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Local knowledge and natural resources management: case study of the Kahuzi Biega National Park in Democratic Republic of Congo

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ABSTRACT

Natural resources have always been one of significant economic and cultural importance to indigenous communities as these communities always dealt with resources from human appearance till now. This study investigates the role of local knowledge in sustainable natural resource management in the Kahuzi Biega National Park in the Democratic Republic of Congo. A mixed-methods approach, involving questionnaires, semi-structured interviews, and participatory workshops, was applied to 550 respondents from 11 villages surrounding the Kahuzi Biega National Park. Data analysis using Chi-square and Fisher's exact tests revealed that 70.2% of participants do not feel involved in park management. Key barriers include lack of information and communication (46.4%), absence of legal recognition (8.9%), and conflicts of interest (21.8%). Notably, 85% reported that traditional ecological knowledge such as seasonal hunting closures, sacred forest protection, and customary sanctions, remains excluded from current management practices. Ethnic variations were observed, with the Shi demonstrating the highest engagement in biodiversity-friendly practices (hunting closures: 66.7%), while groups such as the Lega, Havu, and Tembo did not adopt these measures. The majority (86.7%) perceived the park's socio-economic and environmental impacts as negative. Respondents prioritized legal recognition of ancestral land rights (34.7%), participatory consultation mechanisms (30.5%), and capacity building (19.5%) as critical for effective involvement. Fisher's exact test confirms a statistically significant association between ethnic groups and traditional practices (p-value = 0.0004998). The findings underscore the need for inclusive governance frameworks, integrating local knowledge and fostering co-management, to reconcile biodiversity conservation goals with the cultural values and livelihoods of resource-dependent communities.

KEY WORDS Kahuzi-Biega National Park; Local Knowledge; Natural Resource Management; DRC.

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INTRODUCTION

Since long time, humans have depended on the many services provided by their natural environment through local ecosystems (fauna, flora, soil, surface water, groundwater, energy resources, and

mineral resources) and global ecosystems (atmosphere, climate) for their survival. These services are essential to human life, as well as to animal and plant life (CGDD, 2020).

People value biological resources in different ways: spiritually, economically, aesthetically, culturally, and scientifically (FAO, CIFOR & CIRAD, 2017). This biological diversity is under serious threat in developing countries due to several factors:

(i) unsustainable consumption practices;

(ii) rapid population growth, leading to increased pressure on natural resources; and

(iii) increasing impoverishment, resulting in the development of survival strategies that generally involve the reckless exploitation of available natural resources (Mukinzi, 2014).

Admittedly, in order to better preserve biodiversity and protected areas in developing countries in the Global South, it is necessary to involve traditional societies that have had a relationship with their natural environment since the dawn of humanity and have mastered traditional practices (Mangambu et al., 2021). The Rio Conference on Biological Diversity (CBD, 1992) highlighted the concept of "local knowledge" and emphasized the importance of local populations. This convention underscores the importance of this knowledge, particularly in Article 8, point j. This does not merely signify recognition, but also an obligation on behalf of states to respect and preserve this knowledge.

The conservation of ecosystems and the various resources they contain has long been an important part of traditional African culture, as evidenced by the existence of sacred forests within certain indigenous communities (IUCN, 2008). Biological resources have always been of significant economic and cultural importance to indigenous communities (Bouttoud et al., 2016). Thus, throughout Africa, rural communities have sanctified certain forest areas with various prohibitions to facilitate the organization of a variety of cultural activities (Yameogo, 2015).

However, natural resource management refers to technical and scientific knowledge, whether endogenous or local and the way in which resources are used by a community or state for forestry, agricultural, fishing, or pastoral production purposes. It is similar to the concepts of land use planning or spatial organization, but has a broader scope (Jauhiainen & Hooli, 2017). Natural resource management based on modern practices has shown its limitations, unlike traditional strategies, where communication and knowledge transfer were oral and acquired knowledge was passed down from generation to generation (Koy & Maindo, 2017).

In Democratic Republic of Congo (DRC), the network of protected areas (PAs) covers approximately 11% of the national territory. The PAs in DRC are broadly representative of the region's ecosystems (Maindo et al., 2017) and, despite the heavy pressures exerted on them, biodiversity remains rich and still includes iconic species such as the okapi, gorilla, and Congolese peacock (Somda & Awaïs, 2013).

The integration of local knowledge into natural resource management faces several challenges and obstacles (Van Vliet et al., 2023). In the specific context of Kahuzi-Biega National Park (PNKB), located in eastern DRC, these challenges are particularly pronounced. The residents of the PNKB, like other communities around protected areas, have developed a series of local knowledge systems within their customs and traditions that protect their survival activities and, in turn, contribute to forest conservation (Mubalama et al., 2018).

It should also be noted that many communities living around the PNKB, relying on forest and fishery resources for their livelihoods, often find themselves in conflict with the park management's authorities. This is due to law No. 75–002 of July 22, 1975, amended by ordinance law No. 78-190 of May 05, 1978, creating a public company to manage protected areas, giving the Congolese National Institute for Conservation (ICCN) a management monopoly that does not allow local communities to participate. Although use rights are granted to populations living in and around protected sites, they remain limited. These rights include gathering, artisanal fishing, access to healthcare, and harvesting medicinal plants, among others (ICCN, WCS & FFI, 2008).

Relief Web (2024) shows that in the 1970s, the Batwa community was violently evicted from their homes and dispossessed of their ancestral lands to make way for the creation of the PNKB. This community has been plunged into decades of extreme poverty, severe discrimination, land deprivation, and staggering mortality rates in informal settlements on the outskirts of the park. The deprivation

of access to the PNKB's natural resources by the community, including the Pygmies, has led to serious ecological and social consequences.

According to Kapupu (2001), this marginalization has led to the clandestine exploitation of the park's resources. These lands, once protected, are now used for destructive activities in search of arable land, such as poaching, tree felling, charcoal production, sawing planks, and illegal mining, etc.

These practices, motivated by the desire to survive and the lack of further alternatives, contribute to the degradation of the park's ecosystem. Traditionally, the management of natural resources in the park has been mainly entrusted to government authorities and international organizations. However, this top-down approach, based mainly on external knowledge and guidelines, has shown its limitations. Difficulties in involving and integrating local communities have led to tensions, resistance, and perpetual conflicts, compromising conservation and sustainable development efforts (Consolée et al., 2020; Vitekere et al., 2021). Therefore, it is important to analyze these practices among the communities living near the PNKB in order to guide their integration into public policies related to nature conservation. This study aims, on the one hand, to analyze the contribution of local knowledge to the sustainable management of natural resources in PNKB in eastern Democratic Republic of Congo and, on the other hand, to explore the impact of local knowledge on the management and conservation of natural resources in this park.

The results of this study will try to answer the following questions:

(1) What is the level of involvement of Indigenous Peoples and Local Communities (IPLCs) in the management of the PNKB?

(2) What is needed for the effective involvement of IPLCs in the sustainable management of the PNKB's resources?

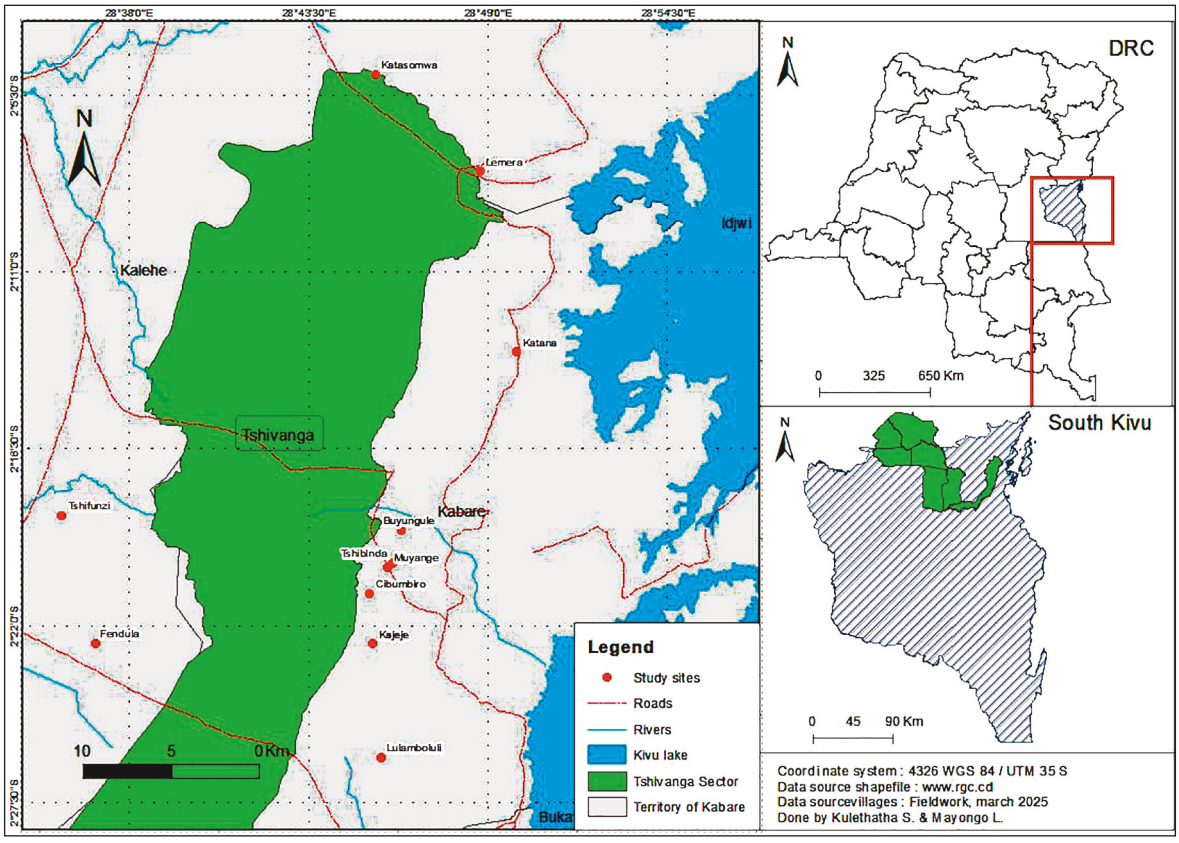

Figure 1. Study area and location of sampling sites around the Kahuzi Biega National Park.

(3) What knowledge IPLC has about the PNKB that could improve the management of the Park?

MATERIAL AND METHODS

Study area

The PNKB is located in the western part of the African Graben, east of the DRC. Its geographical coordinates are 1°36' to 2°37' south latitude and 27°33' to 28°46' east longitude (Fig. 1). It covers 6,000 km^2 and extends over two sectors of different altitudes separated by a corridor as mentioned above: (1) the low-altitude or plain sector (5,400 km^2), at altitudes of 600 to 1,200 m; (2) the high-altitude or mountain zone (600 km^2), situated between 1,800 and 3,308 m above sea level. The Park boasts 194 mammal species, the flagship species being the elephant (*Loxodonta africana cyclotis* Matschie, 1900), the eastern lowland gorilla (*Gorilla beringei graueri* Matschie, 1914) and the chimpanzee (*Pan troglodytes* Blumenbach, 1776) (Godoy et al., 2012; Masumbuko, 2013).

Among the mammals, 14 species are threatened; there are 349 bird species, 11 of which are threatened and 30 endemic to the Albertine Rift, 69 reptile species and 44 amphibian species.

The PNKB is home to 1,178 plant species listed at high altitude (145 of which are endemic to the Albertine Rift), making it the third most species-rich site after Virunga NP and Bwindi NP in Uganda (IUCN/PACO, 2012; ICCN, 2019). The main ethnic groups living in the vicinity of the PNKB include the Shi in the Kabare and Walungu territories in the southeast, the Havu and Tembo in the Kalehe territories in the northeast, and the Lega in the Shabunda and Punia territories and the Nyanga in the Walikale territory in the northwest (DFGF, 2003). It is important to add another ethnic group, such as Hutu in the territory of Kalehe at Katasomwa, a PNKB patrol post where intense pressure from illegal mining and large-scale charcoal production are located.

One of seven national parks and five World Heritage sites in the DRC, PNKB was created in 1970 to protect a species endemic to the eastern forests, the Eastern Lowland Gorilla. In 1937, it was classified as the Mount Kahuzi Zoological and Forest Reserve by the Belgian colonial administration. In 1970, ordinance no. 70/316 classified the reserve as the Kahuzi-Biega National Park, with a surface area of 60,000 ha. The area was increased to 600,000 ha by ordinance no. 75/238 of July 22, 1975 (ICCN, 2019). The park is subdivided into two zones according to altitude variation, including the low-altitude sub-montane zone belonging to the Guineo-Congolese Domain to the west and the high-altitude zone belonging to the Afro-montane domain to the east. These two zones are linked by an ecological corridor to the south of the park (IUCN/PACO, 2012).

Sampling methods

Surveys were conducted in villages located around the PNKB and in those located nearby. A complete list of villages was obtained from the PNKB administration. Eleven of them were randomly selected to conduct our surveys. After determining the number of households to be surveyed (sample) in each village or stratum with the help of local leaders, households were selected at random. Households were selected at intervals of 3 (sampling fraction), meaning that we surveyed every third household. Men, women, and different socio-professional categories had the same chance of being interviewed (equiprobability sample). Respondents were selected at random within communities. Children and adolescents under the age of 18 were not interviewed. To ensure the independence of responses, only one respondent per household was interviewed, and respondents of both sexes engaged in some forms of professional activity were interviewed.

Data collection

We used three techniques:

1) a documentary technique using a literature review to understand and define the theoretical framework of our study,

2) direct observation, and

3) a survey (focus groups and individual interviews) using a survey questionnaire.

The latter was completed during the meeting through discussions with the target population. Documentary sources (ancient) are invaluable in studies focusing on local knowledge and practices, (Bahige, 2009). The information collected in these archives, due to its historical value, was triangulated

through the collective memories of the communities studied and individual interviews. Focus groups, in the conception of Fernandez (2020) were conducted with communities to understand their perceptions of traditional nature conservation practices. Furthermore, Touré (2010) notes the contribution of this technique in qualitative studies as "*to enable researchers to answer questions about social phenomena, to understand these phenomena as they are experienced and perceived, and to act on them with a view to social change*".

Investigations were held in February, March, April, and May 2015 with local dignitaries, local leaders, local elites, and village elders. A circle format was adopted to avoid hierarchical considerations that might hinder freedom of expression between the researcher (facilitator) and participants (Fernandez, 2020). In order to foster productive group dynamics in each of these focus groups, the number of participants was averaged between six and twelve, as recommended by Touré (2010).

The questionnaire focused on the following main points:

a) the identity of the respondent (surname, first names, age, gender, ethnicity);

b) occupation;

c) involvement of PACLs in the management of the PNKB and obstacles;

d) barriers and consideration of local knowledge in the management of the PNKB;

e) reasons for the integration or non-integration of local knowledge;

f) essential requirements for the effective involvement of PACLs;

g) traditional practices of PACLs according to ethnicity and co-management programs.

Data analysis

To document the categories of people linked to the respondents' profiles, PACL involvement in PNKB management and obstacles, barriers and consideration of local knowledge in PNKB management, we calculated the frequency using the equation:

$$\% = \frac{n}{N} x100$$

Equation (1) is the frequency formula in which % represents the percentage or frequency, n represents the sample category, and N represents the total number of the entire sample collected. To highlight differences in respondents' answers, for example to test whether PACL involvement in PNKB management and obstacles differ, to test the main barriers and consideration of local knowledge by PNKB managers, and to test whether living in a specific village and belonging to a specific ethnic group can influence the involvement of traditional PACL practices, we used chi-square tests with the R software. Fisher's exact test was used because some of the respondents who acknowledged traditional practices numbered fewer than five in more than 65% of cases. This test showed that there is a statistically significant association between ethnicity and traditional practices (p value = 0.0004998). In order to understand how these traditional practices vary according to ethnicity, the extended chi-square statistics were calculated. Some of the observed numbers were significantly higher than expected, indicating a very strong link.

RESULTS

Profile of respondents

A total of 550 people were surveyed. Men (62.7%) were more represented than women (37.3%) in all villages. A significant proportion of respondents had not attended school (11.0% for women and 17.8% for men), while only 0.7% of women and 5.1% of men reported higher education. The chi-square test reveals a significant association between education level and gender (p value = 0.001842). By age group, 43% of respondents, both men and women, are in the 20–35 age range. Young people under the age of 20 are the least represented (9.2%). In addition, in terms of economic activities, agriculture dominated (47.8%), followed by trade (19.1%), livestock farming (9.3%) and crafts (3.3%). Hunting (2.4%), fishing (0.2%) and gathering (0.7%) were reported as marginal activities.

Approximately 46.7% of respondents travelled less than one kilometer to work, while 17.8% travelled more than two kilometers. The distance travelled does not depend on the activity performed (p-value = 0.3201). According to the tribe of the respondents, the Shi constitute 61.8% while the Tembo represent only 1.8%. All activities are dominated by the Shi, except fishing, which is practiced

exclusively by the Batwa. Ethnicity influences career choices (p-value = 0.0002572).

Involvement of PACLs in PNKB management and obstacles

Results showing the involvement of PACLs in PNKB management and the obstacles that PACLs recognize to their involvement in the management of natural resources are various (Table 1).

The majority of respondents (70.2%) do not recognize their involvement in the management of the PNKB, while 29.8% of respondents confirmed their involvement in the management of the PNKB. The barriers to PACL participation provide valuable insight into the challenges encountered. Lack of information or awareness is most often cited as the main obstacle, with 46.4% of respondents. It should also be noted that obstacles related to the lack of legal recognition (8.9%) and options for other means of involvement (0.7%) are revealing facts. Respondents' opinions on their involvement remain divergent (p-value = 0.02499).

Barriers and consideration of local knowledge in PNKB management

The main barriers to the involvement of local knowledge in PNKB management by the PACL signifivantly reduce the effectiveness of resources management (Fig. 3).

The lack of participatory consultation emerges as the main obstacle identified (38.0%). In addition, 20.2% of respondents highlight the absence of legal recognition of PACL rights, while 8.9% point to the failure of governance mechanisms, which further complicates cooperation and risks aggravating existing tensions.

In addition, an alarming 85% of respondents indicate that local knowledge is not integrated into PNKB management. The result of the chi-square test confirms a significant relationship between the identified barriers and the insufficient consideration of local knowledge (p-value = 0.02849).

Reasons for integrating or not local knowledge

A wide range of reasons is the basis of integrating or not of local knowledge in the PNKB par management (Table 2)

The lack of communication between managers and PACLs is a major obstacle (28.5%), as is the underestimation of the importance of this knowledge (34.4%) (Table 1, upper part). However, 32%

Involvement of PACLs	Barriers to PACL involvement	Frequency	%
No	Lack of recognition of our rights	49	8.9
	Other	4	0.7
	Lack of information or awareness	253	46.0
	Lack of opportunity or access to decision-making mechanisms	77	14.0
	Participation in meetings or consultation	3	0.5
Total		**337**	**70.2**
Yes	Awareness-raising activities	39	7.1
	Lack of information or awareness	2	0.4
	Participation in meetings or consultation	87	15.8
	Surveillance or Protection of RNs	36	6.5
Total		**164**	**29.8**

Table 1. Involvement of respondents and obstacles to their participation.

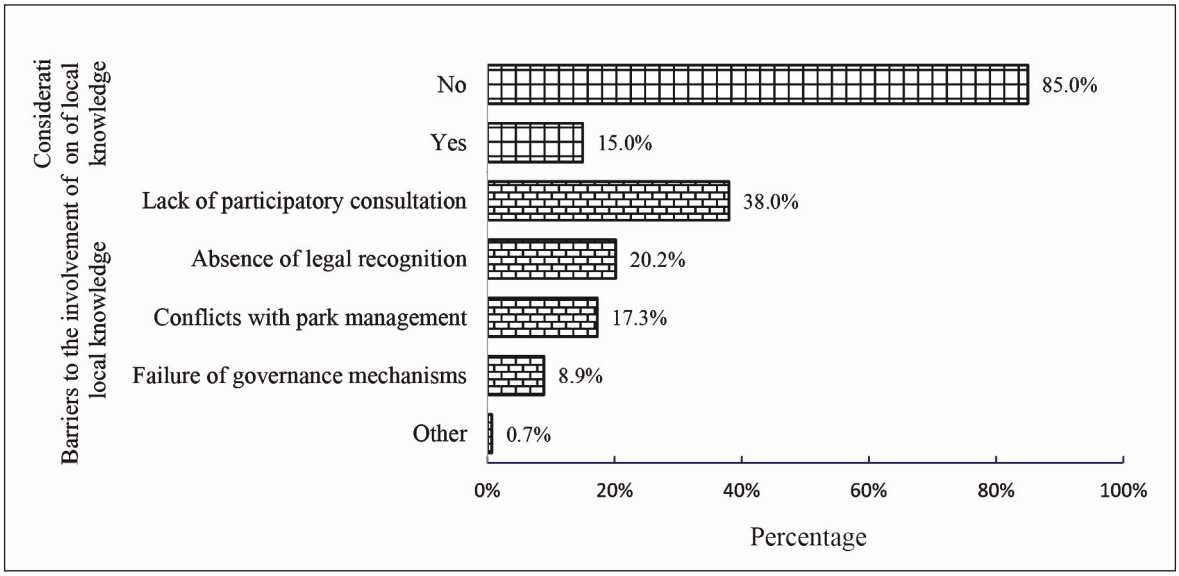

Figure 3. Main barriers and consideration of local knowledge in PNKB management.

of respondents would like to see knowledge about flora and fauna integrated into park management strategies (Table 1, lower part).

Essential needs for effective PACL involvement

Some needs cited by local people are essentials for effective PACL involvement in PNKB management (Table 3).

Legal recognition of ancestral land rights is paramount for 34.7% of respondents. A participatory consultation mechanism is also deemed crucial by 30.5%, while training and local capacity building are seen as essential (19.5%), to help communities better understand and engage in resource management, thus promoting sustainable management approaches.

Traditional PACL practices by ethnic group

Traditional practices of different ethnic groups constitute richness, and that potential wealth can be used to improve the management of the PNKB (Table 4).

The Shi are the most involved in the implementation of conservation practices, notably the closure of hunting (66.7%) and customary sanctions for environmental degradation (58.2%). In contrast, the Lega, Havu and Tembo do not recognize the closure of hunting (0.0%). Fisher's exact test confirms a statistically significant association between ethnic groups and traditional practices (p-value = 0.0004998).

Co-management programs and impacts of PNKB management

Normally a co-management program between local people and the PA managers could be useful for the PNKB. However, the results reveal contrasting realities (Table 5).

A large majority of respondents (86.5%) report that such collaboration exists, while 13.5% indicate the contrary. This highlights a significant imbalance in perceptions of collaboration between PACL and park managers.

The reasons given for these differing perceptions are diverse. The most frequently cited motivations for the co-management are the reduction of conflicts over access to and use of resources (40%) and the strengthening of trust and communication between parties (21.2%). Taking better account of local knowledge in park management (14.5%) and promoting sustainable, shared management of resources (12.3%) are also emphasized. Conversely, barriers include a lack of willingness to collaborate (5.4%), the difficulty of harmonizing divergent visions (3.8%), and, to a

Reasons	Frequency	%
Lack of mechanisms to integrate local knowledge into management	79	14.4
Conflicts of interest between managers and PACL	120	21.8
Lack of communication between park managers and PACL	157	28.5
Underestimating the importance of local knowledge	189	34.4
Other	5	0.9
Total	**550**	**100**
Local knowledge to be integrated	**Frequency**	**%**
Knowledge of local flora and fauna	176	32
Cultural and spiritual practices related to forests	48	8.7
Traditional farming practices	119	21.6
Traditional hunting techniques and collection of NTFPs	138	25
Other	69	12.5
Total	**550**	**100**

Table 2. Reasons for not integrating local knowledge into management.

Needs for involvement	Frequency	%
Training and local capacity building	107	19.5
Participatory consultation mechanism	168	30.5
Legal recognition of our rights to ancestral lands	191	34.7
Economic support or alternatives to illegal activities	77	14
Other	7	1.3
Total	**550**	**100**

Table 3. Needs for PACL involvement in PNKB management.

lesser extent, the lack of capacity or resources (2.0%). The chi-square test indicates that these reasons are significantly divergent between groups (p-value < $2.2e^{-16}$).

These findings are directly reflected in the perceived socio-economic and environmental impacts of PNKB management on local communities. A large majority of respondents consider these impacts to be negative, underlining the urgent need for inclusive governance mechanisms.

DISCUSSION

This part focuses on five main points: profile of the respondents; current level of PACL involvement in PNKB management, essential needs for effective involvement of PACL in the management of the PNKB; PACL traditional knowledge and practices to use improving the PNKB management; and socio-economic and environmental impact of PNKB on PACL.

Profile of respondents

Men accounted for 62.7% of respondents, compared with 37.3% for women. The respondents revealed different levels of education. 0.7% of women and 5.1% of men had a higher education level. A significant proportion of respondents had any education level (11.0% for women and 17.8% for men). The chi-square test reveals a significant difference between level of education and gender (p value = 0.001842).

This imbalance could indicate unequal gender

Biodiversity-friendly practices	Community practice	Frequency of respondents recognizing the practice	%
Customary penalties for environmental degradation	BATWA	69	34.3
	HUTU	5	2.5
	LEGA	2	1.0
	MUHAVU	4	2.0
	MUSHI	117	58.2
	TEMBO	4	2.0
Respect the sacred forests	BATWA	58	33.5
	HUTU	3	1,7
	LEGA	3	1.7
	MUHAVU	1	0.6
	MUSHI	107	61.8
	TEMBO	1	0.6
Slash-and-burn farming	BATWA	18	18.8
	HUTU	6	6.3
	LEGA	6	6.3
	MUHAVU	1	1.0
	MUSHI	62	64.6
	TEMBO	3	3.1
Closed season	BATWA	5	27.8
	HUTU	1	5.6
	MUSHI	12	66.7
Other practices	BATWA	1	1.6
	HUTU	10	16.1
	LEGA	4	6.5
	MUHAVU	3	4.8
	MUSHI	42	67.7
	TEMBO	2	3.2

Table 4. Biodiversity-friendly practices by community.

representation in the sample and raises the question of women's voice in natural resource management in the PNKB area. Particular attention may be required to include more women in future surveys to ensure a balanced perspective. The age of our respondents varies. Both men and women are in the age interval of 20–35.

These people revealed a low percentage of artisanal and hunting activities which may indicate a preference for subsistence-related activities, increasing pressure on local agricultural resources and underlining the importance of sustainable resources management in and around the PNKB. In terms of ethnicity, the population around the PNKB appeared heterogeneous, characterized by a wide variety of ethnic groups with widely differing customs. The Shi make up the majority of those surveyed, while the Tembo account for just a little percentage. All activities are dominated by the Shi, with the exception of fishing, practiced exclusively by the Batwa.

Ethnicity influenced occupational choices (p value = 0.0002572). This highlights a very marked dominance of the Shi group, which could influence the social and cultural dynamics of natural resource management in the region. The inclusion of the knowledge and practices of other ethnic groups, such as the Batwa, could enrich integrated conservation strategies.

Current level of PACL involvement in PNKB management

In the management strategy for PAs, including biodiversity, the human factor remains fundamental to ecosystem management. Indeed, man plays both the role of destroyer and protector of biodiversity. Given this human impact, it is therefore important to devise a development policy that takes into account both the dynamics and the cultural system of each people in their relationship with the environment.

In relation to PACL's level of involvement in the management of the PNKB, our study shows that 70% of respondents do not consider themselves involved in the management of the PNKB. Similar findings were made with low level of participation by local communities in decisions concerning the management of some PAs in DRC.

Collaboration	Frequency	%
No	74	13.5
Yes	476	86.5
Total	**550**	**100**
Why		
Lack of willingness to collaborate	30	5.4
To promote sustainable, shared management of the Park's resources	68	12.3
Taking better account of local knowledge in Park management	80	14.5
To reduce conflicts related to access to and use of natural resources	214	40
To strengthen trust and communication between parties	117	21.2
Difficulties in integrating different visions and objectives	21	3.8
For lack of capacity or resources to implement effective co-management	11	2
Following the risk of persistent disagreements between the parties	6	1
Other	3	0.5
Total	**550**	**100**

Table 5. Collaboration between PACL and managers and reasons for the existence of the co-management program.

The absence of formal structures to include local communities leads to a marginalization of their voices. However, our study highlights specific needs such as the legal recognition of land rights, an aspect that has not been sufficiently addressed in previous research. This system is often reduced to the tenure policy implemented by modern states, whereas traditional societies, as we know, favoured community management. Integrating these legal considerations could provide a new perspective on the need for a regulatory framework to enable real participation by PACL. The case study analysing indigenous knowledge and innovation systems in Namibia, revealed that for developing countries, the make-use-interact innovation mode is best suited when the objective is to integrate indigenous knowledge into an integrative system. An integration system included in indigenous knowledge can facilitate participatory development processes, encourage the socioeconomic resilience of local communities and improve a developing country's comparative advantage (Jauhiainen & Hooli, 2017).

Barriers to PACL participation provide valuable insight into the challenges encountered. Lack of information or awareness was cited as the main obstacle (46.4%). Obstacles related to lack of legal recognition (8.9%) and options for other means of involvement (0.7%) are also revealing. Respondents' opinions on their involvement remain divergent (p-value = 0.02499). These figures highlight the need for formal recognition of PACL rights to empower them and enable them to participate effectively in management, and these findings suggest that PA managers may fail to recognize the potential of this knowledge in conservation strategies, thereby compromising PACL engagement in park management. The lack of communication is a major impediment to collaboration between PA managers and PACLs (Watson, 2021). However, our study extends this analysis by also showing that recognition of rights is essential to overcoming these obstacles. This is a partial affirmation of our first hypothesis, which states that PACL involvement in the management of the PNKB is low or even non-existent due to marginalization, lack of consultation and non-recognition of their rights.

Essential needs for effective involvement of PACL in the management of the PNKB

Management in the PNKB is endangering if the social and economic needs inherent in the survival of the various social groups are taken into account, and if the danger to communities from poor or anarchic management is also taken into account. This study shows that legal recognition of ancestral land rights is paramount for 34.7% of respondents.

A participatory consultation mechanism is also deemed crucial by 30.5%, while training and local capacity building are seen as essential (19.5%), to help communities better understand and engage in resource management, thus promoting sustainable conservation approaches. Whereas in previous studies on the PNKB, such as Mena's (2019), the focus was on partnering for local knowledge, strategies and good practice, as the importance of awareness-raising has mostly been emphasized, without focusing on ongoing training. Our study therefore adds a new dimension, highlighting the need for ongoing support to enable real involvement of PACL in natural resource management. This corresponds in part to our second hypothesis, which states that the needs for effective involvement of Indigenous Peoples and Local Communities (IPLCs) are diverse, and include recognition of their rights to their lands, the creation of a participatory framework, capacity-building and economic support.

PACL traditional knowledge and practices to use improving the PNKB management

The Shi are the most involved in implementing conservation practices, notably the closure of hunting (66.7%) and customary sanctions for environmental degradation (58.2%). This is in line with Berkes & Folke (1998), who emphasize the role of traditional knowledge in sustainable ecological management. However, while these studies often focus on the preservation of biodiversity, they do not always address the social dynamics surrounding this knowledge.

A case study of local people, nature and culture at the Tanoboase sacred natural site in Ghana's Brong Ahafo region revealed that local people actively participate in natural resource conservation if their culture and traditions are properly taken into account in eco-tourism planning and development (Adom, 2019). Another case study, of the Nharira community in Zimbabwe's Chikomba district, revealed that the community used indigenous knowl-

edge to conserve forest and wildlife resources (Mavhura & Mushure, 2019), without outside intervention. Species with similar prohibitions on exploitation between the Okapi Wildlife Reserve and indigenous peoples are *Okapia johnstoni* (Sclater, 1901), *Pan troglodytes, Panthera pardus* (Linnaeus, 1758) and *Smutsia gigantea* (Illiger, 1815). Our research therefore emphasizes the importance of integrating this knowledge into management policies, an aspect often neglected in current literature. In contrast, the Lega, Havu and Tembo do not recognize the closure of the hunting season. Fisher's exact test confirms a statistically significant association between ethnic groups and traditional practices (p-value = 0.0004998).

Members of the Shi, Havu, Batwa, Lega Tembo, Hutu, Nyanga and Bakumu communities stressed the importance of their traditional knowledge for biodiversity conservation. For example, the use of medicinal plants by the Batwa group is super-important for the treatment of illness, a practice that has been passed down from generation to generation. They stated: "*our ancestors knew which plants to use to treat themselves. We still have their traditional recipe books. We don't kill the gorillas; they help us to identify certain plants for medicinal purposes*". For example, "Mumbololo" in Kirega and Urera in Mashi (*Urera* sp.) is consumed for many illnesses and is also a staple food for gorillas. Batwa women often use it when they are about to give birth, to avoid Caesarean sections. They discovered this use in female gorillas during their birthing period. Batwa women accompany Urera with another unnamed plant.

This is why no woman Pygmy will give birth by Caesarean section and cannot go in hospital for giving birth (Cikuru pers. com). In Virunga National Park, the surrounding ethnic communities recognize that their traditional practices, such as the harvesting of medicinal plants or the management of sacred forests, can provide innovative responses to ecological challenges (Ishimwe, 2020). Research has shown that sacred forests, often managed by local communities, play an essential role in preserving biodiversity by serving as refuges for threatened species (Kapupu, 2001). The rituals and totems associated with these forests reinforce the cultural and spiritual importance of biodiversity, providing an incentive for habitat conservation (Mabula & Mwanga, 2021).

The testimonies gathered also reveal the importance of integrating local knowledge into natural resource management. The emphasis placed on documenting this knowledge through training programs and partnerships with NGOs has been crucial in ensuring its sustainability and effective integration into management policies. Moreover, the historical marginalization of these ethnic groups has often led to tensions between local populations and park managers, limiting the cooperation needed for sustainable conservation efforts (Rutakayingabo et al., 2020; Consolée et al., 2020).

The women around the park, especially from the Miti and Mudaka group, demand authorization from PA managers to collect even dead wood, and this is one of the concerns they have every day, according to their statement.

The Batwa are demanding authorization to harvest non-timber forest products (NTFPs), as was the case before the park was created. Among the Lega, the great pangolin (Ikaga) is strictly forbidden to eat or even kill. It is an animal that is totally protected by this tribe. In addition, the Lega have sacred circumcision forests called "lutende" in the Kilega language, and numerous plants for cultural and medicinal purposes. This is confirmed by Malimbo et al. (2020) in their studies on the exploitation of pangolins around the Tayna Nature Reserve, who argue that the great pangolin is strictly forbidden as bushmeat, or even killed by the Lega tribe members. This animal is totally protected by Lega habits and customs. Integrating the knowledge of surrounding ethnic groups, in particular the Bashi, Havu, Batwa, Lega Tembo, Hutu and Nyanga communities, is essential for sustainable natural resource management in the PNKB. Valuing their traditional knowledge not only preserves biodiversity, but also strengthens the livelihoods of local communities, resulting in integrated conservation strategies that respect ancestral knowledge.

Socio-economic and environmental impact of PNKB on PACL

Finally, the perception of the impacts of PNKB management on the community, where 86.7% of respondents report negative effects, is an aspect that deserves particular attention. Managing resources without taking into account the needs of

local communities can have disadvantageous consequences (Dlamini, 2020). However, our study offers a new perspective, emphasizing the need to change the current approach towards collaborative management that respects and values local knowledge.

Traditional rituals associated with environmentally-friendly hunting and harvesting practices were also mentioned by participants. A member of the Havu tribe said: "*We have always respected the reproductive seasons of the animals, and our rituals help us to keep this balance. Today, we are witnessing the disappearance of these because of science and technology. Our children see our traditional practices as old-fashioned fetishism, and they say: you're still back in antiquity, and for this, the ancestors are angry with Africa*".

Therefore, it is obvious that the living way has completely changed, there's no longer the production that there was when we still respected tradition. According to elders in the community, the young people are destroying the park for various reasons (being rich, competing with others, owning all kinds of equipment, etc.). The closed season for hunting, for example, is a practice adopted by many groups, ensuring that wildlife resources are protected, thus demonstrating a sustainable approach (Vitekere, 2015). The integration of this knowledge has been documented in various studies, highlighting its potential to enrich conservation strategies and to promote the long-term sustainability of resources (Berkes & Folke, 1998; Vitekere et al., 2021). Agricultural practices, such as slash-and-burn farming, rotation farming and the use of intercropping mentioned by the Lega Tembo and Nyanga communities, show that traditional knowledge can positively influence land management, thus minimizing environmental impact.

Accordingly, this study highlights significant gaps in the involvement and valorisation of local PACL knowledge in the management of the PNKB. The results show that, although efforts have been made to include community voices, several obstacles such as lack of communication and recognition of rights remain. Compared with previous studies, our research makes a unique contribution by highlighting not only the need for involvement, but also the importance of integrating local knowledge and practices into conservation policies.

CONCLUSIONS

This study examined the role of local knowledge in promoting the sustainable management of natural resources in the PNKB in the DRC. By interviewing community members housing in the park vicinity, we identified not only how IPLC are currently participating, but also the difficulties they face. Although the majority of respondents acknowledge the importance of traditional knowledge in resource management, actual participation by IPLCs remains limited.

The main problems, including inadequate communication and lack of legal recognition, point to the need for a more inclusive approach that truly values the contribution of PACLs. Traditional ecological knowledge, such as traditional practices related to sacred forests and seasonal hunting restrictions could really help conservation programs if integrated into park management policies. Recognizing and respecting PACL's rights to their ancestral lands must become a priority for park managers, to build trust and improve the effectiveness of conservation efforts.

The research underscores the importance of fostering strong partnerships between PNKB managers and local communities. Sustainable and responsible natural resources management requires continuous dialogue, promote active participation and create spaces for discussion. By properly integrating traditional knowledge into conservation strategies, we can not only protect the region's natural heritage, but also ensure the well-being of the communities that depend on it. Among, the recommended actions, improving consultation mechanisms, setting up training programs and supporting co-management initiatives could strengthen PACL commitment and foster more equitable and sustainable management of PNKB resources. On the subject of recommendations, the integration of PACLs into the park's governance bodies is the most supported solution. This shows that there is an urgent need to recognize the voice of local communities in decisions that directly affect them. This strengthens the legitimacy of park management actions and promotes an inclusive approach. Including PACLs in decision-making bodies can also improve park authorities' understanding of local problems and promote appropriate solutions.

Furthermore, the call for official recognition of PACL's rights to natural resources, shows that legal certainty is very important to encourage sustainable management. Such recognition could not only enhance the value of PACL's contributions, but also encourage their commitment and responsibility for resource protection. For natural resources and harvesting NTFPs, these recommendations show that local communities are aware of the importance of a balanced approach that respects traditional practices in resource use. These perspectives are vital to achieving more sustainable and equitable management of the PNKB's natural resources.

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