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REGULAR PAPER

Impacts of the diversity of traditional uses and potential economic value on food tree species conservation status: case study of African bush mango trees (Irvingiaceae) in the Dahomey Gap (West Africa)

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Background and aims – Bitter and sweet African bush mango trees belong to the family Irvingiaceae and produce valuable non-timber forest products in humid lowland areas of West and Central Africa. The bitter and sweet types are treated as distinct taxa at the variety or species level. They have not been studied in the western part of their distribution range, and many aspects of their large-scale utilization remain unknown. In this study, we link differences in socio-cultural groups to the agroforestry status of bush mango trees in order to identify the key factors influencing their abundance and conservation in the study area.
Methods – First, we gathered uses and local management strategies from nine main socio-cultural areas in Benin and Togo, part of the Dahomey Gap. Second, occurrence data were obtained throughout the Gap and imported into DIVA-GIS and MATLAB to calculate the spatial pattern of the density and analyse its structure and variation relative to three factors: the country, the phytogeographical zone and the dominant soil category. Third, agroforestry system characteristics and farmers' social status relative to 841 trees were used in a multinomial logistic regression to identify anthropogenic factors driving the intensive cultivation of bush mango trees. Finally, the impact of socio-cultural activities on extent and density of bush mango tree populations was analysed.
Key results – In the entire study zone, the sweet mesocarp is consumed and the endocarp of bush mangoes is commercialized. The application of endocarp-based diets and socio-therapeutic uses are common to communities in Benin. Sweet bush mango trees are generally found either in home gardens or cultivation fields where they may occur at high densities (up to 1020 trees per 25 ha). Bitter trees, however, are confined to the Volta forest region in Togo and occur at low densities (< 462 trees per 25 ha) in the wild, sometimes in protected areas, in forest gardens and in fields. This indicates a clear difference in cultivation methods between the bitter and sweet trees. Farmland status, farmer socio-cultural group and type of bush mango trees determined the cultivation intensity.
Conclusion – The fact that small farmlands are converted into sweet bush mango tree orchards indicates that farmers actively cultivate bush mango trees in the study area. Diversity of indigenous knowledge, however, is not correlated either to intensive cultivation or domestication efforts and local genetic conservation program. Where slash and burn agriculture and intensive collection of fruits jeopardize bitter trees, traditional fishing systems (using bush mango twigs), a traditional selection strategy, and intensive land commercialization severely threaten sweet bush mango tree genetic resources.

Key words – Benin, conservation, domestication, Dahomey Gap, ethnobotany, geostatistics, *Irvingia*, kriging, spatial distribution, Togo.

INTRODUCTION

Millions of people have a traditional knowledge on Non Timber Forest Products (NTFPs) and use them on a daily basis (Boateng et al. 2007). NTFPs are increasingly being studied due to their growing importance in enhancing livelihoods. They play a key role in sustainable ecosystem management design (MMF & UNBC 2005, Delang 2006) and are shaping land use systems in terms of their specific composition and spatial configuration. The increasing demand for NTFPs is reflected in a growing commercial trade (Arnold & Ruiz-Pérez 2001) which is becoming an important economic incentive for local collectors. Consequently, natural ecosystems may well suffer from over-exploitation of their plant genetic resources (McLain & Jones 2005), especially in areas where people are economically dependent on NTFPs (Ticktin 2004). In the context of the rapid growth of the human population and a NTFP production limited by ecosystem capacity, a sustainable harvest strategy reconciling plant genetic resources conservation and local people livelihood seems to be a utopia (Rai & Uhl 2004). The development of traditional agroforestry systems, from forest gardens to orchards, indicates that local communities carefully select useful plant species for cultivation and domestication (Wiersum 2004). This partially decreases the dependence of communities on natural ecosystems although they still depend on natural forests for the NTFPs that cannot easily be cultivated such as primary rainforest species, wildlife, etc.

Bush mango trees widely occur in the wild in the humid lowland forest areas at least in twenty Sub-Saharan African countries, from the South Senegal to Angola and South Soudan (See Harris 1996, Lesley & Brown 2004, Kengni et al. 2011). However, detailed ecological data related to their occurrence throughout their distribution range remain unknown.They belong to the small family of Irvingiaceae (Harris 1996), of which nine species occur in West and Central Africa. Its fruits are one of the most economically important NTFPs in Sub-Saharan Africa (Asaah et al. 2003, Leakey et al. 2003). They are abundant in traditional agroforestry systems and represent the top priority food tree species subject to ongoing domestication trials led by the World Agroforestry Centre (Franzel et al. 1996, Tchoundjeu et al. 2010). The mesocarp of their mango-like *Irvingia* fruit is either bitter or sweet (Harris 1996). Only the sweet mesocarp is edible, while the seed (kernel) of both bitter and sweet fruits is used as a sauce thickening agent (Leakey et al. 2005a, Tchoundjeu & Atangana 2007). Bitter and sweet trees are taxonomically closely related and there is some debate about the correct level at which their differences should be valued (National Research Council 2006). While Okafor (1975) presented the two types as varieties of the species *Irvingia gabonensis* (*I. gabonensis* (Aubry-LeComte ex O'Rorke) Baill. var. *gabonensis* and *I. gabonensis* var. *excelsa* (Mildbr.) Okafor, respectively), they were recognized at species level (*I. gabonensis* and *I. wombolu* Vermoesen, respectively) by Harris (1996).

In Central Africa, Lesley & Brown (2004) identified more than fifteen indigenous uses of bush mango trees but without any distinction between bitter and sweet trees, regarding therapeutic properties. Therefore, because of the taxonomic uncertainties, it is difficult to assign many of the known biochemical properties to either the sweet or the bitter tree (see Lesley & Brown 2004, Oyen 2007, Tchoundjeu & Atangana 2007). Moreover, even though data on morphological and genetic diversity exist in the eastern part of their distribution range, attempts to compare and separate bitter from sweet trees are rare, and thus, the taxonomic issue remains.

Initially marketed for consumption by African migrants throughout the world (Tabuna 2000), the bush mango fatty kernel is increasingly becoming an important raw material for a growing number of food processing and cosmetic industries (Akubor 1996, Oyen 2007). Many CGIAR-funded organizations, among which the World Agroforestry Centre and Bioversity International, identified bush mango trees as a priority food tree species for West and Central Africa. At the individual tree level, Vodouhê (2003) and Vihotogbé et al. (2007) studied the local economical profitability and the indigenous factors driving the eligibility of trees for conservation purposes in the Dahomey Gap, respectively. Throughout their entire distribution range, however, intensive cultivation systems of bush mango trees remain rare (Lowe et al. 2000) and the basic drivers of and strategies for their domestication and intensive cultivation unstudied.

Food cultivation and traditional knowledge are often shared among socio-cultural groups as an integral part of their social heritage and natural resource management strategy (Reyes-García 2001, De Caluwé et al. 2009). Asaah et al. (2003) presented a unique work describing the on-farm cultivation of bitter bush mango trees, but without the contribution of endogenous knowledge in Cameroon. Thus, assessing the relationship between socio-cultural groups' ethnobotanical knowledge and the difference in the spatial pattern of the abundance of bush mango trees is important in order to evaluate their potential as a crop for Sub-Saharan Africa (Leakey et al. 2005a). This is useful to predict and respond to the increasing future demand of NTFPs (see Scheldeman et al. 2007). Moreover, abundance, size-class distribution and threats are important structural parameters in the management of trees within traditional agroforestry systems (Gouwakinnou et al. 2009). Today, free migration of human populations associated with the cultural connection among communities throughout Ghana, Togo, Benin and Nigeria (see Parrinder 1947, Asiwaju 1979, Dotse 2011) and the increasing economic value of bush mango trees are causing genetic material transfer in various agro/ecosystems (see Vihotogbé et al. accepted) and thus, impacting their potential distribution (Vihotogbé et al. 2012).

This study focuses on the situation that can affect the bush mango tree population structure in the study area. In this area, we quantified how traditional knowledge on AMBT usage and social status of farmers affect the allocation of productive space of bitter and sweet bush mango trees. We aimed at providing answers to three research questions:

- Is there a difference in traditional knowledge on bush mango tree usage between the different socio-cultural areas in the study area and how does this affect the local management strategies for bush mango trees?
- What is the spatial pattern of bush mango trees abundance in the study area?

- Which anthropogenic factors are influencing this spatial pattern and population structure and hence the conservation of bush mango tree genetic resources in the study area?

MATERIAL AND METHODS

Study area

The Dahomey Gap is the dry corridor dividing the West African rain forest block into the Upper and Lower Guinean phytochoria (Salzmann & Hoelzmann 2005, White 1979). This climatically dry corridor, where savannah reaches the coast, extends from Accra (southern Ghana) to Badagry in south-eastern Nigeria (Maley 1996, Sowunmi 2007). This study was carried out in Benin and Togo, representing the majority of the extent of this eco-region. It is postulated that the humid equatorial climate with evergreen forests prevailed in the Dahomey Gap (see Sayer 1992, Nagel et al. 2004, Tossou et al. 2008). This implies that bush mango trees may have occurred in the wild in the Dahomey Gap. Today, small patches of natural forest are scattered over this savannah land largely cultivated in many areas (Kokou & Sokpon 2006) and the nature (wild versus cultivated) of the bush mango trees in this eco-region is controversial. The current bimodal climate regime is characterized by a mean annual rainfall of 900–1,200 mm and a mean temperature of 25–29°C. This study covers the nine major socio-cultural areas in the South of Benin and Togo: Aizo, Adja, Akposso, Ewe, Fon, Goun, Nago, Holli and Watchi (Heldmann 2006, Atato et al. 2010, fig. 1).

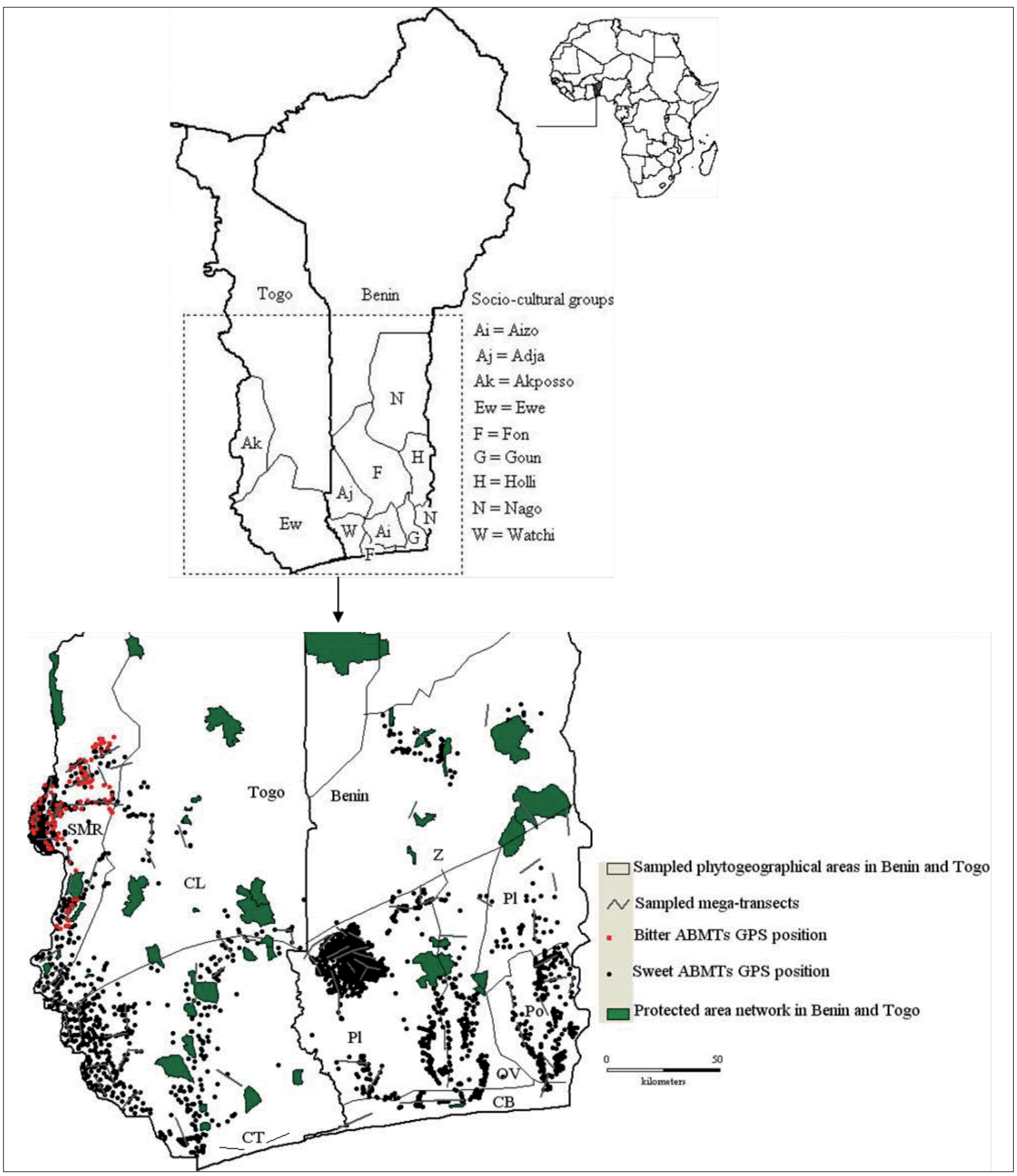

Figure 1 – Sampled socio-cultural areas, mega-transect bush mango trees records in different phytogeographical regions in Benin and Togo. Phytogeographical regions: Z = Zou; Pl = Plateau; OV = Oueme-Valley; PO = Pobè; CB = Coast-Benin; CL = Centre Lowlands; SMR = Volta zone = Southern Mountain Region; CT = Coast-Togo.

Sampling design and data collecting

Ethnobotanical survey – We started with an analysis of the ethnobotanical database gathered by Vihotogbé et al. (2007) in six major socio-cultural areas in Benin (Aizo, Adja, Fon, Goun, Nago, Holli). To complete data from missing target groups, an ethnobotanical survey was carried out in the three other major socio-cultural areas in the study area: Watchi in Benin and Ewe and Akposso in Togo. Moreover, since the 2007 database included relatively few professional users of biodiversity (i.e. traditional healers, religious specialists or vendors of medicinal plants), additional surveys were performed to specifically target such individuals in the first six socio-cultural areas.

Using a structured questionnaire, participants were asked about their knowledge on different uses of any part of bush mango trees (roots, stem, bark, leaves,) as well as his/her acceptance of the consumption of sweet bush mango and that of seed-based diets. Together with the 2007 database, data from a total of 294 respondents were analysed to understand the traditional knowledge and the current importance of bush mango tree in the study area. Additionally, using direct on-farm observations, data on the main traditional management systems were recorded.

Assessing spatial patterns of bush mango trees in the Dahomey Gap – Next, the distribution and density pattern of bush mango trees within the study area was obtained. Given the large size of the geographical area involved, a field research unit area was designed as a modified mega-transect, a technique used by Assogbadjo (2006) to quantify the occurrence of Baobab trees *(Adansonia digitata* L., Bombacaceae). Each mega-transect comprises a 10 km long line, along which observations were made in a zone of 250 m both left and right and covers an area of 5 km^2. In total, 59 such mega-transects were sampled, three to seven in each socio-cultural area (fig. 1).

When scattered at low density in the landscape, all individual adult and young bitter and sweet trees in a mega-transect were geo-referenced. If an area with a high density of bush mango trees was encountered, their number was estimated as follows. The trees bordering such high density areas were all accurately geo-referenced supplemented with all trees within two randomly defined 100 × 50 m sub-plots. Then, the total number of bush mango trees present in the high density area was estimated from these data. Although not exhaustive, trees encountered between sampled mega-transects were also recorded and areas of bush mango trees absence along and between mega-transects were marked as zero density points.

The influence of farmers on the spatial distribution and conservation of bush mongo was assessed by analysing data from 841 adult trees from different agroforestry systems and corresponding to 841 farmers met in the field. To avoid replication of the same characteristics in the database, one tree was thought sufficient to describe the agroforestry system per cultivation field, per farmer and his or her social-cultural status. In the study area, bush mango trees occurred within three agroforestry systems (i) orchards, (ii) agroforestry parks, and (iii) forest gardens. Orchards are well organized cultivation systems with high densities managed as taungya agroforestry systems. The density depends on whether subsistence crops are going to be definitely associated or not with bush mango trees. Agroforestry parks come second in terms of density of bush mango trees as priority crop. Most frequently, such parks are owned by farmers belonging to different families inheriting large and continuous farmlands. Each farmer could mark his trees with a different colour of cloth to secure them. In this confidence-based system of bush mango trees' exploitation, the mesocarp consumption remains free (especially in south-west Benin). Densities in forest gardens are lower than in the first two systems. For all 841 trees throughout those systems, the following eight parameters were recorded: (i) taste of mesocarp, (ii) nationality of farmer, (iii) socio-cultural group of farmer, (iv) farmer's respect of taboos regarding bush mango tree cultivation, (v) reason why the farmer cultivated or preserved bush mango trees, (vi) local marketing system, (vii) land use system in which the tree occurs, and (viii) local land tenure combined with local judgment of farmland size.

To investigate the structure and threat to the population of bush mango trees, six populations with at least 30 adult trees were selected that represent a unique combination of a particular agroforestry system, socio-cultural group, and a particular reason for bush mango tree management (table 1, fig. 1). In low density areas, population data were obtained using two randomly selected 10 × 0.5 km mega-transects, while in high density areas, it was obtained from the two 100 × 50 m sub-plots used to estimate the tree density in four mega-transects (fig. 1). Diameter at breast height (dbh) was measured for all adult trees (dbh ≥ 7 cm) of sampled *Irvingia* populations and all detected saplings and seedlings (dbh < 7 cm) were counted. In addition, these areas were visited throughout the study year, specifically during fruit harvesting and land preparation, in order to identify signs of destructive management strategies and of any other human induced impact rooted in the main economic activities specific to the socio-cultural groups: pruning for different purposes, juvenile clearance and damage caused by harvesting techniques of bush mangoes or other NTFPs. Information on how people protect or destroy seedlings and saplings was also obtained through interviews.

Data analysis

Local use of bush mango trees in the Dahomey Gap – Interviews led to a total of 23 different uses of bush mango trees (table 2). For each respondent, each type of use was recorded as known/present (1) or unknown/absent (0). Thus, we assessed the level of ethnobotanical knowledge (Mn_{id}) for the i^{th} individual by:

$$Mn_{id} = \frac{Ni}{Nt} \times 100\ \% \quad (1)$$

Where Ni =number of uses known by the i^{th} individual and Nt = total number of uses recorded.

We distinguished two groups of *Irvingia* users: professional ones (traditional practitioners, traditional religion priests or vendors of medicinal plants) and non-professional ones (all other respondents).

Table 1 – Sampled socio-cultural areas, main uses and anthropogenic activities impacting on ABMT populations.
T = total surveyed, P = number of professional users (traditional practitioners, traditional religion priests), O = number of ordinary people. Subscript numbers refer to the total number of individuals surveyed in each group.

Type of ABMTs	Geographic areas (see fig. 1)	Socio-cultural groups	Profile of individuals	Most important economic product	Major socio-economic activities	Domestication process
Sweet trees	South West Benin*	Adja	T_{35}:$O_{26}P_{9}$	Endocarp	Subsistence agriculture, Palm oil tree and food tree species	Only cultivated trees under a missal selection process importantly based on endocarp size regardless fruit's parasitism and the firmness and sweetness of the mesocarp.
	South Benin* South Benin Lower South East Benin	Aizo Fon Goun	T_{32}:$O_{22}P_{10}$ T_{31}:$O_{21}P_{10}$ T_{29}:$O_{22}P_{7}$	Entire fruit (based on the mesocarp quality) and less importantly the endocarp	Subsistence agriculture plus most importantly traditional fishing using ABMTs branches for the fishing system construction	Preserved spontaneous trees obtained from human-thrown seeds. No action or interest for traditional selection.
	Upper South East Benin*	Holli	T_{37}:$O_{19}P_{18}$		Subsistence agriculture and palm oil trees	Unclear domestication status (pretended wild + spontaneous + planted). Trees are preserved importantly based on fruits parasitism and the firmness and sweetness of the mesocarp regardless mesocarp size.
	Upper South East Benin	Nagot	T_{22}:$O_{18}P_{4}$			
	Lower South West Benin	Watchi	T_{25}:O13P_{12}	None	Traditional fishing using ABMTs branches for the fishing system construction	
	Upper South West Togo	Akposso (Badou-Bena)	T_{43}:$O_{29}P_{14}$	Endocarp	Cash crops (cocoa, coffee, banana, avocado), food tree species and subsistence agriculture	
	South Togo	Ewe	T_{40}:$O_{29}P_{11}$	Endocarp	Subsistence agriculture and food tree species	Only cultivated trees without selection process
Bitter trees	Upper South West Togo*	Akposso (Kounionhou)		Endocarp, wood	Cash crops (cocoa, coffee, banana, avocado), food tree species and subsistence agriculture	Only wild trees preserved in traditional agroforestry systems
	Upper South West Togo	Akposso (Bena)		Endocarp, wood	Protected areas	Only wild trees still far from cultivation initiative taking exploited by local communities and wood industries.

Table 2 – First two principal components from the PCA on the ethnobotanical variables.

Ethnobotanical variables	First axis (48.56 %)	Second axis (10.95 %)	Third axis (8.49 %)
1- First energetic use: ABMTs' branches + wood for domestic energy	-0.18	-0.27	0.90
2- Second energetic use: Bush mangoes' wooden for domestic energy	-0.18	-0.27	0.90
3- First socio-cultural use: dried branches to serve Holli + Nagot native fetish	-0.82	0.15	-0.06
4- Second socio-cultural use: Mature wood (trunk): incarnation of died twins	-0.78	0.31	0.09
5- Third socio-cultural use: dried mature wood for fetish drum making	-0.80	-0.26	-0.09
6- Economic uses: Leaf + fruit to accelerate other fruits ripening	-0.54	-0.76	-0.12
7- First therapeutic use: immature fruit accelerates the digestion of nitrogenous foods (mainly beans)	-0.24	0.10	0.17
8- Second therapeutic use: mature fruits as laxative	-0.64	-0.05	-0.24
9- Third therapeutic use: endocarp based sauce for ulcer occurring	-0.78	-0.30	0.05
10- Fourth therapeutic use: fresh leaves tea against malaria	-0.81	-0.26	-0.06
11- Fifth therapeutic use: fresh leaves tea to reinforce bladder excitation during the night.	-0.84	0.32	0.03
12- Sixth therapeutic use: fresh leaves for occurring specific children disease	-0.77	-0.43	-0.06
13- Seventh therapeutic use: bark in female gynaecology	-0.89	0.18	-0.07
14- Eighth therapeutic use: roots tea against impotence	-0.65	0.23	0.18
15- Ninth therapeutic use: bark tea against haemorrhoid	-0.72	0.26	0.10
16- Tenth therapeutic use: oil from the endocarp against skin disease	-0.85	0.20	-0.06
17- Eleventh therapeutic use: small branches chewed against bad breath	-0.67	0.22	0.12
18- Twelfth therapeutic use: bark for wounds treatment	-0.84	0.22	0.04
19- Thirteenth therapeutic use: bark tea for balancing human body temperature	-0.58	-0.25	-0.19
20- Fourteenth therapeutic use: bark for reinforcing babies' fontanel	-0.83	0.28	0.05
21- Fifteenth therapeutic use: bark for mycosis treatment	-0.49	-0.19	-0.28
22- Sixteenth therapeutic use: leaf tea as analgesic	-0.54	-0.76	-0.12
23- Seventeenth therapeutic use: bark tea for dyspnoea	-0.84	0.32	0.03

Power transformation for percentage data (Box & Cox 1964) was applied to Mn_{id} in order to normalize the data and stabilize their variance. Using Statistica version 6 (StatSoft 2001), a two way Analysis Of Variance (ANOVA-2) was performed on the transformed Mn_{id} values in order to identify factors influencing the level of knowledge on bush mango tree uses. In this model, the 2 fixed factors are "socio-cultural group" and "user group". The main effect of these factors and the interaction were assessed in this analysis.

In order to detect if respondents could be categorized geographically and to compare the two user groups, a Principal Component Analysis (PCA) was performed on a 0/1 matrix of all known uses per respondent and one column for each geographically defined socio-cultural region. Principal component scores from the first three axes of the PCA were plotted in two-dimensional spaces. Since factors presenting no variability of responses introduce no explainable variation in the PCA, uses known to all respondents were deleted from the matrix.

Occurrence and density data reconstruction – Within each mega-transect, the border trees of each high density area were projected in DIVA-GIS (Hijmans et al. 2001) and its extent was approximated by the derived convex polygon. The total number of bush mango trees (NT_j) in each high density area was estimated by:

$$NT_j = N_s \times S_{tj} \,/\, 10{,}000 \quad (2)$$

Where N_s the number of trees in the two sub-sampled areas of 100 × 50 m and S_{tj} = the extent of the high density area in m².

Using DIVA-GIS, the NT_j trees were artificially generated in a random spatial pattern in the j^{th} area to complete the direct observation database (fig. 1). Then, within each mega-transect, the number of trees that occurred within each 0.5 × 0.5 km, was obtained and geo-referenced in the centre of that unit area. Outside of the mega-transects, adjacent area where continuous occurrences were obtained, the number of trees per 0.5 × 0.5 km was obtained in a similar way. Data on isolated individuals and small tree groups scattered in low density areas was entered as well with their GPS position. Finally, the zero density points were added with their GPS position to thus complete the geo-referenced density database.

Spatial analysis of bush mango tree abundance in the Dahomey Gap – First, to assess which environmental variables influence the density, the layer of density points was superimposed with those of the countries (Benin and Togo), the FAO soil type (http://www.fao.org/geonetwork/srv/en/main.home#soils) and the phytogeographical zones in Benin (Adomou 2005) and Togo (Ern 1979). Using DIVA-GIS, the corresponding values were extracted into a database.

Bitter trees have a limited distribution being restricted in the Volta forest region (the Southern Mountains phytogeographical region in Togo). The density information turned out to have too few data points for a reliable statistical analysis. This is why, in this study, the analysis of their abundance and spatial structure remains descriptive.

For sweet trees, zero density values were replaced by 0.1 and a natural logarithm transformation was applied. Using SAS 9.2 (SAS Institute Inc. 1999) an Analysis Of Variance (ANOVA) was carried out to assess the effect per variable.

Spatial variability of sweet bush mango tree density was measured using a geo-statistical approach (Rossi et al. 1992, Christakos et al. 2002). In this analysis, we ignored all short-term dynamic aspects that might change the spatial pattern, such as abundant regeneration in the rainy season, planting or selective elimination of trees, etc. Therefore, the density pattern was considered as a finite stock of trees expressing the environmental and conservational conditions in the geographic space. As such, we assume it to be a Gaussian random field at the second order stationarity (Goovaerts 1997). This implies that the mean density is constant over the geographic space and the covariance between density values at position x and those at position $x + h$ exists and depends only on h not on x. In this study, we preferred the semivariogram function, which is simpler and more robust than the covariance (Baillargeon 2005) to measure the patchiness or the spatial pattern of bush mango trees' density over the study area. The Bayesian Maximum Entropy Library (BMELib: Christakos et al. 2002) compiles consistent functions written in the Matrix Laboratory (Matlab) language to catch spatial structure by a geostatistical analysis. Using BMELib in MATLAB version R2011a (MathWorks Inc., Natick, MA, USA), the density semivariogram function was calculated as follows:

$$V(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[d(x_i) - d(x_{i+h}) \right]^2 \text{ (Goovaerts 1997) (3)}$$

With $V(h)$ = density (d) semivariogram estimator; $d(x_i)$ - $d(x_{i+h})$ = difference of mean of densities separated by a lag distance of (h) and $N(h)$ = number of data pairs in this lag distance. Omnidirectional as well as directional (North-South, West-East, 30° and 60°) semivariograms were calculated to check significant directional variations in bush mango trees spatial structure. Only the omnidirectional semivariogram was modelled using the "eye fitting technique" (Rossiter 2007) and its parameters (nugget effect, sill and rang) were used to characterize the spatial structure of bush mango trees' based agroforestry systems in the study area.

Kriging is the more reliable estimation technique integrating semivariogram parameters and information regarding observed surrounding data points (mean and distance) and minimizing the prediction variance (Goovaerts 1997, Kumar & Remadevi 2006). It promotes spatial visibility of information contained in the semivariogram. In non-sampled areas random points were generated in 0.5 × 0.5 km grids cells. Using the BMELib in Matlab and based on the model of the obtained omnidirectional semivariogram, the density was estimated at those non-sampled points across the study area by means of the ordinary kriging method (Goovaerts 1997, Christakos et al. 2002):

$$d_e(x_0) = \sum_{i=1}^{N(x0)} W_i d(x_i) \quad (4)$$

Where $d_e(x_o)$ is the estimated density value at location, $\sum_{k=1}^{n(i)} W_k(i) = 1 =$ the sum of the weights (w_i) of $N(x_0)$ surrounding points with $d(x_i)$ values.

Analysis of the anthropogenic drivers of bush mango tree spatial density patterns – Using Statistica version 6 (StatSoft 2001), a Multinomial Logistic Regression Analysis (Hosmer & Lemeshow 1989) was carried out on the eight parameters influencing the conservation and cultivation of bush mango trees. The Global Null Hypothesis (GNH: BETA=0) and the Type 3 Effects Analysis were used to validate the accountability of the CMLRA and identify the most causative parameters, respectively. The Maximum Likelihood Estimate and the Odds Ratio Estimate help to identify parameters that hinder or induce the conservation or cultivation and give a comparative basis of the influences related to different levels of the causative parameters.

Variation of bush mango tree population structure – For each population, the size distribution (DBH) was obtained and the coefficient of skewness (ℓ) was calculated to characterize its structure:

$$\ell = \frac{1}{n} \sum_{\alpha=1}^{n} (z(\alpha) - m)^3 / \alpha^3 \text{ (Goovaerts 1997) (5)}$$

Where n = total number of individuals within the population, $z(\alpha)$ = dbh of the α^{th} individual within the population, σ = standard deviation of dbh values, m = mean of the dbh in the population. For each population, the percentage of trees affected by each type of physical damage was calculated for each diameter size-class: 0–7, 7–20, 20–30, 30–40, 40–50, 50–60, 60–70, 70–80, 80–90, 90–100, and > 100 cm. A two-way ANOVA was run in SAS 9.2 (SAS Institute Inc. 1999) to assess differences in the level of damage per population. A Tukey test was associated to the ANOVA in order to classify populations based on the pairwise differences of their level of threat.

RESULTS

Traditional use and management of bush mango trees

Sweet bush mango trees were recorded in all socio-cultural areas while the bitter ones were only encountered in the Akposso area in the Volta forest region in Togo (fig. 1).

In all areas the mesocarp of the sweet bush mango and the seed of both sweet and bitter bush mangoes are consumed and marketed. Table 2 provides the twenty-three other uses (socio-economic, medicinal and energetic, see also Vihotogbé et al. 2007) that were identified. In comparison to the 2007 study, only one additional use (fruits and / or leaves used for accelerating ripening of other fruits, mostly *Musa* spp. but less often also *Persea americana*, *Ananas comosus*, *Chrysophyllum albidum*) was found.

The ANOVA-2 results are presented in table 3. They show that the level of ethnobotanical knowledge (Mn_{id}) de-

Table 3 – Result of Analysis of Variance of level of ethnobotanical knowledge.

Source of variation	Degree of freedom	Mean Square	F statistics	P value
Socio-cultural group	8	0.75	185.45	< 0.0001
Socio-professional group	1	0.45	112.09	< 0.0001
Socio-cultural group * Socio-professional group	8	0.14	35.39	< 0.0001

pends on both the socio-cultural group and the socio-professional group ($p < 0.001$). Moreover, within each socio-cultural group, the level of knowledge was significantly different between the two professional groups ($p < 0.001$). In the Adja, Holli and Nagot areas, the professional users detained higher local knowledge on *Irvingia* species than the non-professional ones, but in the other areas no clear difference was showed between these two groups. Professional users in the Holli and Nagot areas (mean knowledge = 78% and 65%, respectively) have the most extensive ethnobotanical knowledge of *Irvingia* species in the study area. The Akposso area was that with the least indigenous knowledge (mean knowledge = 1%). Thus, the level of indigenous knowledge (Mn_{id}) appears to be higher in Benin than in Togo and is mostly concentrated in the southeast (Holli and Nagot; fig. 2).

The PCA on the 0/1 matrix of ethnobotanical data shows that the first three axes together account for 68% of the variation within the ethnobotanical data (table 2). The first axis (48.04%) was negatively correlated with all three socio-cultural uses and fourteen medicinal uses. The second (10.95%) was negatively correlated mainly with only one medicinal use, while the third axis (8.15%) represents intensive use of bush mango trees as a source of domestic energy (fuel). The

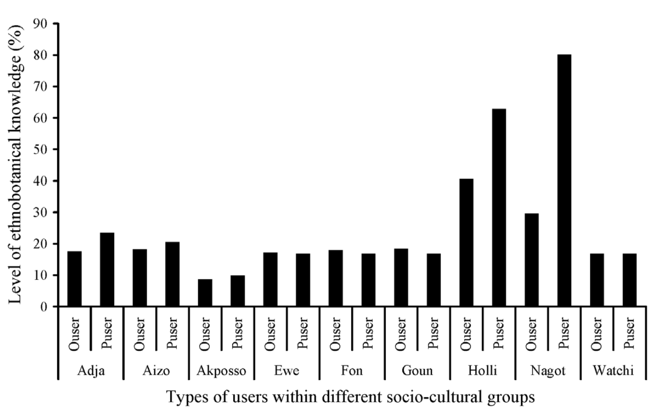

Figure 2 – Result of the Analysis of Variance: comparaison of socio-cultural groups, socio-professional groups and their co-influence. Socio-cultural groups = Adja, Aizo, Akposso, Ewe, Fon, Goun, Holli, Nagot and Watchi. Socio-professional users within each socio-cultural group are: Ouser = ordinary users of NTFPs from bush mango trees, Puser = Professional users of NTFPs from bush mango trees.

first axis (fig. 3A & B) shows, again, that the Holli and Nagot peoples in south-eastern Benin (and most importantly their professional users) had a higher indigenous knowledge than all other communities. The third axis shows that apart from the Akposso and few Nagot people, wood and the hard endocarp are intensively used as fuel everywhere in the study area.

In Togo, the seeds (or more precisely the endocarp containing the seed, so the stone or pyrene) are mostly sold to Beninese and Nigerian customers while small amounts are locally used to thicken vegetable sauces based on *Corchorus olitorius* (Tilliaceae) and *Abelmoschus esculentus* (Malvaceae). Apart from some Togolese Ewe groups, the high thickening property and brown colour of this sauce makes it 'heavy' and not appreciated by Togolese. The seeds are still considered to be an essential part of the diet of the Fon, Goun and Nagot people in Benin and most importantly the Nigerian Ibo.

From the interviews it appears that, there is a taboo on planting bush mango trees among all ethnic groups studied in Benin, since the trees may expose neighbouring households to witchcraft, bad health and even death. However, only few farmers understood and confessed that this taboo actually is rooted in the refuse by elders to accept young owners to freely manage their economically important trees producing fruits with the best and desired mesocarp quality: orange colour, very sweet and deep flesh with low water content and low fibrosity: 'pasty fruit'. However, because of the growing economical value of bush mangoes' and seeds), this taboo is being broken by local communities and trees are being integrated in intensive cultivation systems through the selection of mother trees and seeds for planting. The definition of mother tree depends on the targeted non-timber forest product on bush mango trees. Trees producing very sweet and 'pasty' fruits are prioritized in areas of fruit commercialization. In contrast, sweet fruits with large seeds (mean size $\geq 52 \times 37 \times 23$ mm) are valued in areas where their usage is dominant. Transplanting of seedlings encountered under superior sweet mother trees is common. However, in some areas, seeds are used to establish orchards and agroforestry parks in taungya agroforestry systems.

In the Akposso area, the bitter fruited trees were called 'the never cultivated bush mango trees'. Wild individuals are preserved on lands being transformed to cocoa, coffee and banana fields or in forest gardens in the Akposso area in the Volta forest region of Togo. Akposso communities reported that the marketing of seeds started 20 years ago with the settlement of Ibo communities and is still considered as a marginal, female activity. However, men prefer the wood of bitter trees as the most economically valuable timber after *Milicia excelsa* (Moraceae).

Spatial structure of bush mango tree abundance

Density of sweet bush mango trees ranges between 0 and 1020 trees/25 ha (= 0.5 × 0.5 km). Low densities are frequent while high densities are spatially limited. The overall mean density of sweet trees is 35 (SD = 113) trees/25 ha. Low densities (ranging from 0 to 462 trees/25 ha) have also been recorded for bitter trees in the Southern Mountain phytogeo-

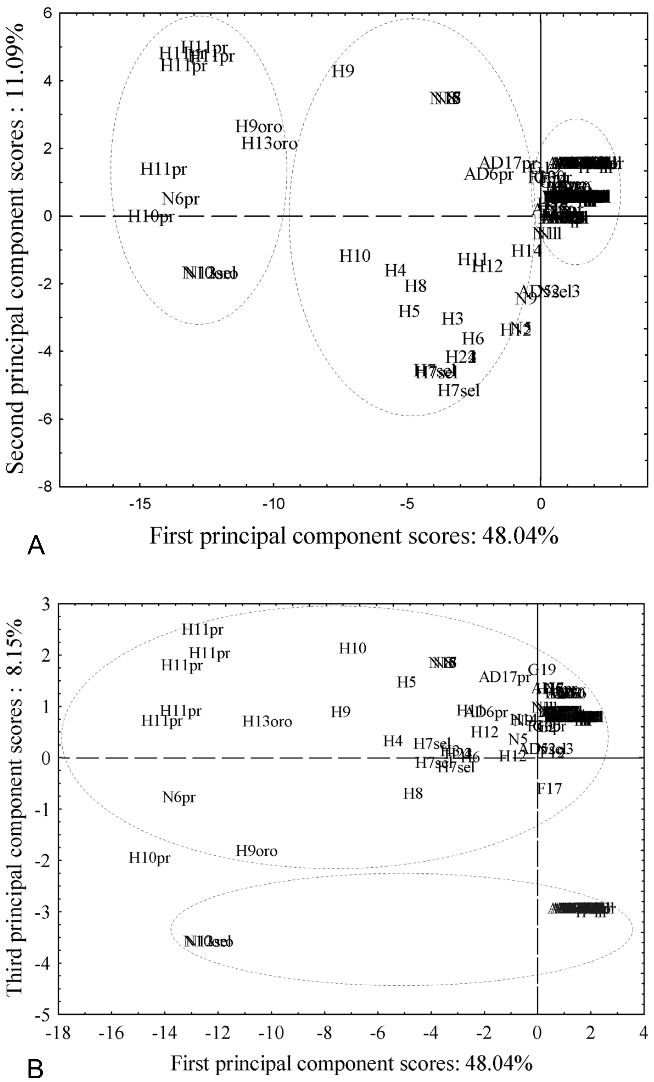

Figure 3 – First three PCA axes of the analysis of the 1 / 0 matrix of the ethnobotanical knowledge of the nine socio-cultural groups. AD = Adja, Ai = Aizo, Akp = Akposso, E = Ewe, F = Fon, G = Goun, H = Holli, N = Nagot, W = Watchi; pr = traditional healer, sel = merchant of medicinal plants, oro = head of 'Oro'; rel = traditional religions keeper

graphical region in Togo, with an overall mean of 55 (SD = 99.8) trees/25 ha. In this phytogeographical region where bitter and sweet bush mango trees co-occur, bitter trees are found in the wild in swampy areas, along streams and on hill slopes, while sweet trees occur everywhere even on the top of hills, following human settlements but not in swamps or along streams.

ANOVA indicates that sweet tree density does not vary significantly at the country level (P = 0.0994). It is, however, significantly correlated with the FAO soil types and phytogeographical zones (P < 0.001 for both factors). The higher densities (mean = 90 and maximum = 1020 trees / 25 ha) are found on lateritic group soils (Nd9 and Ne6-2b types) and on the complex ferric shallow and rocky soil types (I-Lf-Rd type). High densities occur in the phytogeographical regions of Plateau (in Benin), Central Lowlands and Southern Mountains (in Togo). More specifically, the high densities are located around Kpalimè in Togo and in the Adja and Sakété-Pobè areas in Benin. Especially in the south of Benin, very old trees were locally considered as remnant of the natural populations that have been devastated during forest clearance for industrial palm oil tree development on ferralitic soils.

The regionalized density data, that is, the sampled density values projected in the geographical space are presented in figure 4A. The geostatistical analysis of the spatial structure of the density values revealed an isotropic semivariogram model. Only the West-East semivariogram displayed a slightly different spatial continuity while the others are all very similar or identical (fig. 4B). Most importantly, the overall trend of all semivariograms was identical. The model fitted to the omnidirectional semivariogram was composed of a nugget effect (semivariance = 1), followed by a spherical pattern (semivariance = 2, range = 5 km) and an exponential pattern (semivariance = 1.25, range = 22 km). The highest semivariance value (4.5) in bush mango trees' density was observed after 22 km. This means that the study area comprises patches of bush mango tree based agroforestry with uniform densities in an average radius of 22 km. After this range, the density values became significantly different in all directions (fig. 4B) and so, high density areas were spatially limited (fig. 4C). Figure 4C gives the spatial distribution of the density over the study area, as the result of the kriging modelling technique based of the semivariogram characteristics. Even though low density values were common (black and red dots, fig. 4C), their level still fluctuated (presence of the nugget effect), confirming the patchy spatial pattern for sweet trees over the study area (fig. 4C).

Potential drivers of the spatial pattern

In orchards, bush mango trees' density varied between 256 and 400 per ha. The density of 400 trees per hectare was encountered in short-term taungya systems with many spontaneous occurrences, while that of 256 trees per hectare was frequent in permanent taungya systems that combined trees and subsistence crops. Densities in agroforestry parks are low (161 trees per hectare) but densities higher than 400 trees per hectare can be detected in areas of abundant natural regenerations within this same system. Densities in forest gardens were in general lows.

Results of Logistic regression used to investigate the causal factors behind the density patterns observed, presented a Pr > Chi-Sq < 0.001 for the GNH-Beta = 0 test, indicating that some parameters are indeed involved in this decision-making. Farmland status, ethnic group and bush mango type were identified as significant parameters (table 4: Type 3 Effect Analysis). Having the lowest coefficient, an unclear inheritance status of the farmland apparently highly weakens the desire to develop an orchard (table 5: Maximum Likelihood Estimation). Considering farmland tenure, it appears that especially private, poor and small farmlands are being converted into bush mango trees orchards (Odd Ratio Estimation Point = 422 in land tenure options: table 5). On the other hand, farmlands with an uncertain inheritance

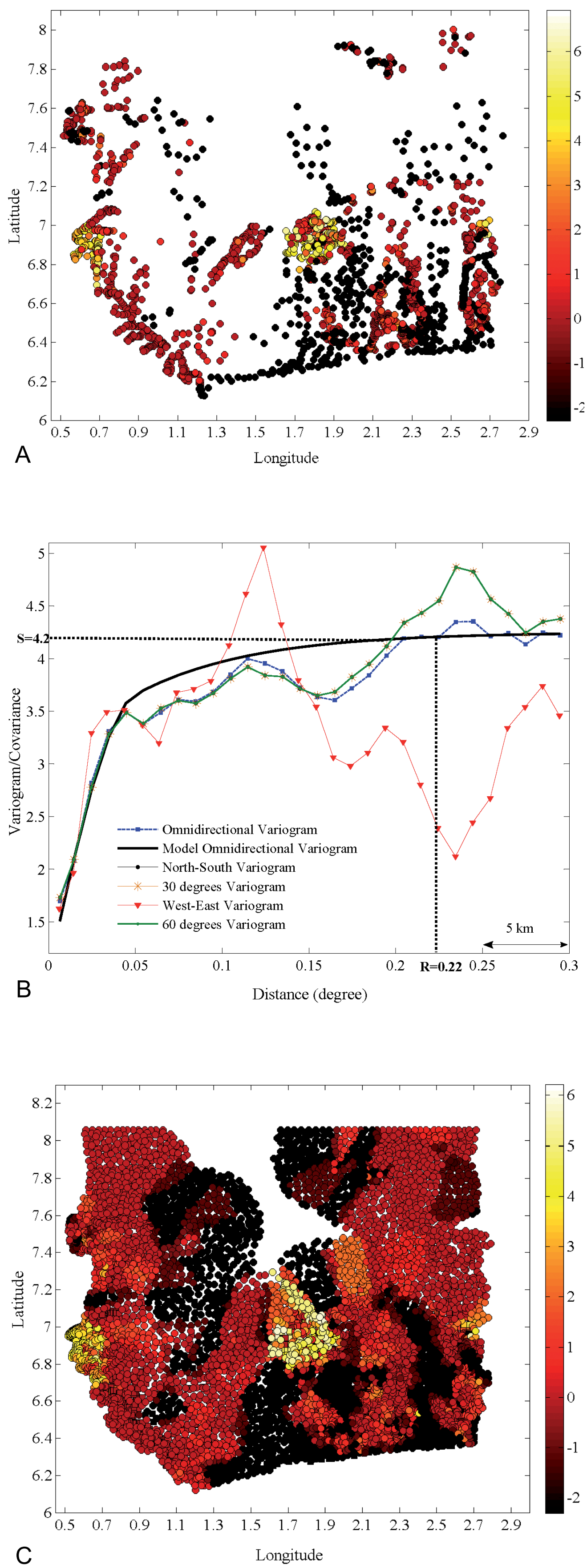

Figure 4A – Location of log transform values of sweet bush mango trees density within 0.5 km x 0.5 k.
Figure 4B – Semivariogram expressing spatial structure of sweet bush mango trees density.
Figure 4C – Kriging map of sweet bush mango trees density across the study area. The colour bar indicates the natural logarithm of the density gradient: darker colours indicate lower density (black colour for zero density) and lighter ones higher densities (white colour for the highest values).

status apparently give no confidence to farmers to engage in intensification of bush mango tree cultivation (Odd Ratio Estimation Point = 0.005; 3B). Regarding socio-cultural groups, significant initiatives for orchards development have been undertaken only by the Adja people. The Akposso people mostly use agroforestry parklands and forest gardens to manage bitter trees in the wild and do not establish any *Irvingia* orchards. Sweet trees are 16 times more frequently cultivated in orchards than bitter trees. Local marketing, the specific reason for bush mango cultivation (seeds), and existing taboos remain key factors determining the desire to intensify cultivation. However, their influence is still limited compared to the other significant parameters.

Differences in population structure and threats

In the Akposso area (Bena and Kounionhou), natural forest and forest gardens are mostly populated by large trees (skewness ≥ 1.5; fig. 5A & B). In forest gardens, with a mean dbh of adult trees of 80 cm and where the largest trees are found, spontaneous regeneration is still abundant (32%). In contrast, regeneration in natural forest, where adult trees are on average slightly smaller than in forest gardens (mean dbh = 70 cm), is only 2%. In the Aizo area, the population is also composed of large trees (skewness ≈ 1; fig. 5E). Here, two sub-populations can be recognized: spontaneous old populations (mean dbh = 70 cm), being replaced by cultivated young ones with a mean dbh of 20 cm. In this area, natural regeneration is very low (3%). A similar replacement initiative appears in the Holli and Nagot areas of Pobè, where the separation of the two sub-populations (mean dbh = 20 cm and 80 cm; fig. 5F) in quasi equal frequency tends to be even clearer (skewness = 0.33). Planting was more intensive in the Adja area (Lalo-Klouekanmey) where young trees dominated the population (skewness = - 0.18; mean dbh = 30 cm) with high regeneration figures and an absence of large trees (> 80 cm dbh; fig. 5C). Similarly, the planted population in the Ewe area (Kpalimè) shows abundant regeneration and less large trees (mean dbh = 30 cm; fig. 5D).

Apart from the intensive collection of fruits (and seeds), five other practices negatively affect the increase in popula-

Table 4 – Assessment of the accountability of the logistic regression model.

Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Sq	Pr > Chi-Sq
Farmland status	4	0.8297	< 0.0001
Socio-cultural group	8	2.4673	< 0.0001
ABMT Type	1	5.4446	< 0.0196

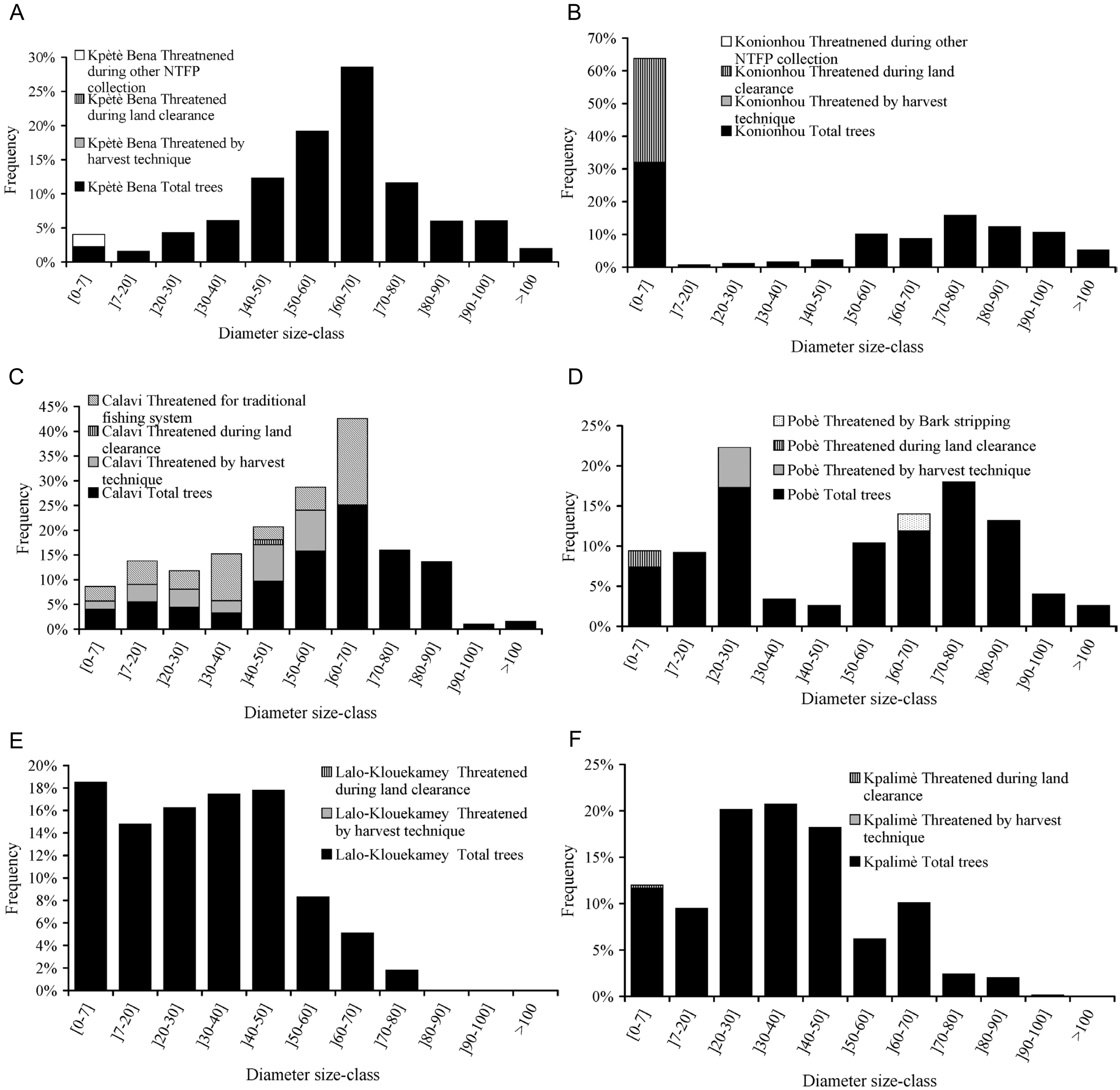

Figure 5 – Bush mango trees population structure and treat levels in different socio-cultural areas. A, wild bitter trees in protected area in the Volta region; B, wild bitter trees in traditional agroforestry systems in the Volta region (Kounionhou); C, sweet trees in old forest and current traditional fishing area in Benin (Calavi); D, sweet trees in old forest region in south east Benin (Pobè); E, cultivated sweet trees in southwestern Benin (Lalo-kouekamey); F, planted sweet trees in the lower Volta region (Kpalimè): A = 1.5; B = 1.63; C = 0.926; D = 0.33; E = -0.18; F = 0.35.

tion density and surface occupied by *Irvingia*. Some trees show the simultaneous occurrence of flowers and fruits and the harvesting of unripe fruits (by shaking the branches or using long sticks or even a machete) causes profound damage: flowering abortion, debarking, and reduction of the crown size. In some areas, saplings and seedlings are cleared for field establishment or maintenance. During other NTFP collecting in natural areas saplings may be systematically cleared. The bark of bush mango trees is sometimes severely stripped for medicinal purposes. Finally, the traditional fishing system uses *Irvingia* twigs for the construction of an ‘Akaja’, a structure that provides a breeding ground for fish. The resulting severe pruning is a major cause of population decrease and of low productivity.

Considering the combined threats, the Tukey test indicates three levels of population threats (table 6). The frequency of threatened trees depends on the socio-cultural location of the population (P = 0.008), but all six identified practices

Table 5 – Analysis of factors driving the desire of local farmers to intensify ABMTs cultivation.
LSH = lend farmland with agreement of sharing the harvest; LP= large and private farmland; UHS = farmland with unclear inheritance status; SPP = small and private farmland with poor soil; SPR = small and private farmland with rich soil; FTS = food tree species; ** = highly significant factor in the desire for intensive cultivation; *** = very highly significant factor in the desire for intensive cultivation; ^{NS} = factor with no significant in the determination of the motivation for intensive cultivation.

			Analysis of Maximum Likelihood Estimates				Odds Ratio	
Parameters		DF	Estimated coefficient	Standard Error	Wald Chi-Square	Pr > Chi- Square	Reference factor	Point Estimates
ABMT type	Edible	1	1.3779	0.5905	5.4446	0.0196**	Vs. Inedible	15.734
Farmland tenure	LSH	1	1.1202	9.5985	0.0136	0.9071^{NS}	Vs. SPR	22.
Farmland tenure	LP	1	3.2262	9.5636	0.1138	0.7359^{NS}	Vs. SPR	181
Farmland tenure	UHS	1	-7.1923	47.7358	0.0227	0.0282**	Vs. SPR	0.005
Farmland tenure	SPP	1	4.0722	9.5669	0.1812	0.0104***	Vs. SPR	422
Ethnic group	Adja	1	11.5780	34.8987	0.1101	0.0041***	Vs. Watchi	> 999.9
Ethnic group	Akposso	1	6.7783	34.9013	0.0377	0.8460^{NS}	Vs. Watchi	> 999.9
Ethnic group	Aïzo	1	3.2863	34.9096	0.0089	0.9250^{NS}	Vs. Watchi	1
Ethnic group	Ewe	1	-8.4624	324.500	0.0007	0.9792^{NS}	Vs. Watchi	2.33
Ethnic group	Fon	1	-9.3084	64.2539	0.0210	0.8848^{NS}	Vs. Watchi	1
Ethnic group	Goun	1	-8.4392	54.7494	0.0238	0.8775^{NS}	Vs. Watchi	2.385
Ethnic group	Holli	1	8.4553	34.9011	0.0587	0.8086^{NS}	Vs. Watchi	> 999.9
Ethnic group	Nagot	1	7.1952	34.9018	0.0425	0.8367^{NS}	Vs. Watchi	> 999.9

Table 6 – Tukey test on population disturbance and categorization.
Populations with different letters are significantly different in terms of their actual disturbance level.

Tukey Grouping		Disturbance levels generated by SAS	Population	Corresponding socio-cultural areas
	A	0.013402	Calavi	Aïzo + Fon
B	A	0.005869	Kounionhou	Akposso
B	A	0.001927	Pobè	Holli + Nagot
B		0.000236	KpètèBena	Akposso
B		0.000060	Kpalimè	Eve (settled inside other socio-cultural groups dominated by Akposso)
B		0.000000	Lalo-Klouekamey	Adja

equally contribute to tree damage (P = 0.2563). Trees in the most intensively fished area (Aizo, Calavi) are the most highly threatened. Figure 5E shows that in this population, apart from the intensive collecting of fruits, all top three threat practices (branches pruning, juvenile clearance and damages caused by harvesting techniques) occur and may affect up to 17% of the adult trees of a given size class. Bitter trees in forest gardens of the Akposso area (Kounionhou) and sweet trees in the Holli and Nagot areas (Pobè) represent the second most disrupted populations with a high damage rate due to juvenile clearance (2–32%) during land preparation and inadequate harvesting techniques (fig. 5B & F). In contrast, bitter trees in the protected area of the Akposso area (the disturbed forest land Kpètè-Bèna) and sweet trees managed by the Ewe community (Kpalimè) as well as most of these trees in the Adja area (Lalo-Klouekanmey) hardly show any damage (only 0–1.8% of threatened trees; fig. 5A, C & D).

DISCUSSION

Heterogeneity of knowledge and implications for bush mango tree occurrence

Given the fact that most of the communities in the Dahomey Gap are socio-culturally linked and have experienced long periods of migration within the Dahomey Gap and between this eco-region and the Nigerian Yoruba socio-cultural areas (see Dotse 2011, Medeiros 1984, Asiwaju 1979), their bush mangoes diets may not significantly vary if there is no difference in the history of trees' occurrence in their environment. In the particular case of bush mangoes in the Dahomey Gap we draw two hypotheses. First, local communities in the Eastern Dahomey Gap had no initial ethnobotanical knowledge and have obtained such knowledge from their contacts with the Yoruba people from Nigeria through population migrations. This demonstrates the importance of physical and cultural environments in ethnobotanical knowledge conservation and transmission (Dickinson 2012). In this situation,

it is very hard to postulate whether the bush mango trees have existed in the wild or not. Second, a diversity of local knowledge on bush mango trees may have possibly existed and eroded due to knowledgeable communities' migration in cities (see Dickinson 2012) and the transformation of their physical environment (Reyes-García 2001). This supposes the bush mango trees did occur in the wild in the Dahomey Gap. The diversity of uses and economic contribution of bush mango trees to livelihoods are leading motives for their cultivation (Asaah et al. 2003). In the 250 km wide area in Benin and Togo where bush mango trees occur, most of the socio-cultural groups are related and have no migration limits (Asiwaju 1979). Only the consumption of the sweet mesocarp and the seeds are known to 100% of the local communities. Thus, the variation of the local socio-cultural knowledge showing a gradient with the lowest level in Togo (see fig. 2 and Lesley & Brown (2004), who reported a high diversity of use in Cameroon and Nigeria) indicates that bush mango tree conservation or cultivation did not initially occur because of the appreciation of their socio-cultural properties but rather for mesocarp and seed consumption and commercialization (Tchoundjeu & Atangana 2007). In this normally slow process of learning (Turner & Turner 2008) food properties may be accepted faster than any other types of use. Therefore, in the study area, bush mango tree cultivation is justified by the consumption of the sweet mesocarp and seeds, and the economic value of these two NTFPs is leading the domestication process in their entire distribution range (Leakey & Tchoundjeu 2001, Vodouhê 2003, Atato et al. 2010).

Thus, the question is whether in the study area sweet bush mango trees did occur naturally, or were introduced and can survive only in cultivation. The fact that the origin of seed-based diets is situated in the Ibo and Yoruba areas (in Nigeria) supplemented by the decrease of ethnobotanical knowledge in a western direction, strengthens the hypothesis that sweet trees spread by population migration from the Lower Guinean forest block in Nigeria west over the study area (Lowe et al. 2000). The change in behaviour caused by the break of taboos related to bush mango tree cultivation in Benin and the beginning of the consumption of the kernel in Togo, further confirms this theory. This confirms that socio-cultural practices are exposed to continuous changes induced by those from the environment and human migrations (Reyes-García et al. 2009, Dickinson 2012).

The purposes of the development of priority food trees species are clearly identified by local communities. There is a need to adopt different strategies in bush mango tree germplasm collecting and propagation. However, other activities, like control of the reproductive biology, tree improvement and breeding (Leakey et al. 2005a), are not significantly taken into account. Therefore, like in many other valuable food tree species, the domestication of sweet trees is mainly initiated by individual farmers and encouraged by market opportunities (Leakey et al. 2005b). In this process, a difference exists in the treatment of bush mango trees depending on the local target. Where fruits are marketed for mesocarp consumption, less well-tasting trees or those having a fibrous mesocarp as well as infested trees are systematically eradicated (Vodouhê 2003). Where seeds are commercial items, trees with small stones (regardless of the mesocarp taste and nutrition quality) are eliminated. This inevitably leads to a loss of characteristics that might be valuable for the success of future agroforestry and plant breeding programs (Wood & Lenné 1997). The very low tree densities in certain areas which potentially seem suitable to grow bush mango trees may highlight not only an ethnic food preference or a lack of ethnobotanical or cultivation experience, but also regional differences in local market value of bush mango trees or even NTFPs in general.

When a plant genetic resource presents no direct opportunity locally (food, medicinal or social), the good 'extractivism approach' proposed by Almeida (1996) as the best strategy of exploiting NTFPs without damaging the species' life cycle guarantees no ecological balance (Rai & Uhl 2004). Thus, the intensive exploitation of the *Irvingia* seeds from wild populations in the Volta forest region and its valuable timber are key factors jeopardizing especially the bitter tasting *I. wombolu* by narrowing its potential areas of occurrence over time.

Variation in *Irvingia* conservation and cultivation

In the study area, *I. wombolu* was found mostly as wild elements on farm, in forest gardens and in natural forest stands, while sweet trees, *I. gabonensis*, were found almost exclusively in cultivation. This difference in cultivation status is primarily caused by people's preference for a sweet mesocarp (Vodouhê 2003). Bitter trees are therefore only preserved *in situ* in the Volta forest region. However, they belong to the most extensively exploited NTFPs in the Volta forest region and therefore this population may well be at severe risk of genetic erosion or even extinction, since the seeds are collected many times a day leading to low or inexistence viable regeneration.

The semivariogram characterizing the spatial pattern of bush mango tree density (fig. 4B) shows a nugget effect with spherical and exponential characteristics within a short range of 22 km. This result implies that within the sampled unit areas (25 ha), variations of densities still exist. However, the isotropic characteristic of the spatial structure implies that this unsteady pattern is repeated in all direction across the study areas where very local initiatives (within a radius of 22 km) of bush mango tree cultivation exist. Therefore, such initiatives are mainly taken by small-scale farmers, who are more involved in indigenous tree species cultivation to enhance the sustainability of their poorer productive space (Leakey & Tchoundjeu 2001).

Both bitter and sweet trees occur in an overall low density across their distribution range (Ewane et al. 2009). In the Dahomey Gap, this is partially rooted in the ancient taboo forbidding their cultivation. This is a typically negative traditional law, which instead of contributing to natural resources conservation (Foppes & Ketphanh 2000) ensures and speeds the erosion of bush mango trees' genetic diversity. The higher density of sweet trees found in some areas agrees with Leakey (2010) who reports that sweet bush mangoes are mostly exploited in traditional agroforestry systems. Therefore, the rapid break of non profitable taboos is valuable for biodiversity conservation and agrosystems productivity enhancement in order to respond to NTFPs increasing demand

and livelihood improvement. This is particularly important in fragile eco-region such as the Dahomey Gap where small size natural forests with the valuable plant species are threatened by climate and human impacts.

Impact of indigenous knowledge, socio-economic and ecological environments

Our results show that, in the study area, products of *I. gabonensis* are generally not collected from wild populations (Lowe et al. 2000). Sweet bush mango trees are integrated in intensive production systems by local farmers, because of their socio-economic value. This involves the manipulation, cultivation, and management of germplasm for a variety of products of the same species established in diverse systems (Wiersum 1996). Since such systems on average need a large surface, the priority crop status given to bush mango trees works counterproductive to solve the crucial problem of farmland availability in the study area raised by Floquet & Mongbo (1998). Sweet *Irvingia* trees are the most intensively cultivated trees in the study area. The fact that mainly small farms are being converted to bush mango tree orchards indicates that the current cultivation process is mainly led by poor farmers (Leakey et al. 2005a). Unfortunately, the future development of bush mango trees thus depends on the current traditional masse selection by those small farmers. So, these unguided selection strategies may lead to a loss of genetic diversity, with undeniable impact on bush mango tree's potential as a crop with diversified marketable products, since big nut is not the only desirable character on bush mangoes.

The cultivation of bush mango trees in more organized systems is related to the presence of the Ibo people who locally organize the endocarp collection. Because the Ibo settlement occurred later than the local initiatives for intensive cultivation, the influence of socio-cultural groups in the cultivation efforts appears justified. This difference in time might be rooted in the variation of ethnic knowledge and taboos as well as the ability and willingness of certain local ethnic groups to break ancient taboos. However, the relationship ethnic group – indigenous knowledge – conservation remains strongly influenced by local economic opportunities. The seed and mesocarp of bush mangoes equally influence the desire to intensify the cultivation. Thus, not only the economical priority of the seed (Tchoundjeu & Atangana 2007), but also the market for the entire fruits (sweet mesocarp, Vihotogbé et al. 2007) is an important stimulus for farmers' cultivation efforts. Moreover, the insignificant influence of the type of local market and the taboos on the desire to intensify the cultivation is indicative of a low production being offered to a very broad and diversified market. This has already led to the erosion of taboos in some areas and a high price of fruit and seed in the study area. However, the areas of intensive organization remain those where the seeds represent the most important economical product, even regardless the nature of the local collectors involved in the marketing. It appears that the presence of Ibo communities as local collectors stimulates a higher economic ambition because they are capable of paying in advance the price of the potential production of the bush mango trees, at the earlier flowering or immature fruit stages, inducing higher prices for seeds. This is brought about by strict planting based on a traditional selection process for large size seed germplasm.

Areas with high sapling densities indicate the core regions where intensive cultivation is practiced and the very low damage to trees confirms the priority crop status of sweet *Irvingia* in these areas. From there, the intensive cultivation process is spreading to reach regions where old populations are being progressively replaced by a better stock. In a continuously changing environment where local species have no direct interest of local communities, where slash-and-burn agriculture prevails, where plantation of exotic tree species increase and where there is a demand for high technological wood, the survival of any food tree species in forest gardens and agroforestry systems is jeopardized. Most importantly, the free access to bitter bush mangoes in natural areas causes competition between collectors, which strongly limits the natural regeneration (Arnold & Ruiz Pérez 2001, Rai & Uhl 2004). Like in the case of bitter bush mango trees, intensive logging of by local communities progressively extending the area of cash crop production is leading to a significant decrease of density (Sodhi 2007). In developing countries, effective control of useful forest genetic resources is hindered by a lack of funding and personnel, inactivity of most of the environmental conservation institutions and social and political instability (Postner 2008). On top of that, the distinction between *I. gabonensis* and *I. wombolu* is difficult, while research institutions in Togo do not even acknowledge their taxonomic integrity (Atato et al. 2010). This remains a key issue to be addressed seeing the current confusing taxonomical trends and debates on bush mango trees (Okafor 1975 and all recent work in Nigeria: Omokaro et al. 1999, Nya et al. 2000, 2006, Nzekwe et al. 2002, Olawale 2010, Harris 1996 and publications by the World Agroforestry Centre). It clearly may harm the protection of bitter bush mango trees against ecologically destructive factors and has a negative influence on its genetic conservation (Freese 1998). Because of that, more thorough investigations on all levels of the assessment of the taxonomic integrity of bush mango trees (ecology, reproduction biology, morphology, and genetics) are needed. In the study area, bush mango trees experience an uncertain conservation situation and, like many other tree species, are suffering from a lack of wise and efficient usage and conservation strategies.

CONCLUSION

The increasing cultivation initiatives, rooted in the high economic potential, are broadening bush mango trees' geographic distribution over exhausted soils in the study area. More organized and intensive cultivation systems are being driven by the Ibo communities that are also involved in the local commercialization systems. As a possible crop for future development, further research is needed regarding bush mango trees' potential cultivatable areas and productivity in different ecological areas. This is important, not only in the study area, but throughout their entire distribution range. This supposes a full morphological characterization, the definition of the bush mango ideotypes with respect to the type

of non-timber forest product targeted, and the capture, fixation and development of desirable genetic characters.

Regarding any food tree species, and bush mango trees in particular, there are two important challenges for scientists and development policy makers regarding the active role of local communities in their domestication process. For scientists, considering the rapid fragmentation of natural habitats in the tropics, at least the distribution of wild populations (and if possible the within-species genetic population structure) of NTFP species needs to be known. Then, for policy makers, especially better insights in the potential cultivatable area of such species would be very useful to assist decisions on land-use planning, while a good knowledge of the genetic variability is necessary for the *in situ* and *ex situ* conservation of germplasm.

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