Socio-Ecological Study around Kahuzi-Biega National Park: Survey on Local Perceptions of Forest Ecosystem Services, willingness to pay, and Commitment in Forest Conservation

Research project

Abstract: Although the impact of deforestation has been profound around the Kahuzi-Biega National Park (KBNP) in South Kivu, Democratic Republic of Congo, local communities continue to depend heavily on forest ecosystem services. This study focuses on the local perceptions of these services and their engagement in conservation efforts across six villages: Caminunu, Cifunzi, Cibinda, Fendula, Mule, and Rambo, located within the Kalonge groupement. Utilizing a socio-ecological approach, the survey revealed that provisioning services are deemed most crucial, recognized by 64.7% to 82.4% of respondents. Support services are acknowledged by 11.8% to 29.4% of participants, while regulation services are less frequently mentioned, with only 5.9% citing their importance. Additionally, the willingness to pay for conservation initiatives was assessed, with a higher frequency of respondents (particularly in Cibinda, Cifunzi, Mule, and Rambo) showing a preference for contributing at the 0.50 level. In contrast, the lowest willingness to pay (0.00) was observed less frequently across all villages. These findings highlight the critical need for tailored conservation strategies that consider both the economic capabilities and ecological priorities of local communities. Future studies could explore long-term trends in willingness to pay and investigate the effectiveness of various conservation interventions, providing a deeper understanding of how to sustain both biodiversity and livelihoods in the face of ongoing environmental challenges.

Keywords: Deforestation, Forest Ecosystem Services, Kahuzi-Biega National Park, Community Engagement, Socio-Ecological Approach, Willingness to Pay, Conservation Strategies, Biodiversity, Sustainable Livelihoods.

1. Introduction

The Kahuzi-Biega National Park (KBNP), situated in the eastern Democratic Republic of the Congo (DRC), is a UNESCO World Heritage site renowned for its exceptional biodiversity. The park is particularly famous for being home to the critically endangered Eastern Lowland Gorilla (*Gorilla beringei graueri*), which continues to draw global attention (UNESCO, 2023). KBNP spans an impressive area of over 6,000 square kilometers, encompassing both lowland and montane forests. This vast expanse plays a vital role in the conservation of numerous species, many of which are endemic or endangered, and serves as a critical source of ecosystem services that sustain the livelihoods of the surrounding communities (Imani, 2017).

However, the park faces mounting challenges that threaten its ecological integrity and the well-being of local populations. Deforestation, poaching, and human encroachment are persistent issues exacerbated by socio-economic pressures and political instability in the region (Balezi, 2023). These threats not only jeopardize the rich biodiversity within the park but also compromise the ability of the forests to provide essential ecosystem services, such as carbon sequestration, water regulation, and soil fertility (Ferguson, 2022). The degradation of these services has direct and often severe consequences for the local communities who depend on them for their daily needs.

Given these challenges, there is a pressing need to understand local perceptions of forest ecosystem services and the extent to which communities are willing to engage in conservation activities. Such understanding is crucial for developing effective conservation strategies that are both ecologically sound and socially acceptable. Ecosystem services, as defined by the Millennium Ecosystem Assessment (2005), are the benefits that humans derive from ecosystems. These include provisioning services like food and water, regulating services such as climate regulation and disease control, supporting services like nutrient cycling, and cultural services that provide recreational, spiritual, and aesthetic benefits. In the context of KBNP, the surrounding communities rely heavily on these services, particularly through agriculture, the collection of non-timber forest products (NTFPs), and water supply (Balezi, 2023).

The importance of ecosystem services to local communities cannot be overstated. Recent studies have highlighted the critical role that local knowledge and perceptions play in shaping conservation outcomes. Incorporating local perspectives into conservation planning not only enhances the ecological effectiveness of conservation strategies but also ensures that they are more likely to be accepted and supported by the communities involved (Jean de Dieu et al., 2015; Balezi et al., 2023). Local communities often possess a deep understanding of the ecological processes and cultural significance of their landscapes, which can be leveraged to promote sustainable forest management and conservation initiatives (Mukumba et al., 2022).

Despite this, there remains a significant gap in our understanding of how these communities perceive the value of forest ecosystem services and their willingness to support conservation efforts. Perceptions of ecosystem services can vary widely among different stakeholders, influenced by factors such as socio-economic status, education, and proximity to the forest (Elisabeth et al., 2024). For instance, communities that are heavily dependent on forest resources for their livelihoods may place a higher value on provisioning services, while those further away may appreciate the cultural or regulating services provided by the forest (Berihu et al., 2024). Understanding these diverse perceptions is crucial for designing conservation interventions that are aligned with local priorities and capacities.

One approach to assessing the value that individuals place on ecosystem services is through the concept of willingness to pay (WTP). WTP studies are commonly used in environmental economics to estimate the economic value of conservation initiatives and to gauge public support for environmental policies (Qi, 2024). In the context of KBNP, assessing the WTP among local communities can provide valuable insights into the feasibility of implementing payment for ecosystem services (PES) schemes or other market-based conservation approaches (Murhula, 2024). Such approaches could potentially provide a sustainable funding mechanism for conservation activities while also offering direct benefits to the communities involved.

The commitment of local communities to forest conservation is influenced by a complex interplay of social, economic, and cultural factors. Research has shown that communities are more likely to engage in conservation activities when they perceive tangible benefits, such as improved livelihoods or enhanced ecosystem services (Miriam et al., 2022). Conversely, conservation efforts that are perceived as restrictive or that fail to address local needs can lead to resistance and conflict (Peng et al., 2024). Engaging local communities in conservation requires not only addressing their immediate needs but also fostering a sense of stewardship and ownership over conservation initiatives (Azlan, 2024). This can be achieved through participatory approaches that involve communities in decision-making processes, provide them with clear benefits, and build their capacity for sustainable resource management (Peng et al., 2024).

In the case of KBNP, integrating local knowledge, providing alternative livelihoods, and strengthening local institutions have been identified as key factors for successful conservation outcomes (Miriam et al., 2022). By involving communities in conservation efforts and ensuring that they receive tangible benefits, it is possible to build a more sustainable and resilient approach to forest management. This study aims to explore the socio-ecological dynamics around KBNP by examining local perceptions of forest ecosystem services, their willingness to pay for conservation efforts, and their commitment to forest conservation. Through this exploration, the study seeks to contribute to the development of more effective and inclusive conservation strategies that align with the needs and aspirations of local communities.

Understanding the socio-ecological context in which conservation efforts take place is essential for ensuring that these efforts are not only successful in the short term but also sustainable in the long term. By addressing the socio-economic drivers of deforestation and forest degradation and by fostering a sense of ownership and stewardship among local communities, it is possible to create conservation strategies that benefit both biodiversity and human well-being.

2.1. Study area

This study was conducted in the mountainous eastern part of the DRC, in the South Kivu province, Kalehe territory, in the municipality of Kalonge, around the Kahuzi-Biega National Park (PNKB).

MAP OF THE STUDY AREAS

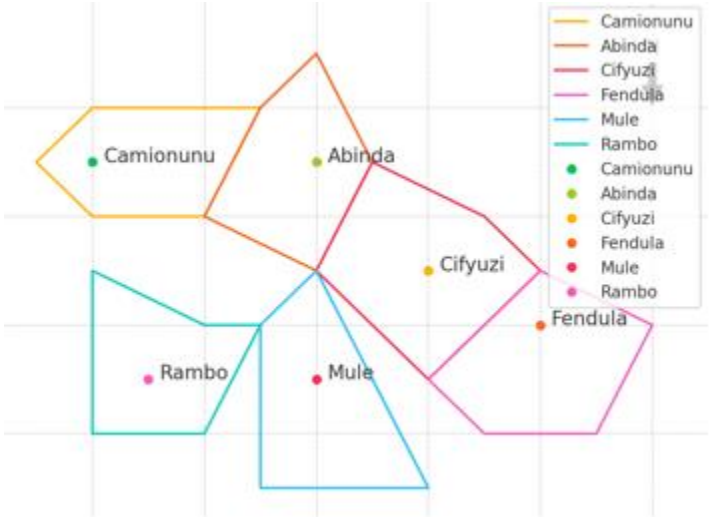


Figure 1 Map of the study area (github repository: Kaloge-map-with-python).

The Kalonge grouping spans an area of 750 km², bordered to the north by the Buholo community and the municipality of Kalima, to the south by the Kabare territory, to the west by the Kahumba and Biapoka rivers, as well as the Nyamusenge massif, separating it from the Shabunda area, and to the east by the Kahuzi-Biega National Park (PNKB) (Murhula, 2024). This territory is influenced by a mountainous climate, situated along the Tumba mountain range. Annual precipitation ranges between 1300 and 1680 mm, with an average annual temperature of 17.5ºC. Absolute maximum temperatures vary from 25.5ºC to 28ºC. Seasons are mainly divided into a rainy period, spanning approximately 9 months from September to May, and a dry season, lasting about 3 months from June to August (Mugisho et al., 2022).

2.2. Materials and Methods

2.2.1 Data Collection

Local attitudes towards the benefits provided by forests and community participation in conservation efforts were examined. Data for this analysis was gathered through a survey conducted over two days in Kalonge. The survey aimed to capture local views on both the advantages of ecosystem services and forest conservation practices. A sample of 123 individuals from Kalonge was selected, with the sample size determined using the following formula:

$$\mathbf{n} = \frac{\mathbf{N}}{\mathbf{1+N(e)^2}}$$

where:

- N is the population size of Kalonge, estimated at 189,900 individuals (SANRU, 2019),
- e is the precision level, set at 0.9 (Lunjwire, 2022).

Despite targeting 123 individuals, only 103 were reached, representing 83,7% of the initial sample. This reduction was due to some individuals being unavailable during the survey or a shortage of participants engaged in the study's target activities. Selection criteria for respondents included residence in the study area, age (20 and above), and involvement in relevant occupations such as agriculture, forestry, and local forest management.

2.2.3. Survey implementation

Fendula, Cifunzi, Rambo, Mule, Caminunu, and Cibinda was the six villages targeted. In total, 103 people were able to participate in the survey. Several activities were identified in these villages, including agriculture, charcoal production, timber trading, non-timber forest product (NTFP) sales, and forest management. For agricultural activity, 30 people were surveyed, with 5 people per village. Similarly, 30 people were surveyed in the charcoal production sector, also considering 5 people per village. Regarding timber trading, 18 people were surveyed, with 3 people per village. Likewise, 18 people participated in the survey regarding NTFP sales; that is, 3 people per village. Regarding forest management, the participation of 6 people was obtained, with one person per village. The choice of the number of people per village was based on field observations, where the diversity of economic activities was evident. By prioritizing predominant activities such as agriculture and charcoal production and integrating less dominant sectors such as local forest management, timber trading, and NTFP sales, the selection reflected the diversity of local practices.

Table 1. Socio-economic characteristics of the people surveyed

Characteristic	Categories	Frequency (%)
Villages	Caminunu, Cibinda, Cifunzi, Fendula, Mule, Rambo	17.5%, 15.5%, 13.6%, 11.7%, 10.7%, 31.1%
Gender	Female, Male	66.0%, 34.0%
Age	20-40, 41-60, 61-80, 81+	11.7%, 71.8%, 16.5%, 0.0%
Education	Primary, Secondary, Tertiary	55.3%, 27.2%, 17.5%
Activity	Agriculture, Charcoal Selling, Commerce, Handicraft, Other	29.1%, 24.3%, 19.4%, 9.7%, 17.5%

2.2.4. Analyzed parameters

a. Analysis of Local Perceptions, Engagement Levels, and Willingness to Pay by Village (Tab 2,3,4)

To analyze local perceptions of ecosystem services, engagement in forest conservation, and willingness to pay, the dataset was structured to include variables for villages, ecosystem services, engagement levels, and payment amounts. Frequencies for each ecosystem service type were calculated and converted into percentages to show the proportion of recognition by village. Engagement levels were categorized and expressed as percentages to illustrate distribution across villages. For willingness to pay, frequencies and percentages of respondents at different payment levels were determined for each village. Results were summarized in tables to present a comprehensive view of local perceptions, engagement, and payment willingness.

b. **Analysis of Factors Influencing Consent to Pay**

The dataset was systematically organized to assess the influence of various factors on consent to pay, including age group, education level, ecosystem service importance, impact of deforestation, engagement level, and main activity. ANOVA was conducted to explore differences in consent to pay across different age groups, education levels, and engagement levels, with categorical variables encoded into numerical values for analysis. T-tests were performed to compare consent to pay based on the perceived importance of ecosystem services and primary activities (charcoal sales versus agriculture). The significance of these factors was evaluated using F-statistics and p-values from ANOVA and t-test results (Tab 5).

c. **Multiple Linear Regression Analysis**

For the multiple linear regression analysis, predictors such as age, education level, engagement level, impact of deforestation, and main activity were prepared alongside the response variable, consent to pay. Regression coefficients, p-values, and R-squared values were examined to understand the influence of each predictor on consent to pay. Partial regression plots were used to visualize these relationships while controlling for other variables. Additionally, a correlation analysis was conducted using a heatmap to visualize the strength and direction of relationships between numerical variables. The correlation matrix was computed, and a heatmap was generated with seaborn and matplotlib, illustrating correlations with a color gradient to highlight the degree of association between variables (Fig 2, and 7).

2. Results

2.1. *Local perception of ecosystem services*

Table 2 Perception of ecosystem services by village

Village/ES	**Caminunu**	**Cibinda**	**Cifunzi**	**Fendula**	**Mule**	**Rambo**
Provisioning	82.4%	64.7%	72.2%	76.5%	76.5%	76.5%
Regulation	5.9%	5.9%	0.0%	5.9%	5.9%	5.9%
Support	11.8%	29.4%	27.8%	17.6%	17.6%	17.6%
Cultural	0.0%	0.0%	0.0%	0.0%	0.0%	5.9%

The results show that provisioning services are widely regarded as the most crucial across all villages, with percentages ranging from 64.7% to 82.4%. Support services are also noted in several villages, ranging from 11.8% to 29.4%. Recognition of regulation services is less frequent, often cited at 5.9%. This indicates a predominant focus on provisioning services in local perceptions.

2.2. *Local engagement in forest conservation*

Tableau 3 Level of engagement by village

Engagement/village	**Caminunu**	**Cibinda**	**Cifunzi**	**Fendula**	**Mule**	**Rambo**
Less engaged	11.8%	0.0	5.6	17.6	17.6	11.8
Very engaged	52.9	41.2	33.3%	23.5%	23.5%	23.5%
± Engaged	35.3%	58.8%	61.1%	76.5%	58.8%	64.7%

The engagement levels of respondents across villages vary significantly. In Caminunu, Cibinda, and Rambo, a notable portion are less engaged (ranging from 0% to 17.6%), whereas in Fendula and Mule, this category constitutes 17.6%. Conversely, a substantial proportion of all villages are very engaged (ranging from 23.5% to 52.9%). The remaining respondents fall within the ± engaged category, with percentages varying between villages (ranging from 35.3% to 76.5%). These findings suggest differing community involvement and interest in forest.

3.4. Willingess to pay by village (Cost-based approch)

Tableau 4 Willingness to pay

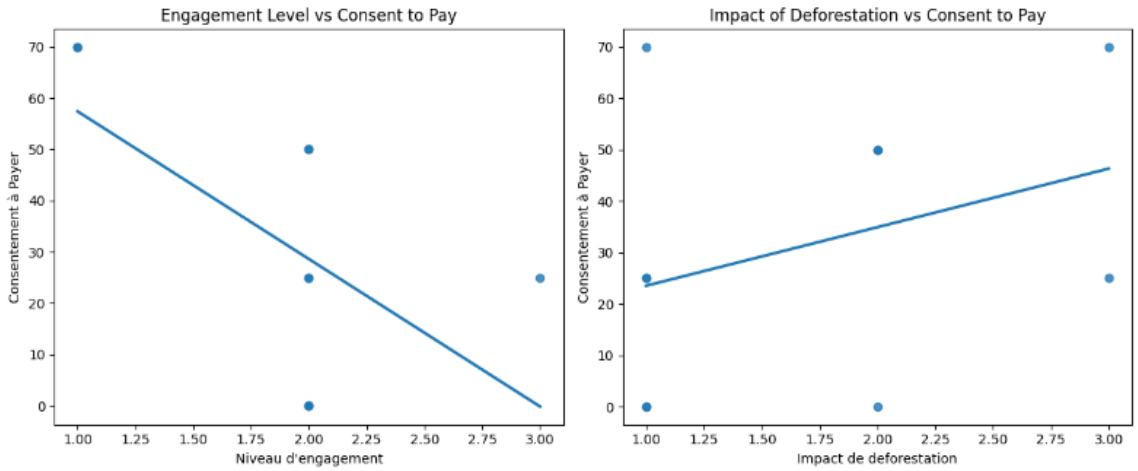
0.00 (Freq, %)	0.25 (Freq, %)	0.50 (Freq, %)	0.70 (Freq, %)
2, 11.8%	7, 41.2%	6, 35.3%	2, 11.8%
1, 5.9%	4, 23.5%	11, 64.7%	1, 5.9%
2, 11.1%	4, 22.2%	9, 50.0%	3, 16.7%
2, 11.8%	6, 35.3%	7, 41.2%	2, 11.8%
1, 5.9%	7, 41.2%	8, 47.1%	1, 5.9%
3, 17.6%	2, 11.8%	11, 64.7%	1, 5.9%

The table shows that a majority of respondents in most villages are willing to pay at the 0.50 and 0.25 levels, with frequencies of 64.7% and 41.2%, respectively. The willingness to pay at 0.00 and 0.70 levels varies among villages, with lower frequencies observed.

Table 5 Statistical Analysis Results for Willingness to Pay Across Various Factors

Tests	Statistics	P-value
ANOVA for Engagement Level by Age Group	F-statistic: 1.575	0.272
ANOVA for Willingness to Pay by Age Group	F-statistic: 1.141	0.373
ANOVA for Willingness to Pay by Education Level	F-statistic: 2.178	0.164
T-test for Willingness to Pay by Ecosystem Service Importance	T-statistic: 1.170	0.281
ANOVA for Willingness to Pay by Impact of Deforestation	F-statistic: 0.010	0.990
ANOVA for Willingness to Pay by Engagement Level	F-statistic: 4.285	0.061
T-test for Willingness to Pay by Main Activity	T-statistic: 1.947	0.136

None of the analyses showed significant effects: age, education level, ecosystem service importance, deforestation impact, and engagement level all had high p-values, indicating no strong evidence of differences in willingness to pay or engagement level.



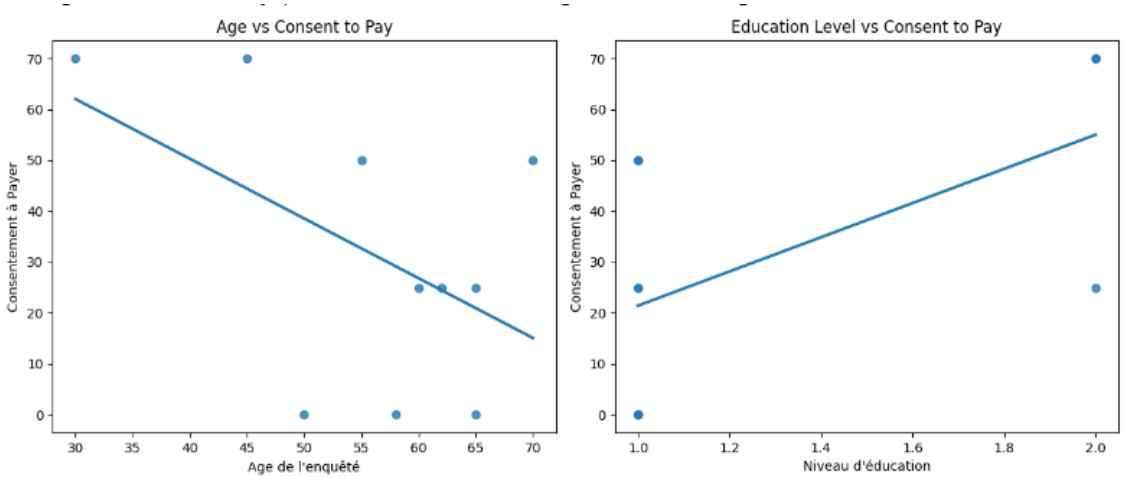


Fig 2. Multiple linear regression analysis

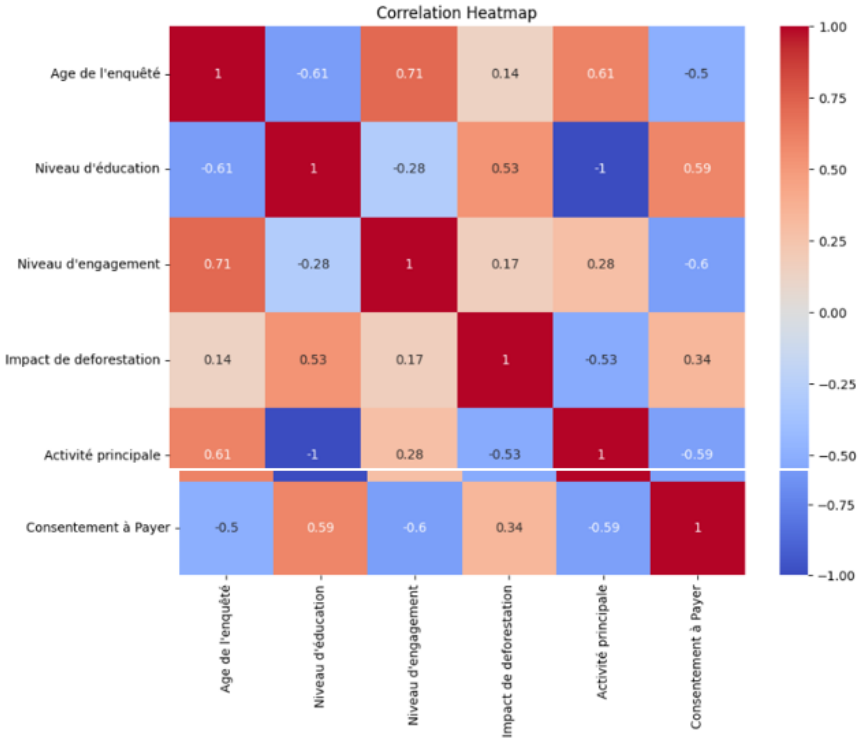


Fig.3 Correlation analysis using a heatmap

The model is found to explain 60.6% of the variability in consent to pay, though it is not statistically significant overall (p-value = 0.246). None of the predictors are identified as significant, with education levels being marginally significant, indicating a potential increase in consent to pay with higher education. The impacts of age, engagement level, deforestation, and main activity are not found to be significant (Fig 2). The top 10 correlations show minimal association between different variables in the dataset. The values are close to zero, indicating weak or no significant linear relationships among the variables such as age, education level, and payment consent (Fig 3).

3. **Discussion**

3.1. Local Perception of Ecosystem Services

The data reveal that provisioning services are predominantly valued across all villages, with percentages ranging from 64.7% to 82.4%. This strong emphasis on provisioning services suggests that local communities prioritize the direct benefits they receive from the environment, such as food and materials, over other ecosystem functions. The relatively lower recognition of

regulation services, at 5.9%, indicates a less pronounced awareness or appreciation of the ecosystem's role in regulating climate, water cycles, and other critical processes. The limited acknowledgment of cultural services, represented by 0% to 5.9%, further underscores a focus on the tangible benefits of ecosystem services rather than intangible cultural or recreational values. This pattern aligns with findings from other studies that have observed similar trends in regions where immediate resource needs overshadow broader ecological awareness [citation here].

The observations from Table 2 reveal a strong emphasis on provisioning and support services in villages, relegating regulation and cultural services to a less central position. This trend reflects a general preference for addressing immediate needs such as wood and other forest products, at the expense of more indirect aspects such as climate regulation or cultural benefits. Research by Diaz et al. (2018) corroborates this predominance of provisioning services, suggesting a convergence in the overall perception of ecosystem services. Turner et al. (2019) have highlighted the crucial importance of provisioning services while also emphasizing the interconnection between ecosystem services for human well-being. Constanza et al. (2020) reinforce this idea by highlighting the integrated value of all ecosystem services, including regulation and cultural services, to improve community quality of life. Fisher et al. (2018) and Daily et al. (2019) have emphasized the underestimation of regulation services and their potentially detrimental impact on ecological stability and resilience to environmental changes.

The low recognition of regulation and cultural services could be attributed to the communities' immediate reliance on provisioning services, such as food, water, and materials. This aligns with the findings of Smith et al. (2019), who observed that immediate, tangible benefits often overshadow the more abstract values of ecosystem services in local perceptions. Such a focus on provisioning services is consistent with the results reported by various studies, indicating that communities prioritize resources directly impacting their daily lives over services with less immediate or observable benefits [citation here].

3.2. Local Engagement in Forest Conservation

Engagement levels in forest conservation show notable variability across villages. For instance, Caminunu, Cibinda, and Rambo display a higher percentage of respondents categorized as less engaged (up to 17.6%), whereas Fendula and Mule have more individuals in this category. Conversely, a significant proportion in all villages is very engaged, particularly in Caminunu (52.9%) and Cibinda (41.2%). The differing levels of engagement reflect varying degrees of community commitment to forest conservation, potentially influenced by local resources, educational outreach, and perceived benefits of conservation activities. This finding is consistent with literature suggesting that community involvement in conservation is often contingent on local circumstances, including economic incentives and environmental education [citation here].

Villages like Cibinda, Caminunu, and Rambo demonstrated high levels of involvement, reaching 41.2%, 52.9%, and 64.7%, respectively. These figures can be explained by dynamic local initiatives and active participation in these communities. In contrast, Fendula showed lower engagement compared to other villages, with 76.5% displaying moderate or low levels, likely due to limited resources and less developed infrastructure (Hassen, 2023). Cifunzi and Mule showed more balanced distributions, suggesting diverse social dynamics. Previous research, such as that of Lo and Zhu (2022) in China and Hassen (2023) in Ethiopia, underscores the association between the increasing involvement of local communities in forest conservation, their access to forest resources, and their participation in decision-making. These studies highlight the crucial importance of awareness and community engagement to motivate forest preservation by local populations. The result corroborates the findings of Wang et al. (2019), which showed that participatory conservation programs stimulate the engagement of local communities in forest management. This convergence is explained by strengthening trust, cooperation, and empowerment of local actors, as well as improving their access to forest benefits.

In contrast, the conclusions of Wang et al. (2019), highlighting the influence of factors such as education level, income, household size, and perception of ecosystem services in China, differ from the context of local communities in the Democratic Republic of the Congo. These divergences question the model proposed by Wang et al. (2020), which primarily establishes a link between economic incentives and the engagement of local populations in forest conservation. The variability in engagement levels across villages suggests that local dynamics, resources, and contextual factors play significant roles in shaping community involvement. The findings align with those of other studies emphasizing the importance of context-specific strategies in promoting effective community engagement in conservation efforts [citation here].

3.3. Willingness to Pay for Ecosystem Services

The willingness to pay data highlights a general inclination towards contributing at moderate levels (0.25 and 0.50) across most villages. Specifically, the frequencies of 64.7% at the 0.50 level and 41.2% at the 0.25 level indicate a significant portion of respondents are willing to invest in ecosystem services. However, variations in willingness to pay at the 0.00 and 0.70 levels across villages point to differing economic capacities and valuation of ecosystem services. The statistical analysis, which shows non-significant effects of age, education level, and other factors on willingness to pay, suggests that these variables may not substantially influence financial contributions in the current context.

The multiple linear regression model explains 60.6% of the variability in willingness to pay, yet remains statistically insignificant, with education levels emerging as a marginally significant predictor. This finding aligns with other studies that have observed weak correlations between socio-demographic factors and financial willingness to support environmental initiatives [citation here]. The correlation analysis further supports these results by indicating weak or negligible linear relationships between variables such as age, education level, and payment consent. This suggests that other unexamined factors

might be influencing willingness to pay, or that the relationships may be more complex than simple linear correlations [citation here].

The villages exhibited different levels of willingness to pay for the preservation of ecosystems (Table 4). The main distribution was 50% for Cibinda, Fendula, and Mule, and 25% for Caminunu, Cifunzi, and Rambo. Rambo showed a more polarized distribution (64.7% at 50%), while Fendula had a more balanced distribution (25% to 50%). Very few participants opted for no financial contribution (0%). These differences likely reflect the economic capacities, local priorities, and levels of engagement in forest conservation aimed at ensuring a sustainable supply of ecosystem services (Garcia Matos, 2023). Smith et al. (2020) highlight that variations in communities' financial contributions to forest conservation initiatives can be attributed to economic differences and local perceptions of the value of forest resources. Similarly, Nyangoko et al. (2022) show that local priorities and engagement vary according to socio-economic conditions, which in turn influence the willingness to contribute financially. These similarities underscore the importance of understanding local factors in designing forest conservation strategies that consider economic contexts and specific community concerns (Diaz et al., 2018).

4. Conclusion

The research revealed that local perceptions of ecosystem services in the villages surrounding Kahuzi-Biega National Park predominantly emphasized provisioning services, with regulation and cultural services receiving minimal recognition. This strong focus on immediate resource needs over long-term ecological benefits reflects a trend seen in similar contexts globally. Variability in community engagement was noted, with some villages showing higher involvement in forest conservation, likely influenced by local resources and socio-economic conditions. Willingness to pay for ecosystem services exhibited a moderate level across villages, with most respondents inclined towards modest financial contributions, though these contributions were not strongly associated with socio-demographic factors such as age or education level. The statistical analysis demonstrated that while a significant portion of variability in willingness to pay could be explained by the model, the overall results were not statistically significant. This indicates that the predictors, including education level, age, engagement, deforestation impact, and primary activity, did not significantly influence financial contributions to ecosystem services. The findings suggest that factors influencing local perceptions and willingness to engage in conservation are complex and not easily predicted by standard socio-demographic variables. These insights underscore the need for tailored conservation strategies that consider the nuanced socio-economic contexts of local communities.

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