Effect of age, gender and formal education on endogenous knowledge of woody plants in communities bordering forest patches of the Lubero Mountain Massif (DR Congo)

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Research

Abstract

Background: In rural human societies, people's knowledge of plants can vary according to some factors, including socio-demographic characteristics. This study was carried out among local communities living near forest patches of the Lubero Mountain Massif in north-eastern Democratic Republic of Congo (DR Congo). Its aim was to assess the effect of age, gender and formal education on the level of endogenous knowledge of woody plants of the forest patches.

Methods: Ethnobotanical surveys were carried out among 449 people in 13 villages bordering forest patches in the study area, using semi-structured individual interviews and focus groups. The different categories of use of woody plants were identified. The effect of age, gender and formal education on the level of local knowledge of woody plants was investigated using negative binomial regression.

Results: A total of 80 woody species belonging to 77 genera and 43 families were mentioned by the respondents, who used them in five main categories: energy, handicrafts, medicine, construction and food. Age and gender had a significant effect on the number of woody species identified ($P<0.05$). Old people (age ≥ 60 years) knew on average twice as many woody species as adults (30 < age < 60) and young people (age ≤ 30 years), while men knew significantly more species than women.

Conclusions: These findings confirm the unequal distribution of endogenous knowledge based on socio-demographic factors and suggests that males and older people with more knowledge of woody species should be considered as key players in the conservation of woody plant resources in the study area.

Keywords: Ethnobotanical hypothesis, Endogenous knowledge, Socio-demographic characteristics, Woody plants, Conservation, Mountain forests, Lubero, DR Congo.

Background

On a global scale, human-plant interactions represent a particular interest for the livelihood of human communities (Avantunde *et al.* 2008; Amjad *et al*. 2013; Kathambi *et al.* 2020). Indeed, for centuries, humans have maintained existential relationships with forest plants, which provide them with enormous ecosystem goods and services, most of which contribute to the satisfaction of the most fundamental human needs (Gouwakinnou *et al.* 2019; Soe & Yeo-Chang 2019; Kaltenborn *et al.* 2020). In Sub-Saharan Africa, rural human societies are most closely linked to forest plant resources for their subsistence, due to the lower living standard of their populations (Kathambi *et al.* 2020; Ndavaro *et al.* 2023). Members of rural communities are endowed with endogenous knowledge and practices that are incorporated into their habits and passed down from generation to generation as a result of their overdependence on forest plant resources (McMillen 2012; Parrotta *et al.* 2016; Badjaré *et al.* 2018; Cissé *et al.* 2018; Ndavaro *et al.* 2023). Endogenous knowledge is dynamic as a result of close interactions with natural systems (Kathambi *et al.* 2020) and the diverse experiences acquired over centuries in constantly changing environmental, socio-economic and political contexts (Parrotta *et al.* 2016). Local knowledge of forest plants and their applications is distributed throughout local communities according to ethnic groupings and household income, and it is also correlated with several individual attributes such as age, gender, religion, education level, and the main activity of the inhabitants (Ayantunde *et al.* 2008; Gaoue *et al.* 2017; Gouwakinnou *et al.* 2019; Gonçalves *et al.* 2021).

The woody plants of the forest patches of the Lubero Mountain Massif play an important role in the socio-economic and cultural life of local communities (Vyakuno 2006; Ndavaro *et al.* 2023) in the Democratic Republic of Congo (DR Congo), which has a population that is 70% peasant (Karume *et al.* 2022). Indeed, more than 80% of this region population in the north-east of DR Congo relies heavily on woody plants of forest patches for their subsistence in terms of food supply, primary medical care, domestic fuel or charcoal, building materials for residential houses, handicraft products, etc. (Ndavaro *et al.* 2023). However, these woody plants are currently in a state of very severe deterioration and acute vulnerability due to their increasing overexploitation by local communities characterized by high population growth (Lutumba *et al.* 2021; Kapiri *et al.* 2023).

Endogenous knowledge relating to woody phytoresources and their uses must be prioritized in fundamental research to ensure the sustainability of the supply and cultural services provided by woody plants to human communities bordering the forest patches of the Lubero Mountain Massif. Documenting this knowledge is more crucial as its erosion could lead to serious consequences, in particular the more gradual loss of woody plants in forest patches (Parrotta *et al.* 2016; Negi *et al.* 2018). Furthermore, several studies (Albuquerque 2006; Estomba *et al.* 2006; Gaoue *et al.* 2017; Kathambi *et al.* 2020) mention that in rural societies, the use of plants by local communities depends not only on their availability (in terms of ecological abundance, seasonality, prices, access to markets and gardens or natural spaces where the plants are found), but also the level of their knowledge by the habitats. Therefore, for management policies for woody plants in the forest patches of the Lubero Mountain Massif to be sustainable, they must integrate the traditional knowledge that local communities associate with them (Dossou *et al.* 2012). More specifically, it is important to understand how endogenous knowledge about woody plants from the forest patches of the Lubero Mountain Massif is distributed within local communities according to the main individual socio-demographic characteristics, namely: age, gender and formal education. This approach is crucial, as it improves the understanding of human-plant interactions and contributes to the conservation and sustainable use of plant resources (Albuquerque & Ferreira Júnior 2023).

Since the seminal work of Phillips and Gentry (1993), some major theories and hypotheses in ethnobotany have examined the distribution of endogenous knowledge about plants and their uses in different human communities around the world according to ecological, geographical, economic and socio-cultural factors (Albuquerque 2006; Gaoue *et al.* 2017; Albuquerque *et al.* 2019; Leonti *et al.* 2020; Ferreira Júnior *et al.* 2021; Albuquerque & Ferreira Júnior 2023). Regarding social factors, the local plant knowledge dynamics hypothesis proposes that various individual sociocultural and demographic traits, such as gender, age and level of formal education are all related to the level of knowledge of a plant (Gaoue *et al.* 2017). However, the way in which these three individual socio-demographic factors affect endogenous knowledge of plants is still being debated in the scientific literature (Voecks & Leony 2004; Havingude *et al.* 2008; De Culuwé *et al.* 2009; Dossou *et al.* 2012; Sop *et al.* 2012). The distribution of endogenous knowledge based on age, gender and formal education could be either equitable or unequal not only depending on the region of study, but also on the plant resources exploited (Dossou *et al.* 2012). This make sense since endogenous knowledge is linked to a specific place, culture or society (Warren 1991). This why the subject merits investigation based on the unique characteristics of each region and plant taxonomic groups. Taking these characteristics into account could help guide conservation actions for plant resources, and also contribute to the well-being of rural human communities (Camou-Guerrero *et al.* 20008; Dossou *et al.* 2012).

The current study investigates the ethnobotanical hypothesis of the dynamics of plants local knowledge by evaluating the effect of age, gender and level of formal education on local knowledge of woody plants of the forest patches of the Lubero Mountain Massif. The hypothesis that we seek to test in this study predicts that the level of endogenous knowledge of woody plants of the forest patches of the Lubero Mountain Massif is higher among people of advanced age and those of the female sex, but it is lower among people with a high level of formal education. The study is of operational interest in two ways: (i) to safeguard the local communities' endogenous knowledge of woody species that contribute to human well-being, given the frequent migrations that occur in the study area, and (ii) to identify the key local players to be directly involved in the program for the conservation and sustainable management of woody forest potential of the Lubero Mountain Massif.

Materials and Methods

Study area

The study was carried out among communities living in villages bordering forest patches of the Lubero Mountain Massif in north-eastern DR Congo, in Central Africa (0°48'14.4'' S; 0°41'52.8'' N; 27°48'3.6''-29°32'9.6'' E). From a phytogeographic point of view, the Lubero Mountain Massif is located in the regional center of Afromontane endemism (White 1983) and covers approximately 9049.5 km^2 (Vyakuno 2006). The altitude varies from 900 to 3117 m above sea level. The environment is under the influence of the equatorial climate, tempered by the mountains (Vyakuno 2006; Ndavaro *et al.* 2023). The average annual temperature varies from 15°C to 17°C in the cool highlands (2000 to 3117 m altitude), from 18°C to 20°C in the warm highlands (1400 to 2000 m altitude) and from 21°C to 25°C in the western high plateau (900 to 1400 m altitude) (Sys 1992; Vyakuno 2006; Ndavaro *et al.* 2021). The soils are thick, poor, fragile and diverse in their grain size (Pecrot & Leonard 1960; Sys 1960; Vyakuno 2006).

The altitudinal variation of precipitation (1250 – 2183 mm) affects the structure of forest plant communities, which are subdivided into three main types: a mountain forest (2000 – 3117 m altitude) containing species characteristic of the mountain such as *Podocarpus milanjianus* Rendle, *Aningeria adolfi-friederici* (Engl.) Robyns & GCC Gilbert, *Macaranga kilimandscharica* Pax and *Oldeania alpina* (K. Schum.) Stapleton, a mid-mountain forest (1400 – 2000 m altitude) dominated by *Markhamia lutea* (Benth.) K. Schum. and *Aningeria adolfi-friederici*, and a low mountain forest (900 – 1400 m altitude) including species characteristic of the lowland and plateau forest such as *Gilbertiodendron dewevrei* (De Wild.) J. Leonard, *Cynometra alexandri* CH Wright, *Piptadenia africana* Hook. f., *Pycnanthus angolensis* (Welw.) Warb., *Ricinodendron heudelotii* (Baill.) Pierre ex Pax and *Staudtia stipitata* Warb. (Vyakuno 2006).

Demographically, the Lubero Mountain Massif is one of the most densely populated high-altitude regions in north-eastern DR Congo, with an average population of 407.8 inhabitants/km^2 (Etat-Civile-Lubero/RD Congo 2023). The inhabitants of the Lubero Mountain Massif are Bantus of the Nande ethnic group, which includes four main clan groups: Baswagha, Basukali, Bamate and Batangi (Ndavaro *et al.* 2021). The local economy is mainly based on agriculture (potatoes, corn, wheat, onions, leeks, beans, cabbage, cauliflower, cassava and carrots), livestock (rabbits, sheep, goats, cattle and poultry), logging and trade (Vyakuno 2006; Kujirakwinja *et al.* 2007; Ndavaro *et al.* 2023).

Ethnobotany survey and identification specimens of woody plants

This study received prior authorization from the Administrator of the Territory of Lubero, for field work, and from the General Academic Secretary of the Catholic University of Graben (DR Congo), for the consultation and use of specimens and the photographic album of woody species of forest patches of the study area. Nobody was questioned without having given their free oral consent. Ethnobotanical surveys were conducted among members of the thirteen (13) local communities adjoining the ten (10) forest patches of the Lubero Mountain Massif (Figure 1) that served as study sites from January to March 2023. The sample size of respondents was determined using the normal approximation of the binomial distribution (E.1) proposed by Dagnelie (2013):

$$\text{E.1: } N = \frac{\left(U_{1-\frac{\alpha}{2}}\right)^2 * p(1-p)}{d^2}$$

with N: the sample size ; $U_{1-\frac{\alpha}{2}} = 1{,}96$ (normal distribution value for α = 0.05); d: marginal error of the estimate set at a value of 5%; p: proportion of people who know and exploit woody resources of the forest patches studied here (0.86: estimated from a preliminary survey involving a sample of 100 people taken at random around each forest patches).

Thus, a total of 449 people, chosen at random, were individually interviewed using a semi-structured questionnaire with photographs and specimens of the 105 woody species (divided into 46 families and 86 genera) collected in forest patches during forest inventories carried out between January and April 2022. The interviews were conducted with the help of two local intellectuals who are familiar with the names of plants in the local language. The specimens and the photographic album of woody species used during ethnobotanical surveys are kept in the private herbarium of the Laboratory of Ecology, Geomorphology and Geomatics of Catholic University of Graben in Butembo (DR Congo). Respondents were given sufficient time to exhaust the information about the woody plants they remembered. Furthermore, in each survey village, group discussions were organized to validate the data collected from individual interviews. It considered four key public services of the village: (i) the village chief, (ii) the head of the Environment and Sustainable Development department, (iii) the head of the Forest Inspection Service and (iv) the head of the Agriculture, Fisheries and Livestock Service (AGRIPEL).

During the interviews, the main data collected focused on: (i) the socio-demographic profile of the respondent (age, sex, level of formal education), (ii) the names of the species recognized in local languages, (iii) the use categories and (iv) the hierarchical preference scores of each species within the use categories. The distribution of respondents by age class followed that of Dje Bi *et al.* (2020), namely: young people (age ≤ 30 years); adults (30 < age < 60); elderly (age ≥ 60 years). In practice, the respondents were asked to give the name and uses of the different species they recognized. Moreover, they were asked to rank in order of preference the species they recognized per use category, to help determine the preference score of each species for its different use categories using the formula E.2. The preference score of a given species for a respondent is the average score of the species considering all the use categories for which it was cited by the respondent. Then, the overall preference score of the species is its average score considering all respondents. The scientific names of the woody species identified by the respondents were verified in the online taxonomic databases Tropicos (www.tropicos.org), World Flora Online (http://www.worldfloraonline.org) and Plants of the World Online (https://powo.science.kew.org). Their conservation status was established from the IUCN database (http://www.iucnredlist.org/).

$$\text{E.2: Score} = \frac{1+N-ni}{N}$$

with N: the number of species recognized by the respondent for a given use category; n: the preference rank of species *i* for this use category. Table 1 presents the names of the forest patches, the survey villages and the sample size of respondents by sex, age and level of formal education.

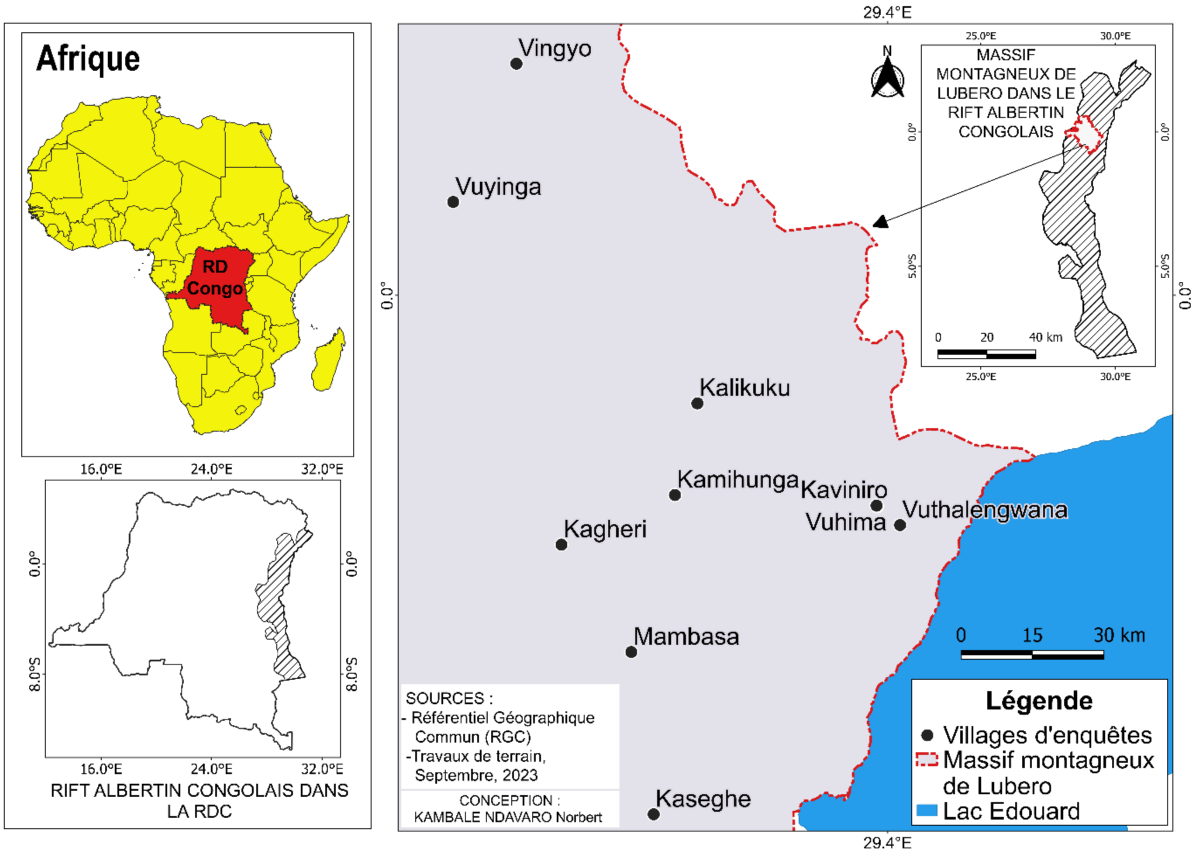

Figure 1. Location of survey villages in the Lubero Mountain Massif, north-eastern DR Congo in central Africa.

Table 1. Forest patches, survey villages and sample size of respondents by sex, age class and level of formal education.

Forest patches	Villages bordering forest patches	Number of people surveyed per village	Number of people surveyed by sex, age and level of formal education							
			Sex		Age classes			Level of formal education		
			Men	Women	Youth	Adults	Old	Illiterate	Primary	Secondary
	Shangola	25	10	15	9	16	0	6	3	16
Kalikuku	Kalikuku	35	12	23	12	22	1	3	5	27
	Vutokonye	35	9	26	25	9	1	7	20	8
Kagheri	Kagheri	50	15	35	35	12	3	12	25	13
Kamihunga	Kamihunga	40	11	29	24	13	3	10	17	13
Kaseghe	Kaseghe	60	28	32	52	4	4	19	27	14
Kaviniro	Kaviniro	28	15	13	23	4	1	10	13	5
Vuyinga	Kudo	30	14	16	23	3	4	14	8	8
	Vuthumbe	28	14	14	21	4	3	11	9	8
Mambasa	Mambasa	30	12	18	25	4	1	11	5	14
Vingyo	Vingyo	30	9	21	25	4	1	9	15	6
Vuhima	Vuhima	34	14	20	26	5	3	17	12	5
Vuthalengana	Vuthalengwa	24	12	12	16	4	4	9	9	6

Data Analysis

Response rate of used plants (F)

The response rate of the used woody species was calculated using the following mathematical expression:

$$F = \frac{S}{N} x\ 100$$

where F is the calculated response rate, S is the number of people who gave a positive response (Yes) for the use of the woody species concerned for the use category considered and N the total number of people interviewed. This rate indicates the most used species for each use category in the environment and varies from 0 to 100. The value 0 indicates that the species is not used and 100 indicates that it is used by all respondents.

Assessment of the informant consensus factor (ICF)

In order to assess the respondents' agreements on the woody species used for a given use category, the factor (degree) of use consensus (Informant Consensus Factor "ICF") was calculated according to the adapted formula from Heinrich *et al.* (1998):

$$ICF = \frac{N_{uc} - N_s}{N_{uc} - 1}$$

with: N_{uc} = number of citations for a use category; N_s = number of woody species used by informants in a given use category. This value varies from 0 to 1. It is close to 1 when the plant is used by a large number of respondents for a particular use category and/or if information is exchanged between informants on the use of species for a particular use category, and 0 (low) when plants are chosen at random or if there is no exchange of information about use among informants.

Assessment of the effect of age, gender and formal education on knowledge of woody plants

Following the calculation of these various ethnobotanical indices, the various processing and statistical analyzes were carried out using R software version 4.1.2 (R Core Team 2021). In order to have a global view of endogenous knowledge on the use of woody species, the percentages of citations from different use categories were presented in a radar diagram using the *circlize package* (Gu 2014). Also, a principal component analysis (PCA) was carried out using the *FactoMineR packages* (Le *et al.* 2008) and *factoextra* (Kassambara & Mundt 2020) to identify the categories of uses that relate to different species. To evaluate the effect of age class, gender and level of formal education on the ethnobotanical knowledge (number of species and number of use categories) of woody species by local communities, we first calculated and represented in a bar diagram using the *ggplot2 package* (Wickham 2016) the average number of species as well as the average number of use categories cited by age group, by sex and by level of formal education with corresponding standard deviations. We then performed negative binomial regression using the *MASS package* (Venables & Ripley 2002). Negative binomial regression was recommended to overcome the overdispersion observed by previously carrying out a Poisson regression because of the discrete nature of the response variables which are the number of species and the number of use categories cited by the respondents. The graph of the effects of the negative binomial model was constructed for each response variable under the *ggstatsplot package* (Patil 2021).

Results

Endogenous knowledge of woody plants and their uses

A total number of 80 woody species distributed in 77 genera and 43 families was mentioned by the interviewed people. Fabaceae was the most cited family by respondents (10 species), followed by Euphorbiaceae (6 species), Meliaceae (5 species) and Annonaceae and Rubiaceae (each with 4 species) (additional file: Table S1: woody plant species are accompanied by their respective families, IUCN conservation status and ICF). These woody species are used by local communities mainly as fuelwood (25.75%), as craft materials (23.13%), for medico-magical purposes (22.01%), as materials for construction of houses (19.78%), and very little as food (9.33%) (Fig. 2). Furthermore, an ICF index greater than or equal to 95% was noted for each of the use categories, which indicates concordance of information between respondents for each use category (Table 2). Considering a threshold of 50% response rate (Table S1), *Myrianthus arboreus* P. Beauv. (ICF = 55.01%) is the best-known species for food while *Maesa lanceolata* Forssk. (ICF = 52.56%) and *Albizia gummifera* (JF Gmel.) CA Sm. (ICF = 50.56%) are the best-known species as energy wood. On the other hand, no species has reached the 50% citation threshold for the other use categories.

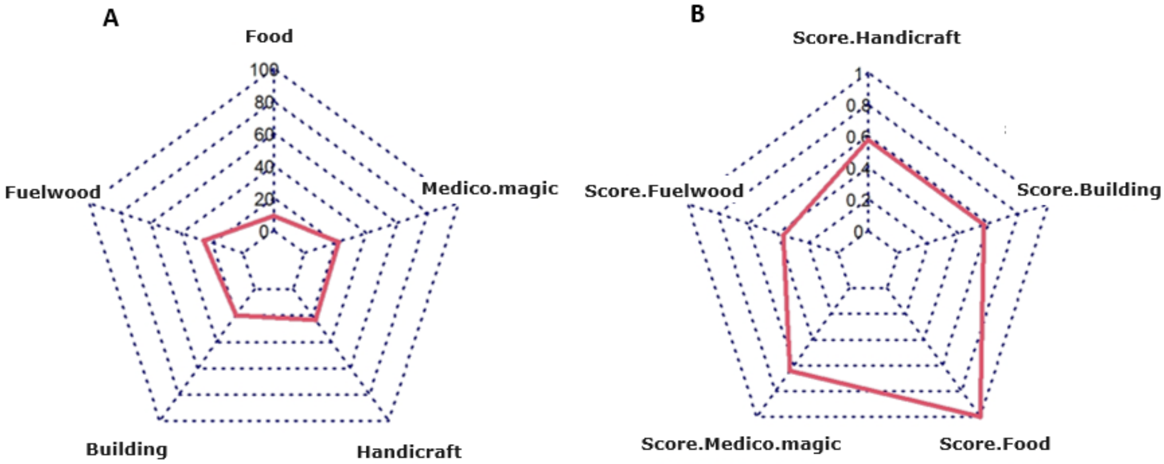

Figure 2. Radar diagrams showing: A) the percentage of use categories and B) the median species preference score by use category.

Table 2. Informant Consensus Factor (ICF) by use category.

Use category	ICF
Food	0.9599
Fuelwood	0.9812
Building	0.9558
Handicraft	0.9645
Medico-magic	0.9656

The PCA enabled the association of woody species with use categories (Fig. 3). The first three principal components of the PCA explain 89.7% of the variation in species preference scores by use category. The first main component rigorously contrasts the “Food” use category with the “Wood-energy” use category. On the other hand, while the second main component combines the use categories “Medico-magic” and “Crafts”, the third main component rigorously opposes them. On one side, the projection of species and use categories in the plane formed by components 1 and 2 (Fig. 3A) suggests that the species *Syzygium guineense* (Willd.) DC., *Myrianthus arboreus*, *Anonidium mannii* (Oliv.) Engl. & Diels are the most preferred for food uses; the species *Albizia gummifera*, *Maesa lanceolata*, *Ocotea usambarensis* Engl., *Piptadenia africana*, *Sapium ellipticum* (Hochst.) Pax, *Ilex mitis* (L.) Radlk., *Harungana madagascariensis* Lam. ex Poir., *Podocarpus milanjianus* and *Musanga cecropioides* R. Br. ex Tedlie are more preferred for energy wood; the species *Prunus africana* (Hook. f.) Kalkman, *Monodora myristica* (Gaertn.) Dunal, *Aphanocalyx cynometroides* Oliv., *Pavetta lasioclada* (K. Krause) Mildbr. ex Bremek. are the most preferred for medico-magical uses. On the other side, the plane formed by components 1 and 3 (Fig. 3B) shows that the species *Mitragyna stipulosa* (DC.) Kuntze, *Trichoscypha ferruginea* Engl., *Dracaena arborea* K.Koch, *Gilbertiodendron dewevrei*, *Entandrophragma utile* (Dawe & Sprague) Sprague and *Xylopia staudtii* Engl. & Diels are most preferred as woody materials in crafts.

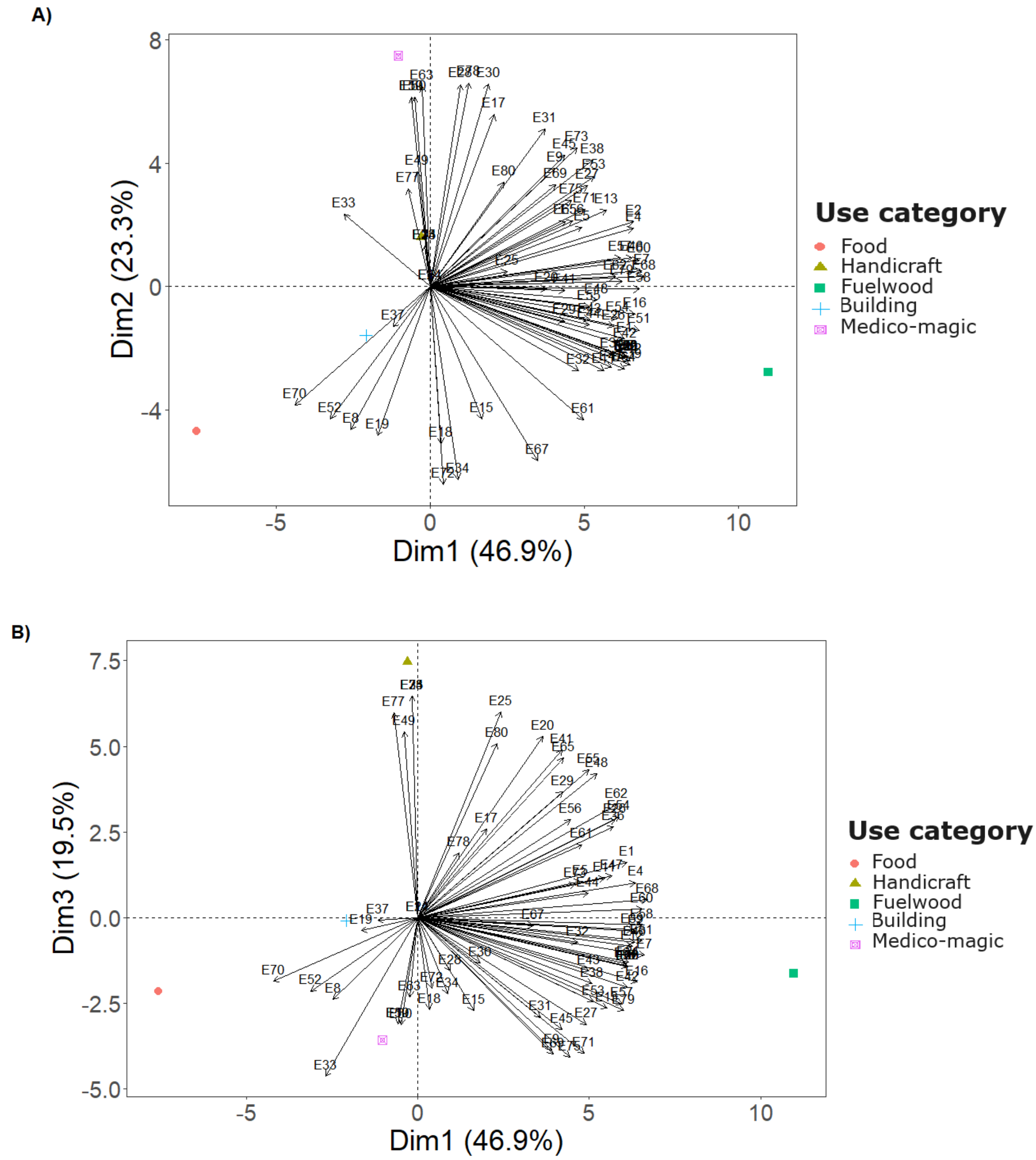

Figure 3. Projection of species and use categories in the plane formed by A) axes 1 and 2 and B) axes 1 and 3 of the principal component analysis on the basis of the preference scores of species by use category.

Note: **E1** = *Vachellia xanthophloea* (Benth.) Banfi & Galasso, **E2** = *Albizia gummifera* (JF Gmel.) CA Sm., **E3** = *Alnus acuminata* Kunth, **E4** = *Alstonia boonei* De Wild. , **E5** = *Amphimas pterocarpoides* Harms, **E6** = *Angylocalyx pynaertii* De Wild., **E7** = *Aningeria adolfi-friedericii* (Engl.) Robyns & GCC Gilbert, **E8** = *Anonidium mannii* (Oliv.) Engl. & Diels, **E9=** *Anthocleista vogelii* Board., **E10** = *Aphanocalyx cynometroides* Oliv., **E11** = *Beilschmiedia louisii* Robyns & R. wilczek, **E12** = *Bersama mildbraedii* Gürke, **E13** = *Bridelia ferruginea* Benth, **E14** = *Buchnerodendron speciosum* Gürke, **E15** = *Canarium schweinfurthii* Engl., **E16** = *Celtis mildbraedii* Engl. , **E17** = *Cleistopholis glauca* Pierre ex Engl. & Diels, **E18** = *Coccineorchis bracteosa* (Ames & C.Schweinf.) Garay, **E19** = *Cola nitida* (Vent.) Schott & Endl. **,** **E20** = *Cordia africana* Lam., **E21** = *Cynometra alexandri* CH Wright, **E22** = *Dombeya rotundifolia* (Hochst.) Planch., **E23** = *Dracaena arborea* K.Koch, **E24** = *Englerina woodfordioides* (Schweinfurth) Balle ex MGGilbert, **E25** = *Entandrophragma cylindricum* Sprague , **E26** = *Entandrophragma utile* (Dawe & Sprague) Sprague, **E27** = *Erythrina abyssinica* Lam., **E28** = *Fagara macrophylla* Engl., **E29** = *Ficalhoa laurifolia* Hiern, **E30** = *Ficus mucuso* Welw. ex Ficalho, **E31** = *Ficus vallis-choudae* Delile, **E32** = *Galiniera coffeoides* Delile, **E33** = *Garcinia epunctata* Stapf, **E34** = *Garcinia punctata* Oliv., **E35** = *Gilbertiodendron dewevrei* (De Wild.) J.Léonard, **E36** = *Grewia louisii* R. Wilczek , **E37** = *Guarea thompsonii* Sprague & Hutch., **E38** = *Harungana madagascariensis* Lam. ex Poir., **E39** = *Ilex mitis* (L.) Radlk., **E40**

= *Juniperus procera* Hochst. ex Endl., **E41** = *Khaya anthotheca* (Welw.) C. DC., **E42** = *Lysimachia ruhmeriana* Vatke, **E43** = *Macaranga kilimandscharica* Pax, **E44** = *Macaranga spinosa* Müll. Arg., **E45** = *Maesa lanceolata* Forssk., **E46** = *Maesopsis eminii* Engl., **E47** = *Markhamia lutea* (Benth.) K. Schum., **E48** = *Maytenus acuminata* (L. f.) Loes., **E49** = *Mitragyna stipulosa* (DC.) Kuntze, **E50** = *Monodora myristica* (Gaertn.) Dunal, **E51** = *Musanga cecropioides* R. Br. ex Tedlie, **E52** = *Myrianthus arboreus* P. Beauv., **E53** = *Myrica mildbraedii* Engl., **E54** = *Neoboutonia macrocalyx* Pax, **E55** = *Ocotea usambarensis* Engl., **E56** = *Oncoba glauca* (P. Beauv.) Planch., **E57** = *Pancovia laurentii* (De Wild.) Gilg ex De Wild., **E58** = *Parinari excelsa* Sabine, **E59** = *Pavetta lasioclada* (K. Krause) Mildbr. ex Bremek., **E60** = *Piptadenia africana* Hook. f., **E61** = *Podocarpus milanjianus* Rendle, **E62** = *Polyscias fulva* (Hiern) Harms, **E63** = *Prunus africana* (Hook. f.) Kalkman, **E64** = *Psychotria palustris* E.Petit, **E65** = *Pycnanthus angolensis* (Welw.) Warb., **E66** = *Ricinodendron heudelotii* (Baill.) Pierre ex Pax, **E67** = *Santiria balsamifera* Oliv., **E68** = *Sapium ellipticum* (Hochst.) Pax, **E69** = *Spathodea campanulata* P. Beauv., **E70** = *Staudtia stipitata* Warb., **E71** = *Strombosia glaucescens* Engl., **E72** = *Syzygium guineense* (Willd.) DC., **E73** = *Tabernaemontana crassa* Benth., **E74** = *Tessmannia africana* Harms, **E75** = *Trema africanum* (Planch.) Blume, **E76** = *Trichilia gilletii* De Wild., **E77** = *Trichoscypha acuminata* Engl., **E78** = *Trilepisium madagascariense* DC., **E79** = *Xylopia staudtii* Engl. & Diels, **E80** = *Xymalos monospora* Baill. **Legend: E** = Species.

Effect of age, gender and level of formal education on knowledge of woody plants

Figure 4 presents the average number of woody species as well as the average number of use categories cited by age class, by sex and by level of formal education with the corresponding standard deviations. Negative binomial regression applied to ethnobotanical survey data shows that the level of formal education influences neither knowledge of woody species nor knowledge of their uses. On the other hand, the factors age and gender have a significant effect on knowledge of species, but do not influence knowledge of their uses (Fig. 5A and 5B). Old people recognize on average twice as many species as adults and young people (Fig. 4A). Men know significantly more species than women (Fig. 4B).

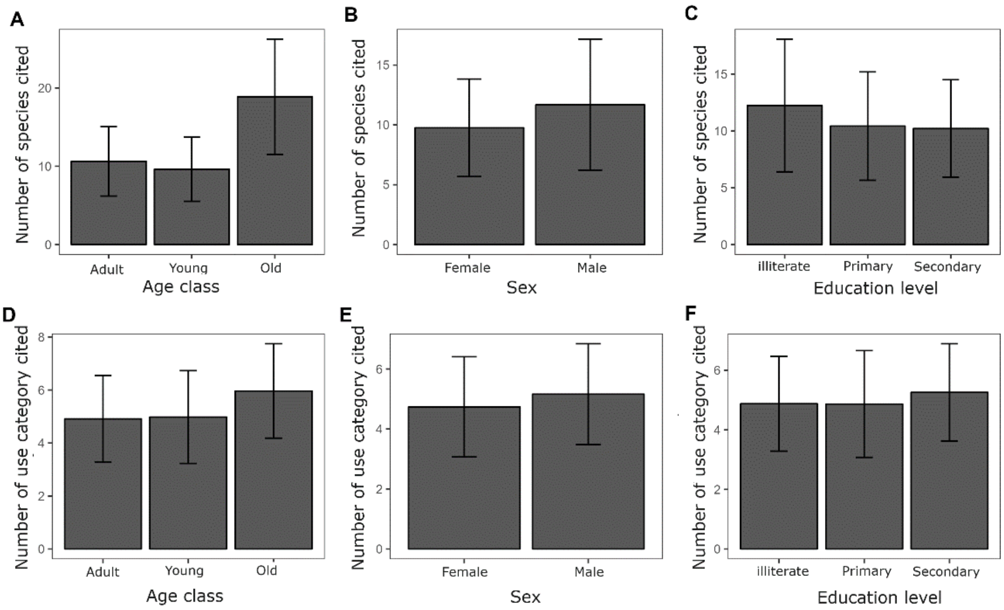

Figure 4. Average number of species cited with standard deviations: A) by age class, B) by sex and C) by level of formal education; number of use categories cited: D) by age class, E) by sex and F) by level of formal education.

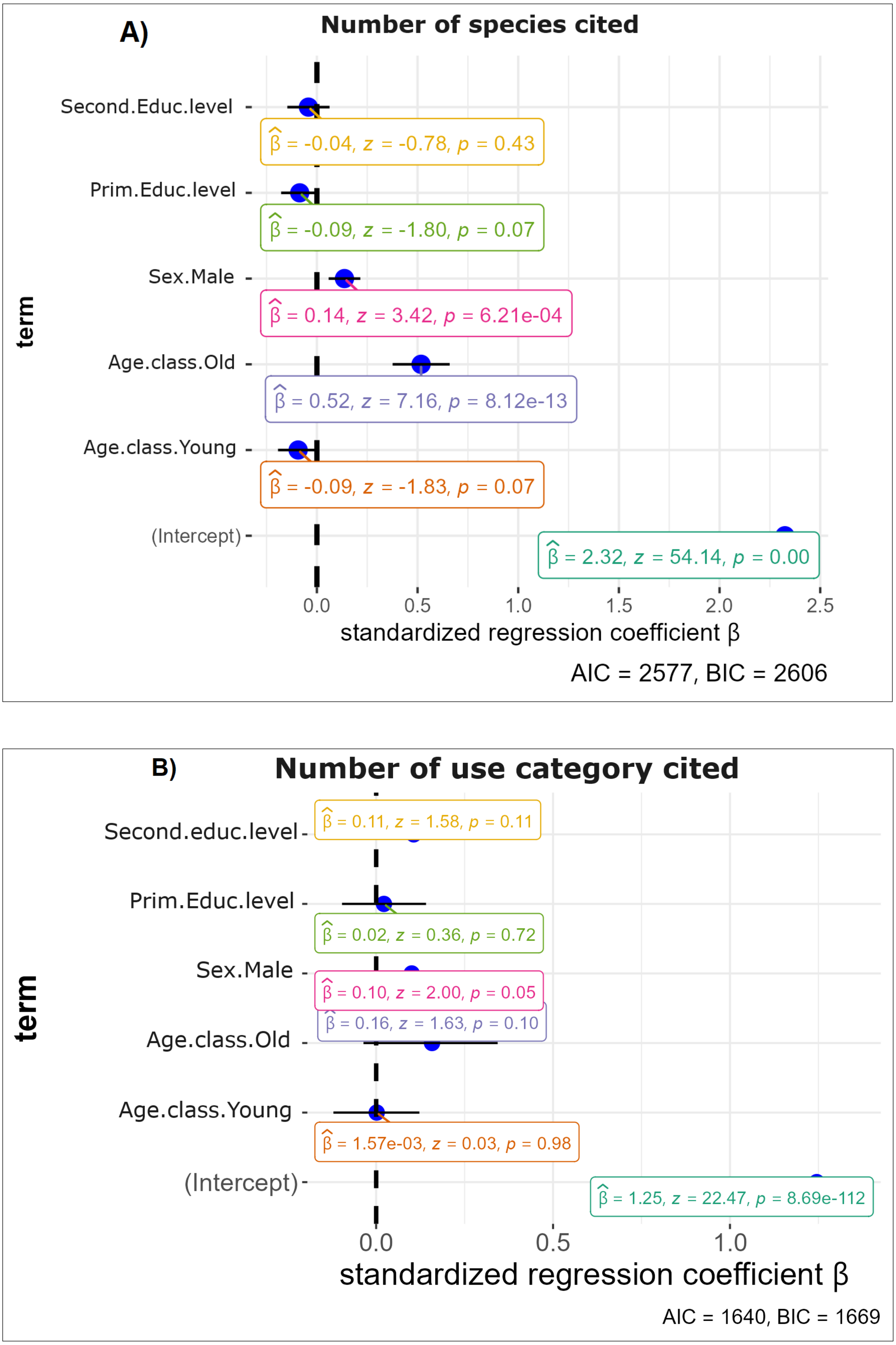

Figure 5. Coefficient of negative binomial regression showing the effect of age class, gender and level of formal education: A) on the number of species cited, B) on the number of use categories cited. Legend: β = coefficient of each modality, z = z statistic, p = probability value, class age = age class, Level.inst = level of formal education, AIC = Akaike Information Criterion, BIC = Bayesian Information Criterion.

Discussion

Endogenous knowledge and uses of woody plants

In total, 80 woody species (77 genera and 43 families) were cited and recognized by the interviewed people during the surveys. These woody species are used by local communities in five main areas of socio-economic and cultural life: energy, crafts, traditional medicine and magic, construction and food. Different studies carried out in several regions of the world have also reported the same categories of uses for woody species (Dossou *et al.* 2012; Sop *et al.* 2012; Moteetee *et al.* 2019; Ouédraogo *et al.* 2019; Mapaya *et al.* 2022). More particularly, the use of plant species for medico-magical purposes is a common trend in certain African countries (Sop *et al.* 2012; Lougbegnon 2019; Dossou-Yovo *et al.* 2021; Gbesso *et al.* 2021), South-America (Paiva de Lucena *et al.* 2012; Alonso-Castro *et al.* 2019), Asia (Ernst *et al.* 2015) and European region (Mateji *et al.* 2020). The PCA mentioned 22 woody species most frequently used by local populations for all of the identified use categories. These useful woody species in greater demand would therefore be the most vulnerable to the strong anthropogenic pressure exerted on the forest formations in the study area (Ndavaro *et al.* 2021, 2023). They should therefore be considered as a priority in the development program for the forest patches investigated, in order to optimize their long-term contribution to the socio-economic and cultural well-being of local populations (Dossou *et al.* 2012; Sop *et al.* 2012; Rocha *et al.* 2019; Peng *et al.* 2021).

The ICF index highlighted information concordance among respondents for each use category. This agreement of viewpoints would result from combining semi-structured individual interviews with group discussions during the surveys. These results agree with other ethnobotanical studies carried out in the Albertine Rift (Shalukoma *et al.* 2015; Gumisiriza *et al.* 2019) and in other parts of the world (Juárez-Vázquez *et al.* 2013; Santhosh Kumar *et al.* 2019). They suggest a strong dependence of local populations on woody forest resources (Upadhyay *et al.* 2011; Shalukoma *et al.* 2015). Furthermore, the very high ICF index value (≥ 95%) for each of the identified use categories indicates that the people surveyed not only have good knowledge of woody species and a coherent collective knowledge of their uses, but also exchange information with each other (McMillen 2012; Juárez-Vázquez *et al.* 2013; Shalukoma *et al.* 2015; Gumisiriza *et al.* 2019; Avakoudjo *et al.* 2020).

Individual socio-demographic factors associated with knowledge of woody plants

The dynamics of local knowledge of woody species was assessed based on three individual factors: age, gender and level of formal education. Unlike the level of formal education, age and gender had significant effect on the number of cited species by respondents. Indeed, regarding the "formal education" variable, the number of woody species cited as well as their uses did not appear to differ among the three levels of formal education studied (illiterate, primary and secondary). These results could suggest that, in the study area, educated people are as interested in forest resources as less educated people. In another sense, this could reflect a stable or even regressive spatio-temporal dynamic of the woody populations in the study area causing the people who left the villages to pursue secondary education elsewhere to return with the same level of knowledge of the resources of woody forests than those who stayed without continuing their studies or going to school. These results are similar to those of the study done by Beltrán-Rodríguez *et al.* (2014) who were unable to associate the level of formal education with ethnobotanical knowledge in Mexico. However, they do not agree with the research hypothesis which indicates that "*the level of endogenous knowledge of the woody species of the forest patches of the Lubero Mountain Massif is lower among people with a high level of formal education*". Our results thus disagree with the general ethnobotanical hypothesis that less educated people know more about plants than people with high formal education (Gaoue *et al.* 2017). Contrary to our findings, many studies have found a negative correlation between formal education and the level of local knowledge (McMillen *et al.* 2012; Avakoudjo *et al.* 2019). For instance, in Brazil, Voecks and Leony (2004) found that literacy and increased access to formal education were negatively correlated with knowledge of medicinal plants. Teixdor-Toneu *et al.* (2021) explain this situation by the fact that by doing extensive investigations, there is a risk of isolating oneself from the channels of transmission of local plant knowledge.

A significant difference between age groups was found in the "age" variable. Indeed, the number of woody species mentioned by people of advanced age (age ≥ 60 years) was double that indicated respectively by adults (30 < age < 60 years) and young people (age ≤ 30 years). This significant effect of age on the number of woody species mentioned by those interviewed confirms our hypothesis that "*the level of endogenous knowledge of woody species in the forest patches of the Lubero Mountain Massif is higher among older people*". Our results thus test the general ethnobotanical hypothesis that older people have more knowledge about local plants than younger people and adults (Gaoue *et al.* 2017). Sop *et al.* (2012) also found that older people reported significantly more woody species than younger people in Burkina Faso. This can be explained by the knowledge of local plants acquired by old people over time. Furthermore, several studies explain this scenario by observing a trend among most young people attending secondary and higher schools to abandon local knowledge related to plants, which they consider obsolete compared to modern dietary and medicinal habits, and to be unwilling to learn this endogenous knowledge from elders (Reyes-García *et al.* 2013; Pasquini *et al.* 2018; Avakoudjo *et al.* 2019). Many other studies carried out in different regions of the world have revealed the age-related dynamics of ethnobotanical knowledge (Ayatunde *et al.* 2008; Gouwakinou *et al.* 2011; Koura *et al.* 2011; Dossou *et al.* 2012; Gaoue *et al.* 2017).

In terms of the "gender" variable, the results of our study also revealed a significant difference in the number of woody species recognized by men and women. Indeed, male respondents mentioned a significantly higher number of woody species than female respondents. Traoré *et al.* (2020) also found that men in Burkina Faso know more medicinal plants than women. Our results do not support the research hypothesis, which predicts that "*the level of endogenous knowledge of the woody species of the forest patches of the Lubero Mountain Massif is higher among females*". They also reject the general ethnobotanical hypothesis that women have more knowledge about local plants than men (Ricker 2002; Voecks 2007; Albuquerque *et al.* 2011; Hanazaki *et al.* 2013; McCarter & Gavin 2015; Gaoue *et al.* 2017). Indeed, the significantly higher number of woody species recognized by men could be attributed to the fact that, in the study area, women solely collect wood in the forests for domestic energy needs and this in accessible places closer to human habitation. On the other hand, men collect wood in mountain forests for a variety of purposes (charcoal, firewood, crafts, traditional medicine, magic, food). In the event of depletion of woody resources in the low mountain forests, they are forced to take them from medium and high altitudes, which are places very far from the villages and not accessible to women; which could potentially strengthen their knowledge of local plants. However, it is useful to emphasize that, contrary to the results of our research, certain studies, such as Sop *et al.* (2012) were unable to consider gender as a factor determining knowledge of woody plants.

Implications for woody plants' sustainable management and conservation

Internationally, out of all the woody species mentioned by respondents, 54 species are classified as *Least Concern* (LC), six species (*Entandrophragma cylindricum*, *Entandrophragma useful*, *Guarea thompsonii*, *Khaya anthotheca*, *Parinari excelsa* and *Prunus africana*) as *Vulnerable* (VU), two species (*Beilschmiedia louisii* and *Mitragyna stipulosa*) as *Near Threatened* (NT) and one species (*Psychotria palustris*) as *Endangered* (EN) (Table S1). Furthermore, *Myrianthus arboreus*, *Maesa lanceolata* and *Albizia gummifera* are among the 22 woody species most frequently used by local communities for all the identified use categories. These species used for food and domestic energy recorded the highest ICF values of 55.01%, 52.56% and 50.56%, respectively. As a result anthropogenic threats weigh on the woody plants of the forest patches of the Lubero mountain massif given their overexploitation by local communities. Indeed, the exploitation of woody plants through irrational harvesting techniques would lead to the destabilization of their population's structure and reduction in their population's density, thus negatively impacting the survival of species in the future. In the current context of the Lubero mountain massif, the damage caused by the overexploitation of woody forest species is amplified by agricultural activities and the extension of pasture areas generating more serious fragmentation effects in the region (Ndavaro *et al.* 2021).

As no effort has been undertaken so far to remedy this, we hereby make some recommendations to the national institutions in charge of forest management and to local populations as well: (i) give conservation priority to the species with highest preference scores as they might be potentially the most threatened , (ii) establish a red list of threatened species of the RD Congo, (iii) involve communities in the governance of forest resources by grouping them into associations of forest owners, forest managers and the different category of users, (iv) involve men and the old people whose ethnobotanical knowledge has proven to be higher in actions aimed at restoring forest patches, (v) educate older people to pass on knowledge of local plants to younger generations, (vi) educate local communities on rational techniques for removing plant organs according to species, (vii) carry out reforestation actions in order to improve the conservation status of useful and multi-use species, (viii) put in place appropriate measures to limit or prohibit access to woody species declared threatened, (ix) set up gardens of medicinal-magical plants around species heavily exploited in medicine or which have become rare in the environment, and (x) promote community or private wood plantations to meet the needs of domestic energy, house construction and crafts.

Conclusion and Recommendation

This study allowed us to explore the distribution of endogenous knowledge on woody plants in the forest patches of the Lubero Mountain Massif according to the age, gender and level of formal education of local populations. The study revealed that the forest patches of the study area are full of useful and multi-use woody species that are widely exploited by local populations. Local inhabitants hold large knowledge about these woody species as well as the different forms of their use, grouped into five main categories: domestic energy, crafts, traditional medicine and magic, house construction and human food. While this knowledge is equitably distributed between people with different levels of formal education (illiterate, primary and secondary), it is, on the other hand, unequally distributed between men and women, on the one hand, and between young people, adults and people of advanced age, on the other hand. These observed variabilities in the factors affecting local knowledge of woody species in the forest patches of the study area confirm the unequal distribution of local knowledge depending on socio-demographic factors. They therefore constitute a technical database to guide conservation strategies for woody plants in the forest patches of the study area which face incessant anthropogenic pressures. Thus, a local group composed of the representatives of the different user categories, forest owners no matter sex and formal education level must be set up. The local group led by males and old people with more knowledge of local plants must be involved, by the forest management office, as key players in the design and implementation conservation plan.

Declarations

List of abbreviations: DR Congo - Democratic Republic of Congo; AIC - Akaike Information Criterion; BIC - Bayesian Information Criterion; ICF - Informant Consensus Factor; IUCN - International Union for Conservation of Nature.

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Consent for publication: Not applicable

Availability of data and materials: Not applicable

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Appendix A. Supplementary data

Table S1: Woody species identified by members of the communities living in villages bordering forest patches of the Lubero Mountain Massif with their botanical families, their IUCN conservation statuses on a global scale and their Informant Consensus Factor indices (ICF) by use category.

Species	Botanical family	IUCN Status	ICF by use categories				
			Food	Wood energy	Construction	handicraft	Medico-magic
Albizia gummifera (J.F.Gmel.) CA Sm.	Fabaceae	LC	0.22	50.56	16.04	31.63	34.52
Alnus acuminata Kunth	Betulaceae	LC	0.00	1.34	0.00	0.00	0.00
Alstonia boonei De Wild.	Apocynaceae	LC	0.00	6.46	0.89	4.90	4.90
Amphimas pterocarpoides Harms	Fabaceae	LC	0.22	0.89	0.00	0.67	0.45
Angylocalyx pynaertii De Wild.	Fabaceae	LC	0.00	0.67	0.00	0.00	0.00
Aningeria adolfi-friederici (Engl.) Robyns & GCC Gilbert	Sapotaceae	NE	1.11	12.25	3.56	5.57	4.90
Anonidium mannii (Oliv.) Engl. & Diels	Annonaceae	LC	15.14	8.24	0.00	0.00	0.22
Anthocleista vogelii Planch.	Gentianaceae	LC	0.00	40.76	11.80	3.79	28.29
Aphanocalyx cynometroides Oliv.	Fabaceae	LC	0.00	0.00	0.00	0.00	0.67
Beilschmiedia louisii Robyns & R. wilczek	Lauraceae	NT	0.00	2.90	0.89	0.45	0.00
Bersama mildbraedii Gürke	Francoaceae	NE	0.00	0.67	0.22	0.22	0.00
Bridelia ferruginea Benth.	Phyllanthaceae	LC	0.22	25.39	14.48	8.02	17.37
Buchnerodendron speciosum Gürke	Achariaceae	NE	0.00	0.00	0.00	0.00	0.00
Canarium schweinfurthii Engl.	Burseraceae	LC	5.57	5.57	0.22	1.56	2.00
Celtis mildbraedii Engl.	Cannabaceae	LC	0.00	6.90	1.56	0.45	0.67
Cleistopholis glauca Pierre ex Engl. & Diels	Annonaceae	LC	0.00	2.23	0.00	2.00	2.90
Coccineorchis bracteosa (Ames & C.Schweinf.) Garay	Orchidaceae	NE	0.22	0.22	0.00	0.00	0.00
Cola nitida (Vent.) Schott & Endl.	Malvaceae	LC	2.00	1.56	0.00	0.45	0.00
Cordia africana Lam.	Cordiaceae	LC	0.00	5.57	0.00	5.12	0.22
Cynometra alexandri C.H.Wright	Euphorbiaceae	LC	0.00	11.36	0.22	0.45	0.00
Dombeya rotundifolia (Hochst.) Planch.	Malvaceae	LC	0.00	0.67	0.00	0.00	0.00
Dracaena arborea K.Koch	Asparagaceae	LC	0.00	0.00	0.00	0.45	0.00
Englerina woodfordioides (Schweinfurth) Bale ex MGGilbert	Loranthaceae	NE	0.00	0.00	0.00	0.00	0.00
Entandrophragma cylindricum (Sprague) Sprague	Meliaceae	VU	0.00	4.90	0.22	10.91	0.22
Entandrophragma utile (Dawe & Sprague) Sprague	Meliaceae	VU	0.00	3.79	0.22	2.23	0.89
Erythrina abyssinica Lam.	Fabaceae	LC	0.00	9.13	0.67	1.34	6.24

Fagara macrophylla Engl.	Rutaceae	LC	0.45	11.58	0.89	7.57	20.94
Ficalhoa laurifolia Hiern	Sladeniaceae	LC	0.22	23.39	17.59	21.83	5.35
Ficus mucuso Welw. ex Ficalho	Moraceae	LC	0.00	13.81	3.56	12.25	13.81
Ficus vallis-choudae Delile	Moraceae	NE	0.00	4.90	1.34	1.34	3.12
Galiniera coffeoides Delile	Rubiaceae	NE	0.00	7.80	4.45	1.11	0.45
Garcinia epunctata Stapf	Clusiaceae	LC	2.45	1.34	0.00	0.67	2.45
Garcinia punctata Oliv.	Clusiaceae	LC	3.34	4.01	3.34	2.00	1.11
Gilbertiodendron dewevrei (De Wild.) J.Léonard	Fabaceae	LC	0.00	0.00	0.00	0.45	0.00
Grewia louisii R. Wilczek	Malvaceae	LC	0.00	4.23	1.56	2.90	0.00
Guarea thompsonii Sprague & Hutch.	Meliaceae	VU	0.00	0.00	0.67	0.00	0.00
Harungana madagascariensis Lam. ex Poir.	Hypericaceae	LC	1.34	36.08	11.14	14.48	31.85
Ilex mitis (L.) Radlk.	Aquifoliaceae	LC	0.00	18.93	9.13	7.35	0.22
Juniperus procera Hochst. ex Endl.	Cupressaceae	LC	0.00	15.14	0.22	0.00	0.45
Khaya anthotheca (Welw.) C. DC.	Meliaceae	VU	0.00	7.57	0.45	8.46	0.45
Lysimachia ruhmeriana Vatke	Primulaceae	NE	0.00	4.90	1.56	0.00	0.45
Macaranga kilimandscharica Pax	Euphorbiaceae	NE	0.00	0.45	0.45	0.22	0.22
Macaranga spinosa Müll. Arg.	Euphorbiaceae	LC	0.00	12.69	10.02	6.90	3.34
Maesa lanceolata Forssk.	Primulaceae	LC	0.22	52.56	18.04	8.24	41.87
Maesopsis eminii Engl.	Rhamnaceae	LC	0.00	3.56	0.00	1.78	0.89
Markhamia lutea (Benth.) K. Schum.	Bignoniaceae	LC	0.00	13.81	6.01	6.90	0.22
Maytenus acuminata (L.f.) Loes.	Celastraceae	LC	0.00	7.57	1.78	4.68	1.11
Mitragyna stipulosa (DC.) Kuntze	Rubiaceae	NT	0.00	0.00	0.00	1.56	1.34
Monodora myristica (Gaertn.) Dunal	Annonaceae	LC	0.00	0.45	0.00	0.00	3.12
Musanga cecropioides R.Br. ex Tedlie	Urticaceae	LC	0.00	23.83	3.56	7.35	4.45
Myrianthus arboreus P.Beauv.	Urticaceae	LC	55.01	35.41	0.89	5.35	7.35
Myrica mildbraedii Engl.	Myricaceae	NE	0.00	18.71	7.35	6.24	19.15
Neoboutonia macrocalyx Pax	Euphorbiaceae	LC	0.00	9.58	1.78	4.68	1.34
Ocotea usambarensis Engl.	Lauraceae	NE	0.00	40.09	24.50	39.64	10.69
Oncoba glauca (P.Beauv.) Planch.	Salicaceae	NE	0.00	2.45	2.67	1.34	0.89
Pancovia laurentii (De Wild.) Gilg ex De Wild.	Sapindaceae	NE	0.00	2.90	1.34	0.89	1.11
Parinari excelsa Sabine	Rubiaceae	VU	0.00	15.81	5.79	4.68	5.35

Pavetta lasioclada (K. Krause) Mildbr. ex Bremek.	Fabaceae	LC	0.00	0.00	0.00	0.00	0.67
Piptadenia africana Hook.f.	Fabaceae	NE	0.45	32.74	6.90	21.16	19.15
Podocarpus milanjianus Rendle	Podocarpaceae	LC	8.46	18.04	8.69	12.25	0.22
Polyscias fulva (Hiern) Harms	Araliaceae	LC	0.22	36.53	19.82	26.95	10.47
Prunus africana (Hook.f.) Kalkman	Rosaceae	VU	0.00	0.89	0.00	0.89	5.12
Psychotria palustris E.M.A.Petit	Rubiaceae	EN	0.00	7.80	2.23	0.45	0.00
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	LC	0.67	10.69	2.90	11.36	6.24
Ricinodendron heudelotii (Baill.) Heckel	Euphorbiaceae	LC	0.00	0.22	0.00	0.00	0.00
Santiria balsamifera Oliv.	Burseraceae	LC	1.56	1.78	0.67	0.67	0.00
Sapium ellipticum (Hochst.) Pax	Euphorbiaceae	LC	0.22	33.63	6.90	16.93	11.80
Spathodea campanulata P.Beauv.	Bignoniaceae	LC	0.45	6.24	0.00	0.22	5.12
Staudtia stipitata Warb.	Myristicaceae	NE	0.89	0.00	0.00	0.00	0.00
Strombosia glaucescens Engl.	Olacaceae	LC	0.00	0.45	0.22	0.00	0.45
Syzygium guineense (Willd.) DC.	Myrtaceae	LC	32.29	30.96	17.37	14.48	6.01
Tabernaemontana crassa Benth.	Apocynaceae	LC	0.45	13.59	1.11	7.35	11.58
Tessmannia africana Harms	Fabaceae	LC	0.00	0.00	0.00	0.22	0.00
Trema africanum (Planch.) Blume	Cannabaceae	LC	0.00	7.13	3.12	0.00	5.12
Trichilia gilletii De Wild.	Meliaceae	LC	0.00	0.89	0.00	0.00	0.00
Trichoscypha acuminata Engl.	Anacardiaceae	NE	0.00	0.00	0.22	1.11	0.45
Trilepisium madagascariense DC.	Moraceae	NE	0.00	0.22	0.22	1.34	0.67
Vachellia xanthophloea (Benth.) Banfi & Galasso	Fabaceae	LC	0.00	0.45	0.00	0.45	0.00
Xylopia staudtii Engl. & Diels	Annonaceae	LC	0.00	0.45	0.00	0.45	0.45

Legend: IUCN = International Union for Conservation of Nature; ICF = Informant Consensus Factor; LC = Least Concern; VU = Vulnerable; NT = Near Threatened; EN = Endangered; NE = Not Evaluated.