Forest Cover Change and Its Impacts on Ecosystem Services in Katimok Forest Reserve, Baringo County, Kenya

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Contents

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Abstract

Forests provide vital ecosystem services to communities living around them, contributing immensely to their livelihoods. Yet, these forests undergo land use changes that threaten the abundance and availability of ecosystem services. This chapter assesses forest cover changes and its impacts on the ecosystem services in Katimok Forest Reserve. Land use changes were quantified using Landsat satellite images for the years 1984, 2001, and 2015. Focus group discussions (FGDs) and household surveys were used to identify and characterize the changes in ecosystem services. Land cover maps were prepared using supervised classification method and post-classification technique was used to detect the changes in forest cover. The results indicate that in the period 1984–2001, there was a decline in dense forest by 4.9%. Open forestland and built-up area had increased by 4.3% and 0.6%, respectively within the same period. These changes led into the reduction and loss of ecosystem services such as loss of certain medicinal plants, decline in mushrooms, and habitat destruction. It is therefore important that the relevant forest resource management agencies formulate sustainable resource utilization options/strategies for the local communities to curb degradation of this life-supporting ecosystem.

Keywords

Ecosystem services · Land use · Forest cover change · Katimok Forest Reserve · Forest ecosystem

Introduction

Forests are among the major world ecosystems whose value lies in the goods and services they provide for the maintenance of both human and environmental welfare. Healthy ecosystems provide goods
and services that are essential for human health and livelihoods, commonly known as Ecosystem Services (Millennium Ecosystem Assessment 2005). Forests sustain major life support systems on earth and are essential for the development of social and economic sectors of many countries. In fact, the expanse of a forest gives the first indication of the relative significance of forest ecosystems in a nation. According to TEEB (2010), forests are estimated to cover about a third of the earth's surface and contains over half of the terrestrial species. In Africa, forests cover approximately 21.4% of the total land area which represent 674 million hectares. The forests of Eastern Africa constitute about 13% of the total land area and Kenya, which is termed as the richest in terms of forest cover in the region, has a forest cover of about 6.07% of the land area (FAO 2008).

Forests and their products play a critical role in the improvement of lives of the local communities. In its Poverty Environment Network (PEN) research, the Center for International Forestry Research (CIFOR 2014) reveals that forests play a major contribution to the livelihoods of communities globally. World Bank (2013) estimates that approximately 350 million people in forest adjacent communities rely on forests for their livelihoods and 60 million of these are entirely reliant on the forest ecosystems. However, deforestation and forest degradation are threatening the capacity of these ecosystems to support livelihoods globally. This is because the well-being of a forest adjacent community greatly depends upon the services provided by the ecosystem. The continued flow of these services, on the other hand, is dependent upon the human activities which can either increase or decrease the benefits derived from the ecosystem, consequently impacting on their livelihood.

Moreover, global consequences of human-induced land use changes affect a wide array of services that ecosystems provide to answer health, social, cultural, and economic needs. Human activities affect forest cover directly through activities such as harvesting of timber and clearing for settlement and agriculture. According to Millennium Ecosystem Assessment (2005), humans can transform ecosystems in ways that can improve or reduce the benefits derived by the community. When a forest is converted into an agricultural land, crop productivity improves and hence ensuring the supply of food but the functioning of other services such as climate regulation, soil erosion control, pollution control, and other services which are important for human welfare are disrupted. In the long run, the value of services lost through conversion of the ecosystem exceeds the short-term benefits obtained from the economic activity of crop production.

Socioeconomic forces may also have significant indirect influences as they encourage policies and sequences of actions that can trigger degradation and ultimate decline in ecosystem services (Bravo 2008). Despite review of Kenyan forest policies to conserve and manage forests through sustainable utilization, the forests are still undergoing significant negative change. In Kenya, many forests are under pressure owing to increasing human populations, and as a result, these forests have been encroached. Clearing of forested areas for agriculture and settlement are seen in most forests, while in others, the population impinge upon the forests for their products such as timber and charcoal. These human activities threaten forest ecosystems and lead to eventual decline or even loss of services that the ecosystem provides.

Katimok Forest in Baringo County, Kenya, is one of such forests that have undergone degradation despite providing several crucial benefits to the community that include: herbal medicine, fruits, mushrooms, fodder, clean water, employment, recreation, and religious values, as well as the protection of the local people's way of life. Katimok Forest is situated in the semi-arid areas of Baringo County, an area susceptible to environmental and climate change and high rates of food insecurity. Dependence on ecosystem for provision of goods and services in this area is highest owing to the community's limited alternative livelihood options due to aridity of the environment that negatively impacts on household production activities (Baringo County Government 2015; Kahuki and Muniu 2004). Overdependence on the forest and unsustainable utilization of the forest resources translates to considerable deterioration in terms of the ecosystem services and forest cover. Therefore, there is need to embrace sustainable forest resource utilization to safeguard the ecosystem against degradation and thus a reliable source of goods and services for various user-groups This chapter was conceived on the premise that the current resource extraction

Table 1 Kabarnet Forest blocks

Block	Size (ha)
Katimok Forest	1956.59
Saimo Forest	750.9
Tarambas Hill Forest	483.8
Morop Forest	212.6
Kimeto Forest	210.4
Mosegem Forest	202.7
Sokta Hill Forest	163.9
Pemwai Forest	117.7
Chebartigon Forest	103.3
Ketwan Forest	46.6
Cherial Forest	42.5
Kabiok Forest	14.2
Tutwoin Forest	12.1

approaches, as witnessed during the preliminary visit (massive logging and presence of heavy trucks carrying timber to nearby sawmills), are unsustainable and consequently compromising the ability of future generations in accessing the same resources and services. Therefore, this chapter aimed at assessing the effects of forest cover changes on the forest's ability to provide ecosystem services.

Materials and Methods

Description of Katimok Area

Geographical Setting

Katimok Forest Reserve, gazetted 1949, is a forest in Baringo County, Kenya. It lies at an altitude of 2162 m and between Latitude of 0.55000000 and Longitude of 35.75000000. The forest is under the management of Baringo County Government and protected by the Kenya Forest Service. It is the largest block of the current Kabarnet Forest which consists of 13 blocks as shown in Table 1, Fig. 1.

Flora and Fauna

A larger portion of the forest is composed of indigenous trees including *Syzygium guineense* Wall*, Olea africana* Mill.*, Prunus africana* Kalkman*, Vitex keniaensis* Turrill, and the endangered *Osyris tenuifolia* L., among other tree species. Exotic plantations, such as *Eucalyptus saligna* Sm.*, Cupressus lucitanica* Mill*, Pinus patula* Schiede, and *Grevillea robusta* A.Cunn, also make up the forest, and they were established as early as 1970s on lands which became vacant after the eviction of illegal settlers. The forest is also home to wild animals and birds which include:

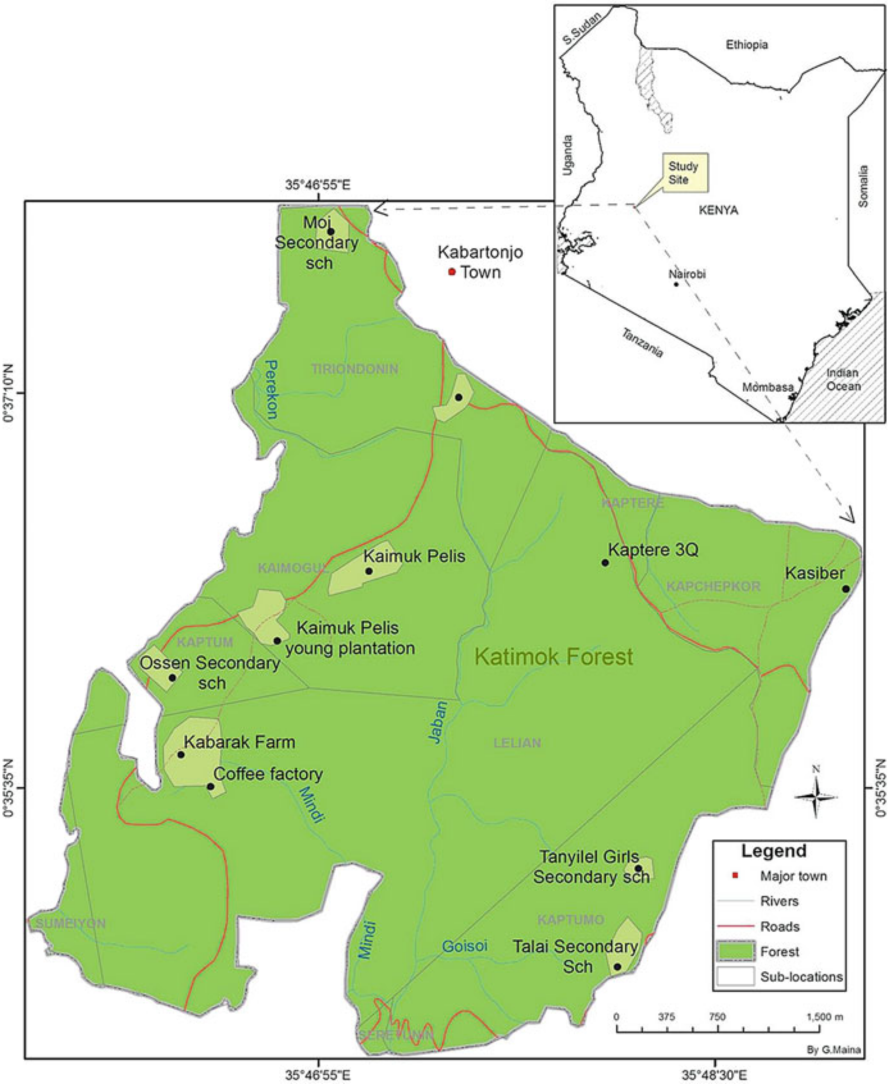

Fig. 1 Map of Katimok Forest Reserve

Colobus angolensis P.Sclater, *Papio anubis* (Lesson), *Lepus capensis* Linnaeus, *Coturnix coturnix* Linnaeus, *Numida meleagris* (Linnaeus), and *Madoqua kirkii* Günther, among others.

Climate and Socioeconomic Activities

According to the annual development plan of Baringo County Government (2015), agriculture is the backbone of the forest surrounding community. This is especially because the soils and the climate of the region are conducive for crop and livestock production. The area receives an annual rainfall of about 1000–1500 mm and temperatures ranging from a minimum of 10 °C and a maximum of 30 °C. This coupled with fertile soils make the forest surrounding populations practice production of different varieties of crops such as maize, sorghum, millet, and beans among other crops. In addition, rearing of goats, sheep, cattle, and bee keeping are other common economic activities in the area. Furthermore, the poverty level of the area is high and as such, the communities surrounding the forest are largely dependent on the forest's ecosystem services, such as honey, wild fruits, construction material, fuel wood, agricultural land, water, traditional ceremonies, and fodder among other benefits, for their livelihood. There are four major streams flowing through the forest, and they are *Goisoi, Mindi, Jaban,* and *Perekon* streams.

Population

The forest is surrounded by Ossen, Kapchemungot, Kabarbet, and Kaimugul sublocations which according to the 2009 population census have household populations of 693, 205, 159, and 399, respectively. The population density is 50 persons per km^2 with an annual growth rate of about 2.6%. The age distribution is 0–14 years (48.4%), 15–64 years (48.2%), and 65 and above years (3.3%) (Kahuthu et al. 2005).

Research Design

This chapter employed a social survey design with the aim of gathering information on the ecosystem, its services, and the local community from the selected sample. In addition, information concerning the current status of the ecosystem as well as describing the relationships between and among variables, such as level of awareness and education level, and between forest cover change and ecosystem services, under study was obtained.

Sample Size and Sampling Procedure

The sampling frame was a list of households adjacent to the forest. This chapter used a combination of stratified random sampling and simple random sampling in selecting the required number of household respondents to participate in the study. This was achieved through identification of strata of interest based on their administrative locations and proximity to the forest. The strata were Ossen, Kapchemungot, Kabarbet, and Kaimugul sublocations with household populations of 693, 205, 159, and 399, respectively. Proportionate sampling was then used to draw 48, 14, 11, and 27 households from Ossen, Kapchemungot, Kabarbet, and Kaimugul strata, respectively totaling to 100 households.

Data Collection Methods

Primary Data

Primary data was obtained from the field by employing both qualitative and quantitative data collection techniques. The chapter used the methodological triangulation technique in order to build a valid and reliable data collection plan. The instruments administered for collecting data from the field were:

(a) Household survey
(b) Focus group discussions
(c) Observations
(d) GPS Points

Household Survey: A structured questionnaire was administered to the heads of households that had been selected into the study. The questionnaire mainly served to assess the provisioning, regulatory, and cultural ecosystem services provided by the forest to the community. This was done by assessing the different uses of the different ecosystem services by the households. The questionnaires were administered in conformity with the sample size.

Focus Group Discussions: Focus group discussion (FGD) instrument was developed and administered to the staff from the Kenya Forest Service, members of Community Forest Associations, and local village representatives of the area. A topic guide to aid the discussion was developed beforehand, and brainstorming was used to explore each topic. FGDs were conducted with the purpose of getting additional information or information which may have not been clearly captured through questionnaires.

Observation: To get a clear picture of the status of the forest and its ecosystem services, an observation checklist was used to gather information. The pressures on the forest, e.g., felling of trees, livestock grazing, firewood collection, etc. were recorded. For more detailed information, photographs were taken. Observation gave a clear condition of the forest and hence enabling an understanding of the relationship between the people and the use of the forest's ecosystem services.

Secondary Data

GIS and Remote Sensing Data Acquisition: The datasets used in this chapter were satellite images. All preprocessing and processing activities were done using Idrisi Kilimanjaro and ERDAS IMAGINE image processing software. Satellite images of the study area taken by Landsat Thematic Mapper ™ sensor for the years 1985, and Enhanced Thematic Mapper for 2001 and 2015 were used. The images acquired were for the dry season to minimize errors that might arise from seasonal differences, and near anniversary dates were chosen for consistency within the time periods.

Table 2 Land cover description

Land cover type	Description
Dense forest	These are lands that have a compact stock of trees capable of producing timber and other wood products
Open forest land	Composed of lands with scattered patches of trees, farmlands, and lands with small trees, grasses, and shrubs
Built-up area	Areas composed of infrastructure mostly rural villages, schools, hospitals, and roads

Image Preprocessing

Preprocessing of satellite images is essential so as to remove data acquisition errors. The most common operations applied to an image during the preprocessing stage include geometric correction, radiometric correction, mosaicking, and subsetting. The images acquired did not need any radiometric and geometric corrections as they were already rectified.

Ground Truth Points

For ground-truthing, each land use type was noted and GPS used to capture the coordinates of the land cover types at each point. These ground control points were used as training samples for supervised classification and also for accuracy assessment.

Land Cover Classification

A supervised classification of the satellite imagery was used to produce land use land cover classes. The following land cover types were generated from the classification as described in Table 2.

Methods of Data Analysis

Data collected from various sources was entered into different software for analysis. Social data was entered into SPSS and Microsoft Excel and GPS ground truth data into ArcGis 10.1, Idrisi Kilimanjaro, and ERDAS IMAGINE. The process of data analysis involved cleaning the questionnaires for errors and coding quantitative data from the household interviews. Descriptive statistics were used for social data, to make cross tabulations, pie charts, bar graphs, and to calculate percentages and means. To determine whether the statistics were significant or not, Chi-square test of independence and Fisher's exact tests were performed.

For digital image processing, false color composites were created using bands 2, 3, and 4 for each of the images. The images were then geo-referenced in UTM projection WGS84 reference ellipsoid. Both supervised and unsupervised classification methods were used to classify the images, but owing to the high accuracy of supervised classification, the change detection base map was prepared using supervised classification.

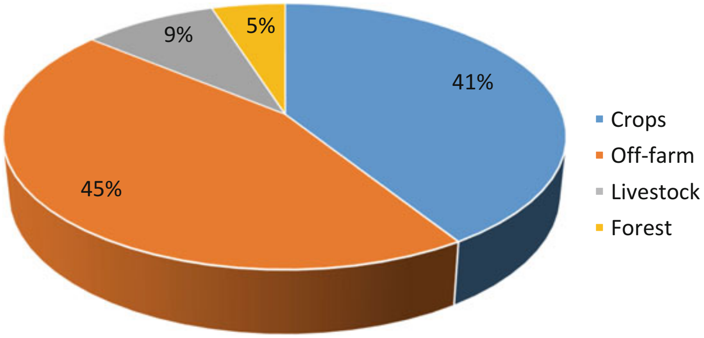

Fig. 2 Sources of income for household

Post-classification comparison method was used for change detection. In this method, images of different dates were first classified and labeled individually, then the classified images were then compared, and changed areas extracted.

Results and Discussion

General Description of the Respondents

A percentage frequency of the household survey indicated that 62% of the respondents were male and 38% were female. Their education levels varied with 42.7% having up to tertiary level of education, 31.8% secondary education, 14.5% primary education, and 1.8% of them having informal education. The major sources of income for the inhabitants were agriculture, off-farm activities, and products from the forest (Fig. 2).

The major ecosystem goods identified by the respondents included provision of fruits 80%, source of water 90%, fuel wood 94.5%, and timber 83.6%. The results indicate that majority (45.5%) of the respondents relies moderately, that is, they do not entirely depend on forest ecosystem for their livelihood. This implies that they have other sources of income for survival. However, only 16.4% greatly depend on the forest ecosystem for their survival. Although this number may seem small, it may have a great impact that leads to forest degradation possibly due to high extraction of products from the forest. Lastly, 29.1% of the household respondents that least rely on the ecosystem services for their livelihood (Fig. 3) is probably due to diverse sources of income as indicated from the high income from off-farm sources which are all waged and salaried nonfarm work like teaching and carpentry. High percentage of the household income from off-farm activities may be a reflection of high number of members of the community with tertiary education hence engaged either in self-employment activities or salaried jobs. However, a small

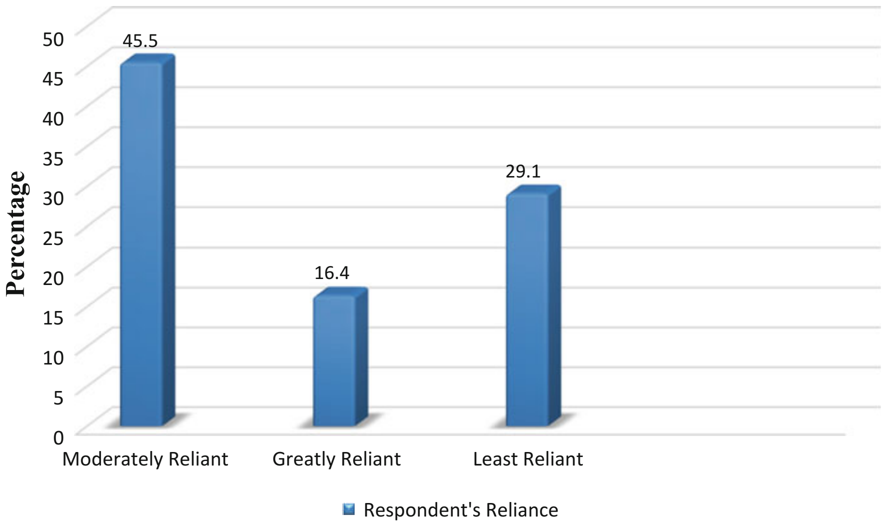

Fig. 3 Extent of reliance on ecosystem services for livelihood

number of residents entirely rely on the forest ecosystem services as a source of income for their households. These could be the people who may be involved in activities such as logging and sale of timber, building posts, firewood extraction, and production of charcoal.

The respondents' reliance on these ecosystem services varies for different households and also depending on the ecosystem service. The sampled households were divided into two categories: those with four or less people were considered small and those with five or more people were considered large households. Smaller households constituted 36% while larger households constituted 64%. The reliance on the ecosystem services was categorized as greatly reliant, moderately reliant, and least reliant. The Fisher's exact test results indicate that there is a significant association ($p < 0.001$, $\alpha = 0.05$) between household size and reliance on the ecosystem services.

Larger household sizes tend to rely more on ecosystem services for income than smaller households who mostly obtain the ecosystem services for domestic uses. These findings are consistent with observations made by Lakerveld et al. (2015). These researchers cite that household size is a demographic factor that influences how a family utilizes the ecosystem services, for example, need for fuel wood and timber for construction. The services that give the most income according to the respondents are timber at 41.7%, charcoal 20.8%, poles 19.4%, and honey 4.2% (Fig. 4). High harvesting of timber and poles (61.1%) for sale may contribute to the degradation of forest ecosystem, hence loss of biodiversity that will affect other forest products such as honey that constitute a source of income for forest adjacent community.

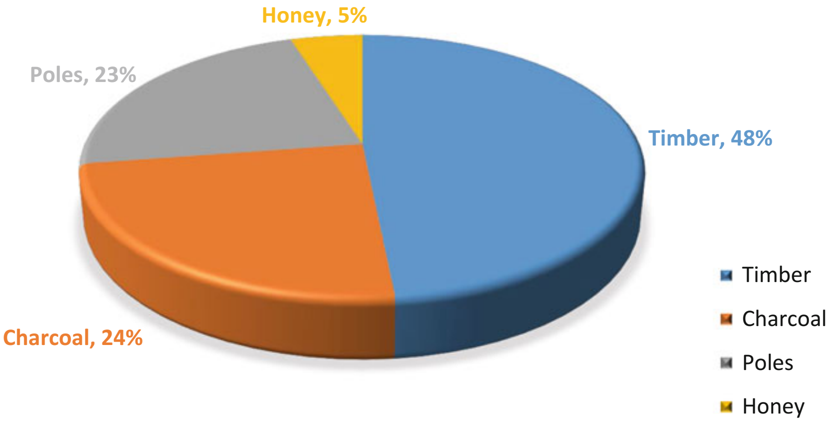

Fig. 4 Income generating from ecosystem services

Table 3 Data analysis summary table

Objective	Variable	Statistical tool
Assess association between forest cover changes and ecosystem services	Forest cover change Ecosystem services	Pearson's chi-square test
Assess relationship between respondent's education level and their awareness on the effects of their derivation of ecosystem services on forest cover	Education level Level of awareness	Pearson's chi-square test
Determine the major sources of income of Katimok residents	Source of income	Pie chart Percentages
Assess the households' extent of reliance on ecosystem services for livelihood and its relationship to household size	Livelihood Household size	Fisher's exact test Bar graph Percentages
Determine the income generating ecosystem services	Ecosystem services	Pie chart Percentages
Determine the forest cover change of Katimok Forest Reserve since 1985 to 2010	Forest cover Land use changes	ERDAS IMAGINE 11 Arc GIS 10.2

Forest Cover Changes

The summary Table 3 of the land use areas given below shows that in 1984, the dense forest occupied 91.4% of the total land area, and is hence the major land use type, followed by open forest land 8.3% and built-up areas 0.3%. The summary table also indicates that in 2001, dense forest still remains the major land use type covering 86.5% of the total land area. Open forest land has increased by 4.3% and now covers 12.6% of the total land area. Similarly, built-up area has increased by 0.6%. The results are as shown in Table 4. The comparison of the 1984 and 2001

Table 4 Fisher's exact test for reliance on ecosystem services

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson's chi-square test	100.000[a]	2	0.000	0.000
Likelihood ratio	130.684	2	0.000	0.000
Fisher's exact test	119.266			0.000
N of valid cases	100			

[a]The minimum expected count - SPSS results

land use areas indicate a decrease in dense forest land and an increase in open forest land and built-up areas. The dense forest has reduced by 4.9%, and this compensates for an increase in open forest land and built-up area by 4.3% and 0.6%, respectively. This reduction in forest cover can be attributed to logging, overgrazing, settlement, and conversion of the dense forest into agricultural land as gathered from the focus group discussions. This observation concurs with those of Giliba et al. (2011), who concluded that human activities such as illegal logging, fodder use, agriculture, and honey harvesting are among the causes of forest cover change (Table 5).

The 2001–2015 summary table indicates that the dense forest has now slightly increased up to 90.4% of the total land area, and it still remains the major land use type. This increase in dense forest land has resulted in a decline in open forest land as well as built-up area to 9.1% and 0.5%, respectively. The changes above can be attributed to the eviction of the illegal settlers in the forest in 1988 during the Kenya African National Union regime that led to a decrease in the built-up area as observed in the land use map. Afforestation was carried out in the lands that were left vacant after the eviction, and this led to an increase in the dense forest land and a decline in open forest land. This afforestation was carried out under the Shamba System, now the Plantation Establishment and Livelihood Improvement Scheme (PELIS), which allowed the community to farm on the land as they tend to the tree seedlings until they attain a certain stage. The trees planted on these bare lands were exotic trees which meant that some of the ecosystem services they provided like herbal medicine could not match those of indigenous forest.

Impacts of Forest Cover Change on Ecosystem Services

Based on the focus group discussion, the participants agreed that there have been changes in indigenous forest cover since 1984 in terms of size, density, and species composition. The forest used to be purely indigenous, but the deforested parts have now been replaced with plantation forests. In their view, though the forest cover may have slightly improved owing to the introduction of the PELIS system, the plantation forest which is normally established for commercial rather than restoration purposes, cannot match that of indigenous tree cover. According to their opinion, there is a strong relationship between the changes in indigenous forest cover and ecosystem services, in that, as the indigenous forest cover decreases the ecosystem services also reduce. Therefore, the changes in land use and forest cover of Katimok Forest have had some effects on the ecosystem services that the forest provides. Some of the examples given in the FGDs include:

Table 5 Land use land cover areas 1984–2001

Class type	1984 (Area Km^2)	1984 (%)	2001 (Area km^2)	2001 (%)	ΔHa	Change %
Dense forest	*18.81*	*91.4*	*17.80*	86.5	−1.01	−4.9
Open forest land	*1.71*	*8.3*	*2.60*	12.6	0.89	4.3
Built-up areas	*0.05*	*0.3*	*0.17*	0.9	0.12	0.6
TOTAL	**20.57**		**20.57**			

Loss of Biodiversity

The FGD participants indicated that there was a deteriorating trend of some important plant species and mostly those used for medicinal purposes such as *Piper umbellatum* L. that cures headaches, *Entada abyssinica* Steudel for stomachache, and *Desmodium adscendens* (Sw.). Special flowering plants for bees, e.g., *Combretum schumannii* Engl., have also disappeared, and so the bees go away in search of nectar. The disappearance of the plant as well as the migration of the bees has resulted in a sharp decline in the amount of honey produced. The reduction in the indigenous forest cover has also led to human-wildlife conflicts since their habitat has been fragmented and disturbed. The forest has become open and the animals which used to come out only at night can now be seen even during the day, as they have nowhere to hide. Some animals such as the *Leptailurus serval* (Schreber) have also disappeared and can no longer be found in the forest. There has also been a decrease in the abundance of mushrooms in the forest and the participants indicated that it has become a rare ecosystem service. It should be noted that, though the forest cover may have increased between 2001 and 2015, logging and timber harvesting still continue, and the PELIS program is not helping much in terms of restoring biodiversity since farming leads to forest disturbance. Moreover, this increase in forest cover between 2001 and 2015 is not up to what was there in 1984. There are farmlands and built-up areas like schools and hospitals within the forest as observed. These built-up areas, according to the focus group discussions, were not there before and hence have contributed to the loss in forest cover.

Hindering of Forest Regulation Services

The focus group discussion participants indicated that some of the regulation services of the forest have been hindered such as soil erosion prevention, which is now a common phenomenon during heavy rains. Flooding downstream is now also observed especially in the *Endao* and *Kampi ya Samaki* Rivers. There has also been a reduction in water levels and quantity, and also in water points owing to siltation which eventually lead to the drying up of some rivers. The rivers have also become seasonal. This may be attributed to the change in land use which reduces the forest cover thereby affecting the ability of the forest to act as a catchment area. A study conducted by the Center for Watershed Protection (2008) and Caja et al. (2018) established that a reduction in forest cover affects the ability of the forest to regulate the quality, quantity, and flow of water. This was

Table 6 Land use areas 2001–2015

Class type	2001 (Area km^2)	2001 (%)	2015 (Area km^2)	2015 (%)	ΔHa	Change %
Dense forest	*17.80*	*86.5*	*18.59*	90.4	0.79	3.9
Open forest land	*2.60*	*12.6*	*1.87*	9.1	−0.73	−3.5
Built-up areas	*0.17*	*0.9*	*0.11*	0.5	−0.06	−0.4
Total	**20.57**		**20.57**			

measured using water balance models which found that a decrease in vegetation cover affects the water balance of an area. Therefore, it can be argued that, this establishment agrees with the focus group inferences of this study. In general, there has been a reduction in the abundance of the ecosystem services, and in some cases, the services have become extinct.

Increase in Agricultural Produce and Construction Material

However, as they cite a reduction of some of the ecosystem services, the participants also point out that there has been an increase in agricultural production as well as forest products such as timber and other building materials as a result of land use change. Logging increases the demand for timber and also the availability of bare land on which the community are allowed to farm on as they tend to young tree seedlings, a system known as the Plantation Establishment and Livelihood Improvement Scheme (PELIS). This concurs with what Lawler et al. (2014) had established that land use change from forestland to farmland increases the production of food crops and timber among other products but at the expense of a decline in other ecosystem services along with biodiversity. Devisscher (2009) also agrees that changes in land use from forests to agriculture as well as other systems of production affects the abundance of ecosystem services since as the land is modified, the resources undergo exploitation.

Local Community's Perception of the Relationship Between Forest Cover and Ecosystem Services

Most of the respondents are aware of the effects of their derivation of ecosystem services on the forest cover. There is a significant association between this awareness and their education level ($X^2 = 124.690$, df = 12, $p < 0.05$). Results of samples of levels of study which are tertiary level, secondary level, primary level, and informal level were compared with those of the multiple categories of awareness on the effects of derivation of ecosystem services on forest cover as shown in Table 6.

Table 7 Education level – level of awareness crosstabulation

			Level of awareness					
			Greatly degrades	Degrades	No effect	Improves	Greatly improves	Total
Education level	Informal	Count	0	1	2	2	1	6
		Expected count	2.6	2.4	0.8	0.1	0.1	6.0
	Primary	Count	1	5	9	0	1	16
		Expected count	6.9	6.4	2.1	0.3	0.3	16.0
	Secondary	Count	5	27	2	0	0	34
		Expected count	14.6	13.6	4.4	0.7	0.7	34.0
	Tertiary	Count	37	7	0	0	0	44
		Expected count	18.9	17.6	5.7	0.9	0.9	44.0
Total		Count	43	40	13	2	2	100
		Expected count	43.0	40.0	13.0	2.0	2.0	100.0

[a]The minimum expected count - SPSS results

Table 8 Chi-square tests

	Value	df	Asymp. Sig. (2-sided)
Pearson’s chi-square test	124.690[a]	12	0.000
Likelihood ratio	99.684	12	0.000
N of valid cases	100		

Chi-Square Tests for Levels of Awareness and Education

Those who are educated tend to have knowledge on the effects of derivation of ecosystem services on the forest cover as compared to those who have little or no education. These findings are in agreement with those of Martinez (1998), who cites that social factors such as education level influence the rate of deforestation. Geist and Lambini (2002), in their research, also agree that education level is important in forest ecosystem conservation since knowledge on the ecological functions of a forest enhances sustainable utilization of forest resources. Education shapes the behavior of an individual causing forest destruction.

Based on the focus group discussion, the participants agreed that there is a strong relationship between forest degradation and ecosystem services. As the forest continues to degrade, the ecosystem services also reduce. The Pearson’s chi-square test results of the household survey also concur with what the FGD participants had indicated. The tests reveal that there is a strong relationship ($X^2 = 151.581$, df $= 16$, $p < 0.05$) between forest degradation and decrease in provision of ecosystem services overtime (Tables 7 and 8).

Table 9 Forest cover change – ecosystem services change crosstabulation

			Ecosystem services change					
			Greatly increased	Increased	Remained the same	Reduced	Greatly reduced	Total
Forest cover change	1	Count	2	2	1	0	0	5
		Expected count	0.1	0.3	0.4	4.1	0.3	5.0
	2	Count	0	0	2	3	0	5
		Expected count	0.1	0.3	0.4	4.1	0.3	5.0
	3	Count	0	3	1	1	0	5
		Expected count	0.1	0.3	0.4	4.1	0.3	5.0
	4	Count	0	0	1	75	1	77
		Expected count	1.5	3.9	5.4	62.4	3.9	77.0
	5	Count	0	0	2	2	4	8
		Expected count	0.2	0.4	0.6	6.5	0.4	8.0
Total		Count	2	5	7	81	5	100
		Expected count	2.0	5.0	7.0	81.0	5.0	100.0

Table 10 Chi-square tests

	Value	df	Asymp. Sig. (2-sided)
Pearson's chi-square test	150.005[a]	16	0.000
Likelihood ratio	82.189	16	0.000
N of valid cases	100		

[a]The minimum expected count - SPSS results

Chi-Square Tests for Forest Degradation and Provision of Ecosystem Services

Household participants were asked to state weather the forest ecosystem services, such as fruits, honey, timber, poles, medicinal plants, firewood, fodder, fiber, charcoal, and water among other goods, had increased or reduced overtime with regard to the degraded forest. The results showed that the ecosystem services have reduced along with forest degradation. According to the research conducted by WWF (2016), forest degradation not only reduces the forest cover but also the ecosystem services that the forest provides and eventually the livelihoods of the people that depend on it (Tables 9 and 10).

Benefits of the Forest to the Community

The forest is the source of livelihood of many of the households in the community living adjacent to the forest as indicated by the data gathered from FGDs and household survey. They obtain socioeconomic as well as cultural benefits from the forest. The forest is a catchment area and the community gets water from the rivers and streams that flow through the forest such as *Sokom, Endao*, and *Kampi Samaki* Rivers. The forest is also important to the community as they rely on it for herbal medicine derived especially from the indigenous plants such as *Garcinia johnstonii*. According to the Focus Group Discussion, the participants also indicated that during the dry season when there is shortage of grass for their livestock, the community relies on the forest for fodder with some of the species like *Trichocladus ellipticus* acting as alternative feed for their livestock (Table 11).

The forest also plays a significant role in fulfilling cultural and spiritual practices of the community. Some cultural benefits of the forest that the participants indicated are that the forest is a ceremonial ground and circumcision is done in the forest. The community also has some designated sacred sites within the forest that are used for prayers: both traditional and modern Christianity. The Governor's Camp is a historical place and a tourist attraction in the forest. Other places of cultural importance are *kebenonin, tuiyobei*, and *kapchumba* where there is a cave. There are also plant species with some cultural significance to the community, and they include *Warburgia ugandensis, Acocanthera schimperi*, and *Euclea divinorum*. These plant species are not available in their farms, and hence the forest is an important source of these species. The forest is also a source of fuel wood which is a readily available form of energy for the community. Moreover, the forest is an ideal place for placing beehives, and as such, it is important for bee farmers.

Other important benefits that the community derive from the forest as gathered from the focus group discussion and as observed include fodder, honey from stingless bee, mushrooms, soil, tree seedlings, farming land, fresh air, habitat for wild animals, recreation, construction material, and wild fruits among other benefits. All these benefits that the community derive from the forest as indicated in the FGDs conducted and field observations agree with the findings of Shackelton et al. (2008). According to these researchers, communities utilize a wide array of ecosystem services such as medicine, food, construction material, and cultural purposes to meet their livelihood needs. Millennium Ecosystem Assessment (2003) findings are also consistent with the current chapter findings in which different communities' value different ecosystems according to the values they attach and obtain from them. The current chapter findings further note that, there are various ecosystem services obtained from the forest and they range from bush meat, water, firewood, wild fruits, as well as spiritual and cultural value.

Table 11 Tree species found in the forest

Local name	Scientific name	Common name	Uses
Tarakwo	*Junipreus procera*	African pencil cedar	Construction material
Auwe	*Polycius kikuyuensis*	Parasol tree	Timber
Arariet	*Ekebergia capensis*	Cape ash	Medicinal for dysentery
Benet	*Podocarpus falcatus*	Yellowwood	Making furniture
Boroa	*Dombeya goetzenii*		Medicinal for indigestion
Kolutwet	*Albizia amara*	Bitter albizia	Fruit and medicinal
Kamilet	*Combretum molle*	Velvet bushwillow	Medicinal for stomachache and headache
Sosionte	*Phoenix reclinata*	Wild date palm	Fruit
	Vitex keniensis	Meru oak	Fruits, medicinal
Bunus	*Eucalyptus saligna*	Sydney blue gum	Building and construction
Yemit	*Olea Africana*	Wild olive	Fruits and oil
Soket	*Warbuginia ugandesis*	Uganda greenheart	Fruit and medicinal for general body pains
Sesia	*Acacia tortilis*	Umbrella thorn acacia	Making furniture
Leketwa	*Carissa edulis*	Simple-spinednum-num	Fruits, medicine for malaria and pain
Kunyukwe	*Prunus Africana*	Red stinkwood	Medicinal for stomachache, malaria, fever
Kuryonte	*Teclea nobilis*	Small-fruited teclea	Fruit tree, timber
Samut	*Cordia Africana*	Sudan teak	Beehives and furniture
Se	*Albizia gummifera*	Peacock flower	Firewood, charcoal
Septa	*Podocarpus latifolius*	Real yellowood	Fruits, making furniture
Ortulet	*Croton megalocarpus*	Croton	Construction material, fuel wood, charcoal
Nerkwo	*Garcinia livingstonei*	African mangosteen	Fruit tree
Lomoiwe	*Syzygium guineense*	Water berry	Fruits, construction material
Koloswo	*Trichocladus ellipticus*	White witch-haze	Fodder, medicine for upset stomach
Tegat	*Bambusa vulgaris*	Bamboo	Construction
Sinendet	*Ficus sycomorus*	Sycamore	Fruits, ceremonial
Kures	*Euphorbia candelabrum*	Candelabra tree	Medicinal for leukemia, tumor, HIV infections

Challenges Faced in the Management of the Forest

There are many challenges that hinder the sustainable management of the forest as gathered from the focus group discussions. One of the challenges is that the community lacks information and awareness on the significance of trees and the value of conservation, so they take part in forest encroachment. Furthermore, there is no restriction in entering the forest, unlike in the past where people had to seek permission to enter the forest. This encourages illegal practices such as logging and poaching within the forest. Carandang et al. (2013) in their research found out that lack of knowledge and awareness on the benefits of protecting the forest is a sociocultural factor that indirectly causes forest degradation. They also add that laxity on enforcement of the laws further fuels the rise in illegal forest activities.

Focus group discussion respondents indicated that grazing of livestock in the forest has not been controlled as before, where the community used to sit and agree on certain water points and certain boundaries. Fodder would be cut and taken to the animals in the field, and goats were not allowed to browse in the forest. This ensures that the animals could not overgraze in the forest and hence curbing forest degradation. Open grazing in forests adversely affects the growing stock as well as the capacity of the forest to regenerate leading to degradation (Nayak et al. 2008).

Another concern was that the residents are threatened and victimized whenever they report illegal poaching. There is no action taken on the offenders and so people do not care anymore about reporting, so they end up poaching as well. What is more, there are only 8 officers managing the entire 13 blocks of Kabarnet Forests and few staff to monitor a vast expanse of forest. Poor remuneration of KFS officers has also contributed to less effort in management of the forest, and thus they also poach and/or receive bribes from illegal loggers. These findings are in agreement with those of Contreras-Hermosilla (2000) who found out that some forest management authorities often abuse the public powers bestowed on them to unlawfully make themselves rich. He further states that this conduct is especially true for those officials who are poorly paid as they start making prejudiced decisions against those activities that do not attract bribes and hence continued illegal logging.

The participants also mention that commercialization of tree products has made the community look at trees in terms of commercial values, and this has led to illegal logging. There is ready market for timber, poles, and other building materials, and hence they practice illegal logging to earn a living. Goll et al. (2014) in their research also indicated that market demand for forest products is one of the root causes of forest degradation.

Moreover, the FGD participants stated that there is corruption among the forest authorities and those trading in forest products, mostly timber. The authorities are offered handsome bribes to give licenses to some few known individuals. Besides, those licensed persons do not even hail from the community. Therefore, the community feels sidelined as they are not given licenses so that they can also obtain the forest products legally. This makes them practice illegal logging and other forms of forest degradation. This is consistent with the findings of Carandang et al. (2013)

who established that corruption is one of the rampant institutional weaknesses that has hindered effective enforcement of forestry laws in developing countries. In addition, they argue that this corruption allows illegal logging to continue as the forest authorities are bribed to issue permits.

Another concern raised in the FGD was that the last batch of the illegal settlers was forcefully evicted in 1988. During this eviction, houses were burnt and property destroyed. For that reason, there is still resentment as evicted persons were not compensated, so they feel neglected and they take part in illegal logging to make up for their lost property. According to FAO when illegal forest settlers are forcefully evicted, they retaliate in form of participating in unlawful forest activities such as illegal logging, and this result in rapid decline of forest resources. Therefore, FAO recommends the resettlement of illegal settlers so as to economically empower the local communities as well as promote forest conservation (FAO n.d.).

Lastly, the FGD results indicates that the community forest associations (CFAs) lack the capacity to make and enforce rules as well as financial resources to carry out their activities. This is consistent with the findings of Chomba et al. (2015) who indicated that the CFAs had no power to even make the basic rules concerning forest management, for example, making decisions regarding the fees to charge the forest users. They also cannot enforce these rules as this mandate is entirely vested on the KFS officers. On top of that, Chomba et al. (2015) adds that the CFAs has no external source of funding but majorly depend on their membership contributions to finance their activities.

Forest Management Interventions

The Kenya Forest Service sows tree seedlings in their tree nurseries and plants them in degraded areas. They also sell the trees to the local people to go and plant them in their farms. This reduces the reliance on the forest in terms of fuel wood and timber since the community has the trees available in the farms. Some of the trees raised in the nursery are listed in Table 12.

The community forest associations (CFAs) also engage in the protection of the forest by offering surveillance and reporting to KFS any illegal activity as well as wildfires that might occur in the forest.

Some of the areas have also been fenced off under the PELIS system to keep off any animals that might enter the forest. The forest is manned by KFS forest rangers that can arrest any illegal loggers and grazers in the forest. The rangers are allowed to detain any livestock found illegally grazing in the forest.

Conclusions

The results from this chapter have indicated that there had been a decline in forest cover from 1985 to 2001, then a slight increase between 2001 and 2015, but even this increase did not match the original forest cover. On the overall, comparing the

Table 12 Trees grown in Katimok Forest nursery

Names	Description
Eucalyptus saligna Sm.	Tall forest tree with height 30–55 m
Cupressus lusitanica Mill.	Evergreen conifer tree; ovoid crown; up to 40 m tall
Fraxinus pennsylvanica Marshall.	Deciduous tree, medium in size. Grows up to 12–25 m
Podocarpus falcatus Thunb.	Evergreen conifer; grows up to 45 m in height
Prunus africana Hook.f.	Evergreen tree native to Sub-Saharan Africa
Grevillea robusta A.Cunn	Fast growing evergreen tree; 18–35 m in height
Olea hochstetteri Baker.	Evergreen tree; varies from 2 to 15 m in height
Croton megalocarpus Hutch.	Drought resistant tree; upto 36 m high
Warburgia ugandensis Sprague.	Evergreen insect resistant tree
Casuarina equisetifolia L.	Slender evergreen tree with gray-green twigs; 6–35 m tall
Pinus patula Schiede.	30 m tall tree that is moderately drought resistant
Vitex keniensis Turrill.	Straight trunk tree that is endemic to Kenya

forest cover of 1984 to that of 2015, it is evident that there has been a decline. These changes affected both the availability and the abundance of ecosystem services in the forest since even as the forest cover slightly increased, some of the ecosystem services provided by the original indigenous forest cover could not be recovered. Three major land use types that were identified were dense forestland, open forestland, and built-up area. In general, the forest cover has decreased since 1984, and areas that were once covered with dense forest lands in the early 1980s have been turned into farmlands and build-up areas. Katimok Forest cover change has had some negative profound impacts on the ecosystem services, and this has affected the forest adjacent community who largely depend on the forest for their livelihoods. For instance, there has been loss of certain medicinal plants, reduction in the water levels and water points, decrease in mushroom and honey, and even disappearance of some wild animal and bird species. All these impacts arise from the community's unsustainable utilization of the forest and forest resources through land use. Therefore, this kind of information is useful for the forest management authorities in order for them to protect the forest resources from exploitation.

Cross-References

► Biodiversity, Ecosystem Degradation and Climate Change Effects on Livelihoods in the Bitumen Area of Nigeria
► Drivers of Deforestation and Land-Use Change in Southwest Nigeria
► Ecosystem Based Climate Change Adaptation and Land Rehabilitation in Northern Ethiopia: Assessment of Interventions, Impacts and Factors Influencing Success

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