

# Traditional Knowledge and Medicinal Importance of African Rosewood (*Pterocarpus Erinaceus* Poir, Fabaceae) Across Sociolinguistic Groups in Benin

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## Research

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# Abstract

## Background

*Pterocarpus erinaceus* Poir. is a spontaneous species from the three ecological zones of Benin. It is multipurpose species integrated to the socio-economic and cultural livelihood of populations, especially in rural areas. This study examined the different uses made of the organs of *Pterocarpus erinaceus* in Benin in relation to sociolinguistic diversity with a view to highlighting the knowledge of local populations on *Pterocarpus erinaceus* and the threats to the species.

## Methods

A total of 355 respondents, spread over 18 townships in Benin, were interviewed using a questionnaire. About 57 uses shared into 7 categories of use have been identified from the different sociolinguistic and socio-professional groups. Relative citation frequencies (FRC) of each habitat were then calculated for the description of habitat variation according to Ecological zones (EZ). In order to describe the diversification of the categories of uses and the organs / part of the tree, Principal component analyzes are carried out on the matrices comprising relative citation frequencies (FRC) grouping together the socio-demographic factors and the categories of use under the packages FactoMineR and factoextra

## Results

This study revealed that the wood of *Pterocarpus erinaceus* is used (25.43%) in crafts, as charcoal, and service wood, while the leaves are mainly used (23.14%) as fodder and by traditional medicine. Concerning the roots and bark, they are used (27.14%) not only for evil spirits and bewitchment but also in animal medicine in cattle. About 60 diseases and symptoms are cured by the various organs of *Pterocarpus erinaceus*. These different uses of *Pterocarpus erinaceus* varied from one sociolinguistic group to another.

## Conclusion

The study showed that all organs of *Pterocarpus erinaceus* are used in various forms of use for various purposes and make it an important species for rural communities. This result suggests the need to define conservation strategies for natural stands of *Pterocarpus erinaceus* for the sustainable management of the species.

## Background

Human beings still depend largely on the use of plant species for the satisfaction of basic needs. Many people thus value species as a source of food and medicine, providing survival and wealth for humans

[1]. This has led researchers to take an increasing interest in studies about traditional knowledge of plant species, including socio-demographic, ecological and botanical factors, such as sociolinguistic groups, socio-professional groups, age, sex, habitats, areas of occurrence of species, etc. [2, 3, 4, 5]. These studies have become very interesting for the sustainable management of endangered species because they make it possible to assess the differences in knowledge about selection and use of plant resources by sociodemographic groups for defining of priorities, planning and monitoring of conservation [6]. The ecological knowledge of populations on plant species and habitats could contribute to the development of co-management strategies of plant resources for sustainable environmental management [3]. Knowledge of local names facilitates the identification and assessment of species because it provides information on their uses, ecology, plant interactions and morphological traits [2].

*Pterocarpus erinaceus* Poir is an endangered multiple-use species on the IUCN Red List [7] and classified in appendix II of CITES since 2016. The threats to this plant resource are linked to the quality of its wood which has a high commercial value [8, 9], its fodder importance in ruminant breeding [10, 11] and its various traditional uses in the treatment of several diseases and symptoms in animals [12, 13] and humans. As a result, the species's natural populations are declining and tending towards extinction in several countries. The first affected countries were Benin, Guinea Biseau, Ivory Coast, Gambia, Ghana and Nigeria. Faced with this phenomenon, some producers of the wood, including Benin, Burkina Faso, Ivory Coast, Mali, Nigeria and Sierra Leone have taken measures to ban the exploitation and export of timber of *Pterocarpus erinaceus* for several years, yet large quantities of *Pterocarpus erinaceus* logs continue to leave these countries fraudulently into China [9].

*Pterocarpus erinaceus* occurs in the semi-arid natural forests of the Guinean savannah in West Africa. Its distribution area in Benin stretches from south to north. It is found in the three ecological zones which are: the Guinean zone, the Guinean-Sudanese zone and the Sudanese zone, in natural populations in forests woodlands and savannas. But, despite the ban on the cutting and export of *Pterocarpus erinaceus* timber in the form of logs, the overexploitation of the species for uses other than timber and service wood may have serious consequences on the relict populations of the species and on the environment. Currently *Pterocarpus erinaceus* is under strong pressure caused by local forms of organ use in some regions of Benin. In the Atakora region for example, *Pterocarpus erinaceus* is used by some people to substitute for many threatened woody species, such as *Khaya senegalensis* (Desv.) A. Juss, *Azelia africana* Smith ex Pers., *Borassus aethiopum* Mart. [14] for various uses.

This study is designed (i) to determine the ethnoecological knowledge of *Pterocarpus erinaceus* across the three ecological zones of Benin, (ii) to determine the uses of *Pterocarpus erinaceus* organs by sociolinguistic groups, and (iii) to determine the implications of traditional uses of the species in its conservation status in order to depict pathways for sustainable management.

## Materials And Methods

### Study area

This study was carried out in the Republic of Benin, a West African country with an area of 114,763 km<sup>2</sup> whose total population is estimated of 10,008,749 inhabitants, making a population density of 87.2 inhabitants per square kilometer according to the last general population and housing census [15]. The country is bordered by the Atlantic Ocean to the south, Togo to the west, Nigeria to the east and Burkina Faso and Niger to the north. It is located in the tropical zone of West Africa, in the eastern part of the Guinean Dense Humid Forests Ecoregion, although it is outside the natural ranges of the Diversity Centers of Upper and Lower Guinea. The surveys were conducted in 18 townships (Malanville, Kandi, Ségbana, Péhunco, Djougou, Kalalé, Parakou, Tchaourou, Ouèssè, Savè, Glazoué, Bantè, Savalou, Dassa, Djidja, Abomey, Bohicon, Covè) located in the three ecological zones (Guinean zone, Guinean-Sudanese zone and Sudanian zone). The human population in the 18 townships is estimated at 2,794,728 inhabitants, representing 27.92% of the total population of Benin. Fig. 1 gives an overview of the study area.

### Sampling and data collected

The surveys were conducted in the 18 townships chosen at random in each of the three ecological zones of Benin. To this end, an exploratory survey on a sample of 50 people taken at random in each of the municipalities made it possible to determine the proportion ( $p$ ) of those who know at least one use of *Pterocarpus erinaceus*. The number of people to be interviewed was then estimated as follows [16, 17]:

$$N = \frac{U_{\left(1-\frac{\alpha}{2}\right)}^2 p(1-p)}{d^2} \quad (1)$$

Where  $N$ , is the overall size of the sample,  $p$ , the proportion of declared informant using the species during the exploratory phase ( $p = 0.95$ ),  $U_{\left(1-\frac{\alpha}{2}\right)}$  is the value of the statistic of the normal distribution at the value of probability  $1 - \frac{\alpha}{2}$  with  $\alpha = 5\%$ , equal to 1.96;  $d$  the margin error of the estimate set at a value of 7%. The exploratory survey indicated that in the Peulh and Nagos sociolinguistic groups, 70% and 87% respectively know and use at least part of the species. Thus, for a margin error of 7%, the numbers of respondents was 82 and 45 respectively in Peulh and Nago sociolinguistic groups. The same approach was used to determine the number of people to survey for the rest of sociolinguistic groups (Table 1). A total of 355 people were surveyed in all the three ecological zones of Benin.

**Table 1** Number of respondents by ethnic group in agro-ecological zones

sociolinguistic groups	Sample size	
	Absolute frequency	Relative frequency in%
Bariba	27	7.61
Boo	39	10.99
Dendi	19	5.35
Fon	59	16.62
Idaatcha	25	7.04
Itcha	24	6.76
Mahi	35	9.86
Nago	45	12.68
Peulh	82	23.10
Total	355	100.00

### Data processing and statistical analysis

Data analysis was carried out on the basis of five factors: ecological zone (EZ), sociolinguistic group, age, sex and profession. Age group distribution was made according to Assogbadjo et al. [5] as follows: young people (age  $\leq 30$  years); adults people ( $30 < \text{age} < 60$ ); old people (age  $\geq 60$  years). To describe local perception of *Pterocarpus erinaceus* ecology (habitat) according to ecological zones, the chi-square test of independence was performed on the  $n \times p$  matrix (with  $n$  ecological zones and  $p$  habitats of the species). Relative citation frequencies (FRC) [4, 18, 19] of each habitat were then calculated for the description of habitat variation according to EZ by the following formula:

$$FRC = \frac{x}{N} \quad (2)$$

With  $x$  the absolute frequency and  $N$  the total number of respondents for each modality of the considered factor (eg: to mean that over 100 respondents in the Sudanian zone, 20 respondents the forest as the habitat of *Pterocarpus erinaceus*).

To highlight the categories of uses and the most reported organs / parts used, multiple proportion comparison tests were carried out and the proportions were structured under the packages multcompView [20] and PMCMR [21]. In order to describe the diversification of the categories of uses (human food, animal food, crafts, symbolic use (use for traditional ceremonies such as dowry), timber and fuelwood,) and the organs / part of the tree (bark, leaf, trunk, seed , latex), Principal component analyzes are carried out on the matrices comprising relative citation frequencies (FRC) grouping together the socio-demographic factors (Ethnicity, Sex, Age and Profession) and the categories of use under the packages FactoMineR [22] and factoextra [23].

# Results

## Profile description of *Pterocarpus erinaceus* users in Benin.

Table 2 shows the profile of *Pterocarpus erinaceus* users in Benin. Adult men are the most users of the species in all ecological zones (90%). Most of users are carpenters (32.5%) farmers (32.5%) and charcoal makers in the Guinean zone while they are mostly pastoralists and traditional therapists in Guinean-Soudanese and Sudanian zones (respectively 10.53% and 17.84% then 24.67% and 74%). Exceptionally, more than 50% of users are farmers in the Guinean-Soudanese zone. With regard to sociolinguistic groups, Fons is major users of *Pterocarpus erinaceus* in the Guinean zone, while the sociolinguistic groups Nagot (26.32%) and Mahi (19.30%) are major users in Guinean-Soudanese zone. The sociolinguistic groups, Fons (15.79%), Idaatcha (14.62%) and Itcha (14.04%) are also users of the species in Guinean-Soudanese zone. In Sudanian zone, the sociolinguistic group Peulh represent about half (44%) of the users of *Pterocarpus erinaceus*. The sociolinguistic group Boo (26%), Bariba (17.33%) and Dendi (12.67%) also use the species for various needs in this region.

Table 2  
Sociodemographic description of *Pterocarpus erinaceus* users according to ecological zones in Benin

Variables	Modalities	Guinean		Guinean-Soudanese		Soudanian	
		n	N	n	N	n	N
Sexe	Female	03	8.82	14	8.19	-	-
	Male	31	91.18	157	91.81	150	100
Age	Adult	31	91.18	125	73.1	111	74
	Old	01	2.94	33	19.3	36	24
	Young	02	5.88	13	7.6	03	2
Profession	Breeder	02	5.88	18	10.53	37	24.67
	Carpenters	11	32.35	05	2.92	-	-
	Charcoal makers	06	17.65	13	7.6	-	-
	Famers	11	32.35	102	59.65	-	-
	Nurseryman	-	-	-	-	02	1.33
	Sawyers	01	2.94	02	1.17	-	-
	Traditherapist	03	8.82	31	17.84	111	74
Ethnic	Bariba	-	-	01	0.58	26	17.33
	Boo	-	-	-	-	39	26.00
	Dendi	-	-	-	-	19	12.67
	Fon	32	94.12	27	15.79	-	-
	Idaatcha	-	-	25	14.62	-	-
	Itcha	-	-	24	14.04	-	-
	Mahi	02	5.88	33	19.30	-	-
	Nagot	-	-	45	26.32	-	-
	Peulh	-	-	16	09.36	66	44

∴ No variable modality in the zone, n: Absolute frequency, N: Relative frequency %.

### Ecology of *Pterocarpus erinaceus* according to populations

According to the populations, forests and farms (44.8% and 34.82% respectively) are the best habitats known for *Pterocarpus erinaceus*. The species can also be found in fallows (15.56%) and savannas (4.78%). Local perceptions of the species' habitat are not the same from one ecological zone to another

( $\chi^2 = 81.91$ ,  $df = 6$ ,  $Prob < 0.001$ ). Thus, whatever ecological zones, respondents indicated that farms and forests are the most occurring areas, while the inhabitants of Sudanian and Guinean-Soudanese zones also mention fallow. In Guinean-Soudanese zone people exclusively mentioned savannas as the preferred habitat of the species.

### **Diversity of knowledge of the specific uses of *Pterocarpus erinaceus***

Knowledge of the specific uses of parts of *Pterocarpus erinaceus* (Table 3) indicates that this species is used in the treatment of around sixty pathologies, symptoms and diseases and has different names depending on the sociolinguistic group. People of the sociolinguistic group Peulh use the bark and roots to treat wounds, colic, appetite disturbances, constipation, viral anemia and diarrhea, calving difficulties, hemorrhage, infectious disorder, toothache, snakebite and peripneumonia in cattle. Respondents from other sociolinguistic groups use the leaves, bark and roots in the treatment of malaria, fever, hernia, anemia, metrorrhagia, menstrual pain, irregular menses, abscess, hemorrhoid, etc. headaches, stomach aches, tooth decay, mental disorders, skin infections, edema, paralysis of the lower limbs, vision problems, female infertility, gastric ulcer, intestinal worms, general fatigue, typhoid fever, dizziness, urinary tract infections. Respondents from Itcha sociolinguistic group use the plant to treat infections and measles, while those from the Boo sociolinguistic group use the plant to treat abscesses, acne pimples, whitlow and scorpion stings. Bariba sociolinguistic group use the species to treat ringworm and wounds, while Dendi use it to treat snakebite in cattle, scorpion stings, and vision disturbances.

Table 3  
Diversity of uses (organs/parts of the plant) of *Pterocarpus erinaceus* in Benin.

Sociolinguistic groups	Local names	Organs/parts	Categories of uses	Diseases/symptoms/pathologies
Bariba	Tonan	Bark, Leaves	Medicinal	Fever, hernia, anemia, metrorrhagia, menstrual pain, irregular menstruation, abscess, hemorrhoid, headache, stomach ache, dental carrie, abscess, mental disorders, skin infections, edema, malaria, paralysis of the lower limbs, vision problems, female infertility, gastric ulcer, intestinal worms, general tiredness, abortion, typhoid fever, dizziness, urinary tract infections (28)
		Bark	Magic	For evil spirits, couple union (2)
		Bark, leaves, roots	Food and Veterinary	Fodder, weight loss in ruminants, haemorrhage in ruminants (3)
		Roots	Medicinal	Gonococcal disease, vaginal bleeding, babies fontanel, edema (4)
		Sap	Medicinal	Ringworm, wounds (2)
Peulh	Banouhi	Bark	Veterinary	Wound, bovine colic, bovine appetite disturbances, bovine constipation, anemia, bovine viral diarrhea, calving difficulties, bovine hemorrhage, bovine infectious disorders, toothache, snake bite, bovine pleuropneumonia (13)
		Bark, roots	Medicinal	Bewitching, hemorrhoid, hypertension, malaria, visual disturbances, menstrual pain, general tiredness, female infertility, stomach aches, body aches, human and bovine asthenia, hypotonia in children, anemia (14)
		Leaves	Food, Veterinary	Bovine mange, diarrhea, intestinal worms, human and bovine asthenia, weight loss in cows (5)
		Sap	Medicinal	Ringworm, abscess, wounds, skin infections, visual disturbances (5)
		Leaves	Medicinal	Sickle cell disease (1)

*The values in brackets represent the number of symptoms/diseases reported for each part/organ by each sociolinguistic group*

Sociolinguistic groups	Local names	Organs/parts	Categories of uses	Diseases/symptoms/pathologies
Dendi	Tolo	Bark	Medicinal, Veterinary	Dental carrie, metrorrhagia, hemorrhoid, dentition, fever, malaria, Anemia, hypotonia in children, bovine hemorrhage, hemorrhoid, bovine infections, skin infections, stomach aches, snakebite in bovines, malaria, visual disturbances, pain menstrual, irregular menstruation, gastric ulcer (18)
		Root	Medicinal	Stomach ache (1)
		Leaves	Medicinal	Paronychia, malaria, bovine infections (3)
		Sap	Medicinal	Snake bite in cattle, scorpion stings, visual disturbances (3)
Nagot	Egui-Enian / Aïké	Bark, Leaves, root	Medicinal	Anemia, infections, menstrual pain, irregular menstruation, gastric ulcer, hypotonia in children, itching, diabetes, fever, general tiredness, measles, cough, virility (13)
		Bark, Leaves, root	Magic	For evil spirits, bewitchments (2)
		Sap	Medicinal	Skin infections, visual disturbances (2)
Boo	Kpinli	Bark	Medicinal, Veterinary	Anemia, diarrhea, human and bovine asthenia, hemorrhoid, headaches  belly, snakebite in cattle, bovine appetite disturbance, menstrual pain, irregular menstruation, cough (10)
		Root	Medicinal	Muscle weakness, asthenia, virility, scorpion stings (4)
		Leaves	Medicinal, Magic	Abortion, bewitchment, malaria, vaginal bleeding (4)
		Sap	Medicinal	Abscesses, acne pimples, whitlow, scorpion stings (4)
Mahi	Kosso	Bark	Medicinal	Anemia, menstrual pain, irregular menstruation, fever, infections, hypotonia in children, leprosy, stomach ache, measles, infertility (10)
		Root	Medicinal	Stomach pain, abscess (2)

*The values in brackets represent the number of symptoms/diseases reported for each part/organ by each sociolinguistic group*

Sociolinguistic groups	Local names	Organs/parts	Categories of uses	Diseases/symptoms/pathologies
		Leaves	Medicinal	General tiredness, gonorrhoea, high blood pressure, malaria (4)
		Sap	Medicinal	Wound (1)
Fon	Kosso / Kozo	Bark	Medicinal	Anemia, fever, general fatigue, female infertility, hypotonia in children, stomach ache, malaria, general tiredness (8)
		Root	Medicinal	Diabetes, virility, sickle cell anemia, stomach ache, teething, internal hemorrhoid (6)
		Leaves	Medicinal	General tiredness, fever, hemorrhoid, hypotonia in children, malaria (5)
Idaatcha	Akpékpé	Bark	Medicinal	Anemia, hypotonia in children, fever, hernia, menstrual pain, hypotonia in children (6)
		Root	Medicinal	Hemorrhoid, hernia, measles, fever (4)
		Leaves	Medicinal	General tiredness, hypotonia in children, stomach pain (3)
Itcha	Akpékpé	Bark	Medicinal	Anemia, diabetes, gonorrhoea, stomach ache, malaria, measles, infertility (7)
		Root	Medicinal	Menstrual pain, general tiredness, itching, hernia, stomachache, intestinal worms, lower abdomen pain (7)
		Leaves	Medicinal	Diarrhea in ruminants, malaria, hemorrhoid (3)
		Sap	Medicinal	Infection, measles (2)
<i>The values in brackets represent the number of symptoms/diseases reported for each part/organ by each sociolinguistic group</i>				

In addition, Bariba, Nago and Boo reported that the leaves, roots and bark are used to for evil spirits, and prevent bewitchments. These organs are particularly used by Bariba for wedding celebrations in order to guarantee peace in the home (Table 3).

### Sociodemographic factors influencing the use of *Pterocarpus erinaceus*

The citation frequencies of use categories are significantly different from one category to another ( $\chi^2 = 967.93$ ,  $ddl = 7$ ,  $Prob < 0.001$  ; Table 4). Thus, respondents primarily use the tree as timber and service wood (respectively 25.66 and 25.41 as Relative Citation Frequency values). They also make it a medicinal use and a source of food for livestock (respectively 20.96 and 19.67 as Relative Citation Frequency values; Fig. 2).

In addition, there was a dependence of the categories of use on ecological zones (EZ), sex, sociolinguistic group and profession of the respondents (Prob < 0.05). Thus only men use *Pterocarpus erinaceus* in crafts. Uses as fuelwood and lumber are in the same proportions for both sexes. In addition, men use the species more for charring, while women use it in human food. The use in handicrafts is exclusively linked to the Guinean-Sudanese and Sudanian zones while the symbolic use is for Guinean and Guinean-Sudanese zones. Food use in humans is noted exclusively in Guinean-Sudanese zone.

Table 4  
Dependence of citation frequencies on usage categories and sociodemographic factors

Sociodemographic factors	Df	$\chi^2$	P value
Ecological zone	12	58.27	< 0.001
Age	12	13.92	0.306
Sex	06	19.99	0.003
Sociolinguistic group	48	80.21	0.002
Profession	48	115.05	< 0.001

Principal Component Analysis (PCA) performed on the Relative Citation Frequencies Matrix (RFC) of use categories and professions indicated that the first two principal components (PC) bear 61.3% of the baseline information. The categories of uses such as timber, fuelwood, carbonization, human food are strongly correlated ( $| \text{Correlation} | \geq 0.5$ ) with the first PC while the use in food livestock is for the second PC. The projection of professions on these two PC shows that the charcoal makers, farmers and lumberjack use *Pterocarpus erinaceus* more in carbonization, timber (Technology) and firewood while breeders use it more for feeding cattle (Fig. 3a). In addition, the PCA carried out on the matrix of relative citation frequencies (RFC) of categories of use and sociolinguistic groups indicated that the first two PC bear 85.7% of initial information. Human and animal food, use for fuelwood and services, use in craft industries are strongly correlated ( $| \text{Correlation} | \geq 0.5$ ) with the first PC while only use for carbonization is for the second PC. Thus, projection of sociolinguistic groups on these two PC indicates that the sociolinguistic groups Bariba, Boo, Dendi, Fon, Itcha and Mahi use more *Pterocarpus erinaceus* in human and animal food, for fuelwood and services and in the handicrafts whereas Idaatcha use it more for carbonization (Fig. 3b).

### Use of *Pterocarpus erinaceus* organs according to sociolinguistic groups

The most harvested organs are the trunk (25.43%) followed by branch (23.90%), leaves (23.14%) and bark (22.09%) (Fig. 4).

Figure 5 shows the results of the PCA on the matrices containing relative citation frequencies of *Pterocarpus erinaceus* organs and the sociolinguistic factors. It indicates that the first two PC explain at least 70% of the initial information for all the sociolinguistic factors.

The correlation matrices indicated a strong correlation ( $|\text{Correlation}| \geq 0.5$ ) of the Guinean and Sudanian zones with the first PC while the Guinean-Soudanese zone is with the second PC; thus projection of the organs on these first two PC indicated that trunk, leaf, bark, branch and seed are the most used organs in the Guinean and Sudanian zones while the roots and latex are more used in the Guinean-Sudanese zone (Fig. 5a). Analyses also revealed that adult and young variants of the age categories are strongly correlated ( $|\text{Correlation}| \geq 0.5$ ) with the first PC while old variant is with the second PC. Thus, projection of the organs on these two PC showed that trunk, leaf, root, branch, seed and latex are heavily used by young and adults people while bark is more sought by old people (Fig. 5b). With regard to sociolinguistic groups, it revealed that the first PC is strongly correlated with the sociolinguistic groups Bariba, Boo, peulh, Dendi, Mahi and Nago; and the second PC is strongly correlated with the sociolinguistic group Itcha and the third PC with the sociolinguistic group Fon. Thus, projection of the organs on these first three PC indicated that trunk, leaf, bark and branches are the organs most used by Bariba, Boo, Peulh, Dendi, Mahi and Nago while the root and latex are more used more by Itcha and seed by Fon (Fig. 5c & d). Finally, they showed that the traditherapist and Sawyers are strongly correlated with the first PC while famers and nurserymen are strongly correlated with the second PC. The projection of organs on these two PC indicated that trunk, leaf, bark and branches are more used by traditherapists and Sawyers while famers and nurserymen more used roots (Fig. 5e).

## Discussion

### Traditional knowledge of *Pterocarpus erinaceus*

In Benin, *Pterocarpus erinaceus* is well known and exploited for the quality of its wood, fodder and therapeutic virtues. The traditional knowledges of people on *Pterocarpus erinaceus* is are for the most part similar to that noted in Niger and Burkina Faso [11] and in in Togo [24] on the same species. A decoction of the bark effectively combats the anemia frequently suffered by children in rural zones, malaria and rheumatism. The sap from the bark is effective in combating skin infections and vision problems. A decoction of the leaves treats malaria, childhood fever and is used as an infusion for evil spirits. The medicinal properties of *Pterocarpus erinaceus* have been confirmed thanks to the work of Gbohaïda et al. [25] and Tittikpina et al. [26] who revealed the presence of certain chemical substances (flavonoids, saponins and alkaloids) in the roots, bark and leaves of *Pterocarpus erinaceus* with proven antifungal and antibacterial actions. Also, Ouédraogo et al. [27] have revealed the presence of friedeline in the various organs of *Pterocarpus erinaceus*, a compound with anti-tumor, anti-inflammatory, anti-analgesic and anti-pyretic effects. The leaves, which are very palatable by ruminants, constitute an important source of nutrients for livestock, especially in the dry season, due to the very appreciable proportions of crude protein, organic matter, fibers and mineral elements they contain [28]. The wood of *Pterocarpus erinaceus* is used extensively in various economic sectors. Carpenters and joiners are the largest users of *Pterocarpus erinaceus* wood. The wood is also used for charring. This enthusiasm for *Pterocarpus erinaceus* wood for the different socio-professional groups could be linked to its better physical and mechanical properties (density and hardness) compared to other woody species [29, 30].

The results showed that traditional knowledge about the use of the various organs of *Pterocarpus erinaceus* depends on ecological zones, sociolinguistic groups, sex and profession. The use of *Pterocarpus erinaceus* in crafts and carbonization by men could be justified by the fact that the exercise of these professions falls to men, while women have the prerogative of cooking within households, which would justify their knowledge of the species in food. Predominant of craft use in Guinean-Sudanese and Sudanian zones is believed to be due to the fact that there are more carvers in these zones. Leaves use in human food in Guinean-Sudanese zone is linked to the fact that the culinary recipes identified (cooking young leaves in the form of vegetable for food) are specialties of the sociolinguistic groups Itcha in Bantè and Nago in Savè, both townships located in Guinean-Sudanese zone. The distribution of use categories in relation to ecological zones would therefore be linked to the traditional knowledge of the sociolinguistic groups live there. The intensity of organ harvesting would also depend on the endogenous knowledge of sociolinguistic groups in the ecological zone. Indeed, the higher use of leaves and bark by sociolinguistic groups Peulh, Dendi, and Bariba in Sudanian zone would be linked to the practice of ruminant breeding in this zone and then the high concentration of cattle and sheep in this part of the country.

### **Traditional uses of *Pterocarpus erinaceus* and pressure on the species in Benin**

The exploitation of *Pterocarpus erinaceus* for animal food and the treatment of several diseases or symptoms results in frequent pruning and debarking (Fig. 6) of trees in forests, farms and wherever the species is found in Benin. These various anthropogenic pressures exerted on its populations have a negative impact on the survival of the species. Indeed, Adjonou et al. [31] have shown that the uncontrolled and repeated harvesting of *Pterocarpus erinaceus* organs by the different socio-professional groups (farmers, breeders, traditional healers) as well as the poor exploitation practices of the species seriously affect growth and natural regeneration of the species.

The strong pressure exerted on the species by human testifies to its importance. But despite this importance of *Pterocarpus erinaceus* in Benin, the species does not receive sustained attention for the long-term management of its natural populations.

### **Pathways for conservation and sustainable management of *Pterocarpus erinaceus* in Benin**

The protection enjoyed by *Pterocarpus erinaceus* in Benin through the prohibition of logging and exporting timber, its inclusion in Appendix II of CITES and its classification in the category of endangered species on the Red List of IUCN are not sufficient for its long-term protection. It therefore appears imperative that additional measures be taken for the restoration of the species' populations, their sustainable management and conservation. With regard to the current conservation status of the species and the degradation speed of its residual population, it is advisable to combine both *in situ* and *ex situ* conservation forms as urgent conservation strategies to keep the genetic diversity of *Pterocarpus erinaceus* and therefore its survival. A key strategy for conservation of this species could be improved habitat management to enable connections between relict populations. Agroforestry systems, if well managed, could help maintain this connectivity across the landscape, thus acting as biological corridors between populations [32]. Relict populations of the species which should be high conservation priority as

well as other protected areas in the savannah regions could also serve as a corridor between the planting plots of the species. This method of conservation was proposed by Ouinsavi et al. [33] and Ouinsavi and Sokpon [32] for relict populations of *Milicia excelsa* in Benin and by Assogbadjo [34] who qualified it as "ex-situ conservation on farm" for stands of *Adansonia digitata*) in Benin. In a practical way, this strategy will consist by conserving plots of *Pterocarpus erinaceus* cultivated within the ecological niche of the species, so that these new populations establish a bridge in terms of gene flow between different sub-populations pre-existing. As such, the research work carried out by Johnson et al. [35], Ouinsavi et al. [36] and Rabiou et al. [37] respectively on the isolation of microsatellites, vegetative propagation trials by stem cuttings and *Pterocarpus erinaceus* layering trials could serve as a basis to ensure the future preservation of the species.

## Conclusion

This study revealed various uses of *Pterocarpus erinaceus* in Benin such as, medicinal, fuelwood, timber and service, artisanal and fodder uses. All organs of the species are used and valued for various purposes, making *Pterocarpus erinaceus* an important multi-use species in the being of rural communities. As a result, the species is subjected to anthropogenic pressures which can cause it to disappear from its natural habitats and even from forest ecosystems. These different forms of organ use of *Pterocarpus erinaceus* reveal the need to define conservation strategies for the natural populations with a view to the sustainable exploitation of the species. To reverse the trends in the conservation status of the species, the combination of *in situ* and *ex situ* conservation measures seems appropriate in addition to the measures already taken against the extinction of the species.

## Abbreviations

EZ : Ecological Zone, PC : Principal Components, PCA: Principal Component Analysis, RFC : Relative Citation Frequencies, IUCN: International Union for Conservation of Nature, EIA :Environmental Investigation Agency, Inc.

## Declarations

### Ethics approval and consent to participate

Individual consent to participate in the study was obtained prior to the administration of the questionnaire. Only people that consented to participate in the study were considered.

### Consent for publication

Not applicable

### Availability of data and materials

The datasets supporting the conclusions of this article are included within the article and its additional files which is available from the corresponding author upon reasonable request.

### **Competing interests**

The authors declare that they have no competing interests.

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### **Authors' contributions**

OC designed the study and supervised all work from protocol writing to the final manuscript. DJ, AY and WA collected the data with advice from SKNB. SKNB, WA, HT and AY designed the structure of the manuscript. AY and WA analyzed the data with input from SKNB. WA and SKNB drafted the manuscript. OC and HT revised and critically improved the manuscript. All authors read and approved the final manuscript.

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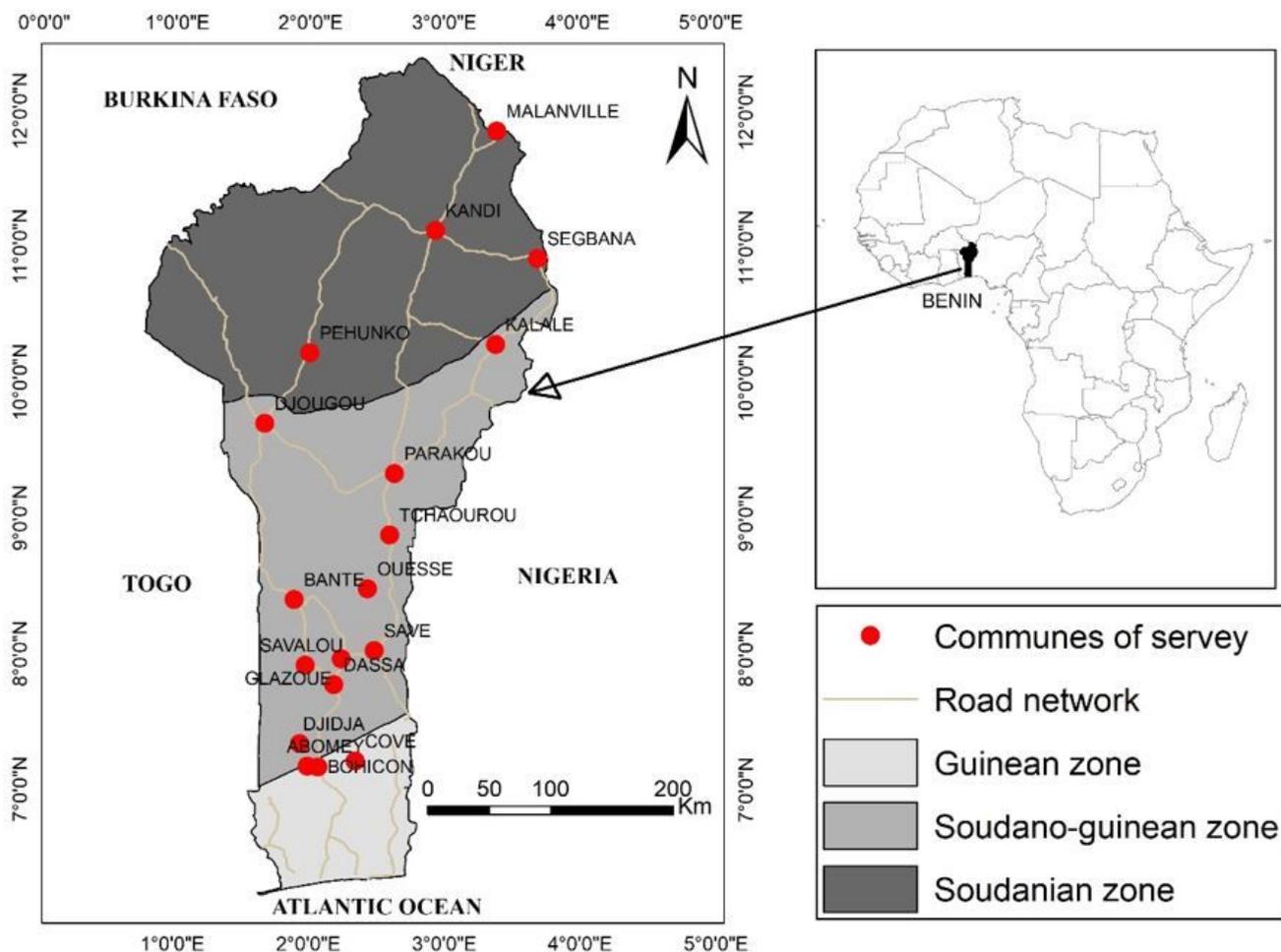
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## Figures



**Figure 1**

Study area location Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

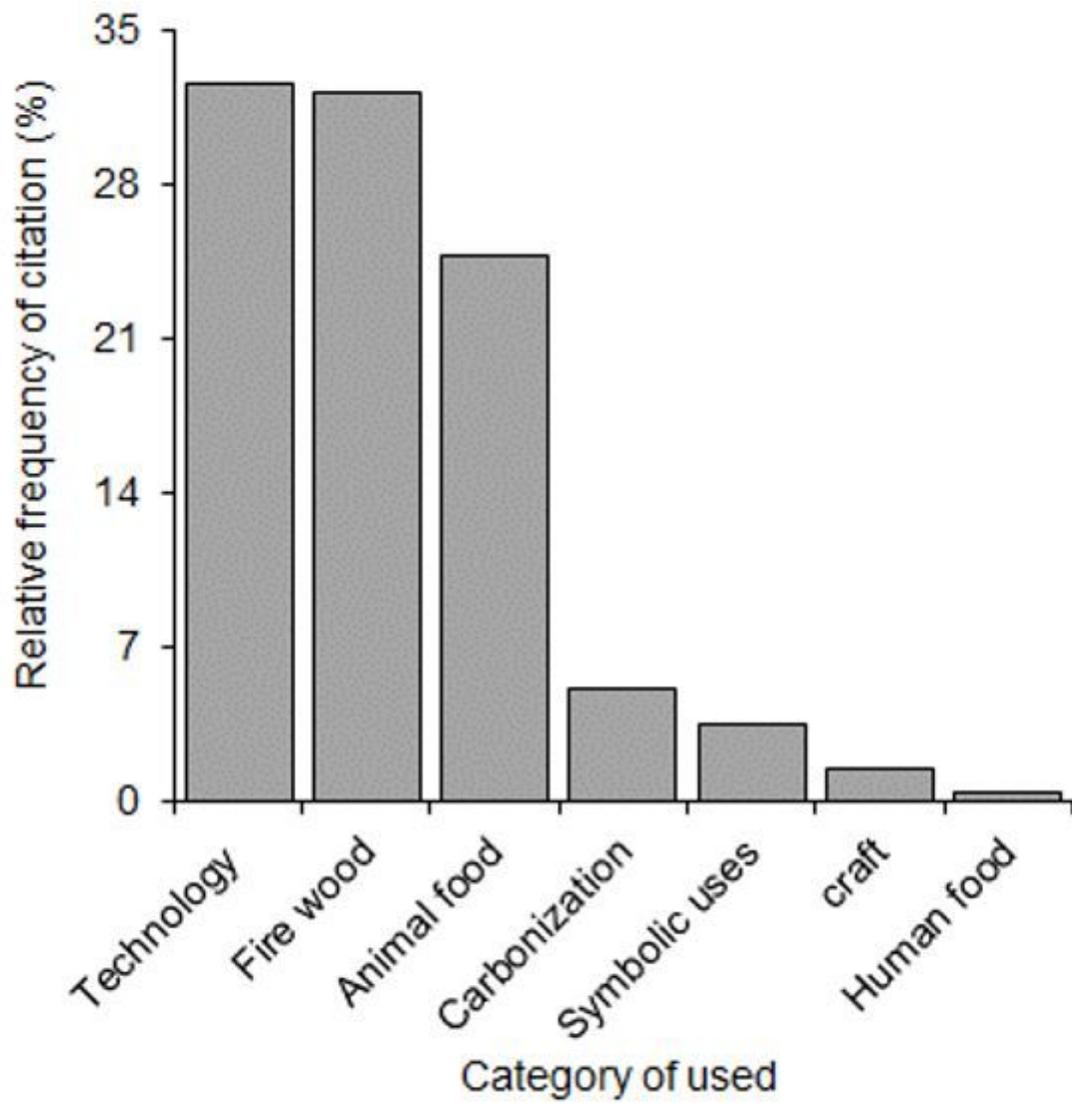
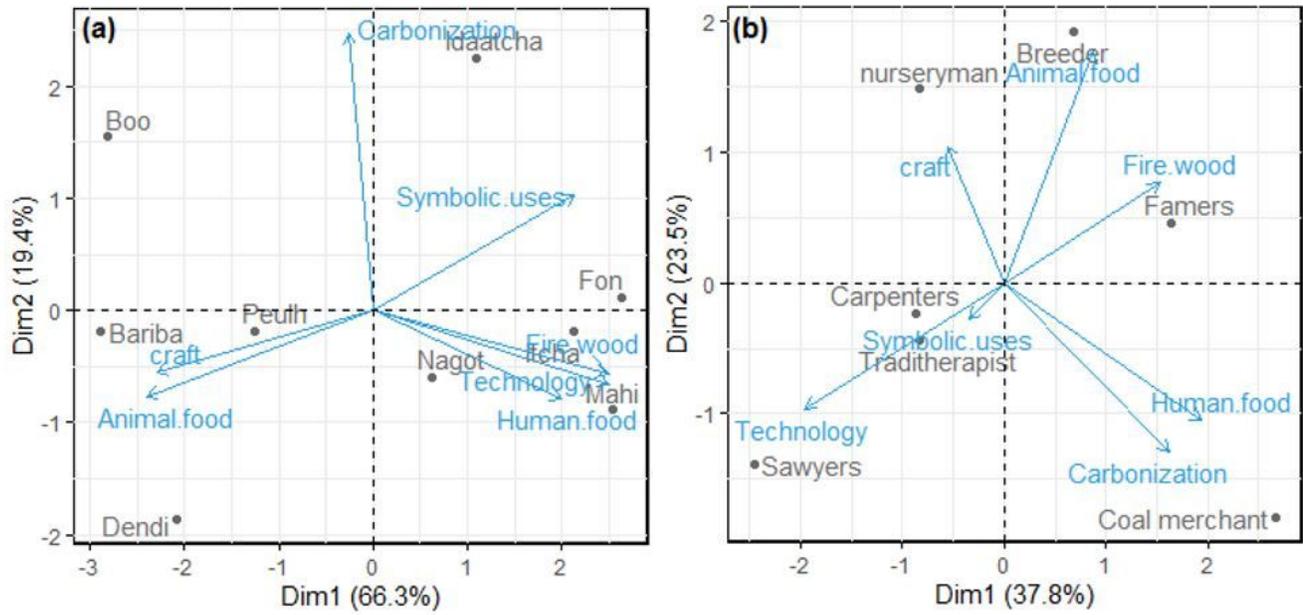


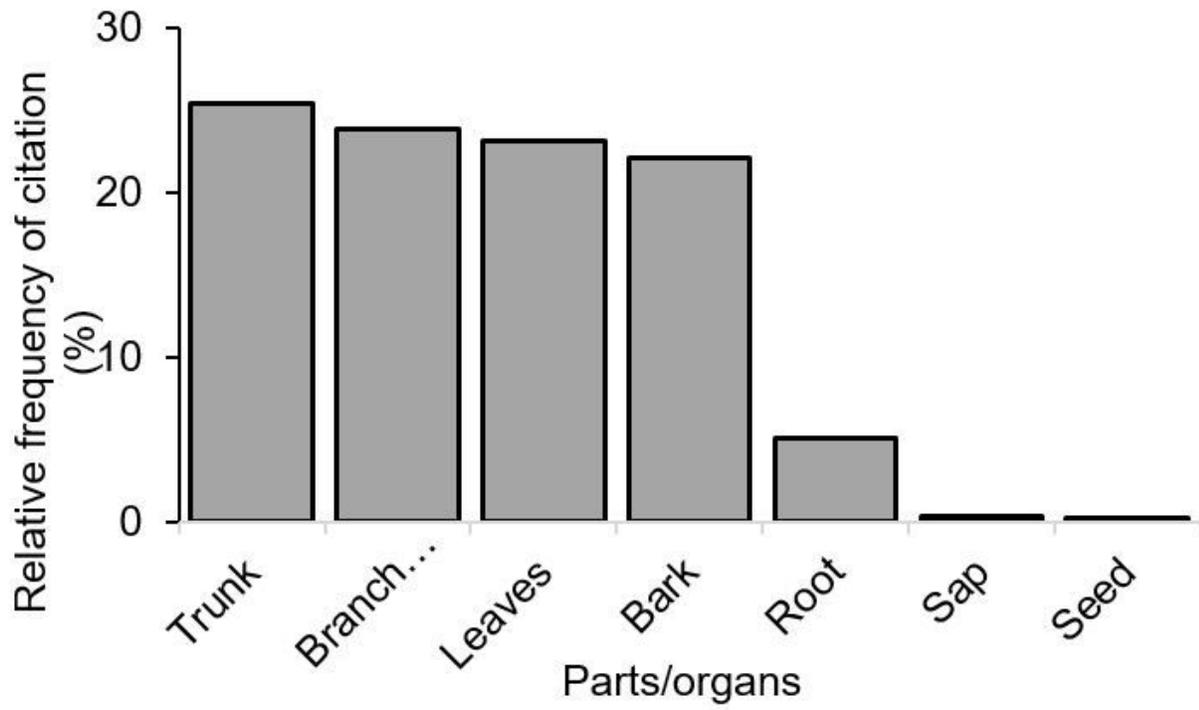
Figure 2

Importance of use categories of Pterocarpus erinaceus for populations



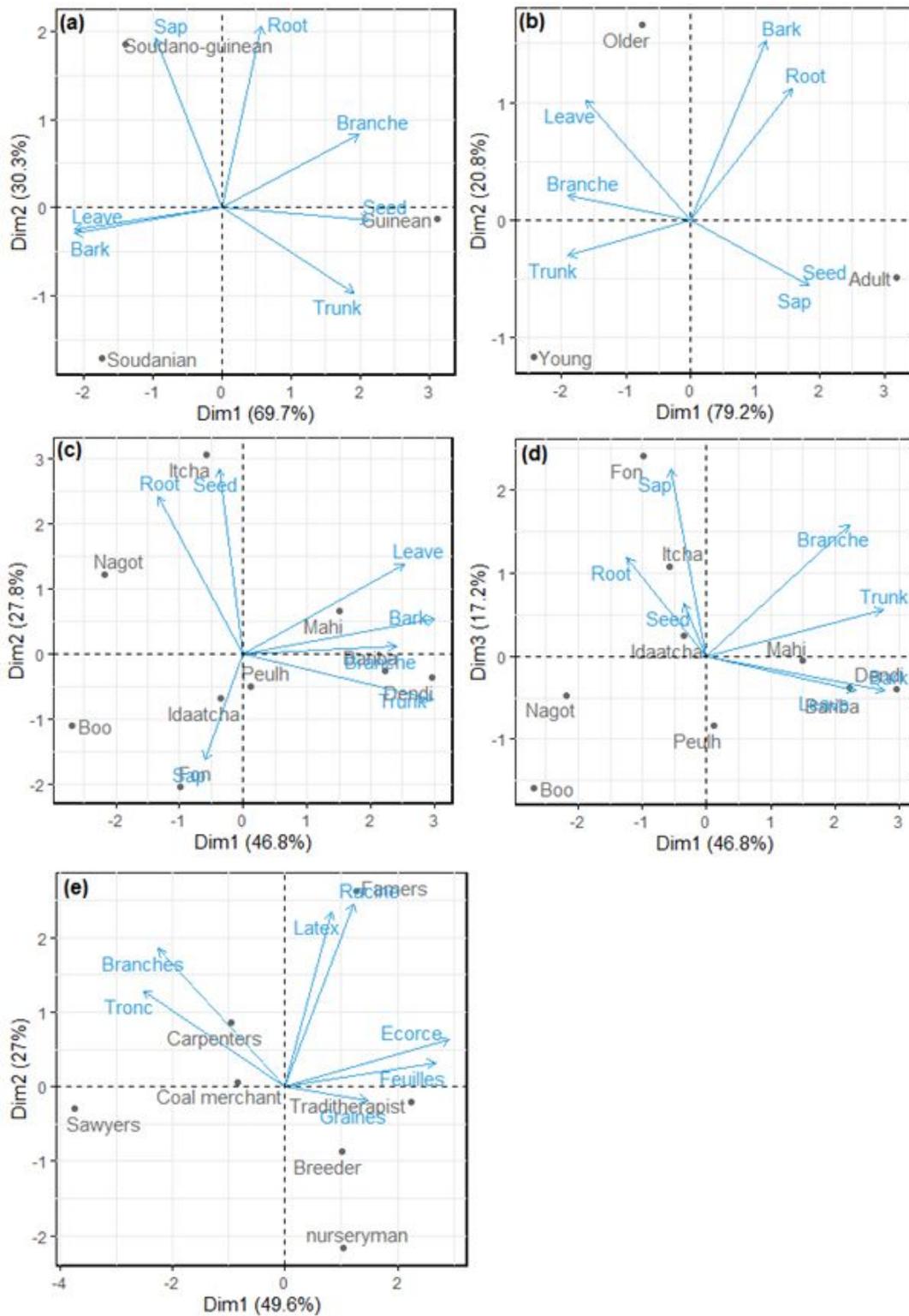
**Figure 3**

Distribution of the sociolinguistic (a) and the professions (b) groups using *Pterocarpus erinaceus*



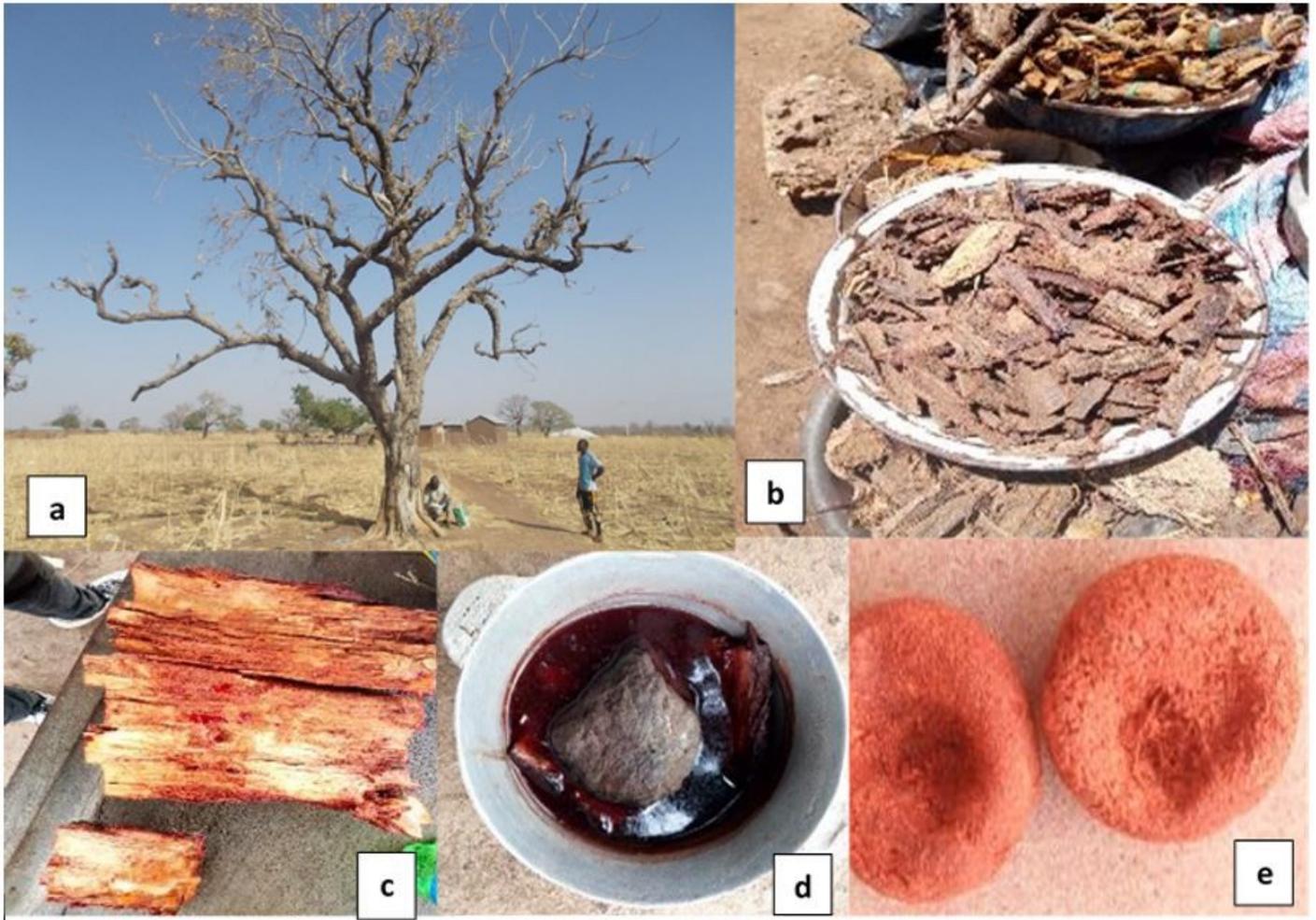
**Figure 4**

Importance of organs take away by populations on *Pterocarpus erinaceus*



**Figure 5**

Relation between *Pterocarpus erinaceus* organs used and the studied factors in the principal components/ Legend : (a): Ecological Zones, (b): age, c & d: sociolinguistic groups, (e): professions



**Figure 6**

Traditional uses of *Pterocarpus erinaceus*/ Legend : (a) : Tree pruned frequently, (b, c) : bark in herbalists market, (d) : bark decocted, (e) : Tamaré made using the bark that used as incense by the sociolinguistic groups Peulh and Bariba for evil spirits