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Perception, Threats, and Management Approaches of Ecosystem Services in the Peri-urban Area of Kinshasa, Democratic Republic of the Congo

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ABSTRACT: Ecosystem Services (ES) are nature's essential benefits to humans, crucial for livelihoods, especially in developing areas such as the Monastery of Our Lady of Assumption (MLA) in the Kinshasa peri-urban zone, DR Congo, which faces significant urban threats. Consequently, the objective of this paper was to assess the Perception, Threats, and Management Approaches of Ecosystem Services (ES) in the Peri-urban Area of Kinshasa, Democratic Republic of the Congo using appropriate standard procedures. Results show that out of the 31 Ecosystem Services (ES) identified, nearly half belong to the regulating category. These regulating services account for over half of all population citations, creating a significant gap compared to provisioning and cultural services. Over 70% of the population considers human pressure and land conflicts to be major threats to ES, while 30% perceive them as minor. Additionally, 60% of respondents identify drought as a major threat, compared to 40% who consider it less significant. Human pressure constitutes the primary threat, followed by drought. Among the cited management methods, boundary setting for agricultural fields is the most utilized, followed by limited, controlled access for specific activities. This analysis highlights the monastery forest's ecological and socio-economic benefits, refines the risk assessment, and proposes appropriate management strategies for its sustainability and development.

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Ecosystem services (ES) are the vital benefits human societies derive from nature, ranging from the provision of resources (e.g., water, food) to the regulation of ecological processes (e.g., climate, soil

fertility) (Wangchuk *et al.*, 2021; Djomo *et al.*, 2023; Tasi *et al.*, 2026a). Over 62% of rural and peri-urban populations depend directly on ES for their livelihoods (Intergovernmental Science-Policy Platform on

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Biodiversity and Ecosystem Services (IPBES), 2018; Sankaran, 2019; Habonayo *et al.*, 2023). These benefits are classified into provisioning services (wood, food), regulating services (pollination, water purification), cultural services (recreation), and supporting services (nutrient cycling) (Millennium Ecosystem Assessment (MEA), 2005; IPBES, 2019). The degradation of ES, often driven by insufficient economic valuation, poses a direct threat to human well-being (Tchatchou *et al.*, 2015; Bogaert *et al.*, 2018; Aberaa *et al.*, 2021). In the Democratic Republic of the Congo (DRC), a country of immense biodiversity facing rapid, urban expansion integrating ecosystem services into development planning is essential for resilience (Chalot, 2015; Koubouana *et al.*, 2016). Addressing the loss of green spaces, increasing climate hazards like flooding, and enhancing urban sustainability requires leveraging nature-based solutions (Sambieni *et al.*, 2018). With a rapidly growing population exceeding 15 million, Kinshasa, one of Africa's largest cities, is expanding into its peri-urban areas, where ecosystems, particularly remnants of the Congo Basin Forest, provide essential ES for the well-being of the local population (Assani *et al.*, 2024). However, these vital ecosystems are under severe, intensifying threat from rampant unplanned urbanization, relentless deforestation, and pervasive pollution, which directly jeopardize their delicate ecological balance, destroy biodiversity, and threaten the long-term food security of local inhabitants (Misilu Mia *et al.*, 2010). These human-driven, destructive forces are shrinking habitats, releasing stored carbon, and creating unsustainable conditions for both wildlife and humans (Kaki *et al.*, 2024). The literature shows that several studies conducted in Africa have highlighted the vulnerability of peri-urban forests and the degradation of their ecosystem services following population growth. For example, Bogaert *et al.* (2018) and Kabanyegeye (2020) demonstrated, respectively in the Katanga region of the Democratic Republic of Congo and Burundi, that urbanization contributes significantly to the degradation of ecosystem services. Kimpouni *et al.* (2021) confirmed the anthropogenic degradation of ecosystem services provided to communities on the outskirts of Brazzaville, Republic of Congo. In the same context, Atchadé *et al.* (2023), in Benin, showed that uncontrolled urbanization and soil sealing expose urban ecosystems and ecosystem services (ES) to a threat in Cotonou. Ndiaye *et al.* (2024), in Senegal, also showed that the ecosystem services of green spaces in Dakar were threatened by urbanization. Similarly, Inogwabini *et al.* (2026) demonstrated that rapid urbanization and the continuous flow of rural-urban migration have an impact on biodiversity, the environment, and social

conditions in the Congo Basin in general. The gallery forest of the Monastery of Our Lady of Assumption (MLA), located in the peri-urban neighborhood of Kindele, serves as a vital model of a biodiversity sanctuary for local ecological balance and resident well-being (Lukoki *et al.*, 2022). In the face of rapid urban sprawl, the sustainable management of the MLA forest, and similar peri-urban forests in Kinshasa, requires integrated strategies to safeguard its ecological, social, cultural, and economic functions, ensuring its resilience and future viability (Ebengo *et al.*, 2025). Given the critical role of humans as key stakeholders in ES (Lhoest *et al.*, 2019), it is essential to analyze local perceptions of the benefits, risks, and management strategies related to this forest. Despite previous studies on natural resources in the vicinity of the MLA's gallery forest (Mukendi, 2009; Kaleka, 2021), there remains a significant research gap regarding local perceptions of the ES provided by this forest, the associated benefits and threats, and the role of local populations in its conservation. Due to a lack of empirical data, this study utilizes local knowledge regarding the ES provided by the MLA to support sustainable management and poverty reduction, aligning with several Sustainable Development Goals (SDGs). Consequently, the objective of this paper is to assess the perceptions, threats, and management approaches of ES in the peri-urban area of Kinshasa, Democratic Republic of the Congo. This strategy balances urgent conservation needs with economic realities, fostering community engagement in land stewardship. Ultimately, this framework ensures the forest remains a robust, productive resource for future generations.

MATERIALS AND METHODS

Study site: The study was conducted in the gallery forest of the MLA (Fig. 1). The site is located at 4°42' S, 15°30' E in the Funa Valley, within the peri-urban district of Kindele, in the municipality of Mont-Ngafula, southwest of Kinshasa (Kisasa, 2013). According to the Köppen-Geiger classification, the region has a tropical savanna climate with a dry winter (A-contre-sens, 2024). The area experiences an average annual temperature of 25.6°C and an average annual rainfall of 799.8 mm (A-contre-sens, 2024). Steep hills and deep, river-carved valleys dominate the landscape. Due to erosion, this landscape is poorly suited for infrastructure (Kaleka, 2018). According to 2023 demographic data from Kindele, the population is 23,770 inhabitants, consisting of 3,930 men, 6,036 women, 11,905 boys, and 1,899 girls (Services of the municipality of Mont-Ngafula, 2023). These statistics reflect the current demographic composition of this locality, which is facing problems of poverty (Services of the municipality of Mont-Ngafula, 2023).

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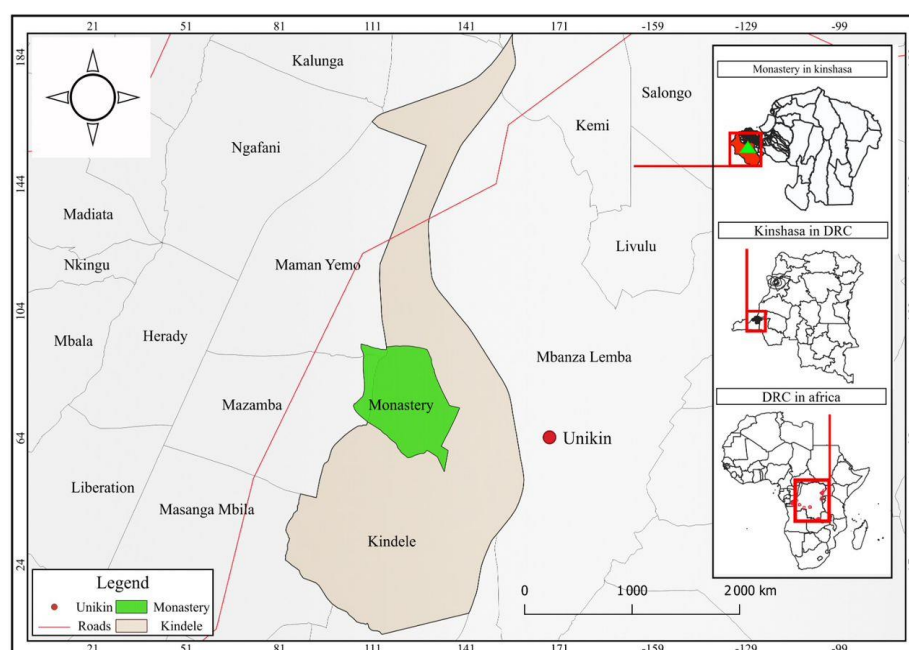


Fig. 1: location of the gallery forest at the Monastery of Our Lady of the Assumption in Kindele, Kinshasa (near the University of Kinshasa - UNIKIN).

The choice of this site is justified by the fact that it not only boasts a forest gallery of approximately 460 hectares but also experiences alarming degradation of its natural environment through fragmentation resulting from population explosion and increasing human activities (Lukoki *et al.*, 2022).

Sampling and data collection in the field: Before deploying the mixed-methods research, the project received approval from the supervisory committee of the Department of Natural Resource Management at the University of Kinshasa, acknowledging the involvement of human subjects. A preliminary survey was conducted on 16–17 March 2024 to establish field contact, define the study scope, and refine the objectives and questionnaire. This pilot phase targeted managers of the MLA forest and households in Kindele. After an initial exploratory phase (pre-survey), a mixed-methods approach was adopted to ensure a comprehensive analysis of the MLA forest's ES. This approach integrates quantitative data (measurable trends) with qualitative data (perceptions/motivations), offering a deeper understanding of the 'why' behind the 'how much'. From 7th to 23rd April 2024, quantitative data were collected from households living near the MLA forest using the Kobo Collect application on a Samsung Galaxy A07 Android phone. The information collected concerned residents' perceptions of provisioning, regulating, and cultural ecosystem services, as well as the management of these services in the MLA and their associated threats

(<https://ee.kobotoolbox.org/x/V0UIuEFJ>). For this quantitative part, we used a probabilistic sampling approach, specifically stratified random sampling, where length of residence in the study area was used as the stratification criterion. Thus, the survey targeted residents living on the outskirts of MLA's Forest who had resided in the area for at least one year. A non-probabilistic snowball sampling method was used until data saturation was reached (Cochran, 1977). This method was selected because the study focused specifically on long-term residents and local economic actors operating around the forest, ensuring the relevance of the sample. Consequently, the final sample consisted of 128 respondents (57 men and 71 women). Between 31st May and 7th June 2024, three focus groups were organized to collect qualitative data. The groups consisted of five MLA managers, 20 users of the MLA's ES, and five non-users. These discussions provided a deeper understanding of perceptions, management, and threats related to ES, tailored to participants' socio-professional backgrounds. Each group met the minimum requirement of four participants, in accordance with Kitzinger *et al.* (2004). Discussions were facilitated using an interview guide via the KoboCollect application (<https://ee.kobotoolbox.org/x/V0UIuEFJ>).

Data Analysis: Following data collection, individual quantitative survey results downloaded via the KoboCollect platform were processed for statistical analyses and ethnobotanical index calculations. The following indices were calculated: The Use value

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(UV) was calculated for three categories of ES: provisioning ES, regulating ES and cultural ES. Based on Dossou *et al.* (2012) and Albuquerque *et al.* (2006), the Total Use Value (TUV) was determined to assess the importance of these services to the community. The formulas used are $UV = \frac{\sum U_i}{n}$ and $(TUV) = \sum UV$, where U_i is the number of citations for each ES and n is the total number of informants.

The Cultural Importance Index (CI), defined by Tardio and Pardo-de-Santayana (2008), addresses the limitations of the Use Value (UV) index by better accounting for inter- and intra- cultural variations in knowledge. The CI evaluates the relative significance of ES use-categories, weighting each by informant consensus rather than just diversity of use. It is calculated as:

$$CI = \sum_{u=1}^{u=NC} \sum_{i=1}^{i=N} \frac{UR_{ui}}{N} \quad (1)$$

Where NC is the total number of usage categories, N is the total number of informants, and UR_{ui} is the number of informants who mentioned a specific usage (use report).

The Level of Fidelity (LF) or frequency of citation (expressed as a percentage) was used to analyze the sub-categories of ES within usage categories (Friedman, 1986). The level of fidelity was calculated using the following formula: $LF = \frac{N_p}{N} \times 100$, where N_p is the number of informants who mention a type of ES or use, and N is the total number of informants who cited any kind of ES. Ethnobotanical indices were calculated and summarized using Microsoft. Bivariate analysis, employing the Chi-square (χ^2) test of independence ($\alpha=0.05$), was performed to compare the relative importance assigned to ES both within and between categories.

To identify the determining factors (major threats or common management practices), binary logistic regression was performed using the 'glm()' function in R software (Generalised Linear Models - GLM). The resulting odds ratios (OR) and their 95% confidence intervals were visualized via forest plots to illustrate the contribution of each factor to its respective classification (e.g., "major threat" or "common method"). The OR represents the ratio of the odds of an event occurring to the odds of it not occurring; an $OR > 1$ indicates an increased likelihood of the classification, while an $OR < 1$ indicates a decreased likelihood. Moreover, focus groups served as an essential source of qualitative data, providing an in-depth

understanding of trends observed in the quantitative survey. Through thematic analysis, we identified the underlying reasons (the 'why') behind the importance of ES, the severity of threats, and the relevance of management approaches. Direct quotes were extracted to contextualize these themes. Finally, these insights were used to validate the interpretation of the survey results, providing evidence for the differences observed (e.g., why one service was considered more important than another).

RESULTS AND DISCUSSION

Perception of ecosystem services provided by the MLA's peri-urban forest: Table 1 shows that 31 ES were identified, nearly half of which belong to the regulating ES category. Overall, the population's dependency on these services varies significantly based on the importance attached to each category ($p < 2.2e-16^{***}$ for provisioning and cultural services; $p=5.793e-05^{***}$ for regulating services). Regarding provisioning services, over half of the population cited NTFPs, food crops, fuelwood, and drinking water, with over 90% showing high loyalty to food crops and drinking water.

Both men and women report that the MLA's Forest manager is actively promoting food crops and developing water sources as alternative forest management solutions. Some residents also enter the forest to hunt, gather NTFPs (caterpillars, medicine), and collect firewood. Regarding regulating services, a majority recognize their benefits, with over 90% highlighting disease control, shade, water availability, erosion control, and soil fertility, citing their necessity in the dense urban environment of Kinshasa. Concerning cultural services, half of the population uses the forest for religious practices and considers it a natural heritage site. Furthermore, over 70% are loyal to leisure activities, ecotourism, and using the forest for physical and mental health. Beyond its economic and ecological importance, the MLA heritage forest serves a spiritual and recreational function, attracting visitors for worship, ceremonies, and urban tourism, supported by local sports facilities. Table 2 shows that regulating services account for over half of the population's citations, creating a significant gap compared to provisioning and cultural services ($p<2.2e-16$).

Consequently, the population attaches greater importance to regulating services, whose cultural importance index (11.6) is significantly higher than that of provisioning and cultural services. The usefulness of regulating services (1.22) also exceeds that of provisioning (1.21) and cultural services (1.12), reflecting the high value the population derives from this forest.

Table 1: ecosystem services (ES) provided by the MLA's Forest.

Category	ES	UR	LF (%)	p-value
Provisioning	NTFP	96	75.0	< 2.2e-16***
	Crop-based food products	126	98.4	
	Bush meat	28	21.9	
	Livestock products	31	24.2	
	Firewood	67	52.3	
	Charcoal	11	8.6	
	Aromatic plants	52	40.6	
	Domestic water usage	56	43.8	
	Fresh water	120	93.8	
	Impact on precipitation	112	87.5	
Regulating	Provision of shade	126	98.4	5.793e-05***
	Availability of water	125	97.6	
	Removal of air pollutants	89	69.5	
	Carbon capture and storage	106	82.8	
	Flood protection	125	97.6	
	Mitigating the effects of drought	114	89.0	
	Landslide mitigation	112	87.5	
	Erosion control	125	97.6	
	Maintaining soil fertility	120	93.8	
	Pollination	100	78.1	
Cultural	Combating harmful insects	106	82.8	< 2.2e-16***
	Combating disease	127	99.2	
	Leisure activities	94	73.4	
	Physical and mental health	93	72.6	
	Ecotourism	101	78.9	
	Aesthetic inspiration, culture and art	52	40.6	
	Natural heritage	70	54.7	
	Spiritual lineage	17	13.3	
	Custom and practice	5	3.9	
	Traditional knowledge	12	9.4	
	Religion	67	52.3	

Key: NTFP: Non-Timber Forest Products; N (Number of informants or respondents): 128. LF: Level of fidelity. UR: Number of informants who mentioned a given usage; p-value: probability at the 5% threshold (Pearson's chi-square test)

Table 2: cultural indices of importance and usage values for different categories of ecosystem services (ES).

ES	NES	AF	RF	CI	UV
Provisioning	9	587	22.7	4.59	1.21
Regulating	13	1487	57.5	11.6	1.22
Cultural	9	511	19.8	3.99	1.12
Total	31	2585	100	-	3.55
P-value	-	-	< 2.2e-16***	-	-

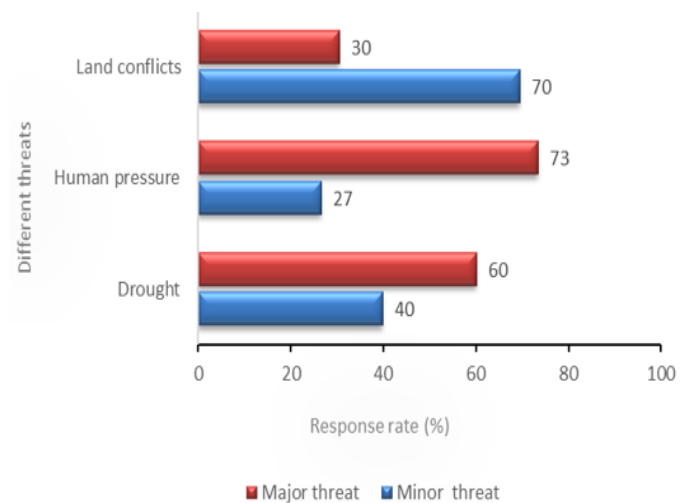
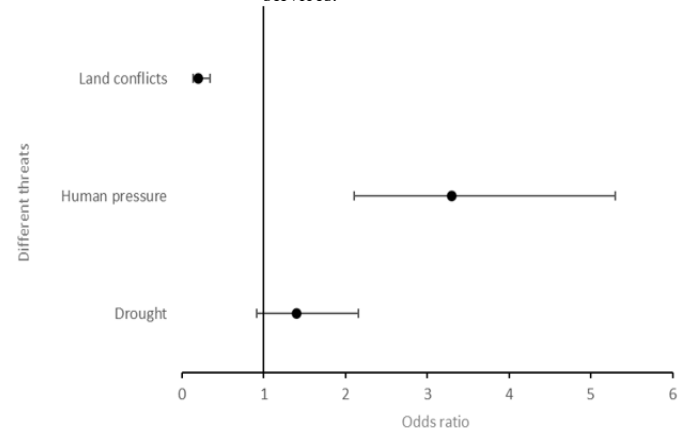
Key: P-value: Probability at 5% threshold with Pearson's chi-square test. NES: Number of citations of ES; AF: Absolute frequency of citations; RF: Relative frequency; CI: Cultural importance index; UV: Use value.

Respondents note that, as most of the population practices subsistence agriculture, the forest's regulating services are crucial for protecting resources like drinking water, soil, and climate, ensuring long-term sustainability.

Without this stable regulation, other services, including provisioning and cultural activities, would be compromised, leading to a decline in forest productivity and security.

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Threats to the ecosystem services of the peri-urban forest of MLA: Figure 2a reveals that over 70% of the population considers human pressure and land conflicts to be significant threats to the degradation of ES, while 30% perceive them as minor threats. In addition, 60% of respondents consider drought to be a major threat, while 40% consider it to be less significant. Analysis of the odds ratios (OR) in Figure 2b indicates that human pressure is the most significant threat (OR of 3.3), followed by drought (OR of 1.4). According to the population, human pressure is mainly linked to urbanisation, while drought results in recurrent bush fires. However, with an OR of less than 1 (OR of 0.2), land conflicts are considered a less significant threat.

**Fig. 2a:** response rate for citations of different threats to ecosystem services.**Fig. 2b:** odds ratio (OR) for citations of different threats to ecosystem services. OR presented as black dots in the figure is calculated at a 95% confidence interval (CI) presented as an error bar. OR is greater than 1 if the threat is major, and less than 1 if it is not. OR = 0.2 (95% CI: 0.1–0.3) for land conflict; 3.3 (95% CI: 2.1–5.3) for anthropogenic pressure; and 1.4 (95% CI: 0.9–2.2) for drought.

Management approach for ecosystem services in the peri-urban forest of PMLA: Figure 3a shows that

respondents identified boundary setting for agricultural fields, official bans on cutting trees, security patrols, and limited and controlled access as methods for managing the MLA's forest to sustain ES. The OR in Figure 3b indicates that while all methods are utilized, boundary setting is the most prevalent (OR of 3.5), followed by limited and controlled access (OR of 1.5). Conversely, official bans on cutting trees and the presence of security guards are less common management methods, with odds ratios of one or less. Finally, the population reports practicing subsistence agriculture with authorization of the MLA forest managers, which helps regulate activities within this protected area.

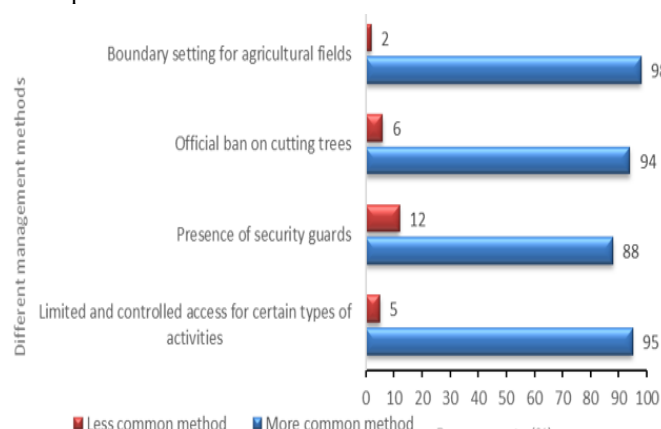


Fig. 3a: response rate for citations of different forest management methods supporting ecosystem service sustainability

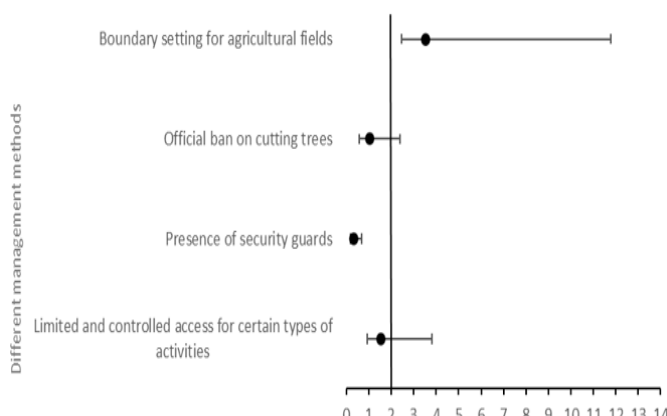


Fig. 3b: odds ratio (OR) for citations of different forest management methods supporting ecosystem services sustainability. OR presented as black dots in the figure is calculated at a 95% confidence interval (CI) presented as an error bar. OR is greater than 1 if the method is very common, and less than 1 if it is not. OR = 3.5 (95% CI: 1.1–11.8) for boundary setting for agricultural fields; 1.0 (95% CI: 0.5–1.3) for official ban on cutting trees; 0.3 (95% CI: 0.2–0.7) for the presence of security guards; and 1.5 (95% CI: 0.6–3.8) for limited and controlled access for certain types of activities.

Perception of ecosystem services: Overall, the study highlights the strong dependence of the Kindele population on the ecosystem services (ES) provided by the MLA forest, revealing substantial impacts on the socio-economic and environmental spheres of the territory. Contradictory opinions were noted on certain types of ES, which can be explained by the fact that each household is free to express its own opinion on its knowledge of these ES. Indeed, the functions and benefits of green spaces differ according to their use and the position of the observer (user or ecologist), as indicated by Choumert (2010); Lucas (2017); Mehdi *et al.* (2017); Kabanyegye (2020). Although provisioning and regulating services are often cited as priorities, ahead of cultural services (Cissé *et al.*, 2018), our study reveals a different hierarchy. In fact, the population values regulating services (disease control, shade provision, water availability, erosion/flood protection, soil fertility) more highly than provisioning services (NTFPs, wood) or cultural services (ecotourism, recreation). This perception contrasts with the practices of the population, as the time that should be devoted to collecting wood and NTFPs for daily needs in peri-urban areas, as mentioned by Loubelo (2012), is mainly invested in subsistence agriculture. Moreover, these agricultural practices provide basic products that are essential to supply services, alongside drinking water. This contradicts the findings of Dieng *et al.* (2016) in Senegal, which highlighted a marked preference for supply services. A peri-urban population that is highly dependent on regulating services rather than direct supply (extracted resources) reduces pressure on local resources, promotes biodiversity, and reduces waste and pollution (Kimpouni *et al.*, 2021). This strengthens the local circular economy and improves public health and resilience, creating ecological (ecosystem preservation) and socio-economic (green jobs, stability) benefits and a better quality of life at all levels, from local to national (Campos *et al.*, 2021). Despite initially low interest among the local population, cultural services (related to ecotourism, recreation and spirituality) nevertheless represent considerable potential (Tasi *et al.*, 2026b). Taking them into account, alongside ES, would strengthen integration and enhance their economic value in the assessment of land rights in peri-urban areas. Integrating these cultural aspects could thus increase the value of land rights, making them more attractive to lenders (Cuni-Sanchez *et al.*, 2019; Moloise *et al.*, 2024).

Threats and management of ecosystem services: Although the population mentions various threats, anthropogenic pressure is the main threat to the ecosystem services (ES) of the MLA forest gallery. The impact of this pressure is more than twice that of drought. Land conflict, on the other hand, does not pose a

significant threat due to its rarity in the territory. Anthropogenic pressure in this area is mainly due to increasing urbanization, which is driving residents to build in and around the forest. These results are consistent with the findings of Ntale (2010), who conducted similar studies on the subject. Indeed, urban sprawl and informal construction near peri-urban forest galleries generally lead to habitat fragmentation, biodiversity loss, and soil and atmospheric degradation (Museme and Mundala, 2021). These phenomena disrupt hydrological functioning, increase vulnerability to flooding and fires, create socio-spatial tensions (conflicts of use) and degrade the ecological integrity of the forest corridor, directly impacting the environmental health and quality of life of residents (Vermeulen *et al.*, 2011). Faced with increasing anthropogenic pressure, the presence of security guards and a formal ban on logging do not seem to be sufficient as a management strategy. Another land use strategy has been implemented to designate areas dedicated to sustainable and intensive subsistence agriculture. This management strategy is reinforced by the establishment of restricted access zones for certain activities in the forest. This strengthens the management strategy, thus ensuring the preservation of biodiversity on multiple scales, from local to international (Marien, 2009; Semeki *et al.*, 2021). The developed agricultural areas are located on the edges of the forests but within the monastery grounds. This approach, now commonplace on the MLA grounds, aims to prevent forest destruction caused by practices such as slash-and-burn and shifting cultivation, as highlighted by Ntale (2010) in a similar study. This offers a sustainable alternative for both local and national supply, like that proposed by Vermeulen *et al.* (2011) in a study on the establishment of agroforestry areas.

Limitations and challenges of the study: The main limitations and challenges of this research stem from its dependence on local knowledge, which can be subjective and a lack of robust quantitative data (e.g., specific forest product volumes or precise forest area conversion). These constraints make it difficult to scientifically validate perceived impacts, particularly regarding the Sustainable Development Goals (SDGs). Additionally, certain threats, such as undeclared illegal logging, may not be fully considered. Finally, translating traditional practices into standardized management strategies, while balancing community needs with conservation objectives, presents a major challenge for holistic forest enhancement.

Conclusion: This study investigated the interdependence between peri-urban riparian communities and surrounding forest ecosystems to address the gap in sustainable resource management under escalating

anthropogenic and climate-induced pressures. The analysis establishes a significant correlation, revealing that while local ecological awareness is high, expanding resource dependency directly contributes to ecosystem vulnerability. These results suggest that adopting participatory, co-management strategies could integrate native ecological knowledge with administrative conservation, offering a scalable solution for vulnerable African urban centers. Although constrained by a localized qualitative focus, this research deepens our understanding of socio-ecological resilience. Future studies should investigate the long-term effects of these interventions across larger, more diverse geographic cohorts, utilizing quantitative ecosystem mapping and predictive impact modeling to establish adaptive, resilient resource baselines for fast-growing urban peripheries.

DECLARATIONS

Ethical Approval: This study involved human participants and therefore ethical approval was obtained from the Department of Natural Resources Management, Faculty of Agronomic Sciences, University of Kinshasa. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer on Artificial Intelligence usage: The authors hereby declare that Gemini, a large language model developed by Google, was used during the editing of this manuscript to improve its grammar. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

Declaration of Conflict of Interest: The authors declare that there are no known conflicts of interest or personal relationships that could have influenced the work reported in this paper.

Declaration of Data Availability: The data generated in this study are available upon request from the corresponding author.

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