. Kathii	F	Farmer
Rose Miriti	F	Ministry of Interior

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