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# A quantitative ethnobotanical approach toward biodiversity conservation of useful woody species in Wari-Maro forest reserve (Benin, West Africa)

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**Abstract** Quantitative ethnobotany researches can contribute much to guide biodiversity conservation, especially in developing countries. Our study presents a step-by-step approach to identify priority species for local conservation of useful woody species. The presented approach includes (1) an investigation of the popularity and versatility of woody species in the local people, (2) an estimation of the ecological availability of useful tree species in the forest and (3) identification of local priority species for conservation. We focused the study on the Wari-Maro forest reserve in the Sudanian zone of Benin as an example to implement such approach and identify useful priority species for sustainable conservation and management strategies development. Ethnobotanical surveys were conducted with people in surrounding villages of the forest composed by different sociocultural groups. Floristic vegetation surveys were performed within the forest to assess the local ecological availability of used woody species. A principal component analysis was performed to analyze the versatility, the popularity and the ecological availability of species. Spearman's correlation test was used to assess relation between variables. In total, 79 woody species were reported for seven main types of uses: technology, construction, medicinal, veterinary, food, forage and energy. Among them, 35 were most popular and

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versatile, and 3 were characterized as priorities for conservation especially regarding their less availability and more versatility. We discussed the used approach by the underlining importance of integrating wood uses or multiples uses in conservation priorities setting and conservation decision-making of useful woody tree species.

**Keywords** Versatility · Ecological availability · Quantitative ethnobotany · Conservation priorities

## 1 Introduction

Biodiversity refers to all species of plants, animals and microorganisms and their interaction within an ecosystem providing the persistence of species as well as their evolution (Vandermeer and Perfecto 1995). Its conservation becomes nowadays very important regarding present challenges by human pressure, climate change and invasive species. In general, tropical countries are characterized by high biodiversity. In Africa, such biodiversity is highly threatened by high habitat degradation with a consequent habitat loss (Burgess et al. 2004). In Benin, the loss of forests was estimated at 75,000 ha per year between 1990 and 2010 (FAO 2010). Additionally, several studies highlighted negative effects of the forest degradation on many plants species (Tchibozo 2014; Gbaï et al. 2011; Vodounou et al. 2011). To restrain such degradation and its effects, in situ and ex situ conservation strategies are both urgently needed, and the integration of local knowledge into forest resources management practices is an important way.

Ethnobotany is a discipline that is gaining most research interests on natural resources in tropical countries these last decades. Indeed, the Convention on Biological Diversity recognized its role in biodiversity conservation (Sop et al. 2012; CBD 1994). Ethnobotanical researches are strengthening wide success in several scientific areas (Bridges and Lau 2006) such as conservation of plant biodiversity (Albuquerque et al. 2009; Lykke 2000), genetic resources conservation (Fandohan et al. 2011; Assogbadjo et al. 2009; Gao 2003) as well as in ethnopharmacology (Weckerle et al. 2011; Bhat et al. 2010) and food technology (Chadare et al. 2008). The importance of ethnobotany to support local management and conservation strategies is now well recognized worldwide (Albuquerque et al. 2009; Cunha and Albuquerque 2006; Sanchez-Azofeita et al. 2005). Recent researches used well-defined methods and analytical tools to guide conservation priority based on quantitative ethnobotanical approaches. For instance, Albuquerque et al. (2009) used an approach adapted from Oliveira et al. (2007) through construction of a local conservation priority index that combines a citation richness (number of use categories given to species), a degree of attention (frequency of occurred species) and a relative density of the species in the considered area. To date, most of studies (van Andel et al. 2015; Yaoitcha et al. 2015; Albuquerque et al. 2011; Oliveira et al. 2007; Kala et al. 2004; Dhar et al. 2000; Cunningham 1993) have prioritized plants species for conservation through ethnobotanical data by different approaches. However, these studies have disregarded non-medicinal uses of woody species (i.e., construction, energy, technology, food) which are often the most significant threats for the species.

In addition, versatility and popularity of a given plant species may provide an indirect evaluation of the effect of pressure (Albuquerque et al. 2009; Phillips and Gentry 1993). The popularity of a tree species defines the attraction of a species for its usability by local people, and the versatility describes the attraction of the species for various purposes. An importance value index combines the relative density, the relative dominance and the relative frequency of a species in a given area and is also widely used to assess the local ecological availability of a tree species (Houehanou et al. 2013; Lucena et al. 2012; Albuquerque et al. 2009; Reitsma 1988).

In a context of limited resources coupled with a high biodiversity, it is necessary to prioritize some biodiversity surrogates for conservation. In tropical ecosystems, woody species are determinant components for the functioning of plant ecosystems (Sagar et al. 2003). They can often be used for multiples purposes such as for medicine, forage, energy and technology. As can be inferred from literature, few studies have been considered the versatility of woody species in the determination of conservation priority (see Lykke 2000; Tabuti 2007).

Thus, we aimed to test an integrated approach combining the versatility, the popularity and the local ecological importance of the woody species to evaluate their priority for conservation. We performed our research in a highly threatened biodiversity hotspot named Wari-Maro forest reserve in Sudanian zone of Benin. This reserve despite its conserved status is currently strongly impacted by anthropogenic pressures such as agriculture, pastoralism, logging and extraction of firewood and plant material used for medicinal and food purposes (Yaoitcha et al. 2015; Adomou et al. 2011).

## 2 Materials and methods

### 2.1 Study environment

The study was carried out in the environment of Wari-Maro forest which was certified as forest reserve in 1955. The forest reserve is located in the Sudanian zone in Central Benin between 8°50′–9°10′ N of latitude and 1°55′–2°25′E of longitude (Fig. 1; Adomou et al. 2011). The study area belongs to the plant Sudanian endemic zone of White (1983) dominated by woodlands, tree and shrub savannas, and is a part of protected areas in the Kouffe mounts region dominated by woodland of *Isoberlinia* spp. (Glèlè Kakaï and Sinsin 2009). The climate is described as Sudanian humid with a dry season of five months (November to March) and a rain season from April to October (Houinato and Sinsin 2002). Annual precipitations fluctuate from 900 to 1200 mm. The relief is constituted of plains and hills reaching partly more than 300 m of altitude. Seasonal rivers cross the forest with a total length of 884,115 km. Main soils are ferruginous (92.64%). Characteristic species are *Isoberlinia doka*, *I. tomentosa*, *Monotes kerstingii*, *Uapaca togoensis*, *Pseudocedrela kotschyi* and *Anogeissus leiocarpa*. Herbaceous stratum is luxuriant within woody and shrub savanna (Houinato and Sinsin 2002). It is a favorable area for livestock herds coming from elsewhere in the dry season, and this fact is emphasizing the pastoral pressure on woody species.

Nagots, Baribas and Fulani are the sociocultural groups that inhabit the area around the forest. Other sociocultural groups include Aniis, Bialis, Yoms, Fons, Adjas, Mahis and Minas, but they are minority. Nagot people are more native of this region, while Bariba are native from the north part of Benin. The minority sociocultural groups are native from south, central or north part of Benin. The people are mainly farmers and craftsmen. The increase of human population in this area was estimated for 6.1% between 2002 and 2013 with a total number of 351,878 inhabitants (INSAE 2016).

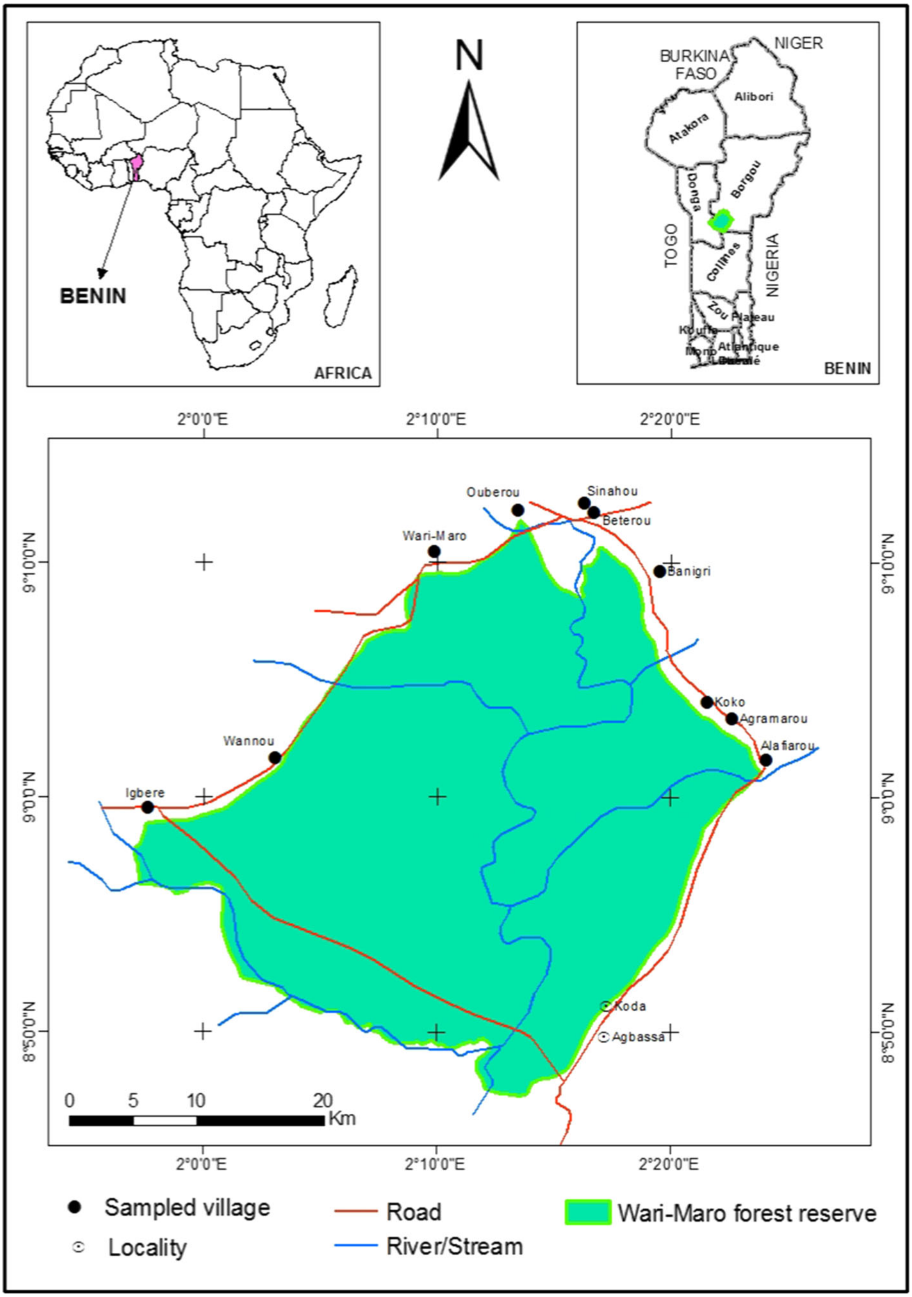


**Fig. 1** Location map of the Wari-Maro forest reserve and villages included in the investigation

## 2.2 Data collection

Ten villages surrounding the forest were chosen for the ethnobotanical survey according to their proximity to the forest and the expected relationships between humans and forest: Agramarou, Alafiarou, Banigri, Bétérou, Igbèrè, Koko, Oubérou, Sinahou, Wannou and Wari-Maro (Fig. 1). Those villages were selected regarding sociocultural groups that dominated the villages. Thus, the relationships between humans and forest in the selected villages were expected to vary according to sociocultural groups.

The ethnobotanical surveys included socio-demographic data inferred from individual semi-structured interviews of 149 chosen people grouped in four main sociocultural groups (Table 1). Minority sociocultural groups (Fon, Mina, Biali, Adja and Mahi) were grouped together as 'other ones'. First, the participants of the survey were selected randomly in each village. However, when the selected participant is not available or does not want to be interviewed, another one is selected. The age of the informants ranges from 18 to 87.

To assess both the use pattern popularity (variation of species use through sociocultural groups) and versatility (variation of species use through use categories) of woody species, a pre-investigation was carried out to confirm seven use categories in the study area. This consisted in verifying with the local people, in an informal way, the woody use categories that were mostly practiced in the study area. Those people were not included in the proper study.

A pre-definition of use categories reduces the bias caused by differences in the knowledge of species' usability (passive) and direct uses (active). Afterward, local people were asked to mention useful tree species according to each of the following seven use categories: food, traditional medicine, veterinary, forage, firewood, construction and technology. These 7 use categories were more active than passive in the study area.

Vegetation surveys were conducted along ten transects from the edge to the core area of the Wari-Maro forest to evaluate ecological availability of useful tree species reported by local people. The total length of each transect was 2000 m, starting in close proximity of each village. Four to five plots (30 m $\times$ 50 m) per transect were established dependent on the observed vegetation abundance (total number of rectangular plots: 42). All tree species were characterized, and diameters at breast height (dbh) of all trees (dbh $\geq$ 10 cm) were measured within each plot. Regeneration (dbh $<$ 10 cm) was counted in four subplots of 10 m $\times$ 10 m established at the corners of all plots.

## 2.3 Data analysis

A quantitative ethnobotanical approach has been displayed step-by-step to assess the priority of Wari-Maro forest tree species for conservation. First, ethnobotanical indices based on the popularity and the versatility of woody species of the forest were calculated. We applied the relative frequency of citation (RFC) according to Tardío and Pardo-de-Santayana (2008) to assess the importance of each species through the use categories ('versatility of observed species'). The RFC is calculated then by dividing the number of informants, who mention a given use of the species, by the number of informants participating in the study. The use value of each species (UVs) was determined for each sociocultural group ('popularity of observed species') by using the formula of Phillips and Gentry (1993), simplified by Rossato et al. (1999):

$$\mathrm{UVs} = \sum Ui/N)$$

**Table 1** Number of interviewed people per village and their affiliation to sociocultural groups

| Villages Sociocultural groups | Alafiarou | Agramarou | Koko | Banigri | Bétérou | Sinahou | Oubérou | Wari-Maro | Wannou | Igbèrè | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nagots | 14 | 15 | 1 | 2 | 2 | 8 | – | 11 | 15 | 12 | 80 |
| Bariba | 1 | – | 14 | 8 | 3 | 7 | 15 | – | – | – | 48 |
| Fulani | 3 | – | – | – | – | – | 1 | 1 | – | 3 | 8 |
| others | 1 | – | 1 | 2 | 6 | 1 | – | 2 | – | – | 13 |
| Total | 19 | 15 | 16 | 12 | 11 | 16 | 16 | 14 | 15 | 15 | 149 |

with $Ui$ = number of different uses mentioned by each informant $i$, $N$ = total number of informants involved in the study.

The use value of each species was calculated at sociocultural group level rather than at individual level. Indeed, ethnic group is a bench social factor that influences plant use and its integration in conservation plan is a successful factor (Zizka et al. 2015). The term sociocultural group used through the study means also ethnic group and can be applied interchangeably.

A principal component analysis (PCA) was used to analyze the popularity and the versatility of tree species according to the sociocultural group and use category, respectively. Only species which were cited by at least five persons, two sociocultural groups and employed within at least three use categories were considered. These criteria were defined for highlighting the most popular and versatile species that should be used for conservation priority setting. Thirty-five woody species have fulfilled these conditions and were considered for the following data analysis. The obtained data matrix containing the calculated values of indices (RFC and UVs) is provided by supplementary file 1.

The knowledge on natural resources was evaluated for all sociocultural groups computing knowledge indices (KI) analogous to the use value of Phillips and Gentry (1993) as follows:

$$\mathrm{KI} = \frac{S}{n}$$

with $S$ = number of useful tree species cited by a given sociocultural group and $n$ = number of informants within the sociocultural group.

Secondly, a versatility index and an ecological availability index were calculated for each of the thirty-five woody species. The versatility index (VI) was computed and was adapted from the versatility index of Bennett and Prance (2000) as follows:

$$\mathrm{VI} = \mathrm{N_{cs}}/\mathrm{N_{cmax}}$$

with $\mathrm{N_{cs}}$ = number of use categories cited for a given species $s$, $\mathrm{N_{cmax}}$ = maximum number of use categories mentioned for the most versatile species.

The ecological availability of useful tree species has been assessed including relative frequencies, relative densities and relative dominances of all tree species. Importance value indices (IVI) were calculated for each species (DBH $\geq$ 10 cm) according to the following formula:

$$\mathrm{IVI} = \sum (\mathrm{Fr} + \mathrm{Dr} + \mathrm{Gr})$$

with Fr = relative frequency, Dr = relative density and Gr = relative dominance.

IVI is a quantitative index, and values >10% for a species indicate a species to be ecologically important (Reitsma 1988).

For regeneration (DBH < 10 cm), a partial importance value index (IVIp) was calculated using relative frequencies (Fr) and relative densities (Dr) following the formula:

$$\mathrm{IVIp} = \sum (\mathrm{Fr} + \mathrm{Dr})$$

Thirdly, we assessed the distribution and the threat status of each of the most versatile and popular woody species in the Wari-Maro forest based on our investigation. The threat status of each species based on IUCN categories (IUCN 2012) was recorded from Benin Red List (Adomou et al. 2011) and was scored similarly to Yaoitcha et al. (2015): endangered (EN) and critically endangered (CR) were scored by 10 (species for which conservation is urgently needed); vulnerable (VU) species were scored by 5 (conservation of this category species is less urgent than the first one) and species whose status has not been assessed yet were scored by 0. Indeed, the IUCN Red List threat status is the most used criterion for determining conservation priority and endangered species receive higher attention than those that are not under threat (Brehm et al. 2010).

As far as the distribution was concerned, we categorized the woody species using chorological types of White (1983). The chorological types were scored similarly to Yaoitcha et al. (2015): Sudanian (S), Sudano-Guinean (SG) and Sudano-Zambezean (SZ) species were scored by 10, Guinean (G), Guineo-Congolean (GC) species were scored by 5; and large distribution types were scored by 0. Priority increases with the more restricted distribution (Brehm et al. 2010) and with the more irreplaceable distribution.

Finally, a principal component analysis (PCA) was performed by combining the VI, the IVI, the IVIp, the distribution, the status and the use categories (medicine, food, construction, technology, forage, energy and veterinary). The used data matrix is provided by supplementary file 2. This analysis was used to define priority species for conservation and also to assess their relationship with use categories. Priority species for conservation are defined as species that are more versatile and less available. Relationships among variables were analyzed by Spearman's correlation tests.

We performed the correlation tests in SPSS version 23.1 software, while PC-ORD for windows version 7 was used for PCA.

## 3 Results

### 3.1 Useful tree species of the Wari-Maro forest reserve

A total of 79 useful tree species grouped into 70 genera and 32 families were reported by local people (Table 2). Most species are used for medicinal applications (Fig. 2). The most prominent families were Leguminosae with 25% of species followed by Moraceae (10%) and Combretaceae (8%). The species *Afzelia africana*, *Vitellaria paradoxa*, *Pterocarpus erinaceus* and *Parkia biglobosa* were mostly cited, while *Acacia nilotica*, *Combretum* sp., *Collinum* sp., *Grewia pubescens*, *Monodora tenuifolia* and *Psorospermum febrifugum* were rarely cited.

### 3.2 Popularity and versatility of useful woody species

Thirty-five species (Table 3) were identified as popular and versatile in the local knowledge. The first two axes of the principal component analysis (PCA) explained about 74.80% of the total variation. The first component was significantly correlated with the variables construction, technology, energy, forage, veterinary, Nagot, Bariba, Fulani and other (minority sociocultural groups) (see supplementary file 3). The second component was significantly correlated with food (see supplementary file 3). The projection of species onto the two axes (Fig. 3) showed that most popular and versatile species were *A. africana*, *A. leiocarpa, D. oliveri, I. doka, K. senegalensis, P. kotschyi* and *P. erinaceus* and were mostly used by Nagot, Bariba, Fulani and minority groups for construction, technology, energy, forage and veterinary. On contrary, *A. digitata*, *A. senegalensis, B. ferruginea, B. africana, C. pentandra, L. acida, P. thoningii, P. laxiflora, S. latifolius, S. setigera, S. spinosa, S. guineense, U. chamae* and *V. doniana* were among less popular and less

**Table 2** Reported tree species, families and use categories

| Families | Species | Use categories (citation) |
|---|---|---|
| Anacardiaceae | *Lannea acida* A. Rich. s.l. | Medicine (06), Food (04), Technology (01), Energy (01), Forage (03) |
| | *Spondias mombin* L. | Medicine (12), Food (22), Energy (01), Veterinary (01) |
| Annonaceae | *Annona senegalensis Pers ssp senegalensis* | Medicine (04), Food (16), Forage (02) |
| | *Hexalobus monopetalus* (A. Rich.) Engl. & Diels | Medicine (02), Veterinary (01) |
| | *Monodora tenuifolia* Benth. | Medicine (1) |
| | *Uvaria chamae* P. Beauv | Medicine (03), Food (01), Energy (01) |
| Apocynaceae | *Strophanthus sarmentosus* DC. | Medicine (3) |
| Araliaceae | *Cussonia arborea* Hoehst. ex A. Rich. | Medicine (1) |
| Arecaceae | *Borassus aethiopium* Mart. | Medicine (01), Food (10), Technology (01), Construction (10) |
| Bignoniaceae | *Kigelia africana* (Lam.) Benth. | Medicine (02), Technology (01), Forage (03) |
| Leguminosae-Caesalpinioideae | *Afzelia africana* Sm. | Medicine (18), Technology (105), Construction (24), Energy (22), Forage (77), Veterinary (02) |
| | *Burkea africana* Hook. | Medicine (02), Energy (06), Veterinary (02) |
| | *Dialium guineense* Willd. | Medicine (21), Food (16), Construction (02) |
| | *Tamarindus indica* L. | Medicine (01), Food (06) |
| | *Isoberlinia doka* Craib & Stapf | Medicine (01), Technology (78), Construction (115), Energy (105), Forage (15) |
| | *Bauhinia rufescens* Lam. | Medicine (02) |
| | *Cassia sieberiana* DC. | Medicine (05) |
| | *Daniellia oliveri* (Rolfe) Hutch. & Dalz | Medicine (22), Technology (07), Construction (07), Energy (17), Forage (33), Veterinary (02) |
| | *Detarium microcarpum* Guill. & Perr. | Medicine (02), Food (34), Energy (06) |
| | *Piliostigma thonningii* (Schum.) Milne-*Redh* | Medicine (4), Energy (01), Veterinary (01) |
| Leguminosae-Mimosoideae | *Tetrapleura tetraptera* (Schum. et Thonn.) Taub | Medicine (1) |
| | *Acacia ataxacantha* DC. | Medicine (02) |
| | *Acacia nilotica* (L.) Willd | Medicine (01) |
| | *Acacia sieberiana* DC. | Medicine (02), Forage (05) |
| | *Entada africana* Guill. et Perr. | Veterinary (01) |
| | *Parkia biglobosa* (Jacq.) R.Br. ex Benth. | Medicine (05), Food (67), Technology (02), Construction (01), Energy (18), Forage (06), Veterinary (02) |
| | *Prosopis africana* (Guill. & Perr.) taub. | Medicine (05), Forage (01) |
| Leguminosae-Papilionoideae | *Aganope stuhlmannii* (Taub.) Adema | Medicine (03), Forage (01) |

**Table 2** continued

| Families | Species | Use categories (citation) |
|---|---|---|
| | *Pericopsis laxiflora* (Benth. ex Baker) Meeuwen | Medicine (02), Energy (06), Forage (01) |
| | *Pterocarpus erinaceus* Poir. | Medicine (04), Technology (128), Energy (92), Forage (106), Veterinary (06) |
| | *Swartzia madagascariensis* Desv | Medicine (01) |
| Celastraceae | *Loeseneriella africana* (Willd.) N.Hallé | Medicine (01) |
| | *Gymnosporia senegalensis* (Lam.) Loes., | Medicine (2) |
| Ceratophyllaceae | *Trema orientalis* (L.) Blume | Medicine (10) |
| Chrysobalanaceae | *Parinari curatellifolia* Planch. ex Benth. | Medicine (87), Energy (01), Forage (03), Veterinary (03) |
| Clusiaceae | *Psorospermum febrifugum* Spach | Medicine (3) |
| Combretaceae | *Anogeissus leiocarpus* (DC.) Guill. & Perr. | Medicine (01), Technology (24), Construction (35), Energy (30), Forage (02) |
| | *Combretum collinum* Fresen. | Energy (01) |
| | *Pteleopsis suberosa* Engl. & Diels | Medicine (05) |
| | *Terminalia avicennioides* GuilI. & Perr. | Medicine (04) |
| | *Terminalia laxiflora* Engl. | Medicine (03) |
| | *Terminalia* sp. | Medicine (07), Energy (12) |
| Ebenaceae | *Diospyros mespiliformis* Hochst. | Medicine (01), Food (31), Technology (16), Construction (21), Energy (05), Forage (01) |
| Euphorbiaceae | *Bridelia ferruginea* Benth. | Medicine (01), Food (02), Energy (02) |
| | *Hymenocardia acida* Tul. | Medicine (01), Energy (08), Forage (01) |
| | *Uapaca togoensis* Pax | Medicine (11) |
| Flacourtiaceae | *Flacourtia indica* (Burm. f.) Merr. | Technology (14), Construction (30), Energy (18) |
| Loganiaceae | *Strychnos spinosa* Lam. | Medicine (01), Food (10), Forage (02) |
| Malvaceae | *Adansonia digitata* L. | Medicine (09), Food (11), Energy (01) |
| | *Bombax costatum* Pellegr. & Vuillet | Medicine (06) |
| | *Ceiba pentandra* (L.) Gaertn. | Medicine (02), Technology (03), Construction (01), Energy (01), Forage (01) |
| Meliaceae | *Khaya senegalensis* (Desr.) A. Juss. | Medicine (11), Technology (117), Construction (74), Energy (27), Forage (74), Veterinary (11) |
| | *Pseudocedrela kotschyi* (Schweinf.) Harms | Medicine (01), Technology (49), Construction (19), Energy (09), Forage (03), Veterinary (04) |
| | *Trichilia emetica* Vahl | Medicine (05) |
| Moraceae | *Ficus abutilifolia* (Miq.) Miq | Medicine (38), Energy (01), Forage (04) |

**Table 2** continued

| Families | Species | Use categories (citation) |
|---|---|---|
| | *Ficus glumosa* DeliIe | Medicine (08) |
| | *Ficus platyphylla* Delile | Medicine (03), Technology (01), Construction (01) |
| | *Ficus polita* Vahl | Medicine (10) |
| | *Ficus* sp. | Medicine (03), Energy (03), Forage (03) |
| | *Ficus sycomorus* L. | Medicine (01) |
| | *Ficus thonningii* Blume | Forage (05) |
| | *Milicia excelsa* (Welw.) C.C Berg | Medicine 06), Technology (16), Construction (05), Energy (01) |
| Myrtaceae | *Syzygium guineense* Wall. | Food (6), Forage (3), Veterinary(2) |
| Ochnaceae | *Lophira lanceolata* Tiegh. ex Keay | Medicine (01), Construction (01), Energy (04), Forage (01) |
| Olacaceae | *Ximenia americana* L. | Medicine (02), Food (15), Forage (01) |
| Polygalaceae | *Securidaca longepedunculata* Fresen. | Medicine (20), Forage (01) |
| Rhamnaceae | *Ziziphus mauritiana* Lam. | Medicine (2), Food (2) |
| Rubiaceae | *Crossopteryx febrifuga* (G.Don) Benth. | Medicine (03) |
| | *Gardenia erubescens* Stapf & Huteh. | Medicine (01), Food (17) |
| | *Gardenia ternifolia* Schumach. & Thonn. | Medicine (01), Food (18) |
| | *Pavetta crassipes* K. Schum. | Medicine (01) |
| | *Sarcocephalus latifolius* (Sm.) E.A.Bruce | Medicine (01), Food (03), Forage (02) |
| Sapindaceae | *Blighia sapida* Konig | Medicine (01), Food (07), Forage (01) |
| Sapotaceae | *Vitellaria paradoxa* Gaertn | Medicine (14), Food (103), Technology (09), Construction (05), Energy (82), Forage (04) |
| Sterculiaceae | *Sterculia setigera* Delile | Medicine (04), Food (01), Construction (03), Forage (01) |
| Tiliaceae | *Grewia puhescens* P. Beauv. | Construction (1) |
| Ulmaceae | *Holoptelea grandis* (Hutch.) Mildbr | Medicine (03) |
| Verbenaceae | *Vitex doniana* Sweet | Medicine (01), Food (19), Construction (02), Technology (01), Energy (01), Forage (05) |
| | *Vitex madiensis* Olïv. subsp. | Medicine (06) |

versatile species and appear to not be used by a specific sociocultural group. *V. paradoxa*, *P. biglobosa, D. microcarpum, D. mespiliformis* and *P. curatellifolia* were among the most used species for food or medicinal purposes.

According to the knowledge index (Table 4), Fulani sociocultural group hold the highest knowledge on natural resources.

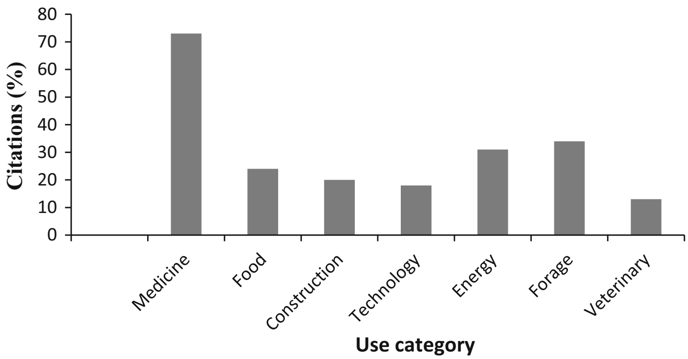


**Fig. 2** Relative proportion of cited useful tree species per use category. The bars represent the number of species for each use category and as percentage of all mentioned species

## 3.3 Ecological availability of useful woody species within the Wari-Maro forest reserve

Sixty-nine species grouped into 54 genera and 26 families were observed within 42 plots established in transects. Leguminosae (28%) were the most abundant family followed by Combretaceae (17%) and Rubiaceae (10%). In general, most species were characterized by less ecological importance. Nevertheless, among the most useful species, *L. acida* (IVI = 85%), *I. doka* (IVI = 41%), *V. paradoxa* (IVI = 37%), *B. africana* (IVI = 21%), *P. erinaceus* (IVI = 17%) and *A. leiocarpa* (IVI = 17%) were ecologically important (IVI > 10%). Moreover, some species such as *A. digitata, B. sapida*, *B. aethiopium, C. pentandra, D. guineense*, *M. excelsa, S. mombin* and *U. chamae* were not recorded within the vegetation plots.

## 3.4 Local priority for conservation of useful tree species

The first two PCA axes explained 56.34% of total variation of species with considered variables (Fig. 4). Correlation of variables with each axis showed that construction, technology, energy, forage, veterinary, versatility index, distribution and status were significantly correlated with the axis 1 while food, importance value index and partial importance value index with the axes 2 (supplementary file 4). The first component showed then a versatility gradient while the second component highlighted a gradient of importance value index. The projection of species onto the first two components (Fig. 4) revealed that species such as *A. senegalensis, B. sapida*, *B. ferruginea*, *C. pentandra, D. guineense, P. thonningii, S. latifolius*, *S. spinosa* and *X. americana* are less versatile. However, the most versatile species were *A. africana*, *D. oliveri*, *I. doka, K. senegalensis*, *P. kotschyi* and *P. erinaceus*. The second axis showed species such as *A. leiocarpa, I. doka, L. acida, P. biglobosa* and *V. paradoxa* as the most available while *A. africana, F. indica, K. senegalensis, M. excelsa* and *P. erinaceus* were the least ones. Then, *A. africana*, *K. senegalensis* and *P. erinaceus* which were the most versatile and the least available species, were characterized as priority species for conservation (Fig. 4).

Spearman's correlation tests showed significant correlations among the versatility index (VI) and construction ($r = 0.623$, $p < 0.0001$), technology ($r = 0.771$, $p < 0.0001$), energy ($r = 0.553$, $p = 0.0006$), forage ($r = 0.709$, $p < 0.0001$), veterinary ($r = 0.492$,

**Table 3** Thirty-five woody species that are most popular and versatile with their abbreviated name and use categories

| Species | Abbreviated name | Use categories (citation) |
|---|---|---|
| *Adansonia digitata* | Adandigi | Medicine (09), Food (11), Energy (01) |
| *Afzelia africana* | Afzeafri | Medicine (18), Technology (105), Construction (24), Energy (22), Forage (77), Veterinary (02) |
| *Annona senegalensis* | Annosene | Medicine (04), Food (16), Forage (02) |
| *Anogeissus leiocarpa* | Anogleio | Medicine (01), Technology (24), Construction (35), Energy (30), Forage (02) |
| *Blighia sapida* | Bligsapi | Medicine (01), Food (07), Forage (01) |
| *Borassus aethiopum* | Boraaeth | Medicine (01), Food (10), Technology (01), Construction (10) |
| *Bridelia ferruginea* | Bridferr | Medicine (01), Food (02), Energy (02) |
| *Burkea africana* | Burkafri | Medicine (02), Energy (06), Veterinary (02) |
| *Ceiba pentandra* | Ceibpent | Medicine (02), Technology (03), Construction (01), Energy (01), Forage (01) |
| *Daniellia oliveri* | Danioliv | Medicine (22), Technology (07), Construction (07), Energy (17), Forage (33), Veterinary (02) |
| *Detarium microcarpum* | Detamicr | Medicine (02), Food (34), Energy (06) |
| *Dialum guinensee* | Dialguin | Medicine (21), Food (16), Construction (02) |
| *Diospyros mespiliformis* | Diosmesp | Medicine (01), Food (31), Technology (16), Construction (21), Energy (05), Forage (01) |
| *Ficus* spp | Ficuspp | Medicine (03), Energy (03), Forage (03) |
| *Flacourtia indica* | Flacindic | Technology (14), Construction (30), Energy (18) |
| *Hymenocardia acida* | Hymeacid | Medicine (01), Energy (08), Forage (01) |
| *Isoberlinia doka* | Isobdoka | Medicine (01), Technology (78), Construction (115), Energy (105), Forage (15) |
| *Khaya senegalensis* | Khaysene | Medicine (11), Technology (117), Construction (74), Energy (27), Forage (74), Veterinary (11) |
| *Lannea acida* | Lannacid | Medicine (06), Food (04), Technology (01), Energy (01), Forage (03) |
| *Milicia excelsa* | Miliexce | Medicine 06), Technology (16), Construction (05), Energy (01) |
| *Parinari curatellifolia* | Paricura | Medicine (87), Energy (01), Forage (03), Veterinary (03) |
| *Parkia biglobosa* | Parkbigl | Medicine (05), Food (67), Technology (02), Construction (01), Energy (18), Forage (06), Veterinary (02) |
| *Pericopsis laxiflora* | Perilaxi | Medicine (02), Energy (06), Forage (01) |
| *Piliostigma thonningii* | Pilithon | Medicine (4), Energy (01), Veterinary (01) |
| *Pseudocedrela kotschyi* | Pseukots | Medicine (01), Technology (49), Construction (19), Energy (09), Forage (03), Veterinary (04) |
| *Pterocarpus erinaceus* | Ptererin | Medicine (04), Technology (128), Energy (92), Forage (106), Veterinary (06) |

**Table 3** continued

| Species | Abbreviated name | Use categories (citation) |
|---|---|---|
| *Sarcocephalus latifolius* | Sarclati | Medicine (01), Food (03), Forage (02) |
| *Spondias mombin* | Sponmomb | Medicine (12), Food (22), Energy (01), Veterinary (01) |
| *Sterculia setigera* | Sterseti | Medicine (04), Food (01), Construction (03), Forage (01) |
| *Strychnos spinosa* | Stryspin | Medicine (01), Food (10), Forage (02) |
| *Syziguim guinense* | Syzyguin | Food (6), Forage (3), Veterinary(2) |
| *Uvaria chamae* | Uvarcham | Medicine (03), Food (01), Energy (01) |
| *Vitelaria paradoxa* | Vitepara | Medicine (14), Food (103), Technology (09), Construction (05), Energy (82), Forage (04) |
| *Vitex doniana* | Vitedoni | Medicine (01), Food (19), Construction (02), Technology (01), Energy (01), Forage (05) |
| *Ximenia americana* | Ximeamer | Medicine (02), Food (15), Forage (01) |

$p = 0.0026$), medicinal ($r = 0.362$, $p = 0.032$), distribution ($r = 0.425$, $p = 0.010$) and status ($r = 0.155$, $p = 0.014$), and between importance value index and partial importance value index ($r = 0.637$, $p < 0.0001$).

# 4 Discussion

## 4.1 Versatility and popularity of tree species around Wari-Maro forest

Seventy-nine species are cited as useful by local people around Wari-Maro forest, and species of Leguminosae are the most mentioned in the local knowledge. This finding corresponds to the general vegetation pattern in the Sudanian zone of Sub-saharan Africa, where Leguminosae is the most abundant plant family as well as mostly used by local people (see Zizka et al. 2015). Among the thirty-five woody species highlighted as most popular and versatile by this study, eleven (*A. digitata, A. senegalensis, A. leiocarpa, D. microcarpum, D. mespiliformis, K. senegalensis, P. biglobosa, P. erinaceus, S. setigera, V. paradoxa, X. americana*) have also been reported by Zizka et al. (2015) in Burkina Faso, and two other (*M. excelsa* and *S. latifolius*) by Tabuti (2007) in Uganda as useful plants species. *A. africana*, *D. oliveri, I. doka, K. senegalensis, P. kotschyi* and *P. erinaceus* are known by almost all the investigated ethnic groups for their construction, technology, energy, forage and veterinary uses. Indeed, these woody species are widely distributed and are effective for the concerned uses.

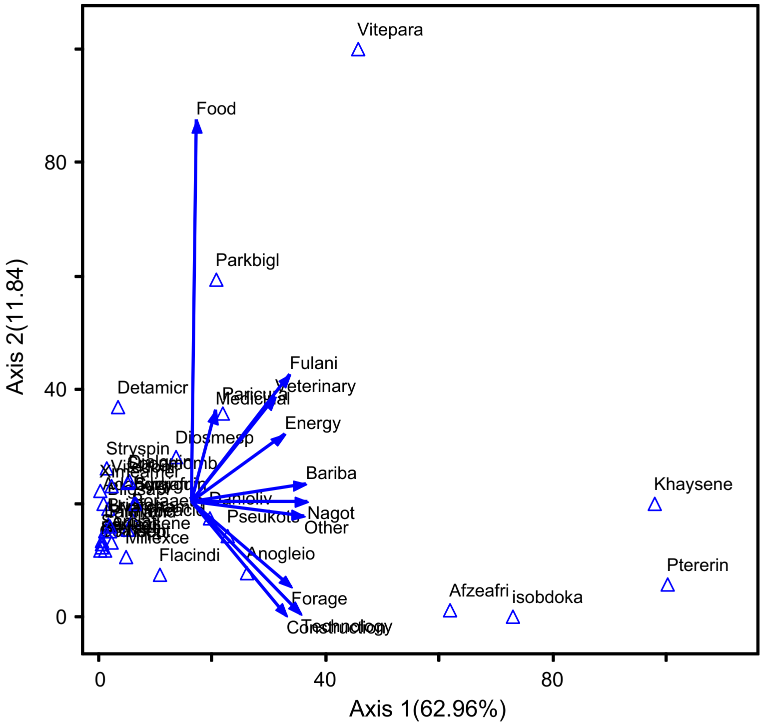


**Fig. 3** Pattern of popularity and versatility of species according to the first two PCA axes. Variables are: nedicinal; energy; construction; veterinary; forage; technology; food; Nagot; Bariba; Fulani and other

**Table 4** Knowledge index (KI) for all sociocultural groups

| Sociocultural group | *S* | *N* | KI |
|---|---|---|---|
| Nagot | 71 | 81 | 0.877 |
| Bariba | 63 | 47 | 1.340 |
| Fulani | 31 | 8 | 3.875 |
| Others | 34 | 13 | 2.615 |

*S* number of cited species; *N* number of informants

In our study, Fulani people had the ability to identify the highest number of useful forest species. This trend has also been observed elsewhere in West Africa (Sop et al. 2012) where Fulani people are known to hold deep knowledge on natural resources as a consequence of close association of their lifestyle and nature, and thus, their dependency on natural resources. Nevertheless, the observation should be used with caution because of lower number of Fulani people involved in the study compared to other sociocultural groups.

In general, the medicinal use holds the highest importance (Fig. 2). Health problems are highly important for humans, and thus, deep knowledge for medicinal usability of native species can be expected. Wealth level has been proved as a potential indicator of local knowledge and natural resource use in rural tropical communities (Gavin and Anderson 2007; Barnham et al. 1999). Thus, similar findings were observed for people living in the surrounding of Kainji Lake National park in Nigeria (Amusa et al. 2010) and around an

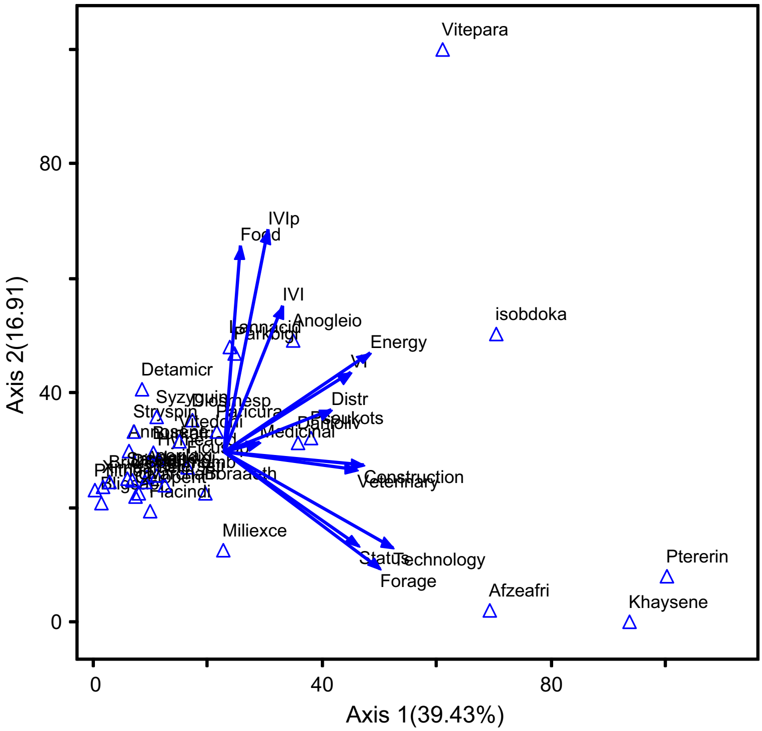


**Fig. 4** Projection of useful woody species onto the first two axes of principal component analysis (PCA). Variables are: *VI* versatility index; *IVI* importance value index; *IVIp* partial importance index; status; distr (distribution); medicinal; food; energy; forage; technology; construction; veterinary

Atlantic forest fragment in northeastern Brasil (Cunha and Albuquerque 2006). Many tree species in the forest reserve are also known for their usability for energy but effective utilization of tree species is depending on beliefs and taboos of the sociocultural groups. For instance, Nagots dispense with *H. acida* as fire wood while Fulani and Bariba are not restricted from this taboo in our study region. Similar restrictions have been reported for *A. africana* for Gourmantche people in the surrounding of Pendjari Biosphere reserve in Benin (Houehanou et al. 2011) as well as for Gourounsi people in Burkina Faso (Kristensen and Balslev 2003).

## 4.2 Ecological availability and conservation priorities of useful tree species

Leguminosae are the most abundant family observed in the Wari-Maro forest and consequently, members of Leguminosae are considered as the most popular and versatile species for local people. Positive correlations between species dominance, frequencies, importance value index and use values are commonly observed (Lucena et al. 2012; Torre-Cuadros and Isabelle 2003) and support the «appearance hypothesis» in ethnobotany which states that abundant species in a given ecological area are mostly used (Guèze et al. 2014; Lucena et al. 2012; Albuquerque et al. 2009; Phillips and Gentry 1993).

In this study, species such as *A. africana*, *K. senegalensis* and *P. erinaceus* are the most versatile and the least available, and consequently, they are characterized as priority species for conservation. Furthermore, a more significant correlation between versatility and wood uses (construction, technology and energy) was found. Thus, wood uses appear to drive the versatility more than medicinal ones.

If *A. africana*, *K. senegalensis* and *P. erinaceus* are among species mostly used for wood and are also the least available, this can mean that wood uses have negative effect on species availability. However, several factors such as plant life history, environmental conditions and land-use context are able to impact the availability of tree species in their environment (Amusa et al. 2010; Ticktin 2004). Unfortunately, these factors are largely unknown for most tropical tree species, and in addition, low ecological availability is also often caused by overexploitation which provides a striking argument for conservation priority. Indeed, low availability of *A. africana*, *K. senegalensis* and *P. erinaceus* could be really attributed to the extreme wood use pressure in the Wari-Maro forest (personal field observation). Conservation priorities setting of used local woody species must then take into account their versatility and availability. Consideration of medicinal usability of woody species alone may have a bias, and thus, non-medicinal uses should be incorporated as well (Oliveira et al. 2007).

Our finding according to which *K. senegalensis* is highlighted as priority tree species for conservation also corroborates Lykke (2000) in Senegal. In the region of our study, *A. africana*, *K. senegalensis* and *P. erinaceus* have also been found as medicinal priority species for conservation (Yaoitcha et al. 2015). Such convergence of results on these woody species is explained by either their highest medicinal and wood (technology, construction, energy) usefulness. In return, considering woody species that are known for some specific uses (for instance *A. digitata* and *T. indica* mostly sought for food use, *S. longipedunculata* mostly sought for medicinal use), our findings are different from those of Yaoitcha et al. (2015). Thus, combining multiples uses in priority setting for conservation of woody species is of great importance to guide their efficient conservation and management strategies.

The three woody species *D. oliveri, I. doka* and *P. kotschyi,* highlighted as most popular and versatile, can also receive a priority for conservation. Indeed, even though the study showed that they were more available in forest than *A. africana*, *K. senegalensis* and *P. erinaceus*, their availability can be compromised in future because of their great usefulness. Then, they can be ranked as woody species of second priority for conservation.

### 4.3 Assessment of used approach, conclusion and implications

Regarding the increasing human population and thus, human pressure on environment, ethnobotany is definitively important for guiding sustainable biodiversity conservation. Recently, human impact is one of the most important drivers of biodiversity. Integration of species' usability for human welfare, e.g., for medicinal and wood uses, may thus increase the success of conservation strategies (Oliveira et al. 2007). We used a step-by-step approach by first, estimating the popularity and versatility of the plant species used by local people, second, to determine their ecological availability, third, to assess their distribution and status, and finally, to identify priority species for conservation in this area. We applied multivariate analyses to implement simultaneously several criteria. This approach allowed us to understand the importance of the integration of wood uses and the local availability in prioritizing woody species for conservation. However, the calculation of the local availability through the importance value index can be biased by some features. Indeed, the low local availability may be linked to genetic and demographic variation of species population (Albuquerque et al. 2011) or to species ecological characteristics such as live and growth forms. At present, only few studies have incorporated multiple uses in a conservation priorities setting of woody species, but this study has attempted to overcome this limitation by using an integrated approach.

As popularity and versatility of species were assessed by citation or knowledge only, our findings may be slightly biased. Local knowledge of tree species and their use are different aspects, and this may lead to differences between number of cited and effectively used species (Albuquerque and Hanazaki 2009; Albuquerque 2006). Indeed, many people know many species and may have heard from their uses. In our study, several use categories were confirmed in the study area before starting the interviews with local people to minimize the bias.

The economic importance is also a good indicator in priority setting of conservation (Brehm et al. 2010). But, it has not been integrated in the used approach because it becomes more complex to estimate the economic value when we integrate the versatility of the woody species. Also, it is evident that versatile woody species can be economically valuable.

In conclusion, since integration of indigenous knowledge in ecological researches can enhance successful conservation strategies and provide objectives for future researches, our findings indicate that conservation of some woody species is urgently needed considering their versatility and their ecological availability. Wood uses are important for setting conservation priority, and they are the most important driver for versatility of woody species. Assisted natural regeneration and growing of artificially produced seedlings may conserve priority woody species in midterm. Awareness of local people to spare and protect priority species in their agroforestry parklands can also be helpful for the conservation of concerned tree species. Successful conservation strategies should therefore not only focus on these species but alternative species and activities may also supply local people livelihoods.

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