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Local community perceptions on ecosystem services utilisation—implications for sustainable management of Kakamega Forest in Kenya

Ibrahim Osewe · Claudiu Coman · Aureliu-Florin Hălălișan · Erick O. Osewe · Leila Ndalilo · Joram K. Kagombe · Ioan Vasile Abrudan · Bogdan Popa

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Abstract Forests play a vital role in supporting local livelihoods by providing resources and services that underpin cultural, economic, and social well-being. In Kenya's Kakamega rainforest, participatory forest management is challenged by population pressures, yet the impact of ecosystem service (ES) flows on local communities remains insufficiently understood. This study examined how communities perceive and use forest ES and how these perceptions vary across socio-economic groups. We used a mixed-methods approach combining qualitative data (17 key informant interviews, 8 focus group discussions) and quantitative data (surveys of 453 households). Statistical analyses (Kruskal–Wallis, Chi-square, Mann–Whitney U, ANOVA) revealed 20 recognized ES, with firewood identified as the most critical (acknowledged by 86% of respondents). Provisioning ES were mainly used for domestic purposes, particularly by male respondents and individuals aged 36–48. Wealthier households placed greater value on cultural ES and associated them strongly with natural forests (2 out of 4). Significant differences in ES importance, use, and supporting land-use types were observed across wealth, age, and gender groups. These findings highlight the importance of management strategies that incorporate diverse community perspectives and promote the equitable and sustainable use of forest resources.

Keywords Human well-being · Land use supporting ecosystem services · Participatory forest management · Wealth groups · Domestic use · Commercial use

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I. Osewe (✉) · A.-F. Hălălișan · E. O. Osewe · I. V. Abrudan · B. Popa
Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov, Sirul Beethoven 1, 500123 Brasov, Romania
e-mail: osewe.ibrahim@unitbv.ro

C. Coman
Department of Social Sciences and Communication, Faculty of Sociology and Communication, Transilvania University of Brașov, Eroilor Street, No. 25, 500030 Brașov, Romania

L. Ndalilo · J. K. Kagombe
Department of Socio-Economic Policy and Governance, Kenya Forestry Research Institute, P.O. Box 20412-00200, Nairobi, Kenya

Introduction

Forest ecosystems provide essential goods and services that support both direct and indirect human use (MEA 2005). These ecosystem services (ES) are vital for economic development, environmental health, and human well-being. Provisioning ES such as firewood, medicinal plants, grazing grass, and food sustain rural livelihoods through both commercial

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and subsistence activities (Hasan et al. 2020). Regulating ES, which include flood protection, climate regulation, and air quality are important for ensuring long term ecosystem stability by keeping key environmental factors within a stable range (Sutherland et al. 2018). Supporting ES, such as rainfall attraction enable other services to flow (Aguilar-Fernández et al. 2020), while cultural ES, such as recreation, environmental education, and religious and spiritual values, are deeply tied to social and cultural fabric of communities. Traditional ecological knowledge, passed down through generations, including practices related to medicinal plant use, and forest conservation, helps sustain both ecosystems and cultural heritage (Darr et al. 2009; Were et al. 2024). However, the way in which different households utilize, access, and prioritize forest ES varies greatly based on land use systems, forest governance structures, and socio-economic conditions (Groot et al. 2010). Understanding the interplay between forest ES and human well-being across diverse socio-economic groups in the community is essential for developing equitable and sustainable forest management strategies (Díaz et al. 2018).

A key factor in understanding the dynamics of the relationship between ES and communities, particularly in assessing the socio-cultural dimensions of ES, is local community perception on ES importance (Bhatt et al. 2024). While indirect benefits such as regulating, supporting and cultural ES are typically explored using biophysical assessments, local perceptions of their importance is frequently overlooked in forest management strategies (Plieninger et al. 2013). As a result, social integration in ES assessment remains limited, and only few studies have linked these services to human wellbeing (Ahammad et al. 2019; Dawson and Martin 2015; Fritz-Vietta 2016; Gao et al. 2024; Hallaj et al. 2024). In forest landscapes, differing perception of these ES can lead to conflicts, misunderstandings and ineffective management strategies (Hassen et al. 2023) and balancing immediate livelihood needs with long-term forest benefits requires understanding how ES importance perception vary across the socio-economic factors.

Another factor that warrants the understanding of this relationship is the way the provisioning ES are used by the community members. While extensive research in developing countries has primarily focused on the economic and biophysical contributions of provisioning ES (Angelsen et al. 2014; Belcher et al. 2015; Oldekop et al. 2020), and income-related studies have assessed the impact of forest dependency on resources utilization across wealth and user groups (Adhikari et al. 2004; Lambini and Nguyen 2022; Robinson et al. 2019; Wekesa et al. 2022), there remains a significant gap in analysis regarding how socio-economic factors, specifically wealth status, affect the utilisation and perception of ES. Understanding these variations is crucial for comprehending how forest ecosystems sustain livelihood across different geographical areas (Hartter 2010). Studies have indicated that wealth groups are acknowledged in terms of their differentiated role in the utilization of provisioning ES (Ahammad et al. 2019; Kalaba et al. 2013; Mensah et al. 2017). However, there has been limited exploration of how these wealth groups and other social groups perceive the value and use provisioning ES. This study specifically addresses this gap by examining these perceptions across diverse socio-economic categories.

Another crucial socio-economic factor to consider are age and gender. These factors shape how communities and individuals perceive, utilize, and prioritize ES (Koju et al. 2023). Comprehending these diverse viewpoints is essential for efficient natural resource management, fair conservation planning, and sustainable flow of benefits from forest ecosystems. Different social groups, influenced by their roles, abilities, and cultural background, interact with and depend on forests in distinct ways, leading to varied perceptions of ES importance and their utilization pattern. Studies have indicated the influence of age and gender on use and perception of ES (Fortnam et al. 2019; Li et al. 2024; Luswaga 2023; Paing et al. 2022; Yang et al. 2015; Yang et al. 2018), but they have limited comprehensive exploration of the well-being needs met by this ES. This is particularly relevant in the context of the Kakamega Forest Ecosystem (KFE) in Kenya, where the need for equity in access to ES is compounded by issues such as elite capture within the country's community forest associations (CFA) (Ongugo 2007).

A third factor is the complex relationship between land use and ES. Land use is a key driver of community well-being, influencing ES flow at global, regional and local scales. However, land use changes often lead to economic benefits at the expense of essential supporting, regulating and cultural ES

(Chettri et al. 2021). Understanding the link between land use and well-being is crucial for sustainable management (Sangha et al. 2018). The benefits derived from land use vary according to rural populations' geographical context, socio-economic status, and resource use (Benra and Nahuelhual 2019; Duguma and Hager 2011; Lau et al. 2018). Wealth status, age, and gender variation is vital to understand the household utilization pattern, relative importance of the ES, and the land use supporting the ES flow (Ahammad et al. 2019, 2022; Kalaba et al. 2013; Paing et al. 2022). While there is extensive research on land use change and its impact on ES, most studies focus on broad ecosystem valuation (Hasan et al. 2020; Wang et al. 2017) or specifically on forest ecosystems (Mbuvi et al. 2022), rather than on the specific contributions of different land uses to the provision of ES. A deeper understanding of how wealth groups, age, and gender of households benefit from diverse land use practices is essential for informed long-term policymaking and sustainable development.

KFE is an ideal location for investigating the aforementioned issues. The country faces significant challenges in natural resource management due to rapid population growth and increasing land demand for food and housing (Wekesa et al. 2023). Projections suggest that Kenya's population will reach 91.6 million by 2050, posing substantial challenges to achieving the Sustainable Development Goals (KNBS 2019). Forests in Kenya support food security and poverty reduction, with forest cover increasing from 5.9% in 2018 to 8.8% in 2021, and a national target of reaching 30% by 2032 (KiPPRA 2023). The Kakamega forest, Kenya's last Guineo-Congolian rainforest, is crucial for local communities but faces degradation due to population pressures (Mbuvi et al. 2022). The forests operates under a participatory forest management (PFM) model, co-managed by Kenya Forest Service and CFAs established under the Forest Conservation and Management Act of 2016 (Republic of Kenya 2016). CFAs represent local forest user groups and collaborate with the forest service to support sustainable forest use (Osewe et al. 2025a). PFM introduced Plantation Establishment and Livelihood Improvement Scheme (PELIS), allowing nearby communities to grow crops while restoring forest plantations. However, PFM faces institutional, economic and ecological challenges across the country (Ongugo 2007). Policy shifts like the 2018 charcoal ban have harmed coastal livelihoods (Wekesa et al. 2023) and the new electric fence around KFE buffer zones has limited access affecting ES flow (UNDP 2023).

This study aims to analyze the relationship between forest ES and local forest communities in order to identify strategies for improving PFM and ensuring mutual benefits for both the forest and the community. The research specifically addressed the following key questions and formulated corresponding hypotheses to be tested: (1) To what extent do target communities recognize the ES provided by the KFE and their contribution to community well-being? Hypothesis 1: Communities have varying levels of recognition regarding the ES provided by the KFE. (2) How do local forest communities perceive the importance of ES across different socio-economic groups? Hypothesis 2: Poor, young adult households place greater importance on tangible ES, while older, wealthier groups may value other types of ES. (3) How do socio-economic groups within these communities compare in their utilization of the identified provisioning ES? Hypothesis 3: Male, wealthier groups utilize provisioning ES more intensively than female, lower wealth groups. (4) How do communities implementing PFM perceive land-use preferences that support these services across socio-economic groups? Hypothesis 4: Older, wealthier groups place greater value on ES supporting land-use preferences, whereas younger, lower wealth groups prioritize immediate economic benefits from land use.

Methods and research design

Study area description

KFE is located in western Kenya between 0° 15′ S and 0° 21′ S latitude and 34° 40′ E and 34° 57′ E30′ longitude (Obonyo et al. 2023). The forest has a total protected area of 133 km^2 and comprises bushlands, secondary and near natural forest, grasslands and tea plantation at the forest edge (Mitchell et al. 2009). Nyongesah and Li (2021) further described that the secondary forest is in diverse stages of succession, mixed exotic and native plantations, disturbed primary forest, and natural glades. The plantations created from 1935 to 2005 have a mix of exotic and indigenous species (Nyongesah and Li 2021) and approximately 50% of KFE has natural

forest (Martins et al. 2015). The main tree species found in the forest are the continents best soft and hard wood: red stinkwood (*Prunus africana*), white stinkwood (*Celtis africana*), several species of *Aningeria altissima* and *omkinduli* (*Croton megalocarpus*), black ironwood (*Olea capensis*), and more than 350 plant species recorded (Fischer et al. 2010). The area receives an average rainfall of 1915 mm per year (Mitchell 2009).

KFE is divided into four zones to balance community and visitor access with the primary goal of conserving KFE and its resources (KWS 2012): *core zone*—natural forest for flora and fauna preservation; *protection zone*—natural forest with minimal historical disturbance; *livelihood support zone*—supports sustainable initiatives like tree nurseries and eco-tourism for nearby communities; *and potential utilization zone*—mainly grazing and bush lands, serving as a buffer and aiding forest restoration. Natural forests are mainly in the core and protection zones, while planted forests dominate the livelihood support and potential utilization zones (KWS 2012).

Rigorous scientific assessment indicates a complex typology of forests in KFE (Lung and Schaab 2004): due to indigenous trees colonization, in many cases plantations are nearly indistinguishable from near-natural forest while almost all of the forest has undergone some form of human intervention at some point in time. However, for this research and for facilitating easier identification by households, the considered land use types supporting the ES flow are: (i) near natural forest land—forest of dense canopy and low disturbance level, older than 50 years for natural forest and secondary forest of 30–50 years old, (ii) planted forest land – consisting of planted exotic species i.e. eucalyptus and pine, as well as some planted native species, (iii) PELIS designated land, and (iv) owned land—privately owned agroforestry plots where local forest community practices subsistence agriculture and agroforestry.

The forest has undergone significant cover loss over the last twenty years due to conversion of forest land to agricultural lands, establishment of provisional structure and shift in the livestock grazing system (Osewe et al. 2025b), coupled with the population pressure that have significant impact on the forest ecosystem and the community that rely on forest for their livelihood (Osewe et al. 2023).

There are four communities located in four sub-counties of Kakamega county that border KFE. They implement PFM and, consequently, have active CFAs: Lurambi, Malava, Shinyalu, and Navakholo (see Fig. 1). These communities have a population of 0.55 million with an average household size of five in Kakamega county (KNBS 2019). There are various livelihood strategies adopted by the targeted local communities in KFE in connection with the forest ES (Saalu et al. 2020): farming, livestock keeping, tour guiding in KFE, sand harvesting, tea leaves picking, small local business, and bush meat hunting.

Conceptual framework

The research framework focuses on the relationship between forest ES and human well-being within local communities by integrating socio-economic perspective. It builds on the approach of Fischer et al. (2015) recognising the two-way interactions between people and forests, where forest provide multiple ES (cultural, supporting, regulating, and provisioning) which contribute to various dimensions of human well-being, including freedom of choice, social relations, health, security, and basic material needs (MEA 2005). The MEA general frame was chosen for its holistic approach, which evaluates ES based on their contribution to human well-being rather than solely their economic value. It's widely recognized approach enhances and facilitates comparability with prior studies.

The concept is based on community recognition of ES, the reasons behind their preferences, and the well-being components of ES (research objective 1). Socio-economic stratification influences community perceptions on ES importance (research objective 2), provisioning ES use (research objective 3), and land use preferences supporting ES flow (research objective 4). The analysis shows that people's social and economic backgrounds influence the extent to which they rely on and value forest resources, offering valuable insights for developing equitable PFM strategies, both within and without the framework of CFAs (see Fig. 2).

Data collection methods

Data were collected during the first four months of 2024 using a mixed-method approach, combining

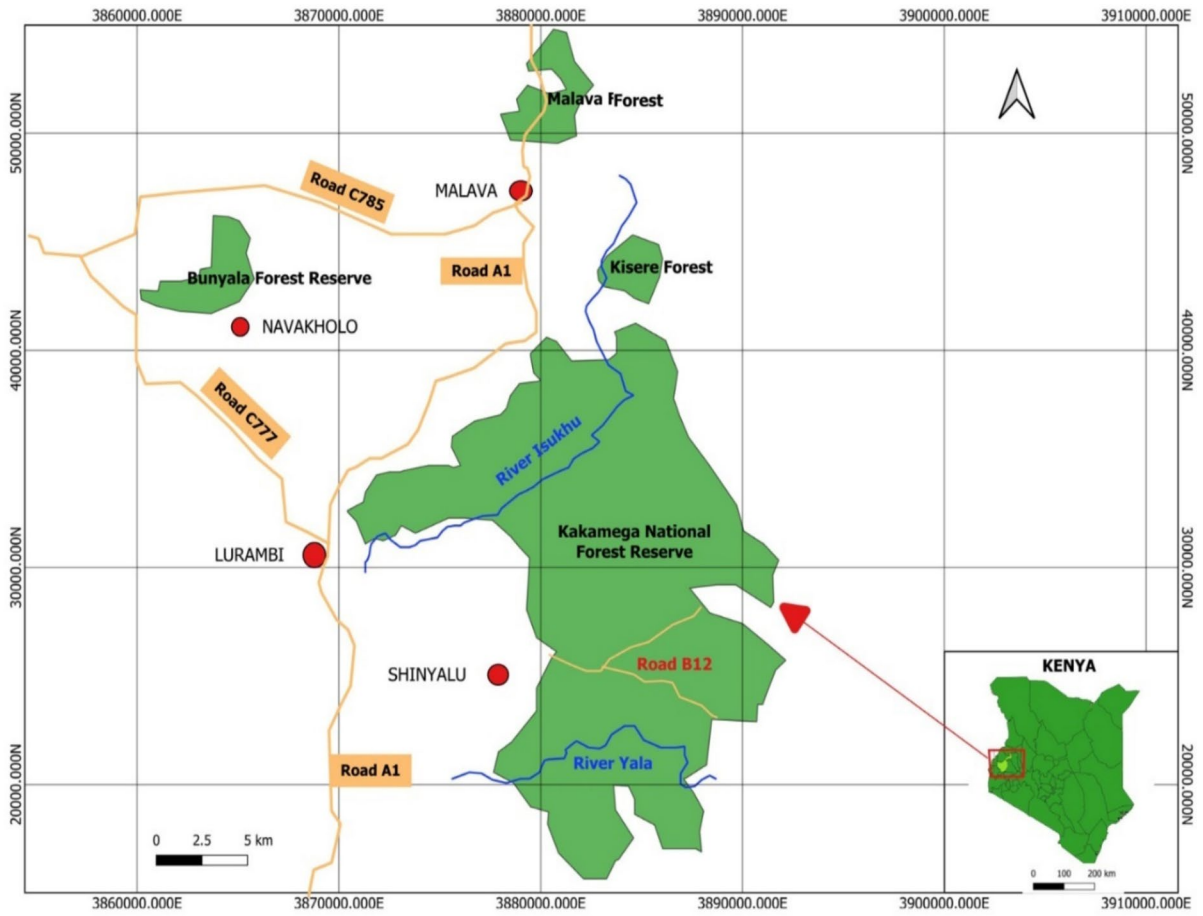

Fig. 1 Map of the study area

qualitative techniques (focus group discussions, key informant interviews, wealth ranking focus groups) with a quantitative household's survey. The research included the following stages:

Focus group discussions (FGD)

Three FGDs were conducted with 8–10 participants (purposively selected), from both CFA and non-CFA members for Malava, Shinyalu, and Navakholo. Lurambi was excluded due to overlapping representation with Shinyalu, as both fall under the same CFA – MUILESHI umbrella (CGK 2015; Ming'ate et al. 2016). The FGD identified the ES benefiting the community, reasons for preferring them, land uses supporting ES and the use of provisioning ES. These discussions lasted 45–90 min and informed the development of the household survey questionnaire.

Key informant interviews (KII)

Seventeen KII was conducted with individuals having specialized knowledge and experience, including forest managers from Malava and Shinyalu (with more than 3 years experience in the area), 3 CFA executive members (who have served in the CFA for more than 5 years) and 3 forest service rangers in each of the sub-counties with more than 3 years of experience in the region. These interviews lasting 30–45 min, helped verify and expand upon FGD findings, further informing the household survey questionnaire.

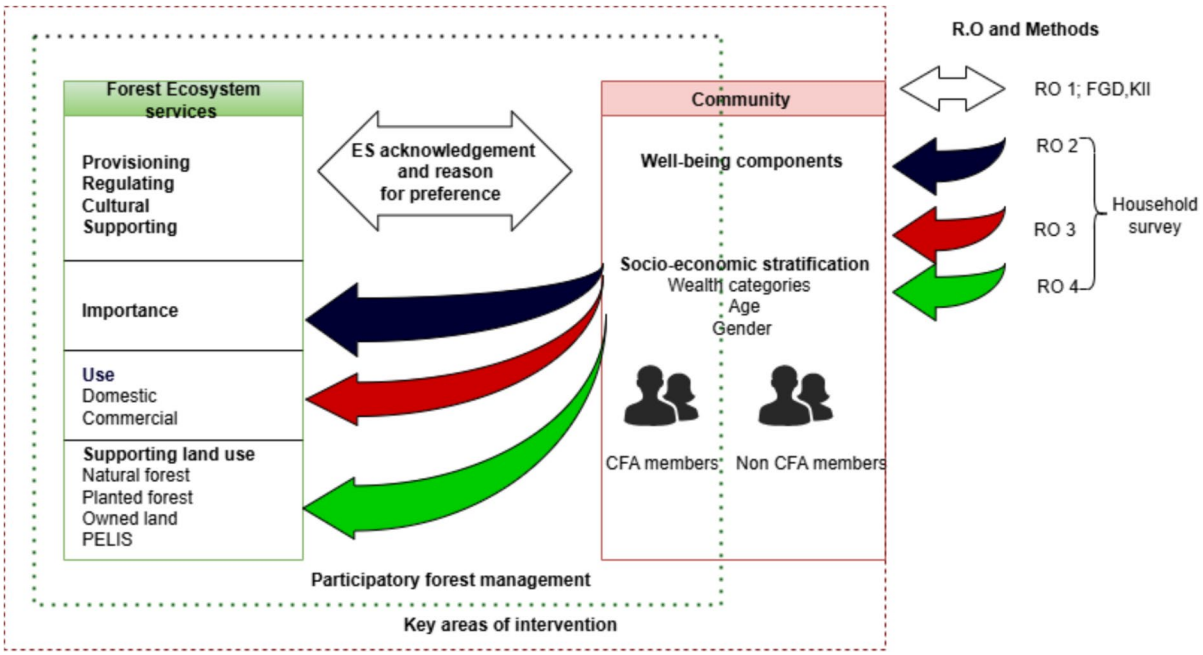

Fig. 2 Conceptual framework for the research—ES acknowledgement and socio-economic stratification influence on community perception (*FGD* focus group discussions, *KII* key informant interview, *CFA* community forest association, *RO* research objectives)

Wealth ranking focus groups

Wealth ranking, a participatory tool (Narayanasamy 2009), was used to identify local socio-economic indicators for classifying households. Focus groups were held (for 45–90 min) in each community with five participants (selected via snowball sampling) including CFA executives, senior community members and a local leader. This method leverages community knowledge to provide a deeper understanding of socioeconomic dynamics that conventional quantitative measures, such as income and asset assessments, may overlook. These groups identified wealth indicators, which were later refined and standardized in a final session with the same participants to ensure continuity.

Household survey

The survey questionnaire was developed based on FGD, KII data, and relevant studies (Ahammad et al. 2019; Kalaba et al. 2013; Osewe et al. 2024). It was tested with 25 CFA members in Lurambi to address potential issues, such as time requirements and possible misinterpretations. The testing phase was concluded once no further concerns were raised. The socio-economic profile of the respondents is presented in SI Table S7.

Qualitative research, including FGDs, explores the meaning people assign to social issues by gathering data in their environment and analysing it inductively (Patricia 2014). FGDs facilitated by a moderator, revealed diverse perspectives and are particularly useful for understanding complex human relationships and behaviours.

Statistical parameters like margin of error and confidence level were used to design the survey (Draugalis and Plaza 2009). Stratified sampling was used with sub-counties as strata (Tipton 2013). The sample size was calculated with a 5% margin of error and 95% confidence level (Siri et al. 2008), with household intervals shown in SI Table S16. The transect method, following roads/footpaths in a zigzag pattern, was used to select households from different community sections (Awuah et al. 2017). Households were chosen at set intervals (SI Table S16) and informed about the study. Willing participants completed the questionnaire, while unwilling households were replaced. Six research assistants, trained by the lead author, administered the survey (Details in SI

Table S15). The questionnaire was available in English and Kiswahili, with assistance in Luhya provided for those uncomfortable with the written languages. The average time to complete the questionnaire was 15 min.

Indicators for wealth

The final FGD indicators included type of wall material, income level, level of education for the household head, and size of land owned were considered as the indicator for wealth (details provided in Sect. "Wealth ranking results"). Based on these indicators the households were then categorized into low, middle, and high-income households (SI Table S17).

A weighted scoring system was used to categorize households into wealth groups through the following steps: (1) each of the four indicators was assigned an equal weight of 25%, (2) households received scores for each indicator based on predefined criteria, with each criterion scoring up to 10 points. For example, education levels were scored 1.25 per level, wall material criteria earned 1.67 points, income criteria 2 points, and land ownership 2 points per level, (3) the total score for each household was calculated by multiplying each criterion score by its respective weight and summing across all indicators; 4) households were classified into three categories based on total scores: rich (10–7), middle-income (6.9–4.2), and poor (4.1–1.7).

Data analysis

The survey data for 453 households were entered into an MS Office Excel spreadsheet with codes assigned to selected options (1 = selected and 0 = not selected) and a column for wealth categories added. The data were imported to SPSS 29. Missing data were checked for patterns and handled using mode/median imputation for categorical responses. Descriptive statistics identified outliers (minimum, maximum, and standard deviations). Extreme values identified as data entry errors were adjusted to the nearest valid extreme value, while legitimate but highly skewed values were also adjusted to ensure data integrity before analysis.

For the relative importance of the acknowledged ES, only the Likert scale ranking was used. A one-way ANOVA was performed, with Levene's test checking for homogeneity of variance ($p > 0.05$). If variance was homogeneous, the ANOVA tested for differences ($p < 0.05$) followed by Tukey's post hoc test. If Levene's test was significant ($p < 0.05$), Welch ANOVA was used, followed by Games-Howell post hoc testing for the wealth and age variables. Descriptive statistics (percentage) were used to summarize the identified ES and their use (domestic or commercial) based on data from the household survey. The Kruskal–Wallis test assessed wealth-based differences in provisioning ES use and Dunn's post hoc test with Bonferroni correction was used for significant results ($p < 0.05$). The same method was applied to land use supporting ES related wealth base differences. The Mann–Whitney U test was employed to assess gender differences in the perceived importance of each ES, with perceived importance as the test variable and gender as the grouping variable. A p value of < 0.05 was considered statistically significant, indicating a meaningful difference in perceptions between genders. To examine differences in the use of provisioning ES (for domestic and commercial purposes) and land use across four age categories, a chi-square test was conducted, with age as the independent variable and ES use (coded as 1 = selected, 0 = not selected) as the dependent variable. Significant variation across age groups was also determined by a p value < 0.05. Fisher's exact test with Bonferroni correction was applied to all six pairwise age comparisons to identify specific group differences. This procedure was repeated for each individual ES.

Data visualization was done using R Studio and MS Excel, with results presented in tables to clarify variable relationships. Table of proportions are used because it standardizes comparisons across wealth groups, making utilization patterns clearer despite differences in sample size.

Results

Wealth ranking results

The wealth ranking resulted in a total number of 264 poor households, 105 middle-wealth households and 84 rich households, with Navakholo having the highest number of poor households and Malava having the highest number of middle and rich households (see SI Fig. 1 for more details).

ES identification and acknowledgment

Provisioning ES were the most recognized, accounting for 11 out of 20 identified ES. Firewood (86%) was the highest acknowledged ES for energy sources. Grazing grass (68%) was acknowledged as an essential raw material for livestock feed. The local communities also rely on food from the forest such as NTFP (traditional vegetables, wild fruits i.e. guava, and mushroom) used for commercial and subsistence use. Beekeeping received unexpectedly low recognition representing 22%. Income-generating activities (IGAs) like tree nurseries and tour guiding led by CFA members, were the least acknowledged representing 24%.

The community recognized four regulating ES: climate regulation, air quality, pollination, and flood protection. Air quality was the most acknowledged ES by 57% of the respondents, this ES was acknowledged as a natural pollutant. While climate regulation (55%) was the second most acknowledged regulating ES, for stable weather and improved agricultural productivity. Flood protection followed (52%) was valued for preventing landslides and soil erosion. While the least acknowledged regulating ES was pollination by 32% of the respondents.

Unexpectedly the rainfall attraction (79%) was the only identified supporting ES (see Fig. 3). The community recognized four cultural ES: recreation, wildlife habitat, environmental education, and spiritual/religious value, accounting for 48% of the identified ES. Wildlife habitat (57%) was most valued for its educational potential, while spiritual and religious ES (45%) were appreciated for strengthening cultural identity and community cohesion. Recreation was the least recognized regulating ES, primarily valued for income generation such as tour guides. For every identified ES, the reason for recognizing the ES was also identified. The results can be seen in Table 1, together with the connection with Millenium Ecosystem Assessment well-being components (MEA 2005). The FGD and the KIIs identified 20 ES, two-thirds of them meeting the income need, safe

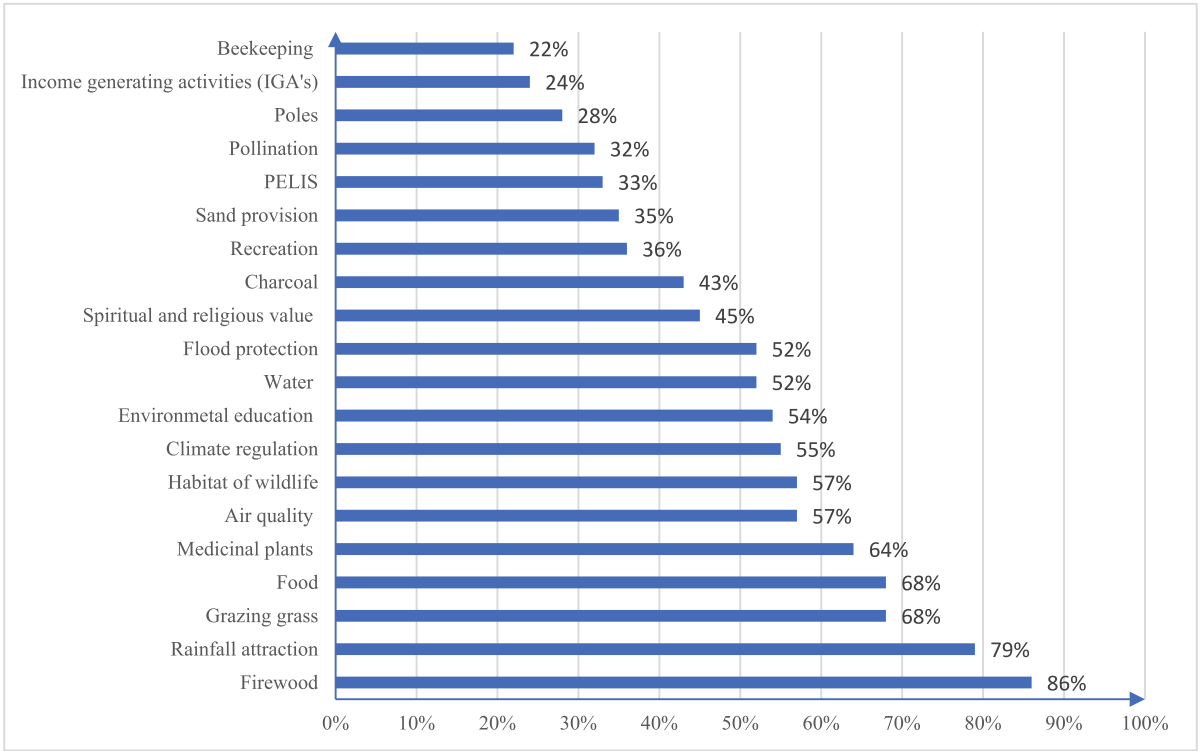

Fig. 3 Frequency of the acknowledged ES among respondents (N = 453)

Table 1 ES identified during focus group discussions and key informant interviews, the preference reasons and the association to well- being component

Preferred ES	Reason for preference	Indicators	Well-being components (MEA 2005)
Firewood (P)	Locally available product for household cooking	Quantity of firewood	Secure energy use
Grazing grass (P)	Animal feeds and income source	Quantity of grazing grass	Income source Food security
Medicinal plants (P)	Available plant material and traditional knowledge of healing/treatment. i.e. Nile trumpet (*Markhamia lutea*), Mukombero (Mondia *whitei),* bark of: Elgon tick (*Olea welwitschia*), Musine (*Croton megalocarpus),* Black ironwood (*Olea capensis),* Shingulotso *(Fagaropsis angolensis),* East African green heart (*Warburgia ugandensis),* and East African satinwood *(Zanthoxylum gilletii)*	Number and type of medicinal plants and trees	Disease avoidance
Food (P)	Mushroom, wild fruits, and traditional vegetables	Number and quantity of food derived from KFE	Food security
PELIS (P)	Cultivation of maize and beans	Number of times they have access to PELIS lands	Adequate nutrition and food security
Income Generating Activities (IGA) (P)	Tree nursery establishment and sale of tree seedlings	Number of times income was generated from the activities	Access to income
Poles (P)	House construction	Type/Number of timber species extracted from KFE	Safe shelter
Charcoal (P)	Cooking	Number of bags of charcoal	Secure energy use
Sand provision (P)	Used for house construction	Number of wheelbarrows of sand extracted from the riverbank	Safe shelter
Water (P)	Drinking water for livestock and humans, irrigation for crops	Number of aquifers and source of water (river, stream)	Basic material for well-being
Beekeeping (P)	Provision of honey and pollination	Number of bee hives and quantity of honey harvested	Income access and basic material for well- being
Climate regulation (R)	Temperature and weather stability, indirect benefit to livelihood (agriculture)	Microclimate	Security: reduced vulnerability to natural disaster
Air quality (R)	Natural filter for pollutants	Fine dust that enters the lungs	Health improvement, physical health
Flood protection (R)	Reduce soil erosion and landslides	Area of degraded lands/forest	Reduce ecological stresses. i.e. soil erosion and landslides
Pollination (R)	Support growth of fruits, vegetables, and honey production	Number of fruits and seeds available	Basic material for well- being
Recreation (C)	Related activities provide jobs for local communities. i.e. service providers and tour guides Cultural identity (bull fighting)	Number of times bull fighting was attended. Number of times served as tour guides	Social relation and strong ties with the community

Table 1 (continued)

Preferred ES	Reason for preference	Indicators	Well-being components (MEA 2005)
Wildlife habitat(C)	Holds recreational and educational values	Number of visitors engaging in birdwatching/monkeys	Freedom of choice and action, ensure future generation can enjoy the benefits
Environmental education (C)	Awareness and knowledge of ES and sustainable practices	Number of schools visiting the KFE	Social empowerment and cultural integrity
Spiritual and religious value (C)	Cultural heritage and places of worship, traditional practices (circumcision)	Sacred sites for worship, and circumcision	Social cohesion and strengthen community bonds
Rainfall attraction (S)	Adequate rainfall supports agricultural lands and primary forest production	Number of rainy days per month	Food and water security

(*P* provisioning ES, *R* regulating ES, *C* cultural ES, *S* support ES). Listed order according to MEA

shelter, basic material for well-being and food security well-being.

ES importance across the wealth categories, age and gender

Wealth categories

The importance of acknowledged ES was ranked on a Likert scale (1–5), with mean shown for each wealth category and the total survey in Fig. 4. Generally, middle income wealth category had the highest importance acknowledgement of provisioning ES (7 out of 10). Additionally, rich households had the highest importance acknowledgement for supporting ES, regulating ES (4 out of 4), and cultural ES (2 out of 4). Results indicated significant differences in perceptions of firewood importance across wealth categories ($F2,45 = 24.151$, $p < 0.001$). Grazing grass also showed significant differences ($F2,45 = 7.143$, $p = 0.001$), with middle-income households owning more livestock. A significant difference was found in perceptions of environmental education ($F2,45 = 4.933$, $p = 0.008$), likely linked to education level indicator. Perceptions of water importance differed significantly ($F2,45 = 8.227$, $p < 0.001$), reflecting poor households' reliance on water from KFE rivers and streams, while wealthier households have alternative sources. Relatively low importance was placed on IGAs, beekeeping, sand provision, pollination, poles, and PELIS across wealth categories. Rainfall attraction was highly valued, as the region depends on rainfed agriculture (Saalu et al. 2020).

Flood protection ($F2,45 = 5.251$, $p = 0.006$) and wildlife habitat ($F2,45 = 12.258$, $p < 0.001$) showed significant differences across wealth categories (see Fig. 4). In both the ES, the rich households have the highest importance acknowledgment. Conversely, spiritual and religious values also varied by wealth ($F2,45 = 5.727$, $p < 0.003$), with highest poor households placing more importance on this ES.

Age categories

Disaggregating the data by age revealed significant differences in the recognition of seven ES across the four age categories (see Fig. 5). Respondents aged 36–48 showed the highest acknowledgment of the importance of provisioning ES (6 out of 11), with a similar trend observed for supporting ES. In contrast, the 18–26 age group reported the highest acknowledgment of the importance of regulating ES (4 out of 4) and demonstrated the strongest recognition of cultural ES (3 out of 4).

Significant differences were observed for only two provisioning ES. For PELIS products ($F_{3,45} = 5.08$, $p = 0.002$), a significant difference was found between the 18–26 age group (0.64) and 36–48 (1.93) age group. For IGAs ($F_{3,45} = 3.24$, $p = 0.02$), a difference was observed between the 27–35 (0.62) and 36–48 (1.29) age groups.

Among supporting ES, only rainfall attraction showed a significant difference ($F_{3,45} = 5.3$, $p = 0.001$), between the 36–48 (4.02) and 49–80 (3.14) age groups. Three regulating ES exhibited significant differences: pollination ($F_{3,45} = 2.87$, $p = 0.04$), between

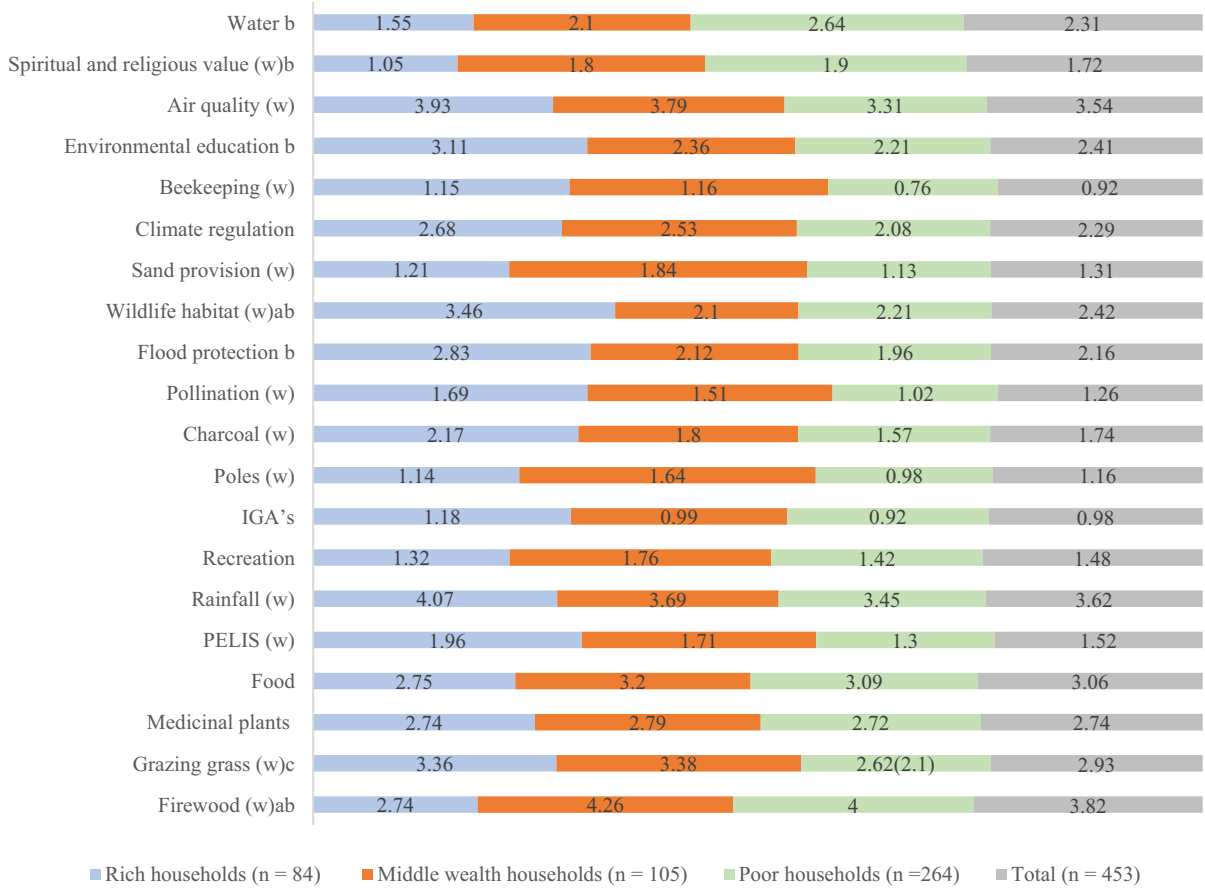

Fig. 4 Perceived importance of the acknowledged ES across the wealth categories. **a** indicates a significant difference between rich and middle household, **b** indicates a significant difference between rich and the poor households and **c** indicates a significant difference between the middle and the poor households at $p < 0.05$. (w)—denotes welch ANOVA. The length of each wealth group section corresponds to the proportion of perception responses

the 27–35 (0.91) and 36–48 (1.54) age groups; flood protection ($F_{3,45} = 3.94$, $p = 0.009$), between the 18–26 (2.65) and 27–35 (1.78) age groups; and climate regulation ($F_{3,45} = 6.99$, $p < 0.001$), with differences between 18–26 (2.93) and 27–35 (1.48), 27–35 (1.48) and 36–48 (2.54), and 27–35 (1.48) and 49–80 (2.31) age groups. For cultural ES, only recreation showed significant differences ($F_{3,45} = 5.08$, $p = 0.002$), with differences observed between 18–26 (2.05) and 27–35 (1.12), 18–26 (2.05) and 49–80 (1.13), and 36–48 (1.79) and 49–80 (1.13) age groups.

Gender

Disaggregation of the importance ranking of ES by gender revealed that male respondents reported the highest acknowledgment of the importance of provisioning ES (7 out of 11), as well as supporting and regulating ES (3 out of 4). In contrast, for cultural ES, both male and female respondents showed an equal frequency of highest acknowledgment of importance.

Only three of the ES had significant difference across gender i.e. flood protection, wildlife habitat, and beekeeping (see SI Table S1 and Fig. 6).

Provisioning ES use across the household's wealth categories, age, and gender

Wealth categories

The use of the 10 identified provisioning ES was divided into two categories: domestic and

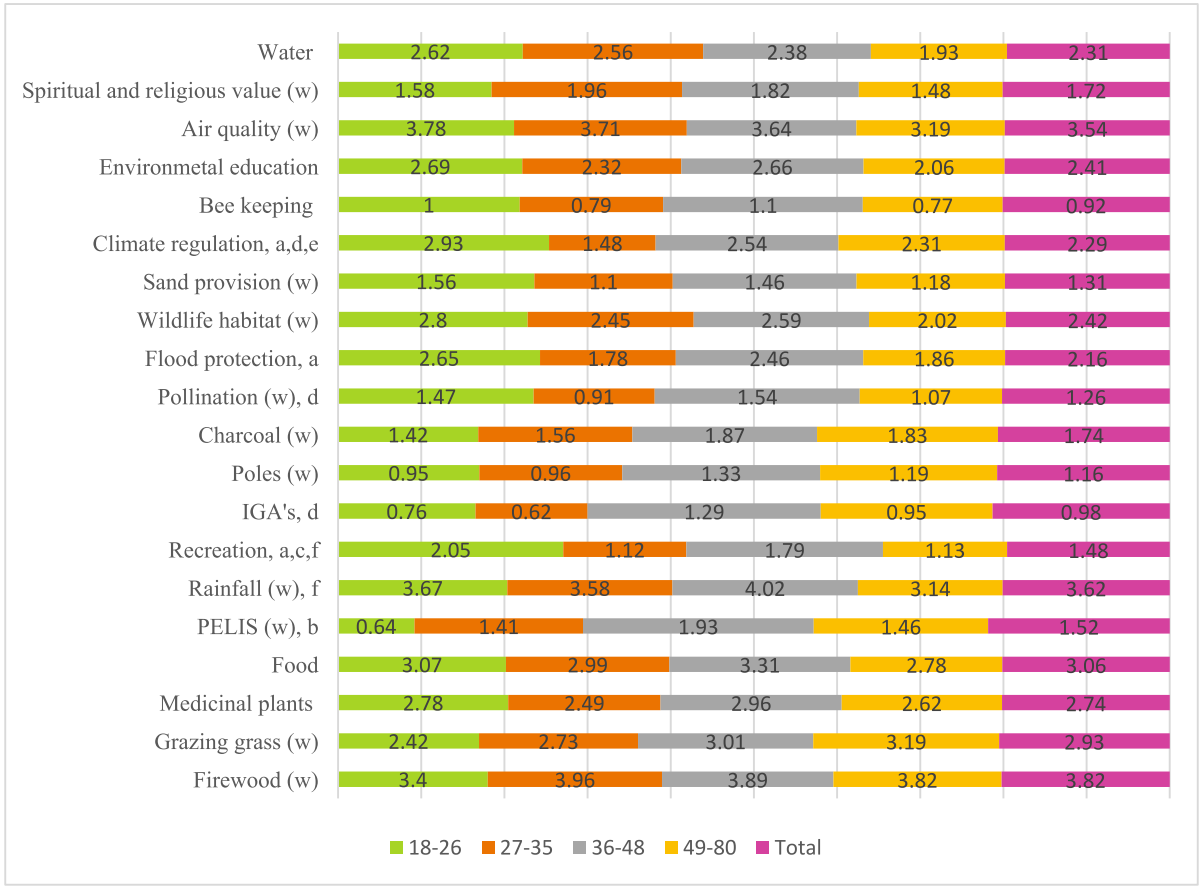

Fig. 5 Perceived importance of the acknowledged ES across the age categories. **a** indicates a significant difference between 18–26 and 27–35, **b** indicates a significant difference between 18–26 and 36–48, **c** indicates a significant difference between 18–26 and 49–80, **d** indicates a significant difference between 27–35 and 36–48, **e** indicates a significant difference between 27–35 and 49–80, and **f** indicates a significant difference between 36–48 and 49–80. The length of each age group section corresponds to the proportion of perception responses

commercial. The types of provisioning ES used by the communities in the study area, as well as the type of use (domestic/commercial) across the household's wealth categories can be seen in Table 2.

Firewood was the most used provisioning ES, with 66% of households using it, followed by medicinal plants (54%) and water (43%). Honey from beekeeping had the lowest usage at 14% (see Table 2). Significant differences across wealth categories were found for firewood, grazing grass, medicinal plants, PELIS products, poles, charcoal, sand, and water (see SI Table S18). Middle-income households showed higher recognition of firewood, grazing grass, poles, charcoal, and sand compared to both rich and poor households.

Only food and honey from beekeeping did not have significant difference across the wealth categories for the domestic use of this ES. Interestingly, medical plants had more than half of the sampled respondents for rich and middle-income households indicating its domestic use.

The most commercially used provisioning ES were PELIS products, firewood, and sand (18%, 17%, and 13%, respectively) as shown in Table 2. Poor households used medicinal plants more for commercial purposes than middle and rich households (see Table 2). However, for beekeeping (honey), the rich had the highest usage (6%), followed by poor households (2%) and middle-income households (2%).

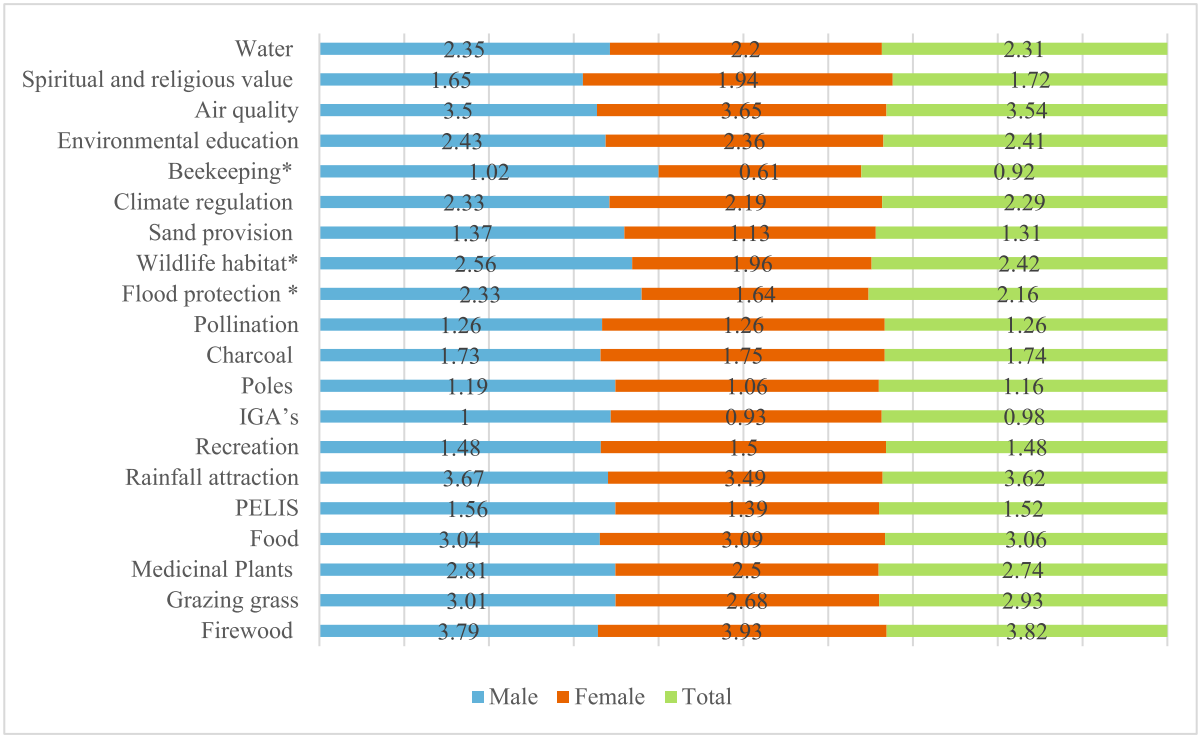

Fig. 6 Disaggregation of the ES importance acknowledgement across gender. * indicates significant difference. The length of each gender section corresponds to the proportion of perception responses

Middle and poor households used firewood more for commercial purposes than other provisioning ES, while rich households used PELIS products i.e. maize and beans more for commercial purpose than other provisioning ES.

Significant difference was observed only for PELIS produce and sand provision ES across the wealth categories (see SI Table S18 for more details).

Age categories

With regard to age, respondents aged 36–48 demonstrated the highest acknowledgment of domestic use of provisioning ES, recognizing 6 out of 10 services. In contrast, the 18–25 age group acknowledged only two ES, a pattern mirrored in the 49–80 age category (see SI Table S2).

Only three provisioning ES (PELIS, sand provision, and beekeeping) showed significant differences across age categories for domestic use (see SI Table S2). Similarly, for commercial use, the 36–48 age group again reported the highest acknowledgment, recognizing 5 out of 10 services. Significant differences across age categories were observed for five provisioning ES: medicinal plants, food, PELIS, charcoal, and sand provision (see SI Table S2).

Gender

Male respondents reported the highest acknowledgment of domestic use of provisioning ES (8 out of 10). In contrast, acknowledgment of commercial use of provisioning ES was evenly distributed across genders (see SI Table S3). Grazing grass was the only provisioning ES that showed significant gender difference for domestic use, while beekeeping was the only ES with a significant difference in commercial use beekeeping.

Table 2 Proportion of use of the provisioning ES across the wealth categories

ES	Rich households. (N = 84)		Middle wealth households. (N = 105)		Poor households. (N = 264)		Total (N = 453)		Kruskal–Wallis Test	
	Domestic (%)	Commercial (%)	Domestic(%)	Commercial (%)	Domestic (%)	Commercial (%)	Domestic (%)	Commercial (%)	Domestic	Commercial
Firewood*	48	7	69	17	42	13	66	17	$X^2 = 21.21$, $p = 2.48e\text{-}05$	$X^2 = 4.17$, $p = 0.12$
Grazing grass*	33	6	36	9	18	5	33	8	$X^2 = 16.55$, $p = 0.0003$	$X^2 = 1.78$, $p = 0.411$
Medicinal plants *	54	7	50	4	35	10	54	11	$X^2 = 13.23$, $p = 0.001$	$X^2 = 3.83$, $p = 0.148$
Food	17	4	27	10	27	7	33	10	$X^2 = 3.76$, $p = 0.152$	$X^2 = 3.44$, $p = 0.179$
PELIS products (maize and beans)*	38	29	38	17	15	8	32	18	$X^2 = 31.09$, $p = 1.78e\text{-}07$	$X^2 = 23.76$, $p = 6.91e\text{-}06$
Poles*	10	4	21	7	11	2	14	3	$X^2 = 7.69$, $p = 0.021$	$X^2 = 5.35$, $p = 0.068$
Charcoal*	26	2	29	7	13	6	25	6	$X^2 = 15.48$, $p = 0.004$	$X^2 = 2.0$, $p = 0.369$
Sand provision*	18	11	34	16	18	7	24	13	$X^2 = 12.35$, $p = 0.002$	$X^2 = 7.63$, $p = 0.02$
Beekeeping(honey)	6	6	12	2	8	2	9	3	$X^2 = 2.79$, $p = 0.25$	$X^2 = 4.35$, $p = 0.113$
Water *	25	2	41	5	49	2	38	2	$X^2 = 14.96$, $p = 0.001$	$X^2 = 2.42$, $p = 0.298$

*Indicate significant differences across domestic use at $p < 0.05$

Land use supporting the ES across the household's wealth categories, age, and gender

Wealth categories

Land uses and the associated acknowledged ES were analyzed across wealth categories, revealing significant differences in ES recognition. As shown in Table 3, natural forests were highly valued for their regulating and supporting services, particularly among wealthier households. In contrast, planted forests were more frequently recognized by middle- and low-income households. Owned land received limited recognition for cultural and supporting ES but was moderately recognized for provisioning ES. PELIS was valued primarily for its provisioning and regulating ES, especially among middle- and low-income households, while receiving the least recognition for supporting and cultural ES.

Regulating and supporting ES were predominantly associated with natural and planted forests, as illustrated in Fig. 7. Cultural ES were strongly linked to natural forest, while provisioning ES were also primarily supported by natural forest. Across all wealth categories, supporting ES received the highest level of acknowledgment compared to other ES categories.

Middle income households had the highest acknowledgement of natural forest (7 out of 11) and PELIS (4 out of 11) land use supporting the flow of provisioning ES (see Table 3). While rich households had the highest acknowledgement of owned land (4 out 11) supporting the flow of provisioning ES and planted forest land use (6 out of 11) for the poor households. For regulating ES, rich households had the highest acknowledgement of natural (3 out of 4), planted (4 out of 4) and owned land (1 out of 4) for supporting the flow of these ES. While for the PELIS land use, it was equally shared by middle and poor households for supporting regulating ES. For the cultural ES, rich households had the highest acknowledgement for natural forest (2 out of 4), planted forest (2 out of 4) and equal share with poor households for PELIS land use. For supporting ES rich households had the highest acknowledgement for natural forest, while middle income households for planted, owned land and PELIS land use.

For natural forest, significant differences were observed for firewood, grazing grass, water, and IGA's for provisioning ES across the wealth category. Similarly, differences were observed for planted forest only for firewood and food for the provisioning ES. Regarding owned land, difference was observed only for grazing grass and food. While for PELIS land use, only food and PELIS products had observed significant differences (see SI Table S19).

Age categories

The 36–48 age group demonstrated the highest acknowledgment of natural forest (6 out of 11 ES) and PELIS land use (5 out of 11) as supporting the flow of provisioning ES (see SI Table S4). In contrast, the 18–26 age group most frequently acknowledged owned land (5 out of 11), while the 49–80 age group reported the highest acknowledgment of planted forest land use (9 out of 11 ES) in supporting provisioning ES. For supporting ES, the 36–48 age group showed the highest acknowledgment of both natural and planted forests, whereas PELIS land use was most recognized by the 27–35 age group. However, the proportion of acknowledgement for PELIS was marginally small, similar to that observed for owned land among respondents aged 49–80 (see SI Table S4).

Regarding cultural and regulating ES, the 18–26 age group recorded the highest acknowledgment of natural forest as supporting the flow of cultural (3 out of 4) and regulating ES (4 out of 4). Conversely, the 36–48 age group showed the highest acknowledgment of PELIS land use in supporting cultural (2 out of 4) and regulating ES (2 out of 4), as well as the highest acknowledgment of planted forest in supporting both regulating (2 out of 4) and cultural ES (2 out of 4). Significant differences were observed for 65% of the identified ES associated with natural forest land use (see SI Table S5). In contrast, only 25% of the identified ES showed significant differences related to planted forest land use. For owned land, firewood was the only ES that exhibited a significant difference. Lastly, PELIS products and food were the only ES with significant differences associated with PELIS land use.

Gender

Male respondents reported the highest acknowledgment of natural forest (11 out of 11), planted forest (7 out of 11), and owned land (6 out of 11) as land

Table 3 Land uses and associated ES across wealth categories

	Rich households (N = 84)				Middle-income households (N = 105)				Poor households (N = 264)				Kruskal–Wallis Test			
	%															
ES	NF	PF	OL	PELIS	NF	PF	OL	PELIS	NF	PF	OL	PELIS	NF	*PF*	OL	*PELIS*
Firewood*	51	13	15	0	69	28	21	4	55	39	19	0	$X^2 = 7.33$, $p = 0.026$	$X^2 = 20.76$, $p = 3.11e\text{-}05$	$X^2 = 0.93$, $p = 0.63$	$X^2 = 13.35$, $p = 0.061$
Grazing grass*	56	7	42	0	48	13	39	1	31	17	25	0	$X^2 = 20.23$, $p = 4.04e\text{-}05$	$X^2 = 5.19$, $p = 0.07$	$X^2 = 11.97$, $p = 0.003$	$X^2 = 3.31$, $p = 0.191$
Medicinal plants	57	10	11	0	51	10	10	1	44	19	7	0	$X^2 = 5.03$, $p = 0.081$	$X^2 = 6.75$, $p = 0.06$	$X^2 = 2.03$, $p = 0.36$	$X^2 = 3.31$, $p = 0.191$
Food*	18	8	45	27	29	14	44	21	27	20	30	13	$X^2 = 3.35$, $p = 0.19$	$X^2 = 6.86$, $p = 0.03$	$X^2 = 10.1$, $p = 0.006$	$X^2 = 10.46$, $p = 0.005$
PELIS*	1	2	0	39	1	0	0	37	1	1	0	27	$X^2 = 0.03$, $p = 0.98$	$X^2 = 2.42$, $p = 0.3$	N/A	$X^2 = 6.48$, $p = 0.039$
Rainfall attraction*	71	61	0	0	62	68	1	3	51	65	1	2	$X^2 = 11.84$, $p = 0.003$	$X^2 = 0.99$, $p = 0.61$	$X^2 = 0.95$, $p = 0.62$	$X^2 = 2.25$, $p = 0.325$
Recreation	24	14	0	0	26	21	0	0	29	17	0	0	$X^2 = 1.11$, $p = 0.58$	$X^2 = 1.51$, $p = 0.471$	N/A	N/A
Income generating activities (IGA'S)*	10	17	0	2	18	8	1	3	9	14	1	0	$X^2 = 6.39$, $p = 0.04$	$X^2 = 3.912$, $p = 0.14$	$X^2 = 0.946$, $p = 0.623$	$X^2 = 7.14$, $p = 0.056$
Poles	10	8	12	0	16	15	17	0	10	8	11	0	$X^2 = 3.33$, $p = 0.189$	$X^2 = 4.75$, $p = 0.093$	$X^2 = 2.62$, $p = 0.269$	N/A
Charcoal	30	12	18	0	30	9	15	0	24	13	14	0	$X^2 = 2.25$, $p = 0.325$	$X^2 = 1.35$, $p = 0.509$	$X^2 = 0.74$, $p = 0.69$	N/A
Pollination*	30	29	0	1	31	23	0	1	23	15	0	3	$X^2 = 3.33$, $p = 0.189$	$X^2 = 8.34$, $p = 0.015$	N/A	$X^2 = 1.99$, $p = 0.37$
Flood protection*	50	54	0	0	38	44	0	2	32	40	0	1	$X^2 = 9.18$, $p = 0.01$	$X^2 = 4.67$, $p = 0.097$	N/A	$X^2 = 1.55$, $p = 0.46$
Habitat of wildlife*	69	67	0	0	38	41	0	0	40	44	0	1	$X^2 = 24.1$, $p = 5.84e\text{-}06$	$X^2 = 15.49$, $p = 0.0004$	N/A	$X^2 = 2.16$, $p = 0.34$
Provision of sand	21	13	0	0	29	18	0	0	19	14	0	0	$X^2 = 4.1$, $p = 0.13$	$X^2 = 1.22$, $p = 0.54$	N/A	N/A
Climate regulation*	50	55	0	0	44	54	0	1	36	41	0	1	$X^2 = 5.85$, $p = 0.056$	$X^2 = 8.16$, $p = 0.017$	N/A	$X^2 = 0.95$, $p = 0.62$
Bee keeping	14	7	14	0	21	3	10	0	13	2	8	0	$X^2 = 3.87$, $p = 0.144$	$X^2 = 5.87$, $p = 0.056$	$X^2 = 3.0$, $p = 0.22$	N/A
Environmental education*	61	55	0	2	43	36	0	1	41	40	0	1	$X^2 = 10.33$, $p = 0.005$	$X^2 = 7.43$, $p = 0.024$	N/A	$X^2 = 0.9$, $p = 0.63$
Air quality*	71	74	2	0	67	72	0	0	53	65	1	0	$X^2 = 11.77$, $p = 0.003$	$X^2 = 3.19$, $p = 0.202$	$X^2 = 2.42$, $p = 0.298$	N/A
Spiritual and religious value*	27	4	0	0	41	10	0	0	35	17	0	0	$X^2 = 3.78$, $p = 0.151$	$X^2 = 10.97$, $p = 0.004$	N/A	N/A
Water*	29	29	0	0	42	31	0	0	47	38	1	0	$X^2 = 8.826$, $p = 0.012$	$X^2 = 3.06$, $p = 0.217$	$X^2 = 2.16$, $p = 0.34$	N/A

*Indicates a significant difference $p < 0.05$. NF = Natural Forest, PF = Planted Forest, OL = Owned Land, PELIS = Plantation Establishment and Livelihood Improvement Scheme

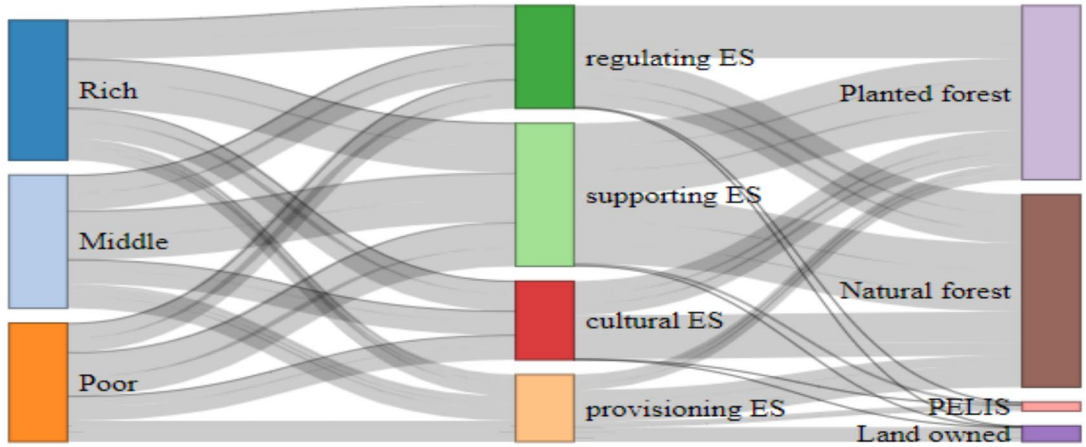

Fig. 7 Sankey diagram representing land use supporting the flow of ecosystem services categories across the wealth groups (the length of the columns represents the proportion of acknowledgement for each ES and land use type)

uses supporting provisioning ES (see S1 Table 6). In contrast, PELIS land use was the only category where female respondents recorded the highest acknowledgment for supporting provisioning ES. For supporting ES, male respondents showed the highest acknowledgment of natural forest, owned land, and PELIS land use, while female respondents reported the highest acknowledgment only for planted forest land use (see SI Table S6).

In terms of regulating ES, male respondents showed the highest acknowledgment of natural forest (3 out of 4), planted forest (4 out of 4), and PELIS land use (4 out of 4), whereas mixed results were observed for owned land. For cultural ES, gender differences were balanced for planted forest land use. However, male respondents reported the highest acknowledgment for natural forest (4 out of 4), PELIS land use (2 out of 4), and owned land use as supporting cultural ES. Among specific services, air quality supported by planted forest was the most acknowledged ES among male respondents, while rainfall attraction, also supported by planted forest, received the highest acknowledgment among female respondents. Two provisioning ES showed significant gender differences: beekeeping associated with owned land, and grazing grass supported by natural forest, as well as medicinal plants supported by owned land (see SI Table S6). For regulating ES, only flood protection supported by natural and planted forests demonstrated significant differences across gender.

Discussions

Wealth ranking

During the wealth ranking exercise, participants identified indicators such as the ability to educate children, livestock ownership, movable assets (motorbikes, vehicles, bicycles), wall material, income, household head's education, informal savings group participation, and land size. However, some indicators were considered misleading. The ability to educate children was seen as unreliable due to free education and external scholarships. Movable assets were seen as income-generating but burdensome due to loan repayments. Participation in informal savings groups reflected financial insecurity rather than wealth. Livestock ownership was seen as a sign of debt, as loans are often taken to purchase livestock, which is vulnerable to shocks, causing wealth fluctuations.

Level of education was considered an indicator of wealth, based on the premise that higher education increases access to formal employment opportunities and is positively correlated with asset ownership (Ahammad et al. 2022). Wall material type was also

considered, with high-quality materials (e.g., bricks, cement blocks, stones) reflecting higher economic status compared to traditional local materials (e.g., mud, wood). Land size was included as an indicator due to its role as a primary source of both subsistence and income-generating activities for households. Finally, household income was used as an indicator of wealth, reflecting the economic capacity to meet basic needs.

ES identification and acknowledgement

The findings support Hypothesis 1, demonstrating that communities have varying levels of recognition regarding the ES provided by the KFE. Provisioning ES were the most recognized likely due to their tangible nature (Wangchuk et al. 2021). Firewood was highly acknowledged, possibly due to limited fuel alternatives in KFE (Kefa, et al. 2018a) and low awareness of sustainable energy sources, a trend also seen in Cambodia (Ehara et al. 2016). Grazing grass, essential for livestock feed, is valued as households balance crop and livestock needs on small plots (average 1.17 acres) in a livestock-focused region (Saalu et al. 2020). Local communities also rely on traditional vegetables, wild fruits (e.g., guava), and mushrooms, similar to findings in Bangladesh (Ahammad et al. 2022) and South Africa (Mensah et al. 2017). Beekeeping received unexpected low recognition, a trend also seen in Ethiopia (Degu and Megerssa 2020) and Laos (Chanthayod et al. 2017), hindered by limited funding and engagement. IGAs like tree nurseries and tour guiding, led by CFA members were the least acknowledged, likely due to CFA membership fees and training requirements (Paul et al. 2007).

For regulating ES, flood protection was recognised by more than half the respondents following heavy rainfall and flooding in March–May 2024 (OCHA 2024). Pollination low recognition is likely due to its less tangible benefits (Aguilar-Fernández et al. 2020). KFE was seen as a natural pollutant filter hence acknowledged by more than half of the respondents, similar to findings in Nigeria (Adeyemi et al. 2022). Stable weather and improved agricultural productivity were linked to climate regulation by KFE and had more than half of the respondents acknowledged it. This outcome contrasted with lower awareness of this ES in the Omo Biosphere Reserve (Adeyemi et al. 2022).

The community recognized four cultural ES, for instance wildlife habitat provided income generating activities for the local communities such as fees charged for tourist for bird watching, similarly, recreation ES also improved the livelihood of the community members such as tour guiding. Interesting the bull fighting on Saturdays in some of the research areas such as Shinyalu generated income for local households who owned the bulls and organised the event. Additionally, bull fighting provided cultural identity and social cohesion to the local community, as well as community pride. Some of the indirect effect of bull fighting included better livestock management practices through nutrition, health and training thereby improving the overall husbandry practices. The low acknowledgement of this ES is consistent global trends recognition (Mengist et al. 2020).

Environmental education ES was especially acknowledged due to the school buses across the country visiting the KFE for field trip, recognition of this ES is valued here than in Nigeria's Omo Biosphere Reserve (Adeyemi et al. 2022). Research conducted by Kandari et al. (2014) in India indicated that spiritual and religious ES were valued for their role in strengthening cultural identity and community cohesion. This was similar to this research outcome where traditional practices such circumcision and sacred worship places in KFE enhanced awareness of ES, through ecological knowledge transfer from the elder generations (Osewe et al. 2025a).

ES importance rank

The middle-income households from research study valued more the provisioning ES compared to other wealth categories. This suggests practical dependence on KFE daily needs. While the rich households placed more value on supporting, regulating and cultural ES, indicating higher economic statues allow for appreciation of intangible benefits of forest resources. This outcome aligns with research from Bangladesh (Ahammad et al. 2019). Observed difference for firewood indicate that rich households can afford alternative energy sources to meet their daily needs. Similar situation was also observed in India (Belcher et al. 2015). Similarly, middle income households place more importance on grazing grass than other wealth categories likely due to more livestock ownership by

this category. Difference observed for water importance from KFE indicated poor households' reliance on it from rivers and streams, while wealthier households have alternative sources such as the Kakamega country government water. Relatively low importance was placed on IGAs, beekeeping, sand provision, pollination, poles, and PELIS across wealth categories, likely due to the association of these ES with CFA membership, which not all respondents had. Rainfall attraction was highly valued, as the region depends on rainfed agriculture (Saalu et al. 2020). This aligns with findings by Hochmalová et al. (2022) in the Czech Republic and China, where locals also prioritized rainfall attraction ES for irrigation, domestic use, and livestock consumption. The difference observed for flood protection and wildlife habitat could be explained by higher income often correlates with greater environmental awareness, and wealthier households may value wildlife habitats and flood protection more due to exposure to conservation activism and environmental education (Suleiman et al. 2017).

The 36–48 age group placed the highest value on supporting and provisioning ES, which can be attributed to their active involvement in productive activities such as farming, small businesses, and the sale of charcoal and firewood, as well as their greater household responsibilities. This is further supported by their higher valuation of PELIS products and IGAs compared to other age groups. These findings are consistent with research from South Africa (Mensah et al. 2017). Interestingly, these results do not support Hypothesis 2. Contrary to expectations, young adults aged 18–26 placed the greater value on cultural and regulating ES, likely reflecting increased awareness fostered by education, cultural engagement, and environmental campaigns.

Male respondents valued more the provisioning, regulating and supporting ES, likely due to traditional gender roles in which men would typically engage in physical demanding and risk-prone activities such as sand harvesting, beekeeping, and farming (Nyangoko et al. 2020; Osewe et al. 2025a). In contrast, cultural ES were equally valued by both genders, suggesting shared participation in social and recreational forest-related activities.

These findings highlight that different demographic groups value different types of ES, which has important implications for conservation strategy design. Specifically, the results suggest that forest access policies must be sensitive to these demographic variations. Male respondents aged 36–48 from middle-income households emerged as the group most directly dependent on forest resources for both their household needs and livelihoods. Their frequent interaction with the forest positions them as key stakeholders in conservation and sustainable use efforts. When effectively engaged, this group could play a critical role in forest health monitoring and protection. Consequently, their involvement in decision-making, particularly through the CFA, is essential, as they are more likely to take active roles in safeguarding ES.

Moreover, the equal valuation of cultural ES across genders presents an opportunity to foster gender-balanced participation in CFAs. The high valuation of cultural and regulating ES by wealthier and younger respondents further underscores their potential to contribute to long-term cultural continuity and ecological stability.

Provisioning ES use

Similar to the importance of the ES, middle-income households had the highest domestic use of provisioning ES, this outcome indicates reliance on forest resources for households needs (firewood, medicinal plants and food). This research outcome is in line with Hypothesis 3, which anticipated greater utilization of provisioning ES by wealthier groups, but it contrasts with studies like Ahammad et al. (2019), which suggest that poor households benefit more from provisioning ES. In our case, this exclusion may be due to limited access to CFA membership and related fees. Studies across the global indicate wealthier households' reliance on firewood as an energy source (Ahammad et al. 2019; Kalaba et al. 2013), this was similar to our research outcome. Conversely, wealthier households' reliance on PELIS for the domestic use indicates their financial means to purchase inputs for crop production, which also serve as a coping strategy for income shocks (Saalu et al. 2020). Regarding medicinal plants, Andel and Carvalheiro (2013) research indicated that medicinal plants were crucial for poor households' health, particularly where medical services are scarce. This outcome contrast with their research as rich and middle-income households benefited more domestically from

medicinal plants, this suggests shared traditional ecological knowledge across higher-income groups.

During the survey, the community described the forest as "msitu ni mpesa yetu" (the forest is our mobile money), highlighting that forest income supplements household earnings. However, commercial use of provisioning ES was generally lower than domestic use, as forest products are essential for daily needs like cooking, heating, and medical care. Poor households relied on medicinal plants for commercial use, this highlights dependence on forest material as income source and economic vulnerability. Middle-income households reported using a wider range of provisioning ES (firewood, grazing grass, food, charcoal, poles, and water) for income generation, reflecting their tendency to diversify income sources, unlike the wealthier households with stable non-forest incomes or poorer households relying mostly on subsistence use. This aligns with studies from Nepal (Rayamajhi et al. 2012) and Bangladesh (Ahammad et al. 2019), which found that middle-income and wealthy households primarily use provisioning ES for commercial purposes.

Land ownership a key wealth indicator influenced access to poles, firewood, grazing grass, and water. Middle and rich households, owning more land, have access to agroforestry or forest plantations, while poorer households must rely on forest access, often paying for it. This mirrors findings from Zambia (Kalaba et al. 2013) where land ownership influences access to provisioning ES.

Sand harvesting was mainly commercial for middle and rich households, due to the financial resources required. Similarly, PELIS products and beekeeping were more commercially used by wealthier households, supporting findings from Humphrey et al. (2016), which showed that PELIS increased livelihoods by 120 USD annually and reduced forest dependency for 90% of participants.

Interestingly, poor households had higher commercial use of medicinal plants, likely due to traditional knowledge and cultural practices passed down through generations (Hamilton 2004). This is consistent with findings from the Peruvian Andes, where poor households use more medicinal plants than wealthier ones (Corroto et al. 2021).

Age 36–48 stands out for both commercial and domestic use, likely reflecting their economic responsibilities and active participation in forest-based livelihoods activities. As anticipated in hypothesis 3, male respondents dominated provisioning domestic use of ES, possibility due to labour requirement and risk as well as well resource collection.

The commercial use of PELIS products (maize and beans), firewood, and sand from the KFE highlights the presence of forest-dependent economic activities that require regulated access to prevent degradation. This concern is particularly relevant as the installation of electric fencing around the forest ecosystem is still in progress. Such interventions are expected to mitigate further environmental degradation.

The observed variation in ES use across wealth categories and gender groups underscore the need for inclusive participation in forest decision-making. For example, because middle-income and poor households are actively engaged in commercial use of firewood, making their involvement in establishing sustainable harvest limits essential. Similarly, the relatively balanced gender participation in IGAs strengthens the case for equitable representation of both women and men within CFAs.

Furthermore, significant differences in the use of grazing grass and beekeeping ES point to the importance of adaptive governance structures that respond to emerging usage trends and incorporate regular input from active user groups. Wealthier households, through low-impact commercial activities such as beekeeping, contribute to ES preservation, particularly in supporting biodiversity and pollination services. In contrast, poorer households, which rely more heavily on KFE, may risk overexploiting unfenced forest areas due to livelihood pressures. This situation underscores the urgent need for targeted support programs and alternative options that reduce dependency while promoting sustainable forest use.

Land use supporting ES

Middle income households' highest acknowledgment of natural forest and PELIS land use as vital for provisioning ES, is crucial since they are the biggest end users of this ES and place the highest value to them. For instance, IGAs such as selling seedlings from natural forests and PELIS, indicated difference across the wealth categories with middle income households being the biggest beneficiaries. This can be attributed to elite capture in the Kakamega Forest CFA, where wealthier households benefit more from

forest resources. A similar trend was found in Adhikari (2005) research, where wealthier households in Nepal earned three times more from natural forests than poorer households. Similarly, for grazing grass where this was due to households having more financial resources to invest in larger livestock herds and pay grazing fees, consistent with findings in Bangladesh where rich and poor households had significant differences in fodder use in natural forests (Ahammad et al. 2019). Additionally, medicinal plants were highly valued across all wealth categories for their use in natural forests. Many of these plants have been used for centuries and contribute to the increased biodiversity in natural forests (Hamilton 2004).

Environmental education services were strongly supported by natural forest land use across wealth categories, with high acknowledgment from rich households. This may be due to the higher education levels of wealthier households, enabling them to better understand the ecological value of natural forests compared to planted forests. Research by Were et al. (2024) in KFE found that traditional ecological knowledge about forest preservation was passed down through native songs. Cudworth and Lumber (2021) also noted that natural forests offer a more authentic and diverse learning environment. Additionally, spiritual and religious values were strongly supported by natural forests, which often evoke feelings of wonder, reverence, and a sense of connection to something larger than oneself, experiences not typically found in planted forests (Plieninger et al. 2013). In the KFE, natural forests contain sacred groves in Kavunyonjes and Tsirhumbi, which serve as traditional cultural sites for the Tiriki community. These groves are used for rituals such as circumcision and prayers, reinforcing the spiritual identity of the local forest communities (Were et al. 2024). The use of forests for circumcision ceremonies spans generations, representing a deeply rooted tradition within the Tiriki community.

Poor households notably acknowledged planted forest and shared recognition of PELIS land with middle income household's category, this indicates diverse reliance based on accessibility of resources. For instance, food sources such as mushrooms, traditional vegetables, and wild fruits showed significant acknowledgment by poor households supported by planted forest. This could be due to wealthier households can afford alternative food sources, while poor households rely on traditional vegetables like African Nightshade (*Solanum nigrum*), also known as "Managu," to meet dietary needs, Similarly, firewood too. This is linked to the availability and proximity of invasive tree species (*Psidium guajava*) in planted forests, which are preferred by poor households for their market value (Kefa, et al. 2018b). A similar trend was observed in Tanzania (Kegode et al. 2017), where poor households prefer firewood from planted forests due to species availability and proximity. These findings support Hypothesis 4, which posited that older, wealthier groups would place greater value on ES supporting land-use preferences.

Planted forests in KFE have expanded due to active reforestation by KFS, CFA, NGOs, and international agencies (Laura et al. 2020). Planted forests were highly valued for their flood protection and climate regulation services across wealth categories. This is likely a result of significant deforestation and degradation in KFE, followed by restoration efforts that have enhanced flood protection. This finding aligns with Vári et al. (2022), who noted that reforestation efforts funded for climate change mitigation and landscape management quickly restored ES like flood protection after degradation.

For PELIS land use, a higher proportion of wealthier households engage in the PELIS system, gaining benefits from it. Focus group participants mentioned that spider plant (*Cleome gynandra*), known locally as "sagaa," is highly nutritious and essential for food security in Kenya. Its stem and roots also have medicinal properties, including anti-malaria and antimicrobial benefits (Onyango et al. 2013).

The 49–80 age category recognition of planted forest for supporting provisioning ES is possibility due to long term land use practices or historical exposure. While strong environmental sensitivity of the young adults from 18 to 26 years was probability due to environmental education ES during schooling years, lead to their recognition high recognition of natural forest supporting regulating and supporting ES flow.

Female respondents' high recognition of PELIS land use supporting provisioning ES while male respondents overwhelming acknowledgement for natural, planted, owned land use supporting provisioning ES, links to gendered balance for tangible forest resources. Similarly, cultural ES showed a gendered balance for planted forest land use.

The research findings have important implications for forest access and management. Natural forests

were the most acknowledged land use type across all the wealth, age and gender groups, underscoring their central role in regulating and provisioning ES. While PELIS land was widely recognized, particularly by middle-income and female respondents, this highlights its importance as a pathway for community-based forest access. These trends demonstrate that land use types directly influence access to ES, with PELIS system under PFM facilitating broader inclusion.

Consistent with the patterns observed in ES ranking and use, middle income households and individuals aged 36–48, who engaged with a diverse range of land uses and ES types, emerge as key stakeholders for participatory planning. Likewise, the balanced gender participation in cultural ES and strong engagement of women with PELIS land emphasize the need for equal gender representation in CFA. The consistent identification of planted forest and PELIS by all demographic groups suggests a moderate success of community co-managed land systems in diversifying forest-related benefits. Notably, female respondents' engagement with PELIS and planted forest, despite lower overall ES acknowledgment compared to males, indicates active involvement in sustainable land practices. The significant differences in ES recognition across land use types reveal both inequities and opportunities in resources distribution. Reducing fees for forest access for services such as grazing and lowering membership fee could enhance equity. Moreover, the variation in ES acknowledgment among demographic groups reflects differing values shaped by experience, exposure, and necessity. Tailored communication and education strategies can therefore improve understanding, foster stewardship, and support inclusive conservation outcomes.

Conclusion and policy implications

The study evaluated the perceived value of the KFE by analyzing local community perceptions of ES derived from the forest and the corresponding well-being needs these services fulfill. The key findings addressing the research questions are summarized as follows:

- The findings support Hypothesis 1, demonstrating that communities have varying levels of recognition regarding the ES provided by the KFE.
- Interestingly, the outcome didn't support Hypothesis 2 contrary to expectations, young adults aged 18–26 placed the greater value on cultural and regulating ES, while middle-come households valued provisioning ES the most.
- The findings aligned with Hypothesis 3 which anticipated greater utilization of provisioning ES by wealthier groups.
- Hypothesis 4 was supported by the findings, which posited that older, wealthier groups would place greater value on ES supporting land-use preferences.

This research contributes to scientific understanding by filling in the identified gaps in previous studies (Osewe et al. 2023) regarding well-being needs met by acknowledged ES, disparities in utilization of the provisioning ES, the importance of ES, and the land use supporting ES flow across socio-economic groups.

This research offers policy-relevant implications across several key intervention areas, including land ownership, land use, subsidies, and incentives:

- Wealthier households aged 36–48 have greater access to forest ES and PELIS, contributing to their economic success. A quota-based allocation system that prioritizes poorer households with young adults, combined with agricultural extension services, could enhance land management efficiency and promote more equitable access.
- The low perceived importance of certain IGAs, such as beekeeping, among poorer female households highlights the need for a targeted training in value addition and sustainable harvesting (e.g., medicinal plants and honey). Community outreach through workshops focusing on supporting and regulating ES could further strengthen awareness and participation.
- The disproportionately high benefits derived from provisioning ES among middle- and high-income households suggest the presence of elite capture within the CFA. Addressing this requires transparent CFA election processes, affirmative action measures to support marginalized members, and

awareness campaigns regarding the declining availability of PELIS.

- Given the widespread dependence on firewood across the socio-economic groups, policies should encourage sustainable alternatives such as biogas from livestock waste or sugarcane residue briquettes, potentially produced at CFA level. While such initiatives may face constraints, including high initial costs, these can be mitigated through micro-financing options offered by grassroots level Savings and Credit Cooperative Organizations.
- The prevalent subsistence use of provisioning ES, especially honey and medicinal plants, indicates weak market linkages. Fostering partnerships between private businesses and local communities, such as contracts for honey procurement, and establishing producer associations could help strengthen market access and value chains.

This study provides valuable insights into the relationship between ES, well-being, and land use within KFE. However, it has several limitations, such as the lack of economic valuation for provisioning ES and the qualitative assessment of intangible ES like soil erosion using remote sensing data on land use supporting agricultural production. Additionally, potential bias in self-reported wealth indicators, such as income, may have influenced the accuracy of the wealth classification. To address these limitations, future research should incorporate economic valuation of provisioning ES (e.g., comparing income from charcoal and firewood) and develop more robust approaches for assessing intangible ES.

Despite these limitations, the study highlights the critical role of wealth differentiation in shaping the flow and perceptions of ES across land uses. These findings offer practical guidance for the scientific community and inform key policy intervention areas, ultimately supporting the development of more inclusive and more informed community development policies.

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Data availability The data that support the findings of this study are available from the corresponding author, I.O, upon reasonable request.

Declarations

Conflict of interest The authors declare no competing interests.

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