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Resilience to stress of woody species in *Faidherbia albida* (Del) A. Chev. and *Prosopis africana* (Guill., Perrot and Rich.) Taub. parklands in the Sahelian Niger

Moussa Massaoudou[1*], Larwanou Mahamane[2], Karim Saley[3], Saadou Mahamane[4]

[1]*Department of Natural Resources Management (DGRN), National Institute of Agricultural Research of Niger (INRAN), P.O.Box 240 Maradi, Niger*

[2]*African Forest Forum (AFF), World Agroforestry Center (ICRAF), Nairobi, Kenya*

[3]*Department of Biology, Faculty of Science and Technology, University Dan Dicko Dankoulodo of Maradi*, Niger

[4]*Department of Biology, Faculty of Science, University Abdou Moumouni of Niamey, Niger*

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Abstract

A quantitative analysis of resilience to disturbances of woody stands of *Prosopis africana* and *Faidherbia albida* parklands in south-central Niger was investigated. Surveys were conducted through individual questionnaires, focus groups and village assemblies and the inventory of vegetation in the two parklands. Twenty-two (22) species belonging to 21 genera and 16 families have disappeared in the *F. albida* parkland against 34 species belonging to 28 genera and 18 families in *P. africana* parkland. In *F. albida* parkland, 21 woody species of which 16 are adult and 5 are sprout while in *P. africana* parkland, 29 woody species of which 20 are adult and 9 regeneration are inventoried. The results also indicated four types of resilience of woody species. 1) Species with high IVI and regeneration (*P. africana, Piliostigma reticulatum, F. albida* and *Combretum glutinosum*); 2) species with low IVI and high regeneration (*Guiera senegalensis, Ziziphus mauritiana, Bauhinia rufescens, Maerua crassifolia, Balanites aegyptiaca, Acacia senegal, Albizia chevalieri, Hyphaene thebaica*); 3) species with very low IVI and without regeneration (*Tamarindus indica, Acacia nilotica Adansonia digitata, Boscia salicifolia, Sterculia setigera and Dyospiros mespiliformis*) and 4) species with regeneration but without adult trees (*Securidaca longepedunculata, Entada africana, Cassia singueana, Terminalia avicennioides, Feretia apodanthera, Combretum micranthum, Commiphora africana, Ficus platyphylla* and *Calotropis procera*). This information can provide guidance on species selection for rehabilitation of disappeared or threatened species and in developing sound agroforest management plans in this part of Niger.

***Corresponding Author:** Moussa Massaoudou ✉ mmassaoudou13@gmail.com

Introduction

In the Sahel, woody species play important role in providing goods and services for rural populations. The uses of these species are reflected in different services they provide, including firewood, timber, traditional medicines, handicrafts and especially ecosystem services (Larwanou, 2005; Souleymane *et al.,* 2005; Ouédraogo *et al.,* 2006; Fabien *et al.,* 2006; Dan Guimbo, 2011; Laouali *et al.,* 2014; Hamidou *et al.,* 2015). The exploitation of these resources for the various uses by local communities is mainly through cutting, debarking, fruit, flowers and leaves collection and uprooting (Larwanou, 2005; Belem *et al.,* 2008; Dossou *et al.,* 2012; Hamidou *et al.,* 2015). Other modes of exploitation include bush fires and land clearing before crop installation. All these activities combined with uncertainty and irregularity in time and space of rainfall (Ozer *et al.,* 2005), inevitably lead to the degradation and the disappearance of some woody species in the Sahel. In several parts of the Sahel, many species have disappeared and others are menaced (Larwanou, 2005; Thombiano *et al.,* 2010; Omar *et al.,* 2013). The direct consequence of all these would be a serious imbalance for different services that these species provide. Parklands in the Sahel are the result of human work, starting with elimination of harmful species and/or limited use, selection and maintenance of useful species in the fields (Smektala *et al.,* 2005 and Yaméogo *et al.,* 2005). Notwithstanding, many tree species are maintained in parklands to varying degrees of abundance and growth stage. It is therefore important to understand the level of disturbance and resilience of woody species of these parklands in order to alert for better decision-making in national planning policies for the development of these village agroforests. In this regard, there is need to evaluate the different tree species that have disappeared in relation to their ethnobotanical uses and the level of resilience of those that remain in the parklands. The hypotheses to be tested in this study are: (1) ethnobotanical uses coupled with modes of exploitation affect the regression of woody species in these parklands; (2) the resilience of woody species in the Sahel is related to their relative dominance and their ability to regenerate. The verification of these hypotheses will provide a basis for selecting the right species for restoration and/or rehabilitation of the agroforests in order to respond to the population uses and improve the management and conservation of these species.

Material and methods

Study sites

South-central part of Niger was used through two parklands. The parkland of *F. albida* located in Dan Mairo and parkland of *P. africana* located in Sarkin Yamma. The choice of these parklands is directed by the wide geographical distribution of the main species like *F. albida* and *P. africana* and especially their socio-economic, cultural and ecological interest for the populations (Williams, 1993; Kho *et al.,* 2001; Garrity *et al.,* 2010; Aina and Wada, 2012; Weber *et al.,* 2015). The parklands of *P. africana* of Sarkin Yamma and *F. albida* of Dan Mairo are respectively located at 13°25'N and to 006°58'E and at 15 km in the south, and 13°54'N and 007°18'E and 75 km in the northeast of Maradi town (Fig. 1). Soils are tropical ferruginous, slightly leached and clayey in the parkland of *P. africana* and ferruginous leached with coarse sands in dry valley in the parkland of *F. albida* (Gavaud and Boulet, 1964). The rainfall and temperature data of 2002-2014 from the synoptic station of Maradi airport were used to characterize the climate. The minimum and maximum annual mean temperatures are respectively 21.4±4.1°C and 35.7±3.2°C. The annual rainfall mean is 509.4 ± 383.08 mm for the same period.

Surveys

The surveys were conducted in two phases. The first phase took place in August 2014 at Sarkin Yamma and the second phase in November 2014 at Dan Mairo. Six villages and two hamlets were used for the investigation. These are the villages of Guidan Kusao, Gourgoumi and Allalafah and a village of blacksmiths (Guidan Ma Keri) at Dan Mairo and Sarkin Yamma Saboua, Saran Maradi and Dan Mazadou with a

Fulani village (Guidan Hardo) located in the district of Sarkin Yamma. Investigations were mainly on disappeared woody species in order to:

(1) Evaluate the dynamics of current woody species and their ethnobotanical uses,

(2) Assess the level of importance of each disappeared species for the populations,

(3) Understand the efficiency of their modes of exploitation as well as the organs exploited.

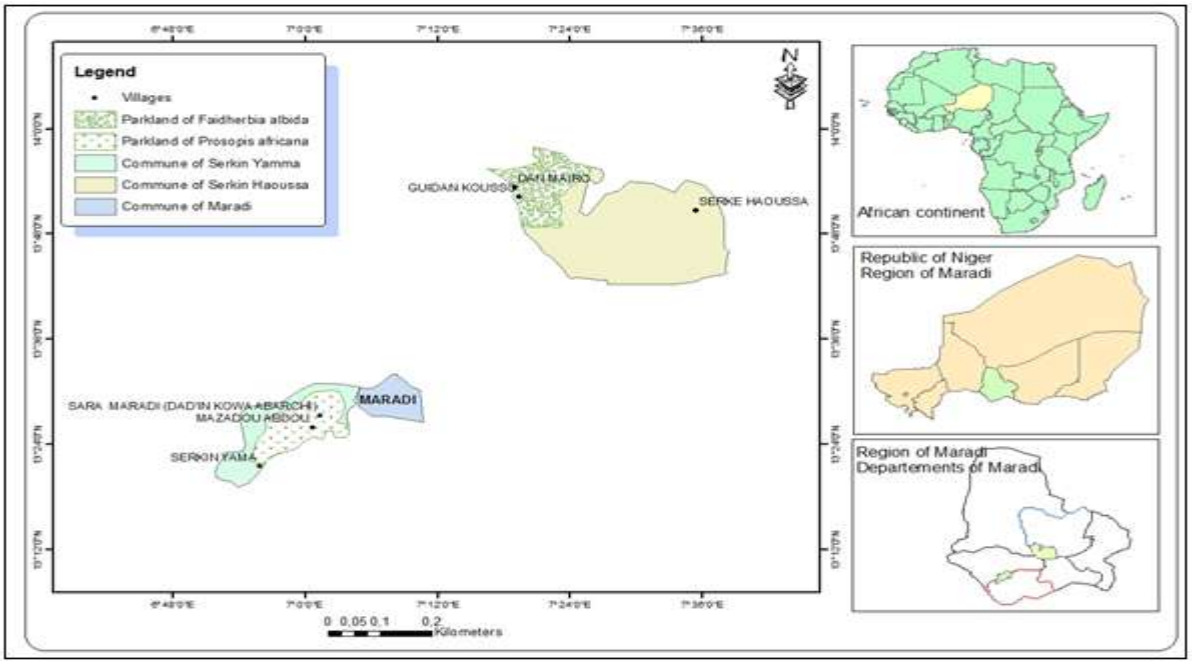

Fig. 1. Location of study sites.

An individual questionnaire was administered to 111 people with 67 at Sarkin Yamma and 44 at Dan Mairo followed by group interviews through three (3) village assemblies around village heads (chiefs and Imams).

Inventory of woody species

The inventory of woody species took place during the months of October and November 2014, when the woody vegetation and regeneration were well expressed in the Sahel. The soil map of Maradi region (Gavaud and Boulet, 1964) was used for sampling after considering the heterogeneity of the sites. At Sarkin Yamma, the soil is homogeneous (ferruginous leached), therefore radial transects from the village of Dan Mazadou following the four geographic directions were used as described by Larwanou, (2005); Larwanou and Saadou, (2011); Larwanou and Saadou, (2012) for woody vegetation inventory in parklands. At Dan Mairo, the geomorphology is marked by the formation of dune, terrace and dry valley of Goulbi N'Kaba. Parallel transects, 1 km apart, and perpendicular to the dry valley were used. The parallel transects are used in the Sahel to apprehend, the variability of woody species biodiversity around the watercourse like the valley (Dan Guimbo, 2011). In the dunes, radial transects 500 m from the village to the bush were used because of the homogeneity of the environment. On each transect, plots of 50 m×50 m (2500 m²) every 500 m interval were used in order to apprehend the environmental heterogeneity (Larwanou and Saadou, 2011). The plot size (2500 m²) corresponds to the minimal area needed for study of woody vegetation in the Sahel (Boudet, 1984). In total 69 plots were installed for plant inventory in which 39 plots at Sarkin Yamma and 30 at Dan Mairo. Within each plot woody species were identified by identifying regeneration or young tree (diameter at breast height (DBH) lower than 5 cm) (Ouédraogo *et al.,* 2006) and the adult or mature trees with DBH higher than 5 cm.

For each plot the following measurements were conducted: the number of all woody species, the diameter at breast height for adult trees and the regeneration, the specific contribution, tree density and basal area. The Importance Value Index was later on determined.

Data analysis

The data from the survey were processed and analyzed using Excel and SPSS 16 Software in order to establish the list of extinct (disappeared) species and the specific contribution by: $pi = \frac{ni}{N}$ (1)

Where ni is the number of positive citations of specie i and N the total number of citations for all species. The different ethnobotanical uses are calculated using:

Ethnobotany Use Value of the specie i, $UV = \frac{\sum u}{n}$ (Phillipps and Gentry,1993 et Rossato *et al.,* 1999) (2)

With u sum of the positive responses of respondents for a given use and n: number of responses

Total Ethnobotanical Use Value $UV_t = \sum_1^p UV$ (3)

With p the uses number for the given species.

In total six main uses were identified based on their importance to the populations: human food, animal feed, firewood, timber, service wood and traditional medicines. For this study the index ranges from 0 to 6. UV below 2 indicates low usage of a given species, the use is average for UV between 2 and 4 and it is high for UV greater than 4. The equitability index of Pielou was used to understand the contribution of each extinct species and assess information quality and knowledge level of the populations on these species. This index is comparable to Begossi, (1996) index, which assesses the knowledge level of the populations about extinct species and their ethnobotanical uses (Camejo-Rodrigues *et al.,* 2003).

$E = \frac{H}{Hmax}$ (4)

With$H = \sum - pi * (\text{Log}2pi)$ (5)

And$Hmax = lnS$ (6)

Where S is the sum of disappeared species.

Inventory data were processed using Excel to list the species identified and determine the specific frequency (Sf in %), relative density (Rd in individuals/ha) and dominance or relative basal area (Ba in m²/ha) of each species. The resilience of woody species in each parkland is appreciated firstly by its Importance Value Index (IVI) and secondly by regeneration.

$IVI = \sum(Sf + Rd + Ba)$ (7)

The Importance Value Index is a quantitative index for obtaining the species ecological important in the environment. This index has been used in many studies to determine the importance of woody species in a stand (Allabi *et al.,* 2011 and Dossou *et al.,* 2012). IVI is on a scale of 0 to 300. The species absent in the environment have zero IVI value, while dominant species have high IVI. The regeneration is expressed by density of generation per hectare. IVI and regeneration are used to classify woody species to their degree of resilience.

The analysis of variance (ANOVA) is made to compare some parameters between the two parklands including diversity of disappeared species and ethnobotanical uses. The difference in ethnobotanical uses between sites gives information on the management and exploitation variance of tree species by the two communities. Therefore, it allows apprehending the impact of anthropogenic action on stand dynamic.

Results

Extinct (disappeared) species of F. albida parkland of Dan Mairo

Results showed that 22 species belonging to 16 families and 21 genera disappeared in Dan Mairo. The family of *Caesalpiniaceae* is the most represented with 3 genera, followed by *Anacardiaceae, Burseraceae, Combretaceae* and *Moraceae* each with

2 genera. The following families have one genus each: *Tiliaceae, Bignoniaceae, Bombacaceae, Capparaceae, Ebenaceae, Loganiaceae, Meliaceae, Mimosaceae, Arecaceae, Polygalaceae* and *Rhamnaceae* (Table 1).

Table 1. List of extinct (disappeared) species in Dan Mairo according to local community.

Families	Genera	Species
Anacardiaceae	Lannea	*Lannea microcarpa*
	Sclerocarya	*Sclerocarya birrea*
Tiliaceae	Grewia	*Grewia flavescens*
Bignoniaceae	Stereospermum	*Stereospermum kunthianum*
Burseraceae	Boswellia	*Boswellia dalzielli*
	Commiphora	*Commiphora africana*
Bombacaceae	Adansonia	*Adansonia digitata*
	Cassia	*Cassia angolensis*
Caesalpiniaceae	Detarium	*Detarium microcarpum*
	Tamarindus	*Tamarindus indica*
Capparaceae	Boscia	*Boscia salicifolia*
Combretaceae	Anogeissus	*Anogeissus leiocarpa*
	Terminalia	*Terminalia avicennioides*
Ebenaceae	Diospyros	*Diospyros mespiliformis*
Loganiaceae	Strychnos	*Strychnos spinosa*
Meliaceae	Khaya	*Khaya senegalensis*
Mimosaceae	Parkia	*Parkia biglobosa*
Moraceae	Ficus	*Ficus iteophylla*
		Ficus platyphylla
Arecaceae	Hyphaene	*Hyphaene thebaica*
Polygalaceae	Securidaca	*Securidaca longepedunculata*
Rhamnaceae	Ziziphus	*Ziziphus spina-christi*
16	21	22

Extinct (disappeared) species of P. africana parkland of Sarkin Yamma

Results showed that 34 species belonging to 18 families and 28 genera have disappeared in the parkland of Sarkin Yamma. The family of *Caesalpiniaceae* is the most cited (6 genera), followed by *Mimosaceae* (3 genera). The families of *Capparaceae*, *Rubiaceae* and *Combretaceae* have each 2 genera. The following families have each one genus: *Asclepiadaceae, Bombacaceae, Burseraceae, Ebenaceae, Fabaceae, Meliaceae, Polygalaceae, Sapotaceae, Tiliaceae, Ulmaceae* and *Verbenaceae* (Table 2).

Table 2. List of extinct species in Sarkin Yamma according to local communities

Families	Genera	Species
Asclepiadaceae	Leptadenia	*Leptadenia hastata*
Bombacaceae	Bombax	*Bombax costatum*
Burseraceae	Boswellia	*Boswellia dalzielli*
	Bauhinia	*Bauhinia rufesens*
	Burkea	*Burkea africana*
	Cassia	*Cassia sieberiana*
Caesalpiniaceae	Daniellia	*Daniella olivera*
	Detarium	*Detarium microcarpum*
	Isoberlinia	*Isoberlinia doka*
	Boscia	*Boscia angustifolia*
Capparidaceae		*Boscia salicifolia*
	Maerua	*Maerua crassifolia*
Combretaceae	Anogeissus	*Anogeissus leiocarpa*
	Terminalia	*Terminalia macoptera*
Ebenaceae	Diospyros	*Diospyros mespiliformis*
Fabaceae	Pterocapus	*Pterocapus erinaceus*
Meliaceae	Kaya	*Khaya senegalensis*
Mimosaceae	Dicrostachys	*Dicrostachys cinerea*
	Albizia	*Albizia coriaria*

	Acacia	*Acacia macrostachya*
		Acacia raddiana
		Acacia nilotica
		Ficus iteophylla
Moraceae	Ficus	*Ficus platyphylla*
		Ficus polita
		Ficus sycomorus
		Ficus thonningii
Polygalaceae	Securidaca	*Securidaca longepedunculata*
Rubiaceae	Gardenia	*Gardenia erubescens*
	Mitragyna	*Mitragyna inermis*
Sapotaceae	Vitellaria	*Vitellaria paradoxa*
Tiliaceae	Grewia	*Grewia flavescens*
Ulmaceae	Celtis	*Celtis integrifolia*
Verbenaceae	Vitex	*Vitex doniana*
18	28	34

Most extinct species

At Dan Mairo, the species frequently cited is *B. dalzielli* (14.3%). Species like *L. microcarpa*, *S. birrea*, *D. microcarpa*, *T. indica*, *D. mespiliformis*, *K. senegalensis*, *F. iteophylla*, *F. platyphylla* and *Z. spina-christi* were each cited by 5.7% of the interviewees. The other species are less cited by 2.9% of the populations. These are *S. khunthianum*, *C. africana*, *A. digitata, C. angolensis*, *B. salicifolia*, *A. leiocarpa*, *T. avicennioides*, *S. spinosa*, *P. biglobosa*, *F. iteophylla* and *S. longepedunculata* (Fig. 2). Extinct species most frequently cited at Sarkin Yamma are *B. dalzielli* and *K. senegalensis* with 8.4% of citations each. They are followed by *V. paradoxa* (7.2%), *F. platyphylla* and *A. leiocarpa* with 6 % each, *F. thonningii* and *F. polita* (3.6% each). Less-cited species (2.4%) are *D. oliveri*, *I. doka*, *B. angustifolia*, *B. salicifolia*, *M. crassifolia*, *P. erinaceus*, *D. cinerea*, *A. macrostachya*, *A. nilotica*, *F. sycomorus*, *M. inermis*, *C. integrifolia*, *V. doniana*, *C. sieberiana*, *T. macoptera*, *D. mespiliformis*, *A. coriaria*, *A. raddiana*, *S. longepedunculata*, *G. erubescens* and *G. flavescens* (Fig. 2). Analysis of variance of population citations from different extinct species between the two sites shows a significant difference (P <0.000).

Table 3. Woody species inventoried in *F. albida* parkland of Dan Mairo.

Families	Genera	Species	Adults	Regeneration
Anacardiaceae	Sclerocarya	*Sclerocarya birrea*	-	+
Arecaceae	Hyphaene	*Hyphaene thebaica*	-	+
Asclepiadaceae	Calotropis	*Calotropis procera*	-	+
Balanitaceae	Balanites	*Balanites aegyptiaca*	+	+
Bignoniaceae	Stereospermum	*Stereospermum kunthianum*	-	+
Burseraceae	Commiphora	*Commiphora africana*	+	+
Capparaceae	Maerua	*Maerua crassifolia*	+	+
Caesalpiniaceae	Bauhinia	*Bauhinia rufescens*	+	+
	Piliostigma	*Piliostigma reticulatum*	+	+
	Tamarindus	*Tamarindus indica*	+	-
Combretaceae	Combretum	*Combretum glutinosum*	+	+
	Guiera	*Guiera senegalensis*	+	+
Euphorbiaceae	Phyllanthus	*Phyllanthus reticulatus*	-	+
Mimosaceae	Acacia	*Acacia nilotica*	+	+
		Acacia raddiana	+	+
		Acacia senegal	+	+
	Faidherbia	*Faidherbia albida*	+	+
	Prosopis	*Prosopis africana*	+	+
Meliaceae	Azadirachta	*Azadirachta indica*	+	-
Rhamnaceae	Ziziphus	*Ziziphus mauritiana*	+	+
Rubiaceae	Xeromphis	*Xeromphis nilotica*	+	-
14	19	21	16	18

+: Presence and -: no

Ethnobotanical uses of extinct species

Extinct species are mainly used as firewood (97.1% and 80%), traditional medicines (57.1% and 81.5%), animal feed (91.4% and 40.7%), human food (51.9% and 71.4%), timber (34.3% and 45.7%) and wood services (2.9% and 17.3%) respectively at Dan Mairo and Sarkin Yamma (Fig. 3). Analysis of variance showed significant differences in the use of extinct species for firewood (P<0.05), traditional medicines (P<0.05) animal feed (P<0.00) and timber service (<0.05) in the two sites. The difference is not significant for timber (P>0.05).

Table 4. Woody species inventoried in *P. africana* parkland of Sarkin Yamma.

Families	Genera	Species	Adults	Regeneration
Anacardiaceae	Lannea	*Lannea microcapa*	+	+
	Sclerocarya	*Sclerocarya birrea*	+	+
Annonaceae	Annona	*Annona senegalensis*	+	+
Arecaceae	Hyphaene	*Hyphaene thebaica*	+	+
Balanitaceae	Balanites	*Balanites aegyptiaca*	+	-
Asclepiadaceae	Calotropis	*Calotropis procera*	-	+
Bignoniaceae	Stereospermum	*Stereospermum kunthianum*	+	+
Bombacaceae	Adansonia	*Adansonia digitata*	+	-
Burseraceae	Commiphora	*Commiphora africana*	-	+
		Commiphora pedunculata	-	+
Capparidaceae	Boscia	*Boscia salicifolia*	+	-
Caesalpiniaceae	Cassia	*Cassia singueana*	-	+
	Maerua	*Maerua angolensis*	+	+
	Piliostigma	*Piliostigma reticulatum*	+	+
Combretaceae	Combretum	*Combretum glutinosum*	+	+
		Combretum micranthum	-	+
	Guiera	*Guiera senegalensis*	+	+
	Terminalia	*Terminalia avicennioides*	-	+
Ebenaceae	Diospyros	*Diospyros mespiliformis*	+	-
Loganiaceae	Strychnos	*Strychnos spinosa*	+	+
Mimosaceae	Albizia	*Albizia chevalieri*	+	+
	Faidherbia	*Faidherbia albida*	+	+
	Entada	*Entada africana*	-	+
	Prosopis	*Prosopis africana*	+	+
Meliaceae	Azadirachta	*Azadirachta indica*	+	+
Moraceae	Ficus	*Ficus platyphylla*	-	+
Rhamnaceae	Zizuphis	*Ziziphus mauritiana*	+	+
Rubiaceae	Feretia	*Feretia apodanthera*	-	+
Sterculiaceae	Sterculia	*Sterculia setigera*	+	-
19	27	29	20	23

Total values of ethnobotanical use of extinct species (UVt)

The total ethnobotanical use value is between 0 and 6. Fig. 4 shows that this value is high for most of the disappeared species in the two parklands. At Dan Mairo, the use value of woody species is between 2.5 and 5. It is high for example for *T. avicennioides* (UVt = 5), *C. africana* (UVt = 5), *S. spinosa* (UVt = 5), *L. microcarpa* (UVt = 4.5), *T. indica* (UVt = 4.5), *B. dalzielli* (STV = 4.2) and middle for *S. kunthianum* (UVt = 3), *A. digitata* (UVt = 3), *G. senegalensis* (UVt = 2.5), *Z. spina-christi* (UVt = 2.5) and *C. angolensis* (UVt = 2.5) (Fig. 4a). At Sarkin Yamma, the total use value of woody species is between 1 and 6. The total use is high for the species like *B. angustifolia* (UVt = 6), *P. erinaceus* (UVt = 5), *L. hastata* (UVt = 5), *C. integrifolia* (UVt = 5), *V. doniana* (UVt = 5), *B. costatum* (UVt= 4.66), *D. microcarpum* (UVt = 4.31). The total use value is low for *A. raddiana* (UVt = 2), *I. doka* (UVt = 1) (Fig. 4b).

Table 5. Importance Values Indexes of woody species in *F. albida* parkland.

Species	Rd(%)	Sf(%)	Ba(%)	IVI	Rank
Faidherbia albida	56.08	56.09	63.32	175.49	1
Piliostigma reticulatum	14.7	14.78	9.96	39.51	2
Prosopis africana	10.89	10.87	14.86	36.62	3
Balanites aegyptiaca	3.91	3.92	3.03	10.86	4
Ziziphus mauritiana	3.06	3.05	1.28	7.40	5
Combretum glutinosum	2.60	2.62	0.98	6.21	6
Acacia senegal	2.18	2.18	0.58	4.95	7
Maerua crassifolia	1.30	1.3	101	3.62	8
Tamarindus indica	0.42	0.43	2.70	3.55	9
Bauhinia rufescens	1.30	1.3	0.71	3.32	10
Acacia raddiana	0.88	0.87	0.44	2.19	11
Commiphora africana	0.88	0.87	0.24	1.99	12
Xeromphis nilotica	0.42	0.43	051	1.37	13
Acacia nilotica	0.42	0. 43	0.167	1.02	14
Guiera senegalensis	0.42	0.43	0.10	0.95	15
Azadirachta indica	0.42	0.43	0.03	0.88	16

Rd Relative density (ind/ha), Sf relative frequency (%) *and* Ba relative basal area (m^2/ha).

Table 6. Importance Value Indexes of woody species in *P. africana* parkland.

Species	Rd(%)	Sf(%)	Ba(%)	IVI	Rank
Prosopis africana	52.51	52.49	60.10	165.11	1
Piliostigma reticulatum	18.62	18.64	10.34	47.60	2
Faidherbia albida	8. 69	869	10.63	28.01	3
Combretum glutinosum	5.29	5.29	2.45	13.04	4
Lannea microcarpa	1.24	1.24	6.56	9.05	5
Azadiracta indica	2.81	2.79	0.81	6.42	6
Sclerocarya birrea	0.93	0.93	2.78	4.65	7
Albizia chevaleri	1.57	1.55	0.87	3.99	8
Annona senegalensis	1.84	1.87	0.19	3.91	9
Adansonia digitata	1.24	1.24	1.42	3.90	10
Ziziphus mauritiana	1.57	1.55	0.53	3.65	11
Sterculia setigera	0.30	0.31	1.63	2.25	12
Hyphaene thebaica	0.90	0.93	0.29	2.13	13
Guierra senegalensis	0.60	0.62	0.03	1.25	14
Balanites aegyptiaca	0.30	0.31	0.56	1.17	15
Maerua angolensis	0.30	0.31	0.48	1.09	16
Diospyros mespiliformis	0.30	0.31	0.16	0.77	17
Strychnos spinosa	0.30	0.31	0.06	0.67	18
Stereospermum kunthianum	0.30	0.31	0.01	0.62	19
Boscia salicifolia	0.30	0.31	0.007	0.62	20

Modes of exploitation for various uses of woody species in the two sites

Human food

The organs used for human consumption are mainly leaves (37.2% and 42.6%), fruit (27.9% and 45.6%), gum and roots grouped in others (23.3% and 4.4%) and flowers/inflorescences (11.6% and 7.4%) (respectively at Dan Mairo and Sarkin Yamma) (Fig. 5a). The exploitation modes consist mainly of gathering (91.4% and 95.1%), cutting (34.3% and 48.1%) and pulling (22.9% and 24.7%) respectively at Dan Mairo and Sarkin Yamma (Fig. 5b).

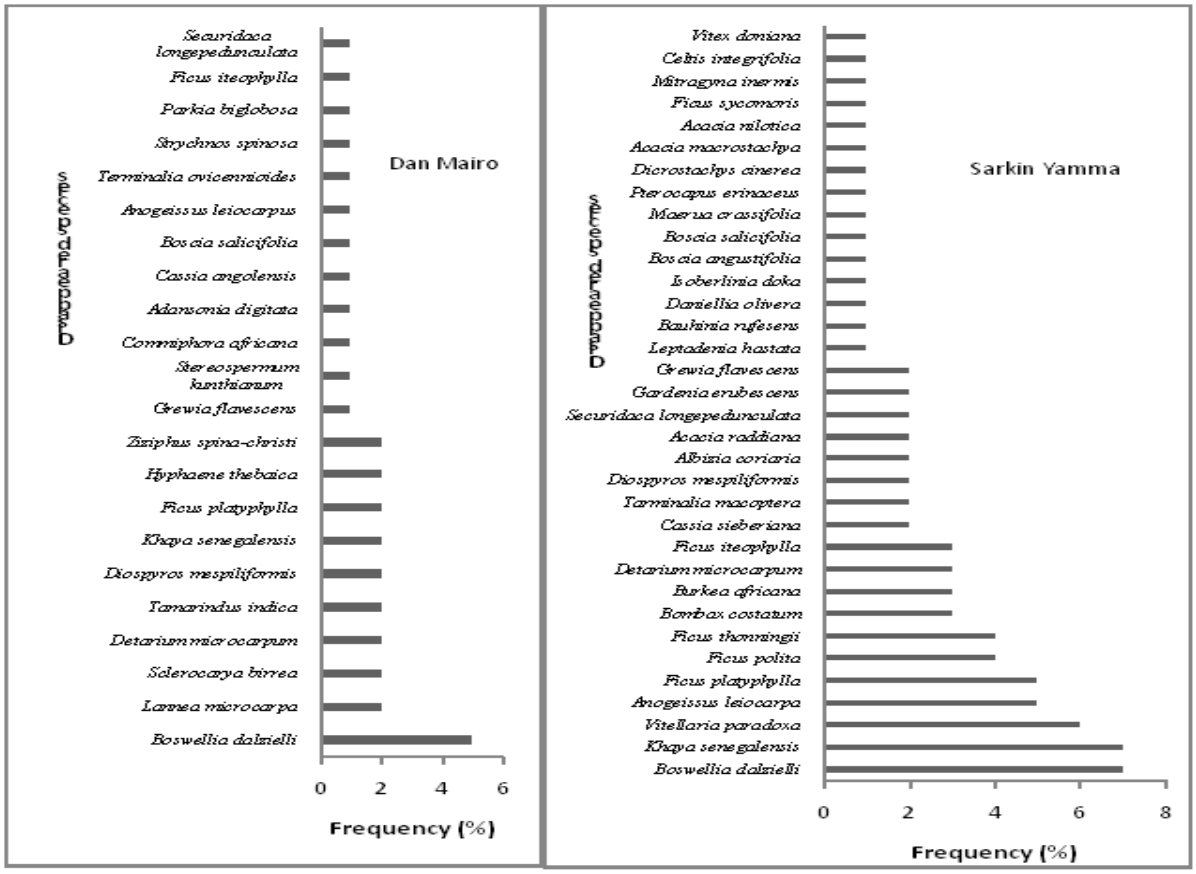

Fig. 2. Frequencies of citation of extinct species in the *F. albida* and *P. africana* parklands.

Animal feed

The parts of woody species used for animal feed are leaves (46.5% and 42.6%), fruit (27.9% and 32.4%), flowers, inflorescences and bark grouped into others (25.6% and 25%) respectively at Dan Mairo and Sarkin Yamma (Fig. 6a). The modes of exploitation of species for animals are mainly grazing (79% and 74.3%), gathering and cutting grouped into other (76.5% and 37.1%) respectively at Dan Mairo and Sarkin Yamma (Fig. 6b).

Traditional medicines

The organs used for traditional medicine are leaves (37.2% and 27.9%), bark (27% and 27.9%), roots (11.6% and 23.5%), fruits (20.9% and 11.8%), flowers (23.3% and 8.8%) and gum (0% and 1.5%) (respectively at Dan Mairo and Sarkin Yamma) (Fig.7a). The operating modes are essentially debarking (80% and 86.4%), uprooting (59.3% and 54.3%), harvesting (48.6% and 55.6%) and gathering (34.3% and 42%) (respectively at Dan Mairo and Sarkin Yamma) (Fig. 7b).

Woody species inventoried in the two sites

Woody species inventoried in F. albida parkland of Dan Mairo

The results showed that 21 species are inventoried including 16 adults and 5 as regeneration in the *F. albida* parkland of Dan Mairo. Adult species belong to 9 families and 14 genera. The stand is dominated by families of *Mimosaceae* and *Caesalpiniaceae*, each with 3 genera followed by *Combretaceae* with 2 genera. The families of *Balanitaceae, Burseraceae, Capparaceae, Meliaceae, Rhamnaceae* and *Rubiaceae* are represented each by one genus. The regeneration is distributed into 5 families each with one genus from *Anacardiaceae, Arecaceae, Asclepiadaceae* and *Euphorbiaceae* families (Table 3).

Woody species inventoried in P. africana parkland of Sarkin Yamma

The results showed 29 woody species including 20 adult and 9 species as regeneration. Adult species are distributed into 20 genera and 17 families. *Caesalpiniacea*e (3 genera) and *Mimosaceae* (3 genera) are the most represented followed by *Anacardiaceae* (2 genera) and *Combretaceae* (2 genera). *Annonaceae, Arecaceae, Balanitaceae, Bignoniaceae, Bombacaceae, Capparaceae, Ebenaceae, Loganiaceae, Meliaceae, Rhamnaceae* and *Sterculiaceae* each has one genus.

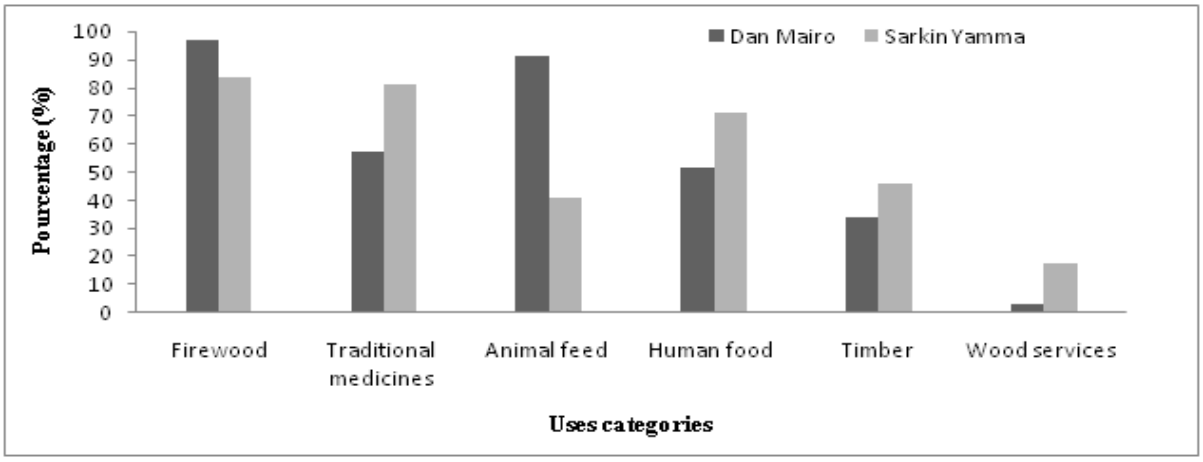

Fig. 3. Ethnobotanical uses of various extinct species according to local communities in the two sites.

The regeneration is represented by *Burseraceae* (2 genera) and *Combretaceae* (2 genera). *Asclepiadaceae, Caesalpiniaceae, Mimosaceae, Moraceae* and *Rubiaceae* each has one genus (Table 4).

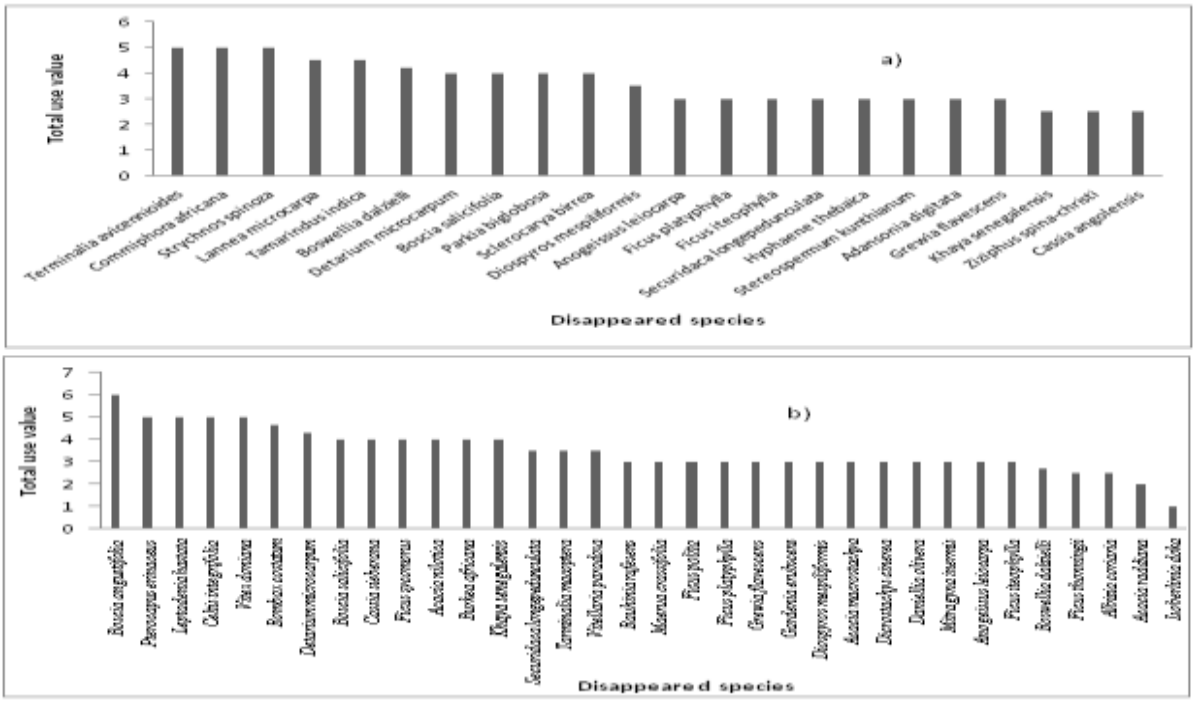

Fig. 4. Index of ethnobotanical use value of extinct species according to the site of Dan Mairo (a) and Sarkin Yamma (b).

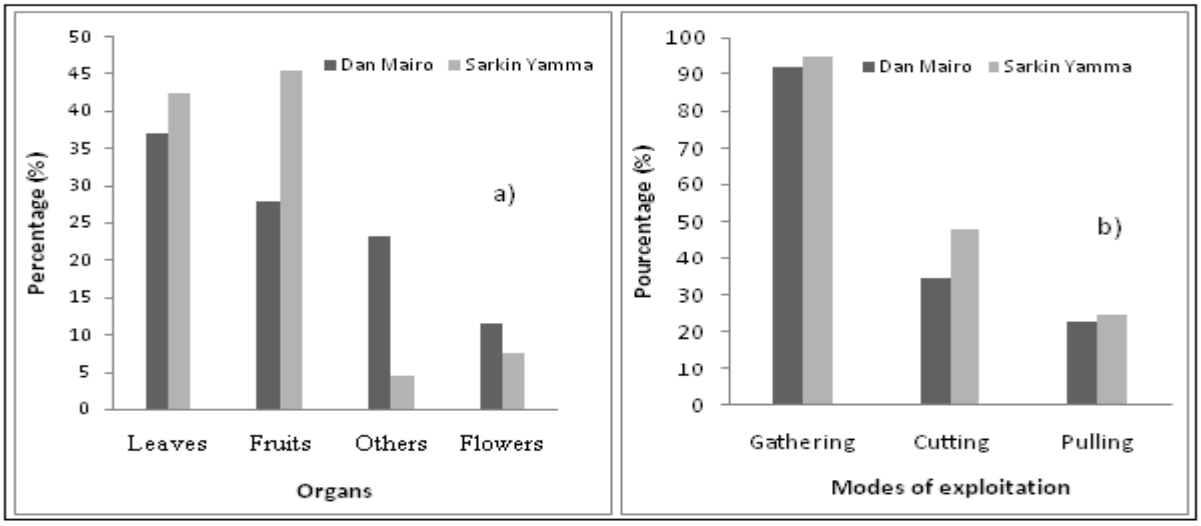

Fig. 5. Organs (a) and modes of exploitation (b) for human food.

Tree species relative abundance in the two parklands

F. albida parkland of Dan Mairo

The dominant species is *F. albida* (17.2 ind/ha), followed by *P. reticulatum* (4.53 ind/ha), *P. africana* (3.34 ind/ha) and *B. aegyptiaca* (1.2 ind/ha). Species like *Z. mauritiana, C. glutinosum*, *A. senegal*, *M. crassifolia, B. rufescens, C. africana, A. raddiana, T. indica, G. senegalensis, A. nilotica* and *X. nilotica* have less than 1 ind/ha (Fig. 8). Other species such as *S. birrea, H. thebaica, C. procera, P. reticulatus* and *S. kunthianum* show no adult trees (Fig. 8).

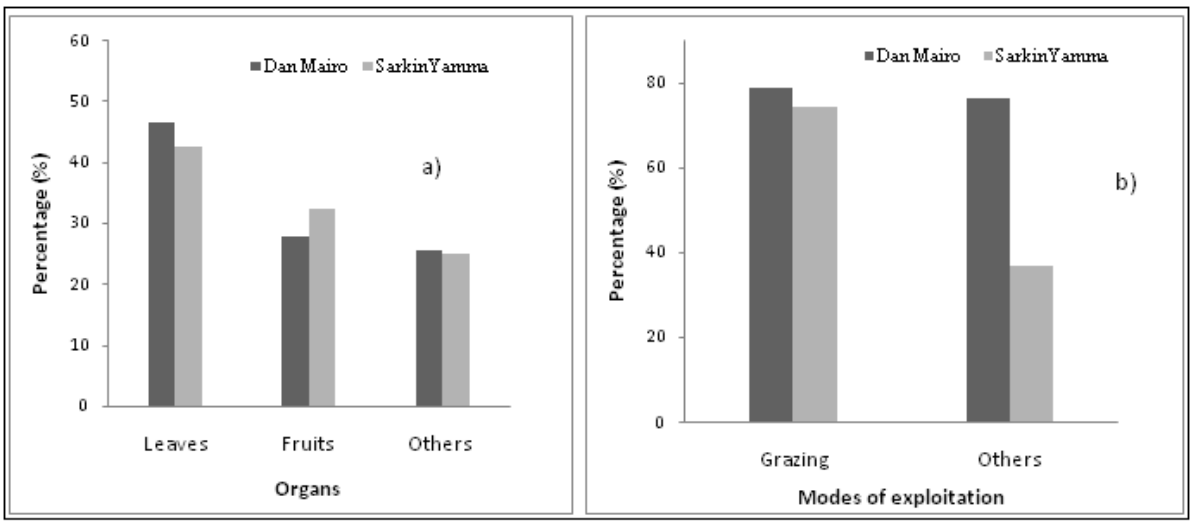

Fig. 6. Organs (a) and modes of exploitation (b) for animal feed.

P. africana parkland of Sarkin Yamma

P. africana is the most represented with 17.34 ind/ha followed by *P. reticulatum* (6.15 ind/ha), *F. albida* (2.87 ind/ha) and *C. glutinosum* (1.75 ind/ha). Species such as *A. indica, A. senegal, A. chevalieri, Z. mauritiana, L. microcarpa, A. digitata, S. birrea, H. thebaica, G. senegalensis, B. aegyptiaca, S. kunthianum, M. angolensis, D. mespiliformis* and *S. spinosa* have less than 1 ind/ha each (Fig. 9).

Importance Values Indexes of woody species in F. albida parkland

In *F. albida* parkland of Dan Mairo, IVI is high for *F. albida* (175.49), followed by *P. reticulatum* (39.51), *P. africana* (36.62) and *B. aegyptiaca* (10.86). The other species like *Z. mauritiana* (7.40), *C. glutinosum*

(6.21), *A. senegal* (4.95), *M. crassifolia* (3.62), *T. indica* (3.55), *B. rufescens* (3.32), *A. raddiana* (2.19), *C. africana* (1.99), *X. nilotica* (1.37), *A. nilotica* (1.02), *G. senegalensis* (0.95) and *A. indica* (0.88) are each marked with a very low IVI (Table 5).

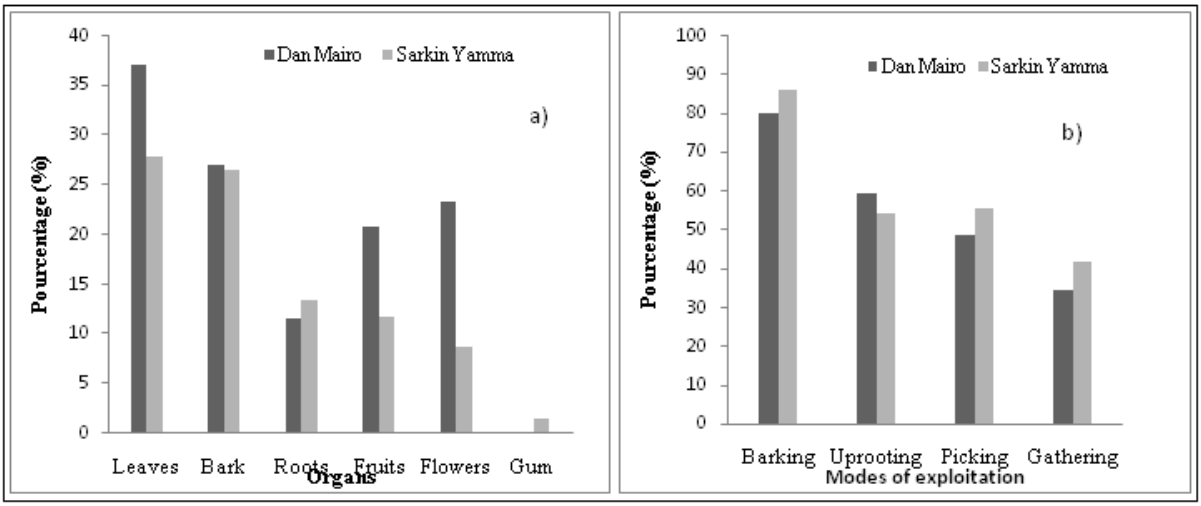

Fig. 7. Organs (a) and modes of exploitation (b) for traditional medicines.

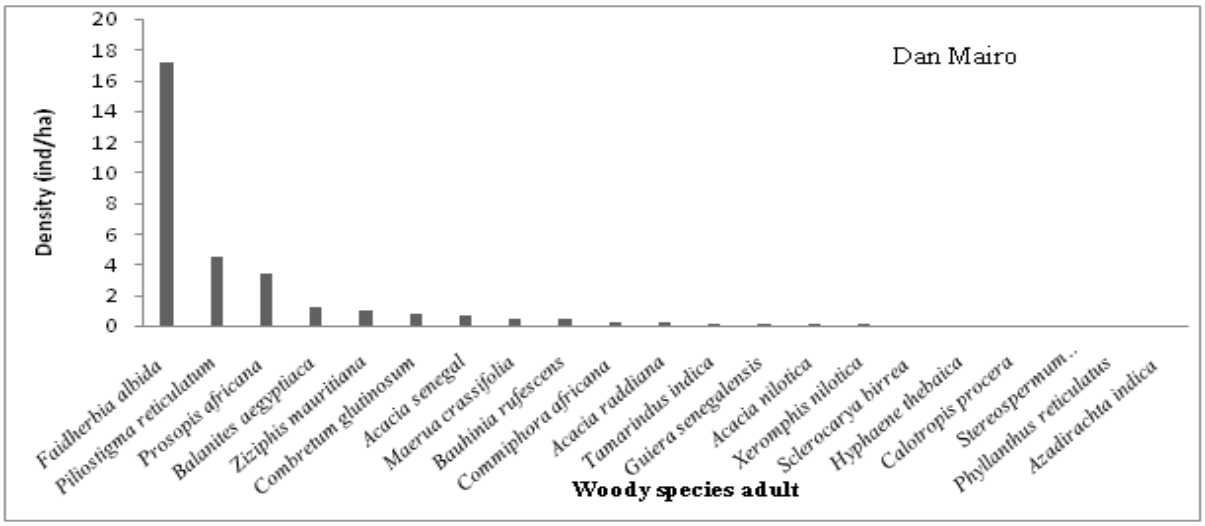

Fig. 8. Relative abundance of adult tree species in *F. albida* parkland of Dan Mairo.

Importance Value Indexes of woody species (IVI) in P. africana parkland

The results showed that the IVI is high for *P. africana* (165.11) in *P. africana* parkland. It is followed by *P. reticulatum* (47.60), *F. albida* (28.01) and *C. glutinosum* (13.04). Other species namely *L. microcapa* (9.05), *A. indica* (6.42), *S. birrea* (4.65), *A. chevaleri* (3.99), *A. senegalensis* (3.91) *A. digitata* (3.90), *Z. mauritiana* (3.65), *S. setigera* (2.25), *H. thebaica* (2.13), *G. senegalensis* (1.25), *B. aegyptiaca* (1.17), *M. angolensis* (1.09), *D. mespiliformis* (0.77), *S. spinosa* (0.67), *S. kunthianum* (0.62) and *B. salicifolia* (0.62) are IVI very low (Table 6).

Regeneration of woody species in the parklands

Regeneration of woody species in F. albida parkland

The Regeneration is dominated by *P. reticulatum* (512.93 sprouts/ha), *G. senegalensis* (324.93 sprouts/ha), *H. thebaica* (162.93sprouts/ha), *Z. mauritiana* (140.13 sprouts/ha), *C. glutinosum* (128.27 sprouts/ha), *A. sengalensis* (122.13 sprouts/ha), *F. albida* (80.93 sprouts/ha), *B.*

rufescens (68,54 sprouts/ha), *P. africana* (51,73 sprouts/ha), *C. procera* (46,67 sprouts/ha), *M. crassifolia* (39.87 sprouts/ha), *B. aegyptiaca* (30.13 sprouts/ha), *A. senegal* (11.47 sprouts/ha), *S. birrea* (4.13 sprouts/ha), *P. reticulatus* (4 sprouts/ha), *A. raddiana* (2.8 sprouts/ha), *B. salicifolia* (2.67 sprouts/ha), *C. singueana* (1.34 sprouts/ha), *C. africana* (1.33 sprouts/ha), *S. kunthianum* (0.93 sprouts/ha) and *A. nilotica* (0.13 sprouts/ha) (Fig. 10). Ultimately, the regeneration is increasingly dominated by the families of *Caesalpiniaceae, Combretaceae* and *Mimosaceae*.

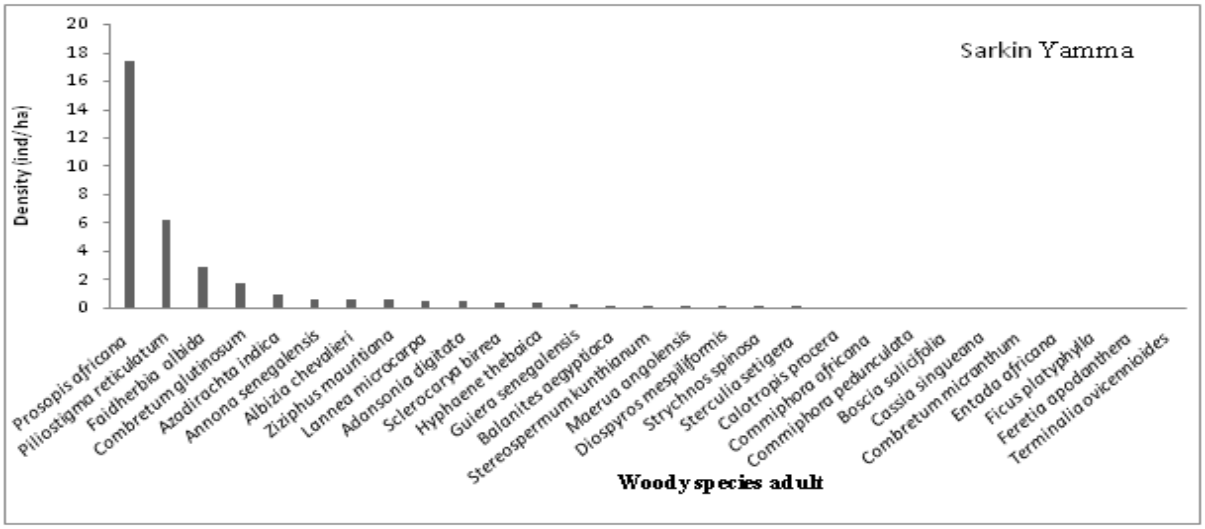

Fig. 9. Relative abundance of adult tree species in *P. africana* parkland of Sarkin Yamma.

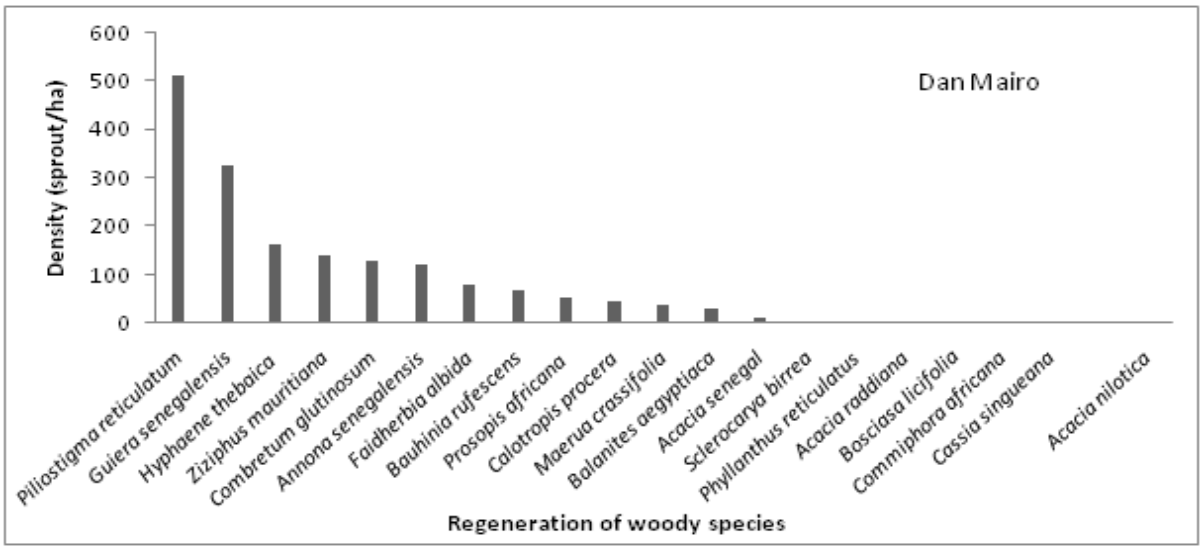

Fig.10. Relative abundance of regeneration of woody species in *F. alida* parkland.

Regeneration of woody species in P. africana parkland

The regeneration is dominated by *P. reticulatum* (1095.38 sprouts/ha), *G. senegalensis* (704.92 sprouts/ha), *A. senegalensis* (206.57 sprouts/ha) *A. chevalieri* (136.94 sprouts/ha), *C. glutinosum* (94.05 sprouts/ha), *Z. mauritiana* (88.42 sprouts/ha) and *P. africana* (78.97 sprouts/ha). It is followed by *F. albida* (52.92 sprouts/ha), *H. thebaica* (30.36 sprouts/ha), *C. pendunculata* (27.79 sprouts/ha), *E. africana* (24 sprouts/ha), *A. indica* (15.9 sprouts/ha), *C. singueana* (15.9 sprouts/ha), *S. spinosa* (12 sprouts/ha), *S. kunthianum* (11.69 sprouts/ha), *T. avicennioides* (9.33 sprouts/ha), *F. apodanthera*

(8.92 sprouts/ha), *M. angolensis* (8.72 sprouts/ha), *S. birrea* (7.18 sprouts/ha), *C. micranthum* (5.74 sprouts/ha), *C. africana* (4.31 sprouts/ha), *L. microcapa* (1.74 sprouts/ha), *F. platyphylla* (1.23 sprouts/ha) and *C. procera* (0.2 sprouts/ha) (Fig. 11). Finally, the regeneration is dominated by *Caesalpiniaceae, Combretaceae* and *Mimosacea.*

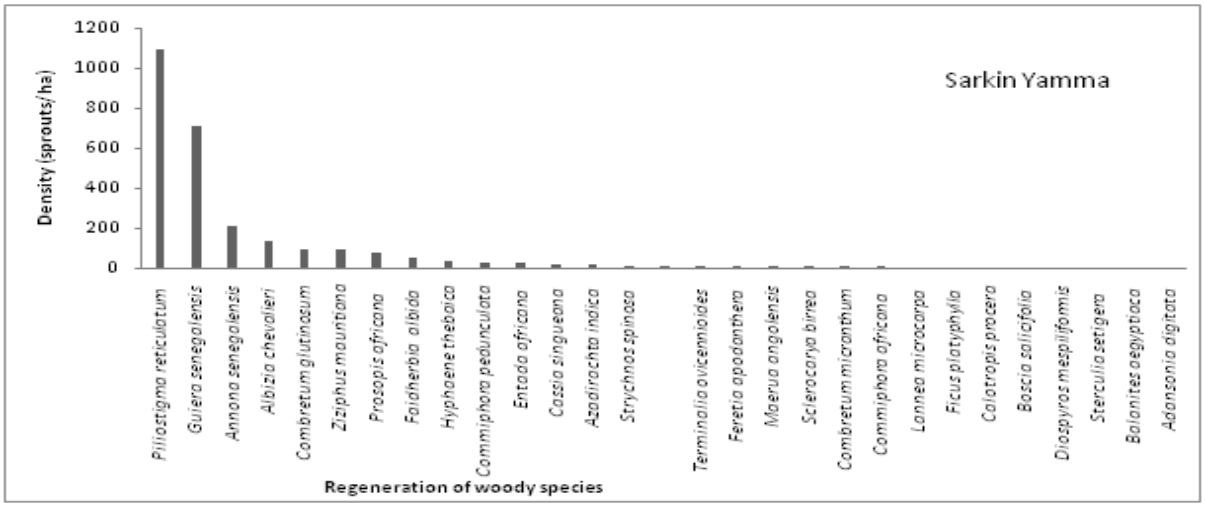

Fig. 11. Relative abundance of regeneration of woody species in *P. africana* parkland.

Discussion

A sample of 111 persons including 44 in Dan Mario and 67 in Sarkin Yamma was investigated. This sample is representative enough compared to those used by Omar *et al* (2013), Souleymane *et al.,* (2005) and Dossou *et al.,* (2012), who respectively used a sample of 45, 132, 20 persons (per village) to carry out ethnobotanical surveys. The average age of respondents was 35.70±14.22 years at Dan Mairo and 42.22±20.62 years at Sarkin Yamma. The survey sample is made of 44.5% and 77.4% educated persons respectively in Dan Mairo and Sarkin Yamma reflecting their ability to respond to the questions and also knowledgeable to the environment. The equitability index of Pielou is 0.96 and 0.91 respectively in Dan Mairo and Sarkin Yamma expressing the balanced citations of extinct species by local communities. In total 22 and 34 species have disappeared respectively in Dan Mairo and Sarkin Yamma. Both parklands have in common nine lost species (16.07% of total species recorded on the two parklands). The difference of citations of disappeared woody species between the two parklands can be linked to rainfall gradient influences because the species richness decreases from Sahel to Sudanian zone in Niger (Larwanou *et al.,* 2012; Dan Guimbo *et al.,* 2011). This influence the various ethnobotanical uses recorded and explain the significant difference between the use of woody species for fire wood, traditional medicine, animal feed, human food and timber in the two parklands. In addition, exploitation modes, including cutting, uprooting and debarking are unfavorable for the conservation of woody species. These results confirm those obtained in many studies in Niger in particular those of Larwanou *et al.,* (2006); Larwanou *et al.,* (2010); Dan Guimbo, (2011); Laouali *et al.,* (2014); Hamidou *et al.,* (2015) in the Sahel. The ethnobotanical uses values explain the interest that local communities have for these species. Indeed, more than 86.36% of disappeared species in the parkland of Dan Mairo and 85.29% in the parkland of Sarkin Yamma have ethnobotanical use values higher than 3 on a scale of 0 to 6. This illustrates the level of human pressure exerted on these species. However depending on sites, the loss of woody species in both parklands is mainly due to three causes groups (Fig. 12). Climatic causes like drought, climate change and thunder cited at 50% at Dan Mairo and 22.22% at Sarkin Yamma followed by anthropogenic causes (30% at Dan Mairo and 66.66%

at Sarkin Yamma) mainly abusive cutting of trees, uprooting, debarking, bush fire, illegal wood theft and lack of good management of woody species. Finally species related causes (20% at Dan Mario and 11.11% at Sarkin Yamma) mainly lack of seeds, aged individuals and lack of regeneration (Fig.12). It is noted that climate-related causes are more cited in Dan Mairo which is in the far north with less rainfall; while in Sarkin Yamma anthropogenic causes are more dominated. The proximity of Sarkin Yamma to the city of Maradi, with high demand for firewood (MME, 2006) and other non-wood products for traditional medicine could explain this supremacy of anthropogenic causes.

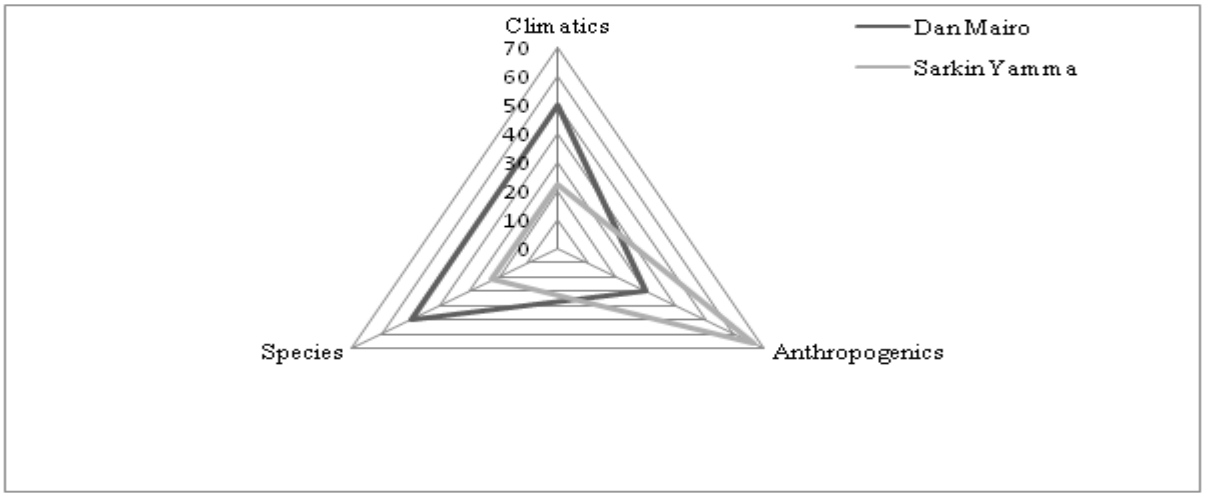

Fig. 12. Causes of woody species loss according to local communities in the two sites.

However in Aïr Mountains, sub-Saharan zone of Niger, Fabien *et al.,* (2006) showed a decline of twelve woody species. In other hand, in the center of Senegal (at Kaffrine) with an average rainfall of more than 700 mm Omar *et al.,* (2013) found a decrease of 23 woody species. In these two studies, the main causes of species extinction are related to drought and anthropogenic pressure. These results are comparable to those found in this study. Four kinds of resilience of woody species are found. In Dan Mario, *F. albida* has the highest IVI, followed by *P. reticulatum* and *P. africana* while in Sarkin Yamma, *P. africana* is dominant followed by *P. reticulatum*, *F. albida* and *C. glutinosum*. The predominance of these species in both parklands could be explained by their ability to adapt through adult individuals that ensure their regeneration by sprouting after cut. Also, some species are present at very low values of IVI, but with a high rate of regeneration per hectare. This reflects their difficulty to grow until to give adult trees in both parklands. They include *G. senegalensis*, *Z. mauritiana, B. rufescens, M. crassifolia, B. aegyptiaca* and *A. senegalensis* to Dan Mairo and *A. chevalieri, C. glutinosum, Z. mauritiana, P. africana, F. albida* and *H. thebaica* to Sarkin Yamma. Other species also have very low values of IVI and no regeneration in both parklands. They reflect the degree of threat for their extinction. These species are *T. indica, X. indica* and *A. nilotica* at Dan Mairo, *A. digitata, B. aegyptiaca, B. salicifolia, D. mespiliformis* and *S. setigera* at Sarkin Yamma. The last form of species resilience is reflected by the presence of sprouts without adult trees in any of the parklands. These include *A. digitata, B. aegyptiaca, B. salicifolia, S. setigera and D. mespiliformis* at Dan Mairo and *C. pedunculata, E. africana, C. singueana, T. ovicennioides, F. apodanthera, C. micranthum, C. africana, F. platyphylla* and *C. procera* at Sarkin Yamma. This could be explained by the survival of strains that push when environmental conditions become favorable and by germination of seeds contained in animal dungs in transhumance. In Dan Mairo, species like *B. salicifolia, C. africana, S. birrea* and *S. kunthianum* were cited extinct while they

appeared in the inventory list. This could be explained by the fact that these species are in the form of regeneration and present at very low density of sprouts and, they were inventoried especially in the fields of dry Goulbi N'kaba valley far from the surveyed villages.

Conclusion

The study has highlighted a total of 56 disappeared species of which 22 are in *F. albida* parkland of Dan Mairo and 34 in *P. africana* parkland of Sarkin Yamma. Disappeared species are each marked by a high total ethnobotanical use value reflecting their importance for the populations. The species inventoried including adult trees and sprouts are 50. Those species are distributed into 21 in *F. albida* parkland and 29 in *P. africana* parkland. Four (4) types of resilience of woody species have been illustrated in the two parklands which are:

1. The species with IVI and high regeneration;
2. The species with low regeneration and high IVI;
3. The species with very low IVI and without regeneration;
4. The species with regeneration without IVI.

The results from this study provide useful guidance for good informed policy formulation in conserving and protecting tree resources in this type of environment. Key species for the rehabilitation and conservation of biodiversity are indicated and can serve as tools for reinforcing the resilience of the parkland ecosystems.

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