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Research Article

Spatial analysis of the trade-offs between forest ecosystem services and disservices in the Bale Mountains eco-region, Southeast Ethiopia

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Abstract: *Forests provide ecosystem services (ESs) and ecosystem disservices (EDs) to the local community living in and around the forest. This study examined the trade-offs between forest ESs and EDs among communities living at different proximities (<1 km and >3 km) to forest edges in the Bale Mountains Eco-Region of Southeast Ethiopia by assessing how local perceptions of ESs and EDs vary spatially and influence community engagement in forest management. Household surveys, focus group discussions, and field observations were conducted along six pair-wise transects across six selected villages, enabling systematic and comparative collection of both qualitative and quantitative data. Logistic regression was employed to identify socio-demographic and biophysical factors influencing farmers' participation in forest/tree management. Results show that forests are vital to rural livelihoods, offering water (93.9%), firewood (89.4%), construction wood (89.4%), and shade for coffee production (87.9%). Perceived benefits were significantly higher among residents near forest edges ($\chi^2 = 37.22$, $df = 5$, $P < 0.05$). About 59.1% of respondents reported engaging in forest/tree management, influenced significantly by education and family size. However, forests were also seen as sources of EDs, mainly crop-raiding by wild mammals like porcupines (86.4%), bush pigs (83.3%), and warthogs (72.7%), with maize being the most affected crop. These impacts were notably higher near forest edges ($\chi^2 = 45.06$, $df = 2$, $P < 0.05$). Crop guarding (93.9%) was the most common mitigation strategy, alongside fencing and tree clearing. The study concludes that while forest ESs support rural livelihoods, associated EDs, particularly crop-raiding, pose serious challenges, leading to trade-offs that may drive deforestation and affect sustainability. Effective, community-driven forest and agricultural management strategies are essential to balance ESs and EDs. Future research should adopt comprehensive approaches to better understand community perceptions and support sustainable human–wildlife coexistence in forested landscapes.*

Keywords: Crop-raiding, Ecosystem, Forest sustainability, Wild mammals
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1. Introduction

Ecosystems are life-sustaining systems that provide a wide range of goods and services essential to human society (Caputo *et al*., 2016; Mamat *et al*., 2018; Sharma *et al*.,2019). These benefits, known as ecosystem services (ESs) (Helian *et al*., 2011; Tripathi *et al*., 2019; Id *et al*., 2020), support human and ecological well-being either directly or indirectly in the form of provisioning services (including material provisions like food, wood, quantity of water, etc.), regulating services (including regulation

of climate. water quality, soil fertility, occurrence of pests and diseases, etc.), supporting services (like biodiversity protection) and cultural services including recreation, ecotourism, aesthetic values, etc. (Song and Deng, 2017; Tolessa *et al*., 2018; Ouko *et al*., 2018). Studying ecosystem services, such as those provided by forests, helps capture the value of nature for human well-being and enhances our understanding of complex socio-ecological systems (Ouko *et al*., 2018).

Forest ecosystems offer a wide array of services that support the livelihoods of millions globally (Vizzarri *et al.,* 2015; Mengist and Soromessa, 2019; Siyum, 2020). They provide timber and non-timber products, including food, medicine, climate regulation, groundwater recharge, flood and soil control, and habitat for biodiversity. They also hold aesthetic, recreational, and spiritual value (Megevand *et al*., 2013; Blackie *et al*., 2014; Ilstedt *et al*., 2016; Douglas, 2017; Jenkins and Schaap, 2018; Netzer *et al*., 2019; Siyum, 2020; Simons *et al*., 2021). Additionally, they contribute to water purification, fisheries protection, and pollination (Chakravarty *et al*., 2011).

While forest ecosystems provide valuable ESs, they also pose ecosystem disservices (EDs) that can negatively affect human well-being (Shackleton *et al*., 2016; Blanco *et al*., 2019). Forests often harbor pests like baboons and bush pigs that raid crops and threaten farmers' livelihoods (Ango *et al*., 2014; Blanco *et al*., 2019). As a result, farmers' negative perceptions of EDs, especially crop-raiding wildlife, have impacted forest and wildlife conservation efforts (Weladji and Tchamba, 2003; Wang *et al*., 2006). In southwest Ethiopia, such conflicts have been linked to growing deforestation and resistance to conservation initiatives (Lemessa *et al*., 2013; Ango *et al*., 2017).

To mitigate crop raiding by forest-dwelling wild mammals, farmers have employed measures such as fences, traps, smoke, burrow destruction (e.g., for porcupines), guarding, crop cooperation and sharing, migration, and tree removal from fields (Ango *et al*., 2017; Kiros and Bekele, 2021; Mamo and Lemessa, 2021). These practices reflect efforts to balance the trade-offs between forest ecosystem services (ESs) and disservices (EDs) (Ango *et al*., 2014). However, some strategies, particularly migration and tree removal from arable land, have led to negative social and environmental consequences, including forest cover decline (Ango *et al*., 2014; Mamo and Lemessa, 2021; Kiros and Bekele, 2021).

The Harenna Forest, part of the Bale Mountains Eco-Region (BMER), is one of the largest forest blocks in southeast Ethiopia (Wakjira *et al*., 2015). Many people and their livestock inhabit areas in and around this protected forest (Tafesse and Yihune, 2018). The forest supports local livelihoods by providing wild coffee, firewood, charcoal, construction wood, honey, and grazing land. Adjacent communities also cultivate crops such as maize, wheat, barley, teff, potato, onion, and other vegetables. However, the forest hosts crop-raiding wildlife, including Bush pigs (*Potamochoerus larvatus)*, Olive Baboons (*Papio anubis*), Vervet Monkeys (*Chlorocebus pygerythrus*), Warthogs (*Phacochoerus africanus*), Porcupines (*Hystrix cristata)*, Grey duiker (*Sylvicapra grimmia*) and other herbivores which damage crops and threaten farmers' livelihoods, leading to significant human-wildlife conflicts (Sefi *et al*., 2017; Tafesse and Yihune, 2018). Balancing ecosystem services and disservices remains a key challenge for both farmers and development actors in the area.

Previous studies in forested landscapes have mainly addressed threats to forest biodiversity, such as crop raiding and overlooked the spatial distribution of ecosystem services (ESs) and disservices (EDs), as well as the strategies farmers use to manage their trade-offs. (Yihune *et al*., 2011; Tafesse and Yihune, 2018; Kiros and Bekele, 2021). Understanding and managing these trade-offs is essential for promoting human–wildlife coexistence and fostering positive attitudes toward forest conservation. This study, therefore, investigates the trade-offs between forest ESs and EDs in the BMER by examining community perceptions, related management practices and their perceived social and environmental impacts across villages situated at varying distances from forest edges.

2. Materials and Methods

2.1. Description of the study area

The study was conducted in the Bale Mountain Eco-Region (BMER), which is geographically ranged from 5°51′21.16″N to 7°23′39.53″ N latitude and 38°56′05.18″E to 40°29′23.20″ E longitude (Ayana *et al*., 2024). The study area belongs to six districts:

Goba, Berbere, Dello Mena and Harenna Bulluk from the Bale zone, and the rest two districts, namely Adaba and Nensibo, are located in the west Arsi zone (**Error! Reference source not found.**). The 2021 projected population size for these six districts was estimated to be 787,167 (Ayana *et al*., 2024).

The BMER is characterized by its various landscapes that include Harenna Forest (the largest moist tropical forest remains in the study area), the afro-alpine plateau (Sanette plateau), mountain peaks, valleys, grasslands, and agricultural land (Farm Africa *et al*., 2008). The second-highest mountain peak in Ethiopia, Tullu Dimtu (4377m), is found in this Eco region. The Bale Mountains National Park (BMNP) is also situated in the BMER (Wakjira *et al*., 2015).

Annual rainfall of the area ranges from 600 mm to 1150 mm (Tafesse and Yihune, 2018) and the mean annual minimum and maximum temperatures range from 1.4 °C to 18.4 °C, respectively (OFWE, 2014). The common soil types in the study area include Cambisols, Vertisols, Luvisols, Lithosols and Nitosols (OFWE, 2014). Small-scale subsistence agriculture (farming and livestock husbandry) and income generation from forest products are the major livelihood strategies for most of the inhabitants in the BMER (Desta, 2007; Hailemariam *et al*., 2015; Mezgebu and Workineh, 2017).

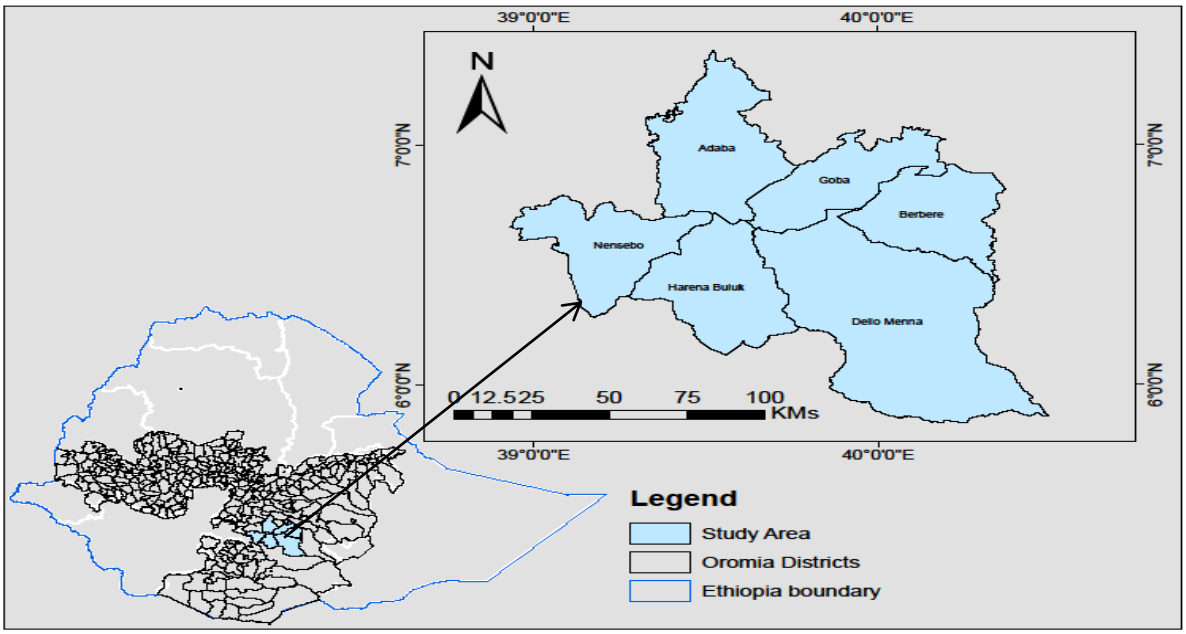

Figure 1: Map of the study area in BMER

2.2. Study design and process

The location of the forest landscape is a factor that can determine the nature of service-disservice distribution (Dorresteijn *et al*., 2017). The Harenna Forest in the Dello Mena district was purposely selected during the reconnaissance survey. The selection was based on the prevailing forest conservation challenges, including agricultural expansion, habitat fragmentation, resource extraction, and human-wildlife conflicts (Sefi *et al*., 2017). The district is characterized by rapidly undergoing environmental changes and the prevalence of human-wildlife conflict in the form of crop-raiding problems; hence, it necessitates the investigation of the distribution of both ESs and EDs and their trade-offs at different distances from forest edges.

The study site selection and identification of land features such as farmlands, settlements and others were done via Google Earth (Figure 1). For the identification of respondents for the household survey, six transects following pair-wise designs were laid out in six areas. Of these, three were located along forest edges (< 1 km), and the other three were placed at a distance away from the forest

edges (> 3km), (Lemessa *et al*., 2013; Osie *et al*., 2020). Furthermore, assessments of associated social and environmental adverse impacts of EDs management, especially their contribution to deforestation and forest degradation, were also focused on. The transects were 2 km long and laid parallel to the forest edge. The stratification of the study sites based on their distance from the forest was guided by two key assumptions. First, forests are sources of both ESs and EDs. Second, most wild mammal crop raiders are unlikely to travel more than 2 km from the forest, making their impact more substantial closer to the forest (Lemessa *et al*., 2013).

To investigate how farmers in the BMER social-ecological system have maintained the trade-offs between forest ESs and EDs, specific ESs and EDs were selected for analysis. The selected provisioning services included the provision of bees and honey, wood for fuel and construction, water, and fodder for livestock. Supportive services such as forest trees offering shade for coffee production and providing sites for hanging beehives were also considered. In terms of disservices, two major forest EDs were identified: wild mammals as crop raiders and ants as raiders of bees and honey. Among several villages within the Wabero, Burkitu, Irba, and Welete Gudina Kebeles of the Dello Mena district, six were identified. Three are located within 1 km of the forest, and the other three, situated 3 km or more away, were chosen in a parallel, pairwise manner to match the first group. Each village is distinguished by its specific land use. In Ethiopia, a Kebele is the smallest administrative unit.

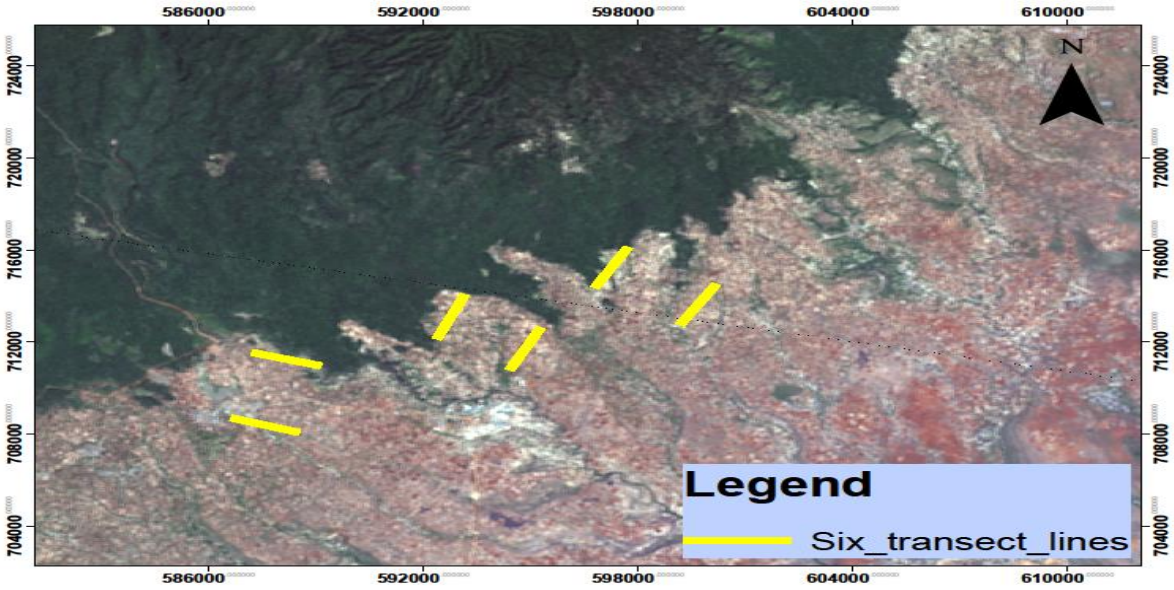

Figure 1: Pair-wise transect lines for data collection

2.3. Data collection

To generate both quantitative and qualitative data, the study employed a triangulated data collection approach combining household surveys, Focus Group Discussions (FGDs), and direct field observations in the selected six villages. Household heads were interviewed using structured and semi-structured questionnaires to assess perceptions and practices related to ecosystem services (ESs) and disservices (EDs). FGDs were also held in the corresponding villages to enrich and validate survey responses through participatory discussions and ranking exercises focused on crop-raiding wildlife and the impacts of ED management. Moreover, complementary field observations were conducted to contextualize and corroborate data from surveys and discussions, enhancing the reliability and depth of the findings. The following paragraph describes the three data collection approaches in detail.

Six study transects were first laid out using Google Earth, and 66 household heads were randomly selected for interviews; 11 households along each transect (hence, 33 near (< 1 km) to and another 33 far (> 3km) from the forests) were interviewed. A zigzag walking pattern along transects guided the selection. The semi-structured questionnaire, containing both open- and closed-ended questions, gathered data on the distribution of selected ESs and disservices EDs, related management practices, and perceived social and environmental impacts of ED management.

To supplement the survey, six focus group discussions (FGDs) were conducted-one in each village-with 10 participants per group. Discussants were asked to rank crop-raiding mammals based on perceived damage and assess the severity of adverse impacts from ED management, particularly regarding impacts on forest cover change and social health and well-being. Field observations further validated and enriched the data by directly documenting farming practices, proximity to forests, visible signs of ESs and EDs, and environmental conditions. Although the study area's population is 787,167, the sample size of 66 households was justified by the study's spatially focused design, which compared perceptions and practices at varying distances from the forest.

In social-ecological systems research, small sample sizes are often appropriate when purposive or stratified sampling is employed to capture variations across specific environmental or spatial gradients (e.g., distance from the forest), as this approach prioritizes capturing key contextual differences over broad population generalization (Etikan and Bala, 2017; Creswell and Poth, 2018). Hence, for this study, stratified random sampling across six transects, combined with FGDs and field observations, ensured robust, context-specific insights, even if not statistically generalizable to the broader population.

2.4. Data analysis

Demographic data such as sex, age, marital status, family size, landholding, and education status of the respondents were summarized using measures of central tendency (mean) and dispersion (range). Descriptive statistics were also used to analyze respondents' perceptions of selected forest ecosystem services (ESs) and ecosystem disservices (EDs). Pearson's Chi-square test was applied to analyze quantitative responses from semi-structured questionnaires administered to farmers residing near and far from the forest edges. Logistic regression analysis was used to examine factors influencing farmers' participation in forest/tree management practices (dependent variable), modeling binary outcomes (participation or non-participation) based on socio-demographic (such as sex, age, marital status, family size, land holding and education status) and biophysical (such as location-near and far from forest edges, and selected forest ESs and EDs) independent variables.

Finally, qualitative data collected through group discussions with resident household heads and field observations were analyzed thematically using content analysis to provide deeper contextual insights. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS), with the household head as the unit of analysis (Merkebu and Yazezew, 2021).

3. Results and Discussion

3.1. Demographic characteristics of the respondents

Out of the total 66 household respondents, 69.2 and 31.9% of them were male and female, respectively. The average age of the respondents was 50.4 years, with a minimum and maximum of 30 and 81 years, respectively. About half of the respondents (54.5%) never attended school and were illiterate (Table 1). All the respondents were married and most of them (50%) had a family size between 4 and 8 children. Most respondents (80.3%) had land holding sizes between 1 and 2 hectares. Crop cultivation was the primary livelihood source for the majority of respondents, accounting for 51.5% (Table 2).

In addition to coffee and honey production, all respondents grow maize (100%), followed by teff (98.5%) and sorghum (63.6%) in the study villages. Additionally, soybeans and, in rare cases, wheat and barley were also mentioned as being produced in the study villages. Mango (88.2%), banana (51.5%), papaya (33.3%), and avocado (28.8%) were commonly cultivated. In addition, vegetables like

chillies/pepper and tomato were also reported to be grown by respondents and discussants in the study villages. Chat production was also reported by a few inhabitants in the villages.

Table 1: Educational status of respondents in BMER, Southeast Ethiopia

Education level	Frequency	Percentage
Never attended school (illiterate)	36	54.5
Attended Grade level		
1-4	20	30.3
5-8	6	9.1
9-10	2	3.0
11-12	2	3.0
Total	66	100.0

Table 2: Study respondents' Major livelihood sources of the respondents in the study villages

Main livelihood sources	Frequency	Percentage
Pastoralism	1	1.5
Crop production	34	51.5
Agro-pastoralism	31	47
Total	66	100.0

3.2. Forest ecosystem services and their management in the study villages

Under this section, selected provision and supporting services of forest ecosystems are discussed together with how farmers manage forests/trees and what socio-demographic and biophysical factors determine their participation in the forest/tree management in the study area.

3.2.1. Perceived forest ecosystem services

In the study area, forests provided diverse ESs to the local community living in and around the forests, such as food, bees and honey, fuel woods (firewood and charcoal), wood for construction (for houses, fences, etc.), fodder for livestock feed and freshwater for livestock and human beings. **Error! Reference source not found.** shows the proportion of respondents who benefited from the selected forest ESs in the study villages at different distances from the forest edges. Most respondents (93.9%) reported the use of forests in BMER as a source of water for their livelihoods. In line with this finding, Mezgebu and Workineh (2017) indicated that BMER is the main source of several streams, springs and rivers providing water for the support of livelihoods and well-being of several people. Similarly other researchers also documented the importance of forest ecosystems as a source of water (Duncker *et al*., 2012; Ouko *et al*., 2018; Kisiwa *et al*., 2021).

As indicated in the present results, forest was also the main source of wood for the construction of houses, fences as well as domestic fuels. Most honey-producing respondents reported that they have been using forest trees for hanging their beehives. Hence, forests are managed and protected for this purpose by farmers. Farmers also depend on forest resources for foraging and shading purposes for their livestock. Similar findings, such as forests being sources of fuels and construction materials, as well as sources of bees and honey production and fodder for livestock forage, were reported by other studies (Ango *et al*., 2017; Ouko *et al*., 2018; Kisiwa *et al*.,2021; Kiros and Bekele, 2021).

About 87.9% of respondents indicated that forests support coffee production under their shade. This finding aligns with previous research by Ango *et al*. (2017), who also reported the benefits of forests and tree wood in supporting coffee production through their coffee shades. The respondents indicated that they have allocated coffee fields in the nearby protected forests not only for their self-benefit from coffee production but also for forest protection and management. About 97% of coffee producing

respondents pointed out that forest tree shade for their coffee production have decreased over the past decades, attributing this decline to several factors such as deforestation for agricultural land expansion (89.4%), overgrazing (65.2%), illegal tree felling (54.5%) and climate change (33.3%). Other than coffee fields, respondents also indicated that they had their cereal crop field (95.5%), grazing land (43.9%), home garden field (72.7%), woodlot (28.8%), and mixed land use field (6.1%) in their villages where they integrate crops with tree plants knowing the benefits of trees for supporting their livelihoods.

Respondents were also involved in honey production using both traditional (71.2%) and modern (7.58%) beehives, mainly located in nearby protected forests (54.5%), home gardens (22.7%), crop fields (19.7%), and grazing lands (4.5%). For household-level energy sources for cooking, lighting, heating and other purposes, all respondents indicated that they used firewood, followed by use of charcoal (22.7%) and solar energy (10.6%). Respondents living near the forest edges primarily rely on forests for firewood and charcoal. Those farther away from the forest edges obtain energy from forests (78.8%), woodlots (42.4%) and other sources (3%). Similar patterns of wood utilization were observed for construction purposes. The average number of livestock owned by respondents was 7.7. A higher proportion of respondents (93.94%) living near forest edges relied on forests as the main source of livestock feed, compared to those residing farther away from forest edges (33.33%). Concerning the forest's role as a source of water for both livestock and human consumption, the proportions of respondents living near and far from forest edges were nearly the same, as those residing farther away from the forests also perceived the forest as their primary water sources.

Significant statistical differences ($\chi 2$=37.22, df=5, P<0.05) were observed in how respondents near (< 1 km) and far (> 3km) from the forest edges perceived selected forest ESs, including tree shade for coffee production, provision of bees and honey, firewood, charcoal, construction wood, fodder and water. In all aspects, respondents residing near the forest edges reported greater access to and extraction of forest ESs than those living farther away. Accordingly, proximity to the forest edge is associated with increased access to forest ESs; showing significant spatial variability among respondents' perceptions thereof, as also reported in other studies (Ango *et al*., 2014; Ke *et al*., 2024).

3.2.2. Management of forests/trees for their ESs

The majority (59.1%) of the respondents actively involved in the management of forest/trees like forest protection, tree planting and retention while about 40.9% of respondents did not practice in any management activities. These practices were mainly carried out in woodlots, mixed land use fields and home gardens, particularly by respondents living farther from the forest edges. The findings corroborate to the results of the previous study (Ango *et al*., 2014), which stated that farmers managed tree species for their ecosystem services by planting them along the boundaries of home gardens and croplands and by retaining them in grazing and coffee lands.

The involvement of farmers in the management of forest ecosystems for the improvement of forest ESs was influenced by different socio-demographic and bio-physical factors such as respondents' sex, age, education level, family size, land size and distance to the forest. The employed regression model was statistically significant ($\chi 2$ = 31.4, df = 6, P<0.05). The model explained approximately 51.1% of the variance in participation (Nagelkerke R^2 = 0.511) and correctly classified 74.2% of cases of the dependent variable (farmers' participation in forest/tree management).

Logistic regression results further revealed that farmers' education level, family size, and landholding size were positively associated with their involvement in forest/tree management (**Error! Reference source not found.**). The association between respondents' education level (p = 0.041) and family size (p = 0.004) with the farmers' involvement in forest/tree management was statistically significant at the 95% confidence level. The significant positive regression result for the education level variable indicates that higher levels of education among respondents are associated with greater participation in forest/tree management. Similarly, the association between participants' family size and their participation in forest/tree management was also

positive and significant, showing that the larger the number of family members, the higher their involvement in forest/tree management. In short, more educated individuals and those with larger families are more likely to be involved in forest management. These findings also corroborate the results in (Ouko *et al*., 2018; Masha *et al*, 2024).

Land size also showed a potential influence on involvement in forest/tree management, though it was not statistically significant at the 95% confidence level (p = 0.055); however, it becomes significant when considered at a 90% confidence level. In contrast, variables such as sex (p = 0.795), age (p = 0.871), and distance to the forest (p = 0.635) did not have a significant effect on the farmers' involvement in the forest management. In other words, the results indicate that the predictor variables of sex, age and distance to the forest did not show a significant association with involvement of the local community in forest management. This suggests that these factors did not meaningfully impact the likelihood of involvement in forest management in the current study. Interestingly, this contrasts with previous studies (Ouko *et al*., 2018; Kazungu *et al*, 2021; Masha *et al*, 2024), which reported significant associations between these variables and forest management participation.

Table 3: Selected ecosystem services from the forest landscape of BMER

Distances from the forest edge	Number of respondents (N)	Selected forest ESs (%)						
		Bees/ honey	Firewood	Charcoal	Woods	Fodder	Water	Tree shades
Near to forest edges (<1km)	33	90.91	100	30.3	96.97	93.94	96.97	90.91
Far from forest edges (> 3km)	33	51.5	78.79	3.03	81.82	33.33	90.91	84.85
Total	66	71.2	89.40	16.67	89.40	63.64	93.94	87.88

Table 3: Results of logistic regression on demographic and biophysical factors

Variables	B	S.E.	Wald	df	Sig.
Sex	0.190	0.732	0.068	1	0.795
Age	-0.005	0.028	0.026	1	0.871
Education level	0.779	0.357	4.190	1	0.041
Family size	0.560	0.241	8.228	1	0.004
Distance to forest (km)	-0.355	0.748	0.225	1	0.635
Land size (ha)	0.207	1.151	3.674	1	0.055
Constant	0.650	1.876	1.995	1	0.158

B = coefficient; SE = Standard error; df; degree of freedom; Sig.: significance level

3.3. Perceived disservices of forest ecosystem and their managements

3.3.1. Crop raiding by wild mammals

All the respondents reported that their crops were raided by one or more crop-raiding mammals. According to the respondents living along the forest edge, their crops were mainly raided by bush pigs (100%) and olive baboons (100%), followed by warthogs and porcupines (87.9%), vervet monkeys (42.4%), and grey duiker (33.3%). In contrast, at villages farther from the forest edge (i.e., >3 km), porcupine (84.8%) was the dominant crop-raiding mammals, followed by vervet monkeys (69.7%), bush pigs (66.7%), warthogs (57.6%), grey duiker (18.2%) and olive baboons (6.1%) as indicated in Figure 3. Porcupines, bush pigs, warthogs, vervet monkeys and olive baboons were frequently cited as raiders of one or more crops such as maize, sorghum, tef, and tree fruits (mango, banana, avocado, papaya and matured coffee barriers) in the study villages. In line with these findings, several previous studies also reported various crop-raiding wild mammal species. (Ango *et al*., 2017; Tafesse and Yihune, 2018; Osie *et al*., 2020; Merkebu and Yazezew, 2021; Mamo and

Lemessa, 2021; Kiros and Bekele, 2021) For instance, Ango *et al*. (2017) identified bush pigs, baboons, giant forest hogs, warthogs, Vervet Monkeys and porcupines as common wild mammal crop pests in the study conducted in an agricultural forest mosaic landscape in southwest Ethiopia.

Discussants further identified olive baboons and vervet monkeys as the most common diurnal crop raiders near and far from forest edges, respectively, while bush pigs, warthogs, and porcupines were the main nocturnal raiders, especially near forest edges though also present farther away. Olive baboons and vervet monkeys primarily raided maize and sorghum; bush pigs and porcupines targeted maize; warthogs raided teff; and grey duikers raided soybeans. Occasionally, Colobus monkeys were reported to raid sorghum and maize. Tree crops such as mango, banana, avocado, and especially ripe coffee were also targeted, particularly by olive baboons. Overall, the most commonly reported crop raiders were porcupines (86.4%), bush pigs (83.3%), warthogs (72.7%), vervet monkeys (56.1%), and olive baboons (53%). These species raided a range of crops both near and far from forest edges, though their presence and impact were notably higher near the forest.

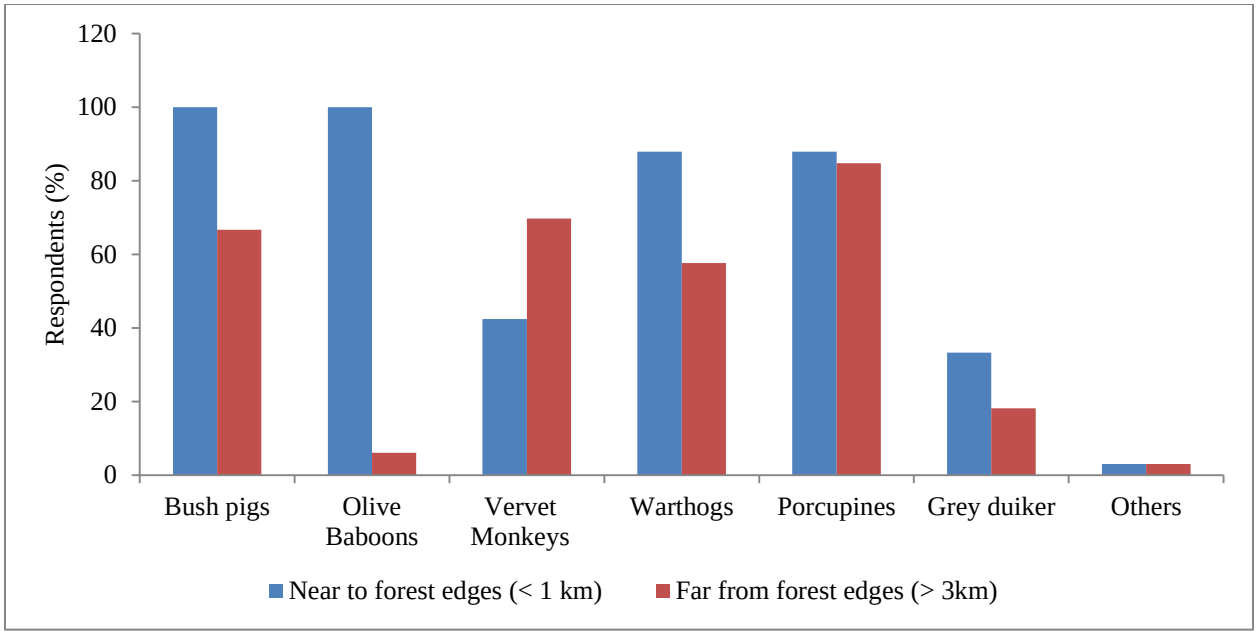

Figure 3: Perception of respondents about crop raiding mammals at different distances from forest edges

Respondents across all study villages identified maize as the most vulnerable (100%) and frequently attacked (47%) crop by wild mammals, largely due to its widespread cultivation. Frequent attacks were reported by 69.7% of those near forest edges, while 60.8% of respondents farther away noted occasional attacks. It was reported that the level of impact on this crop varied across the distances from the forest edges (Table 4). Many respondents (54.5%) living near the forest edge perceived that wild mammal pests had caused higher levels of impact on maize crops, whereas the highest proportion of residents (45.5%) living far distances from forest edges ranked it medium. On average, the levels of crop raiding impact on maize crop yield were ranked medium in the whole study villages. The results showed that the level of impact on maize, the most staple food crop in the study villages, by the crop-raiding mammals was significantly higher along the forest edges compared to the far distances from the forest edges difference ($\chi 2=45.06$, df=2, $P<0.05$). In agreement with this, previous studies showed the existence of higher crop damages by crop-raiding mammals along the forest edges (Ango *et al*., 2017; Osie *et al*., 2020; Mamo and Lemessa, 2021; Merkebu and Yazezew, 2021).

Table 4: Perception of the respondents on the annual yield loss (per hectare) of maize by crop raiders in relation to the total yield

Distances from the forest edge	Number of respondents (N)	High (%)	Medium (%)	Low (%)
Near to forest edges (≤ 1 km)	33	54.5	45.5	1
Far from forest edges (≥ 3km)	33	21.2	45.5	33.3
Total/Average	66	37.9	45.5	17.7

Low, medium and high represent yield losses of <5%, 5-20%, and 20-40%, respectively

3.3.2. Management mechanisms of forest EDs (crop raiding wild mammals)

In all the study villages, most respondents (93.9%) used the mechanism of guarding for controlling the crop raiding problem followed by fencing (75.8%), distancing crop raiders away by tree cutting (31.8%), and use of intimidating techniques such as scarecrow, lighting (fire) and use of smoke (19.7%). Statistical analysis showed significant differences ($\chi^2 = 19.05$, $df = 3$, $P < 0.05$) in these crop raider control practices across varying distances from forest edges. Such crop-raiding controlling mechanisms against wild mammals have been commonly reported in previous research (Ango *et al*., 2017; Osie *et al*., 2020). Women and children were involved in guarding of crops during the daytime while adult men guarded at nighttime. Discussants of FGDs along forest edges also reported that the farmers spent more of their time on guarding practices. Fencing cropland either by use of live fencing and/or by dead-cut trees was more commonly practiced (84.8%) by respondents near the forests than those at far distances (66.7%). It is more effective in protecting nocturnal crop raiders such as bush pigs, warthogs, grey duikers and porcupines.

Farmers near forest edges also cut trees and branches along crop raider paths to deter them from reaching the croplands. About 51.5% of respondents near forest edges used this technique compared to 12.1% of those at a far distance from the forests. Furthermore, farmers reported the use of lighting and smoke to protect nocturnal crop raiders. Nevertheless, the use of intimidating techniques such as scarecrows for protecting olive baboons and vervet monkeys during daytime was not effective as they could easily understand and adapt to it. Trapping crop-raiding wild mammals as another method for controlling crop was also mentioned during FGDs raiders. Distancing crop raiders away by tree cutting and trapping were practiced by farmers in a hidden way as these measures are illegal acts and work against the national and regional legal frameworks, policies, proclamations of sustainable conservation and utilization of natural resources, including wildlife.

There are different legal backgrounds that promote conservation and sustainable use of natural resources, and community participation in Ethiopian including the Constitution (1995), the Environmental Policy of Ethiopia (1997), the Wildlife Proclamation No. 541/2007, the Forest Proclamation No. 1065/2018, and the EIA Proclamation No. 299/2002. Supporting policies such as the Biodiversity Policy (1998), Rural Land Use Proclamations, and the CRGE Strategy (2011) further integrate environmental sustainability into development. At the sub-national level, Oromia Region has adopted complementary forest and land-use regulations aligned with national law, advancing participatory forest management and community-led conservation efforts. Despite hidden threats to natural resources from certain local activities, law enforcement in the BMER has been partially implemented through the coordinated efforts of local authorities, community scouts, and regional institutions, aiming to reduce illegal activities and enhance resource protection.

3.3.3. Bee and honey raiding by ants and their controlling measures

Bee and honey raiding by ants was the other perceived forest EDs. The survey results showed that the highest proportion of respondents (34%) perceived the occasional raiding of their bees and honey in beehives by ants (Figure 4), which adversely impacted their livelihoods. Previous scholars also reported similar results (Osie *et al*., 2020; Dobelmann *et al*., 2023). Respondents used different mechanisms to control ants from their beehives. These include dusting ashes (89.4%) under the trees or places where beehives are set together to destroy the nests of raiding ants (10.6%).

Additionally, participants in the group discussions identified traditional methods for protecting bees and honey from ants, including regular monitoring and cleaning under beehive supporting trees, hanging beehives on tall trees to avoid ant`s access, using fire smoke, and applying chemicals or lubricants such as grease to the base of beehives or the trees where the beehives are hung on.

Generally, apart from being sources of ESs, forests were also perceived as sources of EDs as they harbored crop-raiding and bee- and honey-raiding wildlife in the study villages. These findings corroborate with other previous studies (Yihune *et al*., 2011; Ango *et al*., 2014; Ango *et al*., 2017; Blanco *et al*., 2020).

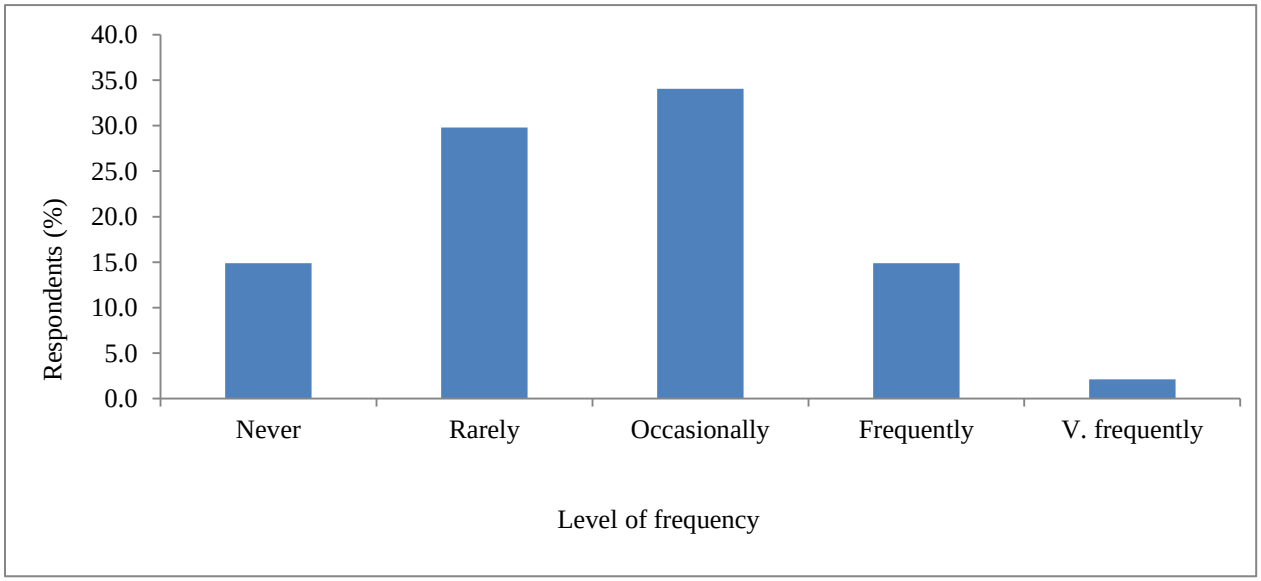

Figure 4: Perception of respondents on bees and honey raiding by ants

3.3.4. Social and environmental impacts of crop and honey-raiding animals

Substantial proportion of the respondents (89.4%) reported that the health of their family members was adversely affected by efforts to control crop-raiding mammals in the study villages. Among these health problems restlessness and anxiety was the major one in areas near the forest edges (93.9%) and areas at far distance (54.5%), which was statistically significant ($\chi 2=9.95$, df=2, $P<0.05$) (Table 6).

Although the majority of the respondents (93.9%) were not physically attacked by crop raiders, few respondents (6.1 %) reported the physical attack of their family members by bush pigs, olive baboons, warthogs and colobus monkeys.

A considerable number of respondents (63.6%) reported that crop raiding affected their livelihoods through income loss (opportunity costs) beyond yield damage by crop raiding mammals. Specifically, 53% had no income due to limited farm activity, and 47% lost income from non-participation in non-farm activities (Table 7).

Another reported social impact of crop raiding was its effect on children's education (62.1%), including reduced study time (50%), increased school dropout (34.8%), and inability to send children to school (30.3%). In a similar fashion, respondents also claimed the inability to participate in social life owing to crop raiding problems (74.2%), specifically, their inability to participate in environmental development community-based activities (36.4%), in government-organized meetings (34.8%) and social events such as funerals and weddings (31.8%). These perceptions varied significantly across different distances from forest edges ($\chi^2 = 8.66$, df = 2, $P < 0.05$).

Table 5: Perception of respondents on the health problems associated with crop-raiding mammals

Different distances from forest edge	Number of respondents (N)	Restlessness and anxiety in mind (%)	Inadequate sleeping (%)	Coldness-related illnesses (%)
Near to forest edges (≤ 1 km)	33	93.9	87.9	78.8
Far from forest edges (≥ 3km)	33	54.5	30.3	18.2
Total/Average	66	74.2	59.1	48.5

Table 6: Perception of respondents on the opportunity costs incurred by managing the crop raiders in the study villages

How opportunity costs are incurred	Frequency	Percent
Unable to participate fully on farm activities	35	53
Unable to participate in non-farm activities	31	47
Total	66	100

About 31.8% of respondents in the study villages indicated that they were involved in forest clearing practices or any other mechanisms for distancing away of the forest edge to control crop-raiding mammals that leads to deforestation. Such practice was perceived to be more common along the forest edges (51.5%) than at far distances (12.1%) from the forest edges. The extent of tree cutting aimed at disrupting the pathway of crop-raiding mammals from the forest to the farmland was statistically significant ($\chi 2=19.05$, df=1, $P<0.05$). Such cumulative practices of tree cutting for different purposes, especially for controlling crop-raiding mammals over the years, have threatened forests and their wildlife.

Very few respondents (16.7%) reported killing of crop-raiding mammals as a mechanism to protect their crops. Along the forest edges, warthogs (15.2%), followed by olive baboons and porcupines (9.1%) were killed. At far distances from forest edges, relatively vervet monkeys (6.1%) and push pigs (3%) were killed by respondents (Table 7). The results showed that the killing of larger numbers and types of crop-raiding mammals was occurred more near the forest edges than at greater distances from the forest edges. Killing of the animals is an illegal activity and happened in hidden ways by farmers.

Table 7: Respondents practiced killing as management options for crop raider

Different distances from forest edge	Respondents involved in killing a particular type of crop raider (%)				
	Bush pigs	Olive baboons	Vervet monkeys	Warthogs	Porcupines
Near to forest edges (≤ 1 km)	3.0	9.1	3.0	15.2	9.1
Far from forest edges (≥3km)	3.0	0.0	6.1	0.0	0.0
Total	6.1	9.1	9.1	15.2	9.1

Tree cutting to distance the crop fields from the forest and illegal killing of wild crop mammals were considered as environmental impacts of the crop raiding animals. These practices can be in the future the causes for the reduction of forest cover and biodiversity loss in the study villages. These perceptions of farmers to the forest EDs may have a negative influence on the conservation of forests and wildlife. These results are in line with the study of Osie *et al*. (2020), who stated that crop-raiding

management strategies through tree clearance result in the loss of biodiversity. Moreover, the crop raiding problem is responsible for reducing the long-term species conservation support of the local communities (Merkebu and Yazezew, 2021) as well as posing challenges to wildlife conservation practices (Ango *et al*., 2017). Furthermore, Ango *et al*. (2014) also showed tree removal, especially from arable fields, as another means of crop raiders controlling strategy practiced by farmers in the Gera district of the Oromia regional state of Ethiopia.

The study findings reveal that crop-raiding animals not only cause direct crop damage, resulting in income loss and food insecurity, but also lead to indirect social and environmental impacts. These include negative effects on community health, reduced participation in social activities, opportunity costs, and disruption of children's education. This aligns with previous studies that highlight similar indirect impacts of crop-raider control strategies, such as increased labor demands, health issues, and school disturbances (Byg *et al*., 2017; Osie *et al*., 2020; Merkebu and Yazezew, 2021; Mamo and Lemessa, 2021; Kiros and Bekele, 2021). For example, Osie *et al*. (2020) noted health effects like cold exposure and sleep deprivation from nighttime guarding. Overall, despite this trade-offs between forest ecosystem services and disservices across different proximities to forest edges in BMER, all respondents (100%) acknowledged the forest's continued importance to their livelihoods.

4. Conclusion

This study explored local communities' perceptions of forest ecosystem services (ESs) and disservices (EDs) in the BMER, along with their management strategies across varying distances from the forest. The findings confirm that forests in the BMER provide essential ESs such as water, honey, firewood, construction wood, fodder and ecological support for coffee and honey production, which are particularly valued by communities living near forest edges. However, these benefits are counterbalanced by EDs, especially crop and honey raiding by wild mammals and ants, with significant spatial variation in perceptions and impacts.

Farmers are practicing various mitigation strategies against crop and honey raiding animals such as guarding, fencing, tree cutting, and scare tactics. However, these methods often lead to adverse social and environmental outcomes, including health problems, disrupted education, deforestation, and biodiversity loss. Therefore, integrated, participatory, and culturally appropriate forest and wildlife management approaches that mitigate the EDs while enhancing the ESs are recommended. These activities may include among others strengthening the engagement of the local communities in the management of forests through training, education, provision of alternative livelihood options, and expanding research to capture a broader range of ESs and EDs. Such strategies are critical for the promotion of human–wildlife coexistence, improving rural livelihoods, and sustaining forest ecosystems in the BMER.

Data availability statement

Data will be made available on request.

Conflicts of interest

The authors declared that there is no conflict of interest.

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