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*Original Research Article*

# Impact of Participatory Forest Management on Livelihood and Forest Cover in Lembus Ecosystem, Baringo County, Kenya

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**Abstract**

**Globally, forests provide critical ecosystem goods and services that directly support livelihood of millions of people. They also play a significant role to the expansion of many economies around the world. With a steady decline in global forests cover due to expansion of agricultural activities in 70% of countries around the globe, the United Nations General Assembly in 1989 convened strategic meeting to devise integrated approaches to halt and reverse the negative impacts of human activities on the physical environment and promote environmentally sustainable development. This led to introduction of participatory forests management (PFM) approaches, which were later incorporated into the forests policies and laws in many countries around the world, including the Sub Saharan Africa. In Kenya, with a forest cover of 7%, PFM became a principal tool in improving forest cover, while enhancing people's livelihood. However, recent reports indicate an escalation of poverty rate coupled with high degradation and deforestation of forest ecosystems. Whereas limited information existed on the impact of PFM on the livelihood as recognized by the International Union for Conservation of Nature, its contribution to the forest cover required further investigation. The study therefore addressed the existing gaps on the contribution of participatory forest management on the livelihood and forest tree cover. It adopted cross-sectional descriptive research design and application of GIS software. Purposive sampling was used and data analysed within a sample size of 384 persons derived from Fisher's formula. Regression analysis was used with the results showing a positive impact (p-value <0.05) on both livelihood and forest cover. In the conclusion, there was a need for enhanced awareness creation on least practiced user rights and improve on the opportunities of already existing ones. A regulated PELIS should be particularly encouraged in public forests due to its positive impact on forest cover.**

**Keywords:** Community Forest Association, Livelihood, Participatory Forest Management, Plantation Establishment and Livelihood improvement Scheme, User rights

## INTRODUCTION

The forest ecosystem which accounts for about 30% of the global land surface (Meng *et al.,* 2015) has systematically been depleted due to expansion of agricultural production and high human population growth (Food and Agriculture Organization, 2006). It is estimated that about 410 million people are highly dependent on forests for subsistence and income and another 1.6 billion on its goods and services for livelihood (Munang *et al.,* 2011). This essentially means, there is an urgent need to introduce participatory approaches towards forest conservation to salvage the situation, as about 10 million hectares of global forests are also lost annually.

Based on projection trend, the United Nations General Assembly in 1989 called for global meeting to devise integrated strategies that would halt and reverse the negative impacts of human activities into the physical environment and promote environmentally sustainable development in all countries (United Nations, 2023). This subsequently led to the implementation of strategies like enactment of new legislations focusing on participatory forest management approaches around the globe in order to comply with the Rio resolutions (United Nations, 2011). India for example, adopted policies in curbing deforestation and came up with laws regulating tree cutting in State and private forests in compliance with the Rio Summit (Maikhuri *et al.,* 1997).These were positive efforts in operationalization of the Rio Summit resolutions, however, funding and inadequate legislations compromised the sustainability of such projects hence led to the deterioration of forest ecological infrastructure.

At the global level, conventional forest management practices like PFM were incorporated into the forest's legislations in many countries, especially in the Sub Saharan Africa (Sauvage *et al.,* 2014). These were meant to stimulate growth and encourage ownership of these natural resources with the participation of local community, but areas of joint engagement for proper forest protection were not identified and this remained a grey area in the success PFM around the world (Saxena et al., 2002). In Uganda for example, the actual benefits that were accruing to local communities under the PFM agreement were still largely unknown (Driciru, 2011). This therefore subjected a lot of forest resources to abuse through unsustainable exploitation and illegal logging by the forest communities (Driciru, 2011). Mvondo (2006) and Bigombé (2007) also confirmed that the livelihood of the forest communities in Cameroon had not changed significantly since the introduction of PFM. This was attributed to poor governance leading to resource mismanagement. In contrast, Saxena *et al.* (2002); Driciru, (2011); Bigombé (2007) and Mvondo (2006) were in agreement that there was mismanagement of forest resources and little information was known on how PFM had changed the economic fortunes of the local forest communities. This only occurred when there was an unequal access and opportunities in the consumption. Further, none of them did provide a way forward in addressing the livelihood impact as a result of PFM.

In India again, there was more emphasis on the distribution of forest benefits to the communities (Dhanapal, 2019), while in Nepal community forest based programmes were initiated to reverse degradation of State forests that could not be managed and protected sustainably by the government (Pariyar, 2021). In both cases, the principal objective was to increase vegetation cover through operationalization of the policies and distribution of benefits. Rural poverty alleviation was another motivating factor behind PFM in Nepal and India (Thomas *et al.,* 2004). In Honduras and Bolivia, the government had to fully involve the local communities in the management of forests in a participatory manner so as to improve the quality of their livelihood (Nygren, 2005). But despite the arrangement, Cavendish (2000) opined that there was still difficulty in measuring the benefits from the consumption of forests and its resources despite Nygren (2005) assertion that the PFM would improve the local livelihood. Both Cavendish (2000) and Nygren (2005) were in agreement that there was a positive effect of PFM on the livelihood, however measuring its effects on the livelihood posed some difficulty and therefore required further determination.

Studies world over had shown increased richness in species abundance, diversity and density due to participatory forest management practices (Gobeze *et al.,* 2009). PFM had therefore been used as an approach to achieve sustainability of threatened or endangered forests ecosystems through increased cover. Scherr et al., (2009) further noted that information was still lacking on how PFM had improved the condition of the forest cover. This information could be instrumental in development of policies and laws aimed at increasing the forests cover. The more the community were involved in PFM, the fewer the number of illegal activities in the forest managed under PFM and the higher diameter at breast height (DBH), the basal area and density of tree (Beck, 2000). Participatory approach was therefore a tool for forest resource management, but how it improved the forest cover still remained a grey area that needed to be accounted for. Gobeze *et al.* (2009) confirmed that there was increased richness in species composition, diversity and density due to participatory forest management practices, while Scherr *et al.* (2009) found out that information was still lacking to show how PFM had improved the condition of the forest. While the latter confirmed the positive effect of PFM on the status of the forest, the former reported that there was lack of information to show the extent PFM contributed to the forest cover.

Finally, in Kenya, farming inside the forests, commonly referred to as shamba system was banned in the 1990s but was later re-introduced as *plantation establishment and livelihood improvement scheme* (PELIS) in 2007, as part of the reform in forest sector (Government of Kenya, 2013). The principal aim was to address the gaps in the forest cover and socio-economic challenges facing the community. However, Cavendish (2000) found out that there was lack of evidence for the impacts of PFM on livelihood and forest cover. The study would therefore assess the impact of participatory forest management on

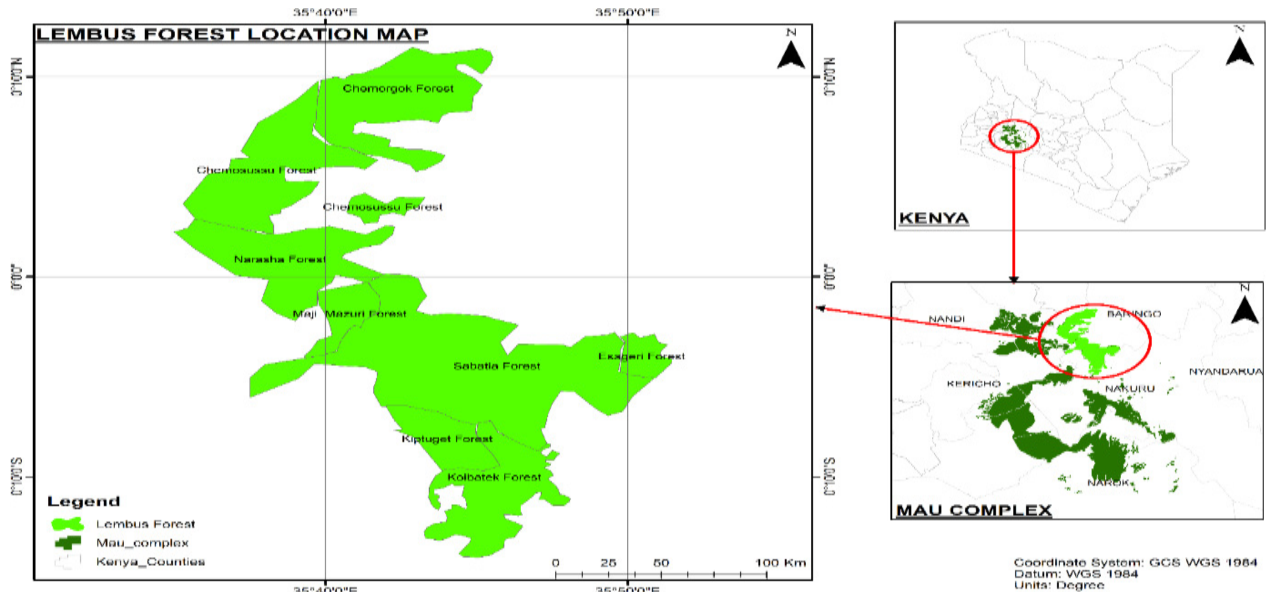


**Figure 1.** Study Area

forest cover and community livelihood in Lembus ecosystem in Baringo, Kenya.

## The Study Area

The study was conducted in Lembus Forest which is part of the Western Mau forests complex. It lies between latitudes 000-4' S and 00-8' N and longitudes 350-32' E and 350- 48' E. The forest is made up of eight major blocks. These are Chemorgok (largely a conservation area), Chemususu, Narasha, Maji Mazuri and Kiptugen. Others are Koibatek, Sabatia and Esageri Forest blocks, covering an area of approximately 98,400 Ha in total, thus accounting for 24% of the total Mau complex forest ecosystem. The forest is located at an altitude of 2391 m and receives a mean annual rainfall between 1200 mm and 1800 mm. The mean annual air temperature ranges from 100ºC to 240ºC. It comprises of both indigenous and plantation forest. Figure 1 above shows the national position of the ecosystem.

## METHODOLOGY

Cross-sectional study design was used to collect data and information from the study population. It provided real data at a particular point in time i.e. food production under PELIS. The population of the study area was ten thousand and two persons comprising of all the eight CFAs within Lembus forest ecosystem with a sample size of 384 persons. The sample size was determined by Fischer's (1998) formula:

n = Z2 p (1-p)/e2

Where **n** is the minimum sample size (population>10,000) required, **Z** is the standard normal deviate at the required confidence level, (set at 1.96 corresponding at 95% confidence level adopted for the study), **p** is population proportion estimated to have a particular characteristic (where there is no reasonable estimate, a default of 50% or 0.5 is acceptable) and **e** is the level of precision or sampling error at 95% confidence level, giving the value of **e** as 0.05 (Glenn, 1992). Stratified sampling was used due to its ability to reduce the sampling error. On forest cover, GIS software was used to analyse digital maps.

## RESULTS AND DISCUSSION

### Impact of participatory forest management on the livelihood in Lembus forest ecosystem

Participatory forest management was introduced as a tool to ensure inclusion in the management of forests resources by Government of Kenya, principally to protect its resources, while enhancing livelihood of the communities. This chapter therefore provides analysis of how PFM did influence livelihood of the forests community and its impact on forests cover.

### Socio economic characteristics of the respondents

### Age group

Age has been analysed to determine the active participants in the PFM. It has been considered a key

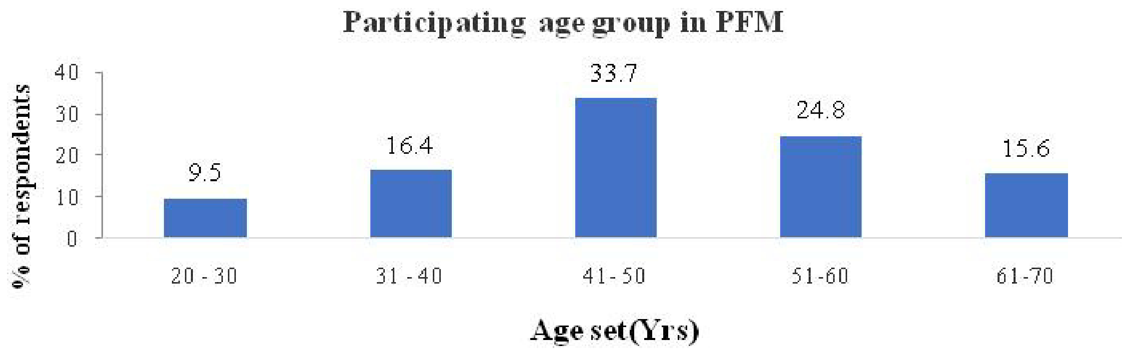


**Figure 2.** Age group participating in PFM


**Figure 3.** Gender participation in PFM in Lembus ecosystem

factor in determining the active stage of the community members that are involved in decision making processes towards achievement of critical socio-economic goals like PFM. The youthful age of between 20 - 30 years accounted for 9.5% of the respondents who never actively participated in PFM. This was a transitional period that saw a high enrolment rate of students in high school and subsequently ended up into institutions of higher learning. However, the active participants were aged between 41 - 50 years, accounting for 33.7%. This was the active age of the society tasked with driving the economic agenda. While Collaborative Partnership on Forests, (2013) appreciated the involvement of the youth in spearheading ecological literacy, the opposite happened in the Lembus ecosystem. This could be attributed to increased enrolment in institutions of higher learning and lack of priority in seeking alternative livelihood venture. Figure 2 above presents the findings as distributed within age sets.

## Gender participation in Lembus PFM

Gender engagement in PFM initiatives is key in realizing sustainable food production and enhanced tree cover (FAO, 2015). In many rural areas of Kenya, women took active role in subsistence farming, unlike their male counterparts. However, in this study results showed men were active participants in forests management at 26% while women were rated at 20%. Most households were headed by men hence offering full socio-economic support to the family (Figure 3).

According to UN General Assembly on Sustainable forest management, women were the principle users of forests for fodder, fuel wood, medicines and food, while men tend to harvest relatively high value products like wood (CPF, 2013). One of the principle roles of women in forests management was to provide livelihood and this explained the underlying factors that constrained food security in Africa (Kabutha and Humbly, 1996). Women reportedly managed as much as 74% of Kenya's smallholding farms, meaning they had the capacity to sustain production of the country's land resources (Kabutha and Humbly, 1996). This essentially contradicted the findings of the study, especially women involvement in forest management. In India, for example over 40% of women income came from the forests. This meant that women were more actively focused on forests management as compared to their male counterparts (Crawford, 2012).

## Education status of CFA members

Level of education has direct impact on livelihood and general socio-economic status of any society (Mutisya et al., 2016). In Lembus, for example, over 35% of respondents accounted for primary school graduates

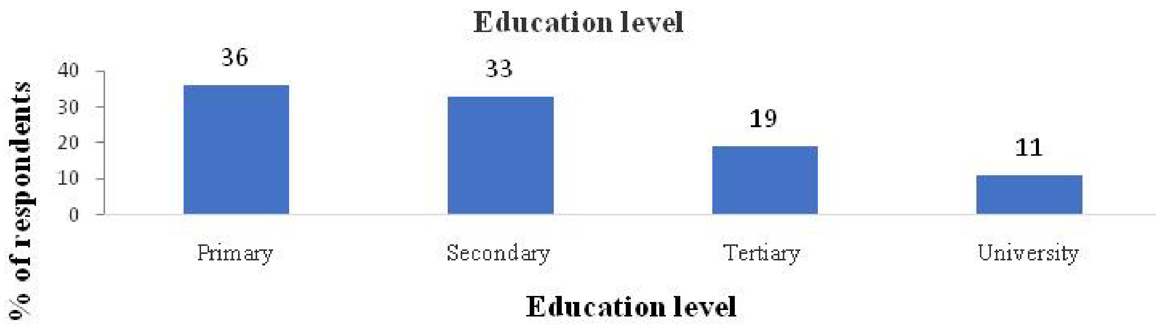


**Figure 4.** Education status in Lembus Forest Ecosystem

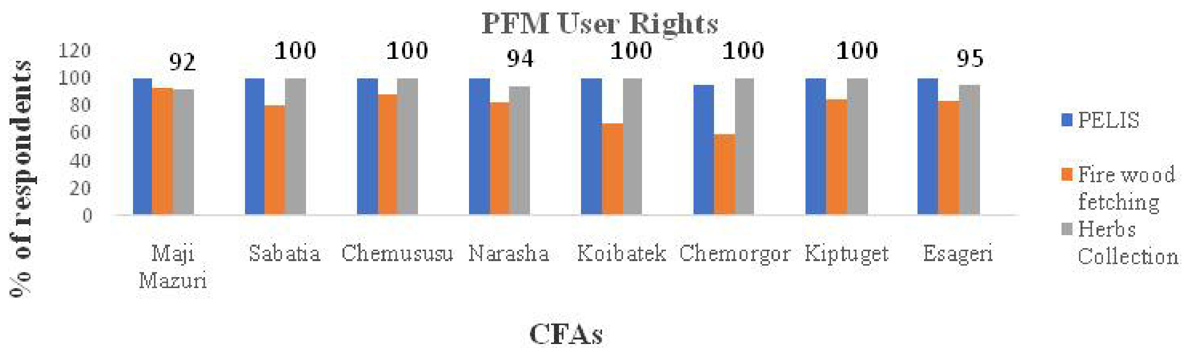


**Figure 5.** PFM user rights in the Lembus ecosystem

while a paltry 11% university graduates. 33% of the respondents accounted for secondary school graduates which was very key in obtaining critical data and information during focus group discussions (FGDs). Figure 4 above presents the findings.

## Impact of participatory forest management on community livelihood, 2015 – 2019

This section operationalizes PFM into specific user rights that the forest law permitted the forest communities to undertake towards improving the livelihood. These user rights included PELIS, bee keeping and firewood collection. Others are ecotourism, grazing, herbs collection and scientific educational sites. However, for the purposes of this study, only three user rights were used namely, PELIS, fuel wood and medicine / herbs collection. The proceeds emanating from these user rights improved the livelihood of the forest communities as well as the forest cover. Figure 5 above shows findings of the rate of adoption of user rights.

As illustrated above, all the seven CFAs have high approval rating for the PELIS at an average of 97.6%. This was attributed to its ability to unlock potentials for livelihood improvement in the county. The immediate effect of adopting the PFM user rights was the decline of poverty levels(Government of Kenya, 2018). The decline in poverty index was a function of full operationalization of PFM with more emphasis on PELIS. About 90 % the Lembus community got their livelihood from the forest. The result also concurred with Wambugu et al. (2018) that the forest adjacent communities tended to gain more economic benefits from the utilization of forest resources, including PELIS. Further, in a study carried out in Bonga forest in Ethiopia, it was found that over 73% of the household within and around the forest heavily earned their livelihood through forest farming (Gobeze et al., 2009).

## Analysis of crop production under participatory forest management on improved community livelihood (CFAs)

Maize and beans were the two crops intercropped with tree seedlings and produced a quantifiable result. At initial stages of intercrop with either *Cupressus* or *Pinus* species, there was no competitive effects on nutrients, however when the plantation reached the fourth year, growing of food crops was stopped. In the Lembus complex, maize and beans were the two main intercrops with a high yielding results that potentially changed the livelihood status of the local population. Table 1 below provides the findings of production (Kg) between 2015 – 2019.

**Table 1.** Crop production under PELIS

| Crop | 2015(Kg) | 2016(Kg) | 2017(Kg) | 2018(Kg) | 2019(Kg) |
|---|---|---|---|---|---|
| Maize | 6,071,310 | 8,538,940 | 12,179,610 | 16,959,960 | 12,179,610 |
| Beans | 85,860 | 145,170 | 183,420 | 216,090 | 386,910 |

***Source:*** *Field survey*

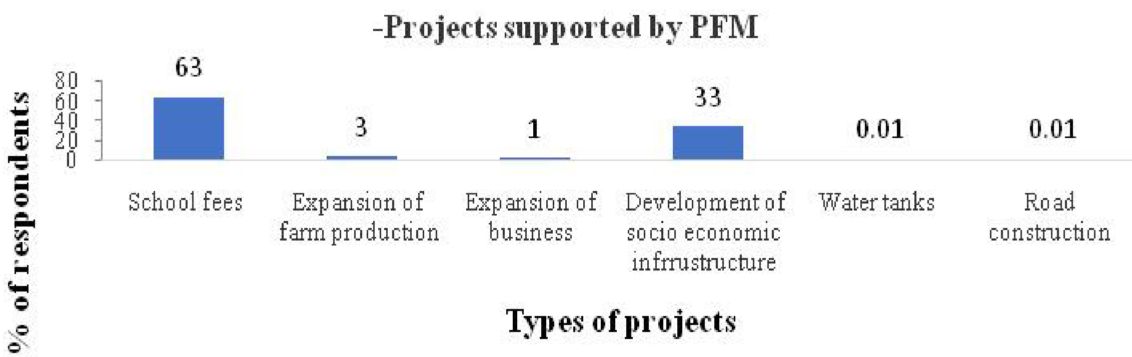


**Figure 6.** Projects supported by PFM proceeds

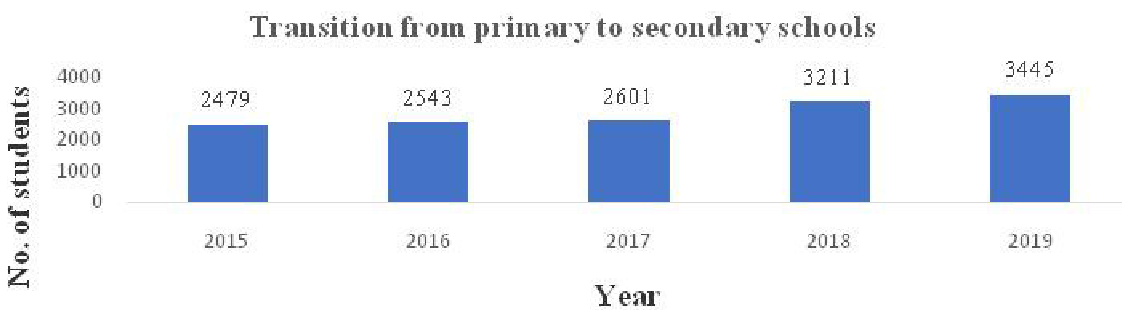


**Figure 7.** Transition from primary to secondary schools (2015 – 2019)

## Projects support through participatory forests management practices

Analysis of immediate social economic intervention of PFM showed a high rating in school enrolment, followed by infrastructural development in areas of commercial building and business enterprises. Figure 6 above provides the result.

## School registration status between 2015 to 2019

During this period, there was a sustained increase in enrolments and transition from primary to secondary schools. The high transition rate was attributed to increased income from PELIS and other related user rights. Figure 7 above presents the students transition from 2015 to 2019, according to the Sub County Director of Education, Koibatek.

## Development of socio-economic infrastructure (commercial and business enterprises

The proceeds from PELIS, herbs and fire wood sales resulted into positive impact on the economic status of CFAs. Before the operationalization of the forest law leading to adoption of user rights, the poverty level had shot up to 60% (Government of Kenya, 2013). However, the economy of the local forest community steadily shot up with increased awareness creation and public participation on the forest farming opportunities comm-only, known as PELIS, hence recording a poverty reduction to 52.2% (GoK, 2018). This subsequently saw an exponential increase in school enrolment and transitional programme as shown in figure 7 above.

Development of the rural infrastructure, especially the construction industry became an indicator of improved livelihood. A number of construction projects were recorded in Eldama Ravine, the local township (GoK,


**Figure 8.** Environmental Impact Assessment reports for livelihood projects (2015 – 2019)

**Table 2.** Participatory forest management variables

| Year | Income for household (Kshs) | Costs for the households Labor, fertilizer (Kshs) | Net income for households (Kshs) |
|---|---|---|---|
| 2015 | 58,786 | 6,550 | 52,236 |
| 2016 | 73,183 | 8,050 | 65,133 |
| 2017 | 87, 780 | 10,050 | 77,130 |
| 2018 | 103, 358 | 13,050 | 90,308 |
| 2019 | 124, 265 | 17,000 | 107,265 |
| **TOTAL** | **447,372** | **54,700** | **392,072** |

***Source:*** *Field survey*

**Table 3.** Major livelihood projects supported by PFM (school enrolment, projects)

| Year | No. of students' enrollment | No. of projects |
|---|---|---|
| 2015 | 2179 | 250 |
| 2016 | 2543 | 387 |
| 2017 | 2601 | 436 |
| 2018 | 3211 | 487 |
| 2019 | 3445 | 534 |
| **TOTALS** | **13,979** | **2,094** |

***Source:*** *Field survey*

2018). According National Environment Management Authority (NEMA), 70% of the projects were commercial and business enterprises. With increased economic status and reversed poverty levels, a number of infrastructure project were evident in towns around the forest ecosystem. Figure 8 above provides the number of projects undertaken between 2015 – 2019.

**Trend Analysis on community livelihood (Costs on school enrolment and transition, commercial projects) under participatory forest management between 2015 to 2019**

In order to test the rate of increment, Mann-Kendall statistical test for trend analysis was used to assess the increasing or decreasing trend over time and its statistical significance. The test was used to examine the trend of PFM (household income, household costs and net household income) while livelihood parameters specifically included the rate of enrollment in schools and the number of projects undertaken as PFM proceeds as main variables. The idea was that if a trend was present, then, there was a direct impact of PFM through its quantified net income to school enrolment and the number of projects across the study period. Table 2 above operationalizes the variables for the participatory forest management in Lembus forest ecosystem.

The Forest Act, 2005 anticipated increased livelihood to the forest communities upon full adoption and operationalization of PFM principles. In the study area, the main beneficiary of PFM proceeds was in education and commercial sectors (construction business enterprises). Table 3 above presents major variables for livelihood, thus including the rate of enrolment in schools and the number of projects undertaken from PFM proceeds.

**Analysis of Net income (Kshs)**

This test was performed to examine trend of the total net


**Figure 9.** Trend in population Net income

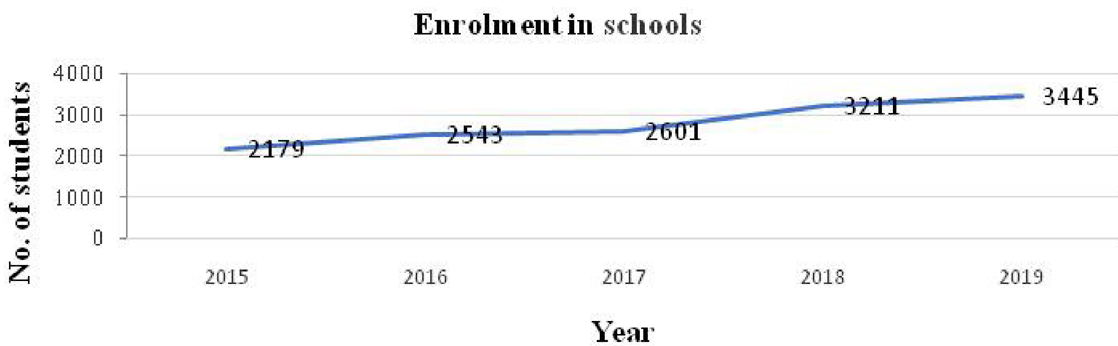


**Figure 10.** Trend in school enrolment

income accumulated each year via PFM from 2015 to 2019, with the p value 0.027486, being less than benchmark threshold (5% significance level). The tau value was positive, the null hypothesis was then rejected and therefore there was an increasing monotonic trend in the net income of PFM across the study period of 2015-2019 (Figure 9 above illustrates the increasing trend of net population income in the study period.

## Analysis of school enrolment

During the study period (2005 to 2019), there was a sustained increase in enrolments and transition from primary to secondary schools. The high transition rate was attributed to increased income and livelihood status due to PELIS and other related user rights. Trend analysis for school enrolment using Mann Kendall tau = 1, 2-sided value =0.027486 was done to test the trend of enrollment from 2015 to 2019 under the PFM**.** The test was performed to examine trend of enrolment in each year from PFM. The p value of 0.027486 was less than benchmark threshold (5% significance level).The results showed the tau value was positive, therefore there was an increasing monotonic trend in the school enrolment number as a result of PFM across the study period of 2015-2019 (Figure 10).

## Analysis of livelihood projects

Another indicator of improved livelihood was the development of the rural infrastructure, especially the construction industry. A number of construction projects were recorded in Eldama Ravine, the local township (Government of Kenya, 2018). With increased economic status and reversed poverty levels, a number of infrastructure projects were evident in towns around the forest. These projects were also evident in Maji Mazuri, Esageri and Torongo townships, all falling within the Lembus ecosystem. Figure 11 below presents the increasing trend in social economic infrastructural projects (2015 – 2019).

Trend analysis for projects using Mann Kendall at tau = 1, 2-sided p-value =0.027486. This test was performed to examine trend in the number of projects each year. The null hypothesis was then rejected and therefore there was an increasing monotonic trend in the numbers of projects as a result of PFM across the study period (2015-2019).

## Analysis of poverty levels

Before the operationalization of the forest law, the poverty level had shot up to 60% poverty index (GoK,


**Figure 11.** Trend in infrastructure development

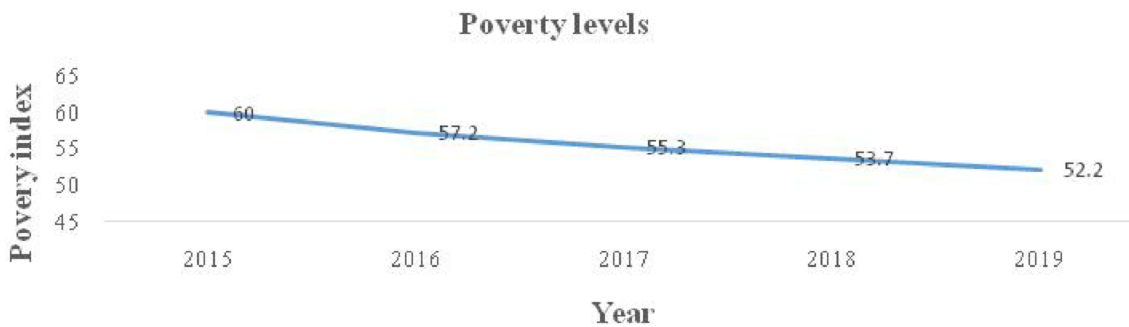


**Figure 12.** Trend in poverty

2013). However, the income of the local farming communities steadily shot up with increased awareness creation and public participation on the User rights in the forests hence recording a poverty reduction to 52.2% (GoK, 2018). This subsequently saw an exponential increase in school enrolment and transitional program. PFM has played a significant role in reducing the poverty index, as the income increased. The poverty index reduced, as shown by the correlation coefficient (-0.98) which was significant at 5% level of significance. With an exponential increase in population, PFM caused the poverty index to fall by 9.5% (Figure 12).

In a concurrence, Gobeze et al. (2009) in a study to assess the impact of PFM in Bonga forest in Ethiopia, also found out its positive influence on poverty reduction of the locals. The study showed 73% of the forest community households depended on forest-based livelihood activities.

### Analysis of impact of PFM (Net income) on livelihood (School fees, Projects)

The impact of PFM on livelihood was assessed using regression analysis. PFM was quantified in terms of the net income of the population which was proportioned to school fees and the number of projects registered in the study period. It was important to note that 40% of the overall income accounted for school fees while 35% accounted for the income that went to project development. The aim was to assess the direct income of PFM through its quantified income that is allocated to both school fees and project development. A simple linear regression model was formulated for the relationship between a response variable and one predictor variables as shown below.

$Y_i = \beta_0 + \beta_1 X_{1i} + \epsilon_i.$

Where $Y_i$ is response variable (school fees, projects development).

,$\beta_0, \beta_1$, are regression coefficients and $\epsilon_i$ is error term or the random component with mean zero and constant variance.

Multiple linear regression lines written in matrix form.

$Y = X\beta + \epsilon.$

Where

$$Y = \begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{pmatrix}, X =$$

Where Y is the vector of response variable, X is the data matrix, $\beta$ is the vector of estimates and $\epsilon$ is the vector of the error terms (random component).

In order to estimate regression coefficients, the least-

**Table 4.** Impact of PFM on livelihood (school enrolment)

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 1337.6331 | 325.1520 | 4.11 | 0.0260 |
| School fees | 4.839 × 10−6 | 1.007 × 10−6 | 4.81 | 0.0171 |

**Table 5.** Impact of PFM on livelihood (development projects)

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 36.6277 | 69.4850 | 0.53 | 0.0061 |
| projects income | 1.392 × 10−6 | 2.459 × 10−6 | 5.66 | 0.0109 |

squares method was used for the equation, and the formula below for regression coefficients.

$\hat{\beta} \quad (X^T X)^{-1} X^T Y$

Equation is possible if and only if the matrix $(X^T X)$ is invertible and full ranked.

In this study, a simple linear regression model was used to determine a relationship between PFM income assigned to livelihood (School enrolment and number of development projects) denoted by $X$ and the response variables, school enrolment, number of projects and forest cover each denoted by$Y$.

$Y = \beta_0 + \beta_1 X_1 + \epsilon.$

Where $\beta_0$ is the intercept, $\beta_1$ are the regression coefficients?

The tabulation was done as shown in table 4 above

Table 4 above shows the estimate, standard error, t-value and p- value for intercept and school fees. The income due to PFM that was allocated to school fees was the predictor variable that was taken to explain the overall school enrolment across the study period. The enrolment of students across the study period was the response variable. Both intercept and school fees were significant (p-value <0.05). The results suggested an increase of the amount due to PFM that was allocated to school fees by one million Kenya shillings caused the number of student enrolled each year to increase by 5 at a constant intercept. This showed that the direct impact of PFM on livelihood through school enrolments was due to increase of income attributed to school fees. The impact of PFM on development project was also examined by simple regression analysis showing the estimate, standard error, t-value and p-value for intercept and number of projects. The income due to PFM allocated to project development was the predictor variables while the annual projects were taken as the explanatory variable as shown in table 5 above.

Both intercept and project development income are significant (p-value <0.05). The results showed the direct impact of PFM on livelihood through project development. In a related study done at Arabuko forest, Kenya, showed livelihood improvement by embracing PFM principle unlike before the introduction of PFM (Matiku et al., 2013). The results also indicated that the benefits accruing from direct consumption of forests resources was much higher than the costs associated with the same and majorly addressed livelihood.

Despite significant livelihood improvement in the last ten years, there was still a need to improve on the legal frame work under which PFM operated. About 90% of the respondents required an expanded public participation to bring onboard number of players. About 90% of the respondents believe that inadequate participation in PFM was a function of lack of training and capacity improvement among the locals. This had led to lack of awareness on the rights and obligations of the local community on the use of forests resources. In concurrence with the result, Wambugu et al., (2018) in a study in Aberdare Forest Ecosystem found out that most of the of the households i.e. 94% derived benefits from the forest ecosystem. Himberg et al., (2009) in a study to investigate the benefits and constraints of participation in forest management in Taita Hills, also found huge benefits the community got from Taita hills under PFM. Figure 13 below, therefore shows the proposed interventions to effective PFM operationalization in the Lembus ecosystem.

### Determination of the impact of participatory forest management on forest cover in Lembus ecosystem

Using GIS software to analyse digital maps, the figure below shows state of Lembus forest in 2006, one year after the enactment of the Forests Act, 2005. The figure offered a bench mark on the gradation and degradation of the forest's ecosystem in the subsequent years (Figure 14).

The forest cover within the ecosystem accounted for 50.63%, while agricultural land, grassland and other uses occupied 32.59%, 16.78% and 0.7% respectively.

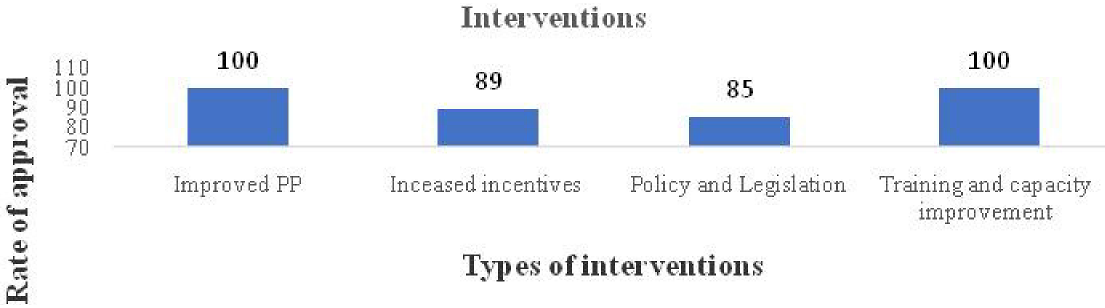


**Figure 13.** Proposed intervention on PFM improvement

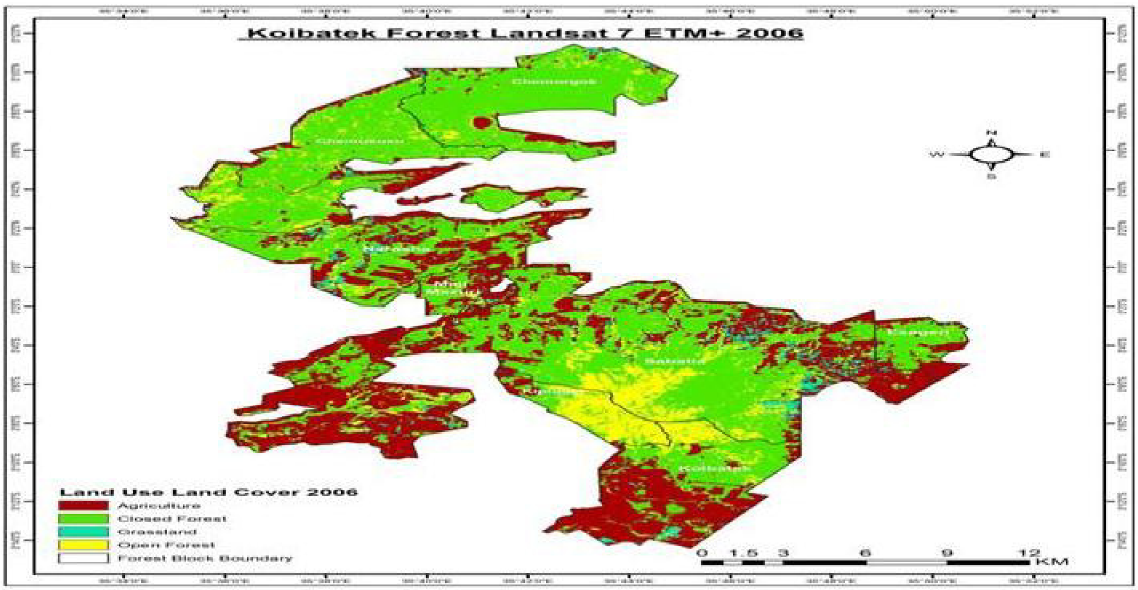


**Figure 14.** Map of Lembus forest, 2006

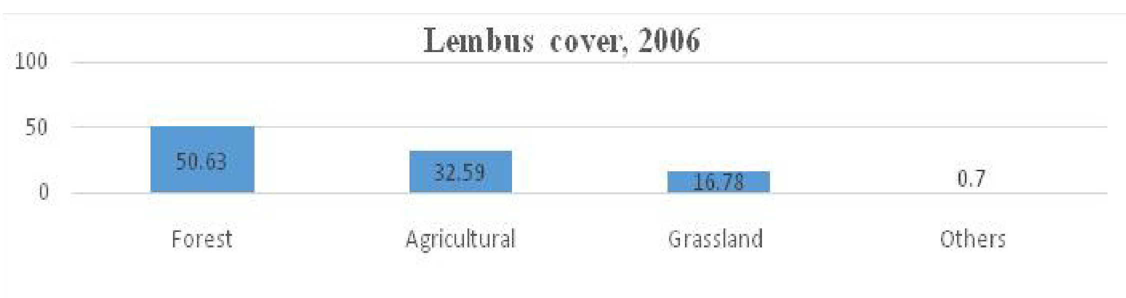


**Figure 15.** Lembus forest cover, 2006

Figure 15 above analyses the state of the forest cover.

### Contribution of PFM on forest cover improvement in Lembus Ecosystem

The ecosystem had a total of eight forest blocks manned by the respective CFAs, each having a tree nursery. Table 6 below shows contribution of PELIS to the improvement of forest cover in Lembus ecosystem. From the year 2015, plantation establishment under PELIS accounted for 3.4% of the total forest area, but steadily shot to 18.1% in 2019. This was evidenced as a positive impact with an annual forest cover increment of 4% under

**Table 6.** Plantation Establishment under PELIS(2015-2019)

| CFA | Size of forest (Ha) | No. of CFA | Area under PELIS 2015 (Ha) | Area under PELIS 2016 (Ha) | Area under PELIS 2017 (Ha) | Area under PELIS 2018 (Ha) | Area under PELIS 2019 (Ha) | Total (Ha) | % of Forest under PELIS |
|---|---|---|---|---|---|---|---|---|---|
| Narasha | 6159.40 | 1256 | 229.0 | 241.5 | 249.0 | 251.9 | 254.3 | 1,225.9 | 20.0 |
| Chemorgok | 5851.56 | 728 | 132.6 | 135.6 | 140.1 | 144.5 | 146.0 | 698.8 | 12.0 |
| Chemususu | 11304.80 | 1249 | 240.3 | 245.4 | 247.8 | 250.4 | 252.9 | 1,236.8 | 11.0 |
| Koibatek | 9145.73 | 2108 | 392.6 | 405.6 | 414.1 | 422.6 | 426.8 | 2,061.7 | 23.0 |
| Kiptuget | 854.75 | 1063 | 93.16 | 107.3 | 118.2 | 129.1 | 150.6 | 598.3 | 70,0 |
| Maji Mazuri | 6097.40 | 1361 | 248.0 | 256.3 | 264.6 | 270.1 | 275.6 | 1,314.6 | 22.0 |
| Esageri | 7797.40 | 1585 | 288.9 | 297.6 | 311.4 | 314.4 | 317.7 | 1,530.0 | 20.0 |
| Sabatia | 4119.40 | 654 | 121.9 | 124.5 | 127.1 | 129.8 | 132.4 | 635.7 | 15.4 |
| | 51,330.44 | | 1,746.4 | 1,813.8 | 1,872.3 | 1,912.8 | 1,956.3 | 9301.8 | |

***Source:*** *Field data, 2021*

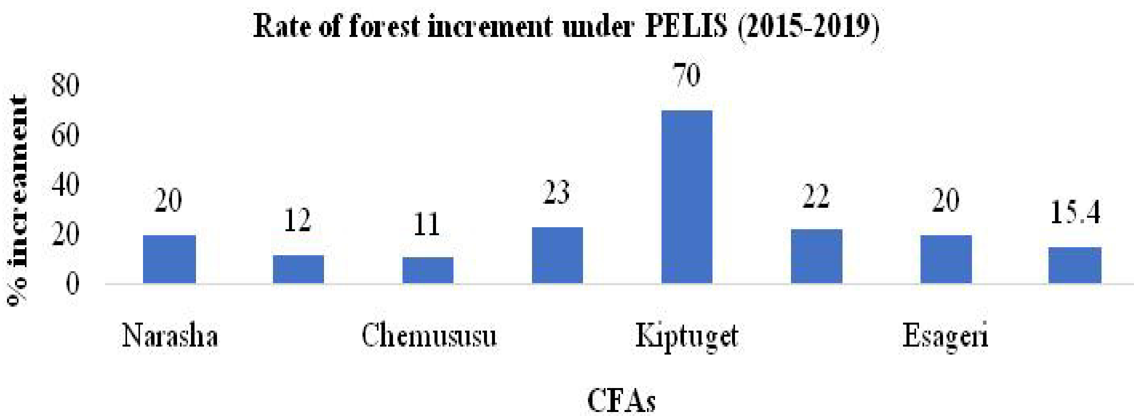


**Figure 16.** Contribution of PELIS on forest improvement

PELIS. The forest area was likely to be closed in by 2025, if the rate of increment remained constant.

PELIS played a significant role in improvement of forest cover in the ecosystem. From 2015 to 2019, there was a general improvement in forest. An average of 24.1% of the total forest area had been converted into plantation of exotic species, primarily *Pinus* spp, *Cupressus* spp and *Eucalyptus* spp (Figure 16).

## Analysis of forest cover improvement (2006 – 2019)

Significant improvement had been achieved between 2006 and 2019 with a 35.97% increment in forest cover. The increment was attributed to increased participation of CFAs into forest protection, development and implementation PFMPs. The agricultural land also reduced by 26.69%. This basically meant that a lot of forest land had been replanted including those under agricultural (PELIS) and grassland. A drastic reduction of grassland by 8.39% was a function of massive afforestation between 2006 to 2019. Figure 17 below provides the state of the forest cover.

This basically meant that a lot of forest land had been replanted including those under agricultural (PELIS) and grassland. A drastic reduction of grassland by 8.39% was a function of massive afforestation from 2006 to 2019. (Figure 18).

Major contributor of increased forest cover was legalization of PELIS into the forest management and active participation of CFAs in firefighting and implementation of PFMPs. Several forest cover improvements across the globe has been attributed to forest farming and extensive engagement of farmers in forest management through PFM. Many countries across the globe had therefore regained the lost forests ecosystems through PFM, where forest farming played a pivotal role (Driciru, 2011). The trend in forest gradation globally replicated itself in the Lembus ecosystem through PFM initiatives as was found out by (Driciru, 2011). The table 7 below shows the status of forest ecosystem in 2019.

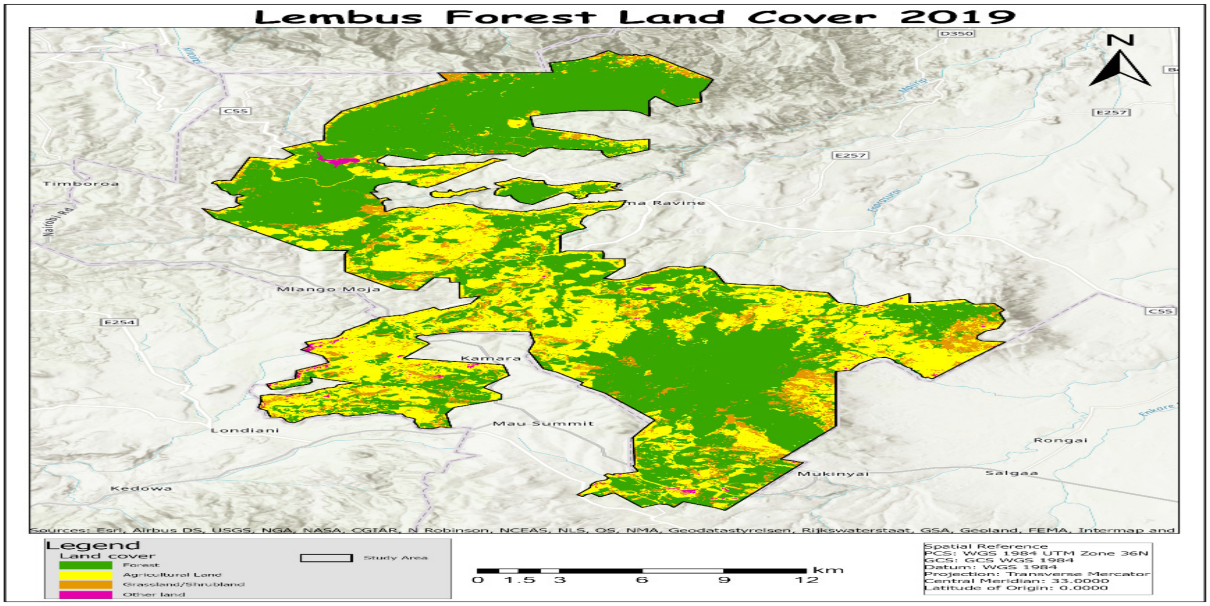


**Figure 17.** Lembus forest cover, 2019

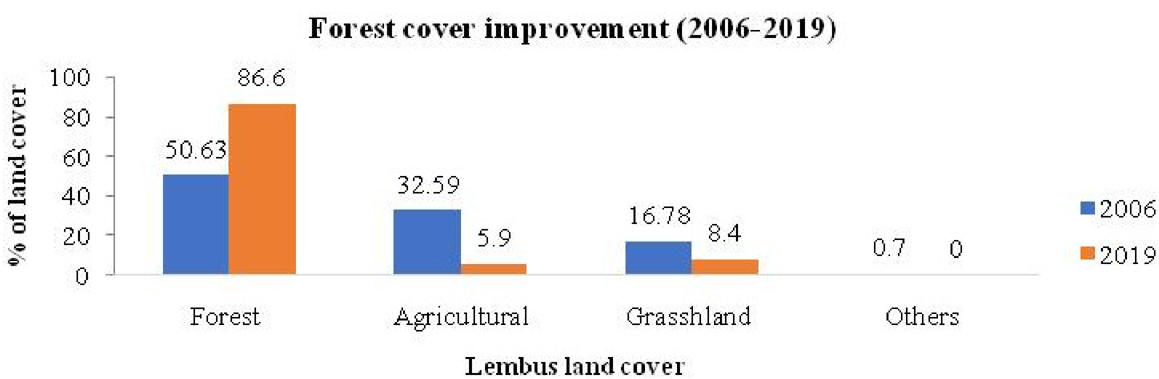


**Figure 18.** Lembus forest cover, 2006

**Table 7.** Status of Lembus forests ecosystem, 2019

| Forest Block | Natural forest (Ha) / Protective | Exotic/ plantation (Ha) | Grassland / Glades (Ha) | Bushland/ Shrubs/ Degraded (Ha) | Bamboo (Ha) | Other uses (Ha) | Total forest area (Ha) | Vegetation cover (Ha) |
|---|---|---|---|---|---|---|---|---|
| Chemususu | 10298.80 | 891.00 | 22.00 | 0.00 | 0.00 | 93.00 | 11304.8 | 98.90 |
| Koibatek | 3256.70 | 2966.53 | 408.50 | 0.00 | 2514.00 | 0.00 | 9145.73 | 68.04 |
| Kiptuget | 450.00 | 374.7 | 0.00 | 30.00 | 0.00 | 0.00 | 854.70 | 96.48 |
| MajiMazuri | 1255.00 | 3671.40 | 131.00 | 720.00 | 320.00 | 0.00 | 6097.40 | 80.70 |
| Sabatia | 1565.10 | 2123.10 | 0.00 | 281.20 | 150.00 | 0.00 | 4119.40 | 89.50 |
| Narashsa | 724.00 | 4208.4 | 1,227.00 | 0.00 | 0.00 | 0.00 | 6159.4 | 80.07 |
| Esageri | 4731.50 | 1516.00 | 1220.00 | 329.90 | 0.00 | 0.00 | 7797.40 | 80.10 |
| Chemorgok | 5647.00 | 164.56 | 40.00 | 0.00 | 0.00 | 0.00 | 5851.56 | 99.30 |

***Source:*** *Researcher, 2019*

**Table 8.** Participatory Forest Management (Income)

| Year | CFA members (N) | Forest cover (Ha) | Poverty index | Net population income (Ksh) | School fees (Ksh) | Projects expenditure (Ksh) |
|---|---|---|---|---|---|---|
| **2007** | 10002 | 307.0740 | 60.2 | 522,464,472 | 208,985,789 | 182,862,565 |
| **2010** | 10002 | 262.9215 | 59.4 | 651,460,266 | 260,584,106 | 228,011,093 |
| **2013** | 10002 | 293.3621 | 58.8 | 771,454,260 | 308,581,704 | 270,008,991 |
| **2017** | 10002 | 301.2657 | 56.9 | 903,260,616 | 361,304,246 | 316,141,216 |
| **2019** | 10002 | 307.4900 | 55.1 | 1,072,864,530 | 429,145,812 | 375,502,586 |

***Source:*** *Authors field data, 2021*

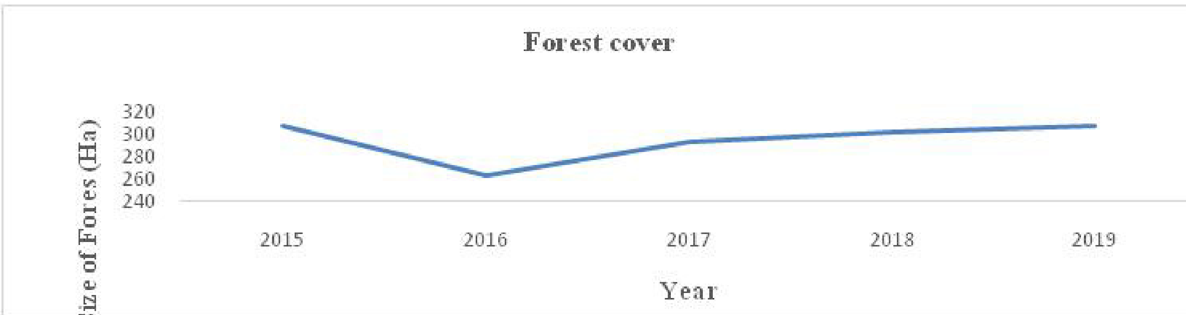


**Figure 19.** Increasing trend in forest cover in Lembus forest ecosystem

**Table 9:** Impact of PFM on forest cover

| | Estimate | Std. Error | t value | Pr(>\|*t*\|) |
|---|---|---|---|---|
| (Intercept) | 210.1706 | 17.0094 | 12.36 | 0.0011 |
| Forest devt fees | $9.517 \times 10^{-7}$ | $2.107 \times 10^{-7}$ | 4.52 | 0.0203 |

## Analysis of impact of participatory forest management on forest cover

The impact of PFM on forest cover was then examined using Mann-Kendall to test possible trend in the net population income, number of projects, school enrollment and forest cover. Then, regression analysis was used to examine how each of the income could lead to livelihood and forest cover improvement (Table 8).

The results indicated that there was an increasing trend (Mann Kendall) in the forest cover observed across the study period, that was Tau=1, p-value=0.027486, being less than the bench mark threshold (5% significance level). The achievement was attributed to regulated access into the forest and economic activities like PELIS, bee keeping and collection of herbs. Similarly, in Ethiopia, Bonga forest, a similar study found a healthy distribution of forest under the PFM (Gobeze et al., 2009). Similarly, studies in countries like India (e.g. Gujarat, Andhra Pradesh, Haryana, Madhya Pradesh and West Bengal) recorded improvements in forest cover increment, productivity and diversity of vegetation (Prasad, 1999). Figure 19 above is a plot forest cover between 2007 to 2019 showing an increment.

## Regression analysis of participatory forest management on forest cover in Lembus forest ecosystem

The impact of PFM on forest cover was directly examined through the income cost from PFM that was allocated to the forest development activities. The income from PFM allocated to forest cover was the predictor variable while the annual forest cover was the response variable. Table 9 above shows the estimates, standard error, t value and p-value of the intercept and forest cover.

The intercept and the forest development fee were significant (p-value<5% significance level). The interpretation of the model was that an increase of the forest development fee due to PFM by ten million Kenya shillings caused the forest cover to increase by 10 ha holding the intercept constant. The standard error of the estimates was low (almost zero).

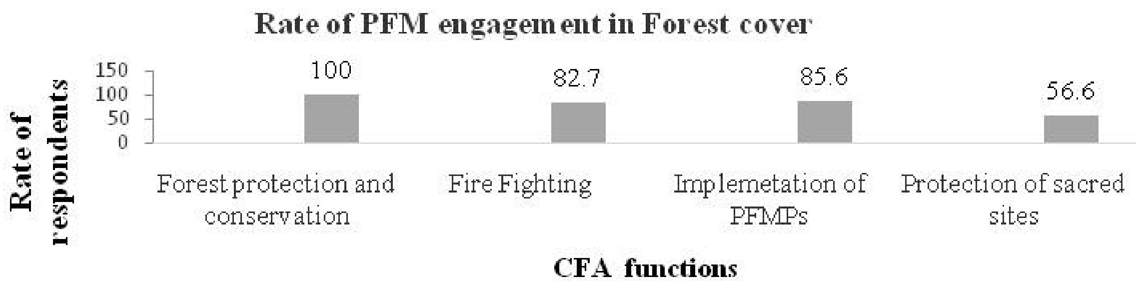


**Figure 20.** Rate of PFM engagement by CFAs

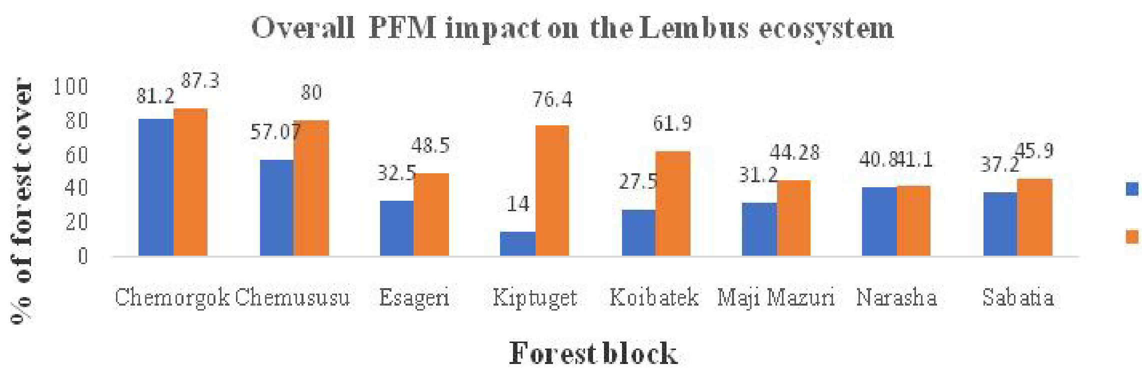


**Figure 21.** Forest cover performance (2007 and 2019) in Lembus ecosystem

**Table 10.** Rate of forest reduction in Lembus ecosystem

| Forest block | % size reduction | % size increment | Causes |
|---|---|---|---|
| Chemorgok | 33.6 | | Illegal encroachment around Kaplomoi |
| Chemususu | 0.4 | | Chemususu Dam construction |
| Esageri | 0.4 | | Illegal Encroachment |
| Kiptuget | 5.2 | | Illegal encroachment |
| Koibatek | 0.36 | | Illegal encroachment. |
| Maji Mazuri | | 41.9 | Gazettement |
| Narasha | 0.19 | | Excision |
| Sabatia | | 49.3 | Gazettement |

***Source:*** *Field Survey, 2022*

## Forest cover change detection outcome (2007 – 2019)

Results showed that the northern part of the study area has been under forest cover throughout the study period and the southern central part experienced gradual increase in forest cover from 2007 to 2019. This was a function of improved vigilance of communities on forest protection and conservation which accounted for 100% participation. The conservation aspect was attributed to PELIS activities that was immediately launched and also recorded a 100% participation. 100% of local communities were also engaged in firefighting activities, especially during dry seasons characterized with the lowest moisture content (Figure 20).

However, the central part of the study area had undergone rapid tree harvesting throughout the study period. In 2007, the forest cover was 226.17 km$^2$ (42%), agricultural land was 73.57 km$^2$ (16%), while grasslands and shrub lands accounted for 225.31 km$^2$ (42%) and other land at 2.46 km$^2$(0.45%). There was a 13% increase in forest cover between 2007 and 2010 amounting to 75.96 km$^{2.}$ During the same period, grasslands and shrub land reduced by 16% and agricultural land reduced by 3%. Figure 21 above presents the status of forest cover between 2007 and 2019.

**Analysis of impact of PFM on forest cover improvement in the Lembus forest ecosystem (2007 and 2019)**

**Analysis of forest size reduction (Ha) between 2007 to 2019**

Sections of forest size reduction was evident in Chemorgok, Chemususu and Esageri. Others included Kiptuget, Koibatek and Narasha. Increment in forest size was also observed in Maji Mazuri and Sabatia. Table 10 above analyses the rate of reduction and increment per block between 2007 to 2019.

Forest area reduction had been attributed to excision for special use purposes like dam construction (Chemususu Dam). According to forest authorities, illegal encroachment accounted for half of forest size reduction. Excision of the forest for major Government flagship projects like Chemususu Dam, greatly had an impact on the reduction of the Chemususu forest.

## CONCLUSION

From the results, it was concluded that participatory forest management did impact positively on the livelihood of the local Community Forest Association (CFAs) as anticipated in the Forest Act, 2005. In all user rights issued to CFA members, PELIS was widely adopted followed by grazing, firewood and herbs collection respectively. This was a direct transformation of rural socio-economic status and improved tree cover. The impact was evidenced by increased transition from primary to secondary school and rapid infrastructure development in commercial and business expansion projects. It also saw increased forest cover mainly through introduction of Plantation Establishment and Livelihood Scheme (PELIS).

## RECOMMENDATIONS

Based on the findings, it was strongly recommended to optimize on the User Rights owing to their potential on improvement of livelihood and forest ecological infrastructure. There was also a need to diversify PELIS by introducing other crops apart from maize and beans. The potential existed in production of millet and sweet potatoes. The forest land still remained fertile to support production of many cash and food crop to supplement livelihood and other socio-economic activities. Finally, there was a need for increased awareness on environmental laws.

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