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Uses and vulnerability of ligneous species exploited by local population of northern Burkina Faso in their adaptation strategies to changing environments

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Abstract

Background: Arid and semi-arid areas of West Africa are highly subject to climate change effects. This is combined to other drivers such as population growth and livestock number increase. To cope with such changing environment, endogenous adaptation strategies of poor local communities rely on the use of natural resources through empirical knowledge. Unfortunately, these knowledge and practices are insufficiently known to policy makers, and this hampers their consideration in the elaboration of adaptation strategies. A household survey was conducted in the Sillia village in northern Burkina Faso using semi-structured interviews. This study identified most used (preferred) species in this changing environment together with their ethnobotanical use value (VUET).

Results: Overall, 86 ligneous species were listed in seven (7) use categories: human nutrition, fodder, fuel, traditional medicine, handicraft, construction and trade. From the 86 species, 11 appeared the most preferred by local population (VUET ≥ 6). Except *Piliostigma reticulatum* and *Boscia senegalensis*, all these species were part of the 21 very vulnerable species as revealed by the study. *Tamarindus indica*, *Balanites aegyptiaca*, *Lannea microcarpa* and *Vitellaria paradoxa* are the first most preferred species (VUET ≥ 7) and also most vulnerable (IV > 2.5). In this changing environment, *Cassia sieberiana*, *Combretum micranthum*, *Balanites aegyptica* have, for instance, become the main species used in traditional medicine replacing *Ximenia americana*, *Coclospermum tinctorim*, *Maytenus senegalensis* and *Securidaca longepedunculata*, formerly used for this need. Also, *Piliostigma reticulatum* is the main species used in farm lands to combat low soil fertility. *Pterocarpus lucens* and *Adansonia digitata* are the main fodder species both during dry and rainy seasons. Apart from the household surveys, vegetation survey was conducted on 96 plots in Sillia. The results showed that 25 species cited in the household surveys had locally disappeared, 22 were rare, 5 were abundant and the others were relatively abundant. Certain collection practices of given species in many use categories increase their vulnerability.

Conclusion: This study documented preferred species in the adaptation strategies to changing environments and also assessed their vulnerability status under human influence; it is therefore of great use for designing sustainable management.

Keywords: Ligneous species, Semi-arid zone, Uses, Vulnerability, West Africa

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Background

Pressure on land resources and climate change which affect agricultural systems in developing countries [1] is making agricultural productions unreliable [2]. Farmers in such climate risky environments have adopted production systems integrating trees and crops to benefit from the ecosystem services provided by trees in difficult years. Indeed, if trees can have a buffer effect on low rain and bad temporal distribution of rains through reduction in evapotranspiration and runoff therefore increasing infiltration on one hand, they also provide for goods used in human consumption [3, 4]. Because the tree component of the production system resists better to climate variability, local population relies on it when annual crops do not give sufficient food. Thus, the ligneous species play an important role in adaptation strategies. Tree species in forest or on-farm lands increase resilience of smallholder farmers to adverse effects of climate variability and changes because of their abilities to improve biophysical characteristics of the environment and the socioeconomic conditions of the households [4]. Most of the African local communities depend on forests and trees for their daily needs including goods and services such as nutrition, medicine, wood, fodder, shelter, soil fertilization, ornamentation and cultural practices [5, 6]. Ligneous species, being the permanent component of the system, play an important role against water and wind erosion. Improving the role of ligneous species in the climate adaptation strategies of Sahelian populations requires a better understanding of the interaction between the different communities and tree resources. In fact, these interactions are often detrimental to the trees and lead to their vulnerability; this vulnerability status should be documented together with the causes in order to facilitate corrective actions. The current study was therefore conducted to identify ligneous species used by local poor population in this changing context and assess the impact of this human pressure on species vulnerability and availability. This knowledge could help guide decision making for better management of tree resources and the resilience of local communities and agricultural ecosystems in arid and semi-arid zones of West Africa. For that, many scientists use ethnobotanical surveys combined with floristic inventories [7–10]. Ethnobotanical surveys help to know plant species of a locality and their use for the population. Floristic inventories help to know state of species (availability, abundance) and habitats (topography, soil) in which they are confined, while creating awareness of the population in their plant resources state. That could arouse population interest to take part in future plant conservation actions.

Methodology

Study area

The study was conducted in the village of Sillia in the sub-Sahelian sector in the Loroum province in northern Burkina Faso (Fig. 1). This sector is the second least humid after the strict Sahelian one. Mean annual rainfall ranges from 500 to 600 mm and is characterized by high spatiotemporal variation. Soils are poor with low vegetation cover. People in Sillia practice both agriculture and livestock breeding. The number of inhabitants in Sillia was 1843 in 2009 with 3% increase rate [11] giving an estimated number of 2201 people for 2015. Meteorological data (rainfall, temperature and potential evapotranspiration) for the period 1983–2012 indicate a nine-month dry season from October to June and a three-month humid period from July to September which is the rainy season (Fig. 2). August is the rainiest month. The dry season is characterized by 2 periods: a cool one from November to February with lower mean monthly temperatures in January (24.72 °C) and a hot period with higher mean monthly temperatures in May (34.02 °C). Mean annual rainfall for the last 28 years was 495 mm with pronounced inter-annual variability. Climate data were provided by National Direction of Meteorology and Civil Aviation and the Provincial Direction of Agriculture and Food Security of Loroum.

Data collection

Ethnobotanical data collection

Exploratory survey With the help of the President of the Village Development Committee (CVD), we first identified the districts of study: Bissighin, Soucka and Roodin. Secondly, lists of all households per district were drawn up. A total of 38 men and 35 women answered to questions related to the uses of ligneous species in the following seven main use categories: human nutrition, fodder, traditional medicine, fuel, handicraft, construction and trade. The main use categories were first revealed in a survey with the CVD comprising 4 men and 2 women very familiar with the realities of their village. In order to get more information in some use categories (fodder, medicine and handicraft), we also interviewed 19 livestock breeders (10 men and 9 women), 9 traditional healers (6 men and 3 women) and 1 craftsman. In total, 102 people (55 men and 47 women) with ages between 30 and 75 were surveyed. At least one person of each identified household was represented.

Semi-structured interviews Semi-structured interviews with questionnaire allowed collecting detailed information on the use of ligneous species within households. It also helped identifying useful disappeared and scarce ligneous species and possible causes of these states, as

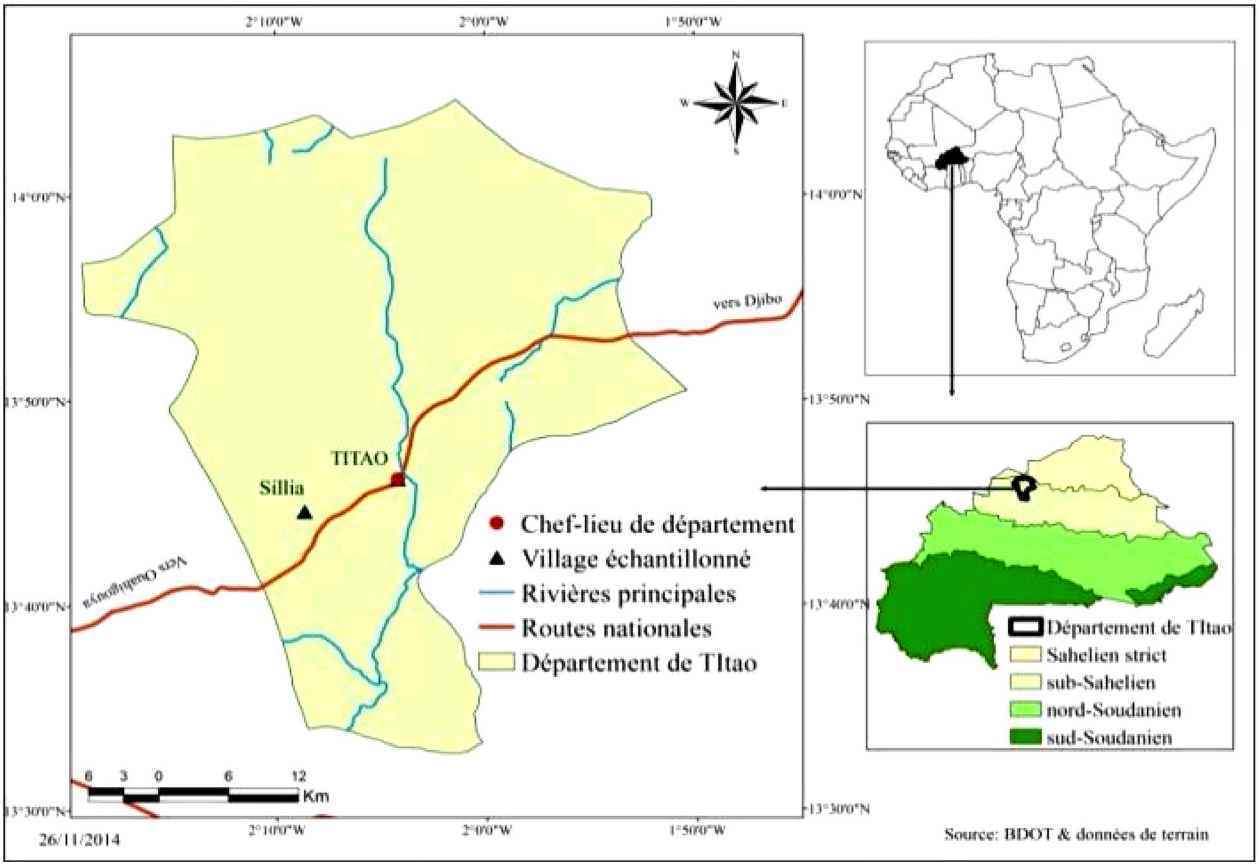

Fig. 1 Localization of the study area (Sillia) in Loroum province, northern Burkina. Source BIOTA and field data (GPS data from floristic plots)

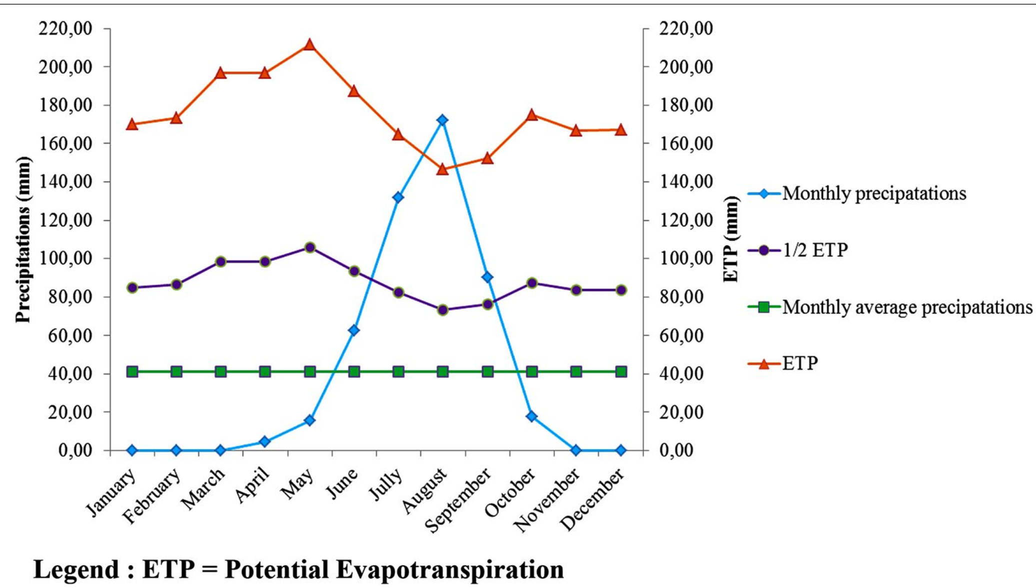

Fig. 2 Mean monthly rainfall together with potential evapotranspiration for the period 1983–2012 in Titao, northern Burkina Faso. Source: Weather and civil aviation service data (2014)

well as current management practices for species conservation. To determine the most used species (preferred), we determined the ethnobotanical use value of species in each use category [8, 9]. A score of 0 is given to a species when people knows no use of it in that specific use category, 0.5 when the species is slightly used, 1 when it is regularly used and 1.5 when the species is highly used. To assess the vulnerability and availability status of a ligneous species, we asked the interviewee to evaluated the current status of quoted species (disappeared, rare, low abundance and abundant). The following data were also collected during the survey: the harvest mode of the plant part**s**, the development stage of the plant part collected.

Floristic data

A vulnerability index was calculated taking into account species frequencies in the study area [12, 13]. For this, vegetation surveys were conducted in 96 plots distributed in the different topographic units (hilltops, hillsides, bareland/glaze and lowland) throughout the land area of the village in order to survey a maximum number of ligneous species.

The sampling unit was a 50 m × 20 m (1000 m^2) in non-cultivated areas and 50 m × 50 m (2500 m^2) in cultivated areas [14]. The rectangular 1000 m^2 in non-cultivated areas was used by many authors in the sub-Sahelian sector [14–17] to take into consideration the spatial distribution of most species with spread individuals [14]. Overall, 44 plots were laid in non-cultivated areas and 52 in cultivated areas. To supplement the survey, signs of human exploitation on ligneous species were recorded to assess the nature of the pressure the species are subject to.

Data analysis

The exploratory survey revealed seven (7) use categories of ligneous species that were considered in subsequent detailed surveys: human nutrition, fuel, fodder, medicine, construction, handicraft and trade. Trade is meant here for sale of non-timber forest products (NTFPs) and wood. The following parameters were calculated from the data:

$$\text{Frequency at which a use category was mentioned} = (\text{Number of people mentioning the use}) / (\text{Total number of surveyed people}) \times 100$$

$$\text{Percentage of use of species in a given use category} = (\text{Number of species used in the category}) / (\text{Total number of species found in all use categories}) \times 100$$

$$\text{Percent of use of a plant part in a given category} = (\text{Number of species for which the part is used}) / (\text{Total number of species found in this use category}) \times 100$$

The ethnobotanical use value (VUE) of the species was calculated following the method of Philips and Gentry [18]:

$$\text{VUETs}(j) = \frac{\left(\sum \text{VUE}ijs\right)}{N}$$

where VUETs (*j*) is the total ethnobotanical use value of a species s in a use category *j*; VUE*ijs* = mean use frequency of species s according to the surveyed person *i* in a use category *j*; *N* is the total number of surveyed people who assessed the species *s* in the use category *j*; this value varies from 0 to 1.5.

$$\text{VUET}s = \sum \text{VUET}(j)$$

where VUETs = total ethnobotanical use value of species s when all use categories are considered. Then, a species is said highly used by the population if its VUET ≥ 3 when all use categories are considered [8]. Here VUETs varies from 0 to 10.5 because we have seven use categories. In our study, we considered a species as preferred when is VUET is ≥ 6.

To calculate an index of vulnerability (IV), a vulnerability scale with three levels from 1 to 3 proposed by Betti [12] was used: 1 is for species less vulnerable for the parameters indicated, 2 is for species moderately vulnerable and 3 for a species highly vulnerable. Seven (7) parameters were used: mean use frequency of a species in the 7 use categories (N1), the number of use (N2), the types of plant parts used in the different use categories (N3), the total number of plant parts of the species used (N4), the collection mode of these plant parts (N5), the development stage (N6) and the frequency of the species in the vegetation survey plots (N7). All these factors affect vulnerability of species (Table 1). For the parameter N3, if a species has many of its plant parts that are used, we considered the highest value. The same was done at collection mode and development stage. Maximum frequency (Fm) corresponds to the frequency of the most frequent species.

$$\text{Frequency (species)} = \frac{\text{Number of plots where the species appears}}{\text{Total number of plots}} \times 100$$

The mean use frequency of a species *i* (FUmoyi) was calculated as follows:

$$\text{FUmeani} = \frac{\sum\left(\text{Use frequency of species } i \text{ in all use categories}\right)}{\text{Total number of use categories}}$$

Use frequency of a species *i* in a use category *j* = (Number of people mentioning the species *i* in the cat-

Table 1 Parameters used to calculate the index of vulnerability (IV)

Parameters	1 (Low scale)	2 (Average scale)	3 (Strong scale)
Use frequency (N1)	N1 < 20%	20% ≤ N1 < 60%	N1 ≥ 60%
Number of uses (N2)	N2 < 2	2 ≤ N2 ≤ 4	N2 ≥ 5
Plant parts used (N3)	Leaves, latex	Fruit, branches	Wood, seeds, bark, root, flower
Number of plant parts (N4)	N4 = 1	N4 = 2	N4 ≥ 3
Collection mode (N5)	Collection on the ground		Collection on the tree, cutting
Development stage (N6)	Old, senescent	Adult	Young
Relative frequency (N7)	Fr ≥ 2/3 Fm	1/3 Fm ≤ Fr < 2/3 Fm	Fr < 1/3 Fm

Fr relative frequency, *Fm* maximum frequency

egory *j*)/(Total number of people who talked about category *j*) × 100

In the use category *j*, when the species *i* is not mentioned, its frequency equals 0. The vulnerability index of a species is the average of the highest values of the 7 selected parameters.

$$IV = (N1 + N2 + N3 + N4 + N5 + N6 + N7)/7$$

According to Traoré et al. [12], if IV < 2, the species is said lowly vulnerable, if 2 ≤ IV < 2.5, the species is said moderately vulnerable and if IV ≥ 2.5, the species is highly vulnerable.

Species availability was assessed through their frequency in the vegetation survey plots using the rarity index (RI) on the whole village area.

$$\text{RI} = [1 - (\text{ni}/N)] \times 100$$

RI = Rarity index, ni = number of plots where the species *i* appears and *N* = Total number of plots. For a given species, if RI < 60%, the species is very frequent, if 60 ≤ RI < 80%, the species is moderately frequent and if RI ≥ 80%, the species is rare [13].

Results

Most used and vulnerability status of species

The household survey showed that 86 ligneous species belonging to 70 genera and 37 families were used in the seven use categories. From these 86 species, 67 were local and 19 exotic. Forty-nine (49) species had VUET ≥ 3 with 11 of them cited as the most appreciated ones (VUET ≥ 6) associated with high frequency of use by the population: *Tamarindus indica* (VUET = 7.69), *Balanites aegyptiaca* (7.58), *Lannea microcarpa* (7.26), *Vitellaria paradoxa* (7.00), *Pterocarpus erinaceus* (6.7), *Sclerocarya birrea* (6.61), *Grewia bicolor* (6.52), *Saba senegalensis* (6.43), *Piliostigma reticulatum* (6.36), *Boscia senegalensis* (6.26) and *Ficus sycomorus* (6.17) (Table 2).

The vulnerability index (IV) showed that 21 species were highly vulnerable (IV ≥ 2.5) and 37 moderately vulnerable (2 < IV < 2.5) (Fig. 3). The first 5 species that are highly vulnerable were *Azadirachta indica*, *Pterocarpus lucens*, *Saba senegalensis*, *Vitellaria paradoxa* and *Tamarindus indica*. According to local people, 25 species have locally disappeared, 22 are rare and 5 are abundant (Table 2). From the 25 species said to have disappeared, only 5 with low frequency of citation during the household survey (0.98% or 1 person) were encountered during our vegetation survey but very rarely. These were: *Gardenia ternifolia* (RI = 92.71), *Capparis sepiaria* (RI = 93.75), *Acacia nilotica* (RI = 95.83), *Maerua angolensis* (RI = 97.92) and *Commiphora africana* (RI = 98.96). With regard to species said to be rare, 19 were encountered in our survey plots with 2 moderately frequent which are *Acacia macrostachya* (RI = 65.63) and *Adansonia digitata* (RI = 68.71). *Ficus sycomorus* was encountered in homegardens. *Entada africana* and *Gardenia erubescens*, mentioned by only one person, were neither encountered during the vegetation survey nor seen in the area. From the 5 species said abundant, 3 were very frequent: *Combretum micranthum* (RI = 46.88), *Leptadenia hastata* (RI = 46.88) and *Piliostigma reticulatum* (RI = 48.96). *Combretum glutinosum* was moderately frequent (RI = 66.67) and *Mitragyna inermis* rare (RI = 93.75). From the 49 species with VUET ≥ 3, 20 (40.82%) were highly vulnerable and 20 others less vulnerable. Vulnerability of the 9 other species was not assessed as we did not encounter them during vegetation survey. Four of them are exotic species planted by the farmers only in their homegardens or courtyard: *Carica papaya*, *Citrus limon*, *Mangifera indica* and *Psidium guajava*. *Mangifera indica* is well represented in the village. However, the other species are very rare partly due to attacks by termites and other parasites, hampering their survival. *Borassus aethiopum*, *Ficus platyphylla*, *Ficus sycomorus* and *Ximenia americana*, appearing usually in humid area, are said to have disappeared due to low rainfall.

Table 2 Ethnobotanical use value (VUET), vulnerability index (IV), rarity index (RI) and quoted frequency at which the species was mentioned in the different use categories in Sillia, northern Burkina Faso

Species	VUET	RI	Human nutrition	Fodder	Medicine	Fuel	Handicraft	Construction	Sale of NTFP and/or LFP
Tamarindus indica	7.69	85.42	80.82	18.48	16.25	5.48	4	0	55.71
Balanites aegyptiaca	7.58	71.88	58.94	39.13	7.5	17.88	72	12.33	7.14
Lannea microcarpa	7.26	65.63	93.15	1.87	6.25	17.81	18.67	2.74	44.29
Vitellaria paradoxa	7	88.54	76.71	7.61	1	17.81	66.67	20.55	57.14
Pterocarpus erinaceus	6.7	97.92	0	28.27	5	5.48	9.33	8.22	1.43
Sclerocarya birrea	6.61	69.79	58.9	46.74	7.5	13.7	36	1.37	34.29
Grewia bicolor	6.52	97.92	13.7	9.78	0	1.37	1.33	5.48	1.43
Saba senegalensis	6.43	94.79	5.68	6.52	1.25	1.37	0	36.97	45.71
Piliostigma reticulatum	6.36	48.96	54.79	47.83	35	61.64	12	28.77	1.43
Boscia senegalensis	6.26	97.92	36.99	6.52	5	0	0	0	11.43
Ficus sycomorus	6.17	100	17.88	4.35	6.25	1.37	6.67	0	1.43
Parkia biglobosa	5.85	98.96	36.99	3.27	16.25	2.74	13.33	1.37	25.71
Ziziphus mauritiana	5.77	80.21	43.84	43.48	1	0	0	0	25.71
Ximenia americana	5.74	100	43.84	3.27	35	0	0	0	14.29
Acacia macrostachya	5.71	86.46	31.57	2.65	1	4.2	0	0	11.43
Acacia senegal	5.71	85.42	0	52.17	8.75	2.74	5.33	1.37	0
Bombax costatum	5.7	95.83	38.36	15.22	0	1.37	8	0	17.14
Adansonia digitata	5.61	68.75	95.89	47.83	8.75	0	0	0	64.29
Diospyros mespiliformis	5.6	84.38	2.55	1.87	3.75	4.2	0	2.74	15.71
Citrus limon	5.43	100	1.96	0	13.75	0	0	0	18.57
Anogeissus leiocarpa	5.38	81.25	0	2.65	1	24.66	6.67	32.88	1.43
Combretum nigricans	5.19	93.75	0	11.96	15	15.68	24	1.37	0
Mangifera indica	5.19	100	49.32	7.69	11.25	0	0	0	67.14
Guiera senegalensis	5.16	90.63	0	22.83	33.75	58.9	0	5.48	1.43
Celtis integrifolia	4.9	100	0	16.34	1.25	1.37	1.33	0	0
Combretum micranthum	4.89	46.88	0	11.96	3	94.53	66.67	68.49	4.29
Acacia erythrocalyx	4.86	98.96	0	2.65	7.5	1.37	1.33	0	0
Dalbergia melanoxylon	4.46	97.92	0	13.43	3.75	0	2.67	8.22	0
Combretum micranthum	4.89	46.88	0	11.96	3	94.53	66.67	68.49	4.29
Acacia erythrocalyx	4.86	98.96	0	2.65	7.5	1.37	1.33	0	0
Dalbergia melanoxylon	4.46	97.92	0	13.43	3.75	0	2.67	8.22	0
Acacia seyal	4.44	89.58	0	53.27	2.5	4.2	38.67	2.74	0
Pterocarpus lucens	4.42	82.29	0	79.35	7.5	58.9	9.33	58.9	4.29
Mitragyna inermis	4.42	93.75	0	55.43	2.5	31.51	25.33	61.64	0
Acacia nilotica	4.35	95.83	0	16.34	7.5	1.37	0	2.74	0
Feretia apodanthera	4.25	97.92	0	2.17	2.5	0	8	0	0
Carica papaya	4.11	100	15.7	0	11.25	0	0	0	2.86
Leptadenia hastata	4.02	46.88	6.27	8.7	0	0	0	0	1.43
Azadirachta indica	3.94	88.54	0	1.87	22.5	23.29	38.67	63.1	17.14
Cassia sieberiana	3.94	66.67	0	1.87	32.5	13.7	0	15.7	0
Khaya senegalensis	3.88	96.88	0	22.83	2	1.96	52	2.74	0
Terminalia macroptera	3.88	95.83	0	0	16.25	2.74	22.67	9.59	0
Faidherbia albida	3.84	98.96	0	53.27	6.25	4.2	0	0	15.71
Ficus platyphylla	3.81	100	1.96	2.17	5	0	0	0	0
Vitex doniana	3.77	98.96	23.29	0	5	0	0	0	15.71
Psidium guajava	3.76	100	13.7	0	5	0	0	0	18.57
Dichrostachys cinerea	3.65	93.75	0	5.43	2.5	0	0	1.37	0
Combretum glutinosum	3.33	66.67	0	6.52	3.75	24.66	2.67	1.37	0

Table 2 continued

Species	VUET	RI	Human nutrition	Fodder	Medicine	Fuel	Handicraft	Construction	Sale of NTFP and/or LFP
Combretum aculeatum	3.23	97.92	0	15.22	5	1.37	0	0	0
Commiphora africana	3	98.96	0	1.87	2.5	0	5.33	0	0
Flueggea virosa	3	69.79	0	4.35	3.75	1.37	2.67	0	0
Borassus aethiopum	3	100	0	0	0	0	24	0	2.86
Maerua angolensis	2.89	76.04	19.18	1.87	1.25	0	0	0	0
Crateva adansonii	2.83	98.96	16.44	3.27	0	0	0	0	0
Grewia flavescens	2.79	96.88	9.59	0	2.5	0	1.33	0	0
Pericopsis laxiflora	2.75	100	0	4.35	2.5	5.48	36	2.74	1.43
Capparis sepiaria	2.5	95.83	0	1.87	3.75	0	0	0	0
Ziziphus mucronata	2.5	98.96	0	1.87	1	0	0	0	0
Ficus thonningii	2.5	100	1.37	0	1.25	0	0	0	0
Lannea acida	2.5	100	1.37	7.69	0	0	4	1.37	0
Sterculia setigera	2.38	98.96	0	0	22.5	0	0	0	0
Calotropis procera	2.33	98.96	0	0	3.75	0	1.33	0	0
Eucalyptus camaldulensis	2.3	100	0	0	31.25	2.74	0	1.96	7.14
Gardenia ternifolia	2.25	92.71	0	2.17	2.5	0	0	0	0
Maerua oblongifolia	2.13	100	16.44	1.87	0	0	0	0	0
Boscia angustifolia	2	98.96	1.37	1.87	1.25	0	0	0	0
Maerua crassifolia	1.83	96.88	2.74	1.87	2.5	0	0	0	0
Acacia dudgeoni	1.5	100	0	0	0	0	2.67	0	0
Acacia ataxacantha	1.5	91.67	0	0	2.5	0	0	0	0
Asparagus africanus	1.5	93.75	0	0	3.75	0	0	0	0
Anacardium occidentale	1.5	100	2.74	0	0	0	0	0	0
Boswellia dalzielii	1.5	100	0	0	1.25	0	0	0	0
Cassia siamea	1.5	100	0	0	15	0	0	0	0
Cochlospermum tinctorium	1.5	100	0	0	12.5	0	0	0	0
Cordia myxa	1.5	100	0	0	1.25	0	0	0	0
Holarrhena floribunda	1.5	100	0	0	1.25	0	0	0	0
Lawsonia inermis	1.5	100	0	35.87	1.25	0	0	0	0
Maytenus senegalensis	1.5	100	0	0	11.25	0	0	0	0
Prosopis juliflora	1.5	100	0	7.69	0	0	0	0	0
Securidaca longipedunculata	1.5	100	0	0	5	0	0	0	0
Vernonia colorata	1.5	100	0	0	15	0	0	0	0
Citrus aurantifolia	1.5	100	2.74	0	0	0	0	0	0
Detarium microcarpum	1.5	100	1.37	0	0	0	0	0	0
Holarrhena floribunda	1.5	100	0	0	1.25	0	0	0	0
Moringa oleifera	1.5	100	6.85	0	0	0	0	0	0
Tapinanthus	1.42	59.38	0	6.52	0	0	0	0	0
Acacia sieberiana	1.33	86.46	0	6.52	3.75	0	0	0	0
Ficus ingens	1.13	97.92	0	4.35	0	0	2.67	0	0
Loeseneriella africana	1	97.92	0	0	1.25	0	0	0	0

Harvesting methods of plants parts used in the different use categories

The household survey confirms the seven use categories proposed by the CVD. Respondents cited the use of woody species in human nutrition (79.81% of the interviewees), medicine (53.92%), fodder (39.22%), fuel (27.45%), construction (6.86%), handicraft (5.88%) and trade (4.9%) (Fig. 4a). The population also pointed out that woody species offers them other services such as shelter (46.08% of the interviewees), soil fertilization (21.57%), reduction in wind and water erosion (12.75%) and rainfall rise (5.88%). The results (Fig. 4b) indicate that 80.43% of the woody species are used for medicine, 61.96% for fodder, 39.13% for human nutrition,

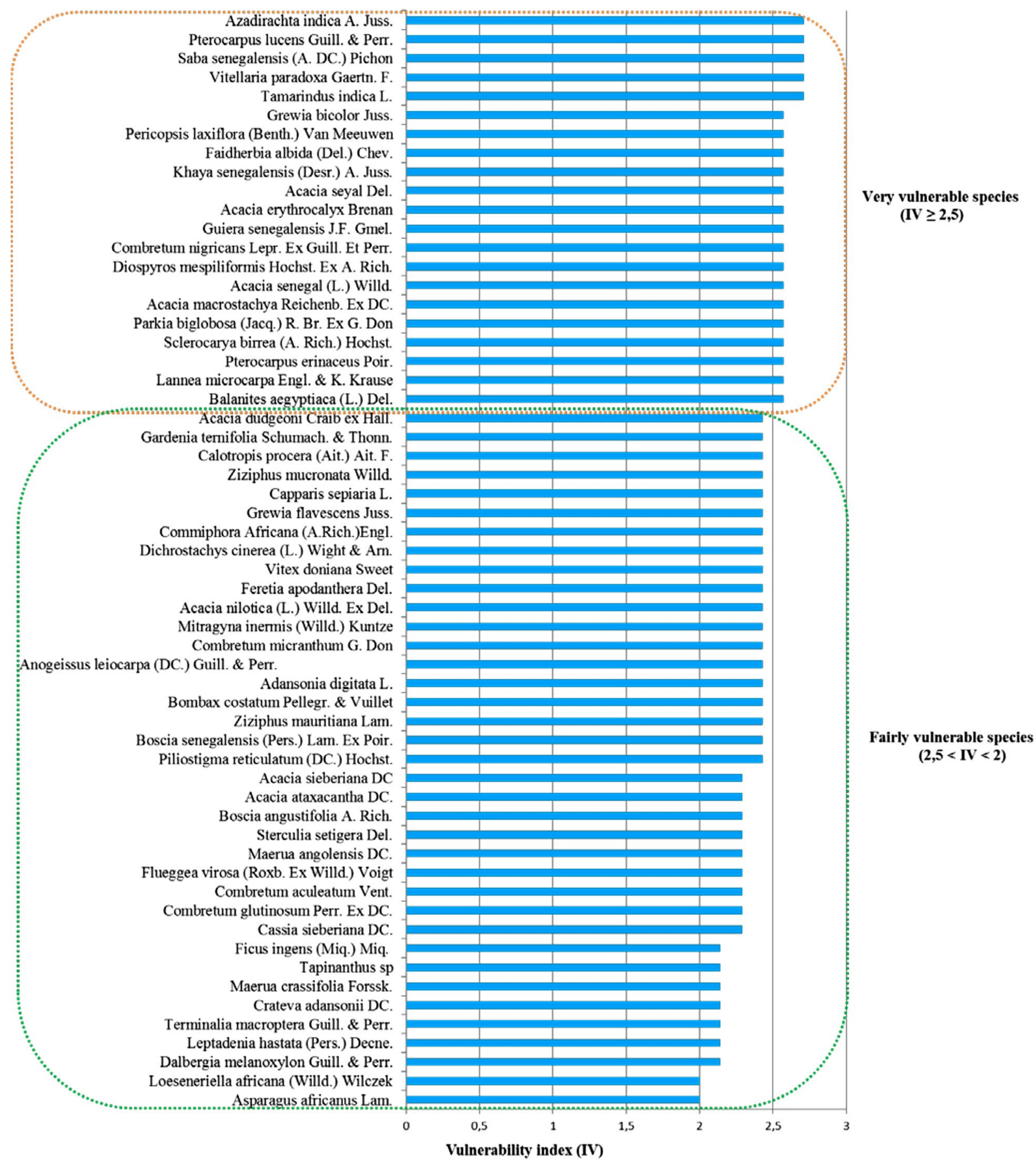

Fig. 3 Moderately and highly vulnerable species in Sillia, northern Burkina Faso

39.13% for handicraft, 38.04% for fuel, 35.87% for trade and 31.52% for construction. Fruits (57.14%) and leaves (28.57%) are the most solicited parts for human nutrition. For traditional medicine, leaves (63.52%), barks of roots (55.41%) and stems (47.3%) are the most used parts. Wood is used in handicraft, construction and as fuel. For fodder species, it is leaves (100% of species) and fruits (91.23%), which are the more searched by animals. The consumption of flowers concerns only 19.3% of fodder ligneous species. As far as the trade is concerned, it is

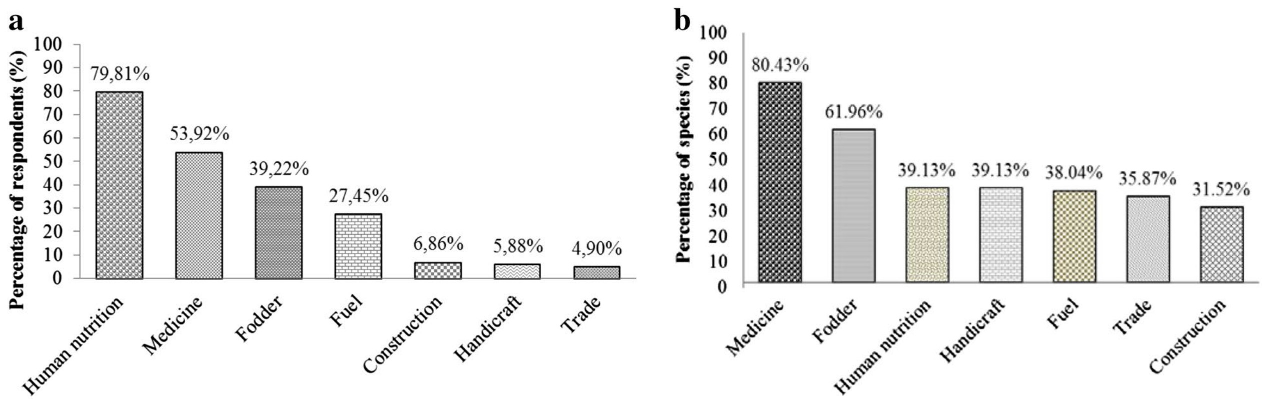

Fig. 4 **a** Use categories of woody species according to respondents. **b** Percentage of the species used in the different use categories according to respondents

fruits (61.76%), leaves (20.59%) and wood (stems) which are sold. Table 3 shows tree parts use percentage for each use category. Harvesting methods of plants parts are principally: cutting, barking and pruning that are considered as harmful for plants. The less prejudicial are leaves harvesting (topping) and harvesting mature fruits under the tree or on the branches. Table 4 shows number of individuals on which we observed these signs during the floristic inventory. Species like *C. micranthum* (504 individuals), *Cassia seberiana* (104 individuals*), Combretum glutinosum* (61 individuals) and *P. reticulatum* (49) are cut for fuel. *V. paradoxa* (40 individuals), *Diospyros mespiliformis* (35) and *M. inermis* (40) are cut for handicraft and construction. Some species are pruned for livestock consumption: *Pterocarpus lucens* (22 individuals), *Combretum nigricans* (16) and *Adansonia digitata* (18). Others are pruned to avoid competition with crop in the fields: *Azadirachta indica* (22 individuals), *Sclerocarya birrea* (33), *Combretum glutinosum (*41) and *Piliostigma reticulatum* (20). Barking concerns medicinal use. The respondents identified women to be the principal actors of tree barking and fuel wood cutting, while pruning concerns men and livestock breeders. Species on which we observed most barking signs are: *Sclerocarya birrea* (25), *Piliostigma reticulatum* (19), *Vitellaria paradoxa* (14) and *Lannea microcarpa* (13 individuals).

Causes of plant vulnerability and management practices

According to the population, the causes (Fig. 5) of woody species degradation are principally rainfall shortage (56.86%), excessive cutting of plant for fuel (38.24%) and drought (29.41%). Demographic pressure, tree**s** fall, grazing, lack of plant regeneration, ants, fields' expansion and barking are also cited as causes of ligneous species degradation. In this village, there are no protected areas. Nature belongs to all, and each person is free to exploit plant species without control. The only controls are done by forestry agents that issue cutting permits. Conscious of the importance of trees, farmers save some useful trees when exploiting new fields. But animals (65.69% of interviewees) and lack of protection during the dry season (3.9%) cause juveniles death. Exotic species (*Azadirachta indica*, *Cordia myxa*, *Cassia senna*, *Mangifera indica and Eucalyptus camaldulensis*) are planted in courtyards or around houses, in collective or private orchards. For exotic species, termites (11.01% of interviewees) are the main causes of death. In this village, collective orchard of *M. indica* on at least 2 hectares exists. *A. indica* collective

Table 3 Percentage of use of plant parts of the ligneous and tree parasitic species in Sillia, northern Burkina Faso

Use categories	Stems	Leaves	Fruits	Flowers	Grains	Pulp	Almonds	Stem barks	Root barks	Tapinanthus sp
Human nutrition	0	28.57%	57.14%	8.57%	5.71%	5.71%	5.71%	0	0	0
Medicine	0	63.51%	20.27%	2.70%	0	0	0	47.30%	55.41%	16.22%
Fodder	0	100%	91.23%	19.30%	0	0	0	0	0	0
Fuel	100%	0	0	0	0	0	0	0	0	0
Handicraft	100%	0	0	0	0	0	0	0	0	0
Construction	100%	0	0	0	0	0	0	0	0	0
Trade	29.41%	20.59%	61.76%	8.82%	17.65%	0	17.65%	0	0	0

Table 4 Signs of human exploitation observed on ligneous individuals in Sillia, northern Burkina Faso

Scientific names	Cutting	Pruning	Bark removal
Acacia nilotica	–	1	2
Acacia senegal	–	2	–
Acacia sieberiana	–	–	7
Adansonia digitata	–	18	4
Albizia chevalieri	–	2	2
Azadirachta indica	–	22	–
Bombax costatum	–	2	4
Faidherbia albida	–	–	2
Lannea microcarpa	–	6	13
Parkia biglobosa	–	1	3
Sclerocarya birrea	–	33	25
Tamarindus indica	–	5	7
Terminalia macroptera	–	–	7
Combretum micranthum	504	–	–
Cassia seberiana	149	6	5
Combretum glutinosum	61	41	
Piliostigma reticulatum	49	20	19
Vitellaria paradoxa	40	–	14
Diospyros mespiliformis	35	–	–
Acacia macrostachya	17	–	6
Acacia seyal	11		
Balanites aegyptiaca	11	10	3
Anogeissus leiocarpus	10	4	3
Guiera senegalensis	8		
Feretia apodanthera	4		
Combretum nigricans		16	
Mitragyna inermis	40		
Pterocarpus lucens		22	

The numbers refer to the number of individuals of species on which we observed human exploitation

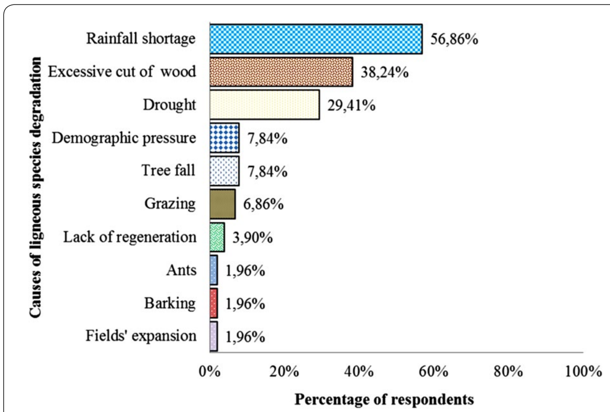

Fig. 5 Causes of ligneous species degradation according to respondents

plantation also exists but at present is threatened to disappear. Some of animals' enclosures are surrounded by *Prosopis africana* hedges. Furthermore, each person can exploit species in the agroforestry parks belonging to other persons. However, cutting, pruning, barking are forbidden by the owners. Fraudulent cutting (8.82% of interviewees) and drought (6.86%) also affect negatively the species.

Contextual changes in the use of ligneous species by local population

The surveys showed that many species used before are no longer used because of their rarity or disappearance from the village and its surroundings. People therefore adopt new behaviors.

Change in the use of human nutrition and trade species

Many species provide food products and therefore contribute to food security; they are especially important during lean period. *Ximenia americana* is well appreciated for its juice and especially during lean period. Juice from this species mixed with flour of millet was consumed throughout the day during on-farm farming operations. However, *Leptadenia hastata* is, nowadays, consumed by the population in replacement of *X. americana*. Due to rarity of *Bombax costatum* and lack of space for women to grow certain legumes such as okra (*Abelmonchus esculentus)*, they use, almost every day, fresh or dry leaves of *Adansonia digitata* as sauce for a local diet "tô." Luckily, the species is well appreciated. According to the surveyed people, fruits and leaves are the most used plant parts in human nutrition. Sale of products from species such as *Acacia macrostachya, Adansonia digitata, Lannea microcarpum, Saba senegalensis, Sclerocarya birrea and Tamarindus indica* improve women and children's income who are the main people in charge of this activity. This is an extra source of income that sustains food security. But in this village, apart from *A. digitata* (64.29% of interviewees) and *T. indica* (55.71%), the sale of the other species is very low due to their rarity (Table 2). In the past, the sale concerned principally Shea butter, *Boscia senegalensis* seeds, *Balanites aegyptiaca* flowers and leaves, *Capparis seperia* seeds, *A. digitata* pulp, *Parkia biglobosa* pulp, seeds or mustard, *L. hastata* flowers and leaves *Z.mauritiana* fruits (25.71%) and *B. costatum* calyxes (17.14%). These species, except *B. costatum*, were also used during lean period. But today, these plants, apart from *A. digitata* and *L. hastata*, are very rare in the village. The population obtains these products in the markets where they come from others localities.

Change in the use of medicine species

In traditional medicine, some important species such as *Ximenia americana, Cochlospermum tinctorium, Maytenus senegalensis* and *Securidaca longepedunculata* have become rare or locally disappeared. Therefore, *C. sieberiana* and *C. micranthum* are highly used in replacement of the above-mentioned first 2 species to treat buco-dental diseases, while *B. aegyptiaca* replaces *S. longepedunculata* in the treatment of mental illness. Exotic species such as *Cassia senna, Eucalyptus camendulensis, Vernonia colorata, Azadirachta indica, Mangifera indica, Citrus limon, Psidium guajava* and *Carica papaya* are more and more mixed and used as treatment against malaria. These species replace local species that became rare such as *Acacia nilotica, Acacia senegal, Anogeissus leiocarapa, Capparis sieperia, Combretum nigricans, Commiphora africana, Dicrostachys cinera, Guiera senegalensis, Khaya senegalensis, Pterocarpus erinaceus, Tamarindus indica, Terminalia macroptera* and *Ziziphus mucronata.* Exotic useful species are therefore being more and more planted in courtyard, farms around houses and gardens. For this category (medicine), leaves and barks of roots and stems are the most used parts.

Change in the use of fodder species

During dry season, livestock breeders prune some species such as *Adansonia digitata, Combretum nigricans, Khaya senegalensis, Mitragyna inermis, Pterocarpus erinaceus* and *Pterocapus lucens* for livestock despite the fact that this type of use is forbidden by the Forestry Office. For other species such as *Faidherbia albida* and *Piliostigma reticulatum,* the pods are collected and stored for use as feed for the animals; pods are also consumed directly in the field. Because of late establishment and quick drying of herbaceous species, and also the disappearance of many ligneous species, farmers prune certain species most dominant in the area and with better fodder quality. These species are *Pterocarpus lucens*, *Combretum nigricans* and *Adansonia digitata*. If *P. lucens* is pruned principally for small livestock (sheep and goats), *Adansonia digitata* for draft oxen and *Combretum nigricans* for cattle, *Leptadenia hastata* is for donkey's consumption.

Change in the use of fuel species

To satisfy fuelwood needs, women in the past collected dead wood. Among the species in which dead wood was collected, we have *Vitellaria paradoxa* (17.81% of interviewees), *P. lucens* (58.90%), *C. glutinosum* (24.66%), *Balanites aegyptiaca* (17.88%) and *Anogeissus leiocarpa* (24.66%) (Table 2). But nowadays, women cut live plants, especially shrubs of most represented species such as *C. micranthum* (94.53% of interviewees) and *P. reticulatum* (61.64%). The surveyed people said that *Guiera senegalensis* (58.90%) was the most used species; then, because of its rarity, *C. micranthum* became the main fuel species today. Moreover, a species such as *Piliostigma reticulatum* which was not used as fuel is ranked second fuel wood species today.

Change in the use of construction and handicraft species

Because construction wood is becoming rare, farmers have developed new habits which consist of recycling woods from old houses and crop storage places (attic) and using wood from exotic species (Table 2) such as *Azadirachta indica* (63.10% of interviewees) and *Eucalyptus camendulensis* (1.96%) instead of local species such as *M. inermis* (61.64%) and *V. paradoxa* (20.55%). These behaviors aim at preserving the local species and also match well their socioeconomic realities (poverty and high number of people in households), which make it difficult to purchase wood. For handicraft products such as mortar, certain local species which were not used before are looked for today because they are present, although they are rare or less abundant: *Balanites aegyptiaca*, *Bombax costatum, Lannea microcarpa Mitragyna inermis, Sclerocarya birrea, Faidherbia albida, Parkia biglobosa.* Species that used to be first choices for this use are: *Celtis integrifolia*, *Dalbergia melanoxylon*, *Anogeissus leiocarpa*, *Ficus sycomorus*, *Khaya senegalensis*, *Pericopsis laxiflora*, *Pterocarpus erinaceus*, *Terminalia macroptera* and *Vitellaria paradoxa*. These species were also used to construct storehouses for crops, shelter facilities (hangars) and roofs for house.

Others changes

People have mentioned that trees also provide shelter and soil and water conservation services. The survey revealed that systematic collection of crop residues leave bare soil during the entire dry season. Soil become vulnerable to water and wind erosion and farmers integrate ligneous species in their soil and water conservation strategies. The most used species for soil fertilization are: *Piliostigma reticulatum* (68.49% of interviewees) and *Faidherbia albida* (41.10%). *Leptadenia hastata*, *C. micranthum* and *C. glutinosum* are also said to be fertilizing species by the population. For *F. albida*, only about 10 individuals were encountered in farms around houses. *P. reticulatum* invades remotely located farm lands on glazes, while *C. glutinosum* is encountered on the rare farms located on hills*. C micranthum* has low frequency in farms. Few individuals of *L. hastata* were encountered in the majority of surveyed plots, but its population establishes on bare lands and is considered by local people as a sign that the Sahel is progressing.

Discussion

Use and vulnerability of ligneous species

According to respondents, rainfall shortage and high pressure on ligneous species, especially for firewood, constitute the most important causes of the vulnerability of these species. The rainy season lasts only 3 months and is uncertain. Rainfall is neither abundant, nor regular and shows recurrent dry spells [11]. These climate characteristics, combined with other human factors (population growth, agricultural expansion, tree parts harvesting methods, excessive wood cutting, species selection in the different use categories, etc.), could explain the changes in the floristic composition of the area.

The diversity and intensity of uses together with the harvesting methods increase vulnerability of the species. This is particularly true for medicinal species, which are subject to many collections on different parts such as trunks and roots [2, 13, 19–21]. *Ximenia americana* and *Conclospermum tinctorium* (used in the treatment of malaria, stomach diseases), *Maytenus senegalensis* (oral sore) and *Securidaca longepedonculata* (evils spirits) disappeared because of the high use of their stems and root barks. In a study in the National park Kaboré Tambi, overexploitation of roots of these species and their scarcity in the park were also observed by [7]. Zerbo et al. [10] also noted the exploitation of roots barks of these species for medicinal use. These species are very important for traditional healers of Burkina Faso. Thus, trees are victims of extreme barking, pruning and cutting that compromise their long-term survival. For example, pruning can stop seed production of *A. digitata* [22]. Bélem et al. [7] also noted that the exploitation of fruits, seeds or flowers could deprive species of seeds for regeneration.

Low regeneration also increases vulnerability of some species. It is the case for *P. lucens* whose density < 3 trees per hectare. Ouédraogo [15] and Ganaba [23] showed a low survival rate of juvenile individuals of this species in the same area. Vulnerability of species can also increase with use. We note that 40.82% of species with high VUET are very vulnerable and 40.82% are moderately vulnerable. This confirms that humans have great responsibility in plant populations degradation. Lack of control exacerbates the overexploitation of some useful species. It is actually the case for *C. micranthum*, *P. lucens*, *M. inermis* and *A. digitata*.

Current management practices in the village cannot avoid plant degradation. There is no protected area, and there is no tree plantation in non-cultivated zones. Most trees are old trees saved during the clearance of news farms several decades ago. Collective and individual plantations concern exotic species (*A. indica*, *E. camaldulensis* and *M. indica*) to the detriment of local species. But while *A. indica* is encountered is some home fields, it is not the case for the two other species. In fact, food crops can hardly grow under *Eucalyptus* as soil becomes acid and soil mineral fraction hardly incorporates organic matter [24]. *A. indica* trees also have invasive characteristics, which hamper the establishment of herbaceous species and species with heliophilous tendency such as *G. senegalensis* and *Piliostigma sp.* Although *A. indica* is adapted to cultivated ecosystems, it is becoming less and less abundant. Indeed, our results showed that it is one of the most vulnerable species partly due to the fact that the common plantation is disappearing because of illegal cutting, animal browsing and lack of a management committee.

Local perception of species availability is also a factor that can affect their vulnerability. The survey revealed that population perception of plant abundance is relative to its density (number of tree of species) rather than its frequency (number of habitats in which the species is encountered). Thus, it is possible it does not realize that a species confined to particular habitats is threatened. *M. inermis* is considered as abundant by the population because it forms a population on lowlands. But, rarity index showed that this species is scarce. It is also the case for *P. lucens*. The perception of abundance also depends on the species importance. For example *A. digitata* is moderately frequent according to rarity index. But, the population considers it as a scarce species because of numbers today as compared to before. Perception depends finally on growth of species. Some species are considered as very scarce to disappear, while the rarity index showed they are moderately frequent. It is the case for *Flueggea virosa* (RI = 69.79) and *Maerua angolensis* (RI = 76.04). These two species, with others such as *Maerua crassifolia*, *Boscia angustifolia*, *Asparagus africanus*, *Grewia bicolor*, *Grewia flavescens* and *Capparis sepiaria* are encountered in juvenile stands under shrubs or tree shelters.

Changes in the use of ligneous species

Changes in the floristic composition of the area and current vulnerability state of woody species affect their use too. This leads to changes in species used for specific uses. Many ligneous species play a crucial nutritive role during lean periods, notably at the beginning of the rainy season when food stock of the last harvest is often finished. Fruit tree species from which many ripen during that period and also species with edible leaves and flowers play a particularly important role for population food security [25, 26]. *S. senegalensis, B. aegyptiaca, L. hastata, V. paradoxa, L. microcarpa, A. digitata, B. senegalensis* and *A. macrostachya* are part of these species that are deliberately kept in the village land areas for their nutritive role [8, 22, 25, 27, 28]. Our study revealed that five of the above species, together with six others, were the most used (VUET ≥ 6). In the past, in bad rainfall years, seeds of *B. senegalensis* were collectively collected at a time decided by the village's notability. This way of collecting aimed at allowing each household to have some seeds from this species to cope with food crisis. *P. biglobosa*'s pulp was also stored to cope with food insecurity. This proves the crucial role of ligneous species in adaptation strategies to cope with food insecurity due to climate variability. However, these key species are threatened. Among the local fruit tree species, only *L. microcarpa* is well represented. Capparaceae species, such as *Maerua angolensis, Maerua crassifolia, Maerua oblongifolia*, because of their leaves, and *Capparis sieperia*, because of its fruits, have saved families from famine according to local population. The same goes for *Balanites aegyptiaca*. These Capparaceae species because of their extreme rarity, bitter taste and changes in dietary habits, are not appreciated by the young generation. *Balanites aegyptiaca,* although still well represented in the areas and with high NTFPs potentials, is not consumed because collection of its leaves and flowers is said to be difficult by young women who prefer *Leptadenia hastata*. *A. digitata* has become the main species used for a sauce that goes with local diet "tô" because *Bombax costatum* is locally rare and women have no fields to grow okra. Only *A. digitata*, *T. indica* and *M. indica* currently procure financial income for some people. This situation increases poverty of underprivileged classes (children and women).

It is estimated that 80% of the population in Burkina Faso are still relaying traditional tree-based medicine as it is more affordable and matches better the socio-cultural realities [29, 30]. However, human and climate pressure negatively affect natural regeneration of most of these species [15, 23]. This is the case for *M. inermis* for instance, which usually grows in ecosystems of humid areas and is threatened by the disappearance of lowlands due to silting of the rivers as a result of erosion induced by heavy rain events in a context of low vegetation cover. To cope with these difficulties, farmers look for substitutes, using both their local and the expert knowledge. This includes the transfer of uses of disappeared species on those still existing and the introduction of exotic species sometimes to the detriment of local species. This explains the presence of exotic species in courtyard and around houses.

Because of rainfall deficit, herbaceous species, the main feed source for livestock, are not available in quantity and quality during the dry season. Farmers therefore integrate fodder from ligneous species such as *P. lucens* and *A. digitata* in their adaptation strategies [19, 23, 31–33]. *F. albida* is by far the fodder ligneous species most appreciated by livestock breeders because it bears leaves and pods during the dry season when most of the ligneous species suffer from the harsh climate. Unluckily, the species is not abundant and its natural regeneration is almost absent in the village land area. *C. nigricans* and *M. inermis* are also pruned by nomad livestock breeders to feed their cattle.

Collection of fuelwood, which is one of the main uses of ligneous resources in this area of Burkina Faso, has changed quite a lot with climate deterioration, population growth and agricultural expansion at the expense of natural resources. In a study in Mali, Montes et al. [34] have observed that shrubs such as *G. senegalensis* and *C. micranthum* have become the main fuelwood species after women discovered that they could immediately use it after cutting. These species have low water content and good calorific value. Our results showed that the first species has become rare, while the second is one the main fuelwood species. *P. reticulatum* appeared also to be used as fuelwood due to its availability because of its good regeneration in farms. These shrubs are resilient species with good regeneration capacity [25].

Recycling woods from old crop storage places and houses have become a common practice to adapt to the lack of preferred wood in the natural stands. This behavior aims to protect the species currently present which could replace those that disappeared. For instance, *P. lucens* has hard wood, but because it is the main fodder species, it is only pruned for livestock. Old infrastructures are made with wood from species that are now rare or have disappeared, such as *V. paradoxa, Pterocarpus erinaceus, Anogeissus leiocarpa, Ficus sycomorus, Khaya senegalensis*, whose wood is resistant to insect borers, termites and rot [35]. Exotic species (*A. indica*, *E. camaldulensis*) are currently used to build houses. The adaptation is also observed in the way houses are built. Traditional houses (huts, houses with roofs in wood) are replaced by modern houses with sheet-metal roofs. This modernization is inevitable because wood has become scarce. But the population appreciates traditional houses that are more adapted to hot weather. For handicraft, most people use the best representative species in the area to make useful objects (mattocks, baskets, mortars) or buy them. Women use more and more modern kitchen utensils made in plastic or aluminum.

Systematic collection of crop residues leaves bare soil during the entire dry season. Soil becomes vulnerable to water and wind erosion. Therefore, farmers integrate more and more ligneous species in their soil and water conservation strategies [36] to compensate for the collection of crop residues [25, 31]. Well-managed crops and trees association improve fruit production [37] while also increasing cereal yields [38, 39], which are the main crops in semi-arid areas of West Africa. *F. albida*, *P. reticulatum* and *Leptadenia hastata* are some of the species well preserved in the agrosystems in Sillia to fight against land degradation. Clump sprouts of *P. reticulatum* keep their green leaves during harmattan time in the dry season and therefore help to protect the farms, after harvest, against wind erosion [25]. At the beginning of rainy season, cutting the shouts provides women with fuelwood while the leaves biomass is used as mulch [40, 41]. *C. micranthum* and *C. glutinosum* are also said to be fertilizing species by the population. While the first species fights against erosion and retains plant residues and soil carried by water and wind, the leaves of the second species provide the soil with humidity and organic matter.

Conclusion

This study pointed out the importance of ligneous species in local people adaptation strategies to their changing environments. It was shown that local people adopt new behaviors or just use existing species to cope with the disappearance of some species due in part to climate change. Most used species were identified based on their ethnobotanical use value. We also assessed species vulnerability and established the list of vulnerable species. The results showed that all preferred species available in Sillia are vulnerable. From the 58 vulnerable species, *P. reticulatum* and *C. micranthum* are the most frequent in the area, 6 are less frequent and the 50 others are rare. Collection modes (cutting, pruning, bark removal and root extraction) jeopardize survival of individuals and species. In addition to harvesting methods, local species availability perception, lack of management and lack of regeneration increase species vulnerability in the study area. The current results on species used in the locality and their status (availability, abundance and vulnerability) are a tool for safeguarding biodiversity. It allows knowing the plant species that can adapt to the locality while being useful to the population. This conservation could be realized through the establishment and monitoring of conservation strategies such as assisted natural regeneration; SWC (soil and water conservation) techniques; and tree planting. The implementation of these strategies should be taking into account the habitats of the species and the characteristics of these habitats, after a presentation of current results to the people for creating awareness. This awakening of conscience would allow the involvement of the population and the success of these strategies.

Abbreviations

INERA: Institute of Environmental and Agricultural Research; DPF: Forests Productions Department; ICRAF: World Agroforestry Centre; ICRISAT: International Crops Research Institute for the Semi-Arid Tropics; CCAFS: Climate Change, Agriculture and Food Security; CoCooN: Conflict and Cooperation Over Natural Resources in Developing; VUET: Total Ethnobotanical Use Value; IV: Vulnerability Index; CVD: Village Development Committee; RI: Rarity Index; NTFPs: non-timber forest products; CGIAR: Consultative Group on International Agriculture Research; CIDA: Canadian International Development Agency; DANIDA: Danish International Development Agency; EU: European Union; IFAD: International Fund for Agricultural Development; PAR-CSA: participatory action research on climate smart.

Authors' contributions

PO, BAB, AT designed data collection instruments and gathered the data. PO, BAB, AT, JS, ST, SB, SDD, JB, MO and SS help in analysis and write up. AT, BAB and JB supervised the design and the entire data collection process and provided guide, corrections and supervision to the entire research. All authors revised critically the manuscript and given final approval of the version to be published.

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Availability of data and material

The datasets analyzed during the current study are available from the corresponding author on request.

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

The present study was validated as part of research programs by the scientific committee of "Institut de l'Environnement et de la Recherche Agricole (INERA)" where the first author carried out work. INERA has mandated and missions to generate scientific knowledge, technological innovations and decision support tools for improving agricultural sector in Burkina Faso (http://www.inera.bf/index.php/inera/missions). All procedures followed were in accordance with Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all participants included in the study.

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References

1. Mbow C, Smith P, Skole D, Duguma L, Bustamante M. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Curr Opin Environ Sustain. 2014;6:8–14.
2. Hahn-Hadjali K, Thiombiano A. Perception des espèces en voie de disparition en milieu gourmantché (Est du Burkina Faso). Berichte des Sonderforschungsbereichs. 2000;268:285–97.
3. Bayala J, Sanou J, Teklehaimanot Z, Kalinganire A, Ouédraogo SJ. Parklands for buffering climate risk and sustaining agricultural production in the Sahel of West Africa. Curr Opin Environ Sustain. 2014;6:28–34.
4. Smith MS, Mbow C. Editorial overview: sustainability challenges: agroforestry from the past into the future. Curr Opin Environ Sustain. 2014;6:134–7.
5. Luedeling E, Kindt R, Huth N, Koenig K. Agroforestry systems in a changing climate—challenge in projecting future performance. Curr Opin Environ Sustain. 2014;6:1–7.
6. Yossi H, Kouyaté AM. Les arbres hors forêt: le cas du Mali. Archives FAO. 2001.
7. Belem B, Nacoulma BMI, Gbangou R, Kambou S, Hansen HH, Gausset Q, Lund S, Raebild A, Lompo D, Ouedraogo M, Theilade I, Boussim IJ. Use of non wood forest products by local people bordering the "Parc National Kaboré Tambi", Burkina Faso. J Transdiscipl Environ Stud. 2007;6(1):1–21.
8. Bélem B, Smith Olsen C, Theilade I, Bellefontaine R, Guinko S, Mette Lykke A, et al. Identification des arbres hors forêt préférés des populations du Sanmatenga (Burkina Faso). Bois et Forêts des Tropiques. 2008;298(4):53–64.
9. Dossou ME, Houessou GL, Lougbégnon OT, Tenté AHB, Codjia JTC. Étude ethnobotanique des ressources forestières ligneuses de la forêt marécageuse d'Agonvè et terroirs connexes au Bénin. Tropicultura. 2012;30(1):41–8.
10. Zerbo P, Millogo-Rasolodimby J, Nacoulma-Ouedraogo OG, Van Damme P. Plantes médicinales et pratiques médicales au Burkina Faso: cas des Sanan. Bois et Forêts Des Tropiques. 2011;307(1):41–53.
11. PDRD. Programme de Développement Rural Durable—Diagnostic de la commune de Titao. Rapport, MATD, Burkina Faso. 2009:93 p.
12. Betti JL. Vulnérabilité des plantes utilisées comme antipaludiques dans l'arrondissement de Mintom au sud de la réserve de Biosphère du Dja (Cameroun). Syst Geogr Plant. 2001;71:661–78.
13. Traoré L, Ouédraogo I, Ouédraogo A, Thiombiano A. Perceptions, usages et vulnérabilité des ressources végétales ligneuses dans le Sud- Ouest du Burkina Faso. Int J Biol Chem Sci. 2011;5(1):258–78.
14. Bondé L, Ouédraogo O, Kagambèga F, Boussim IJ. Impact des gradients topographique et anthropique sur la diversité des formations ligneuses soudaniennes. Bois et Forêts des Tropiques. 2013;318(4):15–26.
15. Ouédraogo A. Dynamique de la végétation ligneuse de la partie orientale du Burkina Faso. Thèse de Doctorat, Université de Ouagadougou, Burkina Faso. 2006:185 p.
16. Ouédraogo I. Diversité et distribution des espèces ligneuses utiles de la région du nord du Burkina Faso; état des peuplements de cinq espèces d'importance socio-économique. Mém d'ingénoriat: Université de Bobo Dsso; 2008. p. 64.
17. Savadogo S. Les bois sacrés du Burkina Faso: Diversité, structure, dimension spirituelle et mode de gestion de leurs ressources naturelles. Thèse de doct, Univ Ouaga. 2013:207 p.
18. Philips O, Gentry AH. The useful plants of Tambopata, Peru. II Statistical hypothesis tests with a new quantitative technique. Econ Bot. 1993;47(1):33–43.
19. Bognounou F. Caractérisation et gestion de ligneux fourragers dans les systèmes de production agro-pastorale du terroir de Dankana en zone sud Soudanienne du Burkina Faso. Mémoire DEA: Université de Ouagadougou; 2004. p. 54.
20. Koadima M. Inventaire des espèces ligneuses utilitaires du parc w et terroirs riverains du Burkina Faso et état des populations de trois espèces a grande valeur socio-économique. Mémoire DEA: Université de Ouagadougou, Burkina Faso; 2008. p. 38.
21. Ouédraogo - Bélem M. Les galeries forestières de la Réserve de la Biosphère de la Mare aux Hippopotames du Burkina Faso: caractéristiques, dynamique et ethnobotanique. Thèse de Doctorat, Université de Ouagadougou, Burkina Faso. 2008:191 p.
22. Bationo BA, Maïga A, Compaoré P, Kalinganire A. Dimension socio-culturelle du baobab Adansonia digitata L. dans le Plateau central du Burkina Faso. Bois et Forêts des Tropiques. 2010;306:23–32.
23. Ganaba S. Caractérisation, utilisations, tests de restauration et gestion de la végétation ligneuse au Sahel. Burkina Faso. Thèse de Doctorat: Université CHEIKH ANTA DIOP, Sénégal; 2008. p. 261.
24. Tchawa P, Demaze MT. Gestion de l'espace et effets écologiques de l'eucalypculture en pays Bamiléké (Ouest Cameroun): stratégie paysanne et prise en compte d'un risque perçu. Les Cahiers d'Outre-Mer. 2002;218:13 p.
25. Ambé GA. Les fruits sauvages comestibles des savanes guinéennes de Côte-d'Ivoire: état de la connaissance par une population locale, les Malinké. Biotechnologie, Agronomie Société Environnement. 2001;5(1):43–58.
26. Atato A, Wala K, Batawila K, Woegan AK, Akpagana K. Diversité des fruitiers ligneux spontanés du Togo. Fruit Veg Cereal Sci Biotechnol. 2010;4:1–9.
27. Millogo-Rasoldimby J, Guinko S. Les plantes ligneuses spontanées à usages culinaires au Burkina Faso. Berichte des Sonderforschungsberichs. 1996;268:125–33.
28. Thiombiano DNE, Lamien N, Dibong SD, Boussim IJ. État des peuplements des espèces ligneuses de soudure des communes rurales de Pobé-Mengao et de Nobéré (Burkina Faso). J Animal Plant Sci. 2010;9(1):1104–16.
29. Benoît E. Les changements climatiques: vulnérabilité, impacts et adaptation dans le monde de la médecine traditionnelle au Burkina Faso. VertigO - la revue électronique en sciences de l'environnement [En ligne]. 2008;8(1). doi:10.4000/vertigo.1467. http://vertigo.revues.org/1467.
30. Guinko S. Les plantes et la médecine traditionnelle au Burkina Faso. Berichte des Sonderforschungsbereichs. 1993;268:47–53.
31. Bayala J, Ky-Dembele C, Kalinganire A, Olivier A, Nantoumé H. A review of pasture and fodder production and productivity for small ruminants in the Sahel. ICRAF Occasional Paper, World Agroforestry Centre, Nairobi. 2014; No. 21.
32. Diallo AK. Problèmes posés par l'utilisation des espèces ligneuses dans l'alimentation des animaux domestiques sénégalais en zone d'élevage extensif. J Association for the Advancement of Agricultural Sciences in Africa. 1973;1:45–55.
33. Smetana G, Peltier R, Sibelet N, Leroy M, Manlay R, Njiti CF, et al. Parcs agroforestiers sahéliens: de la conservation à l'aménagement. Vertigo. 2005;6(2):1–13.

34. Montes S, Weber J, Silva DA, Muniz G, Garcia R, Kalinganire A. Effects of region, soil, land use, and terrain type on fuelwood properties of five tree/shrub species in the Sahelian and Sudanian ecozones of Mali. Ann For Sci. 2012;69(6):747–56.
35. Ganaba S, Ouadba JM, Bognounou O. Plantes de construction d'habitations en région sahélienne. Bois et Forêts des Tropiques. 2004;282(4):11–7.
36. Mbow C, Van Noordwijk M, Prabhu R, Simons T. Knowledge gaps and research needs concerning agroforestry's contribution to Sustainable Development Goals in Africa. Curr Opin Environ Sustain. 2014;6:162–70.
37. Bayala J, Ouedraogo SJ, Teklehaimanot Z. Rejuvenating indigenous trees in agroforestry parkland systems for better fruit production using crown pruning. Agrofor Syst. 2008;72:187–94.
38. Bayala J, Mando A, Ouedraogo SJ, Teklehaimanot Z. Managing Parkia biglobosa and Vitellaria paradoxa prunings for crop production and improved soil properties in the sub-Sudanian zone of Burkina Faso. Arid Land Res Manag. 2003;17:283–96.
39. Bayala J, Teklehaimanot Z, Ouedraogo SJ. Millet production under pruned tree crowns in a parkland system in Burkina Faso. Agrofor Syst. 2002;54:203–14.
40. Yélémou B, Yaméogo G, Koala J, Bationo BA, Hien V. Influence of the leaf biomass of piliostigma reticulatum on sorghum production in North Sudanian region of Burkina Faso. J Plant Stud. 2014;3(1):80–90.
41. Yelemou B, Bationo BA, Yameogo G, Millogo-Rasolodimby J. Gestion traditionnelle et usages de *Piliostigma reticulatum* sur le Plateau central du Burkina Faso. Bois et Forêts des Tropiques. 2007;291(1):55–66.