Ethnobotanical Factors Influencing the Use and Management of Wild Edible Plants in Agricultural Environments in Benin

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Research

Abstract

This study investigates how the socioeconomic status of local people interacts with cultural, botanical, and economic features of wild edible plants to shape the floristic richness and management options of these resources. We interviewed husbands and their wives in 60 households from three ethnic groups in central Benin. We found that ethnicity affected the composition of managed species at the community level. Within communities, the richness and composition of species managed by households were shaped by the age of heads of households and land ownership by women. Within households, gender affected the richness of managed species and a gender specialization for specific groups of species was observed. The intensity of management practices used by locals depended on the level of knowledge they had on the species' propagation and seed conservation combined with their use importance. In any case, they tended to adopt the most intensive strategies to secure the most important resources.

Introduction

Background

Recent ethnobotanical studies have revealed that a large number of wild plant species growing in farming environments are consumed by local people worldwide (Achigan-Dako *et al*. 2010, Dansi *et al*. 2008, High & Shackleton 2000, Msuya *et al*. 2008, Ogle *et al*. 2003, Price 2006, Shackleton *et al*. 1998). For instance, Ogle and Grivetti (1985) reported more than 200 wild edible species gathered mostly from agricultural fields by the Swazi people. Dansi *et al*. (2008) reported more than 187 wild or semi-wild species consumed by 29 ethnic groups in Benin. These wild edible resources have been and continue to be a primary feature of farming systems and can no longer be overlooked in agricultural development (Dovie *et al*. 2007, Price 2006, Vazquez-Garcia 2008). In many instances, farmers are engaged in the management of some of these species (Asfaw & Tadesse 2001, Casas *et al*. 1996, 1997, 2001, Dansi *et al*. 2009, Gonzalez-Insuasti *et al*. 2008, High & Shackleton 2000, Msuya *et al*. 2008, Price 2006, Shackleton *et al*. 1998), whereas in other cases no attempt of management is observed even if these resources are becoming rare (Asfaw & Tadesse 2001, Dovie *et al*. 2007, Price 2006).

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Ethnobotany Research & Applications 10:571-592 (2012)

Published: December 03, 2012

www.ethnobotanyjournal.org/vol10/i1547-3465-10-571.pdf

Wild plant management refers to a set of interventions performed conscientiously by humans to increase the availability of useful plants, either the whole population or individuals of specific phenotypes within populations (Casas *et al*. 1996, Gonzalez-Insuasti *et al*. 2008, Price 2006). The varieties of plant management observed form a continuum from wild to full domestication of plants, with intermediate steps being wild-managed (e.g., tolerance of plant individuals during land clearing and preparation, or enhancement through protection, tendering and nurturing of particular individuals among populations of some species), and cultivated or semi-domesticated plants (Casas *et al*. 1996, 1997, Gonzalez-Insuasti & Caballero 2007, Gonzalez-Insuasti *et al*. 2008, Price 2006, Wiersum 1997).

Managing wild edible plants involves making strategic decisions about practices and techniques of management. Such decisions may be determined by a complex matrix of biological, ecological, ethnobotanical and socioeconomic factors (Casas *et al*. 1997, 2001, Gonzalez-Insuasti & Caballero 2007, Gonzalez-Insuasti *et al*. 2008). Yet, the effects of these factors, especially how they interact in shaping on-farm diversity and management practices of wild plants at community, household and individual levels are not well known, despite the fact that management of wild plants by local communities is a very ancient practice. During the two last decades, a growing amount of literature on the management of indigenous edible species has been published. Most of those studies have concentrated on inventorying wild food or other functional species gathered in many areas of the world, describing their uses and associated knowledge, and in a few cases their management practices (Camou-Guerrero *et al*. 2008, Casas *et al*. 1996, 2001, Dansi *et al*. 2008, 2009, Ogle & Grivetti 1985, Shackleton *et al*. 1998). Only limited attention has been given to the links between management and procurement practices and biological, socioeconomic and ethnobotanical factors that may influence them (Fentahun & Hager 2010, N'Danikou *et al*. 2011, Price 1997). Some studies merely listed some of these factors but did not demonstrate how they combine to shape farmers' decisions and strategies for management (Casas *et al*. 1996, Msuya *et al*. 2008) whereas others focused just on a few practices, such as gathering (Camou-Guerrero *et al*. 2008). At present, it is not clear what factors favor or limit wild edible plants' management at community, household, or individual levels, and what the socio-cultural features of individuals engaged in this practice are (Pfeiffer & Butz 2005).

Understanding factors which influence the diversity and management practices of wild edible species is fundamental to grasping their roles in the livelihoods of local communities (e.g., subsistence, famine foods, income generation, and cultural importance) as well as how individuals make decisions in the management of these resources (Hildebrand 2003, Winterhalder & Goland 1997). It is also crucial for understanding the dynamics of traditional farming systems, the rationale of farmers in the management of wild food resources and their options for adaptive strategies in an ever-changing environment marked by economic and food crises, land degradation, and climate change (Winterhalder & Goland 1997).

This study investigates two interrelated questions: (1) Is there a socioeconomic pattern among people involved in the management of wild edible plants? (2) What ethnobotanical factors shape individual farmers' plant management or procurement practices within a given socioeconomic group?

Previous ethnobotanical studies suggest that local people, thanks to their long-time interactions with nature, have some knowledge of the ecology and reproductive biology of species in their environment (Ellen 1998, Ghimire *et al*. 2004) and it is well known that this knowledge is indispensable to plant domestication process (Dulloo *et al*. 2004, Simon & Leakey 2004). Evidence from previous research also suggests that there may be a division of labor in some use and management activities (e.g., gathering) of wild edible species, which may be determined by socioeconomic status of individuals such as gender, ethnicity, language, age and access to land, and economic activities (Camou-Guerrero *et al*. 2008, Price & Ogle 2008).

We hypothesized that the level of knowledge of the ecology and reproductive biology of wild edible species is combined with their use importance (frequency of consumption and market value), and their biological characteristics (e.g., life form, availability periods) to shape their management or procurement practices at community, household and individual levels. We first examined any possible socioeconomic pattern (gender, age, ethnicity, land tenure and availability, education) in plant management with respect to the richness and botanical characteristics of managed species. Then for sets of species that each possible socioeconomic group might be specialised in, we analyzed how knowledge of the ecology and the reproductive biology was combined with plant use importance to influence the intensity of management practices. Wild edible plant use importance in rural communities is reflected by many variables such as frequency of consumption, the availability during the food shortage periods and the market value.

Physical setting

The study was carried out in the Collines region in central Benin, West Africa (Figure 1). This region covers 13,561 km^2 (12% of the country area) with an estimated population of 747,772 inhabitants in 2011 (7% of the country population). The population density averages 46 inhabitants/km^2.

The region is located in the Sudano-Guinean climatic zone of the country (Wezel & Böcker 2000). Annual rain-

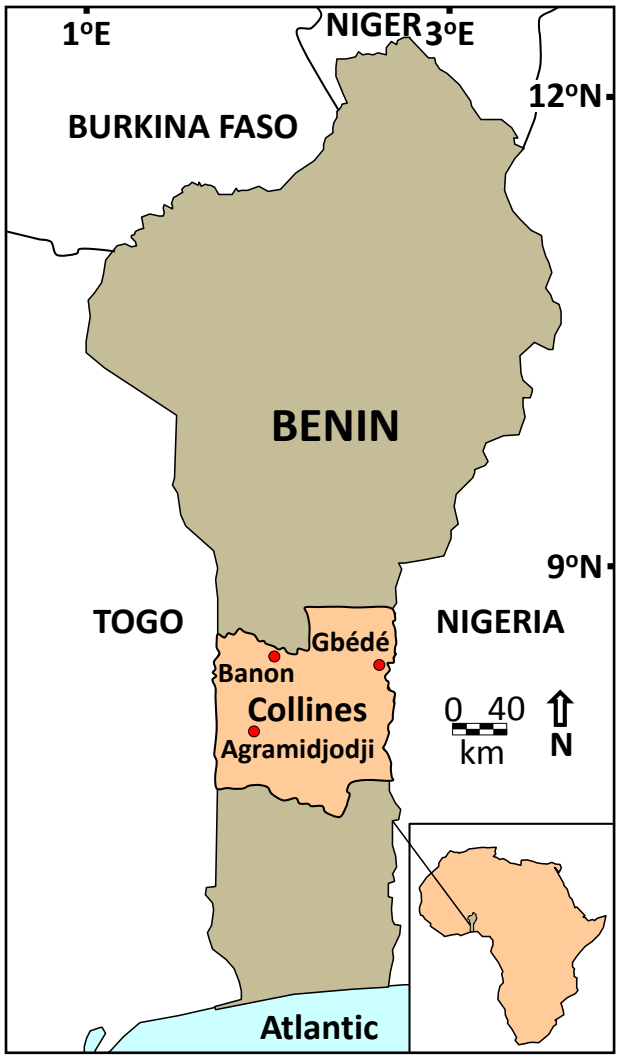

Figure 1. Collines Department, Benin with three study site villages of Aglamindodji, Banon, and Gbédé.

falls average 1100 - 1300 mm/year and the vegetation consists mostly of woodlands, tree savannas and fallows dominated by *Parkia biglobosa* (Jacq.) R. Br. ex G. Don, *Diospyros mespiliformis* Hochst. ex A. DC., and *Vitellaria paradoxa* C.F. Gaertn. (Wezel & Böcker 2000). Forest areas are however rapidly decreasing and fallow lengths (4-7 years) diminishing because of the rapid growth of the population associated with the immigration of other people from marginal regions of the country, especially from the Southwest with high population densities (up to 500 inhabitants/km^2) and the Atacora region with rocky soils and little arable lands (Igue *et al*. 2000, Vissoh *et al*. 2004). Crop fields and fallows are therefore expanding, favoring the expansion of wild edible species of farming environments and the reduction of typical forest species occurrence (Igue *et al*. 2000).

People, culture, and economic setting

The major ethnic groups of the Collines region include the Tchabe, Mahi, Idaatcha, and Ife which represent altogether 72% of the population. Minorities include the Fon, Aja, Fulani, and many other small groups representing altogether 13% of the population (Floquet & van den Akker 2000).

The Tchabe, Ife, Idaatcha and Mahi form the most ancient of these peoples. They have all settled in the area and have been interacting with this environment for centuries (Floquet & van den Akker 2000, Kluge 2000). They are recognized as the native people and landowners of the area by historians and traditional land tenures (Floquet & van den Akker 2000). The Tchabe, Ife and Idaatcha are reported to have close linguistic and cultural affinities because they belong to the same umbrella sociolinguistic and cultural group called Ede-Yoruba which originated in Nigeria (Kluge *et al*. 2011). The Mahi, by contrast, belong to a quite different umbrella sociolinguistic and cultural group called Gbe-Aja which originated in Togo (Kluge 2000). Each of these four groups is known to be tightly attached to its cultural identity. For a long time, historical, ethnic, and political rivalries have existed between the Mahi on one hand and the Tchabe, Idaatcha and Ife on the other. Because of these ancient rivalries, people generally live in settlements dominated by one of the four major ethnic groups.

The Fon and Adja peoples are immigrants who have migrated recently from marginal agricultural areas. Culturally they show close affinities with the Mahi people because they belong to the Gbe-Aja linguistic and cultural group too (Kluge 2000). Usually they live in minorities in settlements dominated by any of the four major ethnic groups and have restricted land rights (Le Meur 2006). The Fulani are nomadic and pastoralist people herding cattle and goats. More and more they settle around villages.

Except for the Fulani, agriculture is the main activity in the region with more than 66% of households depending on farming activities as the sole mean of subsistence. Land is generally inherited and farm size ranges from 2 to 20 ha with some landlords owning even more (Vissoh *et al*. 2004). Maize is the dominant crop followed by cotton, yam, cowpea and cassava, and crop yields are the best recorded in the country (Igue *et al*. 2000). However, many households generally experience seasonal food shortages during a period of the year and the acuity of the famine varies from household to household. Gathering and the domestication of wild plants are also important activities which contribute to enhance food supply and diversity in the area (Achigan-Dako *et al*. 2009).

In 2006, 40% of the population of the area was aged between 18-59 years. An important feature of this genera-

tion is that many of them have migrated from the area in the 1980s-90s towards neighboring countries such as Nigeria, Côte d'Ivoire and big or emerging cities of Benin for better and non-agricultural job opportunities (Le Meur 2006). However, most of them have been coming back to conduct agricultural work in their native villages because of unemployment and the deterioration of the socio-political context in these destination places (Le Meur 2006). Women in the area play an important role in agriculture and household food security. Twenty-nine percent of the households of the area are headed by women.

Methods

This paper is based on field research conducted in September to October 2009. Data were collected at the community level through focus group discussions, and at household and individual levels through semi-structured interviews of a sample of household members.

Prior Informed consent

We obtained prior informed consent verbally both at the community and household levels. At the community level, program leaders of the Crop, Aromatic and Medicinal Plant Biodiversity Research and Development Institute of Benin (IRDCAM), a non-government organization involved in the research, contacted the community leaders (chiefs of villages, advisors and elders). IRDCAM has been conducting research, development, and conservation activities on plant biodiversity in the area for at least nine years (Dansi *et al*. 2008). It has been collaborating successfully with the studied communities since then and is well known to them. The IRDCAM leaders shared the research with the community leaders and obtained their approval and suggestions on practical aspects. A community meeting was then organized in each village to share the purpose and benefits of the research with people. At household level, data interviewers orally obtained the consent of the household heads to participate in the research.

Sampling strategy

Three of the four major ethnic groups of the study area were considered for this study: Tchabe, Mahi and Ife. As the Tchabe and Ife groups show close linguistic and cultural affinities, we expect that they would show greater similarities in the pattern of plant diversity management. Three villages each dominated by one of these three ethnic groups were selected in the area: the village of Aglamindodji mostly populated by the Mahi people, the village of Banon mostly populated by the Ife people and the village of Gbédé mostly populated by the Tchabe people (Figure 1).

In each village, we first formed a focus group including key male and female informants indicated by community leaders to collect general data at the community level. Then, together with the leaders, we developed a list of households to use as sampling basis for individual interviews. To be able to analyze properly how gender affects the management of plants within households, we considered only households including both husbands and their spouses. Because of complex interactions among several spouses (e.g., conflicts, competition, cooperation, knowledge sharing, etc.), we excluded polygamous households. We randomly sampled 20 households from this list and a village guide conducted the interviewers to them. In each household, we interviewed the husband (household head) and his wife separately. Therefore, 120 respondents including 60 males and 60 females were surveyed in the three ethnic groups.

This sampling design allowed an analysis of relationships between men and their wives within households regarding diversity management. It shows however a few limitations. First, it did not include female-headed households. Therefore, it was not possible to compare female-headed to male-headed households and to infer how gender influences decision-making in the management of wild edible plants at the household level. Second, it did not allow studying relationships among spouses in polygamous households.

Focus groups, interviews, and data collection

During the focus groups, we recorded the vernacular names of wild edible plants, the areas where they occur (fields, fallows, gardens, etc.), the various management practices used in the village, the market value based on selling prices (low, medium, high). At the household level, each household head and his wife were interviewed separately using a questionnaire. The questionnaire used both quantitative and qualitative approaches and was structured as follows:

1. Demographic data: age, ethnic group, and education level of the household head and his wife, the household size, and the number of farmers' associations the household participated in,
2. Economic data: principal occupation, off-farm activities of the household head and his wife, the total farmland area, the area under cultivation during the four last years for each interviewee, the crop species grown and their areas during the four last years, and the number of food shortages (exhaustion of stocks of regular meals) experienced by the household during the four last years,
3. Ethnobotanical data:
   (a) the list (free listing) of wild species of farming environments (fields, fallows, etc.) consumed as food by the respondent that he or she managed, that is intentionally gathered to increase food availability at the household level or managed on-farm,
   (b) the frequency of consumption of each species measured on an ordinal scale as follows: everyday (5), 1 - 3 times a week (4), 1 - 2 times a month (3), 1 - 2 times a year (2), more than 2 years ago

(1). We used an ordinal scale because, as the assessment covers the three to four past years, the respondents might not accurately evaluate the frequency of consumption of each species,
(c) the market value of each species as perceived by each respondent: non-marketed (0), marketed (1),
(d) the period of availability of each species in the respondent's environment: all year (0), the food abundance period (1), the food shortage period (2),
(e) the perception of the respondent of the availability of each species in his or her environment on a ordinal scale: rare (1), middle (2), common (3), very common (4) (Pieroni 2001),
(f) the dominant management or procurement practice of each species reported on an ordinal scale from 0 to 5 as described in Casas *et al*. (1996) and Price (2006): gathering (0), on-farm retention (the species is retained when land is cleared while all other undesirable wild species are removed) (1), managed through tendering, nurturing, encouraging growth (e.g., removal of other weeds) (2), transplanting from wild (3), cultivation- propagation (4),
(g) the level of knowledge of the ecology and biology, especially the propagation and seed conservation methods that each respondent has on each species, measured on an ordinal scale: no knowledge (0), knowledge of the fruiting period and places where seedlings or saplings occur (1), knowledge of the propagation modes (seeds, cuttings, etc.) (2), knowledge of effective seed conservation methods, i.e., practices able to conserve seed for more than 12 months (3).

Other qualitative data included the other uses of the species, the complete description of the management practices, and the constraints faced by farmers. Native language speakers translated the dialogues during interviews.

Taxonomic identification and voucher specimens

The first time a species was mentioned (vernacular name) by a respondent, he took the interviewers to find its voucher specimens. Then any time another respondent mentioned the same vernacular name, the interviewers showed the voucher and asked him to confirm whether he was referring to that species. In cases the respondent asserted that the name mentioned referred to a different species or in cases of doubts or hesitations, he systematically took the interviewers to find the specimen corresponding to his description. Dr. Paul Yedomonhan from the National Herbarium of Benin consulted on plant identification. Voucher specimens were deposited at the Herbier National du Bénin, Faculte des Sciences et Technique Université National du Bénin, Campus Universitaire d'Abomey-Calavi (BENIN).

Data analysis

All data were arranged in a matrix including demographic and economic data for each household and its members, and ethnobotanical data for each species as reported by each respondent. The diversity in terms of number and composition of wild edible species was determined at community, household and individual levels. The Sorensen dissimilarity index (H) was calculated to assess communities' similarity with respect to managed species as follows: H = (a+b-2c)*(a+b)-1, where a and b are the number of species in community A and B, and c the number of species shared by both communities. An H of 100% indicates total dissimilarity; an H of 0% indicates total similarity (Höft *et al*. 1999). The species frequency within the communities was determined and the most widespread species identified. We used a generalized linear model with the Poisson distribution (G^2 statistic) and the log-link function to test whether species frequencies varied with their life form in the studied sample.

To examine possible socioeconomic patterns among households with respect to the number and the composition of managed species, we first used a conditional inference tree-based classification model (Hothorn *et al*. 2006, Nagy *et al*. 2010, Zeileis *et al*. 2008). The dependent variable was the number of species (overall, herb or tree) managed at the household level, and explanatory variables included households' socioeconomic characteristics namely the age of the household heads, the area cropped by wives, the area available per head, the number and duration of food shortages that the households experienced during the four last years, the off-farm activities of heads, the ethnic group and the education level of heads and their wives and the household size. Conditional inference trees estimate a non-parametric regression relationship by binary recursive partitioning by means of conditional distributions (Hothorn *et al*. 2006, Zeileis *et al*. 2008). These models show a number of advantages compared with traditional statistical models such as generalized linear models and linear discriminant analysis (Hothorn *et al*. 2006, Nagy *et al*. 2010, Zeileis *et al*. 2008). First, conditional inference tree-based models make no distributional assumptions of any kind. The models' reliance is not affected by outliers, collinearities, heteroscedascities or distributional error structure (Hothorn *et al*. 2006, Nagy *et al*. 2010, Zeileis *et al*. 2008). Second, explanatory variables can be a mixture of categorical and continuous and split points, that is, threshold values of explanatory variables for significant changes in the distribution of the response are computed. The significance of the split points is assessed with a C_{quad}-type statistic ($\sim\chi^2$) and corrected Bonferroni p-values (Hothorn *et al*. 2006, Zeileis *et al*. 2008). In that way no prior grouping is needed for continuous explanatory variables. Third and most importantly, complex interactions with a large set of explanatory variables and nonlinear relationships which are difficult to decipher with traditional statistical methods can be modelled (Hothorn *et al*. 2006, Nagy *et al*. 2010, Zeileis *et al*. 2008).

The model accuracy was assessed with the percentage of misclassification. Then, we used the hierarchical cluster analysis (Sorensen dissimilarity matrix – incidence data) to examine any possible specialization or preferences of households with respect to species managed.

To determine socioeconomic patterns in the number of species managed at the individual level within households, we used a generalized linear mixed model with the Poisson distribution (G^2 statistic), with age, ethnic group and gender as fixed factors and households as the cluster factor (Crawley 2007). The exchangeable correlation matrix was used to take into account any possible correlation between members within households. The distribution of the number of species per individual was compared for the levels of significant factors and their interactions. The distribution of the number of species grown by both genders per household was also examined to decipher any possible specialization of household members with respect to species managed within households. We then used the conditional inference tree-based model to examine ethnobotanical factors that may influence the gender specificity of managed species, that is whether a species is more likely to be grown by one gender or the other. The response was the newly-defined variable called "gender specificity" with three levels: (1) female-specific, (2) male-specific, and (3) both genders. Any time a species was reported only by the wife in a household, the variable was assigned the value "female-specific" and any time it is mentioned only by the husband, the variable was assigned the value "male-specific", otherwise when the species was reported by both genders, the variable was assigned the value "both genders". The explanatory variables were biological and ethnobotanical characteristics of the species namely the species life form, period of availability, market value as perceived by each respondent, and procurement practices (gathering or managed on-farm).

To determine factors that influence the highest intensity of species management at community level, each species was assigned the highest value of management intensity recorded at the community level. Then we used the Spearman's rho correlation statistic to test if species' highest intensity of management at community level was associated with the levels of knowledge people have on their ecology and biology.

To examine factors influencing management practices at the individual level, we used a conditional inference tree model. Explanatory variables included socioeconomic factors determining specialization in managed species that were identified previously, and biological and ethnobotanical characteristics of the species namely their life form, their frequency of consumption, their period of availability and their market value and the level of knowledge that respondents have on their ecology and biology. R statistical software was used for all statistical analyses (R Core Development Team 2009).

Results

Socioeconomic characteristics of the household sample

Heads of households sampled in each village were exclusively from the same ethnic group. Moreover, heads and their wives within households were almost exclusively from the same ethnic group (100% of the Mahi, 95% of the Ife and Tchabe households).

The three samples showed similar distributions of the age of household heads and their wives (Table 1). However, there were many more illiterate people in the Ife group than in the Mahi and Tchabe groups (Table 1). In all three ethnic groups, the proportion of household heads who received no school education was higher in the group aged more than 48 years (50-86%) than in the group aged less than 48 years (31-63%, Table 1).

Farming was the principal activity of all respondents. Though the total farmland area and household size were higher for the Ife (Banon) and Mahi (Aglamindodji) than the Tchabe (Gbédé), the area per head was similar in the three groups (1.8 ha/head for the Ife, 2.0 ha/head for the Tchabe and 2.1 ha/head for the Mahi). Wives rarely own farmlands (Table 1). However, they may grow their own crops on small patches of lands allocated by their husbands (usually less than 10% of the household farmlands, Table 1).

Wild food species diversity and frequency at the community level

In total, 40 wild edible species including 22 herbs and 18 trees were reported as consumed and managed in the three communities (Table 2). Almost 78% of this diversity was observed in the Ife group (31 species), while only 53% and 49% occurred respectively in the Tchabe (21 species) and Mahi groups (19 species). The Sorensen index (Bray–Curtis) of dissimilarity indicated a lower degree of dissimilarity between the Mahi and the Tchabe groups (35%) with respect to managed species, while the dissimilarity was more pronounced between the Mahi and the Ife (48%), or the Ife and the Tchabe (42%).

Only 50% of the herbaceous and 33% of the tree species were reported by at least 15% of the households (Table 2). The most common species in the three communities were *Launaea taraxacifolia* (Willd.) Amin ex C. Jeffrey (herb, 60% of households), *Sesamum radiatum* Schumach. & Thonn. (herb, 41% of households), V*itex doniana* Sweet (tree, 40% of households), *Crassocephalum rubens* (B. Juss. ex Jacq.) S. Moore (herb, 33% of households), *Lippia multiflora* Moldenke (herb, 31% of households, Table

Table 1. Socioeconomic characteristics of households in villages of the Collines region, central Benin. Household ages: Heads aged 48 or more = old; under 48 years = young.

Characteristics			Villages		
			Banon (Ife)	Gbédé (Tchabe)	Aglamaindodji (Mahi)
Number of households			20	20	20
Dominant ethnic group			Ife (100%)	Tchabe (100%)	Mahi (100%)
Farmland area (mean±SD) hectares			25.4±13.5	16.1±11.7	30.0±13.8
Wives' farmland area (mean±SD) hectares			1.0±1.58	0.32±0.65	0.15±0.67
Wives' cultivated area (mean±SD) hectares			2.33±2.0	1.1±0.6	0.40±0.9
Age of heads of households (mean±SD) years			49±13	42±12	46±11
Age of wives (mean±SD) years			42±11	38±11	39±9
Size of households (mean±sd)			14±7	8±4	14±5
Education level of heads of households	No education	old	100%	50%	86%
		young	63%	31%	38%
		total	80%	35%	55%
	Primary school	old	0%	25%	0%
		young	9%	31%	31%
		total	5%	30%	20%
	Secondary school	old	0%	25%	14%
		young	28%	38%	31%
		total	15%	35%	25%
Educational level of wives	No education		95%	90%	90%
	Primary school		5%	10%	5%
	Secondary school		0%	0%	5%

Table 2. Diversity, frequency, market value and uses of wild food species managed by Ife, Mahi and Tchabe communities (n=60) of the Collines region, central Benin. Organs are first presented followed by forms of consumption in brackets.

Life form	Species	Proportion of households	Organs / forms of consumption	Market value
Tree	*Vitex doniana* Sweet	40%	Leaf (vegetable), fruit (eaten fresh)	Medium, increasing
	Caesalpinia bonduc (L.) Roxb.	30%	Leaf (vegetable & medicine), root & seed (medicine)	High
	Parkia biglobosa (Jacq.) R.Br. ex G.Don	25%	Seed (condiment)	High
	Vitellaria paradoxa C.F. Gaertn.	23%	Fruit (eaten fresh), nut (butter)	High
	Adansonia digitata L.	16%	Leaf (vegetable), fruit (commercial juice)	High
	Bixa orellana L.	15%	Fruit (condiment, replacing tomatos in sauce)	Medium
	Cissus populnea Guill. & Perr.	8%	Leaf (slimy sauce), stem (condiment)	Low
	Ceiba pentandra (L.) Gaertn.	7%	Leaf (vegetable & medicinal)	Low
	Ficus abutilifolia (Miq.) Miq.	7%	Leaf (vegetable & medicine)	Low
	Vernonia colorata (Willd.) Drake	5%	Leaf (vegetable & medicine)	Low

Life form	Species	Proportion of households	Organs / forms of consumption	Market value
Tree	*Blighia sapida* K.D. Koenig	3%	Leaf (spinach), fruit (in sauce)	Low
	Bombax costatum Pellegr. & Vuillet	3%	Leaf (slimy sauce, medicine & mystic uses)	Low
	Rauvolfia vomitoria Afzel.	3%	Leaf (medicine & spinach)	Low
	Ximenia americana L.	3%	Fruit (eaten fresh)	Low
	Clausena anisata (Willd.) Hook.f. ex Benth.	2%	Leaf (vegetable), root (medicine)	Low
	Phyllanthus muellerianus (Kuntze) Exell	2%	Leaf (vegetable)	Low
	Psorospermum alternifolium Hook.f.	2%	Leaf (vegetable & medicine)	Low
	Sterculia tragacantha Lindl.	2%	Leaf (slimy sauce)	Low
	Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	2%	Root (condiment & medicine)	Low
Herb	*Launaea taraxacifolia* (Willd.) Amin ex C. Jeffrey	60%	Leaf (vegetable)	Medium, increasing
	Sesamum radiatum Schumach. & Thonn.	42%	Leaf (vegetable)	Medium
	Crassocephalum rubens (B. Juss. ex Jacq.) S. Moore	33%	Leaf (vegetable)	Medium
	Lippia multiflora Moldenke	32%	Leaf (vegetable, medicine & aroma), flower (herbal tea),	Medium, increasing
	Ocimum basilicum L.	28%	Leaf (vegetable & medicine)	Medium
	Talinum triangulare (Jacq.) Willd.	28%	Leaf (vegetable & medicine)	High
	Dioscorea praehensilis Benth.	25%	Tuber (staple food)	High
	Celosia argentea L.	23%	Leaf (vegetable)	High
	Ceratotheca sesamoides Endl.	23%	Leaf (vegetable)	Medium
	Ocimum gratissimum L.	22%	Leaf (vegetable & medicine)	High
	Celosia trigyna L.	18%	Leaf (vegetable)	Medium
	Hibiscus sabdariffa L.	13%	Leaf (spinach), flower (juice)	Low
	Haumaniastrum caeruleum (Oliv.) P.A. Duvign. & Plancke	12%	Leaf vegetable)	Low
	Cleome gynandra L.	7%	Leaf (vegetable)	Low
	Corchorus tridens L.	5%	Leaf (vegetable)	Low
	Momordica charantia L.	5%	Leaf (vegetable & medicine)	Low
	Ocimum americanum L.	5%	Leaf (vegetable & medicine)	Medium
	Platostoma africanum P. Beauv.	5%	Leaf (vegetable)	Low
	Justicia tenella (Nees) T. Anderson	3%	Leaf (vegetable)	Low
	Pergularia daemia (Forssk.) Chiov.	3%	Leaf (vegetable & medicine)	Low
	Solanum erianthum D. Don	2%	Leaf (vegetable)	Low

2). Herbs were generally more widespread in the three communities than trees (11±3 households per herb species against 6±2 households per tree species, G^2=23.50, p<0.001).

Socioeconomic patterns in wild food species' diversity management at household level

Most households consumed and managed a diversity of wild or semi-wild species, with an average of 6±4 species/household (Figure 2a). Herb species diversity at

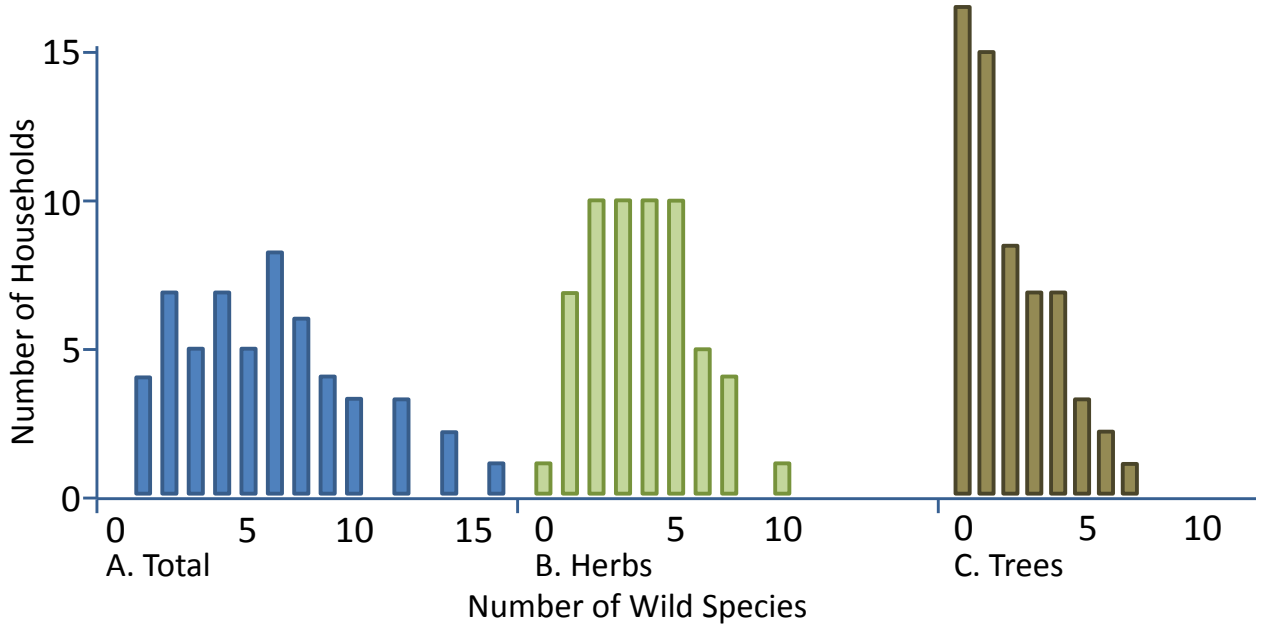

Figure 2. Distribution of the number of wild food species (total,herbs, and trees) managed by households (n=60) in villages of the Collines region, central Benin.

household level (4±2 species/household, Figure 2b) was two times higher than tree species diversity (2±2 species/household, G^2=38.73, p<0.001, Figure 2c). The conditional inference model showed that the total number of wild edible species managed at household level was associated with only the age of the household heads (Bonferroni's p<0.001) which was strongly correlated with the age of their wives (Pearson's correlation, R^2=0.92, p<0.001). Households headed by men aged less than 48 years managed less diversity (4±1 species) than households headed by men aged more than 48 years (9±1 species/household).

This trend was maintained when only herbs were considered (3±1 herb species/household with heads aged less than 48 years and 5±1 herb species/household with heads aged more than 48 years, Bonferroni's p<0.001). When only trees were considered, the area owned by women (Bonferroni's p=0.022) combined with the age of heads (Bonferroni's p<0.001) to influence the observed diversity. In younger households, tree species diversity was significantly lower when the area owned by women was less than 0.4 ha (1±1 tree species/household) compared to when women owned more than 0.4 ha (2±1 tree species/household). This latter case was less frequent as it occurred in only 12% of households. Contrary to younger households, the area of land owned by women did not affect tree diversity managed by older households which managed in average 3±1 tree species (Bonferroni's p>0.05).

There was no influence of the area cropped by women, area available per head, number of food shortages households experienced during the last four years, off-farm activity of the households' heads, ethnic group of heads and their wives, households' size, and the education level of heads and their wives on the herb, tree and overall species diversity managed by households (p>0.05 each of these variables).

Based on similarities among households with respect to managed species, three major household groups differing in the dominant ethnic groups were distinguished (G^2=89.8, p<0.001, Figure 3). Each group was mostly made of one of the three ethnic groups (Ife, Tchabe and Mahi, Figure 3). Within each group, the composition of managed species varied with the age of household heads (Figure 3). Younger households favored a few herbs species which are part of the diet habits and have attractive market values such as *L. taraxacifolia*, *C. rubens* and *S. radiatum* (Table 3). They rarely managed tree species. *Vitex doniana* is the most widespread tree species used among younger households (26.3% of younger households, Table 3). In contrast, older households managed a greater diversity of both herbs (e.g., *L. taraxacifolia*, *S. radiatum*, *L. multiflora*, *Talinum triangulare* (Jacq.) Willd., *Celosia argentea* L., *C. rubens*, *Dioscorea praehensilis* Benth., *Ocimum basilicum* L., *Celosia trigyna* L., *Ceratotheca sesamoides* Endl.) and trees (e.g., *V. doniana*, *Caesalpinia bonduc* (L.) Roxb., *Vitellaria paradoxa* C.F. Gaertn, *P. biglobosa*, *Adansonia digitata* L., Table 3)

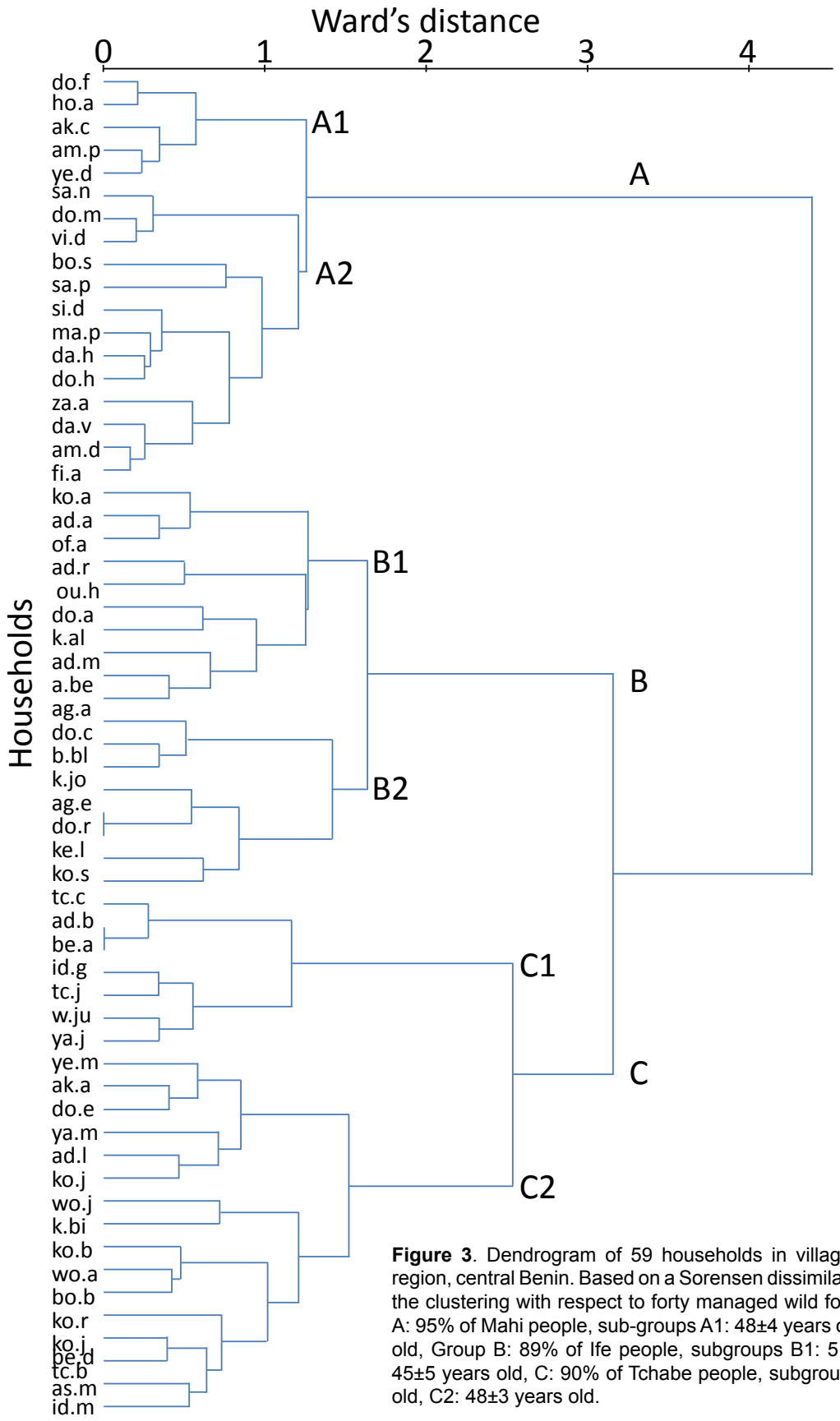

Figure 3. Dendrogram of 59 households in villages of the Collines region, central Benin. Based on a Sorensen dissimilarity matrix showing the clustering with respect to forty managed wild food species. Group A: 95% of Mahi people, sub-groups A1: 48±4 years old, A2: 44±4 years old, Group B: 89% of Ife people, subgroups B1: 51±4 years old, B2: 45±5 years old, C: 90% of Tchabe people, subgroups C2: 32±3 years old, C2: 48±3 years old.

Table 3. Importance of wild edible species managed by two age categories in villages of the Collines region, central Benin. Household ages: Heads age 48 or more = old; under 48 years = young. Higher values/age noted in red.

Life form	Species	Proportion (%) of households	
		older (n=22)	younger (n=38)
herb	*Celosia argentea* L.	40.9	13.2
	Celosia trigyna L.	27.3	13.2
	Ceratotheca sesamoides Endl.	27.3	21.1
	Cleome gynandra L.	13.6	2.6
	Corchorus tridens L.	9.1	2.6
	Crassocephalum rubens (B. Juss. ex Jacq.) S. Moore	40.9	28.9
	Dioscorea praehensilis Benth.	36.4	18.4
	Haumaniastrum caeruleum (Oliv.) P.A. Duvign. & Plancke	13.6	10.5
	Hibiscus sabdariffa L.	18.2	10.5
	Justicia tenella (Nees) T. Anderson	4.5	2.6
	Lagenaria siceraria (Molina) Standl.	13.6	7.9
	Launaea taraxacifolia (Willd.) Amin ex C. Jeffrey	68.2	55.3
	Lippia multiflora Moldenke	50.0	21.1
	Momordica charantia L.	9.1	2.6
	Ocimum americanum L.	9.1	2.6
	Ocimum basilicum L.	36.4	23.7
	Ocimum gratissimum L.	22.7	21.1
	Pergularia daemia (Forssk.) Chiov.	4.5	2.6
	Platostoma africanum P. Beauv.	4.5	5.3
	Sesamum radiatum Schumach. & Thonn.	68.2	26.3
	Solanum erianthum D. Don	0.0	2.6
	Talinum triangulare (Jacq.) Willd.	45.5	21.1
tree	*Cissus populnea* Guill. & Perr.	13.6	5.3
	Adansonia digitata L.	36.4	5.3
	Bixa orellana L.	27.3	7.9
	Blighia sapida K.D. Koenig	9.1	0.0
	Bombax costatum Pellegr. & Vuillet	9.1	0.0
	Caesalpinia bonduc (L.) Roxb.	50.0	18.4
	Ceiba pentandra (L.) Gaertn.	13.6	2.6
	Clausena anisata (Willd.) Hook.f. ex Benth.	0.0	2.6
	Ficus abutilifolia (Miq.) Miq.	9.1	5.3
	Parkia biglobosa (Jacq.) R.Br. ex G.Don	36.4	18.4
	Phyllanthus muellerianus (Kuntze) Exell	0.0	2.6
	Psorospermum alternifolium Hook.f.	0.0	2.6
	Rauvolfia vomitoria Afzel.	9.1	0.0
	Sterculia tragacantha Lindl.	4.5	0.0
	Vernonia colorata (Willd.) Drake	13.6	0.0
	Vitellaria paradoxa C.F. Gaertn.	36.4	15.8
	Vitex doniana Sweet	63.6	26.3
	Ximenia americana L.	9.1	0.0
	Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	4.5	0.0

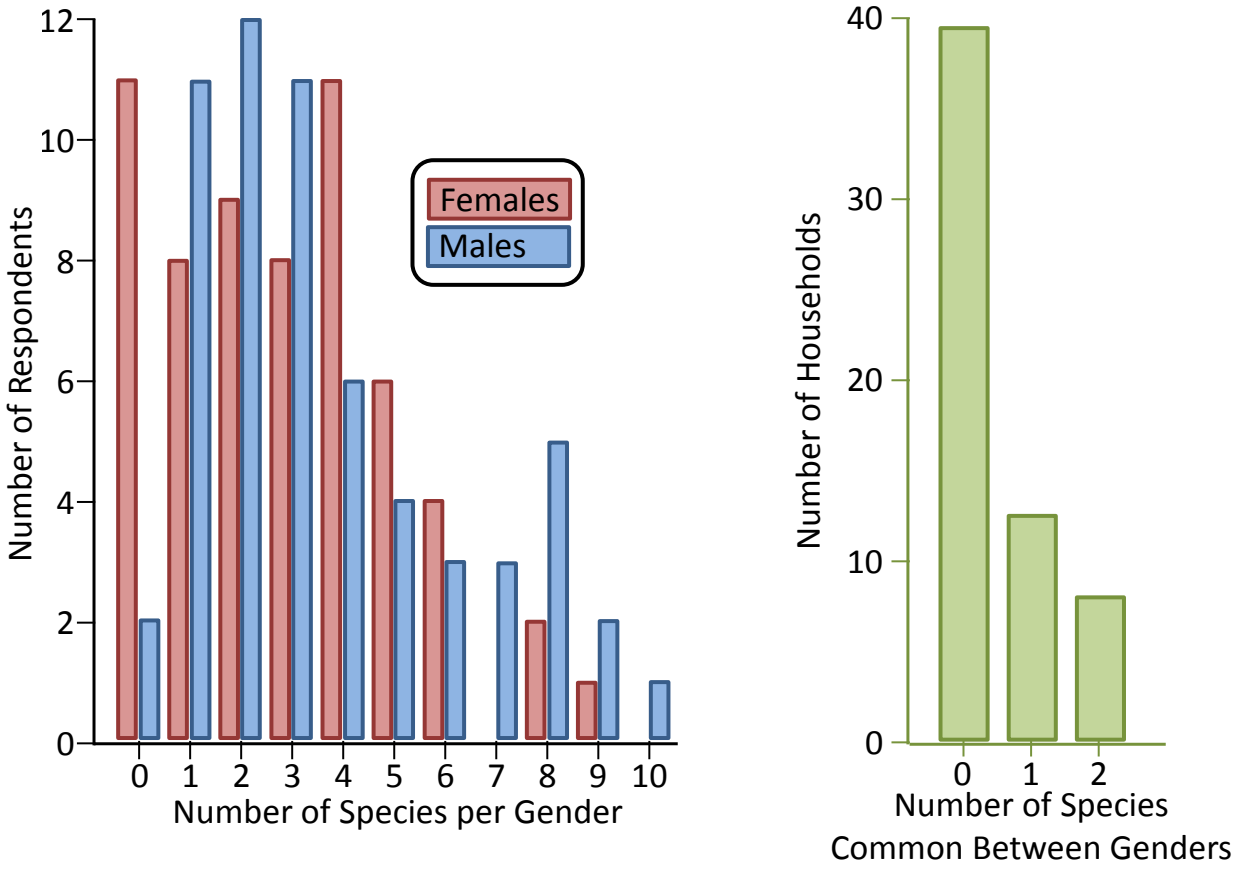

Figure 4. Distribution of (a) the number of species managed per gender within households, and (b) the number of species commonly managed by both genders per household in villages of the Collines region, central Benin.

Socioeconomic patterns in wild food species diversity managed within households

Within households, husbands managed a significantly higher number of species than wives did regardless of ethnic and age group differences (3.8±0.2 species/male and 2.9±0.3 species/female, G^2=4.9, p=0.028 for gender, p>0.05 for all interactions, Figure 4a). Moreover, they rarely managed the same species within households. The mean number of species managed by both men and women per household was 0.5±1.0 species with a minimum of zero and a maximum of two, that is approximately 6.3±1.2% of the average diversity managed at household level (Figure 4b). Men exclusively managed 16 species out of which five were herbs while women exclusively managed four species out of which three were herbs (Table 4). The other species were managed by only men (or women) in some households while in other households they were managed by only women (or men) or by both genders (Table 4). Three factors, namely species life form, periods of availability and market values of the species interacted to influence the gender specificity of species,

Table 4. Wild plant species managed by frequency, gender and life form. Species in red were reported exclusively by one gender for the whole studied sample. Figures in brackets represent the relative frequency (%) of the species per gender (i.e., the number of cases the species is recorded for a gender divided by the number of cases the species was reported among all respondents).

Species	Frequency managed					
	Females		Males		Both	
	Herbs	Trees	Herbs	Trees	Herbs	Trees
Adansonia digitata L.				100%		
Bixa oreliana L.		45%		55%		
Blighia sapida K.D. Koenig				100%		

Species	Frequency managed					
	Females		Males		Both	
	Herbs	Trees	Herbs	Trees	Herbs	Trees
Bombax costatum Pellegr. & Vuillet		50%		50%		
Caesalpinia bonduc (L.) Roxb.				90%		10%
Ceiba pentandra (L.) Gaertn.		25%		75%		
Celosia argentea L.	66%		20%		14%	
Celosia trigyna L.	65%		7%		28%	
Ceratotheca sesamoides Endl.	80%		20%			
Cissus populnea Guill. & Perr.			100%			
Clausena anisata (Willd.) Hook.f. ex Benth.				n.a.		
Cleome gynandra L.	50%		50%			
Corchorus tridens L.	100%					
Crassocephalum rubens (B. Juss. ex Jacq.) S. Moore	45%				25%	
Dioscorea praehensilis Benth.			100%			
Ficus abutilifolia (Miq.) Miq.		25%		75%		
Haumaniastrum caeruleum (Oliv.) P.A. Duvign. & Plancke	58%		42%			
Hibiscus sabdariffa L.	38%		53%			
Justicia tenella (Nees) T. Anderson	100%					
Lagenaria siceraria (Molina) Standl.						
Launaea taraxacifolia (Willd.) Amin ex C. Jeffrey	55%		25%		20%	
Lippia multiflora Moldenke	20%		10%		70%	
Momordica charantia L.			50%		50%	
Ocimum americanum L.	100%					
Ocimum basilicum L.	26%		52%		22%	
Ocimum gratissimum L.	45%		55%			
Parkia biglobosa (Jacq.) R.Br. ex G.Don				100%		
Pergularia daemia (Forssk.) Chiov.	50%		50%			
Phyllanthus muellerianus (Kuntze) Exell				n.a.		
Platostoma africanum P. Beauv.			100%			
Psorospermum alternifolium Hook.f.				n.a.		
Rauvolfia vomitoria Afzel.		50%		50%		
Sesamum radiatum Schumach. & Thonn.	50%		35%		15%	
Solanum erianthum D. Don			n.a.			
Sterculia tragacantha Lindl.		n.a.				
Talinum triangulare (Jacq.) Willd.	50%		40%		10%	
Vernonia colorata (Willd.) Drake				100%		
Vitellaria paradoxa C.F. Gaertn.				100%		
Vitex doniana Sweet		46%		39%		15%
Ximenia americana L.				100%		
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler				n.a.		
Total number of species	**17**	**7**	**19**	**17**	**9**	**2**

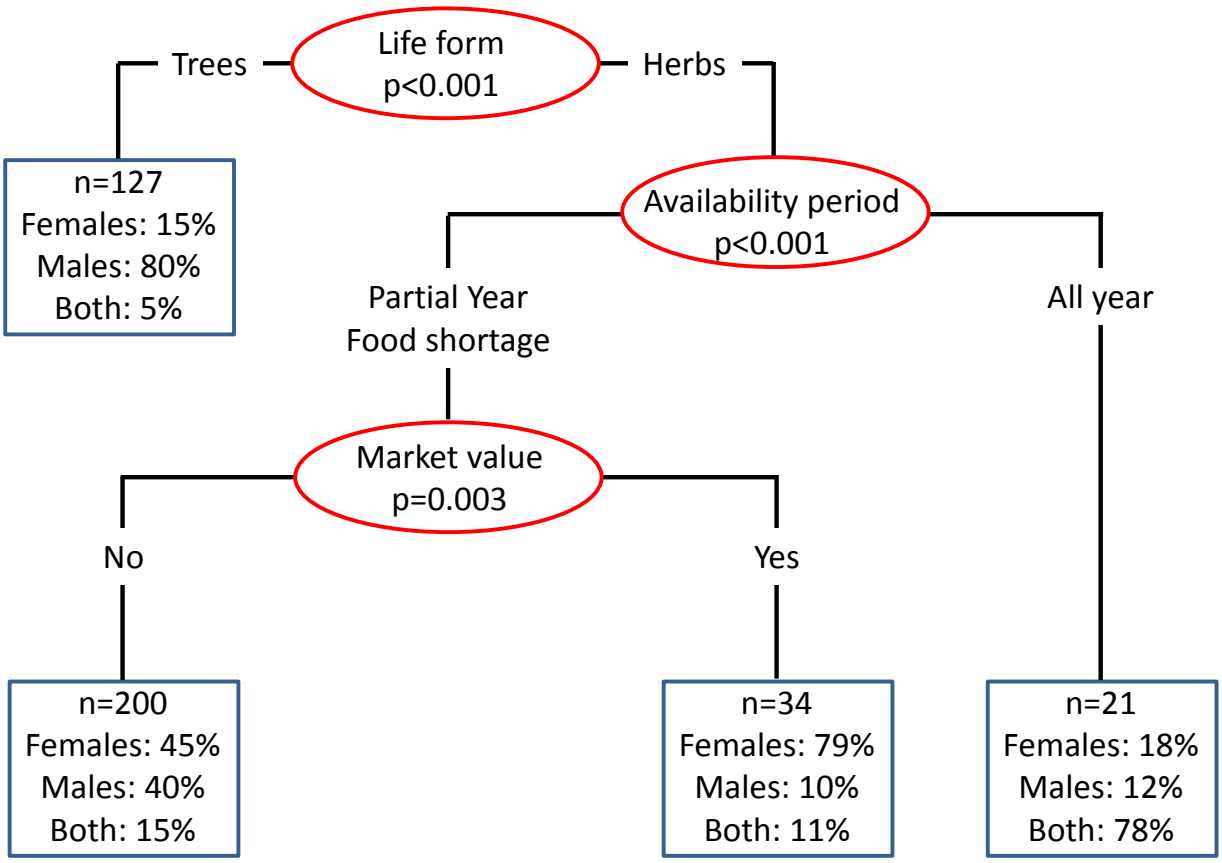

Figure 5. Conditional inference tree showing the factors influencing the gender specificity of managed species in villages of the Collines region, central Benin. p represents the Bonferroni-adjusted p-values, n =number of mentions.

that is whether a species is most likely to be managed by husbands only, their wives only or both members within the household (Figure 5). Trees and lianas were mostly managed by men only (80% of mentions, Figure 5). This is the case for *D. praehensilis*, grown by men to increase the on-farm diversity of cultivated yams. Herbs which were available to households only during the food shortage period and were marketed were mostly managed by women only (79% of cases, Figure 5). This is the case of *Ocimum americanum* L., *Corchorus tridens* L., *Justicia tenella* (Nees) T. Anderson, *C. sesamoides*, *C. argentea* and *C. trigyna* (Table 4). Herb species that were available during the food shortage period and were not marketed were managed either by men only (40% of cases) or by their wives (45% of cases) (Figure 5). By contrast, herb species that were available throughout the year were mostly managed by both genders within households (Figure 5).

Factors influencing highest intensities of management practices at community level

From the 40 wild food species managed by the three ethnic groups, only 15% were exclusively gathered (in old fallows essentially) while 17% reached the cultivation stage and 68% reached intermediate steps. In this last group the species were retained on-farm and tendered, or transplanted from the wild to farms and home gardens (Table 5). Most tree species were either exclusively gathered or retained on-farm (83%). Only three tree species out of 18 were reported to be transplanted from the wild or deliberately planted by farmers (Table 5). Conversely, no herbaceous species was exclusively gathered (Table 5). 40% of the herbs reached the on-farm retention stage, 35% were transplanted from the wild and 25% were deliberately cultivated (Table 5).

The highest management intensity observed was the same in all ethnic groups for some species, while it varied across communities for other species (Table 5). The most contrasting cases observed were *S. radiatum* and *T. triangulare* (herbs), and *C. bonduc* and *P. biglobosa* (trees, Table 5). *Sesamum radiatum* was only retained on-farm in the Ife and Tchabe groups, whereas it was cultivated in the Mahi group. *Caesalpinia bonduc* was only retained on-farm in the Mahi group, whereas it was transplanted in the Tchabe group and cultivated in the Ife group. T*alinum triangulare* and *P. biglobosa* on the contrast were only retained on-farm in the three communities (Table 5).

Table 5. Highest intensity of species management practices observed at community level in villages of the Collines region, central Benin. Observed management practices: **w=** Gathered in the wild (no herbs, 6 trees); **r=** Retained on-farm, enhances through nurturing, tendering (9 herbs, 9 trees); **t=** Transplanted from the wild (8 herbs, 1 tree); **c=** Cultivated (5 herbs, 2 trees).

Species	Community level management practices		
	Mahi	Ife	Tchabe
Adansonia digitata L.	w	w	r
Bixa oreliana L.	-	tc	-
Blighia sapida K.D. Koenig	-	-	w
Bombax costatum Pellegr. & Vuillet	r	-	-
Caesalpinia bonduc (L.) Roxb.	r	tc	t
Ceiba pentandra (L.) Gaertn.	-	t	-
Celosia argentea L.	tc	-	t
Celosia trigyna L.	-	rt	tc
Ceratotheca sesamoides Endl.	w	r	r
Cissus populnea Guill. & Perr.			
Clausena anisata (Willd.) Hook.f. ex Benth.	-	w	-
Cleome gynandra L.	w	-	rt
Corchorus tridens L.	-	-	t
Crassocephalum rubens (B. Juss. ex Jacq.) S. Moore	t	r	t
Dioscorea praehensilis Benth.	-	c	-
*Ficus abutilifoli*a (Miq.) Miq.	-	-	r
Haumaniastrum caeruleum (Oliv.) P.A. Duvign. & Plancke	-	r	-
Hibiscus sabdariffa L.	-	r	t
Justicia tenella (Nees) T. Anderson	-	r	-
Launaea taraxacifolia (Willd.) Amin ex C. Jeffrey	r	rt	r
Lippia multiflora Moldenke	rtc	r	-
Momordica charantia L.	w	wr	-
Ocimum americanum L.	-	rt	-
Ocimum basilicum L.	r	-	rt
Ocimum gratissimum L.	rt	r	-
Parkia biglobosa (Jacq.) R.Br. ex G.Don	r	r	r
Pergularia daemia (Forssk.) Chiov.	-	r	-
Phyllanthus muellerianus (Kuntze) Exell	w	-	-
Platostoma africanum P. Beauv.	-	r	r
Psorospermum alternifolium Hook.f.	-	r	-
Rauvolfia vomitoria Afzel.	-	r	-
Sesamum radiatum Schumach. & Thonn.	c	r	r
Solanum erianthum D. Don	-	r	-
Sterculia tragacantha Lindl.	-	w	-
Talinum triangulare (Jacq.) Willd.	r	r	r
Vernonia colorata (Willd.) Drake	-	-	r
Vitellaria paradoxa C.F. Gaertn.	wr	r	r
Vitex doniana Sweet	r	r	wr
Ximenia americana L.	w	-	-
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	-	w	-

A case-by-case analysis of the most contrasting cases showed that the intensity of management practices at community level was influenced by the level of knowledge communities had on the ecology, propagation modes, and seed conservation methods combined with the use importance of the species (Table 6). Whatever its life form, the more a species was widely and frequently used in a community, the more this community tried to intensify its management, depending on how well it knew its propagation modes (Table 6). First for herbs, *C. sesamoides* for example was retained on-farm in the Tchabe and Ife communities where it was more widely and frequently consumed and where people just knew its period and place of fructification. By contrast, in the Mahi community, where it is less widely and frequently consumed, it is simply gathered though they have the possibility to retain it on-farm (Table 6). Similarly, *C. rubens* was transplanted by the Tchabe and Mahi people who consumed it more widely compared with the Ife people who consumed it less and just retained on-farm though they had the possibilities to transplant it

Table 6. Relationships between management practices, consumption, and knowledge of the reproductive biology of the food species at community level in villages of the Collines region, central Benin. Frequency of consumption: Everyday **(5)**; 1 - 3 times a week **(4)**; 1 - 2 times a month **(3)**; 1 - 2 times a year **(2)**; more than 2 years ago **(1)**. Knowledge of the reproductive biology: no knowledge (**0**); knowledge of the period of fructification and place where seedlings and saplings occur (**1**); knowledge of the reproduction modes (**2**); knowledge of the reproduction modes and effective genetic resources conservation methods (**3**).

Life form	Species	Ethnic group	Community levele management practices	Household consumption of species		Proportion (%) of households with reproductive biology knowledge				
				Proportion (%)	Frequency	0	1	2	3	4
Herb	*Ceratotheca sesamoides* Endl.	Ife	Retained on-farm	15	(4)	0	15	0	0	0
		Mahi	Gathered	5	(3)	0	5	0	0	0
		Tchabe	Retained on-farm	50	(4-5)	15	35	0	0	0
	Cleome gynandra L.	Ife	-	-	-	-	-	-	-	
		Mahi	Gathered	5	(3)	0	5	0	0	0
		Tchabe	Retained or Transplanted	15	(3)	0	0	15	0	0
	Crassocephalum rubens (B. Juss. ex Jacq.) S. Moore	Ife	Retained on-farm	10	(3-4)	0	10	0	0	0
		Mahi	Transplanted	50	(3-4)	0	50	0	0	0
		Tchabe	Transplanted	55	(4)	0	50	5	0	0
	Sesamum radiatum Schumach. & Thonn.	Ife	Retained on-farm	25	(3)	0	25	0	0	0
		Mahi	Cultivated	75	(3-4)	0	0	0	15	60
		Tchabe	Retained on-farm	35	(3)	0	0	35	0	0
	Talinum triangulare (Jacq.) Willd.	Ife	Retained on-farm	20	(3-4)	0	20	0	0	0
		Mahi	Retained on-farm	30	(3-4)	0	30	0	0	0
		Tchabe	Retained on-farm	40	(3-4)	40	0	0	0	0
Tree	*Adansonia digitata* L.	Ife	Gathered	10	(3)	10	0	0	0	0
		Mahi	Gathered	15	(3)	10	5	0	0	0
		Tchabe	Retained on-farm	25	(1-3)	25	0	0	0	0
	Caesalpinia bonduc (L.) Roxb.	Ife	Transplanted or cultivated	25	(3)	0	0	0	0	25
		Mahi	Retained on-farm	50	(2-3)	0	50	0	0	0
		Tchabe	Transplanted	20	(5)	0	0	20	0	0
	Parkia biglobosa (Jacq.) R.Br. ex G.Don	Ife	Retained on-farm	15	(5)	15	0	0	0	0
		Mahi	Retained on-farm	45	(4-5)	45	0	0	0	0
		Tchabe	Retained on-farm	15	(4)	15	0	0	0	0

from the wild. *Sesamum radiatum* was cultivated in the Mahi community in which most households consumed it daily and mastered its propagation and seed conservation practices. By contrast in the Ife and Tchabe communities, it is less widely consumed and just retained on-farm. Contrary to the three herbs above described, *T. triangulare* is just retained in the three communities though its use importance varied across these communities. In the Tchabe community where it was more widely consumed, people knew nothing about its reproductive biology. In the other two communities which have the possibility to practice transplantation, the species is less consumed and people just retained it on farm. The same trends were observed when trees species where considered. Despite that consumption of *C. bonduc* was most widespread among Mahi people, they just retained it on-farm because they knew nothing about its propagation. But in the two other communities which mastered its propagation means, it is cultivated and its consumption is less widespread.

Socioeconomic and ethnobotanical factors influencing management practices at individual level

Though many species reached a certain domestication stage at the community level, management practices varied among respondents. For instance, 22% of species being retained on-farm were also still gathered by some respondents. This is the case for *A. digitata* (tree) and *C. sesamoides* (herb) which were still gathered by respectively 45% and 8% of respondents who mentioned them while 55% and 92% respectively were retaining, nurturing or tendering them on-farm, 85% of species which were cultivated such as *L. multiflora*, *C. argentea*, *C. trigyna* (Table 5) were retained on-farm, or transplanted from the wild by some respondents, but they were rarely gathered from the wild. Eighty-eight percent of species which were transplanted were also retained on-farm (Table 5).

Regardless of species, ethnic groups, gender and age, the management practices at the level of the individual were affected by the knowledge of the biology of the species, their life form, period of availability, and frequency of consumption (Figure 6). When both the propagation modes and seed conservation methods were reported to be well known by respondents, the dominant management practice was plantation or cultivation (78% of cases) regardless of the species life form (Figure 6). When the highest level of knowledge of biology of the species was the propagation modes only, management practices varied with life form (Figure 6).

For trees, when nothing was known about the reproductive biology of species, the dominant management practice was on-farm retention for species which were available only during the food shortage period (90% of cases) while gathering was limited (less than 10% of cases). For tree species, which were available during the food abun-

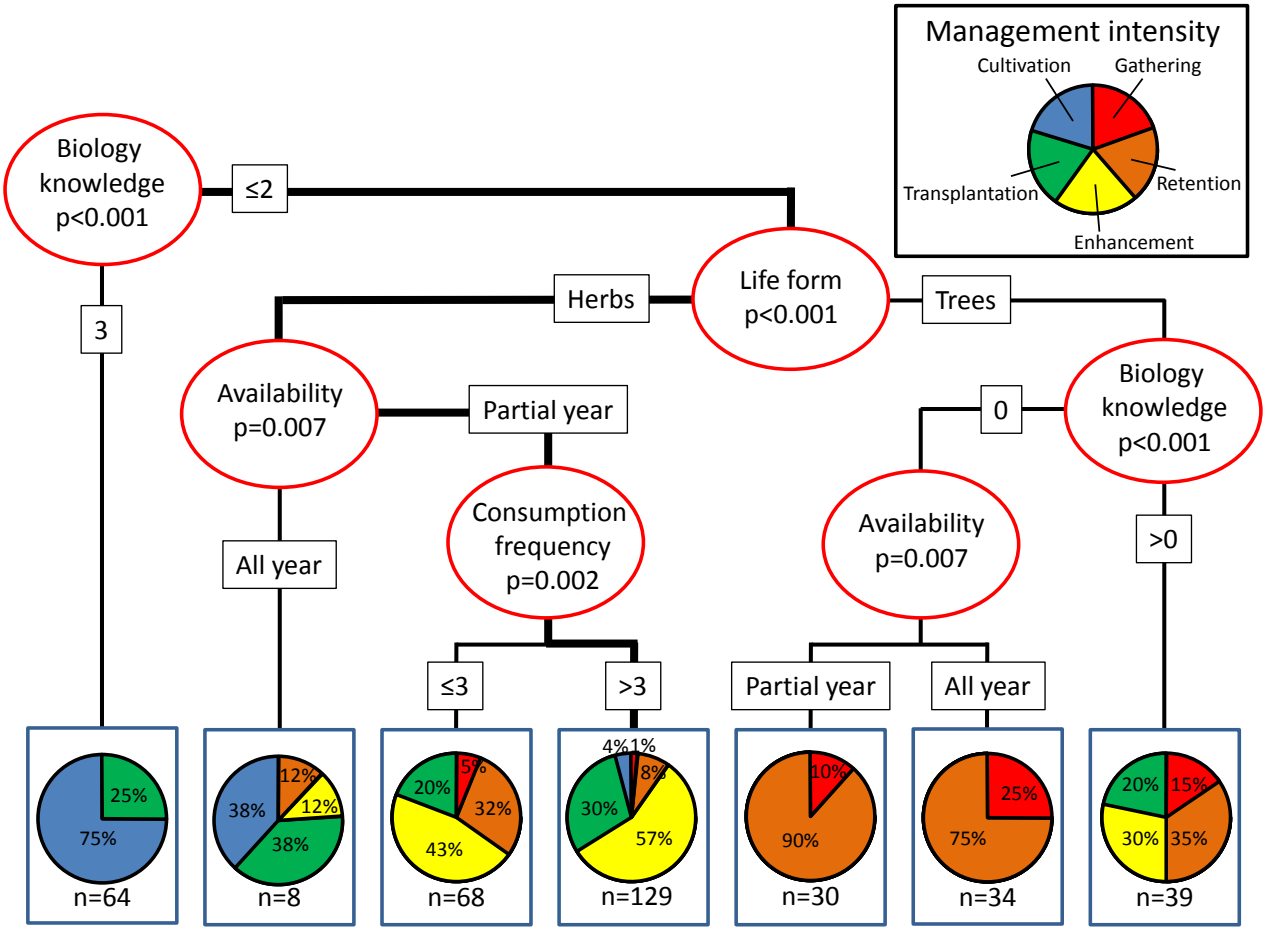

Figure 6. Conditional inference tree showing factors influencing the intensity of management practices by individuals in villages of the Collines region, central Benin. p represents Bonferroni-adjusted p-values; n =number of mentions; Biology knowledge: no knowledge (**0**); knowledge of the fructification period and places where seedlings or saplings occur (**1**); knowledge of the modes of reproduction (**2**); knowledge of the seed conservation methods (**3**). Consumption frequency: everyday (**5**); 1-3 times a week (**4**); 1-2 times a month (**3**); 1-2 times a year (**2**); more than 2 years ago (**1**).

dance period or during the whole year, on farm-retention dominated (75% of cases), despite gathering still being frequent (25% of cases). When the period of fructification or the mode of reproduction were known, on-farm retention and protection (65%) and transplantation (20% of cases) were the most widespread management practices while gathering was limited (<15% of cases, Figure 6).

For herbs, the availability period interacted with the frequency of consumption of the species to influence management practices (respectively p=0.007 and p=0.002, Figure 6). When species were available all the year, on-farm retention and protection, transplantation and cultivation were the most common management practices (respectively 12%, 12%, 38%, and 38% of cases). When species were available only during food shortage period, but were not frequently consumed (less than 1 to 2 times per month), on-farm retention and nurturing (43%), on-farm retention (32%), transplantation (20%) and gathering (5%), were observed. When species were more frequently consumed (every week or every day), on-farm retention and nurturing (58%) and transplantation (30%) were the most widespread (Figure 6).

Discussion

This study analyzed factors influencing the diversity and the intensity of management of wild edible plant species consumed by local people. We started with a large set of potentially influential factors including socioeconomic and biological variables, then identified the most influential ones and demonstrated how they interact in shaping plant diversity and management at community and household levels. We found that two interrelated groups of factors shape the richness, composition and management options of wild food species: first the socioeconomic status of households namely their ethnic group, age, gender and women's access to land, and second, ethnobotanical features of the managed species namely their life form, availability periods, consumption frequencies and the knowledge that communities and people have on species ecology and biology.

Factors influencing the diversity of wild edible species at community, household and individual levels

Though they live in the same agroecological zone, each community managed a set of species which was largely different from those managed by the other communities. Moreover, the Ife people managed a greater diversity than the two other groups did. These findings support the role of culture and ethnicity in shaping plant diversity managed by communities that previous research has already shown (Dansi *et al*. 2008), but offer an important nuance: because of their linguistic and cultural affinities, we expected greater similarities of the diversity managed by the Tchabe and Ife communities. Rather, our data suggests greater similarities of the floristic composition and the richness of species managed by the Tchabe and Mahi. This fact contradicts with results of the countrywide ethnobiological survey of wild and semi-wild vegetables carried out by Dansi *et al*. (2008) who clearly established a closer resemblance of the plant diversity managed by the Ife and the Tchabe communities. Actually, Dansi *et al*. (2008) based their analysis on a countrywide database of plant diversity they designed for each ethnic group and did not contrast villages among them. However, as demonstrated by Achigan-Dako *et al*. (2011) in another countrywide survey which explored similarities and divergences among several villages of various ethnic groups, villages showing cultural and linguistic affinities or even villages of the same ethnic group may show greater divergence among them and more resemblance with other ethnic groups. This situation supports the existence of local driving forces in our study, other than cultural and linguistic affinities, that may shape the diversity used at village level, such as educational level. Indeed, the Ife group we surveyed included much more poorly educated households compared with the Mahi and Tchabe groups (80%, 55%, and 35% of illiterates respectively). School education is well known to favor contact with western culture and lifestyle, especially food habits and farm production purposes.

Each household within each community managed a range of wild edible species. The number of species managed per household was essentially influenced by the age of heads and women land ownership whereas the composition of these species was essentially shaped by the age of heads only. Younger households managed less herbaceous and tree diversity than older households. They were interested mainly in wild or semi-wild species which have attractive market values or are common in local diets (e.g., *L. taraxacifolia*). Therefore, they managed a smaller range of wild or semi-wild species. By contrast, the selection criteria of older households were not restricted to market values. They were interested in a wider range of species with multiple food and non-food functions (e.g., medicinal). A possible consequence of this situation is that the maintenance of species with less important market values or which are managed only by a few older households may be threatened in on-farm conditions in the area in the future. These findings support other studies in pointing out market value as an important criterion in the selection and management of wild edible plants (Danjimo *et al*. 2009, Gonzalez-Insuasti *et al*. 2008, N'Danikou *et al*. 2011). Species lacking commercial values, even if they have a high cultural value, may be neglected (Gonzalez-Insuasti *et al*. 2008, N'Danikou *et al*. 2011).

What explains this difference among age generations with respect to the wild diversity used? Why do younger households manage a more restricted diversity, especially plants with interesting market values or those which are common in local diets? In our case, although we do

not measure the knowledge difference between older and younger respondents, it is plausible that this behavior of younger households is not caused by a weak knowledge of the uses of wild foods of their environments because the study focused only on species of farming environments (fields, fallows, home gardens) which they usually know well. Rather, our data indicated that younger heads had better school education than older heads who had scarcely received school education (up to an illiteracy rate of 80% in some ethnic groups). This education may have influenced their lifestyle and their farming objectives. They are more attracted by the modern lifestyle and produce for market to have enough cash. Other research discussing this question indicated that changes in lifestyle are a major factor explaining the weaker interest of younger generations in wild food diversity; however, this is quite different from what we observed. Shackleton *et al*. (1998) observed in South-African villages that wild food species were more favored by older generations because younger people did not enjoy the taste of wild plants as much as older people did. They preferred modern diets which in fact implies a loss of interest in traditional foods. A similar influence of unpleasant tastes in the non-consumption and non-management of wild edible species was also reported by Achigan-Dako *et al*. (2010) in a survey of vegetable preferences of locals in Benin.

Within households, we found that husbands generally managed a greater diversity than did their wives. Men managed both trees and herbs whereas women managed mostly herbs. This pattern seems to be determined by the customs in the area. Women generally own no land or limited land areas (less than 0.4 ha in 78% of households). Even when they exploit lands allocated to them by their husbands, they cannot plant trees (there was no effect of the area cultivated by wives on tree species richness). Tree planting is highly associated with land ownership and rights which are almost exclusively held by men in the local traditional customs in the area (Neef 2001). These associations between land ownership of women and tree diversity suggest that facilitating access to land to women would increase tree diversity on-farm and thus improve their conservation. It is therefore a critical and very sensitive gender and conservation issue. Though men almost exclusively held a monopoly on wild tree management, women play prominent roles in the use and related-knowledge of their products: it has been reported in the study area that women are responsible for harvesting, processing, and cooking the products of *P. biglobosa*, *V. doniana*, *A. digitata*, and *V. paradoxa* (Vodouhe *et al*. 2009).

This cultural limitation of wives in tree management is probably the reason why they specialised themselves in herb management, especially herbs mainly available during food shortage periods and which they marketed. Herbaceous species which were available during the whole year, largely during food abundance periods or mainly during food shortage periods but with weak market value were managed by both husbands and their wives. This fact supports the more and more active involvement of women in the commercialisation of wild or semi-wild leafy vegetables during food shortage periods and in the management of those resources that Vodouhe *et al*. (2011) recently observed in the study area and in the northern and drier parts of the country. The management and commercialisation of wild or semi-wild herbs during food shortage periods has also been reported in the Sahel as a growing and more and more lucrative activity (Danjimo *et al*. 2009).

This specialization of women regarding the management of herbs may be explained by their search for their own income generating and new market opportunities within households. Actually, the gender specialization regarding diversity management within households is more and more observed with agricultural development and market integration in rural West Africa (Padmanabhan 2007). Any time agricultural innovations or changes in the composition of the resources occur, the two parties within households may enter a process of reorganization to reach an equilibrium that may benefit both (Padmanabhan 2007).

Factors influencing management practices of wild edible species

The most intensive management practice observed for non-domesticated food species at community level varied across ethnic groups for some species whereas it was the same in all communities for other species. A case-by-case analysis for the most contrasting cases of species suggests that the cultural importance of the species in each community combined with the level of knowledge they had on the ecology and propagation methods explain this variation. We found that the more a species was widely and frequently used in a community, the more this community tried to intensify its management, depending on how well it knew its propagation modes. In other words, they resorted to the most intensive management practices they knew to overcome biological barriers and secure and make the most important resources more available, while for less important species they use less intensive practices.

At the individual level, the knowledge of the biology - propagation modes and effective seed conservation methods - combines with the use value of the species for individual respondents to shape management practices. First, when farmers mastered species propagation and seed conservation methods, the management practices were more intensive (cultivation or plantation). Conversely, when farmers were constrained by the knowledge of propagation or seed conservation methods, they adopted other management strategies to secure the resources. These strategies depend on the life form and the use importance of the species. The latter in turn depends on their periods of availability, frequencies of consumption and market value.

For trees, farmers tend to practise more on-farm retention when the edible parts are available only during the food shortage period while gathering still prevails when these parts are available during the food abundance period or the whole year. When they know the periods of fructification of the species or the area where seedlings or saplings grow, transplanting is also practised, but rarely planting directly seeds or cuttings. For herbaceous species, those which are more frequently consumed tend to be more intensively managed through enhancements (e.g., protection, nurturing, tendering), transplanting and a few attempts at cultivation. Contrary to the availability in time, the availability in space and quantity of the edible parts was not influential for domestication, likely because most species occur in farming environments and farmland was not a limiting factor in the study area. However, had land availability been a limiting factor in the study area, this would likely have been an influential factor. Based on these findings and other research in different communities (Gonzalez-Insuasti & Caballero 2007, N'Danikou *et al*. 2011, Price 1997), we can assert that the intensity of management of wild edible plants reflects their cultural importance, biological features, and the level of knowledge local people have on their reproductive biology.

The prominent role that the limited knowledge of propagation and seed conservation methods and the difficulties of obtaining planting materials of wild food species plays in limiting their management intensification by local people has already been emphasized by Msuya *et al*. (2008) and N'Danikou *et al*. (2011). Our study confirmed these limitations. Moreover, it shows how local people attempt to cope with these limitations. If no research is conducted and no technical assistance provided to these people to overcome these constraints, there is a risk of disappearance of many species from farming environments with the intensification of agriculture associated with the homogenization of agricultural landscapes. Seed multiplication and dissemination of newly domesticated species is crucial for the success of any domestication efforts. Unfortunately, seed systems, especially for forest and traditional crops are generally poor in most developing countries. Farmers and local communities have access to seeds of these species thanks to traditional seed systems.

Conclusions

This study identifies ethnicity, age, and gender as the most influential factors in the management and use of wild edible plants by local people. These factors interact to shape the diversity of food plants used. Within the various studied communities, younger households select and used a more restricted diversity of wild edible plants, especially for market purposes. Within households, gender shapes the diversity managed by individuals through local traditional customs related to land rights and a specialization of women on specific sets of plants. Regardless of ethnicity, age, generation, and gender, the intensity of management practices used by local people depends on the level of knowledge they had on the species' propagation and seed conservation combined with their use importance. Generally, people tend to adopt the most intensive strategies to secure the most important resources.

Acknowledgements

This research was funded by Biodiversity International. We are grateful to the local communities of Banon, Gbédé and Aglamindodji for their cooperation. Many thanks to Dr. Achigan-Dako Enoch for advising on voucher specimens handling and field assistants for their support.

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