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Uses, management, and population status of the baobab in eastern Burkina Faso

Katharina Schumann · Rüdiger Wittig · Adjima Thiombiano · Ute Becker · Karen Hahn

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Abstract Many cash-poor households in the semi-arid tropics strongly depend on non-timber forest products (NTFPs) for livelihood. Increasing threats on NTFP-providing tree species, due to land-use intensification, require ecological studies as well as additional information about species' uses and management provided by local people. The objectives of our study were to (i) document uses and management of the baobab (*Adansonia digitata* L.), (ii) investigate knowledge distribution among genders and different villages, and (iii) assess the population status of the baobab in eastern Burkina Faso. We conducted an ethnobotanical survey among Gulimanceba people and performed a quantitative analysis using different measures of knowledge. Interviews reveal that the baobab is harvested by local people for 25 use-types. The fruits are the most important plant part and baobab products are of special importance for nutritional uses. Local management of baobab seems to be so far sufficient to maintain baobab populations. The fact that we found some differences in uses and management of baobab between genders and villages emphasizes the importance of gender- and region-related management recommendation. People are able to use and manage the baobab in a relative sustainable way as human population density is relatively low and as they have relatively good access to the forest compared to other regions of Burkina Faso. However, in the light of land-use and climate changes, adapted management strategies are required. We conclude that ethnobotanical studies on a small-scale level are of high importance in order to develop management strategies that are reliable in a specific region.

Keywords *Adansonia digitata* · Gulimanceba · Non-timber forest products · Quantitative ethnobotany · Traditional knowledge

K. Schumann (✉) · R. Wittig · K. Hahn
Institute of Ecology, Evolution and Diversity, J.W. Goethe University, Max-von-Laue-Straße 13, 60438 Frankfurt, Germany
e-mail: Schumann@bio.uni-frankfurt.de

R. Wittig · K. Hahn
Biodiversity and Climate Research Centre (BiK-F), Senckenberganlage 25, 60325 Frankfurt, Germany

A. Thiombiano
Department of Plant Biology and Physiology, UFR-SVT, University of Ouagadougou, 09 BP 848, Ouagadougou 09, Burkina Faso

U. Becker
Green School in the Botanical Garden of Johannes Gutenberg-University Mainz, Anselm-Franz-von-Bentzel-Weg 9b, 55128 Mainz, Germany

Introduction

In Africa and elsewhere in developing countries, rural households use several different non-timber forest products (NTFPs) from a wide range of plant species for both subsistence and commercial use. NTFPs include any products other than timber derived from forest (e.g. bark, fruits, gums, leaves) and are gathered from the wild, in agroforestry systems, or are cultivated as semi-domesticated plants in plantations (Choudhury and Jansen 1998). In West Africa, NTFPs contribute importantly to the livelihoods and welfares of rural people, i.e. as a source for construction material, fodder, food, fuel wood, medicine (e.g. Lykke et al. 2004; Paré et al. 2010). For instance, Heubach et al. (2011) demonstrated that the income from NTFPs accounted for 39% of total household income for a community in northern Benin.

In recent years, there has been growing concern that populations of NTFP-providing tree species are declining due to land-use intensification and over-harvesting (Shackleton and Shackleton 2004; Ticktin 2004). Consequently, several studies assessed the impact of land-use and harvesting on the population status (e.g. size class distribution, fruit production) of important NTFP-providing tree species in West Africa (e.g. Gaoue and Ticktin 2007; Djossa et al. 2008; Schumann et al. 2010). However, these studies on their own may not adequately justify the conservation assessment of the population status of species (Dovie et al. 2008). Important additional information to these studies can be provided by local people. Their knowledge and opinions on use-preferences, management strategies, and their impact on plant species are based on experiences gathered over generations and are crucial elements for producing culturally and ecologically rational conservation and management strategies (Lykke et al. 2004; Gaoue and Ticktin 2009). Thus, it is important to combine ecological and ethnobotanical knowledge about NTFP-providing species in order to provide appropriate management recommendations. However, only few studies (e.g. Lykke 1998; Dhillion and Gustad 2004) included ecological and ethnobotanical knowledge when assessing the population status of NTFP-species in West Africa.

In a previous study (Schumann et al. 2010), we gained ecological knowledge about one of the most important NTFP-providing trees in West Africa; *Adansonia digitata* L., commonly known as baobab. The multipurpose baobab tree is widely used for household, medicinal, and nutritional purposes and provides additional income to farmers (Sidibé and Williams 2002; Gustad et al. 2004; Wickens and Lowe 2008). For a community in northern Benin, Heubach (2012) showed that baobab NTFPs contributed 2% to total income per year. In our previous study, we documented the impact of harvesting and land-use on the population structure and fruit production of the baobab tree in eastern Burkina Faso. By comparing baobab stands of the W National Park with those of its adjacent communal area, we found that despite the intense harvesting and the land-use impact, baobab populations are still well preserved due to species-specific characteristics (longevity and low adult mortality rates) and particularly due to traditional management practices of local people. Thus, we concluded that contrary to other West African countries (e.g. Benin, Assogbadjo et al. 2005), traditional management strategies of the baobab tree in this area seem to be so far sufficient to maintain viable baobab populations. In order to evaluate this assumption and to gain a better understanding of the particular management, uses, and the population status of the baobab in this area, we conducted an ethnobotanical survey with local people. To date, several ethnobotanical data about the baobab were already obtained. However, most of these studies investigated knowledge distribution of baobab on a larger-scale level, i.e. differences between countries or ethnic groups (De Caluwé et al. 2009; Buchmann et al. 2010), while only little information is available about knowledge distribution on a small-scale level (=differences within a community and between genders, generations, and people from different villages). Consequently, within this study we aimed to study how local knowledge is distributed among genders and people from different villages. Such a detailed small-scale survey can indicate which groups in the community are most dependent on the species and if knowledge is shared among all members of a community or whether it is expert property. Specialist knowledge is usually at higher risk of being lost than commonly shared knowledge when a community is facing environmental or social changes (Byg and Baslev 2001). Moreover, knowledge should not emanate only from and for larger-scales but also from small-scale level (Dovie et al. 2008) as proposals for changes in management on a larger-scale may be impractical or impossible to apply for local harvesters. Thus, management recommendations should focus on adaptation of management strategies currently practiced locally (Ticktin 2004).

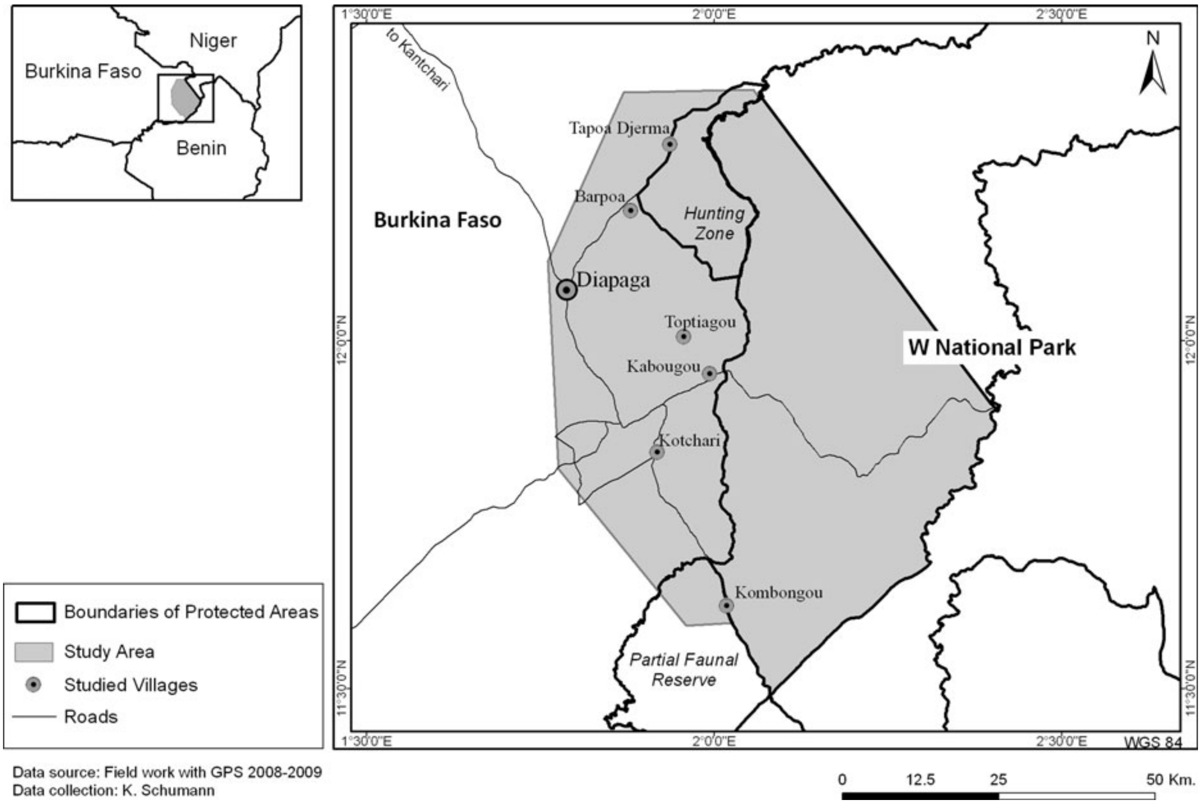

Fig. 1 Study area (UTM zone 31 North, WGS 84)

The specific objectives of the study were to (i) document uses and management (harvesting modes and conservation practices) of the baobab tree within the local community, (ii) investigate knowledge distribution among genders and people from different villages, and (iii) assess the population status of the baobab. We aimed to combine the results of this study with the findings of our former study (Schumann et al. 2010) and to provide management recommendations that are reliable under currently practiced management.

Methods

Study area, ethnic group, and study species

Surveys were conducted in the study area of our previous study (Schumann et al. 2010) as we aimed to combine results of both studies. The study area is located in a semi-arid area in the province Tapoa in Burkina Faso, West Africa (Fig. 1); in- and outside of the transboundary W National Park. It belongs to the North Sudanian vegetation zone (Guinko 1984). Annual precipitation ranges from 700 to 900 mm (Hijmans et al. 2005; http://www.worldclim.org), with a rainy season from May to October followed by a dry season from November to April. The vegetation is characterized by shrub, tree, and woodland savannas. The farming system consists of alternating cycles of cultivation and fallows with an age of 5–15 years. Highly valued trees are preserved on croplands. Grazing activities by cattle, sheep, and goat are extensive. Human population density is relatively low with 16 inhabitants per km^2 (Tapoa province, INSD 2007).

Gulimanceba people are the dominant and autochthon ethnic group in this area and of all eastern Burkina Faso (85% of the total population in the Tapoa province). They are the fourth largest ethnic group in Burkina Faso (7% of the total population) after the Mossi, Fulbe, and Dioula (TLFQ 2011). Gulimanceba people live mainly from farming (cotton, maize, millet, and sorghum), while animal husbandry plays only a minor role. They use several NTFPs on a daily basis, including baobab products.

Table 1 Number of informants, mean annual precipitation, and mean density (individuals/ha ± SE) of baobab seedling and adult trees of the six study villages

	Number of informants	Mean annual precipitation (mm)	Mean density of baobab seedlings	Mean density of adult baobab trees
Tapoa Djerma	7	727	0.00 ± 0.00	0.36 ± 0.31
Barpoa	9	750	1.89 ± 3.01	1.01 ± 0.44
Toptiagou	7	792	1.56 ± 1.70	0.65 ± 0.35
Kabougou	8	805	0.32 ± 0.42	1.37 ± 1.04
Kotchari	9	827	1.88 ± 2.13	0.79 ± 0.29
Kombongou	9	867	1.78 ± 2.45	0.52 ± 0.25

Mean annual precipitation was extracted from the worldclim database (Hijmans et al. 2005; http://www.worldclim.org). Methods for collecting data to baobab density are described in Schumann et al. (2010)

The baobab tree (*Adansonia digitata* L.) belongs to the Malvaceae family (subfamily Bombacoideae) and is known to be an extremely long-lived tree, up to 1,300 years (Patrut et al. 2007), that can reach 23 m in height. The trunk is abruptly bottle-shaped or short and thick, up to 10 m in diameter (Wickens 1982). *A. digitata* is scattered relatively irregularly and patchily in the savanna and is often associated with human settlements. Usually, it grows at low altitudes (450–700 m) with mean annual rainfall between 150 and 1,500 mm (Wickens 1982). It occurs on well-drained, clayey to sandy soils and is often spared when land is cleared for cultivation (Wickens and Lowe 2008).

Data collection

Ethnobotanical surveys were undertaken in six villages (Tapoa Djerma, Barpoa, Toptiagou, Kabougou, Kotchari, and Kombongou, Fig. 1) that are evenly spread in the study area and are located within a 75 × 40 km radius. They show similar cultural, economic, and social structures, e.g. nearly all people perform work as farmers and most of them belong to the ethnic group of the Gulimanceba. All villages have a primary school and a small weekly market. Electricity and pipe water is not available. Households are headed by males, from which each has 1–6 women and 1–20 children. Considering ecological conditions, the villages differ in the amount of annual precipitation (Table 1). Precipitation increases from the North (Tapoa Djerma) to the South (Kombongou) of the study area. The density of baobab trees shows no clear trend along this precipitation gradient (Table 1; results are based on the data from our previous study). In fact, ANOVA showed that the density of seedlings ($F = 0.516$, d.f. = 70, $p > 0.05$) and adult trees ($F = 0.750$, d.f. = 70, $p > 0.05$) did not differ significantly between the study villages.

Ethnobotanical data were collected through structured interviews. The interviews were conducted between September and October 2008. People were chosen randomly and interviewed individually in the local languages (10 persons per village, 5 men and 5 women per village). All participants were at least 18 years old. Informants were asked to describe:

- the uses of each baobab plant part as well as their preparations and applications
- the population development of baobab (decreasing, increasing, or stable and reasons for this)
- applied conservation practices for baobab
- the harvesting modes of baobab (area, season, used tools, and preferences for special trees)

Data analysis

After data cleaning, we used a total of 49 interviews (28 men and 21 women), with at least 7 persons per village (Table 1) for data analysis. To determine the distribution of knowledge and perceptions regarding uses, conservation practices, and population development of *A. digitata* within the community, we performed a quantitative analysis using eight different measures of knowledge (Table 2). For the calculation of two measures (use-diversity value (UD) and use equitability value (UE)), the different mentioned uses were grouped into three different categories: construction, food, and medicine. More details on the measures are provided in Byg and Baslev (2001) and

Table 2 Measures of knowledge and perceptions regarding uses, conservation practices, and population development of *A. digitata* within the community

Index	Calculation	Description	Reference
Informant diversity value (ID) $ID = U_x/U_t$	Number of uses cited by a given informant (U_x) divided by the number of total uses (U_t)	Measures how many informants use the species and how its use is distributed among them	Byg and Baslev (2001) and Monteiro et al. (2006)
Informant equitability value (IE) $IE = ID/ID_{max}$	Informant diversity value (ID) divided by this index's maximum value (ID_{max})	Measures the degree of homogeneity of the informant's knowledge	Byg and Baslev (2001) and Monteiro et al. (2006)
Use-diversity value (UD) $UD = U_{cx}/U_{ct}$	Number of indications recorded by category (U_{cx}) divided by the total number of indications for all of the categories (U_{ct})	Measures the importance of use categories and how they contribute to the total value of uses	Byg and Baslev (2001) and Monteiro et al. (2006)
Use equitability value (UE) $UE = UD/UD_{max}$	Use-diversity value (UD) divided by the index's maximum value (UD_{max})	Measures the degree of homogeneity of the knowledge about use categories	Byg and Baslev (2001) and Monteiro et al. (2006)
Consensus value for use-types (CTU) $CTU = (TU/U_t)/S$	Number of times a given use was reported (TU) divided by the total number of uses (U_t). This value is then divided by types of uses separated into categories (S)	Measures the degree of agreement among the informants concerning species' uses	Monteiro et al. (2006)
Consensus value for plant part (CPP) $CPP = P_x/P_t$	Number of times a given plant part was cited (P_x), divided by the total number of citations of all parts (P_t)	Measures the degree of agreement among the informants concerning the plant part used	Monteiro et al. (2006)
Consensus value for population development (CPD) $CPD = PD_x/PD_t$	Number of citations for a given perception to population development (PD_x) divided by the total citations for all perceptions to population development (PD_t)	Measures the degree of agreement among the informants concerning the perception to population development of the species	Proposed in this study
Consensus value for conservation practices (CCP) $CCP = C_x/C_t$	Number of citations for a given conservation practice (C_x) divided by the total citations for all conservation practices (C_t)	Measures the degree of agreement among the informants concerning the conservation practices of the species	Proposed in this study

Monteiro et al. (2006). Non-parametric tests were applied to evaluate significant differences of diversity of knowledge (ID) between gender (Mann–Whitney test) and villages (Kruskal–Wallis test).

To detect similarities and discrepancies between respondents regarding harvesting modes, the percentage of mentioned answers of each gender in each village (men and women of 6 villages = 12 samples) were merged by means of a Principal Component Analysis (PCA). To detect the explaining variables of the first two PCA-axes, we calculated correlations between PCA-scores of the first two axes and each answer. We examined the ordination diagrams for patterns (diagram is not presented) and used linear models (LM) to test whether harvesting modes differed between men and women and between people from the six different villages. Thus, gender and villages were used as independent variables and the PCA-scores of the first two axes were used as the dependent variable. LMs were run with a maximum fitted model. The non-significant explanatory variables were removed until a reduced final model was achieved, containing only significant explanatory variables.

Statistical analyses were performed using PC-ORD (McCune and Mefford 2006), PASW Statistics 18.0.0 (SPSS Inc., Chicago, IL, USA) and R 2.10.1 (R Development Core Team 2009).

Results

Uses of *A. digitata*

Interviews reveal that the baobab, called *bu tuobu* in Gulimancema, is harvested by local people for 25 different types of uses (Table 3). Baobab products are used for 17 medicinal uses, 7 food uses, and 1 construction use. Different plant parts are applied against the same diseases. The preparations and applications of all uses are presented in Appendix Table 8.

Overall, the principal types of food uses were the utilization of the leaves to prepare sauce (called *ti tuofari kpindi* in Gulimancema, Fig. 2a) (CUT = 0.65), the use of the fruit pulp (Fig. 2b) to prepare the local beverages and porridge *l'eau blanche* (*mi ñimpiema*), *bouillie* (*li kanbiali*), and *juice of pain de singe* (*mi tuokua ñima*) (CUT = 0.35, 0.25, and 0.19 respectively), and the use of the seeds as spice in sauces (CUT = 0.27) and as an additive in *soumbala* (CUT = 0.25). *Soumbala* is a fermented paste made of seeds of *Parkia biglobosa*. The main type of construction purpose was the use of the bark to make

Table 3 Informant consensus values for the use-types (CTU) of *A. digitata* in the six study villages and for men and women

	Men	Women	Tapoa Djerma	Barpoa	Toptiagou	Kabougou	Kotchari	Kombongou
Number of cited use-types	22	20	13	13	16	14	14	15
Consensus value for use-types (CUT)								
Food								
Sauce (leaves)	0.42	0.35	0.18	0.23	0.15	0.19	0.21	0.20
Additive in *l'eau blanche* (fruits)	0.23	0.18	–	0.18	0.04	0.14	0.14	0.11
Spice (fruits)	0.21	0.10	0.18	0.15	0.06	0.02	0.07	–
Additive in *bouillie* (fruits)	0.12	0.18	0.03	0.03	0.06	0.10	0.12	0.11
Juice of *pain de singe* (fruits)	0.12	0.10	0.15	0.03	0.04	0.02	0.02	0.07
Additive in *soumbala* (fruits)	0.15	0.02	0.03	–	0.02	0.10	0.02	0.09
Additive in *galette* (fruits)	0.02	0.03	–	0.08	–	–	–	–
Construction								
Cord (bark)	0.20	0.03	0.05	0.15	0.02	0.10	0.02	0.02
Medicine								
Wounds (bark, roots)	0.17	0.13	0.08	0.03	0.08	0.07	0.12	0.07
Vitamins for babies (bark)	0.11	0.17	0.10	0.05	0.13	0.07	0.02	0.02
Diarrhea (bark, fruits, leaves)	0.12	0.12	–	0.03	0.08	0.10	0.12	0.02
Cough (bark, fruits)	0.06	0.08	–	0.05	0.04	0.02	0.07	0.02
Cardialgia (bark)	0.03	0.05	–	0.03	–	0.05	0.02	0.02
Hemorrhoids (bark, leaves)	0.03	0.05	–	–	0.02	–	0.10	–
Vomiting (bark, fruits, leaves)	0.05	0.03	–	–	0.04	0.05	–	0.02
Cold (bark, fruits)	0.02	0.05	0.05	–	–	0.02	–	0.02
Lactation for women (fruits)	0.02	0.02	–	–	–	–	–	0.04
Stomach ache (leaves)	0.05	–	0.03	–	0.02	–	–	0.02
Parasites (leaves)	0.03	–	0.05	–	–	–	–	–
Snake bite (bark)	0.02	–	0.03	–	–	–	–	–
Cholera (fruits)	0.02	–	–	–	0.02	–	–	–
Leprosy (roots)	0.02	–	0.03	–	–	–	–	–
Appendicitis (bark)	–	0.02	–	0.03	–	–	–	–
Tooth ache (bark)	–	0.02	–	–	–	–	0.02	–
Itching (fruits)	–	0.02	–	–	0.02	–	–	–

Fig. 2 Sauce made of fresh baobab leaves (**a**), dissolved pulp of baobab fruits (**b**), spared baobab tree in cropland (**c**), and harvesting of baobab leaves (**d**) (Fig. 2b–d by K. Schumann; Fig. 2a by K. Heubach)

ropes, cordages, and other items (CUT = 0.20). Fibers of the inner bark are twisted into ropes etc., while fibers of the outer bark are less suitable for these purposes. The bark was the plant part with the highest number of medicinal uses. The principal medicinal use-types were the use of the bark decoction as "vitamins" to strengthen babies (CUT = 0.23) and to heal wounds (CUT = 0.25). The bark, fruits, and leaves were mainly used to treat diarrhea (CUT = 0.20) and cough (CUT = 0.12).

In addition, 5% of respondents declared the value of the baobab for spiritual uses, such as sacrifices (not presented in Table 3).

Men (22 uses) and women (20 uses) cited a similar number of baobab use-types and displayed similar principal use-types (Table 3). However, there were small differences, e.g. the use of the bark to make ropes was of higher importance for men than for women, while the use of the bark decoction for babies' strengthening was of greater importance for women. None of the study villages cited all 25 use-types. The variety of use-types was the greatest in Toptiagou (16 uses) and the lowest in the northernmost villages Tapoa Djerma and Barpoa (13 uses). For people of all study villages, the use of the leaves to prepare sauce was the most important use-type (Table 3). Differences were found regarding the fruit uses. While the juice of *pain de singe* was a well-known fruit use in Tapoa Djerma, it was less important in all other villages, where the use of the fruit pulp in *l'eau blanche* and in *bouillie* was more important. Only the uses of the bark decoction for babies' strengthening and to heal wounds were the principal medicinal use-types in all six study villages. All other medicinal uses were only cited by people from five or less villages.

Informant-diversity value

Informants knew on average 5.08 (± 0.19) baobab uses. This knowledge was similar between men (5.14 ± 0.26 uses) and women (5.00 ± 0.29 uses) and between respondents of the different study villages

Table 4 Informant diversity value (ID) and equitability value (IE) of the knowledge of *A. digitata* in the six study villages and for men and women

Total informants	49
Number of use citations	249
Number of use-types	25
Diversity value of the informant (ID)	**Mean ± SE**
ID total	0.20 ± 0.01
ID for men	0.21 ± 0.01
ID for women	0.20 ± 0.01
ID for people from Tapoa Djerma	0.22 ± 0.03
ID for people from Barpoa	0.18 ± 0.02
ID for people from Toptiagou	0.23 ± 0.02
ID for people from Kabougou	0.22 ± 0.02
ID for people from Kotchari	0.20 ± 0.01
ID for people from Kombongou	0.17 ± 0.01
Equitability value of the informant (IE)	**Mean ± SE**
IE total	0.51 ± 0.02
IE for men	0.51 ± 0.03
IE for women	0.50 ± 0.03
IE for people from Tapoa Djerma	0.54 ± 0.08
IE for people from Barpoa	0.46 ± 0.04
IE for people from Toptiagou	0.59 ± 0.04
IE for people from Kabougou	0.55 ± 0.05
IE for people from Kotchari	0.51 ± 0.03
IE for people from Kombongou	0.43 ± 0.02

(Tapoa Djerma = 5.43 ± 0.84 uses; Barpoa = 4.56 ± 0.38 uses; Toptiagou = 5.86 ± 0.40 uses; Kabougou = 5.50 ± 0.46 uses; Kotchari = 5.11 ± 0.31 uses; Kombongou = 4.33 ± 0.24 uses). In fact, the diversity of knowledge (ID and IE) concerning baobab uses differed not significantly between men and women (U = 284.500, $p > 0.05$) and between people from the different villages (H = 9.124, $p > 0.05$) (Table 4). The total informants equitability value was medium (IE = 0.51), indicating that knowledge concerning this species' uses is more or less homogeneously distributed among respondents.

Use-diversity value

Even though a higher total number of medicinal uses was recorded, the mean number of mentioned food uses (2.90) was higher than the mean number of medicinal uses (1.67) per respondent. In fact, the greatest use-diversity value was found for the food category (UD = 0.57), followed by medicine (UD = 0.37) and construction (UD = 0.06), indicating that food is the most important use category and that knowledge about food uses is more homogenous than for medicine and construction uses. The same tendency was found when calculating the use-diversity values separately for men and women and for people from the different study villages (Table 5). However, men had a higher use-diversity value for the construction category, while women had a higher value for the medicine category. Toptiagou was the only village with higher diversity-value for medicine than for food. Additionally, category of food and medicine obtained the highest values of equitability (UE = 1.00 and UE = 0.65 respectively, see also Table 5), indicating that knowledge of baobab as a food and medicine source is widely and homogenously distributed within the community.

Plant parts

Both the bark and the fruits of baobab were used for 13 uses respectively, while the leaves (6 uses) and the roots (2 uses) displayed considerably lower purposes (Table 6). Nevertheless, consensus value for plant part (CPP) was fairly similar for leaves (CPP = 0.26) and bark (CPP = 0.28). CPP was highest for fruits (CPP = 0.45) and lowest for roots (CPP = 0.01), indicating that baobab fruits are the most important plant part, while roots are only from little importance. The different study villages displayed similar CPP patterns (Table 6). Only people from the two southernmost villages, Kotchari and Kombongou, valuated leaves more important than the bark. Both men and women demonstrated consensus on the use of the leaves, while the fruits were more important for women and the bark was of greater importance for men.

Population development of *A. digitata*

Most of the informants (CPD = 0.52) claimed that the number of baobab trees decreased in the area. Also a high number of informants (CPD = 0.41) stated that the population is stable, while only few respondents (CPD = 0.07) announced that the number of baobab trees increased. Respondents attributed the decline to poor rainfall (17% of respondents), destructive

Table 5 Use-diversity value (UD) and use equitability value (UE) for the three different use categories of *A. digitata* in the six study villages and for men and women

	Men		Women		Tapoa Djerma		Barpoa		Toptiagou		Kabougou		Kotchari		Kombongou	
	UD	UE	UD	UE	UD	UE	UD	UE	UD	UE	UD	UE	UD	UE	UD	UE
Food	0.58	1.00	0.55	1.00	0.58	1.00	0.66	1.00	0.44	0.82	0.55	1.00	0.54	1.00	0.67	1.00
Construction	0.09	0.15	0.02	0.03	0.05	0.09	0.15	0.22	0.02	0.05	0.09	0.17	0.13	0.24	0.15	0.23
Medicine	0.33	0.56	0.43	0.78	0.37	0.64	0.20	0.30	0.54	1.00	0.36	0.67	0.43	0.80	0.31	0.46

Table 6 Informant consensus values for plant parts (CPP), conservation practices (CCP), and population development (CPD) of *A. digitata* in the six study villages and for men and women

	Men	Women	Tapoa Djerma	Barpoa	Toptiagou	Kabougou	Kotchari	Kombongou
Consensus value for plant part (CPP)								
Fruits	0.43	0.56	0.42	0.49	0.42	0.45	0.40	0.53
Leaves	0.27	0.25	0.24	0.22	0.28	0.26	0.32	0.25
Bark	0.28	0.18	0.32	0.29	0.28	0.30	0.28	0.20
Roots	0.01	0.01	0.03	–	0.02	–	–	0.03
Consensus value for population development (CPD)								
Decrease	0.46	0.60	0.43	0.83	0.86	0.50	0.56	0.11
Stable	0.42	0.40	0.14	0.17	0.14	0.50	0.44	0.89
Increase	0.12	–	0.43	–	–	–	–	–
Consensus value for conservation practices (CCP)								
Protection of trees on croplands	0.66	0.60	0.29	0.22	0.71	0.67	0.89	0.89
None protection	0.31	0.35	0.57	0.67	0.29	0.33	0.11	0.11
Protection of seedlings with fences	0.03	0.05	0.14	0.11	–	–	–	–

harvesting modes (13% of respondents), and elephants (4% of respondents).

Just men from Tapoa Djerma saw an increase of baobab trees (Table 6). Only in the southernmost village Kombongou, the majority of people did not see a decline of baobab but thought that the baobab population is stable. In contrast, the majority of respondents from the other five villages reported a decline of the baobab population.

Conservation practices for *A. digitata*

Consensus value for conservation practices (CCD) was highest for the activity of protecting baobab trees on cropland (Fig. 2c) (CCD = 0.63) and lowest for the active protection of baobab seedlings and saplings with fences (CCD = 0.04). Nevertheless, many informants also declared that they do not protect baobab trees at all (CCD = 0.33). Planting, sowing, or transplanting of baobab trees were never mentioned.

Both men and women demonstrated similar consensus values for conservation practices, while there were slightly differences between villages (Table 6). While a high proportion of people in Barpoa and Tapoa Djerma stated that they do not protect the baobab tree at all, the majority of the respondents in the four other villages declared that they spare baobab trees in fields. The active protection of baobab seedlings and saplings was only mentioned in Barpoa and Tapoa Djerma.

Harvesting modes of *A. digitata*

Bark and roots were harvested at any time of the year (71% of respondents). Fresh leaves were collected during the rainy season from May to August (100% of respondents). Collection of the fruits takes place during the dry season from December to June (98% of respondents), when fruits are mature and field harvesting is done. Bark was mainly harvested with a hoe,

Table 7 Results of LM, testing whether harvesting modes of baobab differ between gender and villages

	1. axis				2. axis			
	Bark (hoe, copue-coupe), harvesting area (park, village)							
	Estimate	SE	*t* value	*p* value	Estimate	SE	*t* value	*p* value
Intercept	78.45	12.69	6.18	0.000***	29.12	7.62	3.82	0.003**
Village	−12.94	3.26	−3.97	0.003**				

All non-significant explanatory variables were removed

Eigenvalue of first axis: 4.40 and of second axis: 3.52, explained variance of first axis 25.9% and of second axis: 20.7%

SE Standard error

Correlations of first axis with variables: Coupe-coupe (bark): $r = 0.811$, $p < 0.001$ Hoe (bark): $r = -0.770$, $p < 0.01$; Harvesting area (park): $r = 0.713$, $p < 0.01$; Harvesting area (village): $r = -0.671$, $p < 0.05$

an axe (84 and 37% of respondents, respectively), or a machete (locally called *coupe–coupe* or in Gulimancema *gu handagu*) (10% of respondents). Roots were also harvested with a hoe (2% of respondents). For leaves harvesting, three-fourth of the respondents reported that people have to climb up the tree and harvest the leaves by hand (Fig. 2d), sticks or with a *coupe–coupe*. In addition, leaves were collected from the ground with a knife mounted on a long stick or by throwing sticks (20 and 12% of respondents, respectively). For collecting fruits, nearly all respondents (92%) attested that people have to climb up the tree and use their hands or sticks. Additionally, sticks were thrown into the tree and the fallen fruits were collected from the ground (86% of respondents). A high proportion of the respondents (78%) reported that they do not harvest all baobab trees, but prefer certain trees due to their food quality, i.e. glabrous leaves and sweet fruits. According to harvesting areas, most respondents (67%) stated fallows as the main area of harvesting. Villages, croplands and the park were less often mentioned as harvesting area (35, 8, and 2% of respondents, respectively).

Harvesting modes of the baobab did not clearly differ between respondents. In the ordination plot, only the respondents of the northernmost village Tapoa Djerma were separated along the first axis from the respondents of the five other villages. The first axis of the ordination correlated mostly with harvesting tools for the bark and harvesting areas. For these harvesting modes (=1 axis), we found significant differences between villages (Table 7). People from the two northernmost villages (Barpoa and Tapoa Djerma) used a machete to harvest the bark, while people from the other villages used mainly a hoe for bark harvesting. Regarding harvesting area, only people from Tapoa Djerma reported that they collect baobab products in the park and never mentioned villages as their harvesting area.

Discussion

Uses of *A. digitata*

Interviews emphasize the high importance of the baobab tree for local people. This is consistent with other studies that have shown that the baobab is one of the most important species for rural communities in West Africa (e.g. Kristensen and Lykke 2003; Gustad et al. 2004; Assogbadjo et al. 2008; De Caluwé et al. 2009; Buchmann et al. 2010). All different parts of the baobab are used for several use categories. However, the fruits are the most important plant part followed by the bark and the leaves. The variety of medicinal uses was greater than that of the food uses. Nevertheless, use-diversity values demonstrated that baobab plays a more important role for nutritional than for medicinal uses. This is in concordance with the results of Buchmann et al. (2010) for several West African countries that also showed that the use of baobab products as nutrition was significantly more often cited than other uses and that baobab fruits carry the greatest variety of uses. Especially the use of baobab leaves and seeds for sauce and the uses of the fruit pulp for beverages and porridge are of great importance. In fact, these plant parts add valuable minerals and vitamins to the otherwise micronutrient-"poor" staple crops of the Gulimanceba people. The sauce produced by baobab leaves accompanies millet gruel for daily consumption. Baobab leaves are a significant protein and mineral source, especially of calcium, iron, and magnesium (Yazzie et al. 1994). The roasted seeds are rich in proteins and fats and the fruit pulp has very high vitamin C content (Sidibé and Williams 2002). However, Sidibé et al. (1996) demonstrated that there can be a 3-fold difference in the concentration of vitamin C between individual baobab trees. To retain vitamin C in soft drinks, it is important not to boil the pulp but to add the powder to previously boiled water (Sidibé and Williams 2002). In this way, the Gulimanceba people use the fruit powder, thus, they have a good way of preserving the vitamin contents of baobab fruits.

Albeit lower as for nutritional purposes, the baobab plays also an important role for the medical care of local people. For the Gulimanceba people, the baobab is of special importance for the treatment of cough, diarrhea, and wounds as well as strengthening agent for babies. All medicinal and food uses reported by the Gulimanceba people has been documented elsewhere in Africa for other ethnic groups as well (e.g. Sidibé and Williams 2002; Wickens and Lowe 2008; De Caluwé et al. 2009; Buchmann et al. 2010). To our knowledge, only the use of the bark as "vitamins" for strengthening babies has been firstly described in our study. Despite cultural and environmental differences, this almost complete concordant use of the baobab demonstrate the essential role the baobab plays in maintaining the livelihood of a lot of different rural communities all over Africa. Gulimanceba people could even more benefit from this important species as Buchmann et al. (2010) and other studies (Sidibé and Williams 2002; Wickens and Lowe 2008; De Caluwé et al. 2009) demonstrated more than 300 different uses of the baobab, e.g. for treatment of fever and malaria.

The number of spiritual and religious uses can be assumed to be much higher in reality. However, it is difficult to collect this kind of "secret" information. For this, a set of different approaches including not only structured but also semi-structured interviews, participant observation, group discussions etc. (Cunningham 2001) are necessary to obtain reliable information on religious-sacred uses, which were beyond the scope of this article.

Management (harvesting and conservation) of *A. digitata*

Leaves and fruits were collected during the entire foliage and fruiting periods, respectively and the bark and roots at any time of the year. This emphasizes the high demand on baobab products in this area. Similar harvesting periods were reported in Mali (Dhillion and Gustad 2004). The fact that the bark is harvested at any time of the year and not only during the rainy season is a cause of concern as bark regeneration depends in general on humidity as the moisture content of the exposed wound is the most important factor allowing the start of the bark recovery process (Delvaux et al. 2010). Poor bark regeneration leads to poor quality fibers, leading to debarking from other parts of the baobab tree, causing an increase in the level of injury to the tree (Dovie 2003; Cuni Sanchez 2011). This is also the case in this area as our previous study (Schumann et al. 2010) showed that most of the baobab trees were harvested to rates of 25% of total bark. Next to harvesting period, it is also important to know how long harvesters allow bark to regenerate before they start with debarking again. Romero et al. (2001) showed that for quality bark fiber to be obtained from the first harvest, it takes from 6 to 10 years to restore the pre-harvested conditions.

According to harvesting tools, leaf and fruit harvesting techniques seem not to be very destructive as most people climb up the tree for harvesting and rarely harvest from the ground. Leaf harvesting at close range causes less damages than from a certain distance (Dhillion and Gustad 2004). Harvesting with a knife mounted on a long stick is less specific and often removes complete shoots. This results in a reduction of the number of flower buds, as these are either damaged or removed entirely together with the shoots (Buchmann et al. 2010). The bark was mainly harvested with a hoe. This tool seems appropriate as far as only small pieces are removed.

In regard to preferences of tree individuals, our interviews clearly reveal that certain trees are preferably harvested due to their food quality. These kinds of preferences were also reported for other African countries (Assogbadjo et al. 2008; Buchmann et al. 2010; Cuni Sanchez et al. 2011). Assogbadjo et al. (2008) even showed that people use several criteria to differentiate baobab individuals and used preferred combinations of traits as a guide for harvesting (e.g.

the easier the bark-harvesting, the tastier the pulp and leaves). Hereby, the locally-recognized morphotypes seem to include a substantial amount of genetic variation. This means that the traditional selection of morphotypes with desired traits does not directly alter the natural population genetic structure (Assogbadjo et al. 2009).

According to harvesting areas, respondents stated fallows, villages, and croplands as the areas of harvesting. This corresponds with results from our previous study (Schumann et al. 2010) that showed that nearly all baobab individuals were harvested in these land-use types. The same harvesting areas were reported for Mali (Dhillion and Gustad 2004).

Most of the interviewed people stated that they spare baobab trees as prescribed by law, when chopping the vegetation for agriculture. However, farmers preserve only adult baobab trees as they are of high immediate value, while they mostly cut recruiting baobabs. In fact, our previous study (Schumann et al. 2010) demonstrated that baobab seedlings were completely absent on croplands. Overall, Gulimanceba people have a more passive attitude concerning the conservation of trees as they did not see the sparing of baobab individuals on croplands as an active management and that sowing or planting of baobab were never mentioned. Several studies across West Africa (e.g. Kristensen and Lykke 2003; Buchmann et al. 2009) also showed that local people have no tradition for planting of indigenous trees, as they are considered as "wild". This is not explained by the lack of technical knowledge, but rather by local belief systems, referring amongst other things to tree spirits and taboos (Buchmann et al. 2009).

We conclude in accordance with our hypothesis that traditional management strategies of the baobab tree in this area seem to be so far sufficient to maintain viable baobab populations. However, ongoing land-use intensifications require adapted harvesting and management techniques to guarantee the persistence of this economically important species and to secure the harvesting for future generations.

Distribution of knowledge

Informant- and use-diversity values demonstrate that knowledge about baobab uses is more or less commonly shared among the informants and also among men and women and people from different villages. Thus, we conclude that there is no special group within the community that is most dependent of baobab products and that the knowledge about baobab uses is not of high risk of being lost in case of changing conditions. Nevertheless, use-diversity values show that medicinal knowledge about baobab differs more between people than that of nutritional uses. This might be explained by the fact that people use baobab products on a daily basis for food purposes, while baobab products are used only occasionally for medicinal purposes. Moreover, only few people within the community (traditional healers) have a profound knowledge about medicinal plants and are consulted by the majority of the community.

Although knowledge of baobab uses is very similar between men and women, some differences were found. Men higher acknowledge the bark of baobab and its use for construction than women. In contrast, fruits and the use of baobab products for medicine were of higher importance for women than for men. This might be explained by the traditional tasks of women and men within rural West African communities. While men are mostly responsible for craft and construction, women are in charge of household nutrition and the treatment of common disease, especially in child care. Our findings are consistent with those from De Caluwé et al. (2009) and Buchmann et al. (2010) in several West African countries, which have shown that knowledge distribution of baobab uses was not related to gender, but that the exact knowledge on the preparation is partly linked to gender.

Regarding management of baobab, we also did not find substantially differences between men and women and people from the different villages. However, people from the northernmost village Tapoa Djerma had slightly different management strategies of the baobab in comparison to people from the other villages. These differences might be explained by the fact that this village, being close to the neighboring country Niger, has a high proportion of people from the ethnic group Zerma. In contrast, all other villages are mostly dominated by the Gulimanceba people. Consequently, people from Tapoa Djerma are differently influenced than people from the other studied villages, which may lead to differences in uses and management strategies. The fact that people do not or scarcely protect baobab trees in Tapoa Djerma might have led to a considerable lower density of baobab trees in comparison to the other villages (see Table 1). However, it has to be considered that Tapoa Djerma is the village with the lowest precipitation, which hampers recruitment and thus overall baobab density. In contrast, Kombongou is the village with highest precipitation and high seedling density. This might explain why people from this village did not see a decline of baobab.

Similarly, Kristensen and Lykke (2003) and Lykke et al. (2004) found differences from village to village within one ethnic group when it came to the knowledge of uses, conservation, and dynamics of woody species in Burkina Faso as a consequence of different natural and cultural conditions.

Population status of *A. digitata* and management recommendation

We conclude that the baobab is still well preserved in eastern Burkina Faso because it is very useful for the people. Local people are aware of its high importance and thus adjust management strategies in order to preserve a viable baobab population. However, it has to be considered that people are able to use the baobab in a relative sustainable way as the human population density is relatively low compared to other regions of Burkina Faso and as they have relatively good access to the forest (e.g. they are able to harvest baobab products in the W National Park, see Schumann et al. (2010)). Both factors imply a relative low human pressure on the natural resource in comparison to other parts of Burkina Faso. In addition, the environmental conditions (e.g. precipitation) of the study area are more or less favorable for baobab growth and recruitment. Nevertheless, the fact that half of the interviewed people see a decline of baobab in this area raises concern about the maintenance of baobab population, which should be taken seriously. This assumption is in accordance with other studies from West Africa (Assogbadjo et al. 2005) and from elsewhere in Africa (Edkins et al. 2007; Cuni Sanchez 2011) and is especially true in the light of current land-use intensifications (e.g. shortening of fallow periods, expansions of agricultural land) and climatic changes, which may lead to a decline of baobab population in the future. For instance, shortening or absence of fallow periods may prevent successful recruiting of the baobab tree during the fallow period in the future. Thus, adapted management strategies are required to guarantee the persistence of this important species. Our results provide, in combination with the results of our previous study (Schumann et al. 2010) and other literature, appropriate management recommendations that are reliable under currently practiced management strategies in this area. The fact that we found some differences in uses and management of baobab between men and women and between people from different villages emphasizes the importance of gender- and region-related management recommendation. In reality, it is not very pragmatic to promote management suggestions on a village basis. However, cultural and environmental conditions should be considered when defining management recommendations of plant species. This would give management strategies a better chance for success. For instance, the fact that men higher acknowledge the bark of baobab indicates that management recommendation to ensure sustainable harvest of the bark should rather address men. In contrast, suggestions for a more sustainable harvesting of fruits and leaves should be discussed with women. Leaf harvesting of the baobab trees should be moderate to ensure fruit production (Schumann et al. 2010) and to avoid infections of the tree (CUC 2010). Smaller baobab trees should be only harvested by hand and only to a low degree, as they are especially vulnerable to leaf harvesting (Schumann et al. 2010). The bark was mainly harvested with a hoe. This tool seems appropriate as far as only small pieces are removed and if regeneration time is long enough, at least 6–10 years. This avoids infections and other adverse effects on the physiology of the tree. CUC (2010) declared that the best period to harvest the bark is at the end of the rainy season as the moisture content of the exposed wound is the most important factor allowing the start of the bark recovery process (Delvaux et al. 2010).

Furthermore, some baobab seedlings and saplings should be spared and protected by local people on croplands in order to promote successful recruiting of the baobab in the future. This protection could include similar measures as it has been demonstrated for Mali (Dhillion and Gustad 2004): physical barriers to prevent browsing, irrigation, installing of a basin-shaped bed for water collection and cutting of surrounding vegetation. In addition, as there is a high number of seedlings in villages due to the dispersal of seeds in garbage, seedlings from villages could be transplanted to croplands. Practical details for transplanting of baobab seedlings were demonstrated by CUC (2010). For instance, transplanting should preferably be carried out in the beginning of the rainy season and when individuals have reached a height of 30 cm.

Conclusion

Our study firstly describes uses and management of the baobab tree among the Gulimanceba people in Burkina Faso and firstly demonstrates the use of the baobab bark as "vitamins" for strengthening babies. Gulimanceba people could even more benefit from this important species as other studies demonstrated more uses of the baobab and as none of our study villages cited all 25 use-types. Thus, people of different villages could share their knowledge, especially knowledge about medicinal uses, and management experiences of baobab. Our study also shows that ethnobotanical knowledge adds valuable information to ecological findings of a highly used tree species that can be used to design appropriate management recommendations. The fact that we found some differences in uses and management of baobab between men and women and between people from different villages emphasizes the importance of gender- and region-related management recommendation. We conclude that ethnobotanical studies on a small-scale level are of high importance in order to develop management strategies that are reliable in the specific area under the specific circumstances.

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Appendix

See Table 8

Table 8 Preparation and application of the different food, construction, and medicinal uses of *A. digitata*

Uses	Preparation and application
Food	
Additive in *l'eau blanche*	The fruit pulp is dissolved and added to *l'eau blanche* (a drink based on millet or sorghum and cold water)
Additive in *bouillie*	The fruit pulp is dissolved and added to *bouillie* (a porridge based on millet or sorghum and boiled water), to make them more acidic
Additive in *galette*	The seeds are roasted, pounded, and mixed with flour
Additive in *soumbala*	The boiled seeds are crushed into powder and dried. This powder is used as an additive in *soumbala*, which is a fermented paste made of seeds of *Parkia biglobosa*
Juice of *pain de singe*	The fruit pulp is crushed and mixed with water
Sauce	During the rainy season, the fresh leaves are crushed and prepared as a sauce for daily consumption. In addition, the leaves are dried and crushed to powder. This powder can be stored for a long time, which allows its use during the dry season
Spice	The seeds are roasted, crushed into powder, and used as spice in sauces (mainly to prepare couscous)
Construction	
Rope, cordage	The fiber of the inner bark are used and processed
Medicine	
Appendicitis	The decoction of the bark (mixed with *Dichrostachys cinerea*) is served as drink
Cardialgia	The decoction of the bark is served as drink
Cholera	The fruit pulp is pounded, boiled, and served as drink

Table 8 continued

Uses	Preparation and application
Cold	Bark: The decoction (mixed with the leaves of *Piliostigma thonningii*) is served as drink. Fruits: The pulp is pounded, mixed with vinegar, boiled, and served as drink
Cough	Bark: The decoction is served as drink. Fruits: The pulp is pounded, boiled, and served as drink
Diarrhea	Bark: The decoction is served as drink (often mixed with the bark of other trees). Fruits: The fruit pulp is pounded, boiled (mixed with sorghum or *Combretum collinum*), and served as drink. Leaves: The dry leaves are crushed (mixed with water or *bouillie*), boiled, and served as drink
Hemorrhoids	Bark: The decoction is served as drink. Leaves: The dry leaves are crushed, boiled, and served as drink
Itching	The fruit shell is roasted, mixed with the leaves, and the skin is washed
Lactation for women	The fruit pulp is pounded, boiled, and served as drink
Leprosy	The decoction of the roots (mixed with roots of other plants) is served as drink
Parasites	The dry leaves are crushed, boiled, and served as drink
Snake bite	The decoction of the bark is served as drink
Stomach ache	Bark: The decoction is served as drink. Leaves: The dry leaves are crushed, boiled, and served as drink
Tooth ache	The decoction of the bark is served as drink
"Vitamins" for newborns and babies	The decoction of the bark is served as drink and the babies are washed with the decoction
Vomiting	Bark: The decoction is served as drink. Fruits: The pulp is pounded, boiled, and served as drink. Leaves: The dry leaves are crushed, boiled, and served as drink
Wounds	The bark or roots are dried or boiled, pounded, and applied (mixed with sheabutter) on the wound. Furthermore, the decoction of the bark or roots is used to wash the wound

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