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RESEARCH ARTICLE

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Conservation of food tree species in Niger: towards a participatory approach in rural communities

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Abstract

Aim of study: Indigenous woody species play an important role as a complement on the diet of rural populations in Niger, especially in periods of food scarcity. However, these species are nowadays overexploited and management programmes are necessary to conserve them. In order to design a conservation programme for edible woody species, this paper presents a sociological analysis about the use of edible woody species and their products during shortage periods in Niger.

Area of study: Four villages in two distinct agro-ecological regions were selected to conduct structured enquiries based on focus group discussions and surveys with key informants.

Material and Methods: Perceptions of the conservation status of these species were identified; as well the factors affecting food values, perceptions, management and collection practices.

Main results: Results show that *B. senegalensis* was a staple food in the driest areas, and *M. crassifolia* was used for fodder and human consumption in the most critical situations. The local communities related the drivers of species conservation status specific to the agro-ecological regions, and gender and ethnic differences were also identified.

Research highlights: Understanding these factors constitutes a first step towards adaptive management strategies for the conservation of woody food species in rural communities of Niger.

Keywords: Africa; biodiversity; cultural preferences; food; NTFPs.

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Supplementary material (S1) accompanies the paper on FS website.

Introduction

Forests, wild trees and shrubs in marginal lands and agroforestry systems have great ecological and livelihood value for rural populations in arid regions despite their low growth potential (Assefa & Abebe, 2011; Larwanou & Saadou, 2011; Pingali *et al*., 2014; Thiombiano *et al*., 2013). They supply edible products such as bark, flowers, fruits, leaves, nuts, roots, seeds and tubers that contribute to food security and diet sustainability (Vinceti *et al*., 2013). These products complement staple food crops (Kalinganire *et al*., 2007; Faye *et al*., 2011), and are either consumed as primary ingredients or used as condiments in various dishes. Edible woody species can be important during periods of drought, social unrest or war (Atato *et al*., 2011; Ocho *et al*., 2012). They are also a potential source of income when marketed or traded as a food product (Assogbadjo & Loo, 2011; Ekué, 2011; Muok *et al*., 2011; Sanou & Lamien, 2011).

African dry territories are among the most threatened and least studied agroforestry systems, and there is an urgent need to support the development of sustainable management and conservation policies (Blackie *et al*., 2014). The Sahel has experienced dramatic environmental changes during the last four decades, including the droughts during the 1970s and 1980s, the causes and effects of which are still under debate (Herrmann *et al*., 2005; Hiernaux *et al*., 2009; Lézine *et al*., 2011; Mertz *et al*., 2012; Nutini *et al*., 2013). Despite a recent trend of increasing rainfall over the last decade, the prevailing view is that a decline in annual rainfall has been the main driver of climate change at the regional level, operating in synergy with other factors, such as population trends, land management strategies, management of local natural resources and public policies (Mbow *et al*., 2008; Epule *et al*., 2014). There is a general gap in understanding of land use change in Niger (D'haen *et al*., 2013) and comprehensive studies are necessary to inform actions improving the resilience of the rural populations and buffering the current negative effects on agroforestry systems (van Vliet *et al*., 2013).

Local communities should be involved throughout the planning process, starting with the identification of the problem and any possible solutions, including the design and implementation of conservation schemes. Participatory conservation strategies have more chance of being actually implemented and successful (FAO/FLD/IPGRI, 2004). Muhumuza & Balkwill (2013) suggested that conservation approaches in National Parks in Africa need to place more emphasis on the human dimension of biodiversity conservation than purely on scientific studies of species and habitats. The success of management plans is often based on community-based conservation interventions, including community knowledge and capacity to observe the process and gather key information (Rodríguez-Izquierdo *et al*., 2010; Waylen *et al*, 2010). Furthermore, recognizing how and why people value different resources minimizes the conflicts between stakeholders and promotes the social acceptability of management activities (Ives & Kendal, 2014).

Gender and ethnicity (e.g. in level of knowledge, preferences and types of use) may affect the management and conservation of natural resources (Koura *et al*., 2011; Gómez-Ramos *et al*., 2013). Indigenous knowledge may vary according to gender; for example in the assessment of the importance of an edible tree species, *Blighia sapida*, in Benin (Ekué *et al*., 2010), in the perception of vegetation changes in semi-arid areas in Niger (Wezel & Haigis, 2000), and in local attitudes towards conservation in northern Benin (Gómez-Ramos *et al*., 2013). In contrast, gender was not significant in indigenous knowledge of vegetation dynamics in Burkina Faso (Sop & Oldeland, 2011), wild fruit consumption in the Amhara region in Ethiopia (Fentahun & Hager, 2009), or identifying woody vegetation in south Western Niger (Ayantunde *et al*., 2008).

The participatory approach is a way of incorporating both traditional and scientific knowledge and can result in good outcomes when applied to natural resources conservation management. Participatory approach recognise the existence of different types of knowledge associated with the different stakeholders, and during the analysis phase, both traditional information and scientific knowledge, should be validated (Baia & Luisa, 2016).

The previous literature offers lists of useful wild plants from Niger, including edible species, and the nutritional value of some of them (Freiberger *et al*., 1998; Cook *et al*., 2000) but this study states the base line of the local perception of the food tree species status in two regions of Niger, to be used in participatory conservation planning. It constitutes the exploratory phase for a participatory planning, this is why the approach considered in this study is the Rapid Rural Appraisal Approach (RRA; Blumenthal & Jannink, 2000).

The main question addressed is to what extent local communities identify the conservation status of their resources and the pressure factors on the resource base, given the importance of this information for the implementation of more effective and sustainable conservation actions. For that purpose, the identification of the key woody food species by rural communities was followed by an evaluation of the perception of their conservation status and of the drivers acting on the conservation of the species. The hypothesis was that the perception about the drivers for a particular species would be influenced by the food value attributed to the species, by the perception of occurrence change and regeneration status, but also by the status of residence, gender and ethnicity of the local dwellers.

The results provide an assessment of the use of edible woody species and contribute to the analysis of the current situation considering the rural perception of the species conservation status in representative agroforestry systems of Niger. A picture of the differences on perception found between species and social groups, is offered and should be considered to minimize gaps between social perception and ecological and/or political recommendations in a participatory approach. The results of this participatory assessment, where local communities have prioritize their species and evaluate their current status, should transmit the voices and

opinions of poorer people into national planning and policy processes.

Methods

Study area

Four villages in Southwest Niger were selected, two in each of the main agro-ecological regions (Sudanian and Sahelian). The Sudanian agro-ecological region is characterized by an annual 7-month drought period, and a mean annual precipitation of 650 mm, while the Sahelian agro-ecological region has a 9-month drought period and a mean annual precipitation of 350 mm.

The traditional agro-pastoral system in both regions is extensive and highly vulnerable to drought. The start of the rainy season, of vital importance for cereal production, is subject to fluctuations and affected by delays. In both agro-ecological regions, the diet is largely based on cereals, mainly millet and sorghum, complemented with pulses (cowpea and Bambara groundnut). Consumption of food of animal origin, of fruit and vegetables (rich in micronutrients) remains low, and the consumption of milk, a tradition in an agro-pastoral context, is declining due to the reduction in the number of cattle. The use of wild edible plants (leaves and fruits) is rather a common practice during the dry season. The collection has become systematic after recurrent cases of very severe food shortage (FAO, 2009). Village dwellers are largely dependent not only on agricultural products but also on indigenous woody vegetation for their food security.

In the Sudanian agro-ecological region the two selected villages, Senokonkodje and Weillagorou, are located within the Total Wildlife Reserve of Tamou. In the Sahelian agro-ecological region, the two villages selected were Tondikiwindi and Tondibiya (Table 1). The study sites are characterized by the presence of the major ethnic groups that populate the region (i.e., Zarma, Hausa, and Fulani). The inhabitants of Tondikiwindi and Tondibiya were affected by a severe drought during the 1970s, forcing some of them to migrate and settle in the Tamou area. People living in Senokonkodje are refugees from Tondikiwindi; while the inhabitants of Weillagorou are autochthonous settled originally inside the W National Park in Niger, however cultivating the lands outside the Park. They were forced later to leave their settlements when the W Trans frontier Biosphere Reserve (Benin, Burkina Faso and Niger) was established in 2002.

Zarma and Hausa ethnic groups are smallholder farmers, practising extensive agriculture to produce millet for household consumption. Integration between agriculture and livestock is very low. Fallow reduction and changes in rainfall, combined with structural adjustment measures, have led them to depend increasingly on seasonal migration and small trading. The Zarma are autochthonous in the study sites, while the Hausa are immigrant from the Southwest of Niger.

Traditionally Fulani are nomads; but after many years of integration with other cultures, and due to adverse environmental conditions leading to a reduction of their herds (cows, sheep, goats and dromedaries), nowadays they largely rely on farming for their livelihood. So they are only partly nomadic, setting up temporary camps, where they exchange dairy products for cereals.

Fieldwork description

The field work at household level was divided in two parts: the focus group discussions and the individual interviews. The overall sample is presented in Table 1 and questionnaires in S1. The local communities of the

Table 1. Location of villages studied, characteristics of the population and sample size by village and type of interview

Department	**Say**		**Ouallam**	
Municipality	**Tamou**		**Tondikiwindi**	
Village	Senokonkodje	Weillagorou	Tondikiwindi	Tondibiya
Code	Sudanian 1	Sudanian 2	Sahelian 1	Sahelian 2
Location	02°22’33’’ 12°42’33’’	02°44’82’’ 12°62’30’’	02°02’10’’ 14°18’00’’	02º01’40’’ 14°27’40’’
Ethnic group	Zarma	Fulani	Zarma / Hausa	Zarma
Origin	Ouallam	Autochtonous	Autochtonous (Zarma)	Autochtonous
Status of residence	Climatic refugees	Decamped (WNP)	Inmigrant (Hausa)	–
Activity	Agriculture (28)	Agriculture (10) Agropastoralism (6)	Agriculture (18) Agropastoralism (3)	Agriculture (24)
N. of Focus Group (106)	29	16	37	24
N. of Key Informants (89)	28	16	21	24

region suffer annually of food shortage and food crises due to severe drought, thus we were interested on involving the household representatives as the main actors.

Focus group discussion were performed with the participation of all women of the household, women were the main target due to their responsibility for food preparation and with three to ten women by each focus group. The response was unique, representing the behaviour of the household. A questionnaire was used to guide focus group discussions aiming at identifying the edible woody species used, the parts of the plant consumed and the collection sites for each species (i.e. bush, parkland, plantation on agricultural land, or plantation in home garden), as well as the period of availability compared to the shortage period.

A second questionnaire was addressed to the head of the house, usually a man, considered as key informant. This questionnaire was focused on how the local communities prioritized the edible woody species, how they defined their conservation status, and their perception of the impact of biotic, abiotic factors, management and collection practices on the conservation status of the species. In some cases, the head of the household was a woman, either a widow or a woman leading the household where her husband was temporarily absent working in another region or country. Demographic data were collected for each individual interviewed.

Food value (Fv) was determined by each key informant attributing a ranking to the ten woody species most valued as food. The species list and ranking were generated independently by each informant. For each species, the informant was also asked to indicate his/her perception about the change in occurrence of the species in the area surrounding the village, over the previous 10 years. The parameter was defined as occurrence change (Oc) and a trend was identified by a score from 1 to 4, with 4 indicating a very high decline. A score indicating the status of regeneration (Rg) was also assigned to each of the top ten edible woody species (1=Lack of regeneration; 2= Presence of regeneration).

A total of 12 factors had been pre-identified in the literature as common pressures, associated with management measures for agroforestry systems, harvesting practices for tree products, and biotic or abiotic factors (Assogbadjo & Loo, 2011; Gouwakinnou *et al*., 2011; Muok *et al*., 2011; Sanou & Lamien, 2011; Sop & Oldeland, 2011). Each key informant was asked to give a score from 1 to 4 (with 4 indicating a high effect on the given variable; Figure 1) on the factors (biotic, abiotic, management and collection practices, etc.) driving the conservation status (Oc and Rg) of each species.

The fieldwork was carried out from May to October 2011 during the food-shortage period, in French with support from translators for all the local languages, i.e. Zarma, Hausa and Fulani. Specimens of the edible woody species identified during field activities were used during focus group discussion and interviews to ensure correct species identification. To help resolve issues related to wrong attribution of vernacular names, herbarium specimens and photographs were collected, for later identification at the laboratory of Biology Garba Mounkaila (Faculty of Sciences University Abdou Moumouni, Niamey). Some samples were collected from local markets, given the difficulty of finding the species in the field.

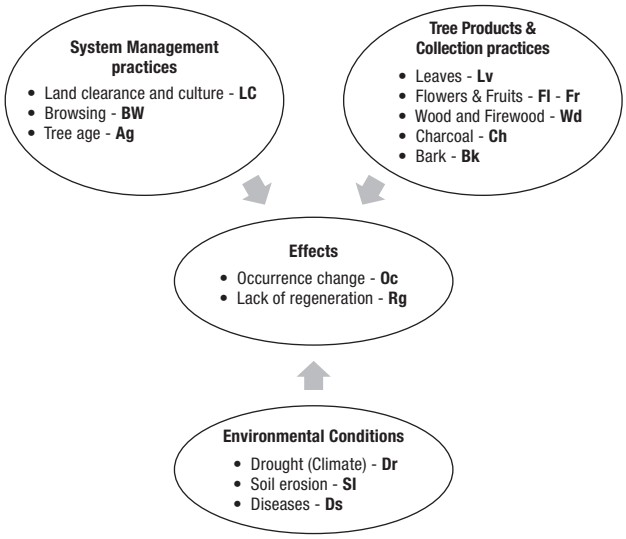

Figure 1. Pressure factors affecting the perception of the conservation status (occurrence change and regeneration).

Data analysis

Two different approaches were used to process the data generated by the individual interviews: i) the median value for all variables (Fv, Oc and Rg) and pressure factors was calculated. Median values were considered as the most appropriate indicators of respondents' perception averages; exploratory approaches for data analyses using medians and non-parametric statistic methods are considered appropriate to treat the type of data collected in this study (Tukey, 1977). The dataset was not suitable for parametric tests, due to the large number of variables analysed in a relatively small dataset, the significant amount of missing values (absence of responses for some variables), and the strong autocorrelation among variables; ii) Seven pressure factors were included in the analyses and the species prioritized by at least 6 key informants were considered. The relationship between the 7 factors (dependent variables), the food value and the two variables associated with the conservation status of an

edible woody species (Oc and Rg; independent variables) were analysed by Partial Least Squares multiple regression models (SIMPLS algorithm).

In order to test for the influence of respondents' gender, ethnicity or status of residence on food value and occurrence change, the three most common species cited in the four villages were subjected to one-way ANOVA using the non-parametric Kruskall-Wallis test. Dependent variables were the food value of an edible woody species (0 to 10 scale) and occurrence change (1 to 4 scale). Regeneration was discarded from this analysis, as this parameter turned out not to have relation with gender, ethnicity or status of residence. Two levels were assigned to gender (male and female), three levels to ethnic group (Zarma, Hausa and Fulani) and four levels to village (one for each village).

Results

A list of key edible woody species was produced with the information provided by focus group discussions, including characterization of the key species identified, the information of parts of the plant used as food, the habitat or location where the species is found, and the agro-ecological region where the species was reported.

A total of 23 woody species (trees, shrubs, a palm tree, a vine and a parasitic sub-woody plant) were valued for their contribution to the diet (Table 2). Five of the species were common to the two agro-ecological regions, 11 specific to the Sudanian agro-ecological region, and 7 to the Sahelian agro-ecological region. The main products used as food were fruits (14 species), leaves (6 species), or both (3 species). For *B. aegyptiaca* the flowers were also reported as edible, while *C. nigricans* was mentioned for its rubber (used as a candy). Some products have to be consumed at the time of harvesting (i.e. leaves of *M. crassifolia* and *C. farinosa*), while the leaves and fruits of *A. digitata*, fruits of *B. aegyptiaca*, *B. senegalensis*, *D. microcarpum*, *T. indica* and *Z. mauritiana* and the gum of *C. nigricans* can be stored for consumption all through the year. Most species and products listed were consumed during periods of food shortage, but a few species, while not available during the shortage period (i.e. *C. farinosa*, *D. mespiliformis* and *P. reticulatum*), were reported by key informants. *A. digitata* leaves are part of the diet of every household throughout the year. Edible woody species were sourced mainly in the bush, and in parklands, with a few products collected from planted trees (i.e. *A. digitata* and *P. biglobosa*, in the Sudanian agro-ecological region).

The results of the Kruskall-Wallis test for the three most commonly mentioned species (*B. aegyptiaca*, *B. senegalensis* and *Z. mauritiana*) indicate that location of the village, gender and ethnic group influence food value of a species and its occurrence change (Figure 2). Food value (Fv) varies significantly between villages for each of the three species but is not linked to the status of residence of the respondents. Weillagorou (Sudanian agro-ecological region, autochthonous) and Tondikiwindi (Sahelian agro-ecological region, autochthonous) tend to cluster with regarding the food value of *B. aegyptiaca* and *B. senegalensis*.

Considering occurrence change (Oc), differences were significant between agro-ecological regions, with a higher perception of Oc in the Sudanian region. The perception of the occurrence change of *B. senegalensis* is significantly different between genders; men's perception of Oc is higher than Oc women's perception.

The food value of *Z. mauritiana* for the Fulani ethnic group was lower and their perception of the occurrence change of *B. senegalensis* and *Z. mauritiana* was higher; both parameters were significantly distinct from the other socio-cultural groups.

The species providing the highest contribution to the diet were *A. digitata* (Fv=10) in the Sudanian region, followed by *B. senegalensis* (Fv=9) in both regions, *M. crassifolia* (Fv=9) in the Sahelian region, and *T. indica* (Fv=9) in the Sudanian region (Table 3). *V. doniana* is the species identified with the lowest contribution of all the species identified (Fv=3).

For all 23 species examined, reduced occurrence through the ten years preceding the interview (Oc between 2 and 4) was found. Except for *Z. mauritiana* (Oc=2), informants expressed the view that all species were under significant pressure (Oc = 3-4). In addition, lack of regeneration (Rg = 1) was recorded for 9 out of 23 species.

The multiple regression models were significant for 12 species (Table 4). Some factors with species-specific effects on conservation status were identified. For example, land clearing was found to affect only *P. reticulatum* and ageing only *P. biglobosa* and *V. paradoxa*. All other factors revealed a similar influence on many more species (affecting 4 to 6 out of the 12 species). The range of perceived pressure factors affecting each species varied widely across species: 1 out of 7 factors affected *A. digitata* (pest and diseases), *L. microcarpa* (browsing), *T. indica* (browsing) or *Z. mauritiana* (drought), while 5 out of 7 factors affected *P. reticulatum* (land clearance, wood collection and bark harvesting, pest and diseases and drought).

Scaled coefficients and autocorrelation showed a significant relation between food value, the variables associated with conservation status (occurrence change

Table 2. Species cited by at least six key informants, agro-ecological area in which they have been mentioned; part of the plant used as food in times of scarcity, and habitat in which the products are collected

						Period of Disponibililty (Months)													
								Sahelian Shortage Period											
								Sudanian Shortage Period											
Species Code	**Scientific name**	**Family**	**Life form**	**Part(s) used as food**	**Consumption**	**Jn**	**Fv**	**Mr**	**Ap**	**My**	**Jn**	**Jl**	**Au**	**Sb**	**Oc**	**Nv**	**Dc**	**Habitat**	**Agro ecological region**
Ad	*Adansonia digitata*	*Malvaceae*	TR	Lv Fr	Prep Raw	x				x	x	x	x	x	x	x	x	Bush / Land / Planted	Sudan
Ba	*Balanites aegyptiaca*	*Zygophyllaceae*	TR	Lv/Fl	Prep			x	x									Bush / Land	Sahel / Sudan
Bs	*Boscia senegalensis*	*Capparaceae*	SH / ST	Fr Fr	Raw Tr/Prep	x						x	x	x		x	x	Bush	Sahel / Sudan
Cf	*Cadaba farinosa*	*Capparaceae*	SH	Lv		x											x	Bush	Sahel
Cn	*Combretum nigricans*	*Combretaceae*	TR	Gum	Raw											x	x	Bush / Land	Sudan
Dm	*Detarium microcarpum*	*Caesalpiniaceae*	TR	Fr	Raw	x	x	x	x									Bush	Sudan
Dy	*Dyospiros mespiliformis*	*Ebenaceae*	TR	Fr	Raw	x	x									x	x	Bush / Land	Sudan
Gb	*Grewia bicolor*	*Tiliaceae*	SH / ST	Fr										x	x			Bush / Land	Sahel
Ht	*Hyphaene thebaica*	*Arecaceae*	PA	Fr	Raw							x	x	x	x	x	x	Bush / Land	Sudan
Lf	*Lannea fruticosa*	*Anacardiaceae*	SH /ST	Fr	Raw		x	x	x	x	x							Bush / Land	Sudan
Lm	*Lannea microcarpa*	*Anacardiaceae*	TR	Fr	Raw		x	x	x	x	x							Bush	Sudan
La	*Leptadenia arborea*	*Asclepiadaceae*	SH	Lv	Prep	x	x	x	x	x	x	x	x	x	x	x	x	Bush	Sahel
Lh	*Leptadenia hastata*	*Asclepiadaceae*	LI	Lv	Prep	x	x	x	x	x	x	x	x	x	x	x	x	Bush	Sahel
Ma	*Maerua angolensis*	*Capparaceae*	TR	Lv	Prep						x	x						Bush	Sahel
Mc	*Maerua crassifolia*	*Capparaceae*	TR	Lv	Prep			x	x	x	x							Bush	Sahel
Pb	*Parkia biglobosa*	*Fabaceae*	TR	Fr	Tr/Prep			x	x	x	x							Bush / Land / Planted	Sudan
Pr	*Piliostigma reticulatum*	*Fabaceae*	SH / ST	Fr	Raw	x	x									x	x	Bush / Land	Sahel / Sudan
Sb	*Sclerocarya birrea*	*Anacardiaceae*	TR	Lv Fr	Prep Raw					x	x	x	x	x	x	x		Bush / Land	Sahel / Sudan
Ti	*Tamarindus indica*	*Fabaceae*	TR	Fr	Prep	x	x										x	Bush / Land	Sudan
Tg	*Tapinanthus globiferus*	*Loranthaceae*	PS	Lv	Prep	x	x	x	x	x	x	x	x	x	x	x	x	Bush	Sahel
Vp	*Vitellaria paradoxa*	*Sapotaceae*	TR	Fr	Tr/Prep						x	x						Bush / Land	Sudan
Vd	*Vitex doniana*	*Lamiaceae*	TR	Fr	Raw						x	x						Bush / Land	Sudan
Zm	*Ziziphus mauritiana*	*Rhamnaceae*	TR	Fr	Raw	x	x									x	x	Bush / Land	Sahel / Sudan

TR: Tree, SH: Shrub, ST: Small Tree, PA: Palm, LI: Liana, PS: Parasite; Lv=Leaves, Fl=Flower, Fr=Fruits; Prep=Prepared, Tr=Transformed; Sudan: Sudanian, Sahel: Sahelian

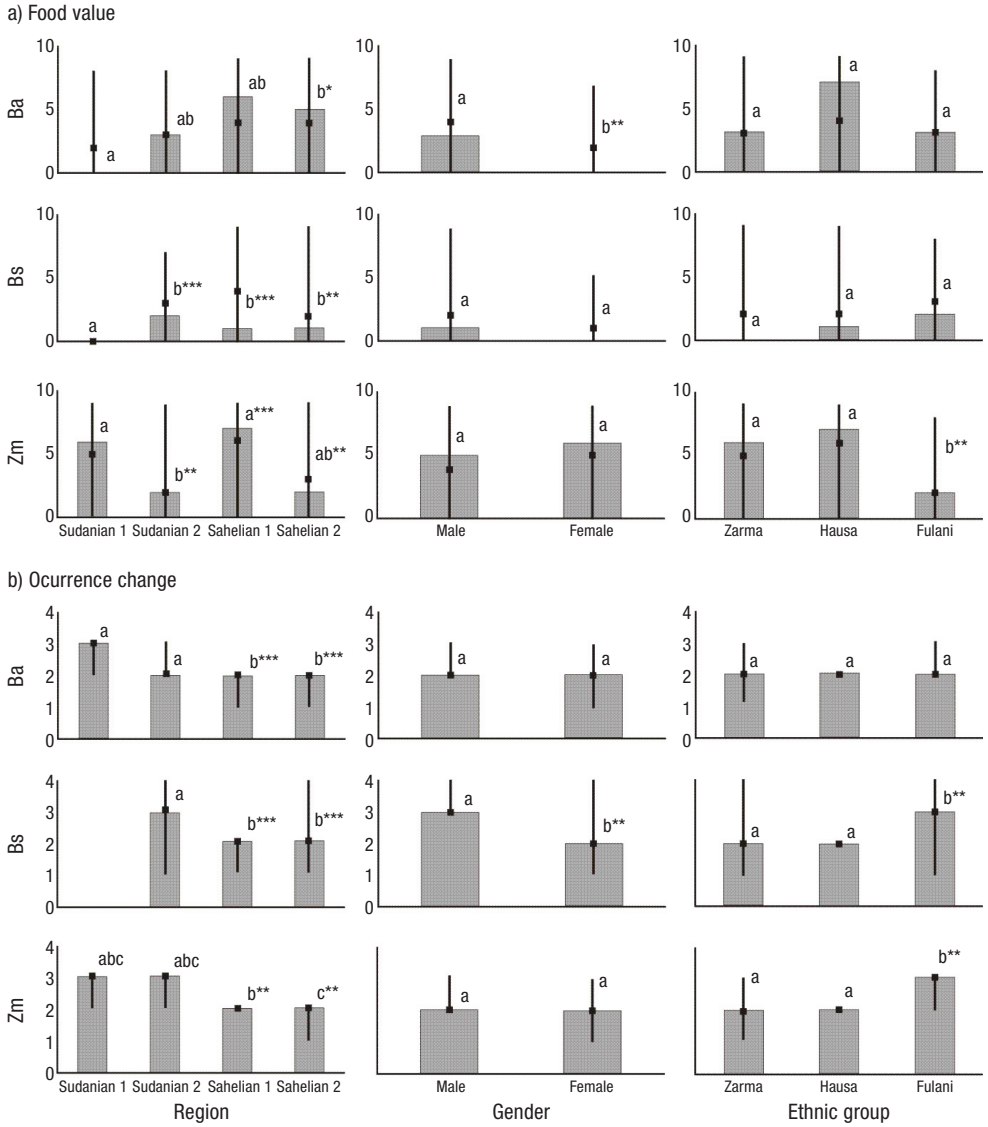

Figure 2. Kruskal-Wallis test for a) Food value and b) Occurrence change of 3 common species: B. aegyptiaca (Ba), B. senegalensis (Bs) and Z. mauritiana (Zm). Different letters show significant differences about the food value/ perception of occurrence change among villages: Senokonkodje (Sudanian1), Weillagorou (Sudanian 2), Tondikiwindi (Sahelian 1) and Tondibiya (Sahelian 2); gender and ethnic group. Vertical grey bars indicate median, vertical black lines indicate range of responses and black points indicate average value of responses (without response is assumed by zero Food value).

and regeneration) and the degree of threats at species level (Table 5). It is to be noted that food value showed a significant relation with the level of threats in 15 out of the 17 significant cases, corresponding to almost all species analysed (10 out of the 12). The pressure factors with a significant relationship with food value and conservation status variables were browsing (3 species), bark harvesting (3 species), pest and disease occurrence (4 species) and drought (4 species).

Occurrence change was significantly and positively correlated with browsing (*L. microcarpa* and *T. indica*), land clearing (*P. reticulatum*), wood extraction (*B. aegyptiaca*) and pests and diseases (*A. digitata* and *P. biglobosa*). Regeneration (lack of regeneration) was positively related with wood or firewood harvesting (*C. nigricans*), bark extraction (*P. reticulatum* and *V. paradoxa*), pest and disease occurrence (*P. reticulatum*) and drought (*C. nigricans*).

Discussion

Edible woody indigenous resources play a noteworthy role in the diets of rural communities. Three woody species emerged from this study as crucial resources contributing to the diet of local communities: *A. digi-*

Table 3. Median for species food value, occurrence change, regeneration and driven factors

Species Code	Region Code	N	Fv	Oc	Rg	Factors											
						Lc	Fr	Bw	Wd	Fl-Fr	Lv	Bk	Ch	Ds	Dr	Ag	Sl
Ad	Sd	45	10	2	2	1	1	1	1	1	4	1	1	2	3	1	1
Ba	Sh/Sd	57	7	2	2	1	1	1	3	1	1	1	1	1	1	1	1
Bs	Sh/Sd	43	9	2	1	2	1	1	1	4	1	1	1	1	3	1	1
Cf	Sh/Sd	17	8	2	1	1	1	1	1	1	4	1	1	3	4	1	2
Cn	Sd	27	7	3	2	2	1	1	2	1	1	1	1	1	1	1	1
Dm	Sd	11	4	3	2	1	1	1	1	1	1	1	1	1	4	1	1
Dy	Sd	22	5	3	2	3	1	1	1	1	1	1	1	1	1	1	1
Gb	Sh/Sd	18	6	2	1	1	1	1	3	4	1	1	3	1	4	1	1
Ht	Sd	15	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1
La	Sd	6	5	4	1	2	1	3	1	4	2	1	1	4	4	1	4
Lf	Sd	13	4	3	2	1	1	1	1	1	1	1	1	1	1	1	1
Lh	Sh	8	5	2	1	4	1	4	1	4	4	1	1	4	4	1	4
Lm	Sh	30	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Ma	Sh	8	5	4	1	3	1	3	1	4	4	1	1	4	4	1	4
Mc	Sh	39	9	2	1	1	1	3	3	1	4	1	1	4	4	1	1
Pb	Sd	30	6	2	2	2	1	3	1	3	1	1	1	2	3	1	1
Pr	Sh/Sd	24	6	2	2	3	1	1	1	4	1	1	1	1	3	1	1
Sb	Sh/Sd	43	5	2	2	1	1	1	4	1	1	1	1	1	1	1	1
Tg	Sh	7	6	4	1	2	1	1	1	4	4	1	1	4	4	1	4
Ti	Sd	43	9	2	2	1	1	3	1	1	1	1	1	1	3	1	1
Vd	Sd	8	3	3	1	2	1	1	1	1	1	1	1	1	3	1	1
Vp	Sd	27	7	2	2	1	1	1	1	4	1	3	1	1	4	1	1
Zm	Sh/Sd	64	6	2	2	1	1	2	1	1	1	1	1	1	1	1	1

Species (see code in table 2) cited in Sudanian (Sd) or Sahelian (Sh) region or both (Sd/Sh)

N= Number of respondents citing the species; Fv Food value (10 the most important species); Oc Occurence change 1=More occurrence than 10 years ago to 4=impossible to find the species nowadays; Rg Regeneration 1=Lack of regeneration; 2= presence of regeneration

Factors 1=Not threatened by this factor; 4= Very important threat

Lc=Land clearing; Fr=Fire; Bw=Browsing; Wd =Wood or firewood; Fl-Fr=Flowers-Fruits; Lv=Leaves; Bk=Bark; Ch=Charcoal; Ds=Diseases, Pests; Dr=Droughts; Ag=Age; Sl=Soil

Table 4. Models fit (R^2Y) of Partial Least Squares (PLS) models (SIMPLS algorithm) to correlate main driven factors (dependent variable) with independent variables of main species (food value, occurrence change and regeneration). Best models fit in bold

Factors	SIMPLS models	Species											
		Ad	Ba	Bs	Cn	Lm	Mc	Pb	Pr	Sb	Ti	Vp	Zm
Lc	R^2Y	0.07	0.12	0.04	0.05	0.05	0.03	0.09	**0.24**	0.17	0.10	0.01	0.11
Bw	(models fit)	0.15	0.07	0.05	**0.26**	**0.23**	**0.23**	0.12	0.03	0.09	**0.24**	0.13	0.03
Wd		0.03	**0.44**	**0.47**	**0.20**	0.02	**0.26**	0.05	**0.31**	0.01	0.02	0.07	0.16
Bk		0.04	**0.28**	0.07	0.00	0.10	**0.21**	0.00	**0.50**	**0.24**	0.00	**0.52**	0.17
Ds		**0.22**	**0.23**	0.15	0.04	0.07	**0.28**	**0.29**	**0.28**	**0.24**	0.03	0.00	0.10
Dr		0.17	**0.35**	**0.29**	**0.33**	0.09	0.10	0.06	**0.21**	**0.35**	0.17	0.17	**0.32**
Ag		0.01	0.07	0.05	0.00	0.08	0.03	**0.29**	0.06	0.08	0.04	**0.20**	0.00

Dependent variables: Lc=Land clearing; Bw=Browsing; Wd=Wood or firewood; Bk=Bark; Ds=Diseases, Pests; Dr=Droughts; Ag=Age.

tata, *B. senegalensis* and *M. crassifolia*. While *B. senegalensis* had been previously reported as a staple food in periods of scarcity in Niger (Muller & Almedom, 2008; Dan-Gimbo & Barrage, 2012), our study revealed that M. crassifolia leaves are also consumed by humans, although they had been reported only as animal forage in other regions of Niger (Dan-Gimbo & Barrage, 2012). *A. digitata* and *M. crassifolia* had previously been highlighted as important famine foods also in the Sahelian region of Burkina Faso (Sop *et al*., 2012; Thiombiano *et al*., 2013, 2012), and marketed locally in Northern Nigeria (Harris & Mohammed, 2003). The food value attributed to edible woody species by key informants from the Sudanian villages seems to be

Table 5. Scaled coefficients and autocorrelation (R^2X) for each PLS model

Dependent	Independent variables	Scaled coefficients and autocorrelation by species											
		Ad	**Ba**	**Bs**	**Cn**	**Lm**	**Mc**	**Pb**	**Pr**	**Sb**	**Ti**	**Vp**	**Zm**
Lc	Fv	-0.16	0.45	0.22	0.09	-0.17	-0.16	0.12	-0.21	0.10	0.11	-0.04	0.21
	Oc	-0.01	-0.36	0.00	0.05	-0.19	0.00	0.16	0.29	0.22	0.26	0.06	-0.23
	Rg	0.23	-0.20	0.10	0.21	-0.01	0.03	-0.22	-0.21	-0.37	0.17	-0.06	0.00
	R^2X	0.30	0.36	0.26	0.35	0.30	0.37	0.34	0.45	0.29	0.31	0.51	0.39
Bw	Fv	0.18	-0.07	-0.06	0.48	0.32	-0.16	-0.11	0.01	0.26	0.40	0.30	0.10
	Oc	0.22	0.20	-0.18	0.03	0.28	0.02	-0.31	0.02	0.04	0.25	-0.12	0.08
	Rg	-0.17	0.15	-0.17	0.12	-0.17	-0.50	-0.03	0.18	-0.16	0.07	-0.19	0.09
	R^2X	0.45	0.36	0.32	0.37	0.40	0.36	0.37	0.34	0.35	0.38	0.32	0.28
Wd	Fv	0.12	0.5	0.14	-0.38	-0.12	0.20	0.06	0.19	0.08	0.08	0.00	0.07
	Oc	-0.03	0.37	-0.30	-0.16	-0.01	-0.39	0.17	-0.37	-0.07	-0.10	0.09	-0.33
	Rg	0.14	-0.20	0.76	0.36	0.08	0.40	-0.12	0.24	0.04	0.13	-0.21	0.21
	R^2X	0.33	0.38	0.29	0.40	0.40	0.25	0.34	0.45	0.42	0.29	0.45	0.33
Bk	Fv	0.05	0.28	0.22	nc	0.15	0.07	nc	0.09	0.27	nc	0.23	0.09
	Oc	-0.18	-0.38	-0.06	nc	0.26	-0.31	nc	-0.42	-0.32	nc	-0.26	-0.31
	Rg	0.03	-0.14	0.29	nc	-0.07	0.41	nc	0.48	0.04	nc	0.47	0.24
	R^2X	0.38	0.38	0.19	nc	0.37	0.30	nc	0.41	0.44	nc	0.52	0.34
Ds	Fv	0.39	0.11	0.39	0.01	-0.09	0.43	0.42	0.08	0.29	0.08	nc	0.02
	Oc	0.20	-0.44	-0.18	0.18	0.21	-0.06	0.24	-0.34	-0.29	0.13	nc	-0.24
	Rg	-0.11	0.09	0.11	-0.09	-0.06	0.40	0.10	0.30	0.08	0.05	nc	0.19
	R^2X	0.40	0.35	0.34	0.36	0.42	0.31	0.39	0.43	0.44	0.34	nc	0.37
Dr	Fv	-0.28	0.29	0.43	0.12	0.16	0.23	-0.05	0.46	0.38	-0.19	0.08	0.23
	Oc	-0.23	-0.47	-0.31	-0.05	-0.14	0.05	0.08	-0.41	-0.32	-0.20	-0.19	-0.47
	Rg	0.10	0.14	0.53	0.55	0.18	0.25	0.22	0.11	-0.05	-0.22	0.27	0.04
	R^2X	0.41	0.36	0.19	0.33	0.41	0.34	0.35	0.40	0.45	0.45	0.51	0.38
Ag	Fv	-0.04	0.11	0.17	nc	0.24	0.14	0.47	-0.19	-0.01	-0.02	0.19	nc
	Oc	-0.05	-0.14	0.02	nc	-0.11	0.10	0.10	-0.19	-0.10	0.05	-0.24	nc
	Rg	0.03	0.22	-0.08	nc	-0.06	0.08	0.19	-0.19	-0.29	-0.10	0.16	nc
	R^2X	0.43	0.30	0.56	nc	0.40	0.35	0.36	0.20	0.30	0.26	0.53	nc

Higher scaled coefficients in bold; nc= no computable

Dependent variables: Lc=Land clearing; Bw=Browsing; Wd=Wood or firewood; Bk=Bark; Ds=Diseases, Pests; Dr=Drought; Ag=Age.
Independent variables: Fv=Food value, Oc=Occurrence change; Rg=Regeneration

consistent with results from research conducted in other sub-Saharan countries, similarly pointing at *A. digitata* as the most important food tree species (Vodouhê *et al*., 2010; Faye *et al*., 2011; Dan-Gimbo & Barrage, 2012; Sop *et al*., 2012; Thiombiano *et al*. ,2013).

The local communities involved in this study valued the woody species differently depending on the agro-ecological context, as was found in a similar study in northern Benin (Assogbadjo *et al*., 2010); however the food value obtained in our study does not seem to be linked to the status of residence of the respondents. No similarities in the food value were found between Tondikiwindi and Senekonkodje inhabitants (the latter ones, climatic refugees in the Sudanian agro-ecological region, former habitants of Tondikiwindi) as we were expecting.

In our study, significant differences were found according to gender: men attributed a greater value to *B. aegyptiaca* than women, and expressed a perception of a more pronounced decline of its occurrence over time. Men also perceived a more pronounced decline in *B. senegalensis* than women, despite this species being quite resilient, broadly distributed and re sprouting. These findings seem to be explained by different gender roles; men are responsible for clearing land for cultivation and therefore they directly affect the density of edible woody species, such as *B. aegyptiaca* and *B. senegalensis*, even if this practice was not perceived as a pressure factor.

In West Africa, ethnicity has been reported as a factor that influences preferences and resource knowledge with regard to food tree species. Examples of such findings are available for *A. digitata* (De Caluwé *et al*., 2009), *P. biglobosa* (Koura *et al*., 2011) and *T. indica* (Fandohan *et al*., 2011). In our study, the Fulani indicated a slightly lower preference for *Z. mauritiana* and

they reported a higher declining occurrence of this species and of *B. senegalensis*. These results can be explained by their semi-nomadic lifestyle and livelihood strategy; they depend less on locally available resources given their mobility; they rely largely on dairy products for their diet, and they have the opportunity to observe vegetation changes on a much wider area, beyond village boundaries.

All informants expressed a general view of all species, except *Z. mauritiana*, being under significant or very strong pressure. These results reveal a certain concern for the conservation of woody resources, similar to participants in research in the neighbouring Pendjari National Park in Benin (Vodouhê *et al*., 2010). Nevertheless, the model developed in this study did not provide a univocal explanation for the observed conservation status of the edible woody species investigated. The relation between the food value of edible woody species and the perception of pressure factors varies among species. For some species with high food value, such as *A. digitata*, *B. aegyptiaca*, *M. crassifolia*, *P. biglobosa*, *S. birrea* and *P. reticulatum*, the perception of key informants indicate pests and diseases as the main threats. For *B. senegalensis* the main threat factors were drought and wood and firewood harvesting; for *M. crassifolia*, drought, pest and diseases, browsing, wood harvesting and bark exploitation. For *V. paradoxa* the most important threat factor turned out to be ageing of individuals, in line with what was observed in parklands in West Africa by Sanou & Lamien (2011).

In a previous study carried out in Niger and Burkina Faso (Wezel & Haigis, 2000; Wezel & Lykke, 2006), *B. aegyptiaca* resulted as a non-threatened, well-preserved species, included among the drought-resistant species. It is remarkable that in our study, *B. aegyptiaca* was cited as being under threat due to wood harvesting and bark exploitation along with drought and pest and diseases. This result constitutes an alert about the continued increase of resource degradation by natural or biological factors (e.g. extreme climate events) and by human pressure, with a consequent loss of genetic resources. *B. aegyptiaca* is used both for human and animal consumption and regularly pruned by women farmers for use in dishes and by men farmers to feed livestock during the dry season. This practice puts pressure on the regeneration capacity of the species because young leaves and flowers are harvested all together generally from the adult trees required for the renewal of the species (Abdourhamane *et al*., 2013).

Based on the perceptions of the people interviewed in our study, almost all key species investigated seem to have undergone a considerable decline in occurrence and a lack of regeneration seems to have affected nearly half of the species examined. Therefore, the availability of the resources in the future is at risk. This perception is in agreement with what has been highlighted in research projects on land use change (USGS, 2013). Rapid population growth and growing demand for food have produced a large expansion of cultivated areas (grown by 42.7% during the period 1975-2000), which has determined a contraction of fallows, bushland and pastures, and increased the pressure on woodlands.

Our study contributes with a general view of the causes of the perceived pressures not being linked to the management practices of the land system but mainly to the collection practices of tree products or to biotic and abiotic factors. Land clearing was not generally cited as a real concern, probably because agriculturalists are obliged to increase arable land at the expense of some food tree species, which they do not perceive as disappearing thanks to their re-sprouting capacity after cutting the main stem. The informants attributed land clearing as a pressure factor of the one species *P. reticulatum*, as it is has been observed by Wezel & Haigis (2000).

According to the perceptions of the local dwellers interviewed (90% agriculturalist), the decline of edible woody species seems mainly attributable to the effects of browsing, reflecting a well-known tension between agriculturalists and pastoralists. However, contrary to expectation, absence of regeneration in species with high food value is associated with an excessive exploitation of wood and bark, worsened by drought, pests and diseases, and not with browsing. In Burkina Faso, when the main causes of changes in the vegetation were identified, drought was the most important factor, followed by deforestation, ageing of the trees and fires (Sop & Oldeland, 2011). In a study in North Benin focused on *S. birrea*, all respondents reported a recent decline (Gouwakinnou *et al*., 2011). Their views indicated that the responsible factors were both anthropogenic (agriculture, grazing and felling for carving) and natural (decreased soil fertility, natural death and drought).

Our findings provide essential elements on local knowledge for a participatory design of conservation activities of priority edible woody species. To strengthen this basis, the present findings should be combined with inventories of the vegetation in representative plots, to link perception of dwellers with a direct assessment of the conservation status of key food tree species and the dynamics affecting occurrence and regeneration. Improving species regeneration dynamics knowledge in the context of human and climatic pressure should contribute to the success of adaptive management and conservation of indigenous edible woody species.

Conclusions

This study confirms the key role played by edible woody species in the diet of rural communities in Niger during periods of food shortage, filling a documentation gap on the local knowledge about the conservation status of these species. Special attention in monitoring the status of natural resources should be paid to species such as *A. digitata* and *B. senegalensis*, found to have a very critical role in the diet, and *M. crassifolia*, used for human consumption in extreme situations. The food value attributed to edible woody species was found to be species-specific and closely associated with the specific agro-ecological region, but not linked to the status of residence or origin of the informants. Our study revealed that gender should be considered in the design of conservation activities because there are notable differences between perceptions of women and men. The Fulani ethnic group could play an important role on the diagnosis of the species status as they have the opportunity to observe vegetation changes beyond village boundaries.

There is a general perception of a declining occurrence of edible woody species and a lack of regeneration, but there is no one clear view among the rural communities involved in this study about the processes influencing this decline. The model explaining the perception of threats by local communities revealed a species-specific relationship and not provide a univocal explanation for the observed conservation status of the edible woody species investigated. A complex system of common threat factors emerges. The main ones identified were the pressure of overexploitation, pests and diseases, and drought. Land clearing for agriculture is not considered the main driver leading to a decline in occurrence of edible woody species.

Further research into the drivers of change determining a lack of regeneration of edible woody species is needed, with the participation and training of local communities on the diagnosis and the identification of potential solutions to the problem. Regeneration dynamics, in particular of re sprouting species suffering periodic cuttings, need to be studied to propose effective conservation actions for the species.

The results of this study provide key elements to determine the main pressure factors and to understand how local communities perceive these factors. This could influence their interest and participation in conservation activities, focused on mitigating the pressures of the identified threats. The study is grounded on the strong belief that understanding local knowledge and perceptions should be considered in an early phase of the design of adaptive management and conservation activities for indigenous woody species.

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