Uses of *Oldeania alpina* (K. Schum.) Stapleton (Poaceae) and local perceptions of its spatio-temporal dynamics in Lubero cool highlands region (DR Congo)

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Research

Abstract

Background: In the Democratic Republic of Congo (DR Congo), *Oldeania alpina* (K. Schum.) Stapleton provides multiple goods and services to rural populations and is the keystone species of mountain forest ecosystems, most of which are in a very advanced state of degradation. The present study was carried out in Lubero cool highlands region, in the North-East of the DR Congo. It aims to highlight the knowledge of local populations on the uses of *O. alpina* as well as their perceptions of the spatio-temporal dynamics of this high-altitude bamboo species.

Methods: Ethnobotanical surveys were conducted in five villages of the study area through semi-structured individual interviews and focus groups with 245 people. The different forms of use of *O. alpina* organs and the local perceptions of its spatio-temporal dynamics were the key axes of the surveys. The software R version 4.1.5 was used to calculate the ethnobotanical indices and to carry out static analyses of the data.

Results: The results showed that *O. alpina* is well known by the populations of the study area and is solicited in seven main categories of use, namely: fuelwood (22.5 %), construction (22 %), handicrafts (17 %), agriculture (14.5 %), pharmacopoeia (14 %), worship (8 %) and food (2 %). For these uses, the populations solicit the following organs: culms (59.2 %), blades (12.24 %), shoots (10.54 %), rhizomes (6.78 %), sheaths (6.56 %) and straw (4.68 %). Also, for the populations of the study area, the bamboo groves of *O. alpina* are in a regressive spatio-temporal dynamics.

Conclusion: In Lubero cool highlands region, *O. alpina* is in constant degradation due to uncontrolled human exploitation. The results of this study provide reliable technical bases for developing conservation strategies for *O. alpina* in the study area.

Keywords: Bamboo, *Oldeania alpina,* ecosystem services, multipurpose species, ethnobotany, threatened species, local conservation policy, multipurpose species, Congo Basin, Lubero, DR Congo.

Background

Humans have always depended on nature, from which they draw both fossil and biological resources for their well-being and survival (Diatta *et al.* 2016, Gnangle *et al.* 2017, Dje Bi *et al.* 2020). Most biological resources used by humans are drawn from forests, which are natural reservoirs of biodiversity (Thompson *et al.* 2009, Boulogne 2016). Indeed, forests provide several resources for food, feed, traditional medicine and many other socio-economic and cultural services (Loubelo 2012, Sonwa *et al.* 2012, Hessavi *et al.* 2019, Traoré *et al.* 2021, Kambale Ndavaro *et al.* 2022a). African societies are the most closely linked to these resources in the world due to the standard of living of the populations, especially in rural areas (Kambale *et al.* 2016, Dicko *et al.* 2017, Masinda *et al.* 2017). This dependence gives them indigenous knowledge and practices that are incorporated into their habits and passed on from generation to generation (Badjaré *et al.* 2018, Cissé *et al.* 2018). This knowledge of forest resources use varies greatly between ethnic groups and is generally correlated with several individual attributes including age, gender, religion, level of education, main activity, etc. (Gaoue *et al.* 2017, Gouwakinnou *et al.* 2019, Gaoue *et al.* 2021, Traoré *et al.* 2021).

The forests of the Democratic Republic of Congo (DR Congo), estimated at over 152 million hectares, represent 10 % of the world's forest cover and 62 % of that of the Congo Basin (Tchatchou *et al.* 2015). They are home to mega plant biodiversity with useful species of great interest to human populations, in terms of their multiple ecosystem services (MEA 2005, Paudyal *et al.* 2019, Kambale Ndavaro *et al.* 2022b). Among the most important and well-known of these forest plant species is the upland bamboo (*Oldeania alpina* (K. Schum.) Stapleton) (Stapleton 2013), a grass (Poaceae) native to Africa (Bahru *et al.* 2021) and the regional center of afromontane endemism (White 1983, Oyicha 1997). In DR Congo, *O. alpina* is found only in the high mountains of the East of the country (2400 and 3200 m altitude) (Safari *et al.* 2015, Kambale Ndavaro *et al.* 2022b) where it is extensively exploited by local populations for various categories of uses (Munyuli Bin Mushambanyi 2001, Amani *et al.* 2008, Safari *et al.* 2015).

Particularly in Lubero cool highlands region, *O. alpina* is one of the most prized non-timber forest products (NTFPs) and of great value to local people who use it to meet their socio-economic and cultural needs (Vyakuno 2006, Kambale Ndavaro *et al.* 2021). However, in many parts of the forests in this region, selective logging of *O. alpina* has resulted in the formation of clearings where secondary, herbaceous-dominated, restocking plant formations develop (Masinda *et al.* 2017, Kambale Ndavaro *et al.* 2021). These clearings represent major signs of degradation of this afromontane species which runs the risk of disappearing locally in the future (Masinda *et al.* 2017). This is all the more evident as in most cases, the selective exploitation of *O. alpina* by the populations of Lubero cool highlands region is done in an accelerated and uncontrolled manner, i.e. without considering their abundance, rarity or regeneration rate (Bada Amouzoun *et al.* 2019). Combined with the galloping population growth in the area (Vyakuno 2006, Masinda *et al.* 2017, Kyungu Kasolene 2019), this uncontrolled exploitation could lead to an alarming degradation of *O. alpina* bamboo groves, thus negatively impacting the benefits that humans derive from these plant resources (Kambale Ndavaro *et al.* 2021).

To ensure the conservation and sustainable management of *O. alpina* in the Lubero cool highlands region, it is necessary, among other things, to explore endogenous knowledge of the uses and functions of this plant resource for local populations. This approach is crucial and is justified by the fact that for the sustainability of ecosystem services of forest plant resources, conservation actions must sufficiently consider the specific uses known by local populations (Bada Amouzoun *et al.* 2019, Garba *et al.* 2019, Hadonou-Yovo 2020). Indeed, knowledge of the ethnobotanical forms of use of forest plant resources provides a solid technical basis for the design and implementation of the sustainable management plan of fragile forest formations (Yedomonhan *et al.* 2017, Abdou Habou *et al.* 2020). In other words, investigations on local knowledge are imperative to capitalise on the traditional knowledge of human communities in natural resource management strategies (Ouedraogo *et al.* 2017, Ouattara *et al.* 2021).

On the other hand, it is also important to document local perceptions on the current ecological status of *O. alpina* bamboo groves, and more specifically their spatio-temporal dynamics in the study region. Several studies have

shown the value of analysing people's perceptions on the spatio-temporal dynamics of plant resources with multiple uses (Weiss *et al.* 2006, Toko *et al.* 2013, Sambieni *et al.* 2015). To this end, Mccorkle (1989) and Hahn-Hadjali and Thiombiano (2000) indicate that in the absence of a reliable scientific basis on past vegetation, the perception of the rural population is necessary and appropriate to detect any evolutionary or regressive dynamics in the flora. Also, according to Brusquet (2006), the continuous adaptation of conservation strategies to the changing needs of people and natural conditions requires the consideration of the traditional ecological knowledge of local communities. For their part, Sambieni *et al* (2015) show that the study of people's perceptions of the spatio-temporal dynamics of forest ecosystems makes it possible to develop appropriate tools to support policies for involving these populations in the conservation of forest resources. As for Ouattara *et al* (2021), they consider that studies of farmers' perceptions, based on reliable ethnobotanical surveys, are an effective means of rapidly assessing the state of vegetation evolution in a locality.

It is in this context that the present study takes place. Its objectives are to: (i) describe the different forms of use of *O. alpina* by local populations; (ii) analyse the perceptions of local populations on the spatio-temporal dynamics of *O. alpina* bamboo groves. The interest of this study is operational. It serves to provide the basic technical elements for the design and implementation of conservation and sustainable management strategies for *O. alpina* in the Lubero cool highlands region affected by the degradation of natural habitats of forest species.

Materials and Methods

Study area

The study was conducted in Lubero cool highlands region located in the North-East of DR Congo. This region lies between 29°04'26.4" and 29°28'51.6" East longitude and between 0°04'26.4" North latitude and 0°32'49.2" South latitude. The altitude varies between 2000 to 3117 m. The climate is equatorial, tempered by the mountains (Vyakuno 2006, Masinda *et al.* 2017, Kambale Ndavaro *et al.* 2021). The average annual temperature varies between 15 and 17° C (Sys 1992, Vyakuno 2006). The average annual rainfall varies from 1110 to 1330 mm (Sys 1992, Demangeot 1999, Vyakuno 2006). The soils are thick, poor, fragile and diversified by their granulometry (Pecrot & Leonard 1960, Sys 1960, Vyakuno 2006). The vegetation consists mainly of forests with *O. alpina*, *Podocarpus milanjianus* Rendle, *Aningeria adolfi-friedericii* (Engl.) Robyns & G.C.C. Gilbert, *Macaranga neomildbraediana* Lebrun, *Newtonia buchananii* (Baker f.) G.C.C. Gilbert & Boutique and *Erica arborea* L. (Pecrot & Leonard 1960, Vyakuno 2006). Phytogeographically, this falls within the afromontane domain (Robyns 1948, Lambinon & Sérusiaux 1983). This region corresponds to what White (1983) called the regional center of afromontane endemism. The population of the Lubero cool highlands region is growing considerably over time. Between 1930 and 2020, it increased from 348,807 to 662,535 inhabitants (Etat Civil-Lubero/RD Congo 2021). The economic activities of this population are dominated by agriculture, small and large livestock breeding, petty trade, logging and the collection of non-timber forest products (Vyakuno 2006, Masinda *et al.* 2017). Logging provides fuelwood, timber and building materials.

Sampling of the surveyed population

Five villages were selected for ethnobotanical surveys based on the presence of *O. alpina* bamboo groves and the existence of indicators of its use in the village. The villages were Luotu, Magheria, Masereka, Kipese and Lubango (Figure 1). The choice of people to be interviewed followed the convenience sampling method, which consists of interviewing people who are available at the time of the study. A key criterion for this method was the respondent's knowledge of *O. alpina* and its uses. Given that the plurality of people to be interviewed always reveals a diversity of points of view and allows for the crossing of opinions (Auzuret *et al.* 2010) and that the diversification of data sources allows for the societal realities of the populations to be considered (Sambiéni *et al.* 2015), the sample size chosen for the study was defined by the normal approximation of the binomial distribution proposed by Dagnelie (1998):

$$N = \mu^2_{1-\alpha/2}\frac{Pi(1-Pi)}{\delta^2}$$

Where: N = sample size; Pi **(80%)** = the proportion of people with knowledge of *O. alpina* in Lubero cool highlands region (50-person survey); $\mu_{1-\alpha/2}$ = 1.96 (value of the normal random variable for a risk α = 0.05); δ = 5 % (Margin of Error).

Thus, 245 (49 per village) people were interviewed, after explaining the aim of the research work and obtaining their oral prior informed consent. In the selection of interviewees, only those who were at least 25 years old were considered in order to better trace the history of the use of this plant species in the region under study.

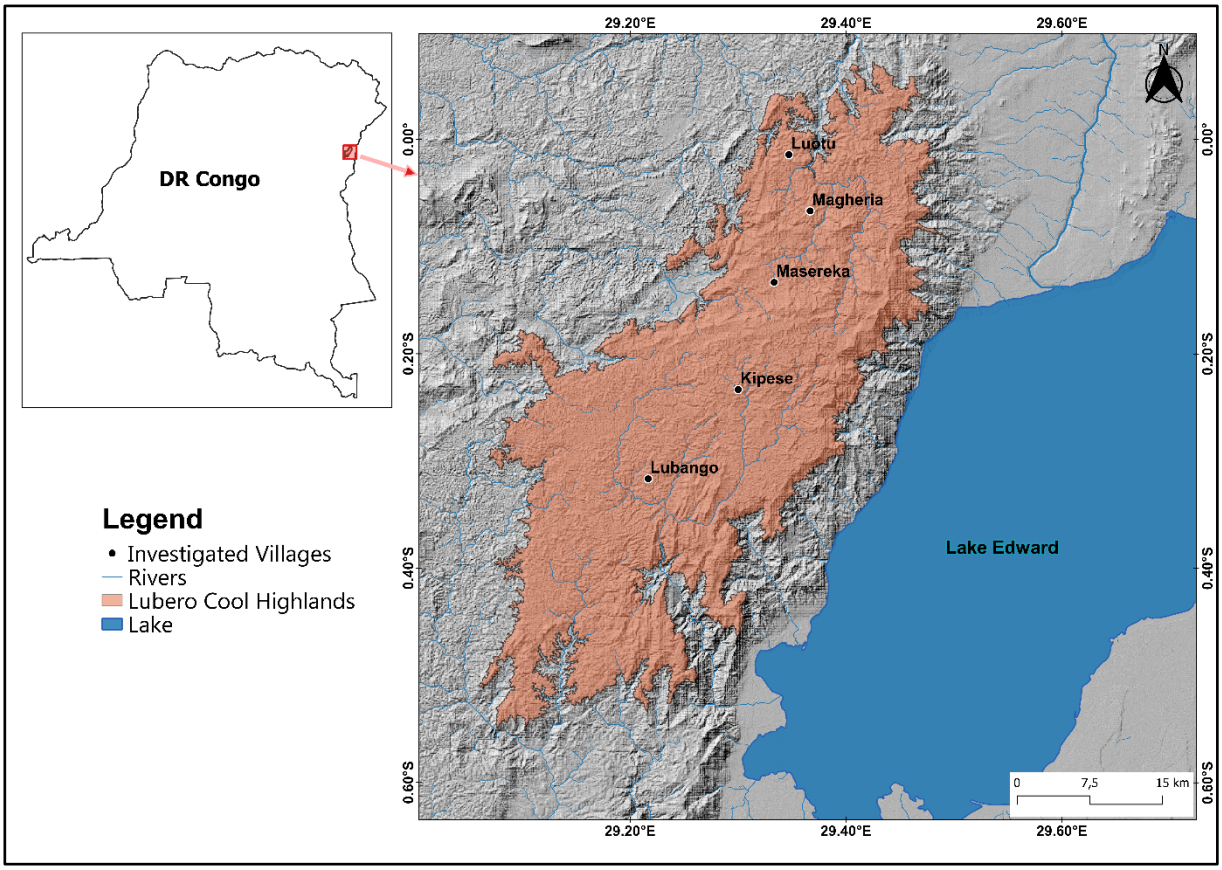

Figure 1. Location of ethnobotanical investigation sites on *O. alpina* in Lubero cool highlands region (DR Congo).

Data collection

Using the technique of semi-structured interviews based on pre-established survey questionnaires, data was collected in each of the five villages in the study area. For this purpose, the *Free Listing* technique was used. This consisted of asking the informant to list the different uses of *O. alpina* and the organs required for each use (Quinlan 2005). In addition to this, specific questions related to vernacular nomenclature, availability, abundance, degree of spatio-temporal evolution and local conservation strategies of the plant resource under study were asked. Also, a focus group was conducted in each village between five experts from local government departments of environment, agriculture, livestock and forest management, as well as community leadership. The synthesis report containing the harmonised elements of the opinions expressed in the focus group was validated by all the stakeholders, in order to complete, by validation or questioning, the data obtained by individual interviews.

Data analysis

The Excel spreadsheet was used to build the database; and all statistical analyses were performed using R 4.1.5 (R Core Team 2021). The use accumulation curve was performed under the "vegan" package (Oksanen *et al.* 2019) to account for the sampling effort and the completeness of the recorded uses. Furthermore, the packages "ggplot2" (Wickham 2016) and "FactoMineR" (Le *et al.* 2008) were used to perform a Multiple Correspondence Analysis (MCA), in order to identify which organs of *O. alpina* are most solicited for given uses, as well as the predominant uses in the different villages. Also, the plant part use value (PPV) index (Gomez-Beloz 2002) was calculated for each organ and stubble type used by the following formula:

$$PPV = (RU/\sum RU)$$

With: ***RU*** = the number of uses reported for each organ.

PPV was compared between organs using a beta regression under the "betareg" package (Zeileis *et al.* 2010).

In order to model the mechanisms involved in the ownership of *O. alpina* bamboo groves in Lubero cool highlands region, the effect of socio-demographic characteristics (gender, village, main activity, age and household size) on the ownership status of *O. alpina* bamboo groves was tested by means of a binary logistic regression under the package "stats" (R Core Team 2021). Ten models were tested, starting from the global model to the null model. The Akaike Information Criterion (AIC) (Akaike 1998) was used to select the minimum adequate model. Statistically significant effects were plotted using the effects package (Fox & Hong 2009).

To better explain the factors that determine local people's perception of the spatio-temporal evolution of *O. alpina* bamboo groves, modelling of the influence of *O. alpina* bamboo ownership status, village and main activity on the perception of the spatio-temporal evolution of the said groves was done using ordinal logistic regression under the "ordinal" package (Christensen 2019). Four models were tested and compared in order to find the most suitable model.
Finally, the Local Conservation Priority Index (LCPI), adapted from Albuquerque (2009), was calculated using the following formula:

$$\boldsymbol{LCPI = NC + DA + DR}$$

With: ***NC*** = Number of Citations (two points are added for each use category cited: scale 1-10)**;** ***DA*** = Degree of Attention which here translates into the ownership status of *O. alpina* bamboo groves: Non-owner =10; Owner = 1; ***DR*** **=** Relative Density of the species in the wild which here translates into the degree of abundance perceived by each respondent: Rare = 10; Not very abundant = 7; Abundant = 4; Very abundant = 1.

This index was compared between survey villages using a simple linear regression followed by a multiple comparison test under the "multcomp" package (Vihinen *et al.* 1992) to assess the urgency of conservation measures for *O. alpina* in the study area.

Results

Sampling effort

The sample of respondents provided satisfactory and comprehensive information on the different categories of use of *O. alpina* in the Lubero cool highlands region, given the asymptote obtained on the accumulation curve of recorded uses (Figure 2).

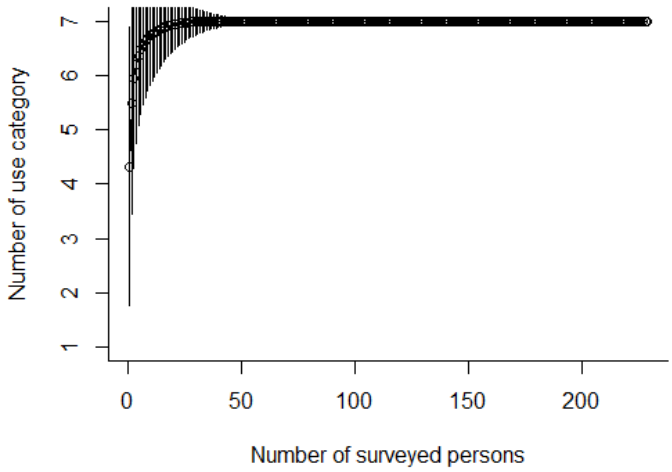

Figure 2. Accumulation curve of *O. alpina* uses.

Uses of *O. alpina*

In descending order of frequency of use, *O. alpina* is used in seven areas by the people of Lubero cool highlands region (Figure 3): wood energy (22.5 %), construction (22 %), handicrafts (17 %), agronomy (14.5 %), pharmacopoeia (14 %), worship (8 %) and food (2 %). The number of specific forms of use reported per organ and stubble type of *O. alpina* was as follows: blades (one form of use), straw (two forms of use), rhizomes (two forms of use), shoots (three forms of use), young culms (four forms of use), mature culms (three forms of use) and old culms (one form of use) (Table 1). Figure 4 illustrates some of these uses of *O. alpina* in Lubero cool highlands region.

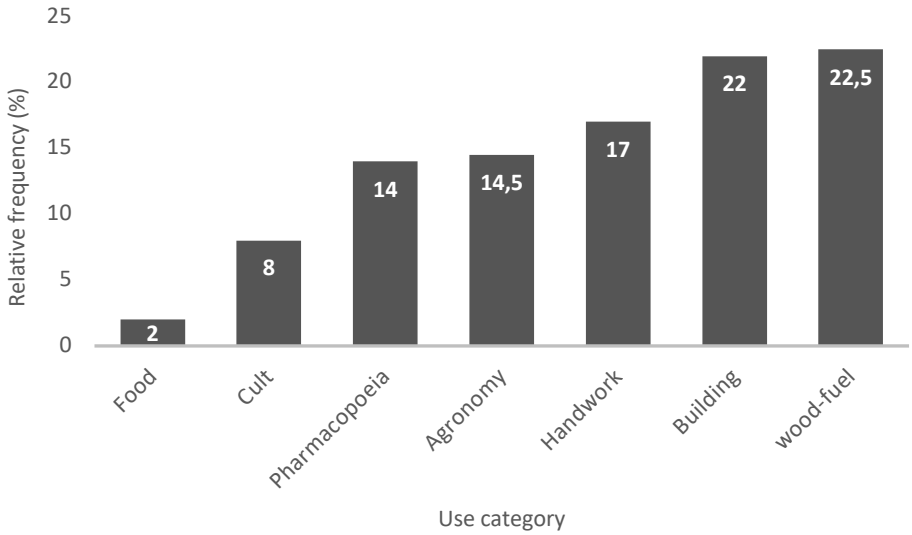

Figure 3. Areas of use of *O. alpina*.

Figure 4. Illustrative photos of some of the uses of *O. alpina* by the people of Lubero cool highlands region: a) Wood energy; b) Construction (house); c) Handicraft (basket); d) Agriculture (staking); e) Construction (fence); f) Handicraft (chair). Pictures of Kakule Vyakuno (2003) and Kambale Ndavaro (2022).

Table 1. Response rate of *O. alpina* organs use by people in five villages of Lubero cool highlands region

Organs	Areas of use	Forms of use	Purpose of use	Relative frequency of *O. alpina* organs users by survey village (%)				
				Luotu (n=49)	Magheria (n=49)	Masereka (n=49	Kipese (n=49)	Lubango (n=49)
Limb	Medicinal	Decoction	Otitis	-	14,3	6,1	4,1	-
		Cooking or powder	Stomachache	36,7	42,8	18,4	6,1	-
		Cooking	High blood pressure	2,9	23,2	10,3	-	11,7
		Decoction	Boil	-	10,2	4,1	-	8,2
		Decoction	Hemorrhoid	42,8	38,8	16,3	30,6	8,2
Straw	Construction	Straw	Hut roofs	49,9	65,3	77,5	67,3	57,1
	Combustible	Straw	Kitchen fire	59,2	75,5	85,7	79,6	45,0
Rhizome	Medicinal	Decoction	Stomachache	-	14,3	4,1	32,6	-
		Decoction	Snake bite	2,0	18,4	10,2	8,2	-
		Decoction or powder	Diarrhea	6,1	16,3	4,1	28,6	-
	Agriculture	Rhizome	Plant material	24,5	34,7	44,9	18,4	22,4
Shoots (< 1 year)	Medicinal	Decoction	Otitis	-	6,1	4,1	2,0	-
		Decoction or powder	Stomachache	-	12,2	16,3	-	8,1
	Artisanal	Cut and slit	Baskets	67,3	77,5	75,5	85,7	79,6
		Cut and slit	Baskets	37,7	48,9	26,5	57,1	28,6
		Cut and slit	Mats	22,4	34,7	65,3	32,6	38,8
		Cut and slit	Zither	-	10,2	14,2	-	-
	Food	Cooking	Vegetable	2	-	-	3	2
Young thatch (1-4 years: green)	Construction	Cut	fences	63,3	67,3	79,6	61,2	34,7
	Artisanal	Cut and split	Doors	10,2	24,5	16,3	21,0	4,0
		Cut and split	Beds	26,5	55,1	69,4	59,2	63,3
		Cut and split	Chairs	59,1	75,5	73,5	77,5	69,4

		Cut and split	Stretchers	-	-	41,1	-	7,0
	Agriculture	Cut out	Staking	71,4	95,9	89,8	83,7	93,9
	Combustible	Cut	Firewood	93,9	100	100	95,9	100
Mature thatch (5-7 years: yellow and hard)	Construction	Cut	Fences	67,3	100	100	95,9	57,1
		Cut	Houses	53,1	63,3	42,8	69,4	75,5
	Artisanal	Cut	Doors	-	18,4	-	-	-
		Cut and slit	Beds	38,8	61,2	48,9	28,6	44,9
		Cut and slit	Chairs	67,3	77,5	87,7	83,7	79,6
	Combustible	Cut	Firewood	100,0	100,0	95,9	100,0	97,9
Old thatch (≥ 8 years: dry)	Combustible	Cut out	Firewood	100,0	100,0	100,0	100,0	100,0

Legend: n = number of people

Almost all organs of *O. alpina* are used by local people in the five villages investigated (Figure 5). These organs are grouped into six categories: culms (59.2 %, of which 16.98 % are young culms, 15.52 % are old culms, 14.58 % are mature culms and 12.12 % are dead culms), blades (12.24 %), shoots (10.54 %), rhizomes (6.78 %), sheaths (6.56 %) and straw (4.68 %).

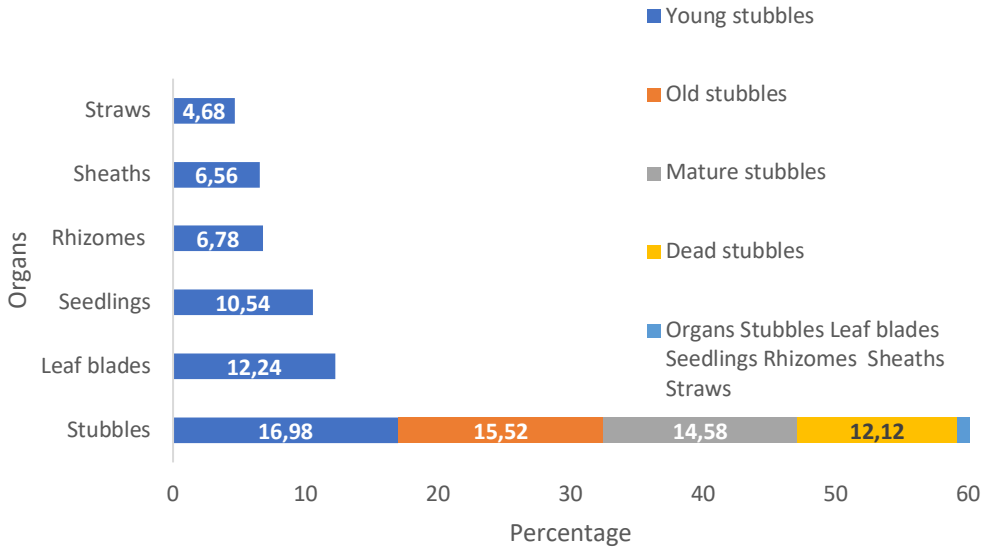

Figure 5. *O. alpina* organs used by local people.

The PPV of these *O. alpina* organs indicates that local people do not place the same importance on them. Figure 6 shows that this index differs significantly between organs used. The different types of culms (young, mature, old and dead) have the same use value as the blades. Similarly, rhizomes, shoots and sheaths have relatively equal use values for local populations. Straw has a significantly different use value than the other organs and types of stubble used. They are the least important part of the plant for local people, while the blades and the different types of culms are the most valued parts.

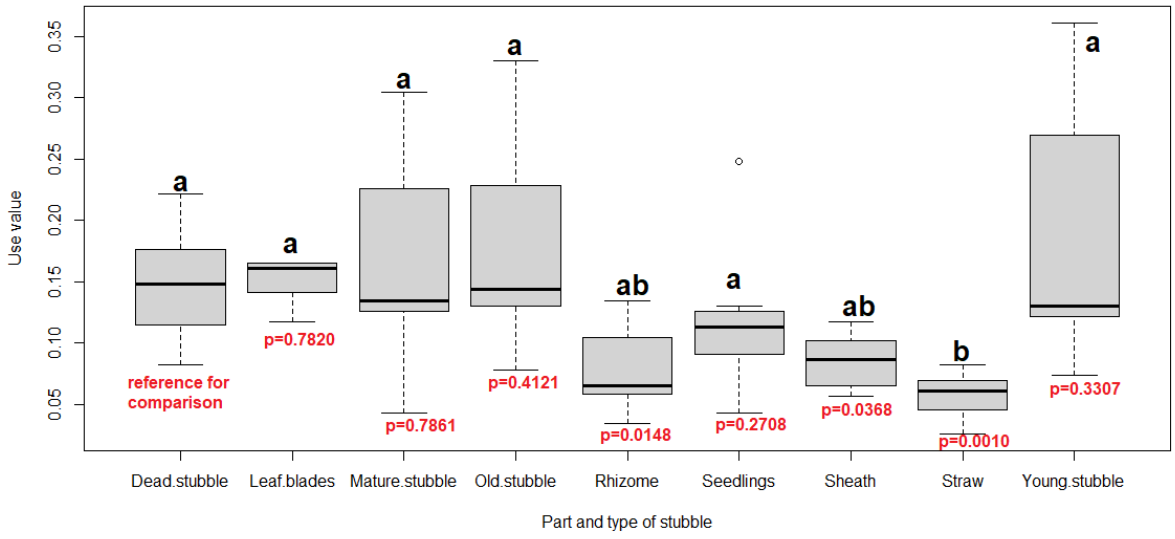

Figure 6. Multiple comparison of the use value of the various organs of *O. alpina* used. *Box plots with different letters differ significantly and are otherwise identical.*

The MCA revealed the organs preferences for certain villages and the corresponding areas of use (Figure 7). It can be seen that young and old culms are mainly used for house and fence construction, while mature culms are used more as energy wood. The shoots of *O. alpina* are much more used for human consumption, while the rhizomes and limbs are more used in pharmacopoeia. Food use is more pronounced in Lubango and Masereka than in the

other three villages. The use of *O. alpina* for construction is more mentioned in Luotu. Kipese shows a strong tendency towards agronomic uses of *O. alpina*.

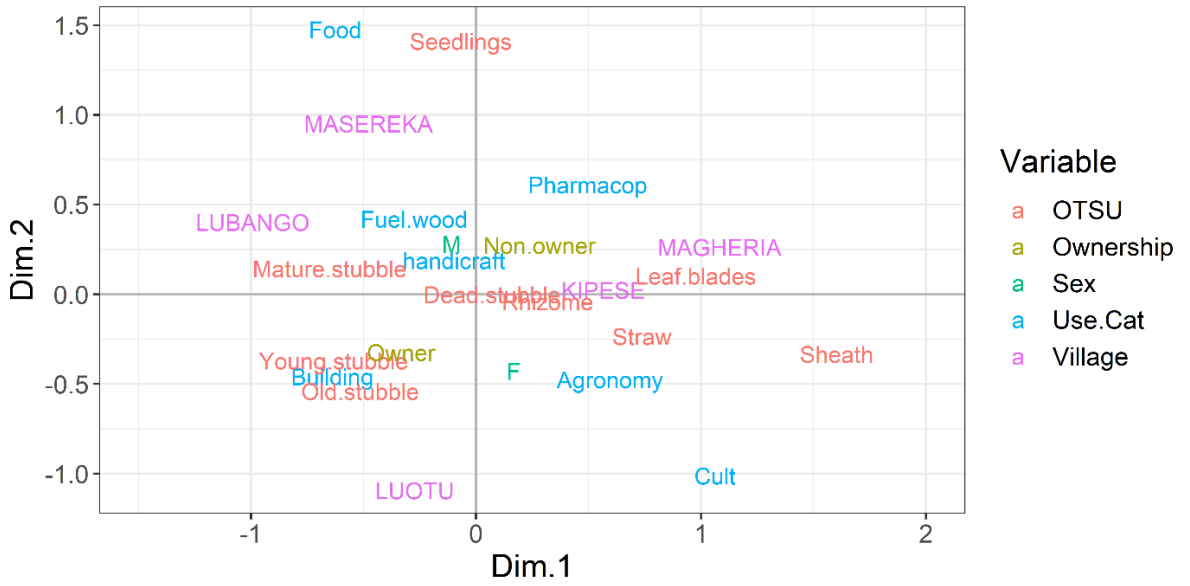

Figure 7. Factor plane (1,2) of the Multiple Correspondence Analysis. Legend: OTSU = organs and type of stubble; Use.cat = use category.

Mechanisms involved in the ownership of bamboo groves (*O. alpina*)

Of the 10 models in the binary regression testing the effect of socio-demographic characteristics on the ownership status of bamboo groves (*O. alpina*), model 9 is more parsimonious according to AIC (Table 2). This model shows that only the main activity is likely to influence ownership status. Thus the probability of owning bamboo groves (*O. alpina*) for a farmer is significantly lower than that of a herder but is the same for a teacher and a practitioner of other activities (Figure 8).

Table 2. Modelling the mechanism influencing the ownership of bamboo groves (*O. alpina*) in Lubero cool highlands region

Models	***Main effects***	***Interactive workforce***	**df**	AIC
fm0	Age; Household size; Gender; Main activity; Village	*Age ∩ Sex; Age ∩ Village Age∩ Main activity*	19	330.5
fm1	Age; Household size; Gender; Main activity; Village	*Age ∩ Sex ; Age ∩ Village*	16	327.6
fm2	Age; Household size; Gender; Main activity; Village	*Age ∩ Gender*	12	323.5
fm3	Age; Household size; Gender; Main activity; Village	-	11	321.9
fm4	Age; Household size; Gender; Main activity; Village	-	7	317.5
fm5	Age; Household size; Gender	-	4	319.6
fm6	Age; Household size	-	3	317.7
fm7	Age	-	2	317.0
fm8	Main activity; Village	-	8	319.3
fm9	**Main activity**	-	**4**	**314.6**
fm10	-	-	1	316.3

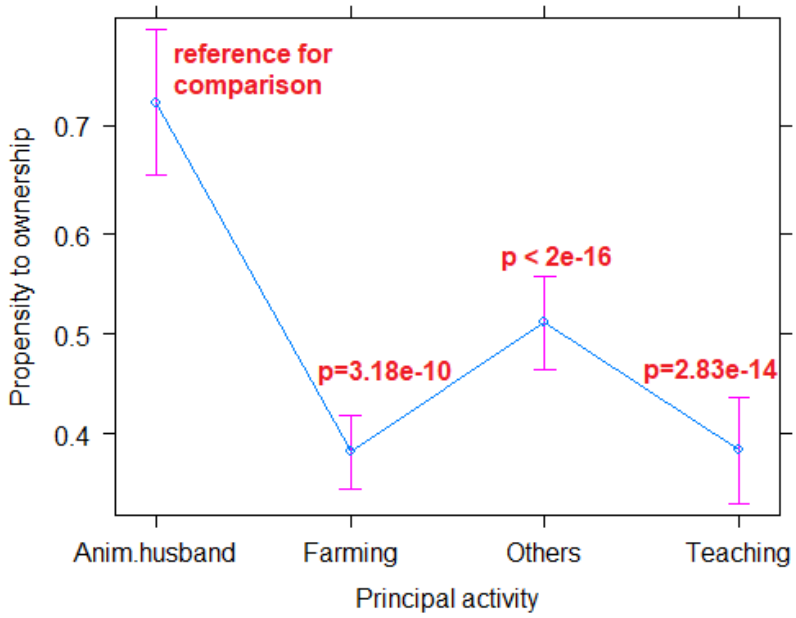

Figure 8. Comparison of the probability of owning bamboo groves (*O. alpina*) according to respondents' main activities.

Perception of the spatio-temporal dynamics of bamboo groves (O. alpina)

In Lubero cool highlands region, seven different types of *O. alpina* habitats were listed. Considering the decreasing order of magnitude of the frequency of citations, we have respectively: dense forests (31.51 %), open forests (21.03 %), cultivated fields (14.11 %), fallows (13.18 %), plantations (12.41 %), riverbanks (6.03 %) and savannah (1.69 %). From the point of view of the perceived abundance of this multiple-use plant resource, most of the respondents found bamboo (*O. alpina*) to be scarce or scarce regardless of the type of habitat considered. In fact, 80 % of respondents perceive that bamboo groves (*O. alpina*) are in decline, while 15 % mention the stability of these groves and, on the other hand, 5 % perceive that bamboo groves (*O. alpina*) are in a progressive dynamic in the study area (Figure 9).

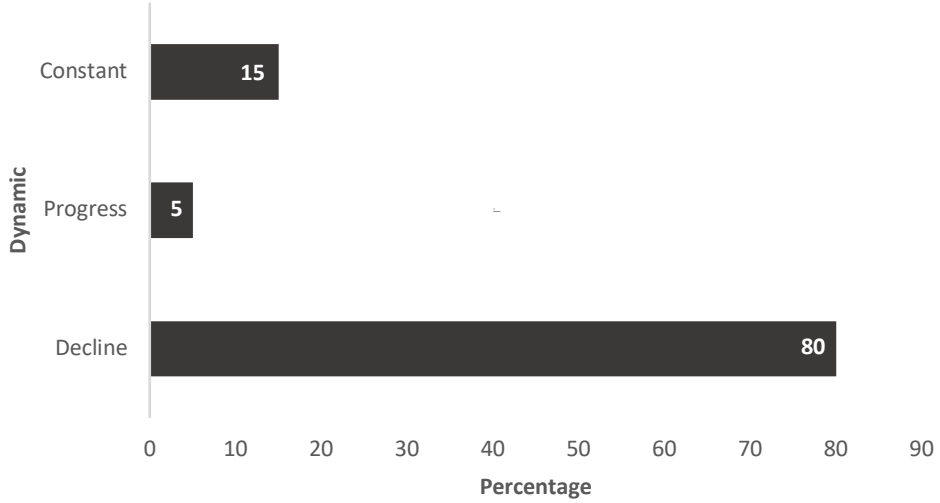

Figure 9. Spatio-temporal evolution of bamboo groves (*O. alpina*) in Lubero cool highlands region according to respondents.

The AIC indicates that model 3 (null model) is the minimum adequate model (Table 3). Table 4 shows that neither location (village of residence) nor ownership status influences an individual's perception of the spatio-temporal evolution of bamboo groves (*O. alpina*). Thus, Figure 10 shows that the probability of perceiving a regressive evolution of bamboo groves (*O. alpina*) is about 100 % regardless of ownership status on the one hand, and at least 70 % regardless of the village considered.

Table 3. Comparison of models of the determinism of local people's perceptions of the spatio-temporal evolution of bamboo groves (*O. alpina*) in Lubero cool highlands region

Models	***Main effects***	***Interactive effects***	**df**	**AIC**
rego0	Village; Ownership status	*Village ∩ Ownership status*	8	65.48146
rego1	Village; Ownership status	-	5	61.47991
rego2	Ownership status	-	2	57.87183
rego3	-	-	1	**55.98417**

Table 4. Effect of ownership status and village on the spatio-temporal evolution of bamboo groves (*O. alpina*) in Lubero cool highlands region

	Coefficient	**Std error**	**z value**	**Pr (>|z|)**
Progression|Stability	**-1.2926**	**0.8129**	**-1.59**	-
Lubango	-0.5197	1.0713	-0.485	0.628
Luotu	0.3650	1.1040	0.331	0.741
Masereka	-0.9744	0.9856	-0.989	0.323
Owner.status	0.3361	0.7111	0.473	0.636

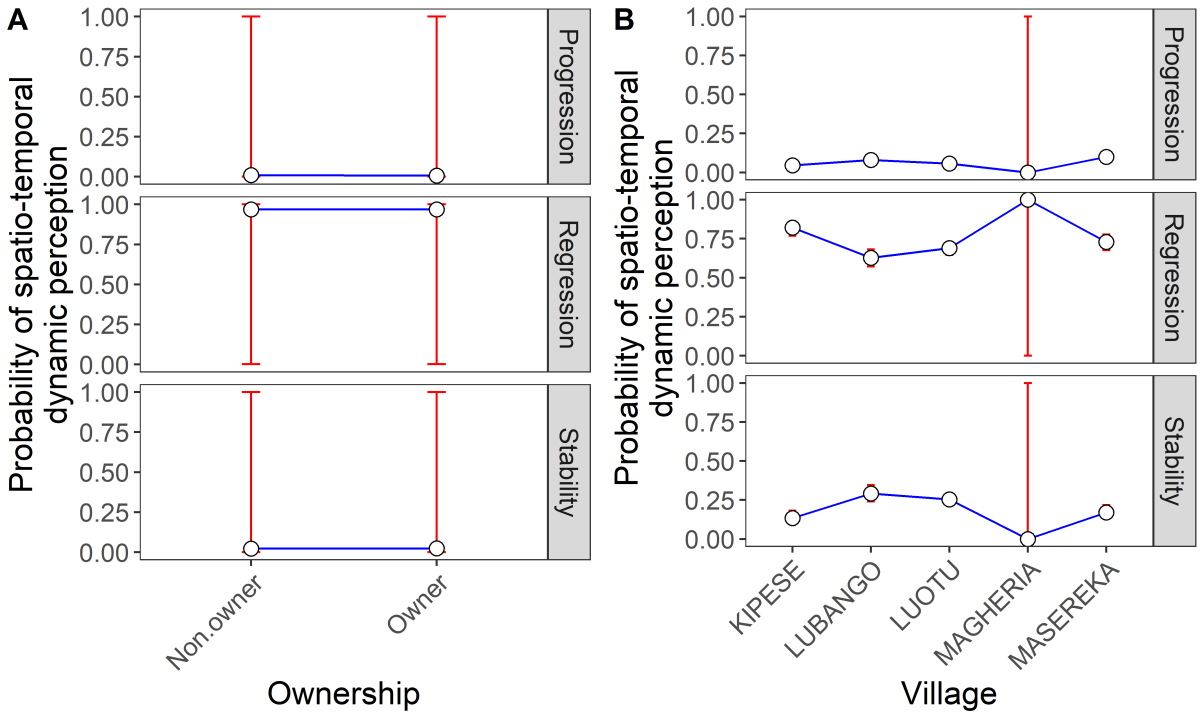

Figure 10. Comparison of the perception of the spatio-temporal evolution of bamboo groves (*O. alpina*) according to A) the ownership status and B) the village of the respondent.

The LCPI is not significantly different between the surveyed villages (LCPI≈18), except for Magheria whose LCPI (22) is significantly different and higher than those of the other four villages (Figure 11). With all LCPI values above 15, this suggests that bamboo (*O. alpina*) is under heavy use pressure and that its availability is critical in the study area. The situation is even more worrying in Magheria where the index is very close to the maximum value (30).

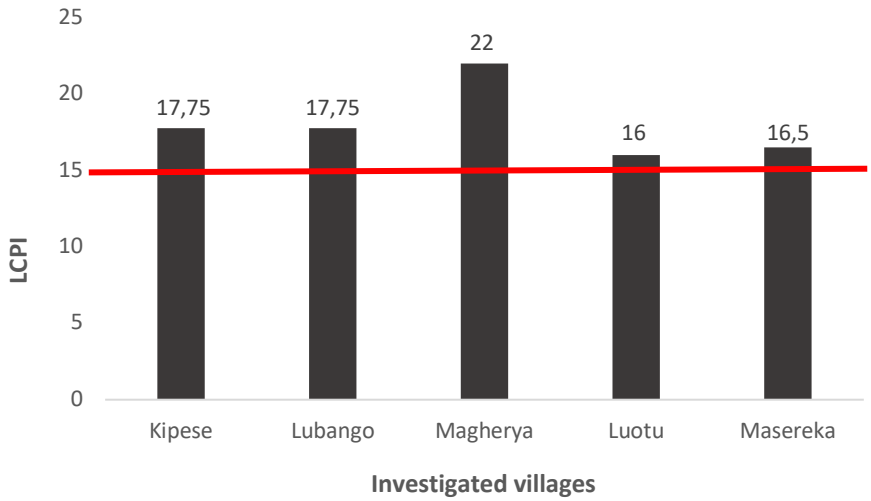

Figure 11. Local Conservation Priority Index of *O. alpina* per surveyed village. *The red line indicates the threshold at which the species can be considered a conservation priority.*

Discussion

Uses and ownership status of *O. alpina*

The results of this study reveal that people in Lubero cool highlands region are familiar with *O. alpina* and use it extensively for several purposes. This confirms the conclusion of Badjaré *et al.* (2018) that the use of a plant resource requires knowledge about it. The accumulation curve of the use domains of *O. alpina* has reached the asymptote. It can be deduced from this that all the information on the uses of *O. alpina* was collected from the people surveyed in the study area. The ethnobotanical surveys identified several uses of *O. alpina* grouped into seven main categories of use: food, worship, medicinal, agronomic, craft, construction and energy. These multiple uses of *O. alpina* are mentioned by several studies conducted in different mountainous regions of Africa (Oyicha 1997, Mekuriaw *et al.* 2011, Guadie *et al.* 2019). Indeed, the use of *O. alpina* as firewood and as construction material for dwellings and fences is reported by Bitariho and Mosango (2005) among the riparian populations of Bwindi and Mgahinga National Parks in southwestern Uganda. Gebrekidan *et al.* (2018) and Bahru *et al.* (2021) also report the consumption of *O. alpina* saplings as a food supplement in some mountainous regions of Ethiopia. The same authors also report the use of *O. alpina* as firewood and as material for beehives, house construction and fences. The use of *O. alpina* in the traditional treatment of several diseases is also reported by Munyuli Bin Mushambanyi (2001), Byabashaija (2004) and Woldetensay (2014), respectively in DR Congo, Uganda and Ethiopia. Furthermore, some studies point to the use of *O. alpina* in religious rituals of some human communities in highland areas (Tamang *et al.* 2014). However, some uses of *O. alpina* not inventoried in the study area are mentioned by several other studies. These include, for example, flooring (Guadie *et al.* 2019), livestock feed (fodder) (Gebrekidan *et al.* 2018), toothpick making (Sigu 1991, Tamang *et al.* 2014), fishing rods (Tamang *et al.* 2014), household utensils (Guadie *et al.* 2019, Bahru *et al.* 2021), charcoal briquettes and paper (Gebrekidan et *al.* 2018). All these forms of use of *O. alpina that* were not recorded among the respondents in the study area can be explained by the fact that the use of a plant resource depends not only on the utility sought by the population, but also on the endogenous knowledge related to the use of this plant resource (Dossou *et al.* 2012, Ouattara *et al.* 2021).

Although knowledge about the use of *O. alpina* is evenly distributed among the populations of the study area, the relative frequency of each of the seven categories of use identified is diverse depending on the locality of origin of the respondents. Indeed, as multiple as the uses of *O. alpina* may be in Lubero cool highlands region, there is a tendency for demand to be oriented towards a given form of use according to the villages. The use of *O. alpina* for food is more pronounced in Lubango and Masereka than in the other three villages investigated. On the other hand, the uses of this species in construction and in agriculture are more mentioned in Luotu and Kipese respectively. This strong tendency towards agronomic uses of *O. alpina* observed in Kipese corroborates the findings of Vyakuno (2006) and Kambale Ndavaro *et al.* (2021) who mention this village as the largest focus of agricultural production in the study area.

In addition, for the different demands on *O. alpina,* six organs of this species are used by the population in the study area. The stubble, at all stages of development (young stubble, mature stubble and old stubble) is the most

used, with a frequency of use of about 60 %. This result is in line with other studies (Sigu 1991, Bitariho & Mosango 2005, Hunde *et al.* 2010, Tamang *et al.* 2014, Bahru *et al.* 2021) that mention the culm as the organ most involved in the different types of use of *O. alpina*. The same finding was observed by Honfo *et al.* (2015), in Benin, regarding the use value of organs of three different other bamboo species, namely: *Oxytenanthera abyssinica* (A. Rich.) Munro, *Bambusa vulgaris* Schrad. ex J.C. Wendl. and *Dendrocalamus asper* (Schult. & Schult. f.) Backer ex K. Heyne. In the same vein, a recent study by Dje Bi *et al.* (2020) indicates thatch as the organ of *B. vulgaris* most valued by the populations of the Azaguié sub-prefecture in south-eastern Ivory Coast. In any case, this suggests that this organ (thatch) would be the purpose of conservation and private plantations of *O. alpina* in different mountainous areas of Africa. Also, the binary regression revealed that only the main activity is likely to influence the ownership status of bamboo groves (*O. alpina*) in the study area. To this end, the most parsimonious model showed that herders are the ones who in most cases own bamboo groves (*O. alpina*) in the study area. This finding points out a competition pattern for space between agriculture and owning bamboo grove in one hand and a mutualistic pattern between animal husbandry and owning bamboo grove in the other hand. Indeed, people whose main income is based on agriculture need more space to expand their farm for more production and they are not willing to allocate space for bamboo plantation. At opposite, bamboo groves offer shade and forage to animals, so breeder find it a good idea to plant bamboo.

Spatio-temporal dynamics of bamboo groves *(O. alpina)*

The results of the surveys showed that, for the populations of the study area (80 % of the interviewees), the bamboo groves (*O. alpina*) are in a regressive spatio-temporal dynamic rather than progressive or even stable. This peasant perception confirms the results of forest inventories carried out by Masinda *et al.* (2017) which highlight a regressive dynamic of *O. alpina* which, until 2011, colonised more than half of the Mount Tshiabirimu forest, in the North-East of Lubero cool highlands region. Furthermore, regardless of the ownership status of bamboo groves (*O. alpina*), the probability of perceiving a regressive trend is 100 %, on the one hand, and at least 70 % regardless of the village considered. These results corroborate the conclusions of Kambale Ndavaro *et al.* (2021), who report a severe degradation of the forest landscape of Lubero cool highlands region, characterised by an estimated net loss of 70.4 % of forest between 1987 and 2019. In this overall context, the regressive dynamics of *O. alpina* in the study area can be explained by the fact that the degradation of a forest landscape affects all the natural resources it contains (Toko *et al.* 2013). It leads, in particular, to the decrease of some important plant species useful for human communities, the rarefaction of large fauna and the impoverishment of soils (Sambieni *et al.* 2015). This concordance of people's perceptions and the results of scientific studies based on satellite remote sensing and Geographic Information Systems (GIS) reveals the relevance of exploring local knowledge on the evolution of natural resources within a degraded landscape.

On the other hand, the regressive dynamics of the bamboo groves (*O. alpina*) perceived by the populations of the study area could be linked to the multiple solicitations of this plant resource for different uses. Indeed, many authors, such as Traoré *et al.* (2011) and Ouattara *et al.* (2021), have demonstrated that the demands made on a species and the nature of the organs harvested provide information on its vulnerability. Indeed, these authors indicate that the abundant exploitation of certain plant species whose fruits are harvested in the green state and whose seeds are consumed or used for purposes other than reproduction would lead to the progressive decline of these species as a result of the problem of dissemination. These conclusions could apply to *O. alpina,* which in only a few cases is able to flower every year. Indeed, like several other bamboo species, it takes 30 and even 80 years for *O. alpina* to start forming flowers (Chao Chi-son & Renvoize 1989; Schmidt *et al.*, 2013). Fournier and Millogo-Rasolodimby (2007) point out that the harvesting of vegetation for human use is a threat to species and environments, as the overexploitation of natural resources makes their sustainability precarious.

Implications for the conservation of *O. alpina*

The present study provides scientific evidence of the degree of threat (LCPI > 15) to which *O. alpina* is subjected in Lubero cool highlands region. This could be a very necessary step towards a general awareness among actors at various levels of the status and urgency of conservation of this plant species, whose disappearance would undoubtedly lead to an enormous imbalance in the ecosystem services enjoyed by local populations. Moreover, the complete disappearance of this species in the study area would be a real ecological disaster. It would lead to the deterioration of the conservation status of the biodiversity that necessarily depends on this upland bamboo, especially the mountain gorillas (*Gorilla beringei graueri* Matschie), which not only have bamboo groves (*O. alpina*) as their preferred habitat, but also feed on its young shoots (Figure 12) (Masinda *et al.* 2017, Kyungu Kasolene 2019, Kamabale Ndavaro *et al.* 2021). And if nothing is done in the shortest possible time, the current population growth in the study area is likely to exacerbate this alarming environmental problem (Vyakuno 2006, Kyungu Kasolene

2019). The results of this study also show that local people are aware of the level of threat to *O. alpina*, which they use to meet various socio-economic and cultural needs. This can therefore be a steppingstone for the success of any participatory initiative involving these populations in the conservation of the species.

Figure 12. View of: (a) a bamboo grove (*O. alpina*) and (b) a mountain gorilla (*G. beringei graueri*) eating a young bamboo shoot. Pictures of Kambale Ndavaro (2021) and Cimbembe and Mangambu (2014).

Conclusions

This study highlights the different uses made of bamboo (*O. alpina*) and the implications for its conservation in Lubero cool highlands region. It shows that the organs used are taken from wild populations of this species. This has led to a regressive trend in the spatio-temporal dynamics of bamboo (*O. alpina*) in the study area. The Local Conservation Priority Index indicates that this species is in a vulnerable state in the face of threats and therefore conservation actions should be considered. Thus, we advocate the promotion of the cultivation of this plant which is of great socio-economic and cultural importance for the populations of Lubero cool highlands region, in order to reduce the pressure on the groves of wild bamboo (*O. alpina*) populations.

Declarations

List of abbreviations: DR Congo: Democratic Republic of Congo; MEA: Millennium Ecosystem Assessment; NTFPs: Non-Timber Forest Products; MCA: Multiple Correspondence Analysis; PPV: Plant Part Use Value; AIC: Akaike Information Criterion; LCPI: Local Conservation Priority Index, df: degree of freedom

Ethics approval and consent to participate: No respondent was interviewed without giving free consent.

Consent for publication: The persons featured in the images contained in this document have given their consent for their publication.

Availability of data and materials: the data processed and analysed in this study are available for possible requests by the Editorial Board of the journal *Ethnobotany Research &Applications.*

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Literature cited

Abdou Habou MK, Rabiou H, Abdou L, Mamadou IM, Mahamane A. 2020. Ethnobotanical knowledge and socio-cultural importance of *Balanites aegyptiaca* (L.) Del. in Central-Eastern Niger. Afrique SCIENCE 16(4):239-252.

Akaike H. 1998. Information Theory and an Extension of the Maximum Likelihood Principle. In: Parzen E, Tanabe K, Kitagawa G. (eds). Selected Papers of Hirotugu Akaike. Springer Series in Statistics. Springer, New York, NY. USA, Pp. 199-213. doi: 10.1007/978-1-4612-1694-0_15.

Albuquerque UP. 2009. Quantitative ethno-medicine or quantification in ethno-medicine? Journal of Ethnobotany Research and Applications 7:1-3.

Amani Y, Nyakabwa M, Lejoly J. 2008. Floristic analysis of the bamboo forest (*Sinarundinaria alpina*) of Kahuzi-Biega National Park. Annales des Sciences et Sciences Appliquées de l'Université Officielle de Bukavu 1(1):16-27.

Auzuret X, Chemrah B, Duclercq M, Echchidmi Z, Foura Y, Machouri L, Miss F, Pavageau C, Salaun N, Taberlet F, Tahrassat M, Van Haaren B. 2010. Management of forest ecosystems in the context of public intervention. The case of the rural commune of Skoura and the Integrated Management of Middle Atlas Forests project. Ecole Nationale Forestière d'Ingénieurs, Morocco.

Bada Amouzoun AAM, Badou BR, Ahamide IYD, Adomou AC. 2019. Ethnobotanical knowledge and conservation of *Uvariodendron angustifolium* (ENGL. & DIELS) R. E. FRIES (Annonaceae) in the Eweadakplame forest patch in South East Benin, West Africa. Revue Ivoirienne des Sciences et Technologie 34:328-348.

Badjaré B, Kokou K, Bigou-laré N, Koumantiga D, Akpakouma A, Adjavi MB, Abbey GA. 2018. Ethnobotanical study of dry savanna woody species in North Togo: diversity, uses, importance and vulnerability. Biotechnology, Agronomy, Society and Environment 22 (3):152-171.

Bahru T, Kidane B, Mulatu Y. 2021. Ethnobotany of Highland Bamboo (*Arundinaria alpina* (K. Schum.)) in Southern Ethiopia. Small-scale Forestry 20:425-455.

Bitariho R, Mosango M. 2005. Abundance, Distribution, Utilization and Conservation of *Sinarundinaria alpina* in Bwindi and Mgahinga Forest National Parks, South West Uganda. Ethnobotany Research and Applications 3:191-200.

Boulogne M. 2016. Vulnerability of forest landscapes in Ranomafana Park (Madagascar): environmental dynamics and agroforestry trajectories. Environment and Society. PhD thesis, University of Grenoble Alpes.

Busquet MB. 2006. Sustainable integrated strategies:traditional ecological knowledge and adaptive management of spaces and resources. VertigO - the electronic journal of environmental sciences 7:2 [Online]. https://vertigo.revues.org/2279.

Byabashaija MD, Esegu JFO, Kidiya JM, Basoga M, Ondia RK. 2004. Traditional uses of indigenous tree species. Uganda Journal of Agricultural sciences 9:367-371.

Chao CS, Renvoize SA. 1989. A revision of the species described under *Arundinaria* (Gramineae) in Southeast Asia and Africa. Kew Bulletin 44(2):349-367.

Christensen RHB. 2019. Ordinal - Regression Models for Ordinal Data. R package version 2019, 4-25.

Cissé M, Bationo BA, Traoré S, Boussim IJ. 2018. Perception of agroforestry species and their ecosystem services by three ethnic groups in the Boura watershed, Sudanian zone of Burkina Faso. Bois et Forêts des Tropiques 338:29-42.

Dagnelie P. 1998. Theoretical and applied statistics. One and two dimensional statistical inference. de Boeck et Larcier, Brussels, Belgium.

Demangeot J. 1999. Tropicality. Intertropical physical geography. Armand Colin, Paris, France.

Diatta AA, Ndour N, Manga A, Sambou B, Faye CS, Diatta L, Goudiaby A, Mbow C, Dieng SD. 2016. Ecosystem services of *Cordyla pinnata* (Lepr. Ex A. Rich.) Milne-Redh agroforestry park in the southern Arachidian Basin (Senegal). International Journal of Biological and Chemical Sciences 10(6):2511-2525.

Dicko A, Natta AK, Biaou HS. 2017. Connaissances ethnobotaniques et conservation de *Lophira lanceolata* (Ochnaceae) au Bénin (Afrique de l'ouest). Annales des Sciences Agronomiques 21(1):19-35.

Dje Bi DPV, Koffi KJ, Yao CYA. 2020. Social importance of *Bambusa vulgaris* Schrad ex. J.C. Wendl. (Poaceae) in the Sous-préfecture of Azaguié, South-East Côte d'Ivoire. Ethnobotany Research and Applications 19(10):1-17.

Dossou M, Houessou GL, Lougbégnon OT, Tenté A, Codjia J. 2012. Ethnobotanical study of woody forest resources of the Agonvè swamp forest and related terroirs in Benin. Tropicultura 30(1):41-48.

Etat-Civile Territoire de Lubero/R.D. Congo. 2020. Demographic statistics 1975-2020. Lubero (R.D. Congo): Archives de l'Etat-Civile Territoire de Lubero.

Fournier A, Millogo-Rasolodimby J. 2007. Vegetation threatened or shaped by humans? In: Fournier A, Sinsin B, Mensah GA. (eds). What protected areas for West Africa? Conservation de la biodiversité et développement. Éditions Institut de Recherche pour le Développement (IRD), Collection Colloques et Séminaires, Paris, France, Pp. 62-73.

Fox J, Hong J. 2009. Effect Displays in R for Multinomial and Proportional-Odds Logit Models: Extensions to the effects Package. Journal of Statistical Software 32 (1):1-24.

Gaoue OG, Coe MA, Bond M, Hart G, Seyler BC, McMillen H. 2017. Theories and major hypotheses in ethnobotany. Economic Botany 71:269-287.

Gaoue OG, Yessoufou K, Mankga L, Vodouhe F. 2021. Phylogeny reveals non-random medicinal plant organs selection by local people in Benin. Plant, People, Planet 00:1-11

Garba A, Amani A, Abdou L, Mahamane A. 2019. Socioeconomic perceptions and uses of tamarind (*Tamarindus indica* L.) in Southwest Niger: Implications for sustainable domestication and conservation. Journal of Animal & Plant Sciences 40 (2):6584-6602.

Gebrekidan S, Tiki L, Mulatu Y. 2018. Indigenous knowledge on highland bamboo (*Yushania alpina*) management and utilization practices in Kokosa Woreda, South East Ethiopia. Scientific Research and Essays 13(11):111-122.

Gnangle RM, Biaou SSH, Gnangle PC, Balagueman OR, Raphiou M, Dicko A, Kouagou M'M, Natta KA. 2017. Ecosystem services provided by shea parks and their contribution to the well-being of rural populations in the commune of Savè (Central Benin). Annales de l'Université de Parakou. Série « Sciences Naturelles et Agronomie » 7 (1):104-112.

Gomez-Beloz A. 2002. Plant knowledge of the Winikina Warao: The case for questionnaires in ethno-medicine. Economic Botany 56:231-241.

Gouwakinnou GN, Biaou S, Vodouhe FG, Tovihessi MS, Awessou BK, Biaou HSS. 2019. Local perceptions and factors determining ecosystem services identification around two forest reserves in Northern Benin. Journal of Ethnobiology and Ethnomedicine 15(1):1-12.

Guadie YW, Feyssa DH, Jiru DB. 2019. Socio-economic importance of highland bamboo (*Yushania alpina* K. Schum) and challenges for its expansion in Bibugn District, East Gojjam, Ethiopia. Journal of Horticulture and Forestry 11(2):32-41.

Hadonou-Yovo AG. 2020. Biodiversity, forms of use and sustainable conservation of woody plant resources of the Mono Biosphere Reserve in Benin. PhD thesis, University of Abomey-Calavi, Calavi.

Hahn-Hadjali K, Thiombiano A. 2000. Perception of endangered species in the Gourmantché environment (Eastern Burkina Faso). Berichte des Sonderforschungsbereichs 268, 14:285-297.

Hessavi BFM, Adjatin A, Ayena A, Agassounon M, Tchibozo D. 2019. Ethnobotanical investigation, phytochemical profile and cytotoxicity of *Bambusa vulgaris* Schrad. Ex J.C. Wendl. (Poacee), a multipurpose and underutilized species in Benin. Journal of Animal & Plant Sciences 39(2):6435-6453.

Honfo H, Tovissodé FC, Gnanglè C, Mensah S, Salako VK, Assogbadjo AE, Agbangla C, Kakaï RG. 2015. Traditional Knowledge and Use Value of Bamboo in Southeastern Benin: Implications for sustainable management. Ethnobotany Research and Applications 14:139-153.

Hunde T, Adane Y, Adilo M. 2010. Assessment of different vegetative propagation techniques on rooting and shooting ability of *Arundinaria alpina*. Ethiopian Journal of Natural Resources 131-139.

Kambale KJL, Asimonyio AJ, Shutsha ER, Katembo WE, Tsongo MJ, Kavira KP, Yokona IE, Bukasa KK, Nshimba SH, Mpiana TP, Koto-te-Nyiwa Ngbolua. 2016. Floristic and structural studies of forests in the Rubi-Télé hunting area (Bas-Uélé Province, Democratic Republic of Congo). International Journal of Innovation and Scientific research 24(2): 309-321.

Kambale Ndavaro N, Dramani R, Mulondi KG, Muhindo Sahani W, Biaou SSH, Natta KA. 2021. Spatio-temporal dynamics of land use and forest cover in the Lubero Fresh Highlands (D.R. Congo). International Journal of Tropical Geology, Geography and Ecology 45(4):641-658.

Kambale Ndavaro N, Meniko To Hulu JPP, Minengu Mayulu JD, Muhindo Sahani W, Biaou HSS, Natta AK. 2022a. Ecologie et ethnobotanique de la flore forestière du système montagneux du Rift Albertin congolais (Synthèse bibliographique). Revue Africaine d'Environnement et d'Agriculture 5(4):146-159.

Kambale Ndavaro N, Hegbe ADMT, Minengu Mayulu JD, Muhindo Sahani W, Biaou SSH, Natta AK. 2022b. Bamboos (Bambusiadeae): plant resources with ecological, socio-economic and cultural virtues: A review. Journal of Biodiversity and Environmental Sciences 21(4):1-14.

Kyungu Kasolene JC. 2019. Analysis of some factors influencing gorilla decline and habitat impact at Mount Tshiabirimu (Democratic Republic of Congo). IOSR Journal of Humanities And Social Science 24(3):1-14.

Lambinon J, Sérusiaux E. 1983. Contribution to the study of lichens in Kivu (Zaire), Rwanda and Burundi. VII. Eco-geographical approach to the lichenic flora and vegetation in eastern Central Africa. Bothalia 14(3-4):533-538.

Le S, Josse J, Husson F. 2008. FactoMineR: An R Package for Multivariate Analysis. Journal of Statistical Software 25(1):1-18.

Loubelo E. 2012. Impacts of non-timber forest products (NTFPs) on the household economy and food security: the case of the Republic of Congo. PhD thesis, University of Rennes 2.

Masinda MM, Muhesi K, Kasereka K, Kyungu Kasolene JC, Vasombolwa K. 2017. Study of the dynamics of the bamboo forest of Mount Tshiabirimu in Virunga National Park (Northern sector, DR Congo). Annales des Sciences et Sciences Appliquées de l'Université Officielle de Bukavu 4(1/2):100-114.

Mccorkle CM. 1989. Towards a knowledge of Local Knowledge and its importance for Agriculture. Agriculture and Human Values 6:4-12.

Mekuriaw Y, Urge M, Animut G. 2011. Role of indigenous bamboo species (*Yushania alpina* and *Oxytenanthera abyssinica*) as ruminant feed in northwestern Ethiopia. Livestock Research for Rural Development 23(9):2011

Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and human well-being. Synthesis. A report of the Millennium Ecosystem Assessment. Island Press, Washington, United States of America.

Munyuli Bin Mushambanyi T. 2001. Contribution on the domestication of forest plants used by peasants from the Kahuzi-Biega national park: the case of *Arundinaria alpina* in Eastern part of Congo Democratic. Tropicultura 19(4):171-175.

Oksanen J, Blanchet FG, Friendly M, Kindt R, Legendre P, McGlinn D, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Szoecs E, Wagner H. 2019. Vegan: Community Ecology Package. R package version 2.5-6.

Ouattara B, Sanou L, Koala J, Hien M. 2021. Local uses and vulnerability of woody species in the classified forests of Oualou and Tissé in Burkina Faso, West Africa. Afrique SCIENCE 19(3):63-77.

Ouedraogo P, Bationo BA, Sanou J, Traore S, Barry S, Dayamba SD, Bayala J, Ouedraogo M, Soeters S, Thiombiano A. 2017. Uses and vulnerability of ligneous species exploited by local population of northern Burkina Faso in their adaptation strategies to changing environments. Agriculture & Food Security 6(1):1-16.

Oyicha K. 1997. Afromontane Bamboo (*Arundinaria alpina*) in Sidama highlands, its utilization and propagation capacity by culm cuttings. MSc. Thesis, Skinnskatteberg.

Paudyal K, Adhikari S, Sharma S, Samsudin YB, Paudyal BR, Bhandari A, Birhane E, Darcha G, Trinh TL, Baral H. 2019. Framework for assessing ecosystem services from bamboo forests: Lessons from Asia and Africa. Working Paper 255. Bogor, Indonesia, CIFOR.

Pecrot A, Leonard A. 1960. Soil and vegetation map of the Belgian Congo and Ruanda-Urundi. 16. Ridge of Kivu. Explanatory note to the soil and vegetation map. Institut National pour l'Etude Agronomique du Congo belge (INEAC), Brussels, Belgium.

Quinlan M. 2005. Considerations for Collecting Freelists in the Field: Examples from Ethnobotany. Field Methods 17 (3):219-234.

R Core Team. 2021. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/.

Robyns W. 1948. The phytogeographical territories of the Belgian Congo and Ruanda-Urundi. General Atlas of the Belgian Congo, Royal Academy of Colonial Sciences, Brussels, Belgium.

Safari AC, Birhashirwa RN, Fatuma FK, Mangambu JDM. 2015. Bamboo (*Sinarundinaria alpina* (K. Schum.) C.S. Chao & S.A. Renvoize) logging as a cause of conflict between Kahuzi-Biega National Park and the surrounding population: conservation and conflict resolution strategy. International Journal of Environmental Studies 72(2):265-287.

Sambiéni KR, Toyi MS, Mama A. 2015. Peasant perception of landscape fragmentation in the classified forest of Ouémé Supérieur in northern Benin. VertigO - the electronic journal in environmental sciences 2 (15):1-19.

Schmidt O, Wei DS, Tang TKH, Liese W. 2013. Bamboo and fungi. Journal of Bamboo and Rattan 12(1-4):1-14.

Sigu GO. 1991. The Need for Conservation of *Arundinaria alpina* K. Schum in Kenya and its Ecological Significance. In: Proceedings 4th International Bamboo Workshop on Bamboo in Asia and the Pacific held at Chiangmai, Thailand, November 27-30, 1991, IDRC, FAO, UNDP, Pp. 48-50.

Sonwa DJ, Somorin OA, Jum C, Bele MY, Nkem JN. 2012. Vulnerability, forest-related sectors and climate change adaptation : The case of cameroon. Forest Policy and Economics 23:1-9. doi: 10.1016/j.forpol.2012.06.009.

Stapleton C. 2013. *Bergbambos* and *Oldeania,* new genera of African bamboos (Poaceae, Bambusoideae). PhytoKeys 25:87-103. doi: 10.3897/phytokeys.25.6026.

Sys C. 1960. Soil and vegetation map of the Belgian Congo and Ruanda-Urundi. Explanatory note to the soil map of the Belgian Congo and Ruanda-Urundi. National Institute for the Agronomic Study of the Belgian Congo, Brussels, Belgium.

Sys C. 1992. Agro-ecological zones as a basis for rational soil management in North Kivu (Zaire). Bulletin of the Sessions. Royal Academy of Overseas Sciences 38(2):225-243.

Tamang DK, Dhakal D, Shrestha DG. 2014. Bamboo resources of Sikkim Himalaya: diversity, distribution and utilization. Journal of Forestry Research 25:929-934.

Tchatchou B, Sonwa DJ, Ifo S, Iani AM. 2015. Deforestation and forest degradation in the Congo Basin: Current status, causes and outlook. Occasional paper 120. CIFOR, Bogor, Indonesia.

Thompson I, Mackey B, McNulty S, Mosseler A. 2009. Forest Resilience, Biodiversity, and Climate Change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems. Secretariat of the Convention on Biological Diversity, Technical Series *No.* 43, Montreal, Canada.

Toko MI, Toko II, Mèdaho AS, Sinsin B. 2013. Local perceptions of the determinants of dense forest patch fragmentation in the Monts Kouffé region of Benin. Journal of Applied Biosciences 66:5049-5059.

Traoré L, Ouédraogo I, Ouédraogo A, Thiombiano A. 2011. Perceptions, uses and vulnerability of woody plant resources in southwest Burkina Faso. International Journal of Biological and Chemical Sciences 5(1):258-278.

Traoré L, Hien M, Ouédraogo I. 2021. Endogenous strategies for the preservation of *Canarium schweinfurthii* (Engl.) (Burseraceae) in the Cascades region (Burkina Faso). Ethnobotany Research and Applications 21(1), 1-17.

Vihinen M, Euranto A, Luostarien P, Nevalainen O. 1992. MULTICOMP: a program package for multiple sequence comparison. Bioinformatics 8(1):35-38.

Vyakuno K. 2006. Anthropic pressure and rational management of the Lubero highlands in D.R.C. Relations between society and physical environment in an equatorial mountain. PhD thesis, University of Toulouse II-Le Mirail.

Weiss K, Moser G, Germann C. 2006. Perception of the environment, professional conceptions and cultural behaviours of farmers in favour of sustainable development. European Review of Applied Psychology 56(2):73-81.

White F. 1983. The vegetation of Africa: a descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. UNESCO, Paris, France.

Wickham H. 2016. Elegant Graphics for Data Analysis. Springer-Verlag, New York.

Woldetensay Z, Amberber M, Tamirat A, Mulatu A. 2014. Opportunities for Bioprospecting Genetic Resources in Ethiopia. Jounal of Biodiversity, Bioprospecting and Develoment 1(133):1-7.

Yedomonhan H, Adomou CA, Aguessy M, Bossou GF. 2017. Evaluation of the ethnobotanical and structural characteristics of *Nesogordonia kabingaensis* (K. Schum.) Capuron ex R. Germ. (Sterculiaceae) in the Ewè sacred forest in Benin in view of defining strategies for its conservation. International Journal of Biological and Chemical Sciences 11(5):2481-2494.

Zeileis A, Cribari-Neto F, Grün B. 2010. Beta Regression in R. http://eeecon.uibk.ac.at/~zeileis/.