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Balancing conservation and community needs: challenges, threats, and socioeconomic disparities in Kakamega Forest, Kenya

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Introduction: This research explores the perceptions of local forest communities in Kakamega Forest Ecosystem (KFE) regarding forest conditions, associated threats, Ecosystem services (ES) provision, and associated challenges with a focus on socioeconomic differences (wealth categories). Effective forest management is imperative for sustaining ES, but in KFE, threats to the forest and challenges local communities face hinder their provision.

Methods: Mixed method research was utilized, with qualitative data collected through Key Informant Interviews (KII), Focus Group Discussions (FGD), and quantitative data gathered through household surveys.

Results and discussion: The findings indicated that wealthier households exhibited a positive correlation with perceptions of unchanged ES provision, while poorer households showed a positive correlation with perceptions of decreased ES provision. Local communities generally perceived an improvement in forest conditions across the wealth categories. However, unexpectedly, poorer households associated highly improved forest conditions with decreased ES provision, indicating challenges related to access to ES. In contrast, middle and rich households expressed a positive correlation with perceptions of severely degraded forest conditions. Illegal logging emerged as the most significant threat to KFE, regardless of wealth category, followed by a lack of awareness of conservation efforts, with significant differences in perception across wealth categories. Surprisingly, animal grazing was perceived as a relatively low threat, with significant differences between wealth groups highlighting the importance of land ownership. The allocation of harvesting rights to non-local community members was identified as the most significant challenge faced by the local community, irrespective of wealth. Additionally, the prohibition of maize planting in the Plantation Establishment for Livelihood Improvement Scheme (PELIS) emerged as another major challenge across wealth categories, underscoring the importance of PELIS lands for cultivating staple foods. The electric fence was also perceived as a challenge by the local

community, with significant differences between rich and poor households, reflecting the greater reliance of poorer households on provisioning ES.

Conclusion: This research provides valuable policy insights on community outreach, agricultural crops, harvesting, and the monitoring of participatory forest management (PFM). The findings support more inclusive, sustainable, and equitable management of KFE and other forest ecosystems to enhance the wellbeing and livelihoods of local forest communities.

KEYWORDS

Kakamega Forest Ecosystem, challenges, threats, forest communities, ecosystem services, access to ecosystem services, local community perceptions, livelihoods

1 Introduction

Forests provide goods and services to people, commonly referred to as ecosystem services (ES) (Mea, 2005). These services operate both globally and locally (IPBES, 2019). Globally, forests contribute to climate regulation, biodiversity conservation, air quality improvement, and water cycle regulation (Aznar-Sánchez et al., 2018). Locally, forests offer provisioning services such as firewood and food that support local livelihoods (Kalaba et al., 2013); cultural and recreational services, including eco-tourism, hiking, etc., (Sherrouse et al., 2017); regulating services such as water purification and erosion control (Cavender-Bares et al., 2022); and supporting services like soil fertility and nutrient cycle (Ahammad et al., 2021). These local level forest ES are vital to the livelihood and wellbeing of rural communities (TEEB, 2010).

To ensure the forest ES are used in a sustainable manner, forest management plans should align with the needs of ES beneficiaries. This requires policy makers to incorporate the perspectives of the local communities to inform improved management strategies (Hallberg-Sramek et al., 2023), particularly addressing the challenges these local communities face in relation to the forest ecosystem, and the perceived threats to forests that underpin their livelihoods (Zulu, 2013; Aerts et al., 2016). Adjacent Forest communities can better manage and protect forests if they participate in decision making (Ongugo et al., 2007). Involvement of local communities in management practices of forest products is based on the assumption that the forest will provide ES, and the accrued benefits are essential for sustainable management (Osewe et al., 2023).

Participatory forest management (PFM) is a synergetic approach that involves local communities in the conservation and management of forest resources. It is gaining recognition as it enhances community involvement and supports decentralization in environmental policy (Tadesse et al., 2017). In PFM, local engagement is vital, as it fosters a sense of responsibility and ownership, leading to more sustainable resource use and improved conservation outcomes (Frank et al., 2017). However, the success of PFM largely depends on both the extent of community participation and their perception of its benefits.

Studies in Tanzania (Luswaga and Nuppenau, 2020) and Ethiopia (Girma, 2022) indicate that when communities perceive their involvement as beneficial, they are more likely to participate and support forest management activities. On the contrary, negative perception – often derived from top-down management approaches or inadequate involvement – can hinder the success of PFM initiatives (Luswaga and Nuppenau, 2020). Therefore, understanding and addressing community perceptions and involvement are crucial for the success of participatory forest management.

1.1 Participatory forest management in Kakamega Forest Ecosystem

Kenya's forest cover spans 37.6 million hectares and 940,423 ha designated as protected forest (GoK, 2016). Among these, the Kakamega Forest Ecosystem (KFE) stands out as a globally significant for biodiversity conservation while also sustaining the livelihoods of the local forest dependent communities (Ouma et al., 2011). However, KFE has faced significant degradation and deforestation due to increasing human population pressure (Saalu et al., 2020). Between 2000 and 2020, KFE lost 826.6 hectares of cover (Osewe et al., 2022). Additionally, policies such as the 2018 charcoal ban (Das et al., 2024) and the electric fencing of KFE's buffer zone, initiated in 2023 (UNDP, 2023), have affected local access to forest resources and, consequently, the livelihoods of local communities. The charcoal ban, for instance, faced criticism for its unintended consequences (Wekesa et al., 2023).

Kakamega Forest Ecosystem in Kenya exemplifies the importance of community engagement in forest management. It is managed under two different governmental frameworks. Kenya Wildlife Service (KWS) manages the forest through command-and-control management regime (Mbuvi et al., 2022), while Kenya Forest Service (KFS) employs participatory forest management (PFM), involving local communities through Community Forest Associations (CFAs) (GoK, 2016). The PFM was a shift from the central forest governance to the rural dwellers in the form of the CFA's, allowing local communities to benefit equitably from

Abbreviations: CFA, Community Forest Associations; ES, ecosystem services; FGD, Focus Group Discussions; KFE, Kakamega Forest Ecosystem; KFS, Kenya Forest Service; KII, Key Informant Interviews; KWS, Kenya Wildlife Service; PELIS, Plantation Establishment for Livelihood Improvement Scheme; PFM, participatory forest management.

sustainable resource use while conserving forests (GoK, 2016). An effective CFA contributes to forest preservation from the communities and improves members' wellbeing.

Over 300 enlisted CFAs in Kenya with user rights conferred to them including honey harvesting, timber harvesting and firewood, gathering of medicinal herbs, ecotourism and leisure activities, and grass harvesting and grazing (Laura et al., 2020). Kakamega's PFM registered CFAs include Muileshi registered in 2007, Bunyala, Malava, and Kibiri all registered in 2008 (Laura et al., 2020). CFAs operate across KFE neighboring sub-counties: Lurambi, Shinyalu, Malava, and Navakholo. The CFA is managed by executive members who are elected by the CFA members every 4 years. The executive members include the chairperson, and other executive members each represent the user rights conferred to them, respectively by the forest management act of 2016.

Participatory forest management initiatives such as Plantation Establishment and Livelihood Improvement Scheme (PELIS) allow communities to cultivate agricultural crops – notably the basic staples of local population within forest areas, thereby helping to satisfy farmers' needs for arable land – encourage environmental awareness, and improve conflict resolutions. The local communities are the immediate beneficiaries of the ES and are involved in the day-to-day interaction with forest protection and management (through CFA). However, challenges such as elite capture within CFAs (Ongugo et al., 2007) and a lack of inclusivity in decision making (Ouko et al., 2018) limit PFM effectiveness. This highlights the need for a deeper understanding of local perceptions of forest challenges and threats to improve management strategies.

1.2 Perspectives of local forest communities

Understanding the perspectives of local forest communities is critical for informing policy reforms that address challenges and threats to forest ecosystems. Research done around the globe has highlighted the main challenges to forests, including illegal logging (Tabarelli et al., 2005), deforestation and climate change (Cavender-Bares et al., 2022; Karjalainen et al., 2010), livestock grazing (Trosper et al., 2012), forest loss through climate change (Aerts et al., 2016), infrastructure development and biodiversity loss (Alamgir et al., 2020), or institutional challenges of social forestry (Rakatama and Pandit, 2020). However, these challenges are often context specific and require localized solutions to achieve sustainable rural livelihood (Scoones, 1998). Eliciting the perception of the local forest communities must account for the socio-economic diversity within communities (Rakodi, 1999), as challenges faced by households affect their perception of the threats faced by the forest ecosystems (Meijaard et al., 2013; Kalaba et al., 2013; Ahammad et al., 2019). Local communities, especially those stratified by different wealth categories, experience and perceive challenges and threats differently, affecting their responses to forest management strategies (Humphrey et al., 2016).

Existing research has often overlooked socio-economic differentiation in forest community perspectives in KFE. For example, Humphrey et al. (2016) focused only on one section of the KFE, which is Malava, and did not consider the variation of views across the different wealth categories of households. Similarly, research in Marsabit forest emphasized the importance of community participation (Ouko et al., 2018) and the associated challenges in management but overlooked socio-economic differentiation. Studies in Gabon (Laurance et al., 2006) highlighted issues in tropical rainforest conservation but lacked insights into user-level perceptions of ES.

As indicated, limited research has explored the perceptions of local forest communities regarding ecosystem threats and challenges, particularly across different wealth categories (Osewe et al., 2023). Understanding these perspectives is critical for achieving sustainable rural livelihoods and developing inclusive policies tailored to the diverse needs of these communities. By acknowledging the varied household perspectives on forest ecosystem threats and challenges in deriving ES, policymakers can foster a sense of ownership among the community members, encouraging their involvement in decision making and promoting sustainable forest management that aligns with the socio-economic realities of KFE communities. Therefore, the specific objectives of this paper seek to answer the following research questions: (a) How does the household wealth status influence the perceived change in forest ES provision? (b) How does the household wealth status influence the perceived changes in forest conditions? (c) How does household wealth status influence the perceived and acknowledged threats to the forest? and (d) How does household wealth status influence the perceptions of challenges experienced by local communities?

Based on these objectives, we formulated the following hypotheses: (H1) Poor households are more likely to perceive a decrease in the provision of forest ES compared to rich households; (H2) Rich households are more likely to perceive an improvement in forest conditions than poor households; (H3) the rich households will acknowledge a greater number of threats to the forest compared to poor households; and (H4) Poor households will recognize more challenges experienced by local communities than their wealthier counterparts.

Based on the findings of this assessment, this study formulated policy recommendations to support sustainable forest management and inclusive decision-making processes that reflect the socio-economic diversity of KFE communities.

2 Materials and methods

2.1 Study area

Situated in western Kenya (34°52' E; 0°19 N) with a population of 1.9 million people (KNBS, 2019), Kakamega county is home to KFE, the only remnant of Guineo-Congolian tropical rainforest in the country (Fashing et al., 2004). KFE consists of tea plantation in the buffer zone (Farwig et al., 2009), natural forests, and planted forest (Fashing et al., 2004). With 350 documented plant species, the predominant tree species in the forest are some of the best soft and hardwoods found on the continent: white stinkwood (*Celtis africana*), red stinkwood (*Prunus africana*), croton (*Croton megalocarpus*), and Elgon teak (*Olea africana*) (Fashing et al., 2004).

Kakamega Forest Ecosystem is divided into four zones, with the objective of balancing restricted access to the KFE with the main aim of safeguarding the forest and its other resource values (KWS,

2012). These zones include: potential utilization zone – mainly consisting of bushes and grazing lands, which acts as a buffer for the forest while also being used as a reforestation area to restore damaged areas; livelihood support zone – area which is intended for implementing programs that promote sustainable livelihoods to reduce reliance on forests and distinguished by a forest community that is located 2 km from the forest boundary, protection zone – characterized by low historical disturbance and natural forest; and core zone – primarily natural forests to preserve the ecology and fauna (KWS, 2012).

Local communities surrounding KFE have become increasingly dependent on the forest due to the rising population (Saalu et al., 2020). Consequently, the forest experienced a loss of 826 hectares over two decades (Osewe et al., 2022). The ES provided by the forest are vital for supporting local livelihoods and meeting the wellbeing needs of the communities (Wang et al., 2017). In leveraging these ES, the local communities in KFE have embraced a variety of livelihood strategies (Saalu et al., 2020), including livestock herding, tour guiding, sand harvesting, farming, small-scale local business, tea leaf plucking, and bush meat hunting. The local communities in KFE have rich culture of bull fighting present in Shinyalu on Saturdays, sacred sites from circumcision for the Bukusu community in the Tiriki sites in the forest every August and December (Were et al., 2024).

For this research all four forest adjacent communities located in the four sub-counties surrounding KFE were selected: Malava, Shinyalu, Navakholo, and Lurambi (Figure 1). These sub-counties exhibit distinct forest characteristics, access influencing policies, and community interactions. Malava, Shinyalu, and Lurambi contain both natural and planted forests, whereas Navakholo consists primarily of planted forests (Obonyo et al., 2023). Access to the forest varies, with Malava and Navakholo lacking electric fences, allowing relatively unrestricted entry, while Shinyalu and Lurambi are fenced, limiting direct community access (UNDP, 2023). Forest resource use is structured through zoning systems, with Malava featuring a core zone, potential utilization zone, and livelihood support zone, whereas Shinyalu and Lurambi incorporate additional protection zones, indicating a stronger emphasis on conservation. Navakholo, with its planted forest, is limited to potential utilization and livelihood support zones (KWS, 2012). Lurambi is the most urbanized, benefiting from better infrastructure due to its location near Kakamega town, while Malava and Shinyalu remain more rural with small trading centers, and Navakholo, the least developed, continues to see gradual infrastructure growth (Barasa, 2014). These sub-counties are inhabited by distinct ethnic communities, including the Idakhos and Kabras in Malava, the Wanyala in Shinyalu, the Watsotso in Lurambi, and the Kabras in Navakholo (Lwangale, 2018), each of which is represented by respective community forest associations, such as Majeto, Lianungo, and Nasina. As regards the infrastructure, Malava is traversed by a national road, Shinyalu and Lurambi buffered by tea zones, and Navakholo intersected by a county road. Livelihood strategies in these sub-counties are in relation with KFE, with communities engaging in farming, small businesses, and resource extraction (Saalu et al., 2020). Malava's residents rely primarily on agriculture and livestock keeping, while Shinyalu and Lurambi have more diverse economies that include tour guiding, tea picking, sand harvesting, and gold mining. In Navakholo, livelihoods are based on farming, sand harvesting, bush meat hunting, and small-scale trade.

2.2 Data collection methods

The study employed a mixed-methods approach, integrating both qualitative and quantitative techniques. Qualitative research methods aim to interpret and explore social phenomena by examining participants' perception, experiences, and the meaning they assign to various aspects of their lives. These techniques prioritize context and rely on descriptive data, patterns, and themes identified by the researcher (Creswell, 2009; Patricia, 2014). Focus group discussions (FGD), a key qualitative method, facilitate group conversations on specific topics and foster interactions among participants, enabling the exploration of diverse thoughts and viewpoints. FGD are particularly effective for investigating complex topics and social dynamics, as they reduce researcher interference, allowing participants to express themselves freely (Patricia, 2014). Moreover, wealth ranking FGD, a participatory appraisal tool, allows communities to evaluate the relative wealth of households using their own criteria and wellbeing indicators that other conventional methods cannot provide (income and land ownership) (Chambers, 1994).

The following methods were used for data collection:

Focus Group Discussions: Three FGD were conducted in Navakholo, Malava, and Shinyalu, each involving 8–10 participants (Patricia, 2014). No FGD was conducted in Lurambi, as it has a representation base in Shinyalu. Participants included both members and non-members of CFAs. Among other things, the FGD aimed to determine a comprehensive list of what the participants see as threats to KFE, what are the benefits (ES) derived from KFE, as well as a list of the challenges the FGD participants identify as being faced by local forest communities. The discussions, which lasted between 45 and 90 min, provided valuable insights that guided the development of the household survey questionnaire. The questions are presented in Supplementary Appendix Table B1.

Key informant interviews (KII): To explore the same topics as the FGD, along with other aspects, in-person interviews were conducted with two executive members of CFAs, forest managers from Malava and Shinyalu, and three KFS rangers from the research location. Lasting between 30 and 45 min, these interviews helped validate and expand the list of identified threats and challenges faced by local communities.

Wealth ranking focus group: In each research location, five participants were selected through snowball sampling. These included two executive CFA members, senior citizens from the community, and a community leader. Participants were asked to identify wealth indicators specific to their respective sub-county (Navakholo, Shinyalu, Lurambi, and Malava) and reach a consensus on these indicators. The focus group lasted between 45 and 90 min. Subsequently, all the participants from all the sub-counties focus group were brought together for a final focus group to reach a consensus on the final wealth indicators. The same participants from the initial sub-county focus groups were retained to ensure continuity, leveraging their familiarity with the discussion and criteria. Their local socio-economic insights played a crucial role for refining and standardizing the final indicators.

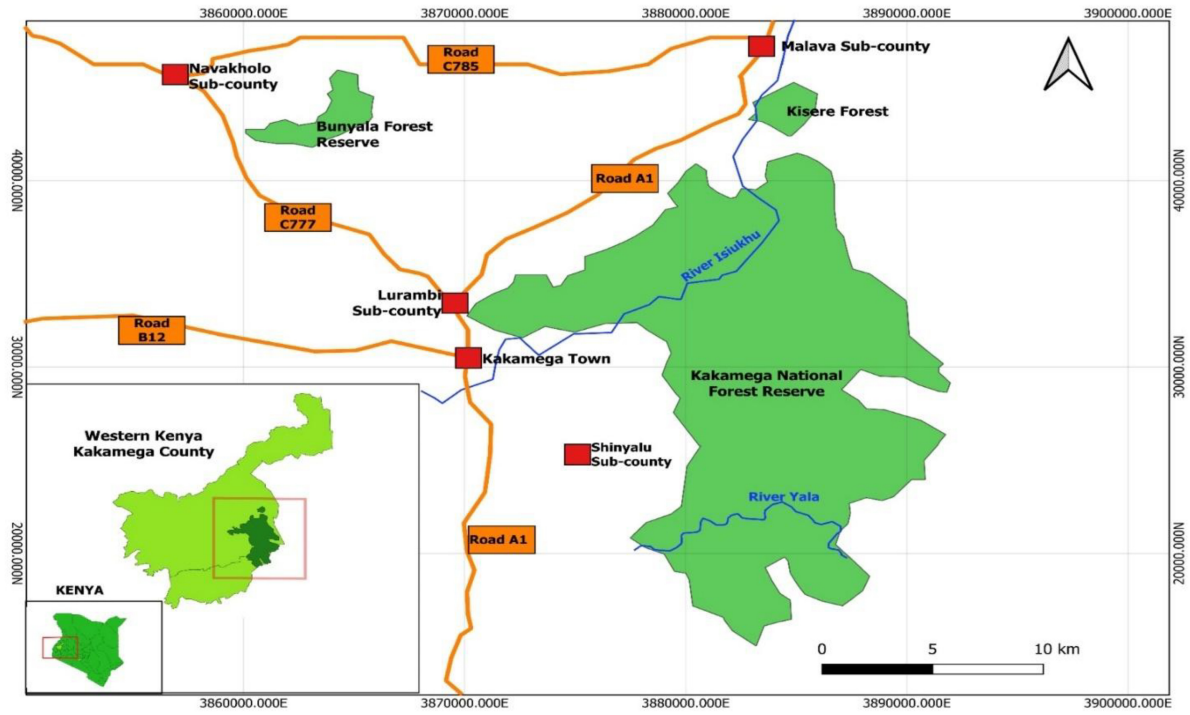

FIGURE 1
Map of Kakamega Forest Ecosystem (KFE) and communities included in the study.

Household survey: The questionnaire for the household survey was developed based on insight from the KII and FGD. Prior to conducting the household survey, the questionnaire was tested with twenty-five CFA members in Lurambi to identify any potential issues. The survey consisted of closed-ended questions designed to address the elements detailed in Supplementary Appendix Table B2.

Sub-counties were used as a stratum in stratified sampling (Tipton, 2013). The sample size was determined using a 95% confidence level and a 5% margin of error (Memon et al., 2020; Siri et al., 2008). Table 1 presents the household intervals. Targeted households were selected using the road transect method (Awuah et al., 2017) in a zigzag pattern to ensure representation of different communities. Households identified based on the intervals in Table 1 were informed about the study's objectives, and those willing to participate were given the questionnaire. Unwilling participants were skipped and replaced with the next eligible household, continuing this process until the required sample size was achieved.

Six trained research assistants facilitated the household survey. The questionnaires were printed in both English and Kiswahili. The research assistants supported household respondents who felt uneasy speaking or writing in the two languages by translating their native "Luhya" into the two primary languages. Additionally, the field teams benefited from the presence of one CFA member for building trust with the community. The household survey took about 15 min to complete.

In our study, the ES we have identified refers to the tangible (provisioning) and intangible (regulating, cultural, supporting) benefits local communities specifically gain from the forest (Appendix C). The reference point for assessing changes in ES provided by KFE was the period before and after the 2018 charcoal ban. This policy intervention introduced stricter regulations on forest resource harvesting, which affected the availability and flow of the ES to local communities.

2.3 Data analysis

The indicators for the wealth categories included the level of education, size of owned land, level of education, and type of house wall material. Table 2 shows the households' wealth classifications based on these indicators: low-, middle-, and high-income households. A weighted scoring system was utilized to categorize households into wealth groups by assigning equal weights (25%) to four indicators. Each indicator was scored based on set criteria (e.g., education: 1.25 per level; wall material: 1.67; income: 2; land ownership: 2 per level), after which total weighted scores were calculated. Households were then classified as rich (scores between 10 and 7), middle-income (6.9–4.2), or poor (4.1–1.7). The socio-economic profile of the respondents is provided in Supplementary Appendix Table A1.

A one-way ANOVA was used to assess the relative importance of threats to the forest and challenges faced by local communities across the wealth categories. Homogeneity of variance was considered satisfied if Levene's test produced a p-value greater than 0.05. Next, the ANOVA table was reviewed to determine if there were statistically significant differences ($p < 0.05$) between the wealth categories. To ascertain which wealth categories had a significant difference, a *post hoc* Tukey HSD test was employed. The homogeneity of variance was not reached, though, if the one-way ANOVA's Levene's $p < 0.05$. Subsequently, a Welch ANOVA was employed, indicating a significant difference between

TABLE 1 Sample size households across the four research locations.

Kakamega Forest Ecosystem sub-counties	Population of sub-county	Households number per sub-county (HH)	Targeted sample size with confidence level 95%, 5% margin of error, 50% population proportion	Strata increased sample size (Hn)	Number of intervals for road/street/pathways Household survey Interval (i) = (HH)/(Hn)
Lurambi	160,229	52,015	94	123	423
Shinyalu	159,475	39,589	93	105	377
Navakholo	116,851	27,671	68	111	250
Malava	115,354	26,049	65	114	229
			Total	453	

TABLE 2 Wealth ranking indicators.

Indicators	High	Middle	Low
Type of wall material	Blocks/stone/bricks	Bricks/semi-permanent	Iron sheet/mud
Income level	> USD 200/month	USD100–200/month	< USD 100/month
Level of education	University level of education/tertiary/secondary	Primary or secondary education.	No formal education or primary education.
Owned land	> 3 acres 6	2–3 acres	< 2 acres/no owned land

wealth categories if $p < 0.05$. It was also determined which wealth groups have a significant difference using the Games-Howell *post hoc* test. A correlation matrix was also generated to determine the correlation between perceptions of ES changes and the forest conditions in the KFE across the wealth categories. The correlation matrix table was color conditional formatted with red color indicating negative relationships, white for non-significant relationships, and green for positive relationships. The high intensity of the colors represented stronger relationships.

3 Results and discussion

3.1 Perceived changes in ES

As a result of the wealth ranking, there were 84 rich households, 105 middle-income households, and 264 poor households. Our analysis indicated that most respondents perceived an increase in ES flow (see Figure 2).

Wealthier households, mainly from Malava (13.1%), perceived ES provision as unchanged (see Figure 2), which could be attributed to their limited reliance on the forest for their livelihood. In contrast, and contrary to H1, poorer households, particularly in Navakholo (13.3%), perceived an increased ES provision, likely due to the active reforestation efforts carried out by some NGOs in collaboration with the CFA. However, H1 is supported in the case of poorer households in Shinyalu (8.7), who perceived a decline in ES provision, this could be attributed to their high dependence on forest resources due to limited job opportunities. Additionally, middle-income households, mostly in Malava (10.5%), reported being uncertain about the status of ES changes.

The correlation matrix (Table 3) indicates that rich households are more likely to perceive ES provision as unchanged, likely due to their access to sufficient resources and alternative goods or services. This reduces their dependency on the forest, making them less sensitive to changes in ES provision (Ahammad et al., 2019). This outcome aligns with the findings of Tallis et al. (2011), which suggest that wealthier households, having economic buffers, are less sensitive to changes in ES provision, leading to an unchanged perception of ES availability.

Land ownership size shows a weak negative correlation, while income exhibits a weak positive correlation with an unchanged ES perception. High-income households have more diversified sources of income, making forest resources a less critical component of their livelihoods. While households with larger land holdings engage in agroforestry or farming, making them more aware of ES changes such as soil erosion and soil fertility loss. This observation is supported by Nyangoko et al. (2022) in their study in Tanzania.

Regarding the perception of decreased ES provision, income shows a weak negative correlation ($r = -0.07$), land ownership size indicates a weak positive correlation ($r = 0.02$), and the level of education presents a weak negative correlation ($r = -0.10$). The negative correlation between income and decreased ES perception suggests that high income households often have access to alternative ES such as piped water instead of relying on forest streams, as a result they perceive less impact of declining ES. While households with large land holdings are more likely to engage in agroforestry and agriculture which can contribute to forest degradation and ES decline. However, the correlation is weak because some might practice sustainable land management. Additionally, households with higher levels of education are more likely to have alternative livelihoods, such as formal employment, reducing their dependence on forest resources. As a result, they experience fewer direct impacts from ES decline and may perceive it as less severe.

Middle income households have weak positive correlations with both increased and unchanged ES perceptions (see Table 3). Their socioeconomic status provides them with access to alternative goods or services and allows them to perceive some changes in the ES provision (Cavender-Bares et al., 2022). However, the weak

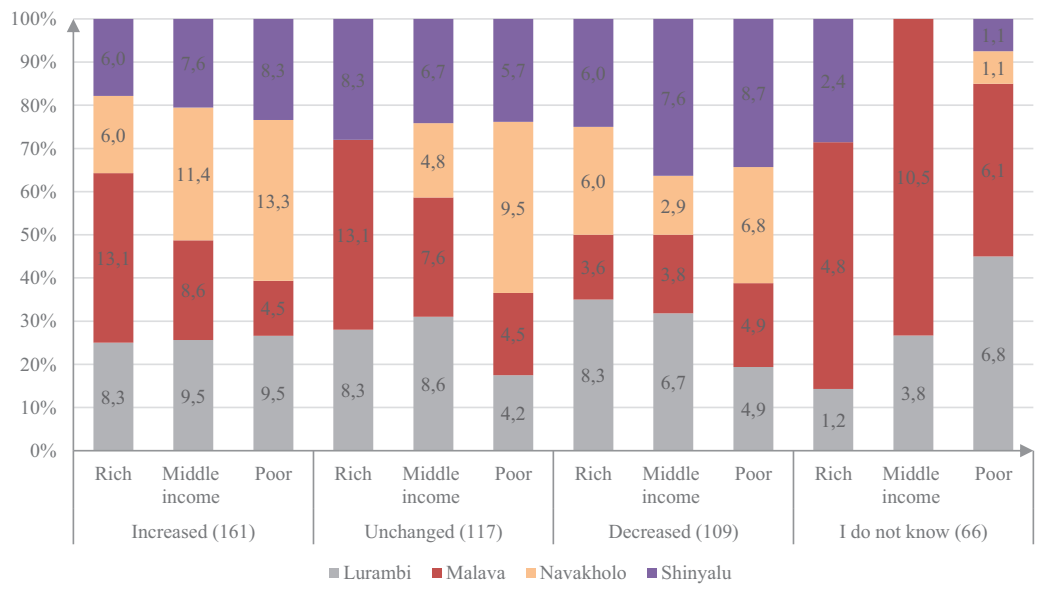

FIGURE 2
Perceived changes in ecosystem services (ES) across the wealth categories.

TABLE 3 Correlation matrix indicating ecosystem services (ES) change perception across the wealth categories and socio-economic factors.

	Increased	Unchanged	Decreased	I do not know	Rich	Middle	Poor
Increased	1.00	–	–	–	–	–	–
Unchanged	−0.44	1.00	–	–	–	–	–
Decreased	−0.42	−0.33	1.00	–	–	–	–
I do not know	−0.30	−0.24	−0.23	1.00	–	–	–
Rich	−0.02	0.04	−0.01	−0.03	1.00	–	–
Middle	0.02	0.02	−0.04	0.00	−0.26	1.00	–
Poor	0.00	−0.05	0.04	0.03	−0.56	−0.65	1.00
	Income	**Size of land owned**	**Level of education**	**Increased**	**Unchange**	**Decreased**	**I do not know**
Income	1	–	–	–	–	–	–
Size of land owned	0.47	1.00	–	–	–	–	–
Level of education	0.52	0.25	1.00	–	–	–	–
Increased	0.00	0.06	0.06	1.00	–	–	–
Unchanged	0.05	−0.01	0.00	−0.44	1.00	–	–
Decreased	−0.07	0.02	−0.10	−0.42	−0.33	1.00	–
I do not know	0.01	−0.09	0.03	−0.30	−0.24	−0.23	1.00

Strong green indicates a high positive correlation, light green indicates a moderate positive correlation, while strong red indicates a high negative correlation and light red indicates a moderate negative correlation.

positive correlation with the perception of unchanged ES provision can be explained by middle-income households' moderate reliance on ES, availability to alternatives, and partial understanding of environmental challenges. A more nuanced and less harsh impression of environmental transformations derives from their intermediate socioeconomic position, between rich households, who can fully minimize the impact of ecosystem changes, and poor households, who are more directly affected (Aznar-Sánchez et al., 2018). Additionally, middle-income households show a weak negative correlation with the perception of decreased ES provision ($r = -0.04$). This could be due to their access to alternative infrastructure that buffers them from ES loss, such as utility of county water as opposed to natural water sources. This outcome can also be observed in China (Wu et al., 2022), where middle-income households focus

more on cultural and provisioning ES rather than regulating services, leading to weak negative correlation with regulating ES.

Land ownership size and education level both show a positive correlation with increased ES perception. This could be because educated household heads are more likely to understand ES and adopt better land management practices. However, the weak correlation suggests that some households prioritize economic gains over sustainability. Similarly, large landowners may have diverse land uses, such as woodlots, that contribute to ES provision.

Poor households show a weak positive correlation (r = 0.04) with decreased ES perception and a weak negative correlation (r = −0.05) with unchanged ES perception. This could be because poor households are more dependent on the forest for their daily needs compared to their counterparts, hence are more sensitive to ES provision change. This sensitivity is also observed in China (Zhou et al., 2023), where poor households rely heavily on ES for their basic needs and are more vulnerable to environmental degradation and policy changes.

3.2 Perceptions of forest conditions

Wealthier households predominantly perceived the forest condition as unchanged, with Malava having the highest proportion (10.7%). This aligns with their perception that ES provision remained stable (see Figure 3). Consistent with H2, rich households were more likely to perceive an improvement in forest conditions, with the highest proportion in Lurambi (14.3%), possibly due to the regional base of the KFS in Lurambi, which helps deter forest degradation. However, poor households also reported a significant perception of forest improvement, with the highest proportion in Navakholo (11%). This was expected, as they also perceived an increase in ES provision. In contrast, middle-income households in Shinyalu had the highest perception of forest degradation (7.6%) and severe degradation (2.9%). This could be attributed to their high reliance on the forest for community livelihood, as indicated by their relative perception of decreased ES provision.

Rich households exhibited a weak negative correlation (r = −0.02) with the degraded forest conditions, indicating that greater wealth is associated with a reduced perception of forest degradation. At the same time, a weak positive correlation (r = 0.02) was recorded with the perception of severely degraded forest conditions, suggesting that higher wealth is linked to a greater awareness of severe degradation (see Table 4). This outcome may result from rich households being less reliant on forest ES for subsistence while still benefiting from recreation and esthetic ES. As a result, they may not perceive the early stages of forest degradation, leading to the weak negative correlation. However, as forest degradation becomes severe, the reduced quality of ES – such as reduced recreational opportunities, poorer air quality, or diminished esthetic value tied to property investments – may increase their awareness and concern (Cavender-Bares et al., 2022). A similar pattern is observed in Tanzania's mangrove forest reserves (Nyangoko et al., 2022), where wealthier households prioritize immediate economic gains over long-term sustainability, thereby overlooking early signs of degradation.

Middle-income households had a weak negative correlation (r = −0.08) with the perception of highly improved forest conditions, suggesting that middle-income status is associated with a reduced perception of significant forest improvements. There was a positive correlation (r = 0.06) with the perception of severely degraded forest condition (see Table 4). This may be attributed to middle-income households not experiencing significant changes in their daily lives, even when forests conditions improve substantially. Nevertheless, severely degraded forest conditions may still have indirect effects on middle-income households, such as increased air pollution, reduced water quality, or increased flood risks. That association is still weak but favorable, though, because they can afford to use some mitigation techniques, such as buying bottled water. A similar trend is observed in research by Parag et al. (2023), where forest degradation and declined water quality led households to shift toward bottled water consumption.

Poor households showed a weak positive correlation (r = 0.06) with the perception of highly improved forest conditions and a weak negative correlation (r = −0.07) with the perception of severely degraded forest conditions (see Table 4). This may be attributed to their direct reliance on forests for essential necessities, such as food, firewood, and NTFP. Better forest conditions can marginally increase their wellbeing and livelihood opportunities, although these benefits may be limited by restricted access and minimal gains. However, since they are negatively impacted by forest degradation, poor households tend to have a weak negative correlation with the perception of severely degraded forests. While forest degradation negatively affects poor households, their long-standing dependence and adaptive strategies, such as participating in the PELIS program – which enables the local forest community to farm on the deforested areas of the forest while continuing the reforestation of KFE – help mitigate the full impact. Thus, the correlation is weak and negative because they continue to derive some benefits even in degraded forest conditions. Similar situation is seen in Vietnam (Lan et al., 2016), where households' payment for ES enabled participants to plant cash crops on degraded lands while simultaneously practicing reafforestation.

Income exhibited a weak negative correlation (r = −0.04) with the perception of highly improved forest conditions. This may be because high-income households rely less on firewood due to access of alternative fuel sources, such as gas, but they might also clear land for development. The weak correlation could be attributed to some high-income households supporting conservation efforts through eco-tourism initiatives. Land ownership size also showed a weak negative correlation (r = −0.02) with the perception of highly improved forest conditions, possibly due to large landowners clearing agroforestry lands for grazing or commercial use. The level of education had a weak positive correlation (r = 0.02) because it encourages adaptation of sustainable practices and awareness. However, not all educated households prioritize conservation.

Land ownership, income, and education level all had weak positive correlation with the perception of improved forest conditions. This could be attributed to wealthier and large landowners having the capacity to allocate land for agroforestry, a sustainable practice, while higher education levels may enhance awareness of sustainable practices benefits. Conversely, these variables showed a weak negative correlation with perceptions (see Table 4). For severely degraded forest conditions, education level exhibited a weak positive correlation. This may be due to higher education sometimes leading to economic activities that contribute to forest degradation or causing some educated individuals to

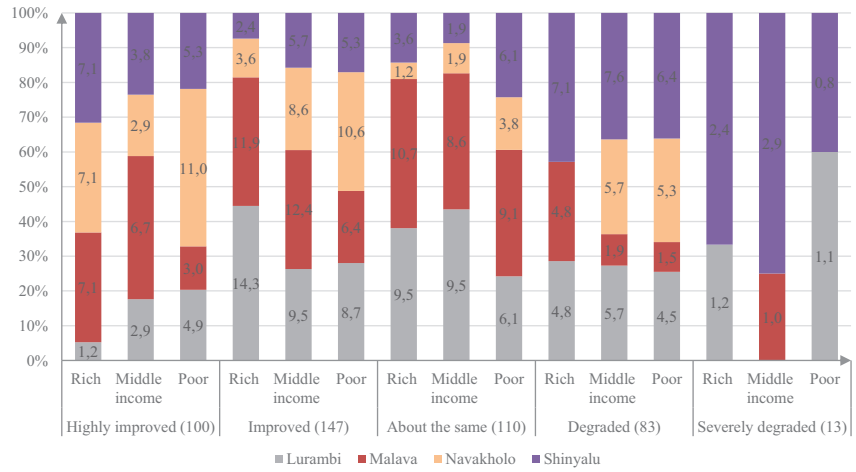

FIGURE 3
Perception of forest conditions across the wealth categories in the four study areas.

TABLE 4 Correlation matrix indicating forest condition perception across the wealth categories and socio-economic factors.

	Highly improved	Improved	About the same	Degraded	Severely degraded	Rich	Middle	Poor
Highly improved	1.00	–	–	–	–	–	–	–
Improved	−0.37	1.00	–	–	–	–	–	–
About the same	−0.30	−0.39	1.00	–	–	–	–	–
Degraded	−0.25	−0.33	−0.27	1.00	–	–	–	–
Severely degraded	−0.09	−0.12	−0.10	−0.08	1.00	–	–	–
Rich	0.01	0.00	0.01	−0.02	0.02	1.00	–	–
Middle	−0.08	0.04	−0.03	0.04	0.06	−0.26	1.00	–
Poor	0.06	−0.04	0.02	−0.02	−0.07	−0.56	−0.65	1.00
	Income	Size of land owned	Level of education	Highly improved	Improved	About the same	Degraded	Severely degraded
Income	1.00	–	–	–	–	–	–	–
Size of land owned	0.47	1.00	–	–	–	–	–	–
Level of education	0.52	0.25	1.00	–	–	–	–	–
Highly improved	−0.04	−0.02	0.02	1.00	–	–	–	–
Improved	0.06	0.03	0.06	−0.37	1.00	–	–	–
About the same	0.01	0.03	−0.01	−0.30	−0.39	1.00	–	–
Degraded	−0.03	−0.01	−0.11	−0.25	−0.33	−0.27	1.00	–
Severely degraded	−0.05	−0.06	0.06	−0.09	−0.12	−0.10	−0.08	1.00

Strong green indicates a high positive correlation, light green indicates a moderate positive correlation, while strong red indicates a high negative correlation and light red indicates a moderate negative correlation.

disengage from direct environmental management. This dual effect results in a weak positive correlation.

3.3 Perceived importance of threats to KFE

The importance of selected threats was ranked on Likert scale from 1 to 5, and their mean and standard deviation are shown in Figure 4. These findings provide partial support for H3. The results demonstrate that for several key threats, wealthier households consistently reported higher concern levels.

A deeper understanding of the specific threats faced by KFE across wealth categories facilitates informed decision-making and improved stakeholder involvement. It is important to involve all stakeholders, including households with varying levels of income, to ensure that conservation policies consider the needs and impacts of all forest users. Research conducted in Kenya's

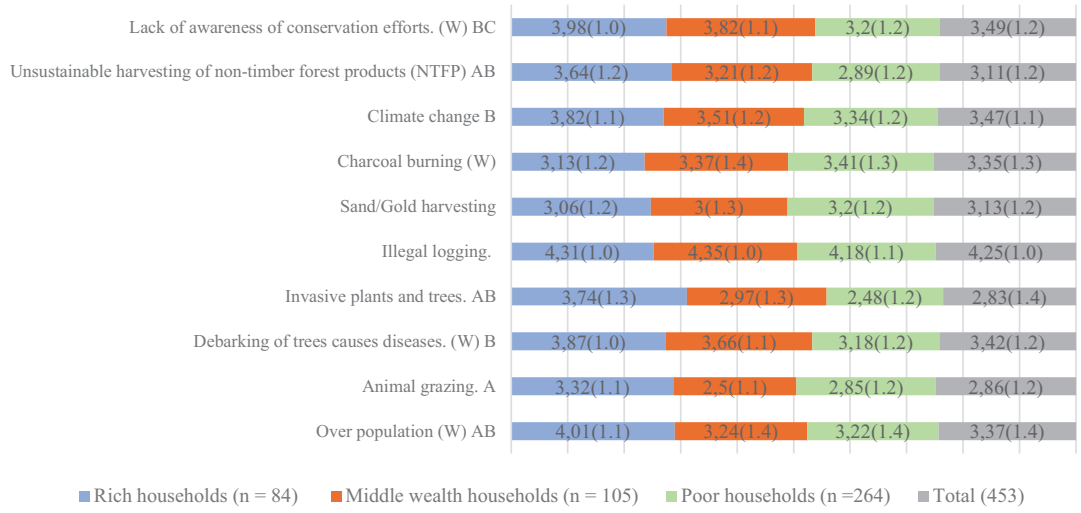

FIGURE 4
Perception of the identified threats across the wealth categories [Numbers outside of the brackets are the means, while numbers inside the bracket indicate the standard deviation. A denotes a significant difference between rich and middle households, B denotes a significant difference between rich and poor households, and C denotes a significant difference between the middle and the poor households, at $p < 0.05$. (W) indicates performance of the Welch one-way ANOVA test].

Mau Forest emphasizes the significance of inclusive management strategies involving a range of socioeconomic groups to effectively conserve forests (Jebiwott et al., 2021). Some of the identified threats to KFE were also identified in research conducted in other forests in the western part of Kenya, such as illegal logging, invasive species, overpopulation, overgrazing, and climate change (Kisiwa et al., 2021).

Overpopulation is one of the major threats to KFE. The region has a high population density, with an average household size of 5 and a density of 614 persons per square kilometer (KNBS, 2019). This high population converts forest land into settlement areas or agricultural land to support their livelihoods (Saalu et al., 2020; Osewe et al., 2022). The results of the present study indicated that the perception for the importance of overpopulation differ significantly across wealth categories ($F_{2,45} = 11.874$, $p < 0.001$) (see Figure 4). The education wealth indicator may be behind this: wealthier households are better educated and have better access to information, which increases their awareness of the long-term effects that population growth has on biodiversity and forest resources. This outcome aligns with research by Sulemana et al. (2016), indicating that in both developed and developing countries, environmental concern perceptions are positively correlated with socioeconomic status of individuals.

Animal grazing was also identified as a threat by the stakeholders in KFE. Due to some livestock browsing on sapling trees in the forest, the regeneration capacity in certain parts of the forest may be reduced. This is also observed in Mau Forest, where research indicated no rejuvenation in heavily grazed areas (Leley et al., 2023). There was a significant difference between wealth categories regarding the perception on the importance of animal grazing ($F_{2,45} = 11.646$, $p = 0.314$). Wealthier households own larger landholdings, which may lead to other local community members grazing on these lands without consent, particularly on agroforestry plots. Conflicts over land use may arise due to grazing pressure, with richer landowners seeing these pressures as threats to both their assets and the forest. A similar situation is observed in Mau Forest, Kenya, where large landowners are more concerned about the impact of grazing on their lands and forest health (Langat et al., 2016). In our analysis, animal grazing was perceived as a less significant threat to KFE by the respondents, possibly because the economic benefit from livestock outweighs the perceived ecological costs from the local forest community.

Focus group discussions and KII revealed that some of tree species were utilized by the community for medicinal purposes through debarking i.e., musine (*Croton megalocarpus*), black ironwood (*Olea capensis*), shingulostso (*Fagaropsis angolensis*), East African green heart (*Warburgia ugandensis*), African satinwood (*Zanthoxylum gilletii*). Debarking these tree species causes diseases to trees (Senkoro et al., 2014). There was a significant difference between wealth categories regarding the perception of the importance of debarking trees causing diseases ($F_{2,45} = 14.559$, $p < 0.001$). The level of education, as an indicator of wealth, may be a reason for this significant difference in perception, as wealthier households tend to be more aware of environmental and natural resource phenomena due to higher education levels compared to poorer households.

Kakamega Forest Ecosystem faces issues with invasive plants and tree species i.e., guava (*Psidium guajava*), wild sage (*lantana camara*), Siam weed (*Chromolaena odorata*), Mathenge trees (*Prosopis juliflora*), and eucalyptus (*Eucalyptus saligna*) (Abonyo et al., 2016). These invasive species rapidly colonize disturbed areas, competing with native tree species. The results suggest that the perception for invasive plants and trees differs significantly across the wealth categories ($F_{2,45} = 31.946$, $p < 0.001$), possible due to the wealth ranking indicators such as land ownership and education level. Wealthier and middle-income households own more land and are better educated; hence their perception of this threat is more enhanced compared to the poor households. This outcome is consistent with the findings in India

(Sarkar and Deb, 2024), where wealthier households are more aware of invasive plants and more likely to engage in control efforts.

Illegal logging in KFE is a significant threat, as expressed during the FGD and KII, and supported in the literature (Humphrey et al., 2016; Kisiwa et al., 2021). This threat contributes to forest degradation and revenue loss to the national government. KFS is mandated to combat illegal logging through forest rangers, and in some forest stations, CFAs have also mobilized forest scouts who volunteer to assist in enforcing rules and regulations. Previous studies indicated a shortage of KFS personnel to fully meet this mandate (Kisiwa et al., 2021). However, in 2023, the KFS managed forest stations in Kenya were boosted with additional rangers who underwent through requisite training. KII revealed that, even with additional personnel, the staff remains inadequate for effective patrol and enforcement. Households identified illegal logging as the biggest threat to KFE. This situation mirrors findings in Brazil (Bösch, 2021), where illegal logging is one of the biggest threats to the Amazon forest and results in revenue and tax income loss for the government due to informal trade.

Sand mining as a livelihood activity was mainly carried out in Navakholo and partly in Shinyalu along the riverbank. Sand mining alters the river's normal flow, resulting in sedimentation and erosion that can weaken riverbanks and increase the risk of flooding. It also lowers the riverbed, causing groundwater levels to drop and impacting on the amount of water available for ecosystems and human use (Sreebha and Padmalal, 2011). Gold mining mostly takes place in Ikolomani in Kakamega, with small scale and artisan miners also operating around the forest. The proximity to KFE raises significant environmental and sustainability concerns. These gold mines leave a lot of big holes deep in the ground, and during the FDG, some participants reported cases of residents sustaining serious injuries from the deep holes in the mine. This outcome is also observed in Ghana (Boadi et al., 2016), where the inception of illegal mining degraded 5% of the forest reserve. Sand and gold mining did not show a significant difference in its perception across the wealth categories.

Charcoal production is a common commercial activity in Kakamega region. The Kenyan government's charcoal ban, imposed in 2018, resulted in an increase in illegal charcoal supply to meet high demand (ISS, 2021). However, research by Wekesa et al. (2023) revealed that the policy generated a negative feedback loop among stakeholders, meaning the policy may not have achieved its intended purpose of reducing deforestation due to its adverse side effects. The authors recommended a policy mix, using substitute products like briquettes. According to our respondents, charcoal burning continues to pose a significant threat to KFE, a finding consistent with research in Uganda, where firewood and charcoal are major drivers of deforestation despite policies to control charcoal production (Bamwesigye et al., 2020).

Climate change was perceived as a significant threat, particularly after the severe drought throughout Kenya between March and June 2023 (IRC, 2023), which led the government to declare it a national emergency. This situation increased the local forest community's dependence on the forest for subsistence, further exacerbated by crop failure. The results indicate that perceptions of the importance of climate change differ significantly across the wealth categories ($F_{2,45} = 6.174$, $p = 0.002$). Wealthier houses, typically owning larger pieces of land on which they practice agroforestry, are more aware of climate change as a threat to KFE, as prolonged droughts directly impact their income sources. This aligns with Stern's (2007) research, which indicated that wealthier households, more likely to possess valuable assets such as land and businesses, are more vulnerable to the impacts of climate change on forests, including higher wildfire risks and decreased water supply.

Unsustainable harvesting of NTFP, which includes medicinal plants, mushroom, grazing grass, sand, and vegetables is one of the identified threats by the respondents. The results indicate that the perceptions of the importance of unsustainable NTFP harvesting differ significantly across the wealth categories ($F_{2,45} = 13.005$, $p < 0.001$). This is also seen in Nigeria (Suleiman et al., 2017), where wealthier households have a higher perception of the importance of NTFP compared to their counterparts.

Lack of awareness of conservation efforts was the second most significant threat perceived by the respondents. This broad term in our data collection covered: (a) limited access to conservation information due to technological, educational and geographical barriers; (b) inadequate outreach and education initiatives to inform the public about conservation efforts and (c) limited media coverage resulting in the public not being informed of these initiatives. The lack of awareness has led to reduced public support for conservation efforts, continued forest degradation, and ineffective policy implementation. The results reveal that perceptions of the lack of awareness of conservation efforts differ significantly across wealth categories ($F_{2,45} = 20.8$, $p < 0.001$), with wealthier and middle-income households being better positioned to consider long-term environmental/forest impacts because their basic needs are met. In contrast, poorer households strive to meet some of their basic needs (food security, housing, and employment) from the forest.

3.4 Perception of challenges faced by local communities across wealth categories

The importance of the selected challenges was ranked on a Likert scale from 1 to 5, and their mean and standard deviation are shown in Figure 5. The findings generally support H4. This was evident in several areas where poorer respondents reported higher concern. During the FGD and KII, numerous challenges faced by the local community were identified, which were narrowed down to 11 challenges, based on the frequency with which they were mentioned by FGD and KII participants.

The installation of an electric fence along the forest edge was identified as a challenge by the respondents. Initiated in 2023, the project aims to curb forest loss and promote biodiversity conservation. It is funded by the Kakamega and Vihiga county governments (KCG, 2020), the United Nations Development Program (UNDP), and the government of Japan (UNDP, 2023). The first phase, covering 155.6 km, started at Isocheno forest station in Shinyalu. The second phase, planned for 2024, will extend the fence by 117 km. Our results reveal that perceptions of the electric fence around the forest differ significantly across the wealth categories ($F_{2,45} = 7.163$, $p = 0.001$). Wealthier households, with greater financial resources, are better able to pay for entry fee to use the forest resources, unlike poorer households. During a

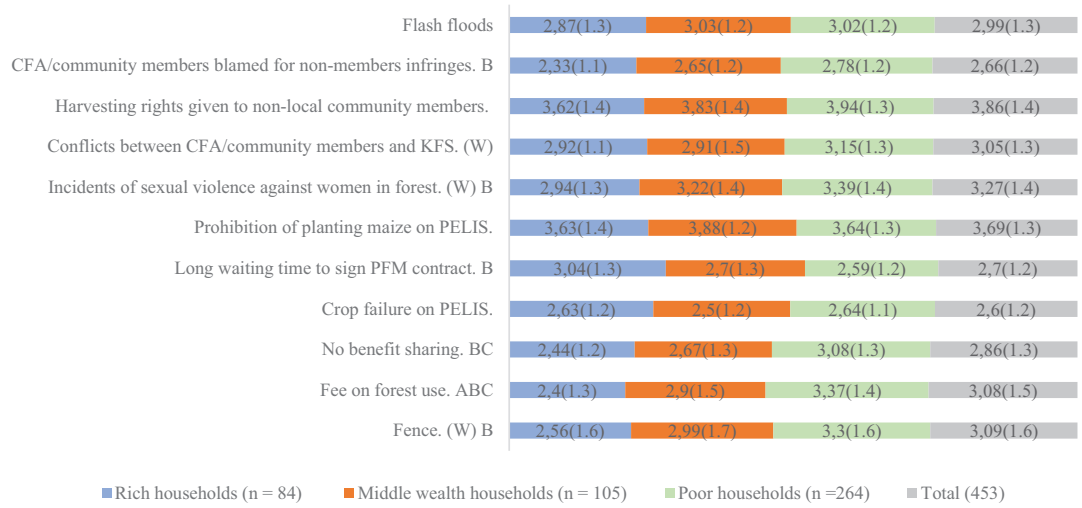

FIGURE 5
Perception of the challenges faced by local communities across the wealth categories [Numbers outside of the brackets are the means, while numbers inside the bracket indicate the standard deviation. A denotes a significant difference between rich and middle households, B denotes a significant difference between rich and poor households, and C denotes a significant difference between the middle and the poor households, at $p < 0.05$. (W) indicates performance of the Welch one-way ANOVA test].

KII interview with the forest manager at Isocheno in Shinyalu, various challenges were cited, including the need for interventions with some community members and vegetation near the fence causing short circuits. For the latter, Kakamega county employed six workers to slash the vegetation around the fence. The manager also cited the challenge of the maintenance cost associated with the electric fence. Overall, the communities neither agree nor disagree that the electric fence is a challenge they experience.

Fees for forest use are another challenge cited by the local community in KFE (See Supplementary Appendix Table A2 for forest fees). Perception of the fee for forest use differ significantly across wealth categories ($F_{2,45} = 15.996$, $p < 0.001$). Rich and middle-income households have enough financial resources to pay entry fee for forest use and perceive that fee is necessary to support the CFA in its function. Chomba et al. (2015) indicated that fees for forest resource use increased the vulnerability of disadvantaged local communities and fostered elite capture of local level institutions.

Regarding the issue of benefit sharing, the local community expressed dissatisfaction, despite the presence of PELIS, which allows forest access for a fee. Many respondents stated that the benefits are still not significant, and some reported not receiving any benefit from KFE. Financial barriers to joining CFA were mentioned as limitations, as membership is required to access forest resources. Even for those who could join the CFA, PELIS was not guaranteed. This is reflected in the significant differences in perceptions among wealth categories, with poorer households expressing greater dissatisfaction compared to their wealthier counterparts ($F_{2,45} = 9.443$, $p < 0.001$). However, the challenge of benefit sharing did not have a high perception as a challenge to the local community, possibly because some members acknowledged the indirect benefits of KFE. A similar challenge has also been documented in Nepal's community forest management system, particularly regarding the lack of social inclusion (Pokhrel and Gautam, 2024).

Crop failure on PELIS plots was identified as a significant challenge. Farmers reported losses caused by wild animals, especially baboons, monkeys and rodents, which damaged crops intended for domestic or commercial use. This further exacerbates forest dependency in KFE. A similar situation has been documented in Myanmar (San et al., 2023), where local communities perceived wild animals as an obstacle to implementing community-based agroforestry. However, crop failure did not have a high perception as a challenge to the local forest community, likely because only a small portion of the population benefits from the PELIS program.

By the time of data collection in March 2024, the PFM contracts (forest management agreements) for all CFAs in the study area had not been signed by the management of KFS since 2018. During the FGD at the four study sites, participants stated that the necessary documentation for finalizing the PFM agreements had already been submitted. They highlighted that the delay posed a challenge to their operation, as some sponsors of conservation initiatives or alternative livelihood activities required signed PFM contracts to continue or start funding. Perceptions of the prolonged delays in signing PFM contracts differ significantly across wealth categories ($F_{2,45} = 4.143$, $p = 0.016$). This may be attributed to wealthier households being more educated and understanding the critical role of PFM agreements in facilitating decision making involvement and supporting livelihood, which helps, in the end, to reduce forest dependence (Joram Kagombe, 2016).

The prohibition of maize planting in PELIS emerged as one of the major challenges identified by the local community. Maize flour is an essential ingredient in preparing "ugali," a staple food in the Kakamega region, and the restriction elicited a lot of negative feedback from the community, many of whom rely on maize for their daily food. The decision to stop maize planting in PELIS came from the concerns at KFS headquarters over the prolonged monoculture of maize, which was depleting soil minerals vital for tree growth. During FGDs, the participants stated that the ban had driven up maize prices in the market due to increased demand,

leaving some of the community members unable to purchase maize. This led to the prohibition of maize planting in PELIS being perceived as the second most significant challenge to the forest community in our analysis.

Incidences of sexual violence against women were also identified as a significant challenge by the local community. Women who went in the forest to collect firewood, vegetables, medicinal plants, and mushroom reported cases of some of their acquaintances being sexually assaulted by men who were in the forest to log or hunt bush meat. KII interviews with the forest rangers confirmed such incidents. In response, some women began to access the forest in groups, and KFS rangers increased vigilance to monitor suspicious activity. Several perpetrators of these acts were caught and prosecuted. Perceptions of sexual violence against women in the forest differs significantly across wealth categories ($F_{2,45} = 3.401$, $p = 0.034$), with poorer households reporting greater concern due to their heavier reliance on forest resources.

Conflicts between the CFA/community members and KFS were perceived as a challenge to the forest community. Some of the CFA executive members in the forest stations did not have a good working relationship with the forest manager in their respective duty stations. This led to exclusion of the CFA members from the community outreach programs and certain decision-making processes. During FGDs, some of the participants stated that this poor working relationship with KFS had delayed the signing of the PFM contract. However, it is important to note that not all the KFS staff had a poor working relationship with the CFA members at their respective stations.

The allocation of harvesting rights to non-locals had the highest perception as a challenge to the forest community. During FGDs, participants expressed concerns that plantation forest harvesting rights were awarded to harvesting companies operating outside Kakamega, thereby directly benefiting people outside their county. This trend was attributed to the decline in the number of harvesting companies in Kakamega, driven by insufficient raw materials and bureaucracy (Kefa et al., 2018).

The issue of CFA members being blamed for infringements committed by non-CFA members was another challenge identified by the forest community. According to our analysis, the local forest community did not perceive this challenge as highly significant. This could be because some of our respondents were not CFA members and were not associated with this challenge. This challenge contributed to a poor working relationship with the KFS, as the CFA members assist in scouting KFE, leading to speculation of collusion with offenders. Perception of CFA/community members being blamed for non-members infringements vary significantly across wealth categories ($F_{2,45} = 8.793$, $p < 0.001$), with poorer households volunteering more for scouting activities compared to wealthier households, thus increasing their awareness of this challenge.

During the later stages of our data collection, Kakamega went through heavy rains resulting in flooding that affected over 82,000 families in Kenya, with Kakamega county being one of the affected regions (OCHA, 2024). The Isiukhu River, which flows through KFE, broke its banks, severely affecting the neighboring local forest community and destroying their assets, including cultivated lands, houses, and livestock, which were vital to their livelihood (Star, 2024). Flooding was widely perceived as a high challenge by the local forest community in KFE, leading to an increased dependence on KFE for the provisioning ES. Our results align with outcomes from Vietnam (Tran et al., 2010), where flooding was also perceived as a major challenge due to similar experiences.

Analyzing the challenges faced by local forest communities across wealth categories helps in the development of targeted interventions tailored to the specific needs of each group (Agrawal and Gibson, 1999). It also provides policy makers with critical information for improving policy formulation by creating more inclusive and effective policies that address the unique difficulties experienced by various wealth groups. Such information ensures that policies do not disproportionately favor one group, promoting social equity and cohesion.

4 Conclusion

This research aimed to elicit the perceptions of the local forest community of KFE regarding the changes in the ES provision, changes in the forest condition, current threats to the forest, and the challenges experienced by the local forest communities across different wealth categories.

The results indicated perceptions that mirrored an increased ES provision across wealth categories, highlighting the crucial role of the forest ES in local community wellbeing, particularly among wealthy households in Malava. However, as expected, the wealthier households exhibited a positive correlation with the perception of unchanged ES provision, while poorer households had a positive correlation with decreased ES provision, indicating their sensitivity to reductions in ES on which they rely for their daily needs. Additionally, the size of land owned, and level of education were positively correlated with increased ES provision.

The local communities generally perceived an improvement in forest conditions across wealth categories, especially for Lurambi, suggesting better management of KFE. However, unexpectedly, poorer households correlated positively with perceptions of significant improvements in forest conditions, with a decreased perception in ES provision, indicating challenges related to access to these ES. In contrast, middle- and rich-households respondents showed a positive correlation with perceptions of severely degraded forest conditions, implying that derived economic activities may lead to deforestation. As expected, income, education level, and land ownership size showed a positive correlation with perceived improvement in forest conditions.

The unexpectedly low perception of animal grazing as a threat to KFE, with significant differences between middle- and rich-households, underscores the importance of land ownership as a wealth indicator. It suggests that middle-income households are more likely to rely on forest grazing for their livestock, making them less sensitive to this threat. This outcome also highlights a potential gap in conservation communication, as intensive grazing, despite its negative ecological impacts, is not widely perceived as a threat. This indicates a lack of awareness among local communities regarding the long-term environmental consequences, emphasizing the need for improved education, awareness, and engagement between policymakers and the forest dependent communities.

As expected, the electric fence was perceived as a major challenge, with significant differences across wealth categories,

highlighting the poor households' heavy reliance on provisioning ES. This finding illustrates how electric fencing, typically perceived as beneficial for forest conservation by reducing illegal logging, has differential socioeconomic impacts that are often overlooked. The significant differences in perception suggest that fencing is not a neutral intervention but rather one that creates economic and social inequalities in access to forest resources.

This research contributes to the scientific community by demonstrating how threats and challenges associated with forest conservation disproportionately affect and involve different wealth groups. The findings enhance the understanding of the intersections between forest conservation, economic inequality, and governance. They also highlight the need for wealth-sensitive conservation policies and opens new research directions on how economic disparities shapes forest threats.

The study's strength relies in its mixed method approach and use of weighted scoring to classify households by wealth, offering valuable insights into how socio-economic status shapes forest dependency in the KFE. Grounded in extensive fieldwork and community engagement, the study captures the lived experience of the forest-dependent communities and highlights the socio-economic complexities influencing conservation outcomes.

However, several limitations exist. The study relies on cross-sectional and self-reported data, which limits its ability to establish causal relationships. The one-time survey design also restricts understanding of evolving perceptions – particularly considering recent interventions, such as the installation of electric fences, whose long-term effects remain unexplored. Future research should adopt a longitudinal approach to capture shifting community perceptions and adaptive strategies over time, especially in response to recent developments. Incorporating participatory mapping and remote sensing could further strengthen both ecological and social insights.

Kakamega Forest Ecosystem presents a clear case of competing interests between biodiversity conservation and community livelihoods, as supported by previous research. This findings of this study show that poorer households rely on forest resources out of necessity, yet they are often disproportionately affected by restrictive conservation measures.

The identified challenges and associated recommendations offer equitable, inclusive, and sustainable solutions that could enhance PFM in KFE and beyond, ensuring the wellbeing of the local communities and contributing to the achievement of the Sustainable Development Goals of the region.

4.1 Policy recommendations

The research findings can inform policy development tailored to local context and provide recommendations for targeted interventions in the Kakamega forest management plan, as well as for non-governmental organizations operating in the region. These recommendations include:

Community outreach – the research revealed that the electric fence, intended to curb threats such as illegal logging, creates a negative feedback loop. Policymakers should consider targeted public awareness campaigns to highlight how the fences not only lower illegal logging incidences and improve forest safety by limiting unauthorized access but also curb incidents such as sexual violence. Additionally, these campaigns should clarify maize planting restrictions within PELIS lands and support public understanding of collective conservation efforts.

Alternative agricultural crops are another area of intervention – policymakers might consider promoting non-palatable crops for monkeys and rodents, such as onions and chilies, or companion/buffer crops like marigold, carrots, and onions. This would solve the crop failure issues identified by the local community and curb the unsustainable harvesting of NTFP by offering more alternative crops that fetch premium prices in the market.

Local based harvesting – establishment of harvesting quotes in favor of local timber harvesting companies operating in Kakamega might be an area of policy intervention, offering synergistic solution by ensuring more benefits remain in the county for the local communities in terms of jobs and taxes.

In the area of monitoring of PFM implementation – policymakers should consider establishing a monitoring mechanism to oversee PFM implementation, resolve contract difficulties between CFAs and KFS, and ensure that CFAs have the necessary documents and meet contract conditions. Such a mechanism would create a conducive environment for the successful execution of PFM.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because the studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because verbal consent was obtained from all study participants.

Author contributions

IO: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft. CC: Data curation, Formal Analysis, Methodology, Supervision, Validation, Writing – review and editing. NT: Visualization, Writing – review and editing. EO: Formal Analysis, Visualization, Writing – review and editing. LN: Validation, Writing – review and editing. JK: Validation, Writing – review and editing. IA: Supervision, Visualization, Writing – review and editing. BP: Conceptualization,

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/ffgc.2025.1554677/full#supplementary-material

References

Abonyo, C., Obiri, J., Muyekho, F., Omayio, D., Humphrey, A., Anastasia, M., et al. (2016). Allellopathic potential of invasive *Psidium guajava* L., against selected native tree species in Kakamega Tropical Forest, Western Kenya. *IOSR J. Pharm. Biol. Sci.* 11, 80–86. doi: 10.9790/3008-1105028086

Aerts, R., Van Overtveld, K., November, E., Wassie, A., Abiyu, A., Demissew, S., et al. (2016). Conservation of the Ethiopian church forests: Threats, opportunities and implications for their management. *Sci. Total Environ.* 55, 404–414. doi: 10.1016/J.SCITOTENV.2016.02.034

Agrawal, A., and Gibson, C. C. (1999). Enchantment and disenchantment: The role of community in natural resource conservation. *World Dev.* 27, 629–649. doi: 10.1016/S0305-750X(98)00161-2

Ahammad, R., Stacey, N., and Sunderland, T. (2021). Analysis of forest-related policies for supporting ecosystem services-based forest management in Bangladesh. *Ecosyst. Serv.* 48:101235. doi: 10.1016/J.ECOSER.2020.101235

Ahammad, R., Stacey, N., and Sunderland, T. C. H. (2019). Use and perceived importance of forest ecosystem services in rural livelihoods of Chittagong Hill Tracts, Bangladesh. *Ecosyst. Serv.* 35, 87–98. doi: 10.1016/J.ECOSER.2018.11.009

Alamgir, M., Campbell, M. J., Sloan, S., Engert, J., Word, J., and Laurance, W. F. (2020). Emerging challenges for sustainable development and forest conservation in Sarawak, Borneo. *PLoS One* 15:e0229614. doi: 10.1371/JOURNAL.PONE.0229614

Awuah, R., Douglass, R., Agyepong, S., and Kuwornu, E. (2017). An adaptive household sampling method for rural African communities. *Afr. J. Food Agric. Nutr. Dev.* 17, 11477–11496. doi: 10.18697/ajfand.77.16680

Aznar-Sánchez, J. A., Belmonte-Ureña, L. J., López-Serrano, M. J., and Velasco-Muñoz, J. F. (2018). Forest ecosystem services: An analysis of worldwide research. *Forests* 9:453. doi: 10.3390/f9080453

Bamwesigye, D., Kupec, P., Chekuimo, G., Pavlis, J., Asamoah, O., Darkwah, S. A., et al. (2020). Charcoal and wood biomass utilization in Uganda: The socioeconomic and environmental dynamics and implications. *Sustainability* 12:8337. doi: 10.3390/su12208337

Barasa, R. M. (2014). Influence of Monitoring and Evaluation Tools on Project Completion in Kenya: A Case of Constituency Development Fund Projects in Kakamega County, Kenya. http://erepository.uonbi.ac.ke/handle/11295/74126 (accessed May 3, 2024)

Boadi, S., Nsor, C. A., Antobre, O. O., and Acquah, E. (2016). An analysis of illegal mining on the Offin shelterbelt forest reserve, Ghana: Implications on community livelihood. *J. Sustain. Mining* 15, 115–119. doi: 10.1016/j.jsm.2016.12.001

Bösch, M. (2021). Institutional quality, economic development and illegal logging: A quantitative cross-national analysis. *Eur. J. For. Res.* 140, 1049–1064. doi: 10.1007/S10342-021-01382-Z

Cavender-Bares, J. M., Id, E. N., Meireles, Id, J. E., Lasky, J. R., Mitevaid, D. A., et al. (2022). The hidden value of trees: Quantifying the ecosystem services of tree lineages and their major threats across the contiguous US. *PLoS Sustain. Transform.* 1:e0000010. doi: 10.1371/JOURNAL.PSTR.0000010

Chambers, R. (1994). The origins and practice of participatory rural appraisal. *World Dev.* 22, 953–969. doi: 10.1016/0305-750X(94)90141-4

Chomba, S., Treue, T., and Sinclair, F. (2015). The political economy of forest entitlements: Can community based forest management reduce vulnerability at the forest margin? *For Policy Econ.* 58, 37–46. doi: 10.1016/J.FORPOL.2014.11.011

Creswell, J. W. (2009). "Research design: Qualitative, quantitative, and mixed methods approaches," in *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 3rd Edn, eds J. W. Creswell and J. D. Creswell (London: Sage Publications, Inc).

Das, I., le Roux, L., Mulwa, R., Ruhinduka, R., and JeulandID, M. (2024). Urban demand for cooking fuels in two major African cities and implications for policy. *PLoS Sustain. Transform.* 3:e0000077. doi: 10.1371/JOURNAL.PSTR.0000077

Farwig, N., Sajita, N., and Böhning-Gaese, K. (2009). High seedling recruitment of indigenous tree species in forest plantations in Kakamega Forest, western Kenya. *For. Ecol. Manage.* 257, 143–150. doi: 10.1016/j.foreco.2008.08.022

Fashing, P. J., Forrestel, A., Scully, C., and Cords, M. (2004). Long-term tree population dynamics and their implications for the conservation of the Kakamega Forest, Kenya. *Biodiv. Conserv.* 13, 753–771. doi: 10.1023/B:BIOC.0000011724.34275.73

Frank, C., Kairo, J. G., Bosire, J. O., Mohamed, M. O. S., Dahdouh-Guebas, F., and Koedam, N. (2017). Involvement, knowledge and perception in a natural reserve under participatory management: Mida Creek, Kenya. *Ocean Coastal Manage.* 142, 28–36. doi: 10.1016/J.OCECOAMAN.2017.03.009

Girma, G. (2022). Assessment of households' perception towards participatory forest management the case of Heban Arsi Woreda, Ethiopia. *Indones. J. Environ. Manage. Sustain.* 6, 143–150. doi: 10.26554/IJEMS.2022.6.4.143-150

GoK (2016). *Forest Conservation and Management Act, 2016 (No. 34 of 2016)*. Available online at: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC160882/ (accessed October 24, 2020).

Hallberg-Sramek, I., Nordström, E.-M., Priebe, J., Reimerson, E., Mårald, E., and Nordin, A. (2023). Combining scientific and local knowledge improves evaluating future scenarios of forest ecosystem services. *Ecosyst. Serv.* 60:101512. doi: 10.1016/j.ecoser.2023.101512

Humphrey, A., Adamba, M. K., Hillary, K., Carolyne, M., Calvince, K. R., Kipruto, K. D., et al. (2016). PELIS forestry programme as a strategy for increasing forest cover

and improving community livelihoods: Case of Malava Forest, Western Kenya. *Am. J. Agric. For.* 4, 128–135. doi: 10.11648/j.ajaf.20160405.13

IPBES (2019). *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services (summary for policy makers)*. Paris: IPBES. doi: 10.5281/ZENODO.3553579

IRC (2023). *IRC: Severe Drought is Projected to Leave about 5.4 Million People in Kenya without Adequate Access to Food and Water between March and June 2023*. New York, NY: International Rescue Committee (IRC).

ISS (2021). *Kenya's Charcoal Bans have Fuelled a Smuggling Problem*. Nieuw Muckleneuk: ISS Africa.

Jebiwott, A., Ogendi, G. M., Agbeja, B. O., Alo, A. A., and Kibet, R. (2021). Mapping the trends of forest cover change and associated drivers in Mau Forest, Kenya. *Remote Sens. Appl.* 23:100586. doi: 10.1016/j.rsase.2021.100586

Joram Kagombe, J. K. S. K. (2016). *Kakamega Forest Strategic Ecosystem Management Plan 2015-2040*. Kenya: Kenya Forest Service.

Kalaba, F. K., Quinn, C. H., and Dougill, A. J. (2013). Contribution of forest provisioning ecosystem services to rural livelihoods in the Miombo woodlands of Zambia. *Populat. Environ.* 35, 159–182. doi: 10.1007/s11111-013-0189-5

Karjalainen, E., Sarjala, T., and Raitio, H. (2010). Promoting human health through forests: Overview and major challenges. *Environ. Health Prevent. Med.* 15, 1–8. doi: 10.1007/S12199-008-0069-2

KCG (2020). *Process to Fence Kakamega forest on track – County Government of Kakamega*. Available online at: https://kakamega.go.ke/process-to-fence-kakamega-forest-on-track/ (accessed February 24, 2020).

Kefa, C. A., Lung, M., Espira, A., and Gregory, A. J. (2018). Quantifying the rate of subsistence wood harvesting from a tropical rainforest in Kenya. *Oryx* 52, 369–373. doi: 10.1017/S003060531600106X

Kisiwa, A., Gatama, S., and Langat, D. (2021). *Community Perception of Ecosystem Services and Management Implications of Three Forests in Western Part of Kenya*. Kenya: Kenya Agricultural & Livestock Research Organisation

KNBS (2019). *2019 Kenya Population and Housing Census Volume I: Population by County and Sub-County - Kenya National Bureau of Statistics*. Kenya: Kenya National Bureau of Statistics

KWS (2012). *Kakamega Forest Management Plan 2012-2022*. Available online at: https://www.kws.go.ke/sites/default/files/2019-11/Kakamega%20Forest%20Ecosystem%20Management%20Plan%20%282012-2022%29_0.pdf (accessed May 5, 2024).

Lan, L. N., Wichelns, D., Milan, F., Hoanh, C. T., and Phuong, N. D. (2016). Household opportunity costs of protecting and developing forest lands in Son La and Hoa Binh Provinces, Vietnam. *Int. J. Commons* 10, 902–928. doi: 10.18352/ijc.620

Langat, D. K., Maranga, E. K., Aboud, A. A., and Cheboiwo, J. K. (2016). Role of forest resources to local livelihoods: The case of East Mau forest ecosystem, Kenya. *Int. J. For. Res.* 2016:4537354. doi: 10.1155/2016/4537354

Laura, A., Kweyu, R. M., and Thomas, K. (2020). The nexus between community participation in conservation and land cover change in Kakamega forest, Kenya. *J. Soc. Sci. Human. Res.* 5, 1–18. doi: 10.53555/sshr.v5i9.3870

Laurance, W. F., Alonso, A., Lee, M., and Campbell, P. (2006). Challenges for forest conservation in Gabon, Central Africa. *Futures* 38, 454–470. doi: 10.1016/j.futures.2005.07.012

Leley, N., Langat, D., Kosgey, C., Kisiwa, A., and Nzove, B. (2023). "Implications of livestock grazing on sustainable management of montane forests: A case of South West Mau forest, Kenya," in *Proceedings of the Conference: XV World forestry congress*, (Seoul).

Luswaga, H., and Nuppenau, E. A. (2020). Participatory forest management in West Usambara Tanzania: What is the community perception on success? *Sustainability* 12:921. doi: 10.3390/SU12030921

Lwangale, D. W. (2018). *Genealogical Reconstruction of the Proto-Luluhyia Language*. Available online at: http://41.89.96.81:8080/xmlui/handle/123456789/1680 (accessed May 3, 2024).

Mbuvi, M., Kungu, J., and Eshitera, A. (2022). The impact of governance regime on land cover and use change and forest structure: Insights from Kakamega and Loita Forests, Kenya. *Open J. For.* 12, 185–215. doi: 10.4236/ojf.2022.122011

Mea, M. E. (2005). *Millennium Ecosystem Assessment*. Available online at: https://www.millenniumassessment.org/en/index.html (accessed March 5, 2024).

Meijaard, E., Abram, N. K., Wells, J. A., Pellier, A.-S., Ancrenaz, M., Gaveau, D. L. A., et al. (2013). People's perceptions about the importance of forests on Borneo. *PLoS One* 8:e073008. doi: 10.1371/journal.pone.0073008

Memon, M. A., Ting, H., Cheah, J.-H., Thurasamy, R., Chuah, F., and Cham, T. H. (2020). Sample size for survey research: Review and recommendations. *J. Appl. Struct. Equ. Model.* 4, 1–20.

Nyangoko, B. P., Shalli, M. S., Mangora, M. M., Gullström, M., and Berg, H. (2022). Socioeconomic determinants of mangrove exploitation and management in the Pangani River Estuary, Tanzania. *Ecol. Soc.* 27:32. doi: 10.5751/ES-13227-270232

Obonyo, O. A., Agevi, H., and Tsingalia, M. H. (2023). Above-ground carbon stocks and its functional relationship with tree species diversity: The case of Kakamega and North Nandi Forests, Kenya. *Sci. Rep.* 13, 1–10. doi: 10.1038/s41598-023-47871-6

OCHA (2024). *Kenya: Heavy Rains and Flooding Update - Flash Update #6*. Available online at: https://www.unocha.org/publications/report/kenya/kenya-heavy-rains-and-flooding-update-flash-update-6-17-may-2024 (accessed May 17, 2024).

Ongugo, P., Mugo, F., and Maua, J. (2007). *Participatory Forest Management in Kenya: Is There Anything for the poor? HimalDoc*. Viluppuram: Kenya Forest Research Institute.

Osewe, E. O., Niță, M. D., and Abrudan, I. V. (2022). Assessing the fragmentation, canopy loss and spatial distribution of forest cover in Kakamega National Forest Reserve, Western Kenya. *Forests* 13:2127. doi: 10.3390/F13122127

Osewe, I., Osewe, E. O., and Popa, B. (2023). Interconnection between ecosystem services and local communities: Knowledge gap identification in the area of Kakamega forest. *Bull. Transilvania Univ. Brasov* 16, 37–68. doi: 10.31926/but.fwiafe.2023.16.65.2.3

Ouko, C. A., Mulwa, R., Kibugi, R., Owuor, M. A., Zaehringer, J. G., and Oguge, N. O. (2018). Community perceptions of ecosystem services and the management of Mt. Marsabit Forest in Northern Kenya. *Environments* 5:121 doi: 10.3390/environments5110121

Ouma, O. K., Stadel, C., and Eslamian, S. (2011). Perceptions of tourists on trail use and management implications for Kakamega Forest, Western Kenya. *J. Geogr. Region. Plann.* 4, 243–250.

Parag, Y., Elimelech, E., and Opher, T. (2023). Bottled water: An evidence-based overview of economic viability, environmental impact, and social equity. *Sustainability* 15:9760. doi: 10.3390/SU15129760

Patricia, L. (2014). "The Oxford handbook of qualitative research," in *The Oxford Handbook of Qualitative Research*, ed. P. Leavy (Oxford: Oxford University Press). doi: 10.1093/oxfordhb/9780199811755.001.0001

Pokhrel, R. K., and Gautam, A. P. (2024). Community forest, environment conservation and rural livelihood. *Geogr. J. Nepal* 17, 151–162. doi: 10.3126/GJN.V17I01.63945

Rakatama, A., and Pandit, R. (2020). Reviewing social forestry schemes in Indonesia: Opportunities and challenges. *For. Policy Econ.* 111:102052. doi: 10.1016/J.FORPOL.2019.102052

Rakodi, C. (1999). A capital assets framework for analysing household livelihood strategies: Implications for policy. *Dev. Policy Rev.* 17, 315–342. doi: 10.1111/1467-7679.00090

Saalu, F. N., Oriaso, S., and Gyampoh, B. (2020). Effects of a changing climate on livelihoods of forest dependent communities. *Int. J. Clim. Change Strat. Manage.* 12, 1–21. doi: 10.1108/IJCCSM-01-2018-0002

San, S. M., Kumar, N., Biber-Freudenberger, L., and Schmitt, C. B. (2023). Agroforestry-based community forestry as a large-scale strategy to reforest agricultural encroachment areas in Myanmar: Ambition vs. local reality. *Ann. For. Sci.* 80:27. doi: 10.1186/s13595-023-01191-x

Sarkar, S., and Deb, P. (2024). Community-level impacts of plant invasion in tropical forests of Northeast India. *Plant Ecol.* 225, 1079–1094. doi: 10.1007/S11258-024-01456-Z

Scoones, I. (1998). *Sustainable Rural Livelihoods: A Framework for Analysis*. Available online at: https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/3390 (accessed March 5, 2024).

Senkoro, A. M., Barbosa, F. M. A., Moiane, S. F., Albano, G., Barros, A. I. R., de, et al. (2014). Bark stripping from forest tree species in Madjadjane, Southern Mozambique: Medicinal uses and implications for conservation. *Nat. Resour.* 5, 192–199. doi: 10.4236/NR.2014.55018

Sherrouse, B. C., Semmens, D. J., Ancona, Z. H., and Brunner, N. M. (2017). Analyzing land-use change scenarios for trade-offs among cultural ecosystem services in the Southern Rocky Mountains. *Ecosyst. Serv.* 26, 431–444. doi: 10.1016/j.ecoser.2017.02.003

Siri, J. G., Lindblade, K. A., Rosen, D. H., Onyango, B., Vulule, J. M., Slutsker, L., et al. (2008). A census-weighted, spatially-stratified household sampling strategy for urban malaria epidemiology. *Malaria J.* 7, 1–10. doi: 10.1186/1475-2875-7-39

Sreebha, S., and Padmalal, D. (2011). Environmental impact assessment of sand mining from the small catchment Rivers in the Southwestern Coast of India: A case study. *Environ. Manage.* 47, 130–140. doi: 10.1007/s00267-010-9571-6

Star (2024). *Kakamega Issues Flooding Alert to Residents Living Near Rivers*. Available online at: https://www.the-star.co.ke/news/realtime/2024-05-02-kakamega-issues-flooding-alert-to-residents-living-near-rivers/ (accessed May 2, 2024).

Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge: Cambridge University Press, 1–692. doi: 10.1017/CBO9780511817434

Suleiman, M. S., Wasonga, V. O., Mbau, J. S., Suleiman, A., and Elhadi, Y. A. (2017). Non-timber forest products and their contribution to households income around

Falgore Game Reserve in Kano, Nigeria. *Ecol. Proc.* 6:23. doi: 10.1186/s13717-017-0090-8

Sulemana, I., James, H. S., and Valdivia, C. B. (2016). Perceived socioeconomic status as a predictor of environmental concern in African and developed countries. *J. Environ. Psychol.* 46, 83–95. doi: 10.1016/j.jenvp.2016.04.002

Tabarelli, M., Pinto, L. P., Silva, J. M. C., Hirota, M., and Bedê, L. (2005). Challenges and opportunities for biodiversity conservation in the Brazilian Atlantic ForestRetos y oportunidades para la Conservación de Biodiversidad en el Bosque Atlántico Brasileño. *Conserv. Biol.* 19, 695–700. doi: 10.1111/J.1523-1739.2005.00694.X

Tadesse, S., Woldetsadik, M., and Senbeta, F. (2017). Forest users' level of participation in a participatory forest management program in southwestern Ethiopia. *For. Sci. Technol.* 13, 164–173. doi: 10.1080/21580103.2017.1387613

Tallis, H., Pagiola, S., Zhang, W., Shaikh, S., Nelson, E., Stanton, C., et al. (2011). *Poverty and the Distribution of Ecosystem Services: Natural Capital: Theory and Practice of Mapping Ecosystem Services*. Oxford: Oxford University Press, 278–293.

TEEB (2010). *TEEB Synthesis Report (2012) - The Economics of Ecosystems and Biodiversity*. Available online at: https://teebweb.org/publications/teeb-for/synthesis/ (accessed July 31, 2024).

Tipton, E. (2013). Stratified sampling using cluster analysis: A sample selection strategy for improved generalizations from experiments. *Eval. Rev.* 37, 109–139. doi: 10.1177/0193841x13516324

Tran, P., Marincioni, F., and Shaw, R. (2010). Catastrophic flood and forest cover change in the Huong river basin, central Viet Nam: A gap between common perceptions and facts. *J. Environ. Manage.* 91, 2186–2200. doi: 10.1016/j.jenvman.2010.05.020

Trosper, R. L., Parrotta, J. A., Agnoletti, M., Bocharnikov, V., Feary, S. A., Gabay, M., et al. (2012). "The unique character of traditional forest-related knowledge: Threats and challenges ahead," in *Traditional Forest-Related Knowledge*, Vol. 12, eds J. Parrotta and R. Trosper (Dordrecht: Springer), 563–588. doi: 10.1007/978-94-007-2144-9_15

UNDP (2023). *Restoring the Jewel of Kakamega: Mission to UNDP Kenya FLARAK's Fencing project in Kakamega Forest by UNDP KENYA. Medium*. Available online at: https://undp-kenya.medium.com/restoring-the-jewel-of-kakamega-mission-to-undp-kenya-flaraks-fencing-project-in-kakamega-forest-b176b5a3c626 (accessed Auguest 2, 2023).

Wang, X., Dong, X., Liu, H., Wei, H., Fan, W., Lu, N., et al. (2017). Linking land use change, ecosystem services and human well-being: A case study of the Manas River Basin of Xinjiang, China. *Ecosyst. Serv.* 27, 113–123. doi: 10.1016/J.ECOSER.2017.08.013

Wekesa, C., Mutta, D., Larwanou, M., Kowero, G., and Roos, A. (2023). Effects of charcoal ban on value chains and livelihoods in Kenyan coast – Stakeholders' perceptions. *Environ. Dev.* 45:100809. doi: 10.1016/j.envdev.2023.100809

Were, L., Kassilly, J., and Ahaya, O. L. (2024). The Indigenous Abaluhyia Worldview in Communicating Conservation of Kakamega Forest, Kenya. *Afr. J. Empiric. Res.* 5, 94–106. doi: 10.51867/ajernet.5.3.9

Wu, B., Liang, W., Wang, J., and Cui, D. (2022). Rural residents' perceptions of ecosystem services: A study from three topographic areas in Shandong Province, China. *Land* 11:1034. doi: 10.3390/LAND11071034

Zhou, L., Guan, D., Sun, L., He, X., Chen, M., Zhang, Y., et al. (2023). What is the relationship between ecosystem services and farmers' livelihoods? Based on measuring the contribution of ecosystem services to farmers' livelihoods. *Front. Ecol. Evol.* 11:1106167. doi: 10.3389/FEVO.2023.1106167/BIBTEX

Zulu, L. (2013). Bringing people back into protected forests in developing countries: Insights from Co-Management in Malawi. *Sustainability* 5, 1917–1943. doi: 10.3390/su5051917