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Knowledge, valuation and prioritization of 46 woody species for conservation in agroforestry systems along Ouémé catchment in Benin (West Africa)

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Abstract The Ouémé catchment abounds an important diversity of woody plant species. However, harvesting pressure on these species seems to lead to threats of their sustainability. Despite this fact, few published studies concerning their conservation have been undertaken. In this regard, our study focused on (1) assessment of impact of socio-demographic factors and climatic zones on knowledge and use of the woody plant species; (2) assessment of the use status of each of these species and (3) ranking within each climatic zone these species according to their priority for conservation. A total of 411 randomly selected informants were interviewed through a semi-structured survey followed by a field survey in 69 random plots of 0.15 ha. Data from available literature were used to complete the surveys. Ecological and ethnobotanical parameters were computed, and the highest priority species for conservation were identified. The results showed significant difference in plant use between women and men, ethnic groups and climatic zones. However, age was not a determinant of plant knowledge. The findings also revealed that more than 50% of native species in the study area are underutilized or widely used by few people. Moreover, six species were identified as priorities and need high conservation efforts in the two climatic zones, namely: *Parkia biglobosa*, *Pterocarpus erinaceus, Milicia excelsa, Prosopis africana*, *Afzelia africana* and *Khaya senegalensis*. Non-governmental organizations, governments and agroforestry research institutions are entreated to incorporate these species in local development strategies aiming at sustainable management and long-term conservation of native species.

Keywords Woody plant · Local people · Knowledge and use · Conservation priorities · Ouémé catchment · Benin

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1 Introduction

Benin is a moderately forested country with vegetation dominated by savannahs mosaics whereby degradation of forests is still a major concern (Akpona et al. 2017a). The forest cover is estimated at 4,511,000 ha, which represents 40% of the country total area. However, the loss of forests was estimated at 75,000 ha/year between 1990 and 2011 (FAO 2011). Land clearing for agriculture, illegal tree felling, bushfires, charcoal production and overgrazing is often referred to as the main drivers of forest degradation in Benin (Akpona et al. 2017a). This has resulted in decline of the populations of many economically important indigenous species (Tchibozo 2014). Additionally, several studies highlighted the negative effects of the forest degradation on many plants species (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 (Ahoyo et al. 2017; Lokonon et al. 2017).

Like in the whole Benin, Ouémé catchment, which represents an important reserve of biodiversity, is experiencing the same decline of the population of many important species (Hiepe and Diekkrüger 2006). Moreover, increasing intensity of human activities such as logging, cutting, harvesting and land clearing has been reported in this area (Hiepe and Diekkrüger 2006). Those activities in combination with drought could induce a decreasing availability of trees and led to the disappearance of many rare and valuable species (Oliveira et al. 2007). As such, it is necessary to establish priorities for the conservation of the most intensively used plant species (i.e., the useful woody species). Although conservation priority setting is seen as a fundamental step for guaranteeing conservation and sustainable use of intensively used woody species (Oliveira et al. 2007), rare scientific works have been carried out in that perspective in Ouémé catchment.

In the past, the conservation of biodiversity has been mostly understood in terms of the management of protected areas (Vodouhê et al. 2011). However, recently, many authors have shown that traditional agroforestry practices contribute to the conservation of biodiversity through in situ conservation of tree species on farms (Ouinsavi et al. 2005; Djossa et al. 2008). Local people preserve in traditional agroforestry systems useful tree species for food, medicine, construction of dwellings, making household implements, beds and sleeping mats, firewood and shade (Vodouhê et al. 2009; De Smedt et al. 2011). In Benin, a traditional agroforestry consists of maintaining useful seedlings or trees on farmlands when preparing a plot for cropping (Vodouhê et al. 2011). However, local people do not use and value plants species equally (Vodouhê et al. 2009). According to the previous studies, factors such as age, gender, ethnic groups and climatic zones influence the valuation of a given plant species (Assogbadjo et al. 2012; Vodouhê et al. 2009). Age and gender determine intra-cultural variations, while ethnic groups express inter-cultural variations (Gouwakinnou et al. 2011; Houessou et al. 2012).

Several researchers have found that, generally, men cited significantly higher number of plants and use them than women (Case et al. 2005; Camou-Guerrero et al. 2008; Paré et al. 2010). They explain this fact by the education and labor responsibilities of men and women in traditional societies. It is also reported that youngest people often possess lowest levels of knowledge and use of plants than older people (Case et al. 2005; Vodouhê et al. 2009). Two of the most widely reported factors likely to result in a difference in the use of plants between different communities are ethnicity and climatic zones they inhabit (Gouwakinnou et al. 2011; Sop et al. 2012). Various authors have suggested that differential species values among ethnic groups are related to specialized cultural transmission (Case et al. 2005; Gaoué and Ticktin 2009). This may lead to greater information heterogeneity and help explain why the various ethnic groups value the useful species differently (Adhikari et al. 2004). At the same time, similarity among ethnic groups has been explained by geographical proximity (Vodouhê et al. 2009). Taking into account socio-demographic and climatic zones may help in sustainable management and long-term conservation of native species (Camou-Guerrero et al. 2008; Vodouhê et al. 2009).

In our previous study (Lokonon et al. 2017), we have inventoried woody species used by the local people in Ouémé catchment and general analysis was made on conservation priority of these species. Despite the presence of useful woody species in the agroforestry systems of this catchment, there is a limited understanding of the factors that determine their value in traditional communities and what woody species are priorities for local people. Moreover, nothing is known on the status of the woody species in Ouémé catchment. This study aims to fill a such gap to enhance conservation of woody plants and biodiversity in this area. Following insights from previous researches showing that the valuation of plant resources depends on social traits and climatic zones (Gouwakinnou et al. 2011; Sop et al. 2012), we tested whether the use of woody species in Ouémé catchment is a function of age, gender, ethnic groups and climatic zones. Moreover, we hypothesized that the local useful woody species in Ouémé catchment are underutilized. In addition, knowing that the climatic zones have an effect on use preference of woody species and then on the species having priority for conservation, we also assume that local people prioritize the woody species according to their localization. The objectives of this study are to: (1) assess the impact of socio-demographic factors and climatic zones on knowledge and use of 46 woody species in Ouémé catchment; (2) assess the use status of the woody species across age, gender, climatic zones and ethnic groups and (3) rank within each climatic zone the woody species according to their priority for conservation.

2 Materials and methods

2.1 Study area

This study was conducted in the Ouémé catchment located between 6.8° and 10.2° north latitude and between 1.5° and 3.5° east longitude (Fig. 1) from central to southern regions of the Republic of Benin. In the central part, the climate is tropical with mean annual rainfall ranging from 900 to 1000 mm (Lawin 2007). The southern part is under the influence of the subequatorial climate with a mean annual rainfall of 1200 mm (Assogbadjo et al. 2006). The central part is called Sudano-Guinean zone, while the southern part is Guinean zone. The landscape is characterized by forest (21.74%), savannah (40.76%) and agriculture lands (34.17%) (Keyzer et al. 2007). About 12,000 households inhabit the catchment, 60% of which are farmers (Keyzer et al. 2007).

The most important socio-cultural groups are Mahi, Goun, Fon, Bariba and Nagot (Floquet and van den Akker 2000). All these ethnic groups are sedentary, farmers and cattle keepers. The most important livelihood activities are agriculture (crop production). The main form of farming system is agroforestry parkland, which involves intercropping of agricultural crops under scattered mature trees in farms. Useful trees are retained by farmers in the agroforestry parklands due to their variety of non-timber uses such as food

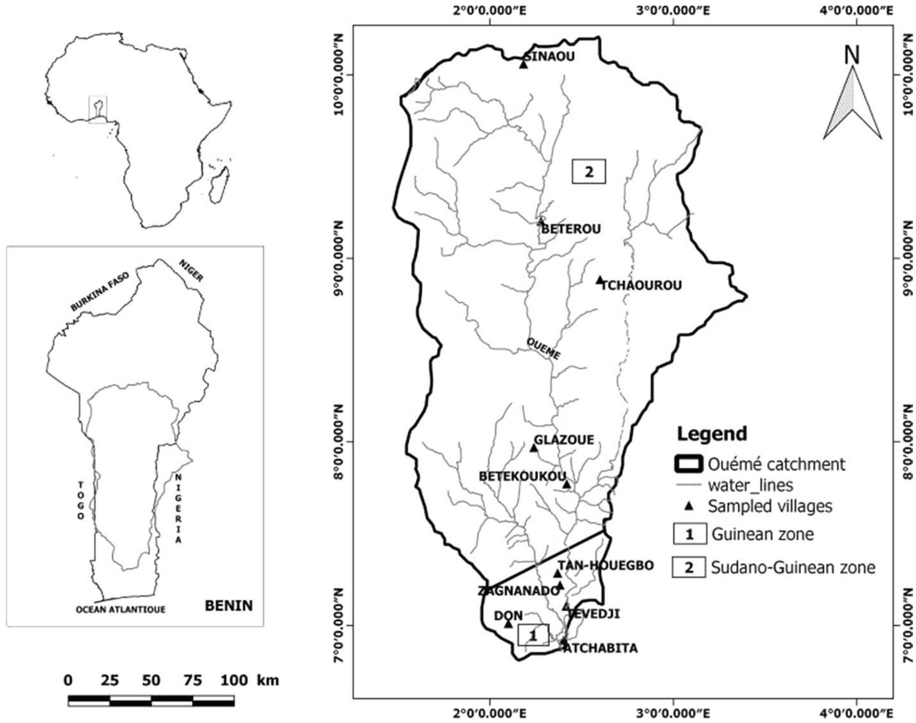

Fig. 1 Location of the surveyed localities within the Ouémé catchment

and medicine (Teklehaimanot 2004). Maize (*Zea mays*), yam (*Dioscorea* spp.) and cassava (*Manihot esculenta*) are the major food crops.

2.2 Sampling and data collection

Two kinds of data were used: the primary data (from the surveys) and the secondary data (from the literature). The primary data were collected in two steps. The first step concerns the ethnobotanical survey and the second the ecological survey. The five most important ethnic groups were sampled for the study. Fon, Goun, Mahi and Nagot are mainly located from southern to central part of the catchment. Goun are situated in the locality of Tévèdji and Atchabita (Fig. 1). Fon and Mahi populate the localities of Don, Zagnanado and Tan-Houegbo, while Nagot are located in the villages of Glazoué and Bétékoukou. Bariba are located at north of the catchment in the localities of Bétérou, Tchaourou and Sinaou. Before collecting the ethnobotanical data, a brief survey on 60 interviewees randomly chosen (Dagnelie 1998) was done in the catchment. The proportion of informants that have at least two woody species involved in the agroforestry systems was estimated. The proportion P of positive answers was $P = 58/60$, $P \approx 0.97$ and have been used in the calculation of the number of the surveyed individuals.

We then conducted the semi-structured interviews with the household using a questionnaire. In total, 10 localities were sampled from the 47 districts of the catchment. Within each climatic zone, five localities were sampled (Fig. 1). These localities were chosen due to their knowledge of agroforestry practices. In each sampled localities, the number n of the surveyed individuals was estimated using the formula (Dagnelie 1998):

$$n = U^2_{1-\alpha/2}\left[P(1 - P)/d^2\right], \quad (1)$$

where n is the total number of surveyed people within a locality; $U_{1-\alpha/2} = 1.96$ for $\alpha = 0.05$; P is the estimated proportion of informants that have at least two woody species involved in the agroforestry systems; d is the expected error margin of any parameter to be estimated from the survey and is considered as 5%. In total, 411 people were surveyed through the study area (Table 1).

Before the proper survey, the questionnaire was pretested and improved. Each informant was asked to list the woody plant species from the agroforestry systems that they actually use. For each species, the participant gave information on the uses, the part of the plant harvested and their preference for this species.

As far as ecological survey was concerned, the inventory design followed a random sampling scheme and was constituted of rectangular plots of 30×50 m (Glèlè Kakaï and Sinsin

Table 1 Repartition of respondents according to localities, ethnic groups, sex, age and climatic zones

Characteristics	Number of informants	Proportion (%)
Localities		
Sinaou	40	9.73
Bétérou	40	9.73
Tchaourou	40	9.73
Glazoué	40	9.73
Bétékoukou	44	10.71
Tan Houègbo	42	10.22
Zagnanado	40	9.73
Tévèdji	42	10.22
Don	42	10.22
Atchabita	40	9.73
Climatic zones		
Sudano-Guinean zone	193	46.96
Guinean zone	218	53.04
Ages (in years)		
Youth	131	31.87
Adults	199	48.42
Old people	81	19.71
Ethnic groups		
Bariba	43	10.46
Fon	47	11.44
Goun	39	9.49
Mahi	202	49.15
Nagot	80	19.46
Sex		
Male	320	77.86
Female	91	22.14

2009). The size of plots was computed to guarantee a margin error of $d = 10\%$ for the estimation of the mean basal area using the following formula (Dagnelie 1998):

$$N = \frac{t^2_{1-\alpha/2}\mathrm{CV}^2}{d^2} \quad (2)$$

where $t^2_{1-\alpha/2}$ ($\alpha = 0.05$) is the critical value of the t-distribution that converges to the normal distribution for a large sample set ($N > 30$) and approximately equal to 1.96; CV = coefficient of variation of the mean basal area. A prior survey was carried out on one hundred woody species randomly chosen in the study area, and the coefficient of variation was calculated to be 42.4%. Considering these values, N was estimated to 69 plots. The 69 plots were shared among the ten localities, proportionally to their importance. In total, five plots were sampled at Atchabita, six plots at Tan Houègbo, Zagnanado, Tévèdji and Don and eight plots at Sinaou, Bétérou, Tchaourou, Glazoué and Bétékoukou. Within each plot, all useful woody species with diameter ≥ 3 cm and height ≥ 1 m were recorded (Trindade et al. 2015).

The secondary data were obtained consulting PROTA4U (http://www.prota4u.org/), IUCN sites and national documents. The origin and the status of the species as well as the list of uses of each species at international level were recorded. The species listed by the respondents using their local names were later identified taxonomically in the Analytic Flora of Benin (Akoègninou et al. 2006). Plant specimens were also collected during the ecological survey, and identification was done by specialists at the National Herbarium of Benin.

2.3 Data analysis

2.3.1 Differences in use category based on gender, age, ethnic groups and climatic zones

The 46 species were grouped into eight use categories: food, medicine, construction, fuel, technology, fodder, veterinary and worship. The definition of the categories of use of the species was derived from (Trindade et al. 2015). The number of species mentioned by each informant for each of the use categories, as well as the total number of species, was calculated. In order to assess differences in the use categories of species based on age, gender (male and female), ethnic groups (Bariba, Fon, Goun, Mahi, Nagot) and climatic zones (Guinean zone, Sudano-Guinean zone), the mean number of species in each use category reported per informant was compared. Age was categorized as follows (Assogbadjo et al. 2008): (1): youth (≤30 years old), adults ($30 < i \leq 60$ years old) and old people ($i \geq 60$ years old). Differences based on gender and climatic zones were assessed using the Mann–Whitney nonparametric test since the data were not normally distributed. Differences between ages and ethnic groups were analyzed using one-way analysis of variance (ANOVA). Thereafter, the Student–Newman–Keuls (SNK) test was performed as a post hoc test. In addition, the relative importance was determined by computing the use value (UV) for each species using the indices proposed by Galeano (2000):

$$\mathrm{UV_s} = \sum U_\mathrm{s} \cdot n_\mathrm{i}^{-1} \quad (3)$$

where UV_s is the use value of each species, U_s is the number of uses mentioned for each species, n_i is the total number of informants. The use value was computed for each species by age category, gender, ethnic groups and climatic zones, and graphs were constructed.

2.3.2 Assessing the use status of the woody species across age, gender, climatic zones and ethnic groups

Two parameters were computed according to age, gender, climatic zones and ethnic groups: the citation rate and the mean use rate. The citation rate (percentage of respondents who use the species) is calculated by dividing the number of respondents citing the species by the total number of respondents. The mean use rate (proportion of use categories) is obtained for each species by dividing the number of use categories cited by the informants by the total number of use categories at an international level. According to age, gender, climatic zones and ethnic groups, a graph was drawn by positioning the species based on their citation rate (*x*-axis) and mean use rate (*y*-axis). This allowed us to distinguish four categories of species on the graph: (1) underutilized species: lower left corner; (2) overharvested species: upper right corner; (3) species widely used by few farmers: upper left angle and (4) species with few use categories but exploited by many farmers: lower right corner. The underutilized species concept refers to the species that both have low citation rate and low mean use rate. On the contrary, overharvested species comprises those that have both high citation rate and high mean use rate.

2.3.3 Local priorities for conservation of the woody species according to climatic zones

The conservation priorities were calculated using and adapting the formula of Oliveira et al. (2007). Indeed, it has been argued previously by some authors (Oliveira et al. 2007; Albuquerque et al. 2009) that incorporating cultural and ecological aspects was effective for assessing local conservation priorities of plants species. The local conservation priority index (LCPI) was computed for each species in Guinean and Sudano-Guinean zones using the formula (Oliveira et al. 2007):

$$\mathrm{LCPI} = 0.5\,(\mathrm{BS}) + 0.5\,(\mathrm{RU}) \tag{4}$$

where BS represents the biological score and RU the risk of utilization score.

The biological score, $\mathrm{BS} = D \times 10$, where D is a score obtained based on the relative density (RD) of each species (RD = ratio between the number of the species and the number of individuals of all the species) (Table 2).

The risk of utilization score was obtained with the formula:

$$\mathrm{RU} = 0.5(U) + 0.5(H) \times 10 \tag{5}$$

The value of U was obtained for each species by taking the greater value between its local importance (L) and its diversity of use (V) (Table 2). The harvesting risk score (H) was deduced from consequences of harvesting on the plants survival (Table 2).

The values of LCPI were used to classify the species in three categories of conservation following Oliveira et al. (2007):

- Category 1: $\mathrm{LCPI} \geq 85$, meaning that the species have high priority for conservation;
- Category 2: LCPI between 60 and 84, indicating that the species have moderate priority for conservation;

Table 2 Parameters and scores used to calculate the priority index (modified from Oliveira et al. (2007))

Parameters	Scores
Relative density score (*D*)	
Not encountered—very low (0–1)	10
Low (1 < 3.5)	7
Medium (3.5 < 7)	4
High (≥ 7)	1
Local importance (*L*)	
High (cited by > 20% of the local informants)	10
Moderately high (cited by 10–20% of the local informants)	7
Moderately low (cited by < 10% of the local informants)	4
Use diversity (*V*)	
One point is summed for each use categories reported	$1-\infty$
Harvesting risk score (*H*)	
Harvesting results in overexploitation of roots, bark or removal of the plant	10
Harvesting affects perennial structures such as the bark and roots. Harvesting does not cause the death of the plant	7
Harvesting affects permanent aerial portions of the plants (leaves), which are removed	4
Harvesting affects transitory aerial portions of the plants (flowers and fruits), which are removed	1

- Category 3: LCPI < 59, species with low priority for conservation.

3 Results

3.1 Impact of socio-demographic factors and climatic zones on knowledge and use of the 46 woody species

3.1.1 Effect of age, gender, ethnicity and climatic zones on plants knowledge

The mean number of plants cited for each use category and the total number of plants did not significantly differ between ages except food (Table 3). However, the overall mean number of plants is greater for the older people than for the younger people. Also, it was shown that the men generally possessed a greater knowledge of plant woody species than the women (Table 3). The number of species cited by the informants of different genders showed significant differences in the following categories: medicine, technology and forage. As far as the climatic zone is concerned, the respondents had a greater knowledge of the plant species in Guinean zone than in the Sudano-Guinean zone (Table 3). The number of species listed by the informants in the different zones showed significant differences in the following categories: food, medicine, construction, fuel and technology. Moreover, considering all use categories, significant difference was found between the total number of the species reported by the five ethnic groups (Table 3). Except medicinal and forage use categories, significant differences were found among the ethnic groups in the other use categories. The Goun cited the higher mean number of species in general but also in

Table 3 Mean number of woody species (± SD) reported by the informants for different categories of use

Factors	Food	Medicine	Construction	Fuel	Technology	Fodder	Veterinary	Worship	Total
Age									
Youth	2.53 ± 1.45a	3.15 ± 1.61a	3.49 ± 1.48a	4.27 ± 1.66a	3.48 ± 1.69a	2.09 ± 1.09a	1.00 ± 0.00a	1.25 ± 0.46a	17.88 ± 7.25a
Adults	3.28 ± 1.69b	3.49 ± 1.72a	3.23 ± 1.71a	4.58 ± 2.00a	3.36 ± 1.82a	2.37 ± 1.18a	1.25 ± 0.68a	1.23 ± 0.59a	18.76 ± 8.22a
Old people	3.25 ± 1.64b	3.71 ± 1.77a	3.18 ± 1.66a	4.47 ± 1.76a	3.57 ± 1.86a	2.37 ± 1.10a	1.71 ± 1.11a	1.30 ± 0.53a	19.81 ± 7.30a
p value	0.023*	0.250ns	0.631ns	0.614ns	0.658ns	0.456ns	0.272ns	0.856ns	0.396ns
Gender									
Female	3.24 ± 1.77	3.04 ± 1.49	2.87 ± 1.45	4.22 ± 1.99	2.78 ± 1.67	2.00 ± 0.86	1.50 ± 0.71	1.21 ± 0.42	16.39 ± 6.77
Male	3.16 ± 1.64	3.61 ± 1.76	3.32 ± 1.70	4.59 ± 1.89	3.58 ± 1.80	2.42 ± 1.20	1.31 ± 0.77	1.25 ± 0.58	19.52 ± 8.06
p value	0.822ns	0.007**	0.056ns	0.103ns	0.0003***	0.028*	0.357ns	0.896ns	0.001**
Climatic zones									
Guinean zone	2.56 ± 1.39	3.63 ± 1.63	4.00 ± 1.52	4.87 ± 1.83	4.15 ± 1.76	2.32 ± 1.09	1.21 ± 0.49	1.24 ± 0.56	21.42 ± 7.34
Sudano-Guinean zone	3.88 ± 1.68	3.31 ± 1.81	2.13 ± 1.17	4.06 ± 1.93	2.44 ± 1.34	2.38 ± 1.26	1.58 ± 1.16	1.27 ± 0.59	16.01 ± 7.44
p value	0.000***	0.04*	0.000***	0.000***	0.000***	0.976ns	0.468ns	0.866ns	0.000***
Ethnicity									
Bariba	3.97 ± 1.38a	3.39 ± 1.50a	2.46 ± 1.17b	3.81 ± 1.61b	2.62 ± 1.05b	2.95 ± 1.21a	1.00 ± 0.00a	1.75 ± 0.87a	17.79 ± 7.43bc
Fon	3.69 ± 1.63a	3.31 ± 1.83a	2.42 ± 1.54b	4.33 ± 1.94b	2.15 ± 0.99b	2.86 ± 1.46a	1.00 ± 0.00a	1.00 ± 0.00b	14.83 ± 7.59c
Goun	3.24 ± 1.43ab	4.27 ± 1.73a	4.14 ± 1.22a	5.41 ± 1.59a	4.43 ± 1.83a	2.33 ± 1.08a	1.00 ± 0.00a	1.54 ± 0.82ab	23.52 ± 7.01a
Mahi	2.74 ± 1.55b	3.52 ± 1.73a	3.59 ± 1.68a	4.71 ± 1.92ab	3.79 ± 1.83a	2.21 ± 1.05a	1.23 ± 0.53a	1.18 ± 0.48b	19.92 ± 7.65b
Nagot	4.05 ± 1.73a	3.19 ± 1.66a	2.11 ± 1.22b	3.93 ± 1.86b	2.48 ± 1.43b	2.63 ± 1.48a	2.17 ± 1.47b	1.10 ± 0.31b	15.89 ± 7.55c
p value	0.000***	0.073ns	0.000***	0.000***	0.000***	0.052ns	0.048*	0.002**	0.000***

SD standard deviation

Information is based on gender, age, ethnicity and climatic zone. Values with no common superscript in each use category are significantly different ($p < 0.05$). ns: non-significant at $P \geq 0.05$; *, significant at $P \leq 0.05$; **, significant at $P \leq 0.01$; ***, significant at $P \leq 0.001$

construction, fuel and technology use categories (Table 3). The Nagot listed a higher mean number of species in food and veterinary use categories.

3.1.2 Relative importance of the species

The relative importance of each species was derived from its use value. Across ages and sex, the species with the highest use values were: *Elaeis guinensis*, *Mangifera indica*, *Tectona grandis*, *Anacardium occidentale*, *Vitellaria paradoxa* and *P. erinaceus* (Figs. 2, 3). The first three species were common to all sex and age categories. Concerning the climatic zones, *E. guinensis*, *A. occidentale*, *M. indica*, *V. paradoxa* and *T. grandis* were the five species most used (Fig. 4). *E. guinensis* is the most used species in the Guinean zone, while *A. occidentale* is the most used in the Sudano-Guinean zone. As far as the ethnic group is concerned, there was difference between Bariba and the other ethnic groups (Fig. 5). When Bariba cited *V. paradoxa*, *P. biglobosa* and *P. erinaceus* as the most used species, the other ethnic groups listed *E. guinensis*, *M. indica* and *A. occidentale*. Except for Bariba, the two used species across socio-demographic factors and climatic zones were exotic woody species (*E. guinensis, M. indica*). On the contrary, most of the less used species across socio-demographic factors and climatic zones were native woody species.

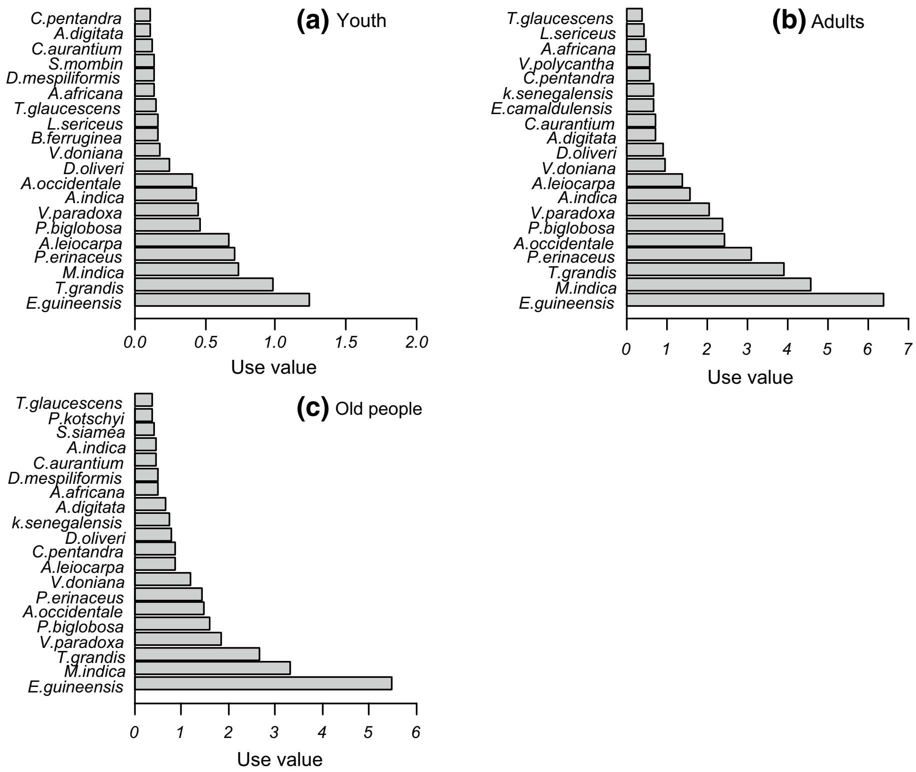

Fig. 2 Mean use values of the 20 most valuable woody species across age

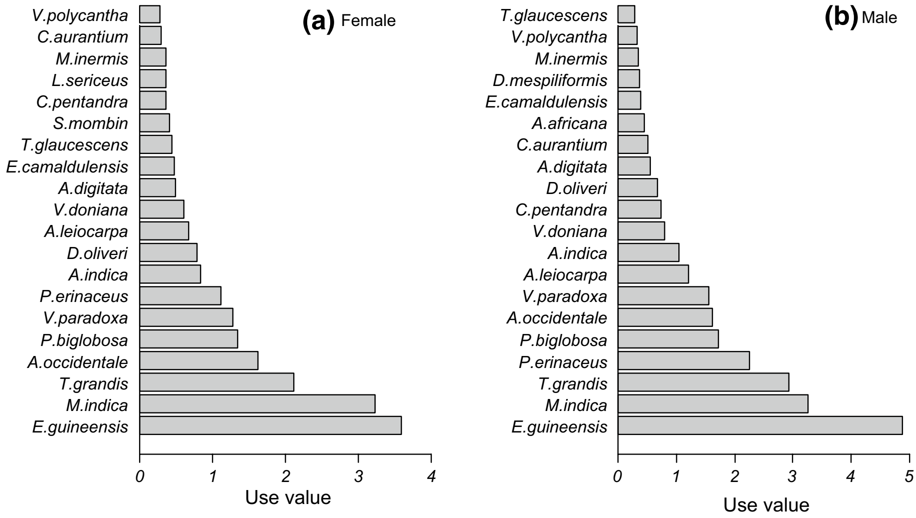

Fig. 3 Mean use values of the 20 most valuable woody species across sex

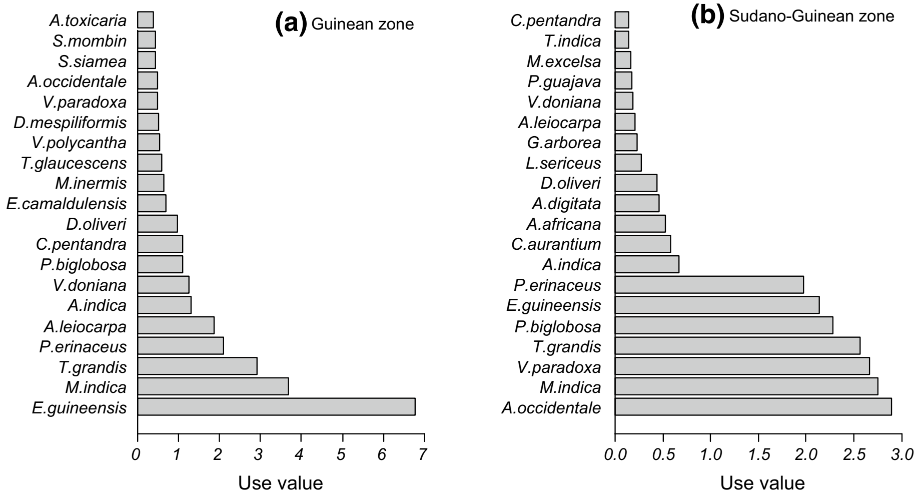

Fig. 4 Mean use values of the 20 most valuable woody species across climatic zones

3.2 Use status of the woody species in Ouémé catchment

Regarding the age of the respondents, the results were relatively similar (Fig. 6). For the three categories of people, *M. excelsa* and *Albizya zygia* were identified as underutilized species while *Eucalyptus camaldulensis* and *Bridelia ferruginea* were recorded as widely used by few farmers (Fig. 6). The men and the women listed the same species in the categories of underutilized species but recorded different species as widely used by few farmers (Fig. 7). Moreover, regardless of age and sex (Figs. 6, 7), *T. grandis*

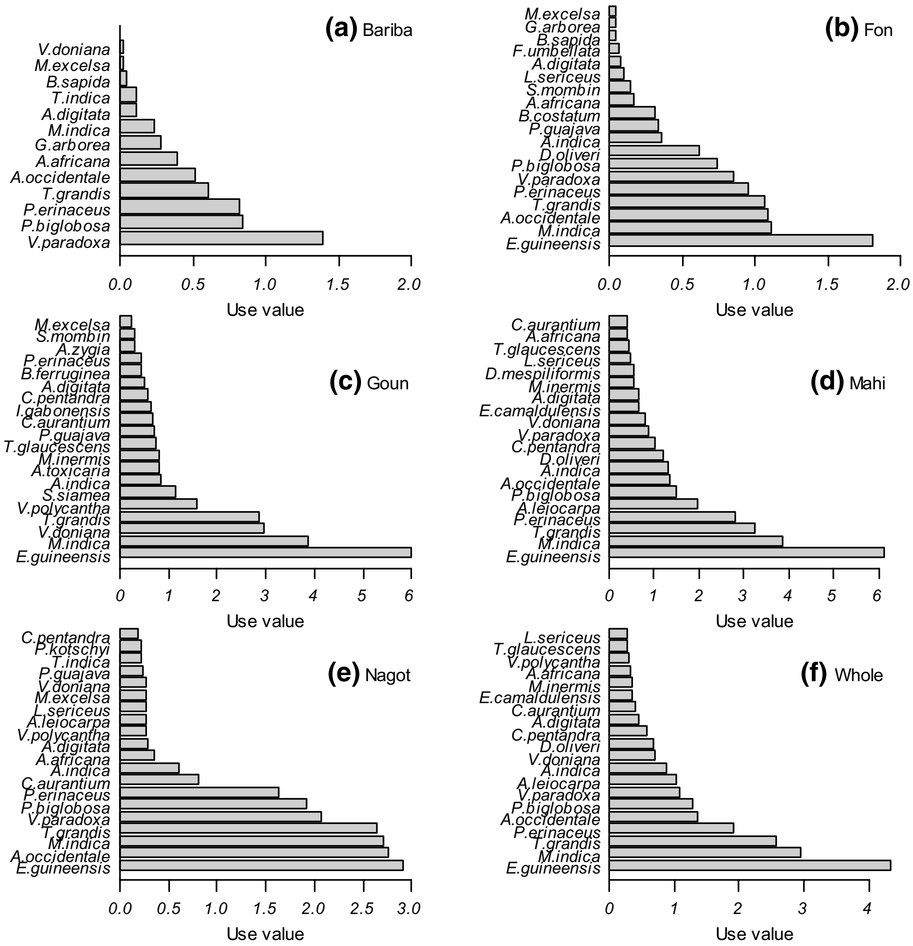

Fig. 5 Mean use values of the 20 most valuable woody species in each ethnic group

and *E. guineensis* usually plot in the down-right corner of the graph (species with few use categories but exploited by many farmers). Out of the similarity between the two climatic zones, *A. zygia* and in the Guinean zone and *M. excelsa* and *Moringa oleifera* in Sudano-Guinean zone were noted as underutilized (Fig. 8).

Concerning the ethnic groups, there was a clear difference between the species identified by Bariba and those of the other ethnic groups (Fig. 9). Within the Bariba ethnic group, the underutilized species were *M. exelsa*, *A. digitata* and *Vitex doniana* while *V. paradoxa* and *P. biglobosa* were assessed as overharvested species. The other ethnic groups recorded *M. indica* and *V. doniana* (for the Goun only) as overharvested and *K. senegalensis, Ficus umbellata, A. digitata, Spondia mombin, A. zygia, Crescentia cujete, Psidium guajava, M. excelsa* and *M. oleifera* as underutilized.

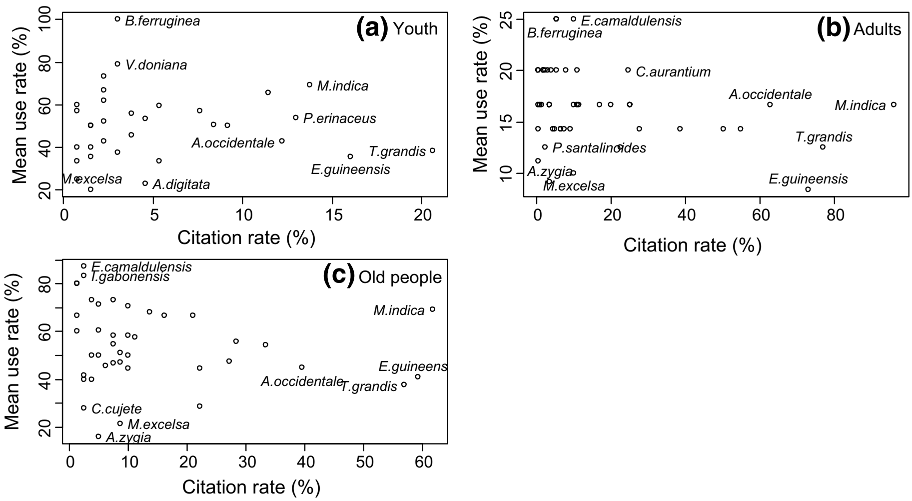

Fig. 6 Distribution of species according to their citation rate and mean use rate following age

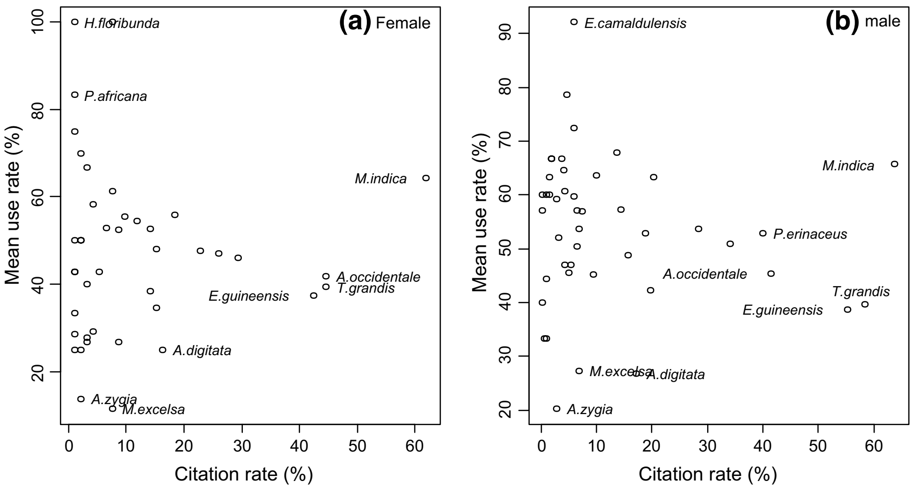

Fig. 7 Distribution of species according to their citation rate and mean use rate following sex

3.3 Local conservation priorities

3.3.1 Conservation priorities in Guinean zone

From the 46 species inventoried in the Ouémé catchment, 45 occurred in Guinean zone (Table 4). Four species (*P. biglobosa*, *M. excelsa*, *P. africana* and *P. erinaceus*) were included in category 1 (scores $\geq$ 85), indicating that continued harvesting could be expected to affect that species (Table 4). Harvesting of these species results in excessive collection of the fruits (*P. biglobosa*) or removal of the plants (*M. excelsa*, *P. africana* and *P. erinaceus*).

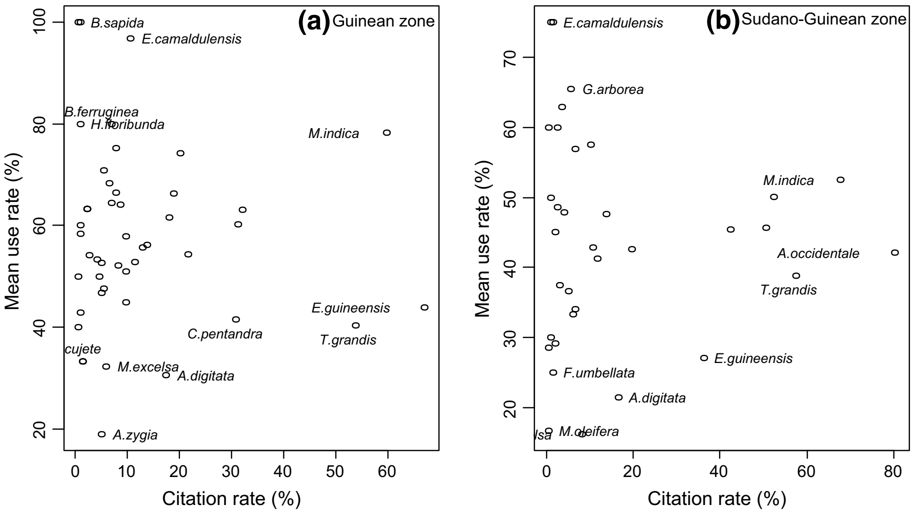

Fig. 8 Distribution of species according to their citation rate and mean use rate following climatic zones

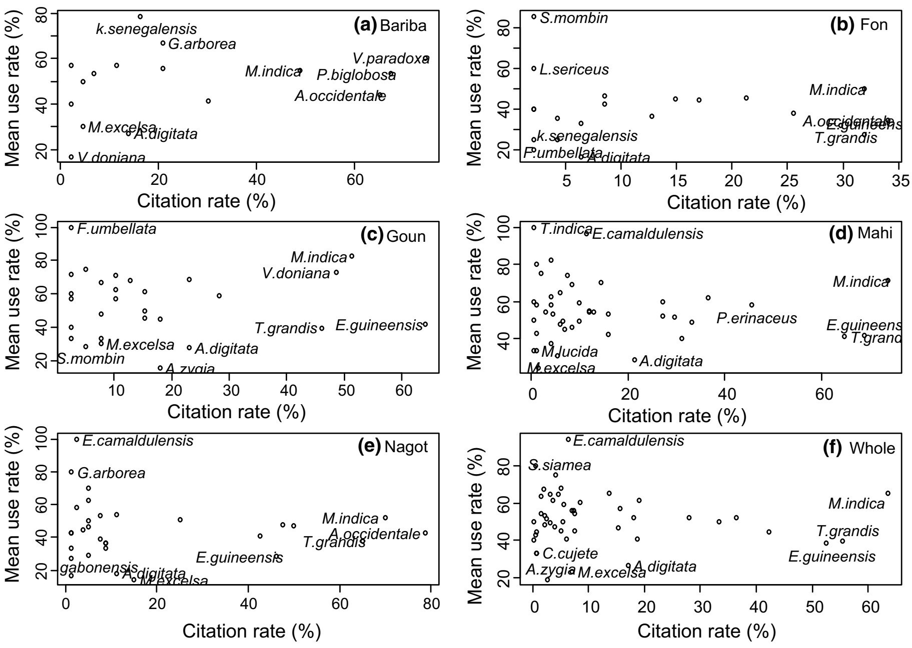

Fig. 9 Distribution of species according to their citation rate and mean use rate following all the informants' perception and the ethnic groups

Twenty-nine species were included within the category 2 (scores between 60 and 84) representing more than half of the inventoried species. Among the most important species in this category, we have: *Pterocarpus santalinoides*, *Tamarindus indica* and *A. digitata*. In

Table 4 List of useful woody species in Guinean zone according to their priority index

Species	Or	RD	*D*	*L*	BS	*H*	*V*	*U*	RU	LCPI
Parkia biglobosa (Jacq.) G. Don	N	0.88	10	4	100	10	5	5	75	87.5
Milicia excelsa (Welw.) C. C. Berg	N	0.49	10	4	100	10	5	5	75	87.5
Prosopis africana (Guill. and Perr.) Taub.	N	0.29	10	4	100	10	5	5	75	87.5
Pterocarpus erinaceus Poir.	N	0.98	10	4	100	10	5	5	75	87.5
Vitellaria paradoxa C. F. Gaertn.	N	0.49	10	4	100	7	6	6	65	82.5
Pterocarpus santalinoides DC.	N	0.49	10	4	100	7	5	5	60	80
Khaya senegalensis (Desr.) A. Juss.	N	0.68	10	4	100	7	5	5	60	80
Tamarindus indica L.	N	0.29	10	4	100	7	5	5	60	80
Adansonia digitata L.	N	0.59	10	4	100	7	5	5	60	80
Irvingia gabonensis Baill.	N	1.47	7	4	70	10	5	5	75	72.5
Ceiba pentandra (L.) Gaertn.	N	1.18	7	4	70	10	5	5	75	72.5
Vitex doniana Sweet	N	3.14	7	4	70	10	5	5	75	72.5
Vachellia polycantha Willd.	N	1.18	7	4	70	10	4	4	70	70
Antiaris toxicaria Lesch.	N	1.08	7	4	70	10	4	4	70	70
Albizia zygia (De.) J. F. Macbr.	N	1.57	7	4	70	10	3	4	70	70
Diospyros mespiliformis Hochst. ex	N	1.57	7	4	70	10	3	4	70	70
Anacardium occidentale L.	E	0.88	10	4	100	1	6	6	35	67.5
Citrus aurantum L.	E	0.98	10	4	100	1	6	6	35	67.5
Psidium guajava L.	N	0.20	10	4	100	1	6	6	35	67.5
Bligia sapida K. D. Koenig	N	0.29	10	4	100	1	5	5	30	65
Bombax costatum Pellegr. and Vuillet	N	0.20	10	4	100	1	5	5	30	65
Brideria ferruginea Benth.	N	0.39	10	4	100	1	5	5	30	65
Eucalyptus camaldulensis Dehnh.	E	0.49	10	4	100	1	5	5	30	65
Gmelina arborea Roxb.	E	0.69	10	4	100	1	5	5	30	65
Mitragyna inermis (Willd.) O. Kuntze	N	0.88	10	4	100	1	5	5	30	65
Pseudocedrela kotschyi (Schweinf.) Harms.	N	0.49	10	4	100	1	5	5	30	65
Annona senegalensis Pers.	N	0.10	10	4	100	1	4	4	25	62.5
Crescentia cujete L.	N	0.29	10	4	100	1	4	4	25	62.5
Holarrhena floribunda Durand and Schinz	N	0.49	10	4	100	1	4	4	25	62.5
Jatropha curcas L.	N	0.69	10	4	100	1	1	4	25	62.5
Lannea barteri Oliv.	N	0.98	10	4	100	1	4	4	25	62.5
Lophira lanceolata Van Tiegh. ex Keay	N	0.39	10	4	100	1	3	4	25	62.5
Moringa oleifera Lam.	N	0.39	10	4	100	1	4	4	25	62.5
Anogeissus leiocarpa (DC.) Guill. and Perr.	N	2.55	7	4	70	4	6	6	50	60
Lonchocarpus sericeus (Poir.) Kunth	N	5.88	4	4	40	10	3	4	70	55
Mangifera indica L.	E	1.96	7	7	70	1	6	7	40	55
Daniella oliveri (Rolfe) Hutch. and Dalziel	N	4.80	4	4	40	7	6	6	65	52.5
Ficus umbellata Vahl	N	1.37	7	4	70	1	5	5	30	50
Terminalia glaucescens Planch. Ex Benth.	N	1.57	7	4	70	1	5	5	30	50
Morinda lucida Benth.	N	1.57	7	4	70	1	2	4	25	47.5
Azadiratha indica A. Juss.	N	5.88	4	4	40	1	6	6	35	37.5
Senna siamea (Lam.) H. S. Irwin and Barneby	N	4.02	4	4	40	1	6	6	35	37.5
Spondia mombin L.	N	4.41	4	4	40	1	6	6	35	37.5

Table 4 (continued)

Species	Or	RD	*D*	*L*	BS	*H*	*V*	*U*	RU	LCPI
Elaeis guineensis Jacq.	E	32.06	1	7	10	1	6	7	40	25
Tectona grandis L.f.	E	9.41	1	7	10	1	5	7	40	25

Or origin, *E* exotic, *N* native, *RD* relative density, *D* relative density score, *L* local importance, *BS* biological score, *H* harvesting risk score, *V* diversity of use, *U* use, *RU* risk of utilization score, *LCPI* local conservation priority index

the category 3, eleven species whose harvesting would not immediately threaten their conservation were observed.

3.3.2 Conservation priorities in Sudano-Guinean zone

From the 46 species inventoried in the Ouémé catchment, 25 species occurred in Sudano-Guinean zone (Table 5). From the 24 species, six (*A. africana*, *M. excelsa*, *P. africana*, *P.*

Table 5 List of useful woody species in Sudano-Guinean zone according to their priority index

Species	Or	RD	*D*	*L*	BS	*H*	*V*	*U*	RU	LCPI
Afzelia Africana Pers.	N	0.16	10	7	100	10	5	7	85	92.5
Milicia excelsa (Welw.) C. C. Berg	N	0.16	10	4	100	10	5	5	75	87.5
Prosopis africana (Guill. and Perr.) Taub.	N	0.16	10	4	100	10	5	5	75	87.5
Parkia biglobosa (Jacq.) G. Don	N	2.44	7	10	70	10	6	10	100	85
Pterocarpus erinaceus Poir.	N	2.93	7	10	70	10	6	10	100	85
Khaya senegalensis (Desr.) A. Juss.	N	1.60	7	10	70	10	5	10	100	85
Ceiba pentandra (L.) Gaertn.	N	1.30	7	4	70	10	5	5	75	72.5
Vitex doniana Sweet	N	1.30	7	4	70	10	5	5	75	72.5
Citrus aurantum L.	E	3.25	10	7	100	1	6	7	40	70
Daniella oliveri (Rolfe) Hutch. and Dalziel	N	1.30	7	7	70	7	6	7	70	70
Bligia sapida K. D. Koenig	N	0.81	10	4	100	1	5	5	30	65
Gmelina arborea Roxb.	E	0.81	10	4	100	1	5	5	30	65
Psidium guajava L.	N	0.16	10	4	100	1	5	5	30	65
Adansonia digitata L.	N	1.63	7	7	70	4	5	7	55	62.5
Elaeis guineensis Jacq.	E	1.30	7	10	70	1	6	10	55	62.5
Anogeissus leiocarpa (DC.) Guill. and Perr.	N	1.63	7	4	70	4	6	6	50	60
Ficus umbellata Vahl	N	0.49	7	4	70	1	5	5	30	50
Eucalyptus camaldulensis Dehnh.	E	1.14	7	4	70	1	5	5	30	50
Pseudocedrela kotschyi (Schweinf.) Harms.	N	2.28	7	4	70	1	5	5	30	50
Terminalia glaucescens Planch. Ex Benth.	N	1.14	7	4	70	1	5	5	30	50
Mangifera indica L.	E	4.23	4	10	40	1	6	10	55	47.5
Vitelaria paradoxa C. F. Gaertn.	N	18.05	1	10	10	7	6	10	85	47.5
Anacardium occidentale L.	E	23.25	1	10	10	1	6	10	55	32.5
Tectona grandis L.f.	E	19.84	1	10	10	1	5	10	55	32.5
Azadiratha indica A. Juss.	N	10.24	1	7	10	1	6	7	40	25

Or origin, *E* exotic, *N* native, *RD* relative density, *D* relative density score, *L* local importance, *BS* biological score, *H* harvesting risk score, *V* diversity of use, *U* use, *RU* risk of utilization score, *LCPI* local conservation priority index *biglobosa*, *K. senegalensis* and *P. erinaceus*) were classed in category 1 (scores ≥ 85). The categories 2 and 3 contained, respectively, ten and nine species.

4 Discussion

4.1 Factors affecting plants knowledge and use

This study illustrates uneven distribution of knowledge and use of the woody species due to factors such as age, gender, ethnicity and climatic zones. Our results showed that age was not an important determinant of plant knowledge except plants used for food. This result is partly consistent with the finding of Lykke et al. (2004) but contrary to other studies on useful woody species (Ayantunde et al. 2008; Paré et al. 2010; Sop et al. 2012; Houessou et al. 2012). Local knowledge of plants used for food in the study area seems to be accumulated with age. The younger generation (less than 30 years old) was less knowledgeable about woody species used for food than older generations, and this fact could be explained by an increased contact with the natural environment (Ayantunde et al. 2008). However, this cannot be generalized to all use categories. There was an overall significant difference in knowledge of plants between genders. Men and women from the Ouémé catchment showed differential knowledge about useful woody species, with men having more knowledge of medicinal, technological and fodder plants. Several authors have explained that by the sexual division of labor in rural communities (Camou-Guerrero et al. 2008; Vodouhê et al. 2009). We also found that men and women had similar knowledge of plant species used for food, firewood, construction, veterinary and worship. Moreover, our finding could not confirm the general assumption that men know more about species used for construction and energy generation while women know more about food plant species.

Our results also revealed an inter-cultural variation. In fact, there is a significant difference between the ethnic groups in all categories except medicine and fodder. Previous studies in Benin (Houehanou et al. 2011; Assogbadjo et al. 2012) have found similar results. The Goun cited the higher mean number of species in general but also in construction, fuel and technology use categories. Goun, Fon Mahi and Nagot rely on quasi-similar species but with different intensities of use (Fig. 5), while the Bariba valued other species. Goun, Fon and Mahi are native from Guinean zone, while Bariba are native from Sudanian and Sudano-Guinean zones. This outcome may be explained by the cultural proximity of people from Guinean zone (Assogbadjo et al. 2012).

Moreover, two main reasons may explain the significant different in knowledge of the woody species between the two climatic zones: socio-cultural conditions of the people and natural conditions. In the Guinean zone, cultivable land is reduced due to demographic pressure, involving decrease in income. Therefore, people from this area increase the use of edible trees, in particular the exotic species (Assogbadjo et al. 2012). That is why the most used species by Goun, Fon and Mahi are exotic species such as *E. guinensis*, *M. indica*, *T. grandis* and *A. occidentale* (Fig. 9). This finding is consistent with the results from Vodouhê et al. (2011) and Assogbadjo et al. (2012) who concluded that for the small farmers the maintenance of diversified tree cover within a small farm area is an element of their livelihood strategy. Conversely, the Bariba in Sudano-Guinean zone use mostly *V. paradoxa*, *P. biglobosa* and *P. erinaceus*, which are native species. In this climatic zone, the land is more available for the farmers. Moreover, the Guinean zone is more favorable for the diversity of the species because of rainy regime. This justifies the significantly high mean number obtained in Guinean zone compared to the Sudano-Guinean zone (Table 3).

4.2 Status of the species

Among the 46 species inventoried in the Ouémé catchment, 39 were native (Tables 4, 5). The exotic species were *A. occidentale*, *T. grandis*, *Gmelina arborea*, *E. guineensis*, *Citrus aurantium*, *M. indica* and *E. camaldulensis*. The outputs from objective 2 of this study showed that *T. grandis*, *E. guinensis*, *E. camaldulensis* and *M. indica* were the species with few use categories but most utilized by many farmers. These species are all exotic. The outputs also showed that most of the native species were classified as underutilized or widely used by few people. This fact may be explained by the increasing promotion of exotic species in West African (Awodoyin et al. 2015). The fact that the exotic species were seen as the most used species did not mean that they were the most threatened species. The exotic species are planted by the local people themselves, whereas the native species are simply preserved in the field after their natural regeneration. This is clearly shown by the high relative density of the exotic species (Tables 4, 5). The degree of threat on native woody species depends on the forms and frequencies of harvest, the part of the plant harvested, the cutting intensity and the regeneration capacities of each species (Lokonon et al. 2013). Species of low rate of use may face a greater threat of disappearance. For instance, a tree species with low regeneration capacity and which are completely pruned in each dry season cannot produce seeds for regeneration (Buyinza et al. 2015). In other words, the resilience of each species to different pressures of use and their degree of adoption in agroforestry systems determine their evolution in the environment.

4.3 Conservation priorities of local woody species

In our knowledge, this is the first study in Benin prioritizing useful woody species in two contrasting areas in terms of ecological characteristics for long-term conservation purpose. *P. biglobosa*, *M. excelsa*, *P. africana* and *P. erinaceus* were ranked as most priorities for conservation in Guinean zone, while *A. africana*, *M. excelsa*, *P. africana*, *P. biglobosa*, *K. senegalensis* and *P. erinaceus* were identified in Sudano-Guinean zone. It appears that all the species assessed as most priorities in Guinean zone were also in the Sudano-Guinean zone. Two species were specific for Sudano-Guinean zone, *A. africana* and *K. senegalensis*. These species are often cited as most priority species for conservation in West Africa (Kristensen and Lykke 2003; Vodouhê et al. 2011; Sop et al. 2012; Assogbadjo et al. 2012). The essential criteria that lead to the choice of these species are the nutritional and socioeconomic values of their fruits and seeds (Nikiema 2005) and timber (Lokonon et al. 2017) to local people (species with highest values of parameters *D* and *H*). They are characterized by high commercial and nutritional value (Kristensen and Lykke 2003). Schreckenberg (1999) identified *P. biglobosa* as one of the most vital species for people's livelihoods in Bassila (northern Benin), confirming the national significance of this species. Fermented seeds and yellow floury pulp of *P. biglobosa* are both highly appreciated as food (Koura et al. 2011). In most countries of West Africa, the food condiment from *P. biglobosa* seeds is the main seasoning sauce (Ouoba et al.

2003; Koura et al. 2011) and the fruit pulp is rich in carbohydrates and vitamin C (Kater et al. 1992). Both seeds and pulp are largely consumed by rural and urban populations, and their sale generates substantial income for many women (Muhammad and Amusa 2003). *P. biglobosa* is also chosen as a symbol of peace in several communities, and it harmonizes social life and well-being (Ouédraogo 1995). Moreover, stands of *P. biglobosa* play an important role in improving soil fertility and protection against erosion by wind and rain (Bayala et al. 2005).

M. excelsa, *P. africana*, *P. erinaceus*, *A. africana* and *K. senegalensis* represent the most economically important indigenous timber species. Their timber is of first quality. In a recent work of Akpona et al. (2017b) on timber species conservation in Benin, they have prioritized *K. senegalensis*, *Khaya grandifoliola*, *A. africana*, *M. excelsa* and *P. erinaceus* as top five priority timber species. This finding is really consistent with our result. *M. excelsa*, *P. africana*, *P. erinaceus*, *A. africana* and *K. senegalensis* are evaluated in Benin red list as endangered (Adomou et al. 2011). *P. erinaceus*, *A. africana* and *K. senegalensis* have also been ranked as medicinal priority species for conservation by Yaoitcha et al. (2015). Furthermore, due to the usefulness of these species, they are harvested at rate that is far beyond their regeneration rhythm (Ahoyo et al. 2017). Indeed, in situ regeneration rate of these species is poor (Akpona et al. 2017a).

Moreover, the results revealed that some species seen as priority for conservation in a climatic zone could be common in the other and whose harvesting would not immediately threaten their conservation. It is the case for instance of *V. paradoxa* (LCPI = 47.5 in Sudano-Guinean zone against 82.5 in Guinean zone).

4.4 Implications for conservation

Differences in plants knowledge and use were found and could be explained by gender and cultural differences but also variability in climatic zones. The differentiation of knowledge along gender lines reinforces the need for gender awareness in development and policy interventions regarding conservation of the species (Ayantunde et al. 2008). Inclusion of men's and women's knowledge in design and implementation of conservation projects will ensure that their priorities will be taken into account.

Our results are without importance if they are not converted into management strategies. Indeed, two categories of species have been found among the six high priority species for conservation. The first category is represented by *P. biglobosa* from which the choice is more related to the fruits and seeds. The second category is represented by *P. erinaceus, M. excelsa, P. africana*, *A. africana* and *K. senegalensis* from which the choice is more related to the timber. Species producing firewood, medicinal products and construction materials were not seen as having high conservation status by the local people, probably because these products are available (Kristensen and Lykke 2003). Conservation activities could take into account the specificity of each species seen as necessitating conservation. The diversity of traditional uses and knowledge should also be considered (Lokonon et al. 2013). For example, the Bariba are more present in Sudano-Guinean zone and in this zone *A. africana* and *K. senegalensis* are specifically of the highest priority for conservation. Thus, they should be involved in strategies aiming at the improvement of the status of both species. In addition, as *P. biglobosa* is the most priority species in Guinean zone, all actions aiming the conservation of this species should take into account the knowledge of Fon, Goun and Mahi. Non-governmental organizations, governments and agroforestry research institutions should develop simple vegetative propagation techniques of the best genotypes to domesticate this multipurpose species (Belem et al. 2008). Moreover, in situ and ex situ conservation approaches could also be used for *P. biglobosa*.

Concerning *P. erinaceus, M. excelsa, P. africana*, *A. africana* and *K. senegalensis*, they are suffering from overharvesting for fuel wood, charcoal, construction and timber commercializing. These prized timber species have relatively low recruitment rates (Akpona et al. 2017a). This calls for research on regeneration. Generally in West Africa and particularly in Benin, local people have no tradition for planting trees (Lykke et al. 2004). This needs to be changed in order to maintain sustainable use under the increased pressure on natural resources (Kristensen and Lykke 2003). Methods such as assisted regeneration and planting of appreciated and prized timber species identified in this study as priority for conservation instead of exotic species are simple but important management tools. Moreover, it is of great importance to take into account the specificity and preference of different social groups in each step of conservation process.

We strongly recommend the implication of the identified species in this study to tree-based landscape restoration initiatives that are being promoted in Africa in general and in Benin in particular. For instance, these species could be integrated in African Forest Landscape Restoration Initiative (AFR100) where Benin has committed 0.5 MHa.

5 Conclusions

This study reveals that the 46 woody species encountered in the traditional agroforestry systems of Ouémé catchment provide to the local people various goods and services. They preferred differently the woody species according to gender, ethnicity and climatic zones. The difference between sex and ethnic groups merits consideration in conservation of the useful woody species in Ouémé catchment. In addition, many species are underutilized or widely used by few people. Moreover, this study has identified the most important useful woody species that should be considered as priorities for conservation in each climatic zone of the catchment. These species are: *P. biglobosa*, *P. erinaceus, M. excelsa, P. africana*, *A. africana* and *K. senegalensis*. With the aim of establishing the sustainable management in the catchment, we suggest that more attention be paid to the aforementioned species. Non-governmental organizations, governments and agroforestry research institutions are also entreated to incorporate these species in local development strategies aiming at sustainable management and long-term conservation of these native species.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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