Genet Resour Crop Evol (2014) 61:313–330
DOI 10.1007/s10722-013-0035-8

RESEARCH ARTICLE

Home gardens: an assessment of their biodiversity and potential contribution to conservation of threatened species and crop wild relatives in Benin

Valère Kolawolé Salako · Belarmain Fandohan · Barthélémy Kassa · Achille Ephrem Assogbadjo · Alix Franck Rodrigue Idohou · Rodrigue Castro Gbedomon · Sebastian Chakeredza · Mohammad Ehsan Dulloo · Romain Glele Kakaï

Received: 17 April 2013 / Accepted: 15 August 2013 / Published online: 12 September 2013

Abstract Despite growing literature supporting the importance of home gardens (HG) as biodiversity hotspots, knowledge of patterns of their contribution to conservation of threatened species and crop wild relatives (CWR) across climate and culture in Africa is still limited. This investigation was conducted across three climatic zones to assess the floristic diversity of home gardens and the extent to which they contribute to conservation of threatened species and CWR. Overall, 240 home gardens were sampled and their floristic diversity assessed. The ecological importance of recorded species was determined per climatic zone using the importance value index (IVI). A cluster analysis was performed to group the species according to their IVI-values and a principal component analysis helped to identify the most important species. 285 species were inventoried throughout the study area. Home garden species' diversity globally declined from the drier to the wetter zone but was highest in the transition zone. The average number of species found per HG was 10.1 and varied weakly across zones (9.07, Guineo-Congolean zone; 10.77, Sudano-Guinean zone; and 10.53, Sudanian zone). The most important home gardens species in the Sudanian, the Sudano-Guinean and the Guineo-Congolean zones were respectively: *Abelmoschus esculentus* (L.) Moench and *Hibiscus asper* Hook.f.; *Solanum lycopersicum* L. and *Zea mays* L.; *Ipomoea aquatica* Forssk. and *Senna occidentalis* (L.) Link. They were mainly vegetables and used as food and/or medicinal plant species. Twenty CWR and twelve threatened species were recorded and were also mainly used for food and medicinal purposes. Thorough research on socioeconomic factors supporting possession of HG and choice of managed species as well as indigenous management strategies of HG and dynamic of traditional knowledge related to HG may help to deeply assess home gardens' effectiveness in biodiversity conservation.

Keywords Conservation status · Climatic zones · Floristic inventory · Importance value index · West Africa

V. K. Salako · B. Fandohan (✉) · B. Kassa · A. E. Assogbadjo · A. F. R. Idohou · R. C. Gbedomon · R. Glele Kakaï
Laboratoire d'Ecologie Appliquée, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 01BP 526 Cotonou, Benin
e-mail: bfandohan@gmail.com; belarmain.fandohan@unep-iemp.org

B. Fandohan
International Ecosystem Management Partnership (IEMP), United Nations Environment Programme, c/o Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, No. 11A Datun Rd., Beijing 100101, China

S. Chakeredza
ANAFE, PO Box 30677-00100, Nairobi, Kenya

M. E. Dulloo
Bioversity International, Headquarter, Rome, Italy

Introduction

Millions of the world's poor rely on a wide variety of plant genetic resources to sustain their livelihood (Anley et al. 2007). The importance of conserving some key plant species has received increasing attention over the last decades (Galluzzi et al. 2010). A large body of research has also demonstrated that conservation of tropical biodiversity in degraded tropical landscapes can be assisted through the management of diverse agroforestry systems (Bhagwat et al. 2008; Gardner et al. 2009). These systems allow people to diversify their income and represent an effective way to conserve moisture and control soil erosion (Agbahungba et al. 2001; Hodgkin 2001). Due to their economic and ecological uses, many farmers adopt these systems.

Home gardening, the agroforestry practice of planting a mixed patch of livelihood-oriented perennial and annual species within a clearly bounded area near the homestead (Fernandes and Nair 1986) is receiving increasing attention. Several studies have highlighted their importance in the maintenance of plant genetic resources (Agelet et al. 2000; Sunwar et al. 2006; Perrault-Archambault and Coomes 2008). Home gardens have been reported as small but highly diversified ecological niches. For instance, Quiroz et al. (2004) have reported 591 species in 36 home gardens across a wide elevational transect (0–1500 m) whereas 573 species were found in 30.5 ha of home gardens surveyed in southern Vietnam (Hodel and Gessler 1999). The role of home gardens as repositories of biological diversity has then been acknowledged although a comprehensive, interdisciplinary investigation of their agro-biodiversity is lacking (Galluzzi et al. 2010).

Home gardens are primarily built for consumption and also for their medicinal purposes (Sunwar et al. 2006). But over time, the activities of the gardens have become more intensive and plants are chosen according to market orientation (Sunwar et al. 2006). The home garden found in rural areas, is characterized by structural complexity and multifunctionality that provides various benefits to ecosystems and people (Galluzzi et al. 2010). The logic of the gardens is to have small amount of fresh plants for daily consumption. Particular attention is devoted to spices and medicinal plants (Engels 2001). Some fruit species, roots and tubers can also be found (Engels 2001) and many home garden products are rich in micronutrients and vitamins (Odhav et al. 2007). All these evidence home garden as a critical contributor to the income and food security of the household.

The IUCN results of 2009 show that among 47,677 species studied, 17,291 are threatened with extinction. Since 1500s, 1159 species have already gone extinct or probably extinct, among which 65 species are extinct in the wild. According to the same IUCN results, 70 % of plants are considered threatened. Following the fact that home gardens represent a viable mechanism for biodiversity conservation (Engels 2001), they can be an *ex situ* and/or *circa situ* conservation area for rare and threatened species and therefore help balancing such an alarming threat on biodiversity sustainability. In fact, a botanical survey in more than 400 home gardens totaling 45.2 ha in south western Bangladesh revealed 419 species (59 % native, 51 % trees and shrubs), six of which were on the IUCN Red List for Bangladesh (Kabir and Webb 2008). Thus, these conservation systems of the diversity should be kept to continue ensuring the daily needs of the rural populations and also conserving biodiversity.

Home gardens are often utilized as testing plots for new crops, as nurseries for plantlets later destined for planting in open fields and as sites for domestication of weedy forms (Kulpa and Hanelt 1981; Leiva et al. 2001). Studies carried out in various countries demonstrate that high levels of inter- and intra-specific plant genetic diversity, especially in terms of traditional crop varieties, landraces and crop wild relatives (CWR) are preserved in home gardens (Hammer et al. 1999; Galluzzi et al. 2010). CWR include the progenitors of crops as well as other species more or less closely related to them (Hajjar and Hodgkin 2007). They have been undeniably beneficial to modern agriculture, providing plant breeders with a broad pool of potentially useful genetic resources. It is therefore important to preserve them for the needs of mankind.

Home gardens are also found in Benin, where some key species are kept by local farmers near their houses. Unfortunately, despite their importance, little is known about them in Benin and even in West African countries. Our knowledge of their biodiversity and patterns of their contribution to conservation of threatened species and crop wild relatives (CWR) across climate and culture in Africa is still limited. This is mainly due to the fact that most researchers have often focused on agroforestry systems such as intercropping trees with crops, thus neglecting home gardens.

According to White (1983), Benin covers three contrasting climatic zones which are (from the south northwards and increasing in altitude): the Guineo-Congolean zone, the Sudano-Guinean transition zone and the Sudanian zone. The climate becomes drier northwards i.e. from the Guineo-Congolean zone to Sudanian zone. Provided that diversity tends to decline with increasing altitude (Shall and Pianka 1978) and also with declining precipitation (Brown and Davidson 1977), we hypothesized that the floristic diversity of home gardens declines northward. In addition, assuming that farmers will select species in their closed environment, it was hypothesized that species found in home garden are dominated by native species. Finally, on the basis of recent works in Benin that highlighted the contribution of human migrations to conservation and distribution of a threatened species (*Caesalpinia bonduc* (L.) Roxb.; Assogbadjo et al. 2012a), we hypothesized that home gardens also contribute to conservation of non native plant species.

Materials and methods

Study area

The study was conducted in the three contrasting climatic zones of Benin (6°20′ and 12°25′N and 1° and 3°40′E, West Africa, see Fig. 1; Table 1): Guineo-Congolean zone, Sudano-Guinean transition zone and Sudanian zone (White 1983). Climatic patterns of each zone are described in Table 1.

The rainfall regime is bimodal in the Guineo-Congolean zone. Above this zone northwards, rainfall distribution becomes unimodal. Throughout the country, vegetation has suffered severe degradation as a result of various intense economic and human activities. In the southern part, where the population density is high, vegetation is composed of fallows and small forest patches of less than 5 ha (Sinsin et al. 2004). The transition zone is characterized by mosaics of woodlands while the Sudanian vegetation zone consists of savannas and gallery forests with small trees and shrubs slightly covering the ground.

Adja, Sahouè, Fon, Aïzo, Mahi and related (belonging to the language family Kwa) are the main socio cultural groups in the studied area (Zou and Couffo departments) in the Guineo-Congolean zone whereas Yoruba, Idaasha, Nagot and related (belonging to the language family Defoid) are the main socio-cultural group in the studied area (Collines department) in the Sudano-Guinean zone (INSAE 2003; Lewis 2009). According to the same authors, Ditammari, Berba, Waama, Gurma, Natimba and related (belonging to the Gur family language) dominate the study area (Atacora department) in the Sudanian zone.

Sampling and data collection

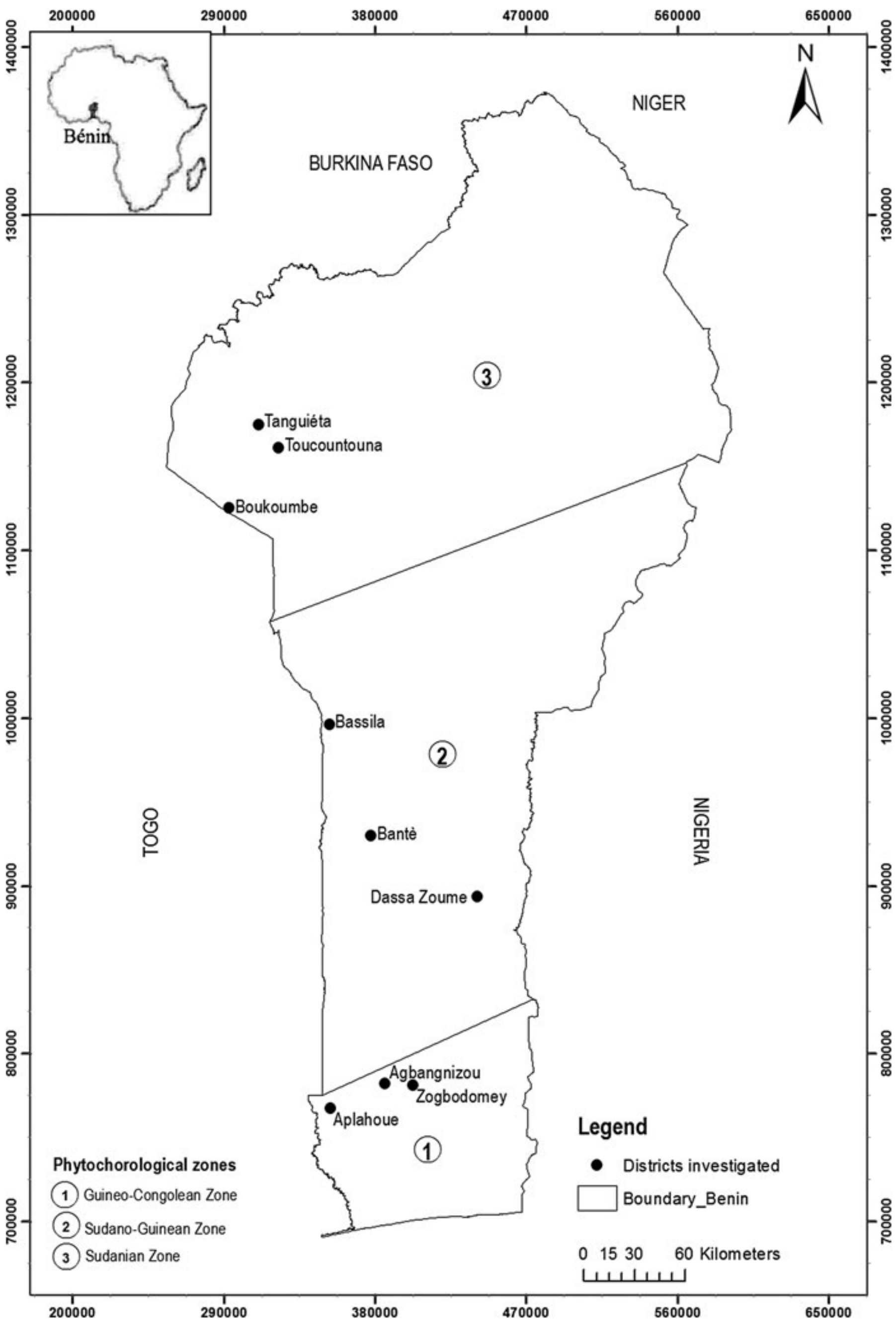
The data collection phase of this study took place between August 2011 and November 2011. First, an exploratory survey was conducted in three districts randomly chosen in each climatic zone: Tanguiéta, Toucoutouna and Boukombé in the Sudanian zone; Bassila, Bantè and Dassa in the Sudano-Guinean zone; Aplahoué, Agbangnizoun and Zogbodomey in the Guineo-Congolean zone. In each district, 60 informants were randomly chosen and were asked whether they have a home garden. 180 informants were thus considered in each climatic zone. The proportion (*p*) of positive answer (home garden owners) was then computed for each climatic zone and the number of informants (*n*) to sample in each climatic zone for the investigation was computed using the normal approximation of the binomial distribution (Dagnelie 1998):

$$n = \frac{U^2_{1-\alpha/2} \times p(1-p)}{d^2} \quad (1)$$

where $U_{1-\alpha/2}$ is the value of the Normal random variable corresponding to a probability value of 1 − α/2. For a probability value of 0.975 (or $\alpha = 0.05$), $U_{1-\alpha/2} \approx 1.96$; d is the margin error of the estimation of any parameter to be computed from the survey and a value of 8 % (Assogbadjo et al. 2011) was considered.

All *n* values were then rounded to 80 which was the highest *n* value. Finally, in each climatic zone, the number of respondent *m* to consider in each district (for a given climatic zone) was computed proportionally to the proportion (Ø) of home garden owners in that district ($m = 80 \times Ø$). The final number of respondents in each climatic zone was as follows: Sudanian zone (32 at Tanguiéta, 24 at Toucoutouna and 24 at Boukoumbé), Sudano-Guinean zone (30 at

Fig. 1 Location of the study sites



Bassila, 26 at Bantè and 24 at Dassa-Zoumè) and Guinea-Congolean zone (26 at Aplahoué, 29 at Agbangninzoun and 25 at Zogbodomey). Since each interviewee had only one home garden, overall 240 home gardens were studied.

In each sampled home garden, an exhaustive floristic inventory was carried out and species were named following the Botanical nomenclature of Lebrun and Stork (1991). The total numbers of individuals of each species as well as the area covered by each species in a home garden were also recorded. The covered area of each species was recorded as the abundance/dominance coefficient following Braun-Blanquet (1964). In addition, the use category of each species was noted and the size (covered area) of each home garden measured.

Table 1 Characteristics of the three climatic zones

Climatic parameters	Sudanian zone	Sudano-Guinean zone	Guineo-Congolean zone
Location	9°45′–12°25′N	7°30′–9°45′N	6°25′–7°30′N
Rainfall regime	Unimodal	Unimodal	Bimodal
Rainfall (mm)	<1,000	900–1,110	1,200
Temperature (°C)	24–31	25–29	25–29
Relative humidity (%)	18–99	31–98	69–97
Climate type	Dry tropical	Humid tropical	Humid tropical

Source: Natta (2003); Hijmans et al. (2004); Sinsin et al. (2004)

Most of the respondents' age ranges between 30 and 60 years old. The average age was 45.93 ± 2.88 *y* in the Guineo-Congolean zone, 45.31 ± 3.24 *y* in the Sudano-Guinean zone and 40.20 ± 1.42 *y* in the Sudanian zone. 73.75 %, 67.5 and 25.33 % of the respondents were men respectively in the Guineo-Congolean zone, Sudano-Guinean zone and Sudanian zone. 47.46 % of the men and 80.95 % of the women informants were illiterate in the Guineo-Congolean zone. In the Sudano-Guinean zone, 55.56 % of the men and only 26.92 % of the women informants were educated whereas 63.15 % of the men and 51.79 % of the women were educated in the Sudanian zone.

Data analysis

Assessment of the floristic diversity of home gardens across climatic zones

For each home garden and climatic zone three parameters of floristic diversity were considered: the species richness (S, in species), the Shannon diversity index (H, in bits) and the Pielou evenness (Eq) (see Favrichon et al. 1998; Gillet 2000 for details). The Kruskal–Wallis test was performed to compare the climatic zones according to these parameters. This test was used because the ANOVA assumptions, namely normality and homoscedasticity were not fulfilled by the data.

Similarities (with respect to hosted species) among the three climatic zones were assessed with the similarity index of Jaccard (see Choi 2008 for details).

To evidence the most common life form and analyze the relative abundance of native and non native species in each climatic zone and the whole country, life forms (Raunkiaer 1934) and phytogeographical spectra (White 1983) were built. Finally, to analyze the importance of each home garden species in each climatic zone, the importance value index (IVI) of each species was computed using the method of Curtis and Macintosh (1951). For a species i of a given climatic zone, the IVI was computed as follow:

$$IVI_i = RD_i + RF_i + RDo_i \tag{2}$$

In Eq. (5),

- RD_i is the relative density of the species i:$RD_i = Ni/\sum_{i=1}^{P} Ni$; where *p* is the total number of species recorded in the climatic zone and N_i is the mean density of the species i in that climatic zone,
- RF_i is the relative frequency of the species i: $RF_i = f_i/\sum_{i=1}^{P} f_i$, with $f_i = \frac{j_i}{k}$; where f_i is the frequency of the species i, j_i the number of home gardens at which the species i was counted, and k is the total number of home gardens (k = 80).
- RDo is the relative dominance of the species i: $RDo_i = Do_i/\sum_{i=1}^{p} Do_i$, Do_i is the mean dominance of the species i in the climatic zone. $Do_i = \frac{a_i}{A}$; a_i is the area covered by species i in a home garden of area A.

The IVI-value is referred to as the importance percentage. It gives an overall estimation of the level of importance of a species in the home gardens of a given climatic zone. Cluster analysis was performed using SAS 9.2 software to group the species according to their IVI-values in the three climatic zones. Principal components analysis was then applied to the IVI data to characterize the clusters. Projection of the cluster of species according to their IVI-values in the axis system defined by the principal components helped in identifying the most important species in each climatic zone.

Assessment of the diversity of crop wild relatives in home gardens through climatic zones

From the list of home garden species established for each climatic zone, the wild crop relatives list was derived using the National list of CWR recently established by Idohou et al. (2013). Thus the species richness of crop wild relative was calculated as well as their importance value index.

Analysis of the conservation status of home gardens species

Conservation status of home gardens species was analyzed at two levels: in Benin and in the world. It was done following the international union for conservation of nature (IUCN) categories of threatened species which are: extinct (EX), extinct in the wild (EW), critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), least concern (LC), data deficient (DD) and not evaluated (NE). The conservation status of each species in Benin was assessed using reports of Adomou et al. (2010) and Neuenschwander et al. (2011) who, following IUCN criteria, recently established a red list of threatened species in Benin. The conservation status of those species in the world was assessed with the database of IUCN Red list of Threatened species (IUCN 2012, www.iucn.redlist.org version 2011.2). For the two levels of assessment, the percentage of each category was computed for each climatic zone and the whole country and then plotted on a histogram.

Results

Floristic diversity and importance of home gardens species across climatic zones

Floristic diversity of the home gardens species, genera and family were evaluated across climatic zone (Fig. 2). The Sudano-Guinean zone had the highest species, genera and family richness (181 species, 150 genera and 77 families) while the lowest species, genera and family richness were encountered in the Guineo-Congolean zone (96 species, 79 genera and 44 families). Taken together, the three climatic zones embody a richness of 88 families, 203 genera and 285 species. The three most encountered families were: Euphorbiaceae (11.46 %), Leguminosae.-Caesalpinioideae (8.33 %) and Malvaceae (5.21 %) in Guineo-Congolean zone; Euphorbiaceae (9.02 %), Solanaceae (8.27 %) and Leguminosae-Papilionoideae (6.02 %) in the Sudanian zone; Leguminosae-Papilionoideae (6.52 %), Euphorbiaceae (5.43 %) and Leguminosae.-Caesalpinioideae. (5.44 %) in the Sudano-Guinean zone and Euphorbiaceae (7.88 %), Leguminosae-Papilionoideae (7.2 %) and Leguminosae-Caesalpinioideae (4.80 %) for the whole country. Whatever the climatic zone, most of the species were found to be used as food or medicinal plant (Fig. 3). Some species were used for cultural purposes (especially in the Guineo-congolean zone) and at a lesser extent for other purposes such as fodder, ornamental, timber and fence. The fact that the sum of proportions was greater than 100 % (>120 %, Fig. 3) clearly evidenced some of the species to belong to more than one use category (most often food and medicinal uses).

Assessment of similarities among climatic zones with respect to hosted species (Table 2) showed the highest similarity between Sudano-Guinean zone and Sudanian zone. The lowest similarity was observed between Guineo-Congolean zone and Sudanian zone. More species were shared by adjacent climatic zones (Table 2). Furthermore, results of the Kruskal–Wallis

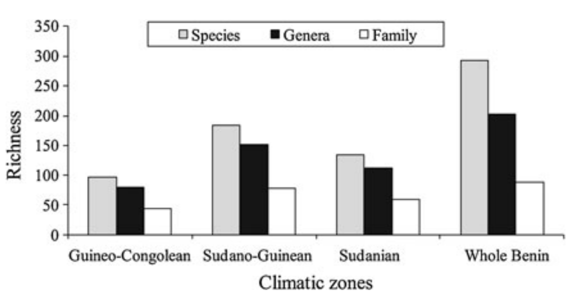


Fig. 2 Species, genera and family richness of home gardens according to the climatic zones

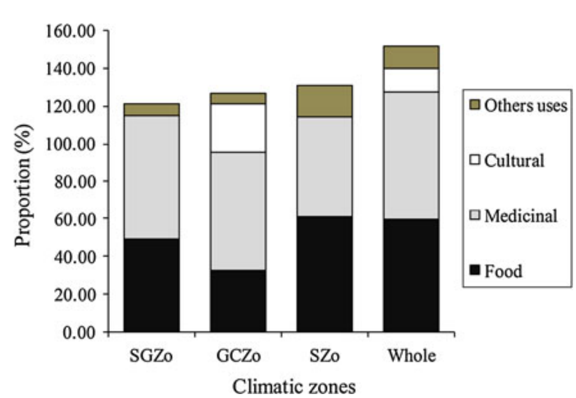


Fig. 3 Uses categories of home gardens species according to the climatic zones. *GCZo* Guineo-Congolean Zone, *SGZo* Sudano-Guinean Zone, *SZo* Sudanian Zone. Other uses = Fodder + ornamental + timber + fence

Table 2 Similarities (Jaccard similarity Index) among climatic zones according to the species composition of home gardens

	GCZo	SGZo	SZo
GCZo	1		
SGZo	0.22 (50)	1	
SZo	0.21 (39)	0.24 (61)	1

Values in brackets are the number of shared species

GCZo Guineo-Congolean Zone, *SGZo* Sudano-Guinean Zone, *SZo* Sudanian Zone

test showed a significant difference ($P < 0.05$, Table 2) between climatic zones with respect to both Shannon diversity index and Pielou eveness but not for species richness ($P > 0.05$, Table 2). The Sudanian zone home gardens were more diversified (H = 2.79) than those of the Sudano-Guinean zone (H = 2.49) which in turn were more diversified than those of the Guineo-Congolean zone (H = 1.49) (Table 2).

As for the covered area of home gardens, it varied significantly by climatic zones (Table 3). Home gardens of Sudanian zone were three and six times larger than those of Sudano-Guinean and Guineo-Congolean zones, respectively. The area of home gardens covered increased from the southern to the northern part of the country. Quartiles (Table 3) revealed that seventy five percent of home gardens had an area less than 400 m^2 in Guineo-Congolean zone and 500 m^2 ha in the Sudano-Guinean zone whereas more than 75 % of Sudanian zone home gardens covered more than 800 m^2.

Evaluation of life forms of home gardens species (Fig. 4a) showed Phanerophytes as the most represented life forms whatever the climatic zone. For the whole country, they accounted for 58.39 % of the life-forms. They were followed by Therophytes (22.48 %), Chamephytes (10.06 %) and Geophytes (8.05 %). Hemicryptophytes were only found in Guineo-Congolean region (2.63 %).

For the phytogeographic types of home garden species (Fig. 4b) the most occurring, was the Pantropical type (22.59 %) for the whole country followed by Pluriregional-African (19.25 %), Guineo congolean (15.18 %) and Sudano-Zambezian (12.96 %). However, this ranking differed across climatic zone. Climatic zones were not dominated by their basic elements (native species). For the whole country, Afro-American and Cosmopolitan types occurred as the lowest phytogeographical types (respectively 0.37 and 0.74 %). Afro-American type was not found in Guineo-Congolean and Sudano-Guinean Zones whereas Cosmopolitan was not found in Sudano- Guinean and Sudanian zones.

Twenty one species were common to the three climatic zones. However, their importance greatly varied by climatic zones (Fig. 5). For instance, *Nicotiana tabacum* L. and *Corchorus olitorius* L. were more important in Guineo-Congolean and Sudanian zones whereas *Anacardium occidentale* L., *Mangifera indica*

Table 3 Species diversity and extend (m^2) of home gardens according to climatic zones

	GCZo		SGZo		SZo		*Prob.*
	m	Cv (%)	m	Cv (%)	m	Cv (%)	
Species diversity of home gardens							
S (species)	9.07	66.22	10.77	63.74	10.53	35.53	0.094
H (bits)	1.91	43.73	2.49	40.38	2.79	19.31	0.000
Eq	0.65	30.04	0.94	153.99	0.84	13.20	0.000
Home gardens extend							
s (m^2)	293.44	96.82	508.15	124.76	1667.08	88.72	0.000
Q1 (m^2)	96.75	–	172.00	–	840.00	–	–
Q2 (m^2)	187.00	–	298.00	–	1250.00	–	–
Q3 (m^2)	398.50	–	496.80	–	2220.00	–	–

GCZo Guineo-Congolean Zone, *SGZo* Sudano-Guinean Zone, *SZo* Sudanian Zone; Probability of the test

m means, *Cv* coefficient of variation, *S* species richness, *H* Shannon diversity index, *Eq* Pielou evenness

s = area (m^2); Q1, Q2 and Q3 are respectively first, second and third quartiles

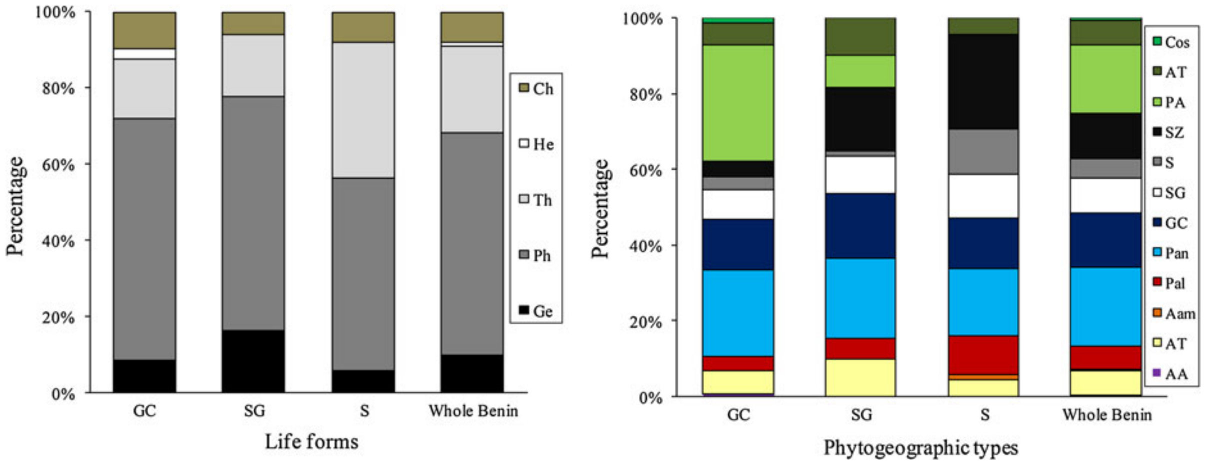


Fig. 4 Life forms types (a) and phytogeographic types (b) of home gardens species. Climatic zones: *GCZo* Guineo-Congolean Zone, *SGZo* Sudano-Guinean Zone, *SZo* Sudanian Zone. Life forms: *Ch* Chamephytes, *He* Hemicryptophytes, *Th* Therophytes, *Ph* Phanerophytes, *Ge* Geophytes. Phytogeographic types: *GC* Guineo-Congolean, *SG* Sudano-Guinean, *S* Sudanian, *AT* Afro Tropical, *Aam* Afro American, *Pal* Paleotropical, *Pan* Pantropical, *PA* Pluriregional African, *Cos* Cosmopolitan, *SZ* Sudano-Zambezian

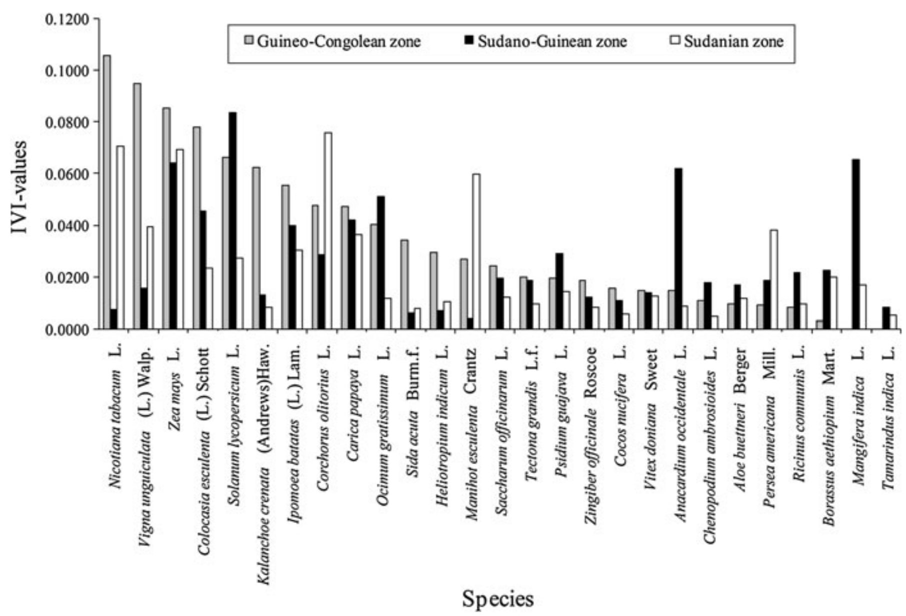


Fig. 5 Common species to the three climatic zones and their importance value index according to climatic zones

L. and *Solanum lycopersicum* L. were more important in Sudano-Guinean zone (Fig. 5).

The cluster analysis resulted into five clusters of species (Table 4) with 74.2 % of the information represented. Cluster 1 encompassed most of the species (54 %) and was followed by Cluster 3 (20 %) and Cluster 2 (12 %). Clusters 4 and 5 had only 8 and 6 % of the species, respectively. Results from the principal component analysis (with 84.4 % of information saved by the two first axes) revealed on axis 1 that the Sudano-Guinean and Guineo-Congolean zones shared the same important species (highest IVI-values) (Fig. 6a). Projection of the five clusters in the axes system (Fig. 6b) showed that cluster 4 had the most important species in home gardens of Sudanian zone whereas cluster 5 had the most important species in home gardens of Guineo-Congolean and Sudano-Guinean zones. Clusters 3, 2 and mainly 1 had species which were less important, even not important in the three climatic zones.

Table 4 Composition of the five clusters of home garden species identified by the cluster analysis: Top 10 species of each cluster, their IVI-values, use categories and status of vegetable or not (see Fig. 7)

Clusters	Species	IVI	Use categories	Vegetable[a]
Cluster 1	*Agave sisalana* Perrine ex Engelm.	0.0111	Foo	
	Solanum aethiopicum L.	0.0100	Foo	Yes
	Arachis hypogaea L.	0.0097	Foo	
	Khaya senegalensis (Desr.) A. Juss.	0.0091	Foo, med, cult	
	Lactuca sativa L.	0.0089	Foo, med, cult	
	Voandzeia subterranea (L.) Verdc.	0.0087	Med	
	Premna angolensis Guerke	0.0084	Foo, med, fod	
	Dioscorea bulbifera L. var. *bulbifera*	0.0083	Med	
	Brassica oleracea L.	0.0082	Med	
	Daucus carota L.	0.0082	Foo	
Cluster 2	*Hibiscus sabdariffa* L.	0.0333	Foo, med, cult	Yes
	Capsicum annuum L.	0.0299	Foo, med	
	Kalanchoe crenata (Andrews) Haw.	0.0279	Med, Cult	
	Leucaena leucocephala (Lam.) de Wit	0.0231	Med	
	Argemone mexicana L.	0.0221	Foo, med	
	Citrus aurantiifolia (Christm. et Panzer) Swingle	0.0212	Foo, med	
	Vernonia colorata (Willd.) Drake	0.0209	Foo	Yes
	Lactuca taraxacifolia (Willd.) Schumach. ex Hornem.	0.0189	Foo, Med	Yes
	Amaranthus spinosus L.	0.0180	Foo, med	Yes
	Sida acuta Burm.f.	0.0161	Foo, med, fod	
Cluster 3	*Anacardium occidentale* L.	0.0285	Foo, Med, Orn	
	Mangifera indica L.	0.0275	Foo, med	Yes
	Persea americana Mill.	0.0220	Foo, med, orn	
	Psidium guajava L.	0.0211	Foo, med	
	Musa sapientum L.	0.0209	Med	
	Vitellaria paradoxa C.F.Gaertn.	0.0189	Foo	
	Saccharum officinarum L.	0.0187	Foo, med	
	Strychnos innocua Delile	0.0183	Foo, med, fod	Yes
	Parkia biglobosa (Jacq.) R. Br. ex G. Don	0.0175	Foo, med, cult	Yes
	Jatropha gossypiifolia L.	0.0169	Foo, med, cult	Yes
Cluster 4	*Abelmoschus esculentus* (L.) Moench	0.0636	Foo, med	Yes
	Corchorus olitorius L.	0.0507	Foo, med	Yes
	Capsicum frutescens L.	0.0368	Foo	Yes
	Hibiscus asper Hook.f.	0.0335	Med, cult	Yes
	Hibiscus cannabinus L.	0.0311	Foo	
	Solanum annuum C.V. Morton	0.0305	Foo	Yes
	Manihot esculenta Crantz	0.0303	Foo, med	Yes
	Amaranthus cruentus L.	0.0292	Foo, med	Yes
	Talinum triangulare (Jacq.) Willd.	0.0269	Foo, med	Yes
	Cymbopogon citratus (DC.) Stapf	0.0267	Foo, med	

Table 4 continued

Clusters	Species	IVI	Use categories	Vegetable[a]
Cluster 5	*Zea mays* L.	0.0729	Foo, med	
	Nicotiana tabacum L.	0.0612	Med, cult	
	Solanum lycopersicum L.	0.0591	Foo, med	Yes
	Vigna unguiculata (L.) Walp.	0.0499	Foo	Yes
	Colocasia esculenta (L.) Schott	0.0491	Foo, med	Yes
	Ipomoea aquatica Forssk.	0.0462	Med, cult	Yes
	Carica papaya L.	0.0419	Foo, med	
	Ipomoea batatas (L.) Lam.	0.0419	Foo, med, cult	Yes
	Senna occidentalis (L.) Link	0.0416	Orn	Yes
	Vernonia amygdalina Delile	0.0398	Foo, med	Yes
	Ocimum gratissimum L.	0.0342	Med, cult	Yes

Foo Food, *Med* Medicinal, *Cult* Cultural, *Orn* Ornamental, *Fod* Fodder

[a] After Achigan-Dako et al. (2010, 2011) and Avohou et al. (2012)

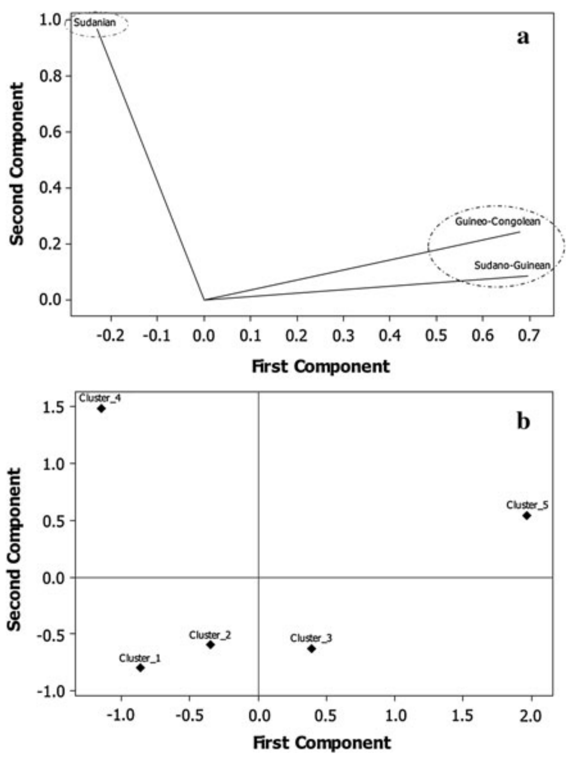


Fig. 6 Principal Components analysis of the IVI-values of home garden species according to climatic zones: (**a**) projection of the IVI-values for each climatic zone in the system axis defined by the principal components; (**b**) projection of the 5 clusters of home gardens species in the system axis defined by the climatic zones IVI-values

The first five most important home gardens species (high IVI-values) were successively *Ipomoea aquatica* Forssk., *Senna occidentalis* (L.) Link, *Nicotiana tabacum* L., *Musa* spp. and *Vigna unguiculata* (L.) Walp. in the Guineo-Congolean zone, *Solanum lycopersicum* L., *Zea mays* L., *Ocimum gratissimum* L., *Colocasia esculenta* (L.) Schott and *Citrus aurantium* L. in Sudano-Guinean zone and *Abelmoschus esculentus* (L.) Moench, *Hibiscus asper* Hook.f., *Capsicum frutescens* L., *Hibiscus cannabinus* L., *Solanum annuum* C.V. Morton in Sudanian zone (Fig. 7a, b). Although Guineo-Congolean and Sudano-Guinean zones shared the same group of important species (from cluster and principal components analyses), thorough observations (Fig. 7b) revealed different levels of importance. Therefore, the most important home garden species varied among climatic zones.

Diversity of crops wild relatives (CWR) in home gardens through climatic zones

From the 285 species recorded in all the 240 home gardens surveyed, 20 crop wild relatives (CWR) were identified (Table 5). From these 20 CWR, 8 were found in Guineo-Congolean zone, 7 in Sudano-Guinean zone and 9 in Sudanian zone. They were mostly confined to one climatic zone. Only four of them (*Amaranthus spinosus* L., *Pennisetum purpureum*

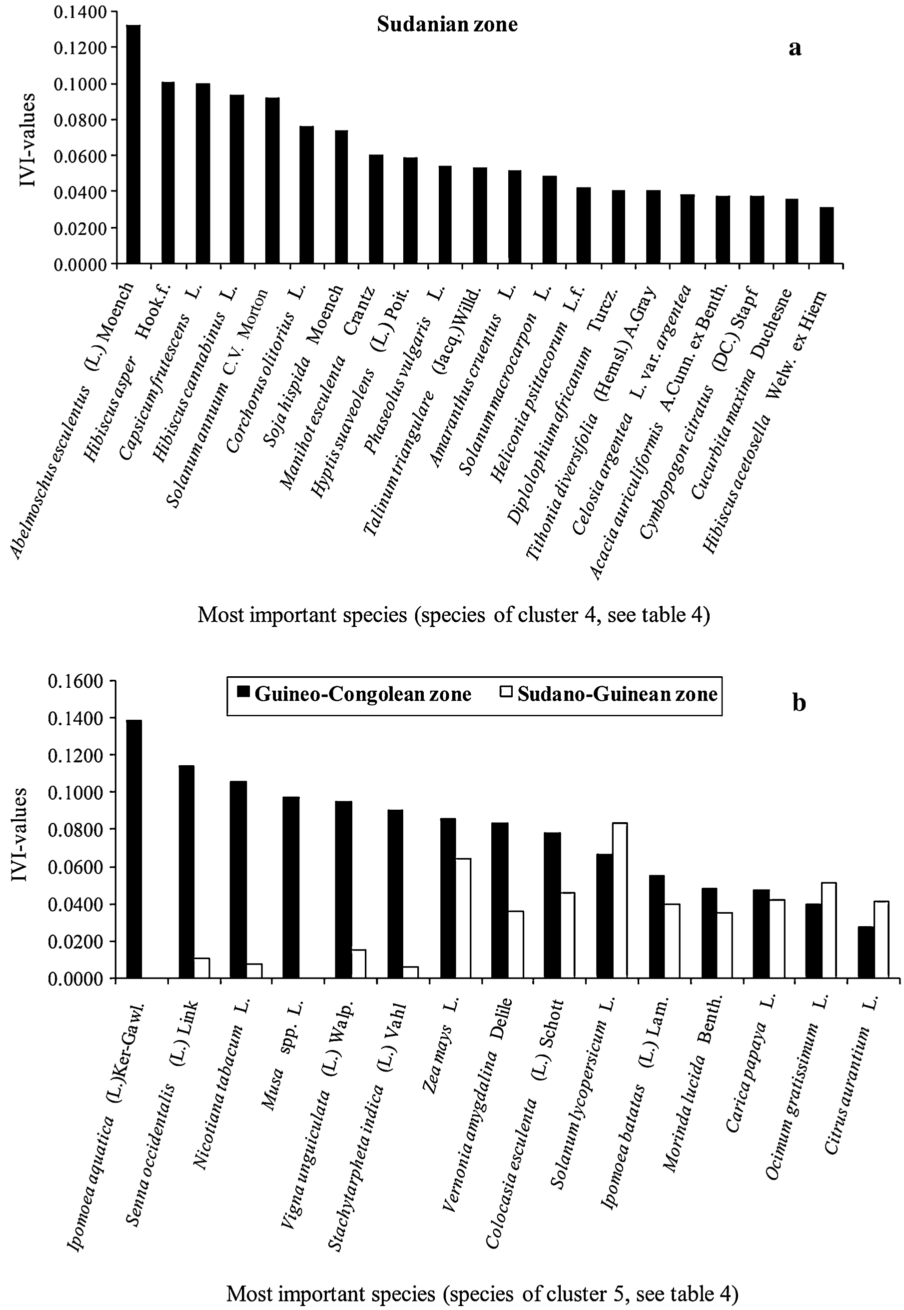


Fig. 7 Most important home gardens species according to climatic zones

Schumach., *Talinum triangulare* (Jacq.) Willd. and *Vernonia colorata* (Willd.) Drake) were found in two climatic zones namely Guineo-Congolean and Sudanian zones. The three most important crop wild relatives were respectively *Ipomoea aquatica* Forssk., *Amaranthus spinosus* L. and *Vernonia colorata* (Willd.) Drake in Guineo-Congolean zone; *Ipomoea involucrata* P. Beauv., *Solanum erianthum* D.Don and *Ipomoea eriocarpa* R.Br. in Sudano-Guinean zone; *Talinum triangulare* (Jacq.)Willd., *Corchorus tridens* L. and *Solanum torvum* Sw. in Sudanian zone. Overall, the highest IVI-values were recorded respectively for *Ipomoea aquatica* Forssk., *Talinum triangulare* (Jacq.) Willd. and *Vernonia colorata* (Willd.) Drake. Contrary to the former, which is confined to the Guineo-Congolean zone, the latters were found in two

Table 5 List of CWR found, their ecological importance value index in each climatic zone and their use categories

Species	PT	Hosted species				IVI-values				Use categories
		Whole	GCZo	SGZo	SZo	GCZo	SGZo	SZo	Mean	
Amaranthus spinosus L.	Pan	×	×		×	0.0448	0.0000	0.0090	0.0180	Food, medicinal, cultural
Citrullus colocynthis (L.) Schrad.	Pan	×			×	0.0000	0.0000	0.0037	0.0012	Food
Blighia unijugata Baker	GC	×		×		0.0000	0.0027	0.0000	0.0009	Medicinal
Corchorus tridens L.	Pal	×			×	0.0000	0.0000	0.0242	0.0081	Food, medicinal
Corchorus trilocularis L.	Pal	×			×	0.0000	0.0000	0.0170	0.0057	Medicinal
Dioscorea abyssinica Hochst. ex Kunth	SG	×		×		0.0000	0.0087	0.0000	0.0029	Food
Dioscorea cayenensis Lam.	–	×	×			0.0276	0.0000	0.0000	0.0092	Food, cultural
Gossypium arboreum L.	Pan	×	×			0.0072	0.0000	0.0000	0.0024	Medicinal
Ipomoea aquatica Forssk.	GC	×	×			0.1387	0.0000	0.0000	0.0462	Food
Ipomoea eriocarpa R.Br.	Pan	×		×		0.0000	0.0134	0.0000	0.0045	Food
Ipomoea involucrata P. Beauv.	AT	×		×		0.0000	0.0477	0.0000	0.0159	Food
Manihot glaziovii Müll.Arg.	GC	×	×			0.0139	0.0000	0.0000	0.0046	Food
Ocimum americanum L.	–	×			×	0.0000	0.0000	0.0135	0.0045	Food
Pennisetum purpureum Schumach.	Pan	×	×		×	0.0000	0.0000	0.0135	0.0045	Food
Sesamum radiatum Schum. et Thonn.	Pan	×		×		0.0000	0.0130	0.0000	0.0043	Food
Solanum erianthum D.Don	Pan	×		×		0.0000	0.0227	0.0000	0.0076	Food, medicinal
Solanum torvum Sw.	GC	×			×	0.0000	0.0000	0.0241	0.0080	Food, medicinal
Talinum triangulare (Jacq.) Willd.	Pal	×	×		×	0.0279	0.0000	0.0528	0.0269	Food, medicinal
Terminalia glaucescens Planch. ex Benth.	S	×		×		0.0000	0.0090	0.0000	0.0030	Timber
Vernonia colorata (Willd.) Drake	SZ	×	×		×	0.0357	0.0000	0.0271	0.0209	Food, medicinal
Total		20	8	7	9	–	–	–	–	–

PT phytogeographic types, *GCZo* Guineo-Congolian Zone, *SGZo* Sudano-Guinean Zone, *SZo* Sudanian Zone, *IVI* Importance value index

Phytogeographic types: *SZ* Sudano-Zambezian, *S* Sudanian, *SG* Sudanian/Guinean transition, *GC* Guineo-Congolian, *Pan* Pantropical, *Pal* Paleotropical, *AT* Afro-tropical

climatic zones (Sudanian and Guineo- Congolean) but *Talinum triangulare* (Jacq.) Willd. was mostly found in Sudanian zone whereas *Vernonia colorata* (Willd.) Drake was mostly found in Guineo-Congolean zone. Almost all the CWR were used for food and medicinal purposes (Table 5) and were mostly pantropicals or paleotropicals (10 out of the 20).

Apart from the 8 (8.33 %), 7 (3.87 %) and 9 (6.77 %) species reported as CWR respectively in Guineo-congolean, Sudano-Guinean and Sudanian zones, 28.74, 23.92 and 29.54 % were found to be either species found in the wild but which genera does not have a cultivated species (>50 % of the total) or agroforestry tree species (<4 % of the total).

Conservation status of home gardens species

Overall, conservation status of only 3.86 % (Fig. 8) of home gardens species has already been evaluated. 23.15 % (i.e. 66 species) were not found in the database of IUCN. Among the three climatic zones, the Sudanian zone's home gardens hosted the smallest number of evaluated species in Benin (Fig. 8).

Among species recorded in home gardens, nineteen were evaluated either in Benin (11) or in the IUCN database (11) (Table 6). All the eleven species evaluated in Benin were threatened (7 Vulnerables, 3 Endangered and 1 Extinct in the Wild, see Table 6). Five of them (*Borassus aethiopum* Mart., *Caesalpinia bonduc* (L.) Roxb., *Khaya senegalensis* (Desr.) A. Juss., *Vitellaria paradoxa* C.F.Gaertn. and *Zanthoxylum zanthoxyloides* (Lam.) Zepernick et Timler) were encountered in two of the three climatic zones. The remaining species were confined to one climatic zone. Sudano-Guinean home gardens appeared to host the highest number (9) of the threatened species and were followed by Guineo-Congolean zone (5). Only 3 threatened species were recorded in Sudanian zone home gardens.

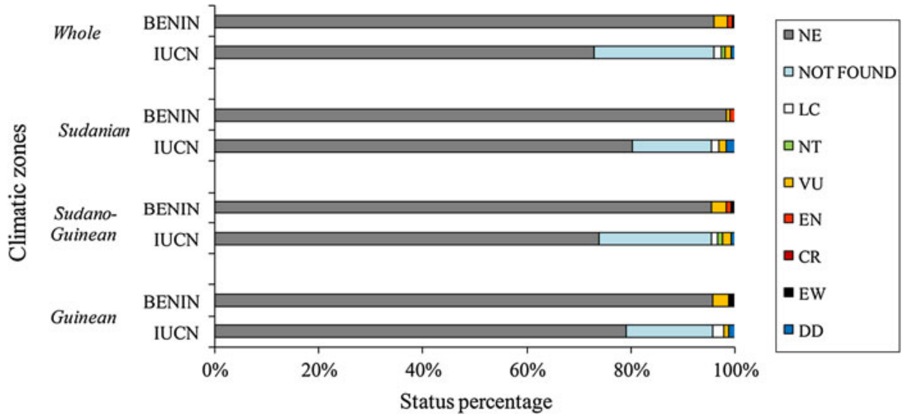


Fig. 8 Home gardens species conservation status according to climatic zones. Threatened status: *LC* least concern, *NT* near threatened, *VU* vulnerable, *EN* endangered, *CR* critically endangered, *EW* extinct in the wild, *DD* data deficient, *NE* not evaluated, *NF* not found

Table 6 List of home garden species evaluated either by UICN or Benin, their ecological importance value according to climatic zones and use categories

Species	PT	Conservation status					IVI-values				Use categories
		Whole		GCZo	SGZo	SZo	GCZo	SGZo	SZo	Mean	
		IUCN	Benin								
Borassus aethiopum Mart.	SZ	NE	VU		×	×	0.0000	0.0199	0.0198	0.0132	Food, medicinal
Brassica oleracea L.	–	DD	NE			×	0.0000	0.0000	0.0247	0.0082	Food
Caesalpinia bonduc (L.) Roxb.	Pan	NE	EW	×	×		0.0231	0.0116	0.0000	0.0116	Medicinal
Christiana africana DC.	Pan	NF	EN		×		0.0000	0.0026	0.0000	0.0009	Medicinal
Colocasia esculenta (L.) Schott ex Schott et Endl.	GC	LC	NE	×	×	×	0.0781	0.0457	0.0235	0.0491	Food
Commelina erecta L. subsp. *erecta*	Pan	LC	NE			×	0.0000	0.0000	0.0039	0.0013	Medicinal
Culcasia scandens P.Beauv.	GC	LC	NE		×		0.0000	0.0414	0.0000	0.0138	Medicinal
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill.	GC	NT	NE		×		0.0000	0.0054	0.0000	0.0018	Food, medicinal
Khaya senegalensis (Desv.) A. Juss.	S	VU	EN		×	×	0.0000	0.0092	0.0180	0.0091	Fodder, medicinal
Kigelia africana (Lam.) Benth.	SG	NE	VU	×			0.0033	0.0000	0.0000	0.0011	Cultural
Mangifera indica L.	AT	DD	NE	×	×	×	0.0000	0.0654	0.0170	0.0275	Food
Milicia excelsa (Welw.) C.C. Berg	GC	NT	EN		×		0.0000	0.0114	0.0000	0.0038	Medicinal
Pentadesma butyracea Sab.	SG	NE	VU		×		0.0000	0.0096	0.0000	0.0032	Food
Pterocarpus santalinoides L'Hér. ex DC.	SG	LC	NE	×			0.0176	0.0000	0.0000	0.0059	Medicinal
Rhodognaphalon brevicuspe (Sprague) Roberty	GC	VU	NE	×	×		0.0212	0.0195	0.0000	0.0136	Food, medicinal, fence
Terminalia superba Engl. et Diels	GC	NE	VU		×		0.0000	0.0219	0.0000	0.0073	Timber
Vitellaria paradoxa C.F.Gaertn.	S	VU	VU		×	×	0.0000	0.0362	0.0204	0.0189	Food, medicinal
Voacanga africana Stapf	SG	NF	VU	×			0.0095	0.0000	0.0000	0.0032	Medicinal, cultural
Zanthoxylum zanthoxyloides (Lam.) Zepernick et Timler	SG	NF	VU	×	×		0.0063	0.0154	0.0000	0.0072	Food, medicinal
Total		3	11	5	9	3	–	–	–	–	

PT phytogeographic types, *GCZo* Guineo-Congolean Zone, *SGZo* Sudano-Guinean Zone, *SZo* Sudanian Zone

Phytogeographic types: *GC* Guineo-Congolean, *SG* Sudano-Guinean, *S* Sudanian, *AT* Afro Tropical, *Pan* Pantropical, *SZ* Sudano-Zambezian

Threatened status: *LC* least concern, *NT* near threatened, *VU* vulnerable, *EN* endangered, *CR* critically endangered, *EW* extinct in the wild, *DD* data deficient, *NE* not evaluated, *NF* not found

Of the 11 home garden species evaluated by IUCN, only three species were found to be threatened (Table 6), most of them being Least Concerned (LC) or Near Threatened (NT). Among the three, only *Rhodognaphalon brevicuspe* (Sprague) Roberty (Vulnerable in IUCN database) found in the Guineo-Congolean and Sudano-Guinean zones' home gardens was not yet evaluated in Benin.

The two highest IVI-values were obtained for *Colocasia esculenta* (L.) Schott ex Schott et Endl., and *Mangifera indica* L. which were not evaluated in Benin. They were respectively Least Concerned (LC) and Data Deficient (DD) in IUCN database. In addition, they were the two species found in all the three climatic zones with different level of importance however (see Table 6). The only one species Extinct in the Wild (*Caesalpinia bonduc* (L.) Roxb.) was more important in Guineo-Congolean zone home gardens while the three Endangered species (see Table 6) recorded their highest IVI-values in Sudano-Guinean zone except for *Khaya senegalensis* (Desv.) A. Juss. which recorded its highest IVI-value in the Sudanian zone. Most of the threatened species recorded in home gardens of the studied area were used for food and/or medicinal purposes (Table 6).

Discussion

This paper reveals the floristic diversity of home gardens in Benin and how they contribute to the conservation of threatened species and Crop Wild Relatives (CWR). It provides basic information for implementation of conservation strategies by highlighting the most important home garden species as well as the Threatened species and the CWR they host.

A total of 285 different species (about 10 % of the floristic diversity of the whole country) were recorded in home gardens throughout the three climatic zones of the country. Although the species richness greatly varied among climatic zones, this finding strongly reinforced the evidence of home gardens serving as biodiversity reservoirs (Edward and Kabir 2009; Pavia et al. 2009; Galluzzi et al. 2010). The highest number of species found in Sudano-Guinean zone (which is not the wettest zone) could be due to the fact that as a transition zone, in addition to its native species, it shares many other species from its adjacent zones i.e. both from the Guineo-Congolean and the Sudanian zones as revealed by Jaccard similarity index. We then reject the first hypothesis and conclude that floristic diversity in home gardens does not decline with increasing altitude or declining precipitations. The numbers of ethnical groups reported for each climatic zone: 9 in the Guineo-Congolean, 6 in the Sudano-Guinean and 7 in the Sudanian zone seem also to show that the obtained pattern of diversity is not a matter of ethnical group diversity. Indeed, from the south towards the north of the country, the ethnical groups' diversity declines (INSAE 2002). Some reasons may explain the greater species diversity northward. Among the 285 species found in home gardens, 27 were shared by the three climatic zones. Many species native to the Guineo-Congolian region were encountered in the other regions. This may have resulted from cultural exchanges and population migrations in Benin as previously illustrated for *Caesalpinia bonduc* (L.) Roxb. (Assogbadjo et al. 2012a). Indeed, most of the concerned home garden species are either edible or medicinally (Fig. 3; Tables 4, 5, 6) important to alien ethnic groups and may have been introduced through migrations.

Average range of home gardens sizes (from 293 m^2, Guineo-Congolean zone to 1667 m^2, Sudanian zone) was found to be congruent with several previous findings (Birol et al. 2005; Sunwar et al. 2006; Yongneng et al. 2006). Moreover, the average size of home gardens increased from the south (Guineo- Congolean) which is the most urbanized area, to the northern part (Sudanian zone) which is the most rural area (see Fig. 1) of the country. This is consistent with the land availability in the country and may indicate that the more available the land, the larger the home gardens area. Indeed from the south of the country toward the northern part, agricultural land become more available and the population density decreases (RGPH 2002). Such observations are congruent with the fact that average size for home gardens is context-dependent (Galluzzi et al. 2010). Whereas in rural area, their size is to some degree proportional to the size of the overall farm (Guarino and Hoogendijk 2004), in cities they largely depend on the competition for land from buildings and infrastructural development (Linares 1996). Nevertheless, results showed that species richness did not vary and was on average around 10 species/home garden.

Results from the analysis of the phytogeographic types of home gardens species showed that climatic zones were not dominated by their basic elements (native species) leading to the rejection of the second hypothesis and the conclusion that home gardens are not dominated by native species. This reinforces the hypothesis of migration but would also suggest in some extent that home gardens are made to conserve non native plants brought by the owner of his/her trips or his/her connection with other ethnical groups. This thus confirms the third working hypothesis.

Overall, the most important home garden species were the same for Guineo-Congolean and Sudano-Guinean zones but differed from that of the Sudanian zone. As suggested by Assogbadjo et al. (2012b), this could be explained by the cultural relatedness of people from Guineo-Congolean and Sudano-Guinean zones compared to those from the Sudanian zone. According to language families' classification, ethnic groups leaving in the Guineo-Congolian and the Sudano-Guiean regions belong to the *Kwa* group while those in the Sudanian region ally to the Voltic group (Bokula 1984). Home gardens are important social and cultural spaces where knowledge related to agricultural practices is transmitted and through which households may improve their income and livelihood standards (Galluzzi et al. 2010). In addition, human cultures have profound influence on the diversity of the eco-systems they belong to (Schneider 2004; Eyzaguirre 2006) and it is often people's cultural and economic values which explain differences even among adjacent areas and gardens.

The three most important home gardens species were found respectively, to be (1) *Abelmoschus esculentus* (L.) Moench, *Hibiscus asper* Hook.f. and *Capsicum frutescens* L.; (2) *Solanum lycopersicum* L., *Zea mays* L. and *Ocimum gratissimum* L.; (3) *Ipomoea aquatica* Forssk., *Senna occidentalis* (L.) Link and *Nicotiana tabacum* L. in Sudanian, Sudano-Guinean and Guineo-Congolean zones. Except for *Musa* spp., *Nicotiana tabacum* L., and *Zea mays* L. the most important species are used for both food and medicine. Such results are consistent with findings of Achigan-Dako et al. (2010, 2011); Avohou et al. (2012), who reported these species as vegetables. Moreover, when we crossed our list of HG species with the database of leafy vegetables of Benin (Achigan-Dako et al. 2010), 103 (out of the 285 i.e. 36 %) of the recorded species were found to be vegetables indicating HG to be primarily targeted for household livelihood, especially consumption (Sunwar et al. 2006; Odhav et al. 2007; Avohou et al. 2012).

As for Crop Wild Relatives (CWR), 20 were identified among the 285 species recorded. They were mostly confined to one climatic zone. Four of them were found in two climatic zones whereas only one was found in all the three climatic zones. As for home garden species in general, the most important CWR also differed among climatic zones. The cohabitation of those CWR with their cultivated plants may have profitably led to genetic exchanges (Galluzzi et al. 2010) probably with or without the knowledge of the farmers themselves. Gene-flow involving crop wild relatives and modern varieties, is indeed facilitated by the limited spatial separation of individuals grown in home gardens. By favoring gene-flow between plant populations inside and out of the garden (Galluzzi et al. 2010), home gardens contribute to the functioning and sustainability of the whole local agricultural ecosystems (Engels 2001; Hughes et al. 2007). This gene-flow often results in significant intra-specific diversity (Eyzaguirre and Linares 2004) which not only increases a species' chance for adaptation and survival over time (Nunney and Campbell 1993), but also provides crucial material for breeding (Feuillet et al. 2008) and for establishing, complementing or restoring germplasm collections (Castiñeiras Alfonso et al. 2007).

As far as the conservation status of home gardens is concerned, findings from this study clearly showed that even if strong efforts have been engaged either by IUCN or conservation institutions in Benin, little has been done yet in assessing the species. More than 96 % of recorded species were not yet assessed in Benin whereas around 73 % were not assessed by IUCN. Twenty three percent of the recorded species were not found in the IUCN database. Among the 106 threatened plant species in Benin (Neuenschwander et al. 2011), eleven were found in home gardens. Five out of them were encountered in two of the three climatic zones. All the remaining species were confined to one climatic zone. Sudano-Guinean home gardens were seen to host the highest number (9) and also had the highest number of species (183). The importance of threatened species strongly varied according to climatic zone. For instance, the only one species Extinct (EX) in the Wild (*Caesalpinia bonduc* (L.) Roxb.) was more important in Guineo-Congolean zone home gardens. This has previously been reported by Assogbadjo et al. (2012b). However, the three Endangered species had their highest IVI-values in Sudano-Guinean zone except for *Khaya senegalensis* (Desr.) A. Juss. for which the highest IVI-value was recorded in the Sudanian zone. The importance of these species for local populations could lead to their propagation in home gardens (Assogbadjo et al. 2012a) offering therefore protection and long-term conservation.

As stated by Edward and Kabir (2009), tropical home gardens deserve increased research attention as their potential for conservation is being considered. Investigation of (1) socio-economic factors supporting possession of HG and the choice of species managed in HG, (2) use value of the most important home garden species identified and (3) indigenous management strategies of HG species will provide more insights in their importance and in assessing effectiveness of HG in sustainable conservation biodiversity, especially rare and threatened species and CWR. There is also increasing concerns on the heavy erosion of traditional knowledge (due to globalization, urbanization, deriding of traditional beliefs, etc.) which has been pointed as a great threat to biodiversity conservation (Brosi et al. 2007; Arya et al. 2010; Lohani 2011). As such a cross-generation analysis of the transmission of traditional knowledge related to HG management will be an added-value to whether HG are relevant as sustainable mean of biodiversity conservation in a context of globalization and socio-cultural changes.

Acknowledgments We are grateful to E.A. Assogbadjo who financially supported this study. B. Fandohan also received a post doctoral research fellow grant from the Chinese Academy of Sciences (Grant No 2012Y1ZA0009) and a research grants from the National Natural Science Foundation of China (Grant no 312111172) which provided him with excellent scientific environment to contribute to the manuscript. We also thank anonymous reviewers for helpful discussions and criticisms on a previous version of this manuscript. The first author also thank his fellows of the 14th Student Conference on Conservation Sciences (SCCS) for their valuable comments on his presentation about this work.

References

Achigan-Dako E, Pasquini MW, Assogba-Komlan F, N'danikou S, Dansi A, Ambrose-Oji B (eds) (2010). Traditional vegetables in Benin: diversity, distribution, ecology, agronomy and utilization

Achigan-Dako EG, N'danikou S, Assogba-Komlan F, Ambrose-Oji B, Ahanchede A, Pasquini MW (2011) Diversity, geographical, and consumption patterns of traditional vegetables in sociolinguistic communities in Benin: implications for domestication and utilization. Econ Bot 65(2):129–145

Adomou AC, Sinsin B, Akoégninou AA, Van der Maesen J (2010) Plant species and ecosystems with high conservation priority in Benin. In: van der Burgt XM, van der Maesen J, Onana JM (eds) Systematics and conservation of African plants. Royal Botanic Gardens, Kew, pp 427–441

Agbahungba AG, Sokpon N, Gaoué OG (2001) Situation des ressources génétiques forestières du Bénin. Note thématique sur les ressources génétiques forestières. FAO. IPGRI/SAFORGEN/DFSC and ICRAF

Agelet A, Bonet MA, Vallès J (2000) Homegardens and their role as a main source of medicinal plants in mountain regions of Catalonia (Iberian Peninsula). Econ Bot 54:295–309

Anley Y, Bogale A, Haile-Gabriel A (2007) Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district, Wester Ethiopia. Land Degrad Dev 18:289–302

Arya D, Tewari A, Shah S (2010) Erosion of biodiversity knowledge between younger and older generation regarding plant identification and their uses in oak and pine dominated zone of Garhwal Himalaya. NY Sci J 3(6):108–111

Assogbadjo AE, Fandohan B, Glèlè Kakaï R, Kyndt T, Hardy OJ, Gheysen G, Sinsin B (2012a) Genetic evidence of the contribution of ethnic migrations to the propagation and persistence of the rare and declining scrambling shrub *Caesalpinia bonduc* L. Hum Ecol 40:117–128

Assogbadjo AE, Glèlè Kakaï R, Adjallala FH, Azihou AF, Vodouhê GF, Kyndt T, Codjia JTC (2011) Ethnic differences in use value and use patterns of the threatened multipurpose scrambling shrub (*Caesalpinia bonduc* L.) in Benin. J Med Plant Res 5(9):1549–1557

Assogbadjo AE, Glèlè Kakaï R, Vodouhê FG, Djagoun CAMS, Codjia JTC, Sinsin B (2012b) Biodiversity and socioeconomic factors supporting farmers' choice of wild edible trees in the agroforestry systems of Benin (West Africa). Forest Policy and Economics 14:41–49

Avohou HT, Vodouhe RS, Dansi A, Bellon M, Kpeki B (2012) Ethnobotanical factors influencing the use and management of wild edible plants in agricultural environments in Benin. Ethnobot Res Appl 10:571–592

Bhagwat SA, Willis KJ, Birks HJB, Whittaker RJ (2008) Agroforestry: a refuge for tropical biodiversity? Trends Ecol Evol 23:261–267

Birol E, Bela G, Smale M (2005) The role of home gardens in promoting multi-functional agriculture in Hungary. EuroChoices 3:14–21

Bokula M (1984) Le point des recherché sur la classification des langues Niger-Congo Kordonfaniennes. Ann Aequatoria 5(1984):127–137

Braun-Blanquet J (1964) Pflanzensoziologie. Grundzüge der Vegetationskunde. 3e ed., Springer, Wien-New York

Brosi BJ, Balick MJ, Wolkow R, Lee R, Kostka M, Raynor W, Gallen R, Raynor A, Raynor P, Lee Ling D (2007) Cultural erosion and biodiversity: canoe-making knowledge in Pohnpei Micronesia. Conserv Biol 21(3):875–879

Brown JH, Davidson DW (1977) Competition between seed-eating rodents and ants in desert ecosystems. Science 196(4292):880–882

Castiñeiras Alfonso L, Guzmán FA, Duque EMC, Shagarodsky T, Cristóbal R, De Vicente MC (2007) AFLPs and morphological diversity of *Phaseolus lunatus* L. in Cuban home gardens: approaches to recovering the lost *ex situ* collection. Biodivers Conserv 16:2847–2865

Choi SS (2008) Correlation analysis of binary similarity measures and dissimilarity measures, Dissertation, Pace University

Curtis JT, Macintosh RP (1951) An upland forest continuum in the prairie forest border region of Wisconsin. Ecology 32:476–496

Dagnelie P (1998) Statistiques théoriques et appliquées. De Boeck et Larcier, Brussels

Edward L, MdE Kabir (2009) Home gardening for tropical biodiversity conservation. Conserv Biol 23(6):1641–1644

Engels J (2001) Home gardens—a genetic resource perspective. In: Watson JW, Eyzaguirre PB (eds) Proceedings of the second international home garden workshop. Bioversity international, Rome, Italy, pp 3–9

Eyzaguirre P (2006) Agricultural biodiversity and how human culture is shaping it. In: Cernea M, Kassam A (eds) Researching the culture in agriculture. CABI, Wallingford, UK, pp 264–284

Eyzaguirre P, Linares O (2004) Introduction. In: Eyzaguirre P, Linares O (eds) Home gardens and agro- biodiversity. Smithsonian Books, Washington, pp 1–28

Favrichon V, Gourlet-Fleury F, Bar-Hen A, Dessard H (1998) Parcelles permanentes de recherche en forêt dense tropicale humide. Eléments pour une méthodologie d'analyse des données CIRAD-Forêt. Série FORAFRI, document 15

Fernandes ECM, Nair PKN (1986) An evaluation of the structure and function of tropical home gardens. Agric Syst 21:279–310

Feuillet C, Langridge P, Waugh R (2008) Cereal breeding takes a walk on the wild side. Trends Genet 24:24–32

Galluzzi G, Eyzaguirre P, Negri V (2010) Home gardens: neglected hotspots of agro-biodiversity and cultural diversity. Biodivers Conserv 19:3635–3654

Gardner TA, Barlow J, Chazdon R, Ewers R, Harvey CA, Peres CA, Sodhi NS (2009) Prospects for tropical forest biodiversity in a human-modified world. Ecol Lett 12:561–582

Gillet F (2000) La Phytosociologie synusiale intégrée. Guide méthodologique. Université de Neuchâtel, Institut de Botanique. Document du Laboratoire d'Ecologie Végétale1

Guarino L, Hoogendijk M (2004) Microenvironments. In: Eyzaguirre P, Linares O (eds) Home gardens and agrobiodiversity. Smithsonian Books, Washington, USA, pp 31–40

Hajjar R, Hodgkin T (2007) The use of wild relatives in crop improvement: a survey of developments over the last 20 years. Euphytica 156:1–13

Hammer K, Laghetti G, Perrino P (1999) A checklist of the cultivated plants of Ustica (Italy). Genet Resour Crop Evol 46:95–106

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2004) The WorldClim interpolated global terrestrial climate surfaces. Version 1.3. http://biogeo.berkeley.edu/

Hodel U, Gessler M (1999) In situ conservation of plant genetic resources in home gardens of southern Vietnam. International Plant Genetic Resources Institute, Rome

Hodgkin T (2001) Home garden and the maintenance of genetic diversity. In: Waston JW, Eyzaguirre PB (eds) Home garden and in situ conservation of plant genetic resources in farming systems. International Plant Genetic Resources Institute, Rome, Italy, pp 14–18

Hughes CE, Govindarajulu R, Robertson A, Filer DL, Harris SA, Bailey CD (2007) Serendipitous backyard hybridization and the origin of crops. Proc Natl Acad Sci 104:14389–14394

Idohou R, Assogbadjo AE, Fandohan B, Gouwakinnou GN, Glèlè Kakaï RL, Sinsin B, Maxted N (2013) National inventory and prioritization of the crop wild relatives: case study for Benin. Genetic resources and crop evolution. Genet Resour Crop Evol 60:1337–1352

Institut National de Statistique Appliquée et d'Economie (INSAE) (2002) Recensement général de la population humaine du Bénin. INSAE, Cotonou, Benin

Institut National de Statistique Appliquée et d'Economie (INSAE) (2003) Analyses des résultats. Troisième recensement general de la population et de l'habitation cotonou

IUCN (2012) IUCN red list of threatened species. Version 2011.2. <www.iucnredlist.org>. Accessed 15 Aug 2012

Kabir MdE, Webb EL (2008) Floristics and structure of southwestern Bangladesh homegardens. Int J Biodiversity Sci Manag 3:1–11

Kulpa W, Hanelt P (1981) Activities regarding collection and evaluation of Polish landraces. Kulturpflanze 29:81–90

Lebrun JP, Stork AL (1991–1997) Enumération des plantes à fleurs d'Afrique tropicale. 4 volumes. Conservatoire et Jardin Botanique de la ville de Genève

Leiva JM, Azurdia C, Ovando W, López E, Ayala H (2001) Contributions of home gardens to in situ conservation in traditional farming systems—Guatemalan component. In: Watson JW, Eyzaguirre PB (eds) Proceedings of the second international home gardens workshop. Bioversity International, Rome, Italy, pp 56–72

Lewis MP (ed.) (2009) Ethnologue: Languages of the World, Sixteenth edition. Dallas, Tex.: SIL International. Online version: http://www.ethnologue.com/

Linares OF (1996) Cultivating biological and cultural diversity: urban farming in Casamance, Senegal. Africa 66:104–121

Lohani U (2011) Eroding ethnozoological knowledge among *Magars* in Central Nepal. Indian J Tradit Knowl 10(3):466–473

Natta AK (2003) Ecological assessment of riparian forest in Benin: phytodiversity, phytosociology and spatial distribution of tree species. PhD dissertation, Wageningen University

Neuenschwander P, Sinsin B, Goergen G (2011) Protection de la nature en Afrique de l'Ouest: une liste rouge pour le Bénin. Nature conservation in West Africa: Red List for Benin. International Institute of Tropical Agriculture, Ibadan, Nigeria

Nunney L, Campbell KA (1993) Assessing minimum viable population size: demography meets population genetics. Trends Ecol Evol 8:234–239

Odhav B, Beekrum S, Akula U, Baijnath H (2007) Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. J Food Compos Anal 20:430–435

Pavia R, Barbagiovanni I, Strada GD, Piazza MG, Engel P, Fideghelli C (2009) Autochthonous fruit tree germplasm at risk of genetic erosion found in home gardens in the region of Latium (Italy). In: Proceedings of a workshop on crop genetic resources in European home gardens. Bioversity international, Rome, Italy

Perrault-Archambault M, Coomes OT (2008) Distribution of agrobiodiversity in home gardens along the Corrientes River, Peruvian Amazon. Econ Bot 62:109–126

Quiroz C, Gutiérrez M, Rodríquez D, Pérez D, Ynfante J, Gámez J, de Fernandez TP, Marques A, Pacheco W (2004) Home gardens and in situ conservation of agrobiodiversity—Venezuelan component. In: Watson J, Eyzaguirre PB (eds) Home gardens and in situ conservation of plant genetic resources in farming systems. International Plant Genetic Resources Institute, Rome, Italy, pp 73–82

Raunkiaer C (1934) The life forms of plants and statistical plant geography. Clarendron Press, London

Schneider J (2004) Toward an analysis of home garden cultures. On the use of sociocultural variables in home garden studies. In: Eyzaguirre PB, Linares O (eds) Home gardens and agrobiodiversity. Smithsonian books, Washington, pp 41–55

Shall JJ, Pianka ER (1978) Geographical trends in number of species. Science 201(4357):679–686

Sinsin B, Eyog Matig O, Assogbadjo AE, Gaoué OG, Sinadouwirou T (2004) Dendrometric characteristics as indicators of pressure of *Afzelia africana* Sm. trees dynamics in different climatic zones of Benin. Biodivers Conserv 13:1555–1570

Sunwar S, Thornström CG, Subedi A, Bystrom M (2006) Home gardens in western Nepal: opportunities and challenges for on-farm management of agrobiodiversity. Biodivers Conserv 15:4211–4238

White F (1983) The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO UNESCO. Nat Resour Res 20:1–356

Yongneng F, Huijun G, Aiguo C, Jinyun C (2006) Household differentiation and on-farm conservation of biodiversity by indigenous households in Xishuangbanna, China. Biodivers Conserv 15(2687):2703