Forest Provisioning Ecosystem Services (FPES) Economics and Forest Dependency in the Elgeyo and the Nyambene Water Catchment Ecosystems, Kenya

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Abstract - Forest provisioning ecosystem services (FPES) play a critical role in societal wellbeing, particularly in the low-income forest adjacent communities. Despite reported benefits, the contribution of these ecosystems to communities has not been reflected in the national economic accounting systems. The dependency and factors influencing forest exploitation are decimally understood, which among other factors lead to irrational management actions. This study endeavoured to assess the economic value of FPES and the dependency on forest resources in the two selected water catchment ecosystems of Elgeyo and Nyambene in Kenya. Structured questionnaires were administered whereby 384 households were drawn from forest adjacent communities each for the two ecosystems. Product prices were sources from the local and the neighbouring urban markets while surrogate product prices were utilized for products with distorted data and unclear market prices. The logistic regression model determined socio-economic factors influencing forest dependency. The aggregated FPES valuation was estimated at KES 90,042.89 (US$ 841.52) and KES 48,803.48 (US$ 456.11) per household annually for the Elgeyo and the Nyambene ecosystems respectively. The study indicated that FPES contributes about 33% and 35% of the household income for the Elgeyo and Nyambene respectively. Similarly, a majority of the forest community in the two ecosystems are highly dependent on forest resources as exhibited by about 69% and 59% of households respectively. Socioeconomic traits such as household income, tropical livestock unit, the size of the household, distance from state forest, and the locality influence forest dependency. As such, communities with lower income, larger households, and HH with large livestock and those living closer to the ecosystem are highly dependent on forest resources. This, therefore, calls for a concerted effort to not only account for the FPES values, but to also propose policies, and data-based strategic ecosystem management actions directed towards diversifying livelihood, reducing pressure on the state forest thus enhancing the stock and flow of ecosystem services in the Country for humanity.

Keywords **-** Ecosystem, Water Catchment, Forest Provisioning Ecosystem Services (FPES), Forest Adjacent Community, Livelihood, Socio-economic & Culture, Attributes, Dependency

I. BACKGROUND

Forest ecosystems provide goods and services, that are essentially critical to community livelihood, biodiversity conservation, local economy, and poverty alleviation [1]–[6]. On a global scale, forest ecosystems support more than 1.6 billion people [7] 70% of whom are rural populations. They provide food, fuel energy, building materials, fodder, and medicine among other goods [8]–[12]. Forests not only act as a resource for household subsistence but also as a source of income and employment particularly so for the poor forest-reliant community in developing countries [3], [12]–[15]. In Sub-Saharan countries, for instance, forests income constitutes about 40% of the total household income [3], [16], [17] while in Asia and America(North and South) it contributes from 10 to 20% of the total household income respectively [4], [6], [18].

In Kenya, the forest adjacent communities utilize the forest ecosystems as a source of fresh water, food, grazing areas, medicine, timber, and fuelwood among other uses [19]. Generally, forested water catchment ecosystems, otherwise referred to as Water Towers in Kenya contribute about 80% of the country's energy hydro-electric power (HEP)[20] and about 36% of the country's GDP through direct and indirect support for agricultural production, manufacturing, trade, and tourism [19]. However, the forest ecosystems in Kenya are increasingly being threatened by anthropogenic pressures such as encroachment, degradation, illegal logging, and conversion of forest land for other land uses among others [21]. According to Kenya Water Towers Agency [22], [23] for instance, over 4000 and 300 ha of forest land for the Elgeyo and Nyambene respectively was lost to other land-use practices between 2000 to 2019, an indication of the continued degradation of critical forest ecosystem in the country. Hence attendant adverse effects not only on forest adjacent communities but also on other downstream users [24].

In developing countries (Kenya included), rural livelihoods are highly dependent on environmental and natural resources such as forests [25]. However, forest reliance is a function of a wide range of socio-cultural, economic, and environmental attributes [5], [26]–[29]. This is brought about by the heterogeneity of forest communities globally, making dependency variance across the globe, regions, ecosystems, and landscape inevitable [18], [30]. In Kenya, however, studies focused on community dependency on forest resources are few hence the influence of socioeconomic factors on forest resources is not well understood (Langat et al. 2016). The scarcity of such useful information coupled with anthropogenic pressure in the country threatens these critical ecosystems and the very livelihood that depends on these resources for survival [31].

Albeit an increased ecosystem services assessment and valuation, there is still a paucity of data on forest provisioning

ecosystem services (FPES) in Kenya. Limited data on FPES presents challenges in understanding household factors influencing forest dependency [25] useful for the designation of empirically supported ecosystem-based policies, and conservation strategies [32], [33].

As reported in earlier studies by [34] and [35] among others, information on FPES helps promote diversification of forest community livelihood programs that reduce overreliance on forest resources thus enhancing sustainable biodiversity conservation, especially in the forested water catchment ecosystems such as Elgeyo and Nyambene Water Towers. This study seeks to determine how socio-economic, cultural, and environmental factors influence forest dependency among communities living around Elgeyo and Nyambene Water Towers in Kenya.

II. MATERIALS AND METHODOLOGY

A. Study area

The study focused on forest communities living around the Elgeyo and Nyambene water Towers ecosystems that cover 108,194 and 30,313 hectares respectively. The Elgeyo ecosystem consists of 40% industrial forest, 38% indigenous, and about 22% open grass and bushland [36]. Administratively, it largely falls within Elgeyo Marakwet County with a small section in Uasin-Gishu County. It expands from 35° 20" to 35° 45" Eastings and 0° 10' to 0° 20' Northings bordering Baringo County to the east, West Pokot and Transnzoia Counties to the North (Fig. 1). The two counties have a combined population of 1.7m with Elgeyo's being 0.5 million and Uasingishu's 1.2 million [37]. The rainfall regime is biannual with a mean average of 1200mm, where short rains are recorded between March and July and long rains between August and October. The altitude ranges from 1000 m asl and 3350 m asl and temperatures from 11.2°c to 30°c [38]. The area has well-drained, extremely deep, dark reddish-brown, friable clay eutricnitisols soils with moderate to high levels of fertility [36]. The communities around the ecosystem are largely agropastoral with over 70% practicing crop and livestock production, though some households are engaged in small-scale enterprises[36], [39].

The Nyambene ecosystem is predominantly (95%) indigenous forest with small pockets of industrial forest and tea plantations (KWTA, 2020). Administratively, the ecosystem is located within Meru County and traverses five sub-counties including Igembe South, Igembe Central, Tigania East, Tigania West, and Tigania Central Sub-Counties (Fig. 2). Geographically, it extends from 0º 17' to 0º 8' Northing, and from 37º 48 to 37 º 52' Easting. The mean annual rainfall is about 1800mm with long rains occurring between March and May and short rains in October and November. Altitude ranges from 1000 m asl to 2528 m asl and annual temperature from 13.7°C to 28.7^{0}C [22]. The five sub-counties sharing the Nyambane ecosystem host a population of 691,298 with 173,743 households [37] that directly or indirectly utilize and benefit from the ecosystem. The ecosystem) has well-developed soil horizons that are rich in organic matter making them ideal for agriculture. The main soil groups are Nitisols, Cambisols, and Vertisols. Agriculture is the main economic activity with Miraa (Khat) and Tea being the major cash crops [22].

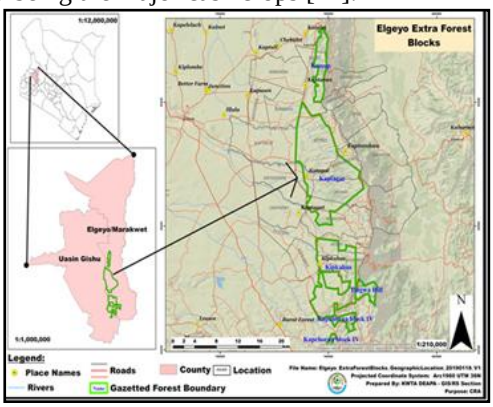

Fig. 1 Map of Elgeyo Water Towers with sampled sites as marked (Sourced: KWTA GIS database)

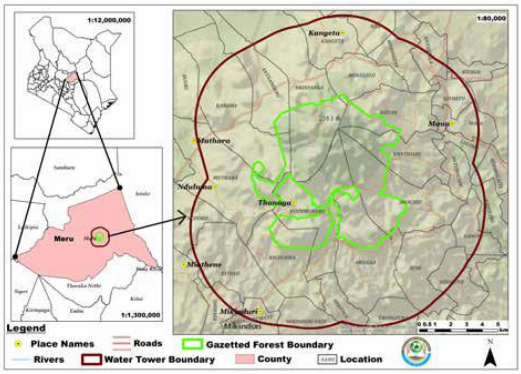

Fig. 2 Map of Nyambene Water Tower With Sample Site as Marked (Source: KWTA GIS Database

Elgeyo ecosystem is largely an industrial forest dominated, with less restriction while the Nyambene ecosystem is dominated by indigenous forest with more restricted access. The selection of the two ecosystems was intended to understand how forest type and management regime would influence forest dependency among forest community's socioeconomic traits.

B. Data Analysis

Descriptive statistics were used to summarize household demographics, socio-economic parameters, nature, and the type of forest products extracted. Forest extractions were quantified, analyzed, and reported in terms of extraction frequency, a measure of central tendency, and dispersion. The value of forest provisioning ecosystem services (FPES) including firewood, wild vegetables, fruits, honey, etc., was derived from their market prices and actual costs (e.g. transportation costs or fees payable) incurred in extraction. The product unit price was sourced from the local and neighbouring urban markets. The total household income was calculated as the combination of all incomes generated from the forest, livestock, business, on-farm, remittance, rental and lease, pension, and off-farm income among others as reported in most similar studies[25], [32], [41] refer to (1). Extraction cost was not factored in the computation of the net household

and forest income due to variability and distorted information on production cost [42].

$$T_{HHincome} = \sum_{(i=1)}^{n} Y_Z \quad (1)$$

Where $T_{HHincome}$ shows total household annual income and Y_Z indicates income from source Z

Forest income, on the other hand, was a summation of household quantities of all the forest products extracted multiplied by the local unit prices [43] i.e. aggregate monetary value for FPES utilized by the forest community refer to (2).

$$T_{F\ income} = \sum_{(i=1)}^{n} I_P \quad (2)$$

Where $T_{Fincome}$ shows total annual forest income and I_P indicates income from forest products P

Income levels were clustered on an interval of KES 75,000/ (US$ 700) annually translating to approximately US$ 2 a day. The choice of the interval value was on the basis that any HH value less than US$ 2 a day would be regarded as abject poverty, US$ 2-6 a day as moderately poor, and income >US$ 6 would be regarded as rich. These categories were based on the forest community context and similar studies undertaken in Kenya [41] and may not necessarily reflect the world bank poverty indexes. The socio-economic data commonly exhibits extreme monetary values brought about by the heterogeneity of the forest community[41]. In that regard, before running the forest dependency test, the data were subjected to a normality test, and where necessary transformation was undertaken to conform with normal distribution assumptions. The normality test, however, exhibited p values ≤0.05 suggesting a violation of normal distribution. In that regard, Kruskal-Wallis and Mann-Whitney were used for significance testing of forest product quantities across the household and ecosystem respectively. Similarly, logistical regression was utilized for establishing the forest dependency and attributes since the predictors violated the linear regression assumption on linearity, homoskedasticity, and normal distribution on residuals. A collinearity test was also carried out before the logistical test, whereby overlapping and higher variable inflating factors (>0.5) and lower tolerance levels (<0.5) were eliminated from predictor variables. The study hypothesized that the level of utilization and dependency of FPES would be influenced by diverse socio-economic attributes. In that regard, the study ran a binary logistical regression model [44] referring to (3) placing forest dependency ratio as the response variable and socio-economic parameters (Ward, Gender, Age, Education, Residency length, household size, land size, TLU, Distance, Expenditure-Bands, Income Bands, place of birth) as the predictor variable. The forest dependency was further categorized into levels i.e. low and high where 0.5 was utilized as a cut-off point and as such values ≤0.5 would be categorized as low while those ≥0.5 would be categorized as a high dependency [32], [45].

$$\log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \ldots\ldots, \beta_k X_k \quad (3)$$

Where, p represents Probability that Y=1 given X; Y represents Dependent Variable (forest dependency level); X_1, X_2,…, X_k represent Independent Variables (socio-economic attributes); β_0, β_1,…, β_k Parameters of Model

The forest dependency level was computed using relative forest income defined as the ratio of household aggregated forest income to total household income [41] refer to (34). The mean relative forest income values were used to categorize forest dependency in two levels i.e. low and high dependency, with a cut-off point of 0.5 as commonly adopted forest dependency studies [45].

$$F_D = \frac{T_{F\ income}}{T_{HH\ income}} \quad (4)$$

Where F_D is forest dependency level, $T_{Fincome}$ is the total forest income and $T_{HHincome}$ is total household income

III. RESULT AND DISCUSSION

The study assessed the social-economic traits of communities living within and around the two ecosystems including age, period lived in the area, and the size of the household. The mean age of the respondent was estimated at 45.2 ±12.0 and 44.8±13.7 for Elgeyo and the Nyambene ecosystem respectively. While the overall mean household size was estimated at 6.2±2.2 and 5.6±3.0 for the Elgeyo and the Nyambene respectively. The majority of the respondent were men at about 58% and 60% for Elgeyo and Nyambene respectively. On education and literacy, the majority of the respondent reported having attended between primary and secondary levels as reported by about 76% and 82% for the Elgeyo and the Nyambene ecosystems respectively. About 20% and 10% reported having post-secondary education with less than 5% reported not having attended school. On the primary occupation, a majority of the population are crop farmers at about 79% and 62% for Elgeyo and Nyambene respectively. That notwithstanding significant population is also engaged in the enterprise, craftsmen work, and unskilled labour. The family leadership and management, for the case of Elgeyo, where the dominant ethnic group was Kalenjin, most were headed and managed by men as reported by about 67% with less than 8% being headed and managed by women. However, the Nyambene ecosystem is dominated by a Meru ethnic group, though a majority is headed by men, and spouses manage family issues as reported by 53% of the households (TABLE I). The demographics of HH in Elgeyo exhibited significant differences across the administrative unit (Sub-county) with P-Values <0.01. However, there was no significant difference in most of the social traits for the respondent within the Nyambene ecosystem. Overall, the significant socio-economic traits demonstrate the heterogeneity of the forest community. mean age across the two ecosystems indicates most of the population within this ecosystem is within the active population cohort thus a growing population and more demand on socio-economic

needs including food, energy, and social amenities in coming years.

TABLE I. SUMMARIES OF HOUSEHOLD SOCIO-ECONOMIC ATTRIBUTES

Variables	**Components**	**Elgeyo (HH=99,119)**				**Nyambene (HH=173,743)**			
		Percent	**Mean**	**Std. Dev**	**Sig.**	**Percent**	**Mean**	**Std. Dev**	**Sig.**
Age		0.96	45.23	11.99	0.00	0.74	44.75	13.69	0.14
Residency		0.96	38.43	17.36	0.00	0.76	41.92	15.10	0.14
HH Size		0.99	6.18	2.22	0.00	0.99	5.55	2.96	0.08
Gender	Male	0.58				0.60			
	Female	0.42				0.40			
Education level	None	0.03				0.10			
	Primary	0.31				0.54			
	Secondary	0.46				0.26			
	Tertiary College	0.17				0.07			
	Undergraduate	0.03				0.03			
	Postgraduate	0.01				0.01			
HH Leadership and Mgt	Male-headed, male managed	0.67				0.32			
	Male-headed, female managed	0.25				0.53			
	Female-headed, female managed	0.08				0.15			
Ethnic Group	Kalenjin	0.98							
	Meru	0.00				0.99			
	Others	0.02				0.01			
Primary Occupation	None	0.01				0.08			
	Crop farmer	0.79				0.62			
	Pastoralist	0.00				0.01			
	Business	0.12				0.10			
	Salaried	0.06				0.05			
	Craftsman	0.01				0.14			
	Pensioner	0.01				0.01			

C. Income and Expenditure

The community living within and around the two ecosystems rely on diverse livelihoods and income options including but not limited to farming, livestock production, forest product sale income, and business among others. The average household income was estimated at a Mean of KES 277,179.84 and KES139,552.89 for the Elgeyo and Nyambene respectively. The mean income varied across households and locality, where for instance the aggregated household income varied across administrative units in Elgeyo with the Kruskal Wallis exhibiting significance $F_{(3,373)}=104.195$, $P<0.01$. The scenario was similar with households around the Nyambene ecosystem where household income varied across administrative units with Kruskal Wallis exhibiting significance $F_{(3,363)}=73.646$, $P<0.01$. The aggregate household income and expenditure analysis indicate that only about 30% of the population within the Elgeyo ecosystem earn less than KES 75,000 annually while a majority reported an income of more than KES 75,000. On the contrary, a majority (≈53%) of households within the Nyambene ecosystem earn less than KES 75,000/ and about 25% of the population reported in the second-level income band. High-income households have less expenditure while lower-income earners expend more than the income earned. This could be attributed to the failure to disclose the actual income, source, and expenditure.

D. Harvest and sourcing of forest provisioning ecosystem services (FPES)

The community adjacent to the two ecosystems harvest forest products at different scales and frequencies as reported by aggregated estimates of about 72% and 14% for households in the Elgeyo and Nyambene ecosystems respectively. From the sixteen ecosystem services quoted, fuelwood was recorded at the highest harvest frequency in both the ecosystems of 97% and 79% for Elgeyo and Nyambene respectively. The least harvested forest products in both ecosystems included thatch grass and game meat for Elgeyo and thatch grass, marram, reeds, mushroom, and game meat for the Nyambene. Overall, households within the Elgeyo ecosystem higher frequency in the harvest of direct-use ecosystem services than the households within Nyambene.

Although the harvest of FPES products recorded higher frequency in both the ecosystems, the sources differ and they include own farms, neighbours' farms, local markets, and public forests. The aggregate values indicate that a majority (54%) of the community around the Elgeyo ecosystem acquires FPES from the local traders while 29% from own-farm sources. The community around the Nyambene on the other hand mainly sources the products from their farms as reported by about 46% followed by public forest sources as reported by 31% of those harvesting. Narrowing to the public forest, fuelwood is more highly reported than any other products as the most product collected from the public forest as reported by about 38% and 56% for those harvesting at the Elgeyo and the Nyambene ecosystem respectively. The other significantly reported product sourced from Elgeyo public forest is natural medicine and mushroom as reported by 12% and 17% respectively. While in Nyambene, the second most common product sourced from the public forest is natural medicine and honey as reported by 67% and 40% of those harvesting the products. Overall, the findings exhibit the significance of the two ecosystems in supporting the community around them in energy provision, and medicinal and nutrition provision among other benefits. Household Harvest and Quantities of Forest Provisioning Ecosystem Services (FPES)

E. Elgeyo Ecosystem

Although not the whole adjacent community harvests forest products, a significant number of the households collect/ harvest and benefit from forest products albeit at different scales and frequencies. Water resource was reported by 100% as the most essential product sourced from the ecosystem followed by fuelwood as reported by about 67% of the population. On average, about 626 liters are used domestically per household weekly translating to about 90 liters per day. Similarly, about five backloads of fuelwood are collected per household weekly with an estimated duration of three hours spend one way per trip made to the source. Similarly, the household makes about three trips weekly in search of fuelwood. Charcoal production is carried out by about 7% of the household with an estimated mean of four bags produced weekly whereby the collectors spend at least one hour on one way to the source. Cumulatively, about two hours are spent per household in search of forest products, and about two trips are made in search of the product weekly. The other products (Table 3) although reported by less than ten percent of each of the households also recorded significant quantities as indicated. Overall, the average distance to the nearest forest is about four km which takes about 2 hours one way at normal walking speed. Worth noting, that most of the forest products sourced from Elgeyo are used domestically as reported by about 78% of those harvesting while about 22% of the collections are sold as a source of income. Worth noting, that apart from the mushroom collection, the mean weekly harvest for all the other products was almost constant across the administrative units around the ecosystem thus not significantly different in terms of the average quantities collected.

F. Nyambene Ecosystem

The water resource is the most critical product that the community around the Nyambene ecosystem benefit from as would be confirmed by all the respondents. On average, about 610 liters of water are collected and utilized per household weekly for domestic use, translating to 87.2 liters per household daily. Fuelwood is the second most harvested product as reported by a majority (74%) of the household around the Nyambene ecosystem with a mean of 3.17±2.32 backloads weekly per household. The time spent in the collection of the fuelwood is estimated at one and half hours one way and about two trips to the forest are made weekly per household. The other products collected by more than ten percent of the households include wild fruits, farm tools, fodder, honey, and charcoal recorded with an estimated mean of 9.44±24.99 kg, 1.12±0.38 pieces, 107.40±185.4 kg, 67.23±170.73kg, and 2.47±2.50kg respectively (Table 13). The majority of the products harvested however are used domestically as reported by about 94% of the household harvesting with only six percent sold in the markets as a source of income. Overall, the household harvest quantities for most of the products vary significantly as denoted by the superscript (a) while others are not significant as denoted by a superscript (b), and the rest of the products are constant across the administrative units. Overall, about 18% of the household around the Nyambene ecosystem rely entirely on it and about one and half hours are spent in the collection and about two trips weekly are made to the forest in search of the products.

G. Summary for Forest Provisioning Ecosystem Services (FPES)

The aggregated economic value FPES was estimated at KES 11.8 billion (US$ 100.9 million) and KES 8.5 billion (US$ 79.2 million) for the Elgeyo and the Nyambene ecosystems respectively. The Mann-Whitney test exhibited significance (U=31,929, NElgeyo=373, NNyambene=402, P<0.01, two-tailed) depicting the difference in the direct use economic value between the two ecosystems where the mean rank placed the Elgeyo DUV higher compared with the Nyamebne ecosystem. The FPES for the Elgeyo ecosystem placed fuelwood, grazing, water for livestock, and charcoal production account for 28.2%, 23.2%, 16.2%, and 14.8% respectively of aggregated FPES value. The Nyambene ecosystem, placed fuelwood constituent value at 40.7%, followed by the value for domestic water, fodder, and water for livestock at 15.35, 14.9%, and 8.9% respectively (

TABLE II). Overall, the findings demonstrate that fuelwood and water (domestic and livestock) and pasture the high-value products and account for over 80% of FPES value from the two ecosystems. The aggregated estimates can be equated to KES 90,042.89 (US$ 841.52) and KES 48,803.48 (US$ 456.11) per household annually for the Elgeyo and the Nyambene ecosystems respectively. The aggregated for the two ecosystems was higher compared with the findings for the Elgon and Cherangany ecosystems valued at KES 3.44 billion and 6.98 billion respectively, but consistent with the Mau complex study estimated at 12.5 billion [46]. The

difference in the findings would be attributed to the difference in the number of beneficiaries, accessibility, conservation status, and the ecosystem services valued. For instance, the case of Mt. Elgon could be lower to due limited human access and extraction while the case of Mau is could be consistent because of more pronounced open access and illegal encroachment similar to the Elgeyo.

TABLE II. TOTAL ANNUAL HOUSEHOLD DIRECT USE PRODUCTS AND ECONOMIC VALUATION

FPES	**Elgeyo**			**Nyambene**		
	Mean	**Total Value (KES)**	**(%)**	**Mean**	**Total Value (KES)**	**(%)**
Fuelwood	37,902.44	3,317,657,267.59	28.21	26,059.64	3,446,443,183.68	40.65
Timber	42,000.00	14,705,292.23	0.13	13,766.67	89,248,580.85	1.05
Charcoal	183,788.89	1,737,430,276.41	14.77	25,221.82	359,725,805.37	4.24
Honey	64,500.00	180,665,018.77	1.54	33,615.38	377,739,756.22	4.45
N/Medicine	7,845.00	32,960,862.14	0.28	12,600.00	43,565,408.96	0.51
F/Poles	82,060.00	430,970,100.00	3.66	22,650.00	19,578,502.24	0.23
B/Poles	50,000.00	140,050,402.14	1.19	750.00	648,294.78	0.01
Wild Fruits	2,615.00	4,577,897.52	0.04	472.22	7,347,340.80	0.09
Fodder	30,035.14	73,612,592.12	0.63	56,172.21	1,262,426,578.52	14.89
Grazing	109,005.64	2,733,275,361.66	23.24	36,595.76	508,660,570.37	6.00
Farm Tools	175.00	245,088.20	0.00	55.77	1,253,369.90	0.01
Q/Stones	-	-	-	140,000.00	181,522,537.31	2.14
Marram	133,333.33	140,050,402.14	1.19	-	-	-
Mushroom	10,862.31	49,441,293.22	0.42	99,900.00	86,352,864.18	1.02
Reeds	-	-	-	60,000.00	25,931,791.04	0.31
Game Meat	-	-	-	21,600.00	18,670,889.55	0.22
D/Water	7,668.38	1,001,467,893.15	8.52	7,477.78	1,299,211,315.61	15.32
L/Water	15,175.64	1,902,221,414.86	16.18	5,095.03	750,937,098.08	8.86
Total		**11,759,331,162.2**	100.0		**8,479,263,887.46**	100.0

H. Forest Community Dependency on Forest Ecosystem Provisioning Services (FPES)

The model for the Elgeyo ecosystem exhibited omnibus tests with significance where $X^2_{(22)}$ =301.964, P<0.01 while Hosmer and Lemeshow test recorded non-significance with $X^2_{(8)}$ =1.721, P=0.988, both suggesting that the model fits the data analysed. Similarly, the model explains 88% of the variance on community forest dependency as shown by Nagelkerke R-squared equivalent to 0.878, with a classification accuracy of 94% as highlighted in the group classification accuracy. The findings demonstrated that a majority (69%) of the households categorized as a higher dependency while about 31% as a low dependency. The binary regression analysis indicated that HH expenditure, income, and tropical livestock unit influence the community forest dependency significantly at a 95% confidence level. Where for instance, the increase in the household expenditure and income level decreases the community forest dependency by a factor of 2.3 and 3.6 respectively while an increase in household livestock number (TLU) increases the dependency by a factor of 1.3 other factors held constant. The other important parameters though not significant at a 95% confidence level include the household size and length of residency where for instance an increase in household size increases the forest dependency by a factor of 0.3 and while an increased length of residency reduces the dependency level by a factor of 0.05 other factors held constant. Overall in terms of impact, TLU is ranked higher (3.7), followed by expenditure (0.1) and income (0.03) as exhibited by Exponentials (

TABLE ///). The findings, therefore, suggest that household income, expenditure, and livestock influence forest dependency significantly while the length of residency, and household size, influence the forest dependency though insignificant at 95% level though at different confidence levels. The findings on household size and income bands were in agreement with a study by [46] and contrary to [32] which placed a decrease in dependency, particularly on household size increase.

TABLE III. ELGEYO FPES AGGREGATE VALUE AS A FUNCTION OF HH SOCIO-ECONOMIC ATTRIBUTES

Elgeyo	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Expenditure	-2.346	.837	7.861	1	.005	.096	.019	.494
Income	-3.586	.752	22.722	1	.000	.028	.006	.121
Locality			5.189	3	.158			
Ward			5.027	9	.832			
Gender	-.055	.721	.006	1	.939	.946	.230	3.887
Age	.002	.040	.002	1	.963	1.002	.927	1.083
Education	-.224	.361	.384	1	.535	.799	.394	1.623
Residency	-.050	.032	2.408	1	.121	.951	.892	1.013
HH Size	.277	.178	2.406	1	.121	1.319	.930	1.871
Land Size	.058	.080	.538	1	.463	1.060	.907	1.239
TLU	1.329	.284	21.825	1	.000	3.777	2.163	6.596
Distance	-.029	.114	.067	1	.796	.971	.777	1.214
Constant	6.577	2.633	6.239	1	.012	718.440		

Forest Dependency		Frequency	Percent	Valid Percent	Cumulative Percent
	Low dependency	104	27.9	31.0	31.0
	Higher Dependency	231	61.9	69.0	100.0
	Total	335	89.8	100.0	

Omnibus tests $X^2_{(22)}$ =301.964, P=0.000, Hosmer and Lemeshow test $X^2_{(8)}$ =1.721, P=0.988, Nagelkerke R-squared equivalent to 0.878, Classification accuracy 94.1%

The Nyambene analysis on the other hand exhibited significance with omnibus tests $X^2_{(22)}$ =159.919, P<0.01, and Hosmer and Lemeshow test $X^2_{(8)}$ =6.368, P=0.606 suggesting that the model fits the data. The model explains about 74% of the variance on the dependency ratio attributed to the socio-economic traits quoted as highlighted by Nagelkerke R-squared equivalent to 0.744 with an accuracy of about 88% as demonstrated by the group classification. From the analysis, HH income, tropical livestock unit, distance from state forest, and the sub-county recorded significance on the influence on forest dependency. On a 95% confidence level, an increase in household income and distance from the state forest decreases community dependency on forest resources by a factor of 2.9 and 1.3 respectively. While an increase in TLU and HH increases forest dependency by a factor of 1.7 and 0.32 respectively when other factors are held constant (TABLE IV). The assessment of the income indicates that communities with lower incomes are highly dependent on forest resources compared to those with higher incomes. The distance dependency suggests that communities closer to the forest are more reliant on forest resources than those further away from the forest consistent with [47]. While the increase in the household livestock number enhanced the community forest dependency, an indication that larger livestock would mean more grazing areas and thus more reliance on forests is consistent with the literature [48]. Similarly, the size of the household also recorded significance, where an increase in household size increases the community forest dependency on a factor of 1.3. This is a demonstration that larger families require more resources and have higher chances to rely on forest resources to supplement on-farm production consistent with the literature[3], [33], [46]. Other important factors though not significant at 95% CL include age, gender, and education where for instance increase in age reduces the dependency by a factor of 0.03. The factor of age inverse on dependency could be attributed to a lack of other alternative income sources and since forest exploitation is labour intensive thus older people are less engaged as opposed to the younger folks consistent with[32], [46], [49], [50]. This is contrary to [45] who suggested that elder people rely more on forests compared to younger folks who are more interested in pursuing well-paying careers, particularly in urban areas and cities. The findings, therefore, exhibit a paradigm shift, particularly where the younger persons are now engaging in forest resource extraction and enterprise contrary to the norm for the elderly engaging in more forest resources. Similarly, there was an inverse dependency on forest resources where an increase in education level reduces the dependency by a factor of 0.4. This could be attributed to the fact that education opens up other opportunities e.g. employment and

enhances knowledge on ecosystem conservation thus reducing reliance on forest resources similar to literature suggestions [51]–[54]. The study also demonstrates that gender as well influences dependency on a factor of 0.6 positively though insignificantly in favour of women. The findings on this factor suggest that females were highly reliant on forest resources than men consistent with the growing literature [55]–[58]. Overall in terms of impact factor, TLU records the highest (5.5), followed by HH size (1.4), distance (0.3), and income (0.05) as exhibited in the table exp(B).

TABLE IV. NYAMBENE FPES VALUES AS A FUNCTION OF SOCIO-ECONOMIC ATTRIBUTES

Nyambene	B	S.E.	Wald	Df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Expenditure	.093	.114	.669	1	.413	1.098	.878	1.372
Income	-2.911	.532	29.943	1	.000	.054	.019	.154
Locality			4.060	3	.255			
Ward			10.325	7	.171			
Gender	.636	.615	1.068	1	.301	1.889	.566	6.309
Age	-.027	.024	1.206	1	.272	.974	.928	1.021
Education	-.389	.399	.947	1	.330	.678	.310	1.483
Born There	.826	.920	.806	1	.369	2.284	.376	13.856
HH Size	.315	.138	5.232	1	.022	1.371	1.046	1.796
Land Size	-.294	.558	.277	1	.599	.746	.250	2.226
Woodlot Owned	.026	.034	.584	1	.445	1.026	.960	1.097
Cropland Size	-.031	.020	2.313	1	.128	.969	.931	1.009
TLU	1.709	.339	25.463	1	.000	5.523	2.844	10.726
Distance	-1.320	.343	14.848	1	.000	.267	.136	.523
Constant	21.377	10986.184	.000	1	.998	1.9x10^9		

Forest Dependency		Frequency	Percent	Valid Percent	Cumulative Percent
	Low Dependency	150	37.3	41.1	41.1
	Higher Dependency	215	53.5	58.9	100.0
	Total	365	90.8	100.0	

Omnibus tests $X^2_{(26)}$ =159.919, P=0.000, Hosmer and Lemeshow test $X^2_{(8)}$ =6.368, P=0.606, Nagelkerke R-squared equivalent to 0.744, Classification accuracy 86.8%

IV.CONCLUSION

The forest provisioning ecosystem services (FPES) contribute significantly to the forest community's household income. The majority of rural poor households are highly dependent on forest products with more than half of the neighbouring relying on the forest for their sustenance. The dependency however varies significantly across diverse socio-economic traits, similar to what has been reported in the literature [5], [26], which confirms the heterogeneity of forest adjacent communities [18], [30]. Thus, making any inference on forest dependency would be a function of a couple of parameters including community socioeconomic traits, time, culture, and scale [32], [59], [60]. Overall, lower household income, large livestock size, large HH size, and HH closer to the ecosystems are more dependent on the forest ecosystems. This is a clear demonstration that poor households are highly dependent on forest resources, largely attributed to limited access to income-creating opportunities and involvement in low-income activities, and as such forest resources become the only available livelihood option[25]. Similarly, large households and herders are more reliant on forest resources a confirmation that households with more livestock, large household size 'more mouth' to feed, and thus on-farm production may not be sufficient thus reliance on other sources for livelihood. Other attributes through record less significance, include, period of residency, locality, education level, age, and gender that in one way or the other may influence forest resources dependency[17], [25], [32], [61]. In that regard, and to strike a balance between forest community livelihood and biodiversity conservation, state and non-state actors must invest in poverty alleviation, livelihood enhancement, and diversification, education, conservation knowledge enhancement, capacity building, and establishment of social protection programs among others. Investment in poverty alleviation and diversification of

livelihood options would go a long way in reducing pressure on forest resources and providing alternative income sources for the rural and poor forest communities. Similarly, investment in education would not only enhance chances of employment but would also create more productive opportunities, particularly for the youth. Conservation education and awareness creation would also enhance conservation knowledge, and promote sustainable conservation. Such conservation education and awareness programs should be tailored towards addressing multiple conservation challenges including, overgrazing and grazing management, livestock management and destocking, sustainable land management, family planning, and farm forestry among other strategies.

Kenya has some robust environmental policy and legal frameworks, however, failure to fully enforce/implement these frameworks contributes to the slow adoption of sustainable conservation strategies. This calls for, proactively implementing the existing policies such as the 10% on-farm woodlots, adoption of sustainable land management, natural resources benefit-sharing, project appraisal as part of environmental impact assessment among others, and incentivization of conservation. Actualization of such programs will enhance forest community knowledge and perception of forest resources' sustainable conservation and management.

Overall, diversification of livelihood options, promotion of farm forests, incentivization of forest conservation, and enforcement of the existing forest laws and policies, will not only reduce pressure on already shrinking state forests, but also promote sustainable conservation, enhancing stock and flow of ecosystems service, and ultimately improving forest community livelihoods.

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COMPLIANCE WITH ETHICAL STANDARDS

The researchers engaged the local administration and community leadership who gave a go-ahead and subsequently, a Free Prior Consent was carried out before the actual interviews. Other ethical standards were strictly adhered to in the entire study process.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY

Survey data would be made available upon request through the corresponding author's email.

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