academicJournals

Vol. 5(4), pp. 223-239, April 2013
DOI: 10.5897/IJBC12.131
ISSN 2141-243X ©2013 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Varietal diversity and genetic erosion of cultivated yams (*Dioscorea cayenensis* Poir - *D. rotundata* Lam complex and *D. alata* L.) in Togo

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Accepted 22 March, 2013

Yam (*Dioscorea cayenensis* Poir - *Dioscorea rotundata* Lam complex; *Dioscorea alata* L.) is one of the major food crops that significantly contribute to food security and poverty alleviation in Togo. To assess its cultivar diversity and document the performence of existing cultivars vis-à-vis biotic and abiotic factors, 50 villages were randomly selected throughout the country and surveyed. The study reveals the existence of important diversity. The number of cultivars varied from 5 to 51 per village, with an average of 27. Central Region and Region of Plateau were the richest (31 to 37 cultivars on average per village) and the Savannah region, which is highly affected by climate change, was the poorest (7 cultivars on average per village). Based on vernacular names and subject to synonymy, 470 cultivars of *D. cayenensis - D. rotundata complex* and 134 cultivars of *D. alata* were identified. The spatial distribution of the diversity was established using Ordinary Kriging modelling approach. The rate of cultivar loss recorded per village was high (37.01% on average) and call for urgent definition of a national strategy to preserve yam diversity in Togo. Through participatory evaluation, the performances of the identified farmer-named cultivars were documented against 21 variables of which 12 were agronomic, three were technological and six were culinary. Very few tolerant or resistant varieties were identified per biotic and abiotic stress, indicating the urgent need to establish a national yam breeding program in Togo. This would help supply the different agroecological zones with performing varieties in relation to their needs. To clarify synonymies, exhaustive germplasm collections followed by morphological and molecular characterizations have been recommended.

Key words: Cultivar loss, diversity, genetic erosion, participatory evaluation, spatial analysis, yam, Togo.

INTRODUCTION

Yams (*Dioscorea* spp.) are the world's fourth most important tuber crop in economic terms (Mignouna et al., 2002) after potatoes (*Solanum tuberosum* L.), cassava (*Manihot esculenta* Crantz) and sweet potatoes (*Ipomoea batatas* (L.) Poir.). Although they are cultivated in most tropical countries, West Africa alone produces over 95% of the world's output (FAO, 2010). Yams serve as the staple carbohydrate source for millions of people (Mignouna et al., 2002; Adejumo et al., 2013). The genus Dioscorea comprises over 600 species (Sesay et al.,

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2013) but only 10 of them are cultivated. These are: *Dioscorea alata* L., *Dioscorea esculenta* Lour, *Dioscorea batatas* Decne or *D. opposite* Thumb. originating from Asia, *Dioscorea bulbifera* L., *Dioscorea cayenensis - rotundata* complex, *Dioscorea dumetorum* Kenth originating from Africa, *Dioscorea trifida* L. originating from America, *Dioscorea nummularia* Lam. and *Dioscorea pentaphylla* L. originating from both Asia and Oceania (Girma et al., 2012). Of all these species, *D. alata* and the *D. cayenensis – D. rotundata* complex are the most widely cultivated and have real economic significance in Africa (Norman et al., 2012). In West Africa, guinea yam (*D. cayenensis – D. rotundata* complex) is the most important and represents more than 95% of the total production (Sesay et al., 2013) with considerable varietal and genetic diversity due to the continuous process of domestication from related wild species that are *Dioscorea abyssinica* Hochst, *Dioscorea praehensilis* Benth and *Dioscorea burkilliana* J. Miège (Mignouna and Dansi 2003; Dumont *et al.,* 2005). In West Africa, yam is both subsistence and a cash crop (Baco 2004). Nutritionally, yam tuber is rich in carbohydrates, proteins, vitamins and minerals (Lawal et al., 2012). It is often consumed boiled, pounded, fried or in the form of paste obtained from the flour of yam chips (Auriole and Ramanou 2006; Lawal et al., 2012).

Togo is one of the most important yam-producing countries of the West African yam belt. In terms of tonnage, it ranks fifth after Nigeria, Cote d'Ivoire, Ghana and Benin (FAOSTAT, 2010). In this country, yam production is unfortunately faced with many constraints (pests and diseases, poor soils, drought, flooding or high soil moisture, etc.) that cause servere yield losses and genetic erosion (Dansi et al., 2013). To address these constraints, genetic control through use of tolerant or resistant cultivars is necessary. Such cultivars are expected to be found within the existing yam diversity in Togo, which is yet to be studied. Contrary to Benin (Loko et al., 2013), the diversity of yam cultivars maintained per village and per household throughout agro-ecological and ethnic zones have never been assessed in Togo and the rate of cultivar loss (genetic erosion) is still unknown. The landrace cultivars have not been documented anywhere (that is, ethnobotanical data, agronomic and culinary characteristics) for use by scientific research and development and this retards producers' and breeders' access to yam genetic resources in Togo.

We report in this paper the results of an ethnobotanical survey conducted on yam in the Republic of Togo in order to: 1) assess the cultivar diversity within the cultivated yams (*D. Cayenensis - D. rotundata*; *D. alata*) and analyze their distribution and extent, 2) evaluate the level of cultivar loss (or genetic erosion) and analyse its variation across villages and agro-ecological zones, 3) map the spatial distribution of the yam diversity and identify the diversity zones within the country, and 4) carry out a participatory agronomic, technological and culinary evaluation of the landrace cultivars in order to identify those that are performing per trait of economic importance.

MATERIAL AND METHODS

The study area

Republic of Togo is located in West Africa between Burkina Faso (in the North), Ghana (in the West), Benin (in the East) and the Atlantic Ocean (in the South). It covers a total land area of 56,600 km² with a population estimated at about 6 million (Adjatin et al., 2012). The country is partitioned from North to South into five administrative regions (Savannah region, Kara region, the Central region, the Hills region and the Maritime region) inhabited by 21 principal ethnic groups (Adja, Akposso, Akébou, Ana, Anii, Atchè, Bassar, Ewé, Gam-Gam, Gourma, Ifè, Kabyè, Konkomba, Kotokoli, Lamba, Moba, Para, Tchokossi, Tém, Temmari and Yaka). Togo has two climatic regions (Afidegnon, 1999): the Southern and the Central regions characterized by a subequatorial climate with two rainy seasons and two dry seasons and the Northern region with Sudanian climate type, characterized by only two seasons (that is, a rainy season and a dry season). The average rainfall varies from 800 to 1400 mm per year (Afidegnon, 1999) according to the agroecological zones. The north is situated in arid and semi arid agro-ecological zones characterized by unpredictable and irregular rainfall oscillating between 800 and 950 mm/year. The country's mean annual temperatures range from 26 to 28°C and may exceptionally reach 35 to 40°C in the far northern localities (Afidégnon 1999). The vegetation is mainly Savannah type with some strips of dry dense forests, open forests and gallery forests (Kokou 1998, Afidégnon 1999).

Site selection and survey

To allow for an exhaustive biodiversity inventory, 50 villages located in diverse agro-ecological (humid, semi arid and arid) and ethnic zones were randomly selected (Figure 1) following the method described by Dansi (2011) and distributed as follows: Kara region (14 villages), Plateau region (14 villages), Savannah region (4 villages), Central region (14 villages) and Maritime region (four villages).

Data were collected during expeditions from the different sites through the application of participatory research appraisal tools and techniques, such as direct observation, group discussions, individual interviews, and field visits using a questionnaire following the procedure described by Kombo et al. (2012). In each village, interviews were conducted with the help of a local translator. Group surveys were also done of 20 to 40 yam producers of both sexes and of different ages, who were identified and assembled with the help of the local farmers' associations and village chiefs involved in the study to facilitate the organisation of the meetings and the collection of data (Kombo et al., 2012).

Prior to the meeting, farmers were requested in advance to bring samples of the yam cultivars they cultivated or knew about. Information on the location (name of district, name of village and ethnic group) was first collected after a detailed presentation of the research objectives to the farmers. After this, farmers were asked to list (by providing vernacular names) and display (where possible) the different cultivars of yam they grew in their village. Through discussions, detailed agronomic and culinary characteristics of the listed cultivars were documented. The distribution and extent of the cultivars were assessed using the four squares analysis approach described by Kombo et al. (2012) and Loko et al. (2013) and which help, at community level and on participatory way, to classify

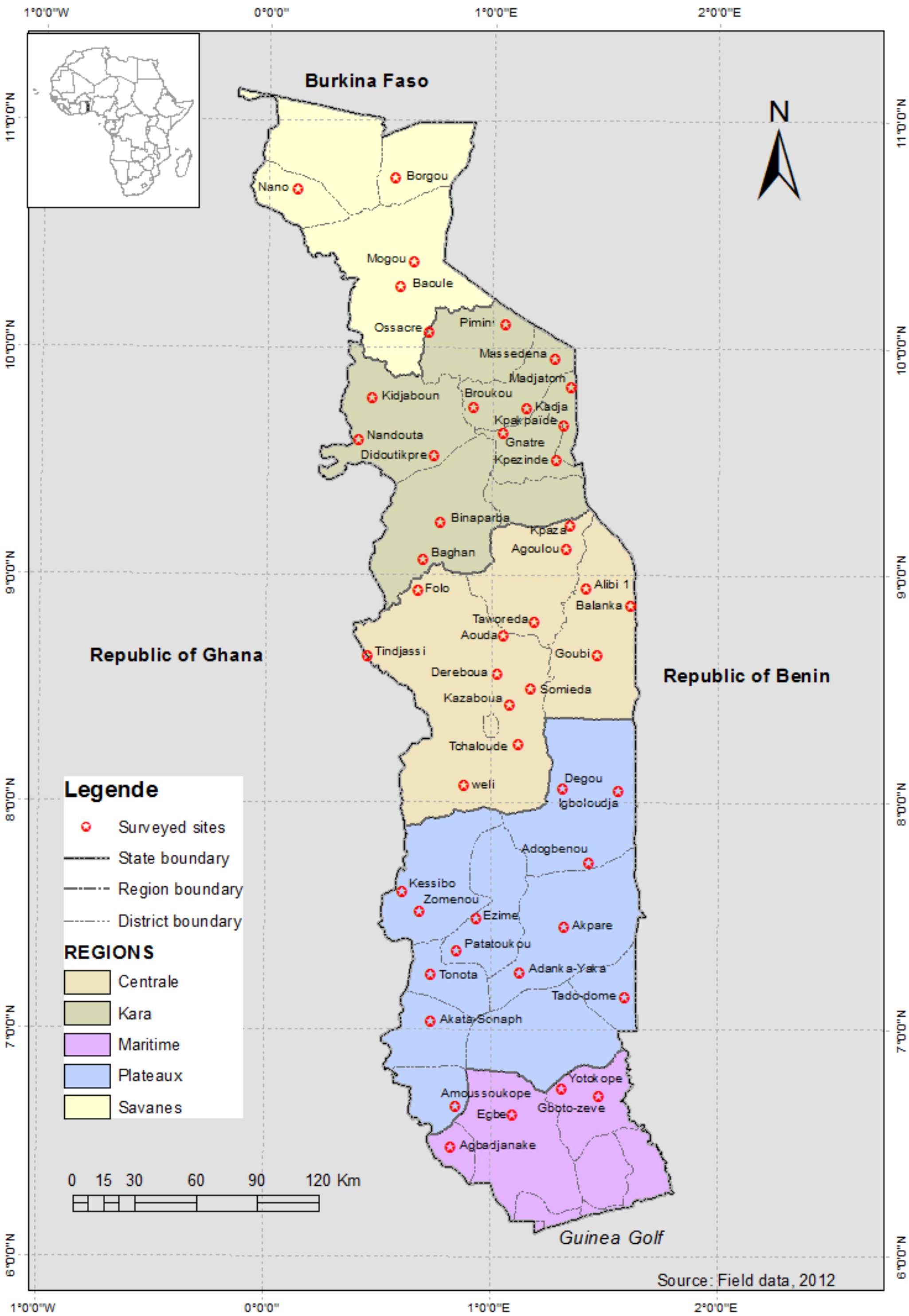

Figure 1. Map of Togo showing the localisation of the villages surveyed.

existing cultivars into four groups base on area apportioned to the variety and the relative number of households cultivating it (Kombo et al., 2012). These were cultivars cultivated by many households on large areas; cultivars cultivated by many households on small areas; cultivars cultivated by few households on large areas, and cultivars cultivated by few households on small areas. Thereafter, justification for the cultivation of each cultivar by many or few households and on large or small areas were discussed and documented. In each of the survey sites, 10 farmers (both men and women) were randomly selected, after the group discussion, for individual interviews with the objective of documenting the yam diversity at household level.

Table 1. Parameters used for the participatory evaluation of yam cultivars in Togo.

Categories of variable	Evaluation parameter	Scoring
Agronomic	Productivity	1 (High) – 0 (low)
	Seeds production rate	1(high) - 0 (low)
	Post-harvest storage aptitude	1(Good) – 0 (low)
	Adaptability to lowlands (high soil moisture)	1(Good) – 0 (low)
	Tolerance to drought	1(Tolerant) – 0 (susceptible)
	Tolerance to poor soils	1(Tolerant) – 0 (susceptible)
	Tolerance to weeds	1(Tolerant) – 0 (susceptible)
	Adaptability to all type of soil	1(Tolerant) – 0 (susceptible)
	Staking demanding	1(high) - 0 (low)
	Resistance to termites	1(Resistant) – 0 (susceptible)
	Résistance to nematodes	1(Resistant) – 0 (susceptible)
	Resistance to scale insects	1(Resistant) – 0 (susceptible)
Technological	Quality of the chips (dry yam)	1(Good) – 0 (bad)
	Resistance of the chips to storage insects	1(Resistant) – 0 (susceptible)
	Oxidation of the tuber during peeling	1(Oxidizable) – 0 (Not Oxidizable)
Culinary	Quality of the boil yam	1(Good) – 0 (bad)
	Pounding easiness	1(Easy) – 0 (Difficult)
	Expansion capacity of the pounded yam	1(high) - 0 (low)
	Texture of the pounded yam (lumps)	1(Good) – 0 (bad)
	Quality of the pounded yam	1(Good) – 0 (bad)
	Quality of fried chips	1(Good) – 0 (bad)

Identified yam cultivars were also assessed against 21 agronomic, technological and culinary traits of economic importance (Table 1) using participatory method and on group basis with the two-level (0, 1) scoring evaluation method described by Dansi (2011). Hence, for a given trait like adaptability to lowland (high soil moisture content), tolerant cultivars or those clearly known as "lowland yam" were given a score of 1, or otherwise given a score of 0. At both individual and group level, the discussions were free, open-ended, and without a time limit being set, following the method described by Kombo et al. (2012).

Statistical analysis

Ethnobotanical data were analysed through descriptive statistics (frequencies, percentages, means, etc.) to generate summaries and tables at different (villages, ethnic areas and regions) levels using SAS software version 9.3 (SAS Institute 2000). Shannon–Weaver diversity index (H) was computed for the whole country following Shannon and Weaver (1948). The rates of landraces' lost (RLL) were calculated per surveyed village using the formula RLL = [(n-k)/N]/ 100 where n = number of cultivars cultivated by few households on small areas, k = number of newly introduced cultivars and N = total number of cultivars recorded in the village.

A yam producing village is characterized by its total yam (*D. alata* and *D. cayenensis* – *D. r*otundata) cultivar diversity (TD), the relative importance of the early (double-harvest) and late (single-harvest) maturing guinea yam cultivars expressed by the relation Q = (DH/SH) x 100. To analyse the relationships between the surveyed villages, these two parameters (TD and Q) were con-sidered and their various evaluation levels were taken as variables (Table 2) and scored 1 where applicable or 0 were not applicable. Using this methodology, a binary matrix was compiled. Pairwise distances between villages were computed by NTSYS-pc 2.2 using the simple matching coefficient of similarity and a dendrogram was designed with unweighted pair-group method with arithmetic average (UPGMA) cluster analysis (Rohlf 2000).

To analyse the spatial distribution of the yam diversity throughout the country, the geostatistical modelling approach known as ordinary Kriging (Merckx et al., 2010; Yan et al., 2010) was used. Ordinary Kriging is an interpolation method based on the spatial autocorrelation between closed sites (Bio et al., 2002). This method takes into account the spatial structure in the data from sampled locations to generate point estimates for unsampled sites. Kriging provides not only predictions but also the prediction errors or kriging variances at each prediction location (Bilgili 2013). The spatial autocorrelation is quantified through a function called a semi-variogram (Meng et al., 2013; Arslan 2012) computed from:

$$\gamma(h) = \frac{1}{2n}\sum_{i=1}^{n}\left(Z\,(xi) - Z\,(xi+h)\right)^2$$

Where, $Z(xi)$, in this study, is the cultivar diversity (number of cultivar inventoried) in the village *i*, $Z(xi+h)$ is the cultivar diversity of other villages separated from *xi* by a discrete distance *h*; *n* represents the number of pairs of observations separated by *h*, and γ (*h*) is the estimated or "experimental" semi-variance value for all pairs at a lag distance *h*. Semi-variances were calculated for each possible pair of sampling villages, and the mean values of semi-variances were plotted for increasing distance intervals (*h*) to produce the experimental semi-variogram. The semi-variogram is represented as a graph and reveals the underlying spatial pattern of

Table 2. Parameters and variables used for the analysis of the relationship between the villages surveyed.

Parameter	Variable	Description
Total yam diversity (TD)	1 ≤ TD ≤ 10 cultivars	Low diversity
	11 ≤ TD ≤ 30 cultivars	Average diversity
	TD ≥ 31	High diversity
Relative proportion between double-harvest and single-harvest cultivars (Q)	0 % ≤ Q ≤ 40 %	Dominance of single-harvest cultivars
	40 % < Q < 60%	Single-harvest and double-harvest cultivars in almost equal proportions
	Q ≥ 60%	Dominance of double-harvest cultivars

variables, having more similar values when they are spatially closer. In this study, the spatial prediction of cultivar diversity was based on the geographical information (latitude, longitude) collected with GPS in the 50 villages surveyed. A lag size of 25 km is used for the calculation of semivariogram and the diversity maps were constructed using ArCGIS 10.

RESULTS AND DISCUSSION

Diversity of yam cultivars at community and household levels in Togo

Throughout the fithy (50) villages surveyed and subject to synonymy, 470 farmer-named cultivars of guinea yam (*D. cayenensis-D.rotundata* complex) and 134 farmer-named cultivars of water yam (*D. alata*) were identified. The number of cultivars per village varied from 5 to 51 with 27 on average. The lowest diversity was observed in Nano in the Savannah region and the highest in Goubi in the Central region (Table 3). At the species level, guinea yam cultivars were by far the most numerous. Their numbers varied from five to 43 (average 22) per village against 0 to 11 (average 5) for *D. alata*. On average, 83.23% of *D. cayenensis- D. rotundata* complex cultivars were recorded per surveyed village compared to only 16.77% for *D. alata* cultivars (Table 3). According to Dumont et al. (2005) and ITRA (2010), all cultivars are locally bred and none imported from elsewhere meaning that there has not been any cross breeding with foreign cultivars. Scarcelli et al. (2011) reported that yam landraces are products of sexual reproduction that have evolved by mutation. Sexual reproduction involves the mixing of genes, and results in a population that is more diverse and able to adapt to changing conditions. When plants sexually reproduce, some of the offspring might possess genes that give them resistance to a disease or tolerance to environmental extremes (e.g. drought, high soil Salinity, etc.). Through natural selection that acts exclusively by the preservation and accumulation of variations, these plants are more likely to survive such conditions to reproduce and to pass on their genes to offspring. Vegetative propagation nature of yam enables to fix favorable combinations of important traits, and superior genetic variance interactions. It also preserves high levels of heterozygosity that is necessary for high hybrid vigor (Chair et al., 2010). Apart from the environment, and random evolutionary processes, the genetic variation found within yam in Togo has been also shaped over time by farmers. Gene flow through cross-pollination and seed exchange encourages novel variation and recombination, as well as differentiation among cultivars (Dumont et al., 2010). The combination of human-mediated and natural selection continues as farmers select for traits of interest while the environment selects for traits that augment fitness. Mutations and transgenerational epigenetic inheritance also introduce novel variations. Taken together, these factors produced a dizzying array of landrace diversity and continually reshape that diversity now.

The net dominance of guinea yam cultivars observed in Togo which has already been reported in Benin (Loko et al., 2013) and in Cameroon (Mignouna et al., 2002), appears to be common for all the countries of the West African yam belt and can be explained by two reasons:

1) The African origin of *D. cayenensis- D. rotundata* complex and the domestication process (Mignouna and Dansi 2003; Scarcelli et al., 2006; Vodouhe and Dansi 2012) that continuously strengthens its diversity. In fact all the cultivars of *D. cayenensis- D. rotundata* complex are locally (that is, Africa) domesticated from wild yam collected in the bushes (Forests, savannah and gallery forests) or in the ancient fallows. In these habitats and following Mignouna and Dansi (2003) material collected by farmers for domestication are of different natures: related wild species (*D. abyssinica* Benth, *D. burkilliana* J. Miège *and D. praehensilis* Benth), interspecific hybrids generated by gene flows between wild relatives or between wild species and cultivars, and, traditional cultivars involuntary abandoned in the fields in the past after harvest that have turned wild. The cultural practices of yam characterised by the establishment of the fields with-in savananhs or forests combined which shifting and the absence of genetic or hybridisation barrier between the cultivated species and the wild relatives (Dumont et al., 2005) facilitate gene flows (Chair et al., 2010; Dumont

Table 3. Status of yam diversity in the villages surveyed.

Region	Village	TNC	Dal	Dcr			DET				NIC	RCL %
				TO	SH	DH	++	+-	- +	- -		
Centrale	Agoulou	35	3	32	13	19	13	3	5	11	4	21.86
	Alibi 1	38	4	34	13	21	15	0	1	18	5	38.24
	Aouda	27	3	24	12	12	6	2	1	15	5	41.67
	Balanka	29	5	24	9	15	10	1	2	11	4	29.17
	Déréboua	43	5	38	12	26	5	5	3	25	9	42.11
	Folo	47	9	38	8	30	11	1	6	20	9	28.95
	Goubi	51	9	42	21	21	14	2	14	12	4	19.05
	Kazaboua	38	3	35	11	24	8	3	2	22	9	37.14
	Kpaza	41	5	36	13	23	3	5	1	27	9	50
	Somiéda	24	4	20	9	11	5	2	1	12	1	55
	Taworèda	44	8	36	11	25	6	2	6	22	3	52.78
	Tchaloudè	23	4	19	9	10	5	1	4	9	1	42.11
	Tindjassi	38	8	30	4	26	8	2	2	18	4	46.67
	Wèli	36	6	30	14	16	3	2	5	20	5	50
Kara	Baghan	16	0	16	8	8	4	0	10	2	0	12.5
	Binaparba	17	0	17	9	8	6	0	2	9	2	41.18
	Broukou	9	0	9	5	4	6	0	0	3	2	11.11
	Didoutikprè	17	3	14	6	8	6	0	2	6	0	42.86
	Gnatre	23	0	23	11	12	8	2	1	12	2	39.13
	Kadja	20	2	18	7	11	7	1	0	10	0	55.56
	Kidjaboun	13	0	13	11	2	8	0	0	5	0	38.46
	Kpakpaïdè	13	2	11	5	6	5	1	0	5	0	45.45
	Kpézindé	25	4	21	12	9	5	1	0	15	5	47.62
	Madjatom	19	2	17	12	5	5	2	1	9	2	41.18
	Massédéna	15	2	13	7	6	6	0	2	5	2	23.08
	Nandouta	24	1	23	17	6	7	0	2	14	2	52.17
	Ossacré	14	4	10	9	1	1	1	4	4	4	0
	Pimini	12	0	12	6	6	7	0	0	5	1	33.33
Maritime	Agbadjanakè	35	10	25	10	15	13	3	0	9	1	32
	Egbé	26	11	15	6	9	4	4	0	7	1	40
	Gboto-zeve	29	11	18	3	15	6	1	1	10	1	50
	Yotokopé	36	10	26	6	20	7	3	0	16	8	30.77
Plateau	Adanka-Yaka	13	2	11	4	7	5	0	2	4	2	18.18
	Adogbenou	47	4	43	12	31	22	3	1	17	5	27.91
	Akata-Sonaph	43	9	34	16	18	12	3	0	19	7	35.29
	Akparé	33	5	28	12	16	9	1	1	17	5	42.86
	Amoussoukopé	34	10	24	11	13	10	0	0	14	3	45.83
	Dégou	38	5	33	11	22	9	4	1	19	7	36.36
	Ezimé	13	3	10	4	6	3	2	0	5	1	40
	Igboloudja	45	7	38	14	24	8	2	3	25	8	34.21
	Issati	38	4	34	13	21	10	6	0	18	5	38.24
	Kessibo	20	5	15	4	11	5	0	0	10	2	53.33
	Patatoukou	23	6	17	7	10	7	1	1	8	5	17.65
	Tado-dome	29	9	20	4	16	5	0	3	12	2	50
	Tonota	25	8	17	5	12	3	0	1	13	3	58.82
	Zoménou	35	7	28	12	16	7	3	4	14	8	21.43

Table 3. Contd.

Savane	Baoulé	9	2	7	0	7	5	0	1	1	0	14.29
	Borgou	8	0	8	1	7	3	0	3	2	0	25
	Mogou	6	1	5	0	5	2	1	0	2	0	40
	Nano	5	0	5	0	5	2	0	0	3	0	60
Mean		27	5	22	9	14	7	2	2	12	3	37.01

TNC, Total number of cultivars; Dal, *D. alata*; Dcr, *D. cayenensis-D. rotundata* complex; TO, Total; SH, Single-Harvest cultivars; DH, Double-harvest cultivars; DET, Distribution and extent; RCL, Rate of cultivar loss; NIC, Newly introduced cultivars; H+A+, many households and large area; H+A-, Many households and small area; H-A+, few households and large area; H-A-, few households and small area.

Table 4. Synthesis of the yam diversity per region surveyed.

Location	Total diversity			*D. alata*			SH cultivars of *D. cr*			DH cultivars of *D.cr*			Rate of diversity loss %		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Savanes	5	9	7	0	2	1	0	2	1	3	7	6	14.29	60	34.82
Kara	9	25	17	0	4	1	5	17	9	2	12	7	0	55.56	34.54
Centrale	27	51	37	3	9	5	4	21	11	10	30	20	19.05	55	38.82
Plateau-Maritime	13	45	31	2	11	7	3	16	9	6	31	16	17.65	58.82	37.15

Min, Minimum; Max, maximum; Ave, average; *D. cr*, *Dioscorea cayenensis- D. rotundata.*

et al., 2010) and keep ongoing between species a dynamic coevolution (Loko et al., 2013) coupled with natural selection that should be conserved.

2) The poor culinary quality of water yam and more specifically, its inability to make good pounded yam which is incontestabily the most preferred and widely consumed yam food among the populations in the sub-region (Baah et al., 2009). Water yam has good storage ability, better resistance to weeds (Egesi et al., 2009) and is highly demanded during the shortage period from March to July when guinea yams become rare on the markets (Udensi et al., 2008). Therefore one can understand why, despite its not very much appreciated culinary qualities, it is still widely cultivated in the regions (Maritime and Plateau) near the major towns.

Within the *D. cayenensis- D. rotundata* yams, there are some early maturing or double-harvest cultivars that naturally produce one or two large-sized tubers and some late maturing or single-harvest cultivars that generaly yield small tubers in relatively high numbers per mound (Dumont et al., 2005). In Togo and with regard to all the surveyed villages, early maturing cultivars signify-cantly outnumber late maturing ones. Per village, there were on average 9 late maturing cultivars against 14 early maturing cultivars (Table 3). However, this proportion varied across villages and regions (Tables 3 and 4). In the village of Nadouta (Table 3) for example, there weremore late maturing cultivars than early maturing ones (17 against 6). In Dégou, it was rather the early maturing cultivars that outnumbered the late maturing ones (22 against 11) while in Aouda, both cultivar types appeared in the same numbers (12 against 12). In all the regions, the dominance of early maturing varieties over the late maturing ones was observed, except in Kara region where late maturing varieties slightly outstripped the early maturing ones (Table 4). This Kara region, which is near Djougou and Ouaké in Benin (neighbouring country), is populated with the Kabiè people, who are culturally close to the Lokpa and Yom

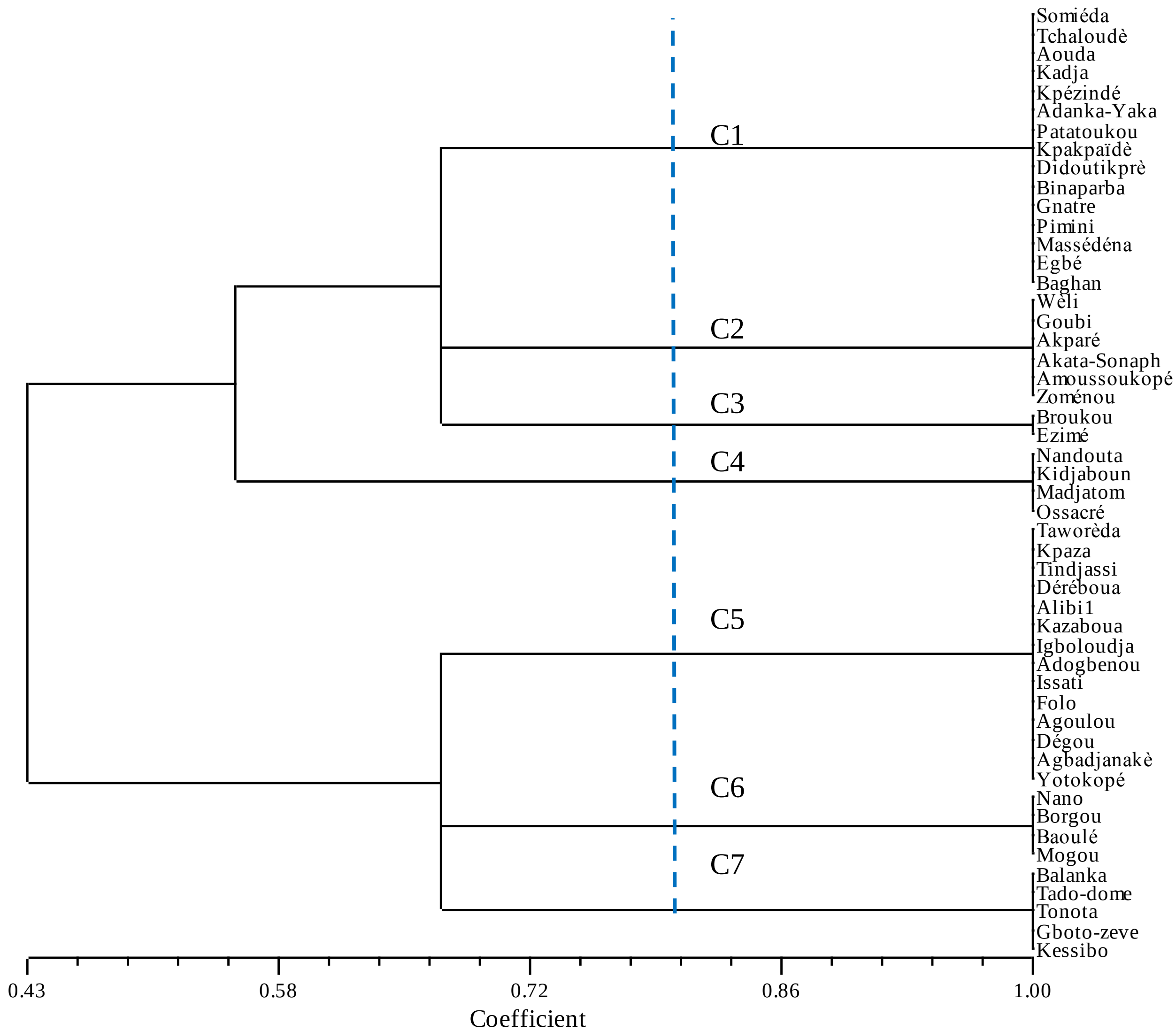

Figure 2. Dendrogram constructed with the UPGMA method showing le grouping of the villages surveyed into seven classes.

people of Benin who are characterized by an important production of late maturing yams especially for the fabrication of dried yam chips for local markets (Loko et al., 2013). Therefore, the predominance of late maturing yams in Kara region may be linked to a cultural preference coupled with commercial reasons.

The dendrogram (Figure 2) constructed using the UPGMA method to examine the relationships between explored villages in terms of total diversity and relative proportions of early and late maturing cultivars of guinea yams (*D. cayenensis- D. rotundata complex*) led to seven classes (C1 to C7). Apart from the villages of classes C3 and C7 which were geographically very scattered, those in classes C1, C2, C4, C5 and C6 were located in the same regions (Figure 3) and defined on the map of Togo as very distinct geographical areas which are Z1, Z2, Z3, Z4 and Z5, respectivelly. Hence, C6 comprised of villages of the extreme North (Savannah region) characterized by a low diversity of yams and a net dominance of early varieties (Table 5). The Savannah region is characterized by the predominance of drought. Very few varieties could adapt to the long drought and short rainy seasons and farmers had to produce early maturing varieties to mitigate the risks.

C1 and C4 shared Kara region characterized by an average diversity. C4 located in the North gathers the four villages surveyed that particularly and unexpectedly (arid zone), present a dominance of late maturing varieties (Table 5). As it was the case in Northern Benin (Loko et al., 2013), producers in these villages explained this dominance by the market demand for dried yam chips for which they have some recognised cultural, long standing expertise. In C1 villages, both late and early maturing cultivars appeared almost in the same proportions.

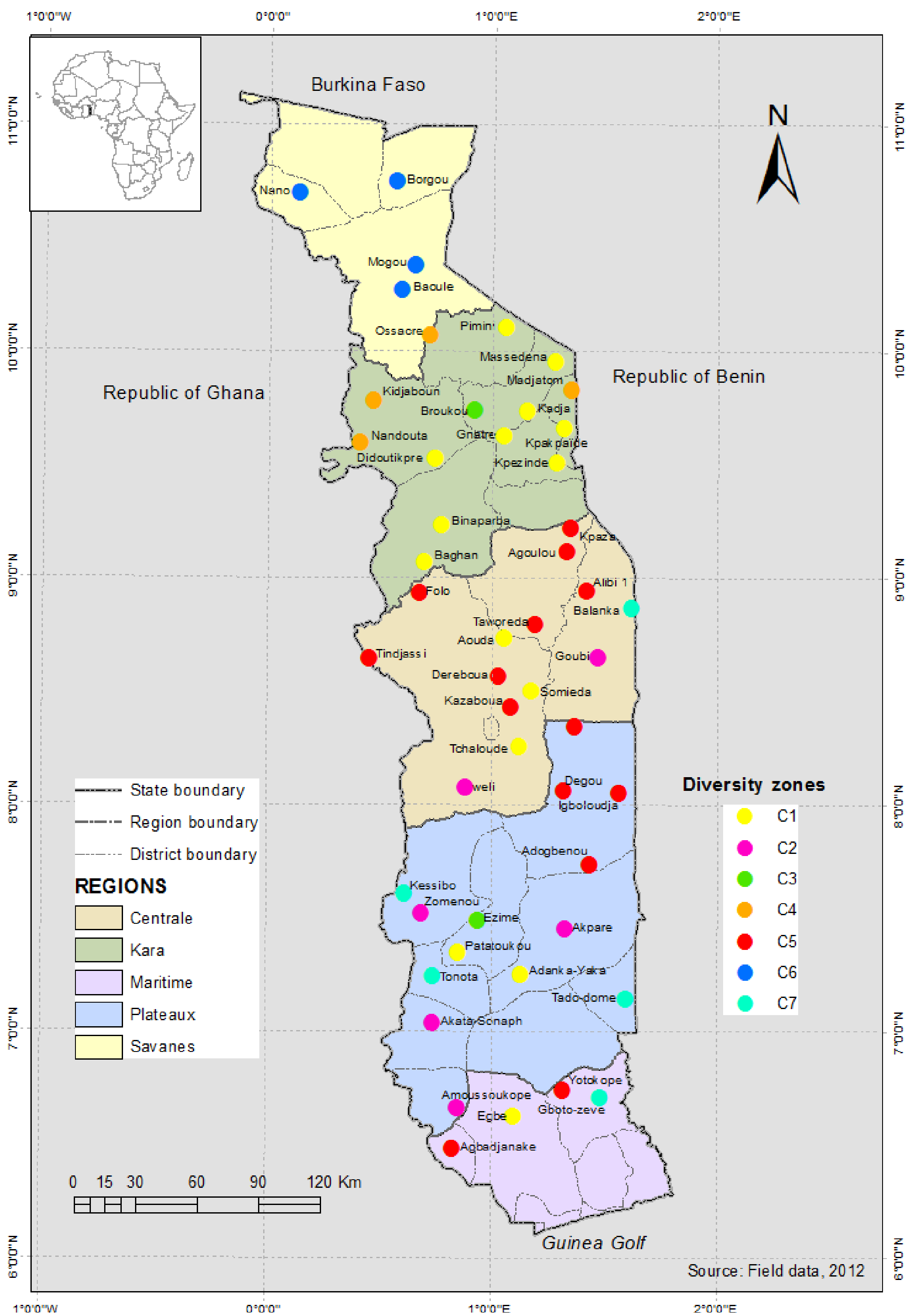

Figure 3. Map of Togo showing the yam diversity zones identified. C1 to C7 are clusters defined in Figure 2.

C2 and C5 were located together but differently in the Centre of the country. C5 groups together the villages of the Central region and of the Northern part of the Plateau region charicterized by a high diversity and a dominance of early maturing varieties. C2 associates some villages of the South and the Centre of the Plateau region

Table 5. Caracteristics of the yam diversity zones revealed by the UPGMA cluster analysis.

Diversity zone	Corresponding cluster	Number of villages	Total diversity			SH cultivars of *D. cr*			DH cultivars of *D. cr*		
			Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Z1	C1	15	12	44	21	4	12	8	6	12	9
Z2	C2	06	33	51	39	11	21	14	16	21	17
Z3	C4	04	13	24	18	9	17	12	1	6	4
Z4	C5	14	35	47	40	4	14	11	15	31	23
Z5	C6	04	5	9	7	0	1	0	5	7	6

Min, Minimum; Max, maximum; Ave, average; *D. cr, Dioscorea cayenensis- D. rotundata*.

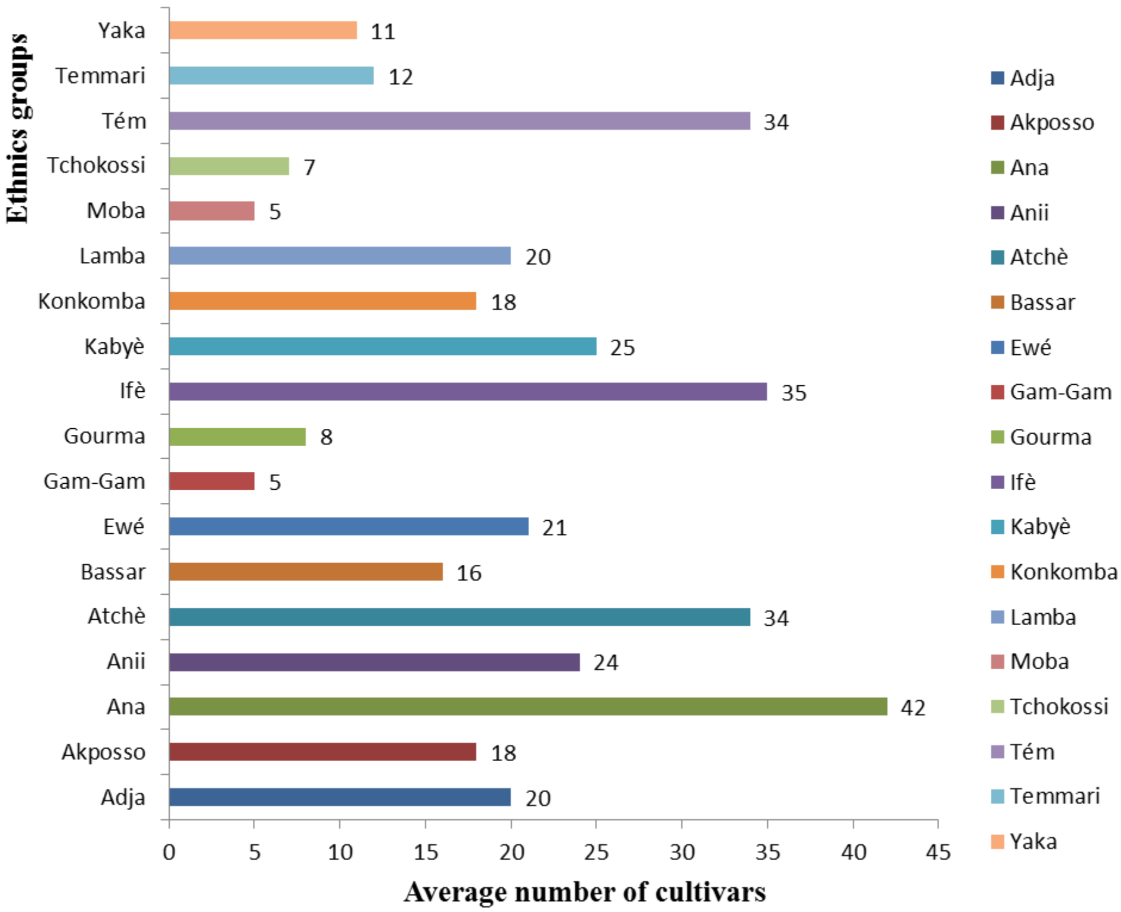

Figure 4. Average number of cultivars recorded per ethnic group.

characterized by a high diversity but with a balance between early and late maturing cultivars of *D. cayenensis-D. rotundata*. Contrary to C6 zone, the dominance of early varieties in C5 is mainly due to the food habits. In fact, the populations (Moba, Gourma and Tchokossi) of this region have mainly pounded yam as staple food. They should therefore produce early maturing cultivars in order to have yams in time after a relatively long period (March to July) of shortage.

In total, a North to South diversity gradient was noted with a maximum level of diversity observed in the humid forest zone of the Centre (Central region and Plateau region) where climatic and pedological conditions were more favourable for yam domestication (prevalence of related wild yam species in natural populations) and yam cultivation (Mignouna and Dansi 2003; Dumont et al., 2005). These results are similar to those reported in Benin by Loko et al. (2013).

The variation of the cultivar diversity observed throughout villages and agro-ecological zones also seemed to have ethnic bearings (Figure 4). The highest diversities were observed among the Ana, Ifè, Atchè and Tém ethnic groups located in the central zone of Togo, while the lowest diversities were observed with the Gam-Gam and Moba ethnic groups located in the Savannah region. These results are similar to those reported by Loko et al. (2013) according to which the ethnic groups Bariba and Yom of Benin had the widest diversity of yams.

The number of cultivars inventoried per household in the study area varied from one to 21. Among the farmers surveyed, 5.20% used only one cultivar, 20.2% cultivated two to four cultivars, 59.4% cultivated five to seven cultivars, 2.4% utilised eight to 10 cultivars and 4.6% had more than 10 cultivars. Households using five to seven cultivars were therefore the most common. The same general tendencies were observed through the different ethnic areas and agroecological zones, although there were some slight variations. The highest cultivar diversities (14 and 21 cultivars) per household were found in the regions of Kara and Plateau, while the lowest was noted at the region of savanes. The average number of cultivars maintained by an individual household was much lower than the total number of existing cultivars. The results suggest that there is a low overlap in the setsof cultivars that each farmer grows. For *in situ* conservation purpose there will therefore be necessary to sample several farmers, if the maximum diversity of landraces is to be captured at a village level.

It is unlikely that the 470 farmer-named cultivars identified thoughout the villages corresponded to 470 genetically different cultivars. In fact, in the traditional system of vernacular nomenclature of crop varieties in general (Meckbib, 2007; Adjatin et al., 2012) and particularly in yam (Loko et al., 2013), local names often vary from one ethnic group to another and sometimes from one village to another within the same ethnic zone. Each village has its own series of names for yam varieties. In this context, a given cultivar may be designated by different names in different villages, and different cultivars may also be designated by the same appellation. To clarify synonymies and facilitate the efficient use of the local yam cultivars identified, exhaustive germplasm collection should be carried out and collected materials should be characterised using both morphological and molecular markers (Otoo et al., 2009, Chakanda et al., 2012; Sartie et al., 2012).

Distribution and extent of yam cultivars and rate of landraces loss

In all the surveyed villages,only a few cultivars (7 on average per village; Table 3) were cultivated by many households and on large areas. According to the producers, these varieties were those presenting interesting agronomic (high productivity, good post-harvest conservation, high multiplication rate, etc.), technological and culinary characteristics and therefore their production are economically profitable. Cultivars cultivated by many households but on small areas (2 on average per village; Table 3) were those with exceptional culinary characteristics (good taste, good quality of the pounded yam) but presenting a lot of weaknesses. They have low productivity, high staking demand, poor post-harvest storage and post-maturity conservation in the mounds, high susceptibility to poor soils, low germination rate, low multiplication rate, pounding difficulty with quick lump formation, etc. making their production economically unprofitable. Some cultivars (2 on average per village; Table 3) were cultivated by few households on large areas. According to the producers, these were cultivars with good agronomic and culinary qualities but presenting some particularrities: difficulty to harvest, soil selectivity, low multiplication rate (producers who had seeds refuse to share with others), high susceptibility to late first harvest (absence of seed production). Finally, many cultivars (12 on average per village; Table 3) were cultivated by few households and on small areas. These cultivars were not very performing or present real agronomic and/or technological shortcomings and, except those newly introduced, were threatened or being disappeared.

In the 50 villages explored in Togo, the rate of genetic erosion (loss of cultivar diversity) varied from 0% in Ossacré to 60% in Nano with an average rate of 37.01% (Table 3). The zero rate of diversity loss recorded in Ossacré village is not an indication of a better preserver but rather a maximum threshold of varietal abandonment reached. Similar results were obtained on acha (Dansi et al., 2010), cassava (Kombo et al., 2012), cowpea (Gbaguidi et al., 2013) and even yam (Loko et al., 2013).

The reasons for abandoning cultivars identified throughout the villages were diverse and varied from one region to another (Table 6). Among these, introduction of new performing cultivars, poor culinary quality, high susceptibility to soil types and low productivity remain the main reasons. New cultivars which are supposed to offer better yield to producers are therefore partly responsible for diversity loss. According to Mbabwine et al. (2008), the race towards high yields using new varieties usually leads to the abandonment and extinction of old varieties. In Cote d'Ivoire, the introduction of the improved variety Florido of *D. alata* from the West Indies (Doumbia et al., 2004) resulted in the abandonment of old varieties. To prevent such a situation in Togo, *in situ* and *ex situ* complementary conservation strategies (Gao et al., 2012, JianZhan et al., 2012) are necessary. In the Savannah region, poor culinary quality and susceptibility to drought were the most important factors while in Kara region, low productivity ranked first. Knowledge of the reasons for the abandonment of yam cultivars in each region will allow better orientation of cultivar introduction and exchanges.

With regard to the conservation of genetic resources, cultivars of the first cadran were not threatened and could simply be monotired *in situ* while those of the last cadran that were threatened should be collected and conserved *ex situ*. In fact, the disappearance of varieties inevitably goes with that of a set of genes that could be used for

Table 6. Principal raisons of diversity loss and their variation across zones in Togo.

Raison	Importance in the study area and per region (% of villages)				
	Pays	Savannah	Kara	Central	Plateau-Maritime
Introduction of new varieties	16.67	-	13.6	2.89	-
Bad culinary qualities	17.04	33.33	14.5	6.60	14.69
Soil selectivity	13.58	11.11	10.9	16.5	10.03
Low productivity	12.9	11.11	18.1	14.8	15.05
Post-harvest storage inaptitude	6.99	-	9.09	4.13	10.75
Susceptibility to poor soils	6.45	11.11	4.54	4.13	8.6
Low market value	5.91	-	5.45	10.3	5.38
Low multiplication rate	4.3	-	6.36	6.19	4.3
Susceptibility to pests and diseases	4.03	-	2.72	4.13	5.37
Susceptibility to drought	4.03	33.34	6.36	2.89	4.66
High staking demanding	2.69	-	0.9	2.89	4.66
Undesirable Shape and aspect of the tuber	2.55	-	3.63	2.89	-
Difficulty to process into pounded yam	1.88	-	0.9	3.71	1.1
Difficulty to be harvest	0.54	-	0.9	-	1.43
Susceptibility to weeds	0.4	-	0.9	-	-

breeding purposes (Hammer and Laghetti 2005; Tsegaye and Berg, 2007). Varieties in intermediary situation (cadrans 2 and 3) should be the subject of complementary conservation approaches (*ex situ* and *in situ*) according to Gao et al. (2012), JianZhan et al. (2012) and Sun et al. (2012). For *in situ* conservation, the villages of Adogbénou, Goubi and Folo located in the heart of the Plateau and Central regions seem to be well indicated because each of them has a high cultivar diversity (43, 42 and 38 cultivars respectively) with a relatively low rate of diversity loss (27.91, 19.05 and 28.95%, respectively; Table 3).

Spatial analysis of yam diversity

Loko et al. (2013) reported that yam cultivars produced by few households and on small areas considered as threatened last generally only five years and, most often, effectively disappear after this period from the villages where they were identified. From this observation, diversity in each explored village can be predicted for the next five years. Using survey data and the ordinary Kriging method, which is a geo-spatial modeling, predicting and mapping method, spatial distribution of current yam diversity in Togo was mapped (Figure 5) as well as that of the year 2017 (Figure 6). The comparison of both maps shows that by 2017, Togo will experience a deep degradation of cultivar diversity in all zones. In the absence of appropriate action, the situation may worsen with severe consequences on the food security of the population. Like in Benin (Loko et al., 2013) and following Weltzien et al. (2008), it will be important to establish in Togo an integrated and concerted conservation program through the use of yam cultivar diversity that includes, but not limited to, varietal exchanges among villages, diversity fairs, community gene banks and the introduction in certain villages of good performing cultivars identified within the existing diversity through participatory evaluation.

Participatory evaluation of the yam cultivars

Among the two yam species investigated, only *D. cayenensis- D. rotundata* complex yams presented some qualities desired by producers and was considered for the evaluation. Subject to synonymy, only 17 to 98 performing guinea yam cultivars have been identified per evaluation criteria (Figure 7). Four morphologically distinct cultivars selected among those found good per evaluation criterion are presented in Figure 8. Evaluation criteria provided with greatest number of cultivars were quality of the pounded yam, post-harvest storage aptitude, seeds multiplication rate and productivity. Parameters that have recorded the lowest numbers of cultivars were resistance of dried yam chips to insects, resistance to nematodes, mealybugs, termites, tolerance to weeds and adaptability to lowland areas (high soil moisture). Moreover, none of the evaluation criteria was able to record, subject to synonymy, 25% (approximatively 115) of the 470 farmer-named guinea yam cultivars identified. There is therefore an urgent need to set up a national yam improvement and development program in order to provide the different zones with performing cultivars and to monitor existing diversity. Per criterion, the identified cultivars represent a pool of performing clones that could be exploited by scientific research and development (cultivar exchange) programs as is the case in Benin.

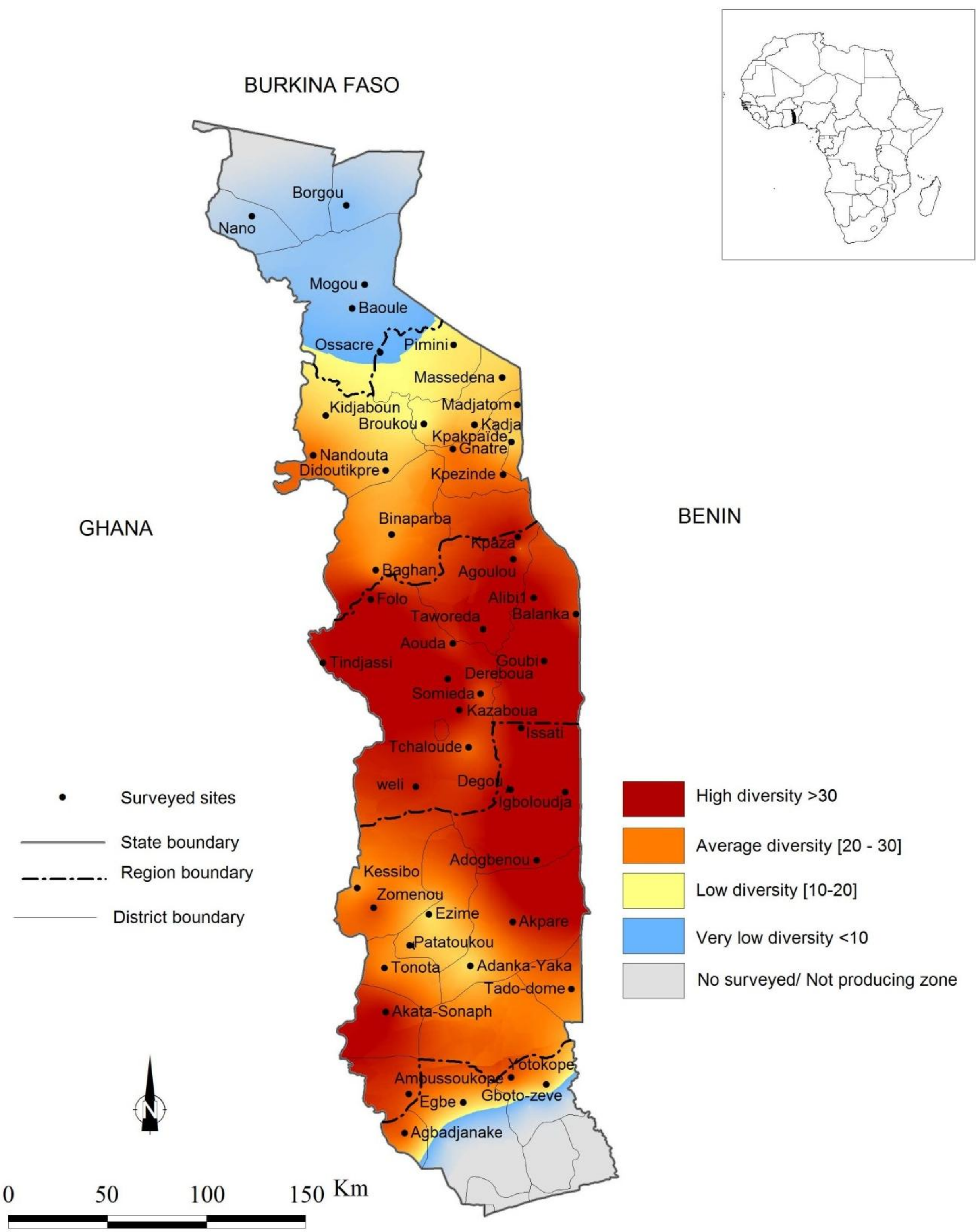

Figure 5. Map showing the current status of the yam (*D. cayenensis – D. rotundata* complex) diversity in Togo.

Conclusion

The nationwide ethnobotanical investigation carried out has revealed that Togo has wide yam diversity distributed throughout the country following an increasing North-South gradient. The Central and Plateau regions are the richest zones and the most appropriate for on-farm conservation. For different agronomic, technological and

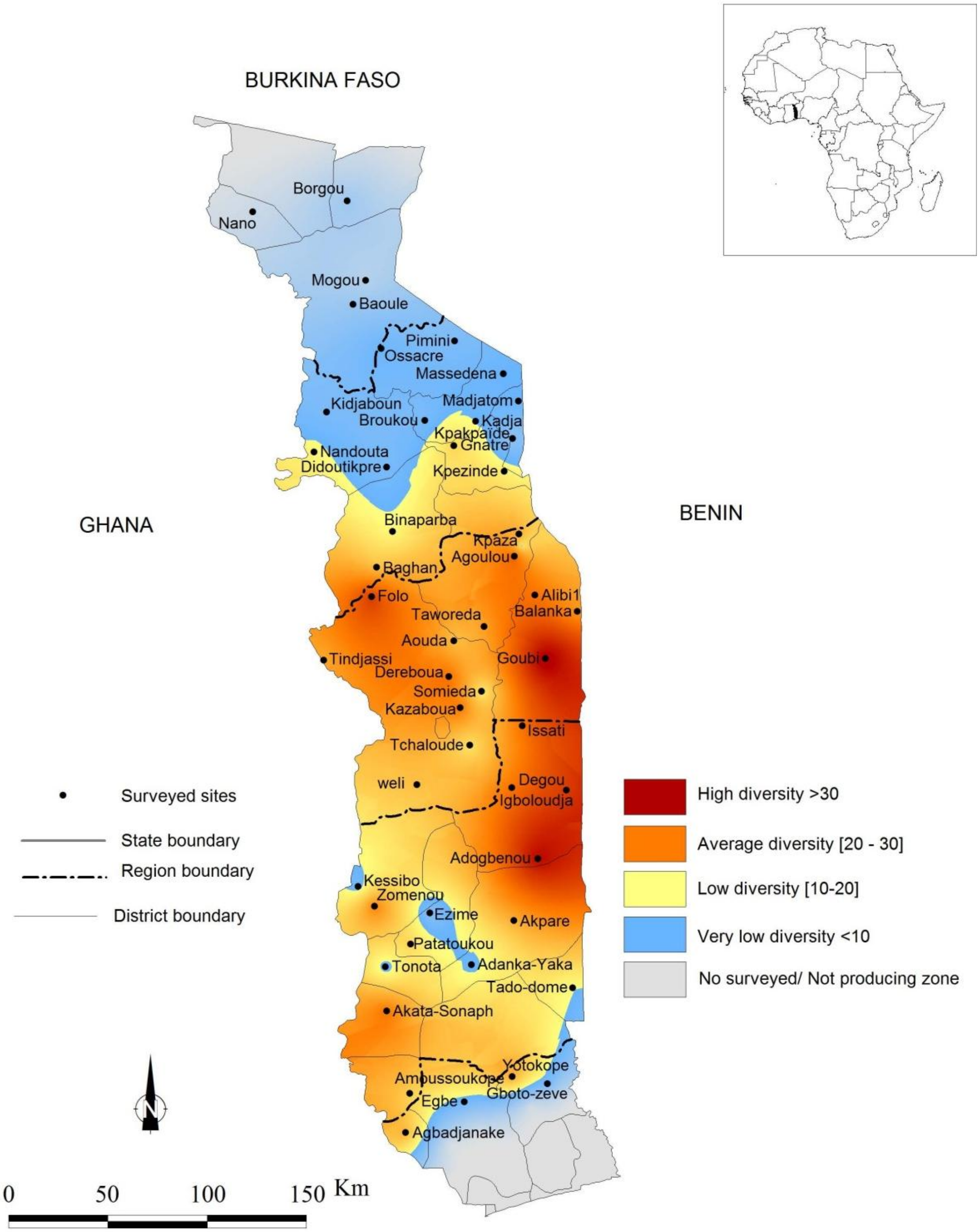

Figure 6. Map showing the prediction of yam diversity in Togo for year 2017.

culinary traits, the participatory evaluation revealed the existence of some performing cultivars that can be used to enhance yam production in Togo in the actual context of climate change. To further increase farmers' and breeder's access to good yam diversity in Togo, the following key research and development actions are suggested:

1) Exhaustive germplasm collection and participatory agro-morphological characterization per diversity zone.
2) Molecular characterization for duplicates identification and clarification of synonymies.
3) Definition of a national integrated strategy of on-farm conservation through use of the yam diversity in Togo. This includes among others, farmers' networks establish-

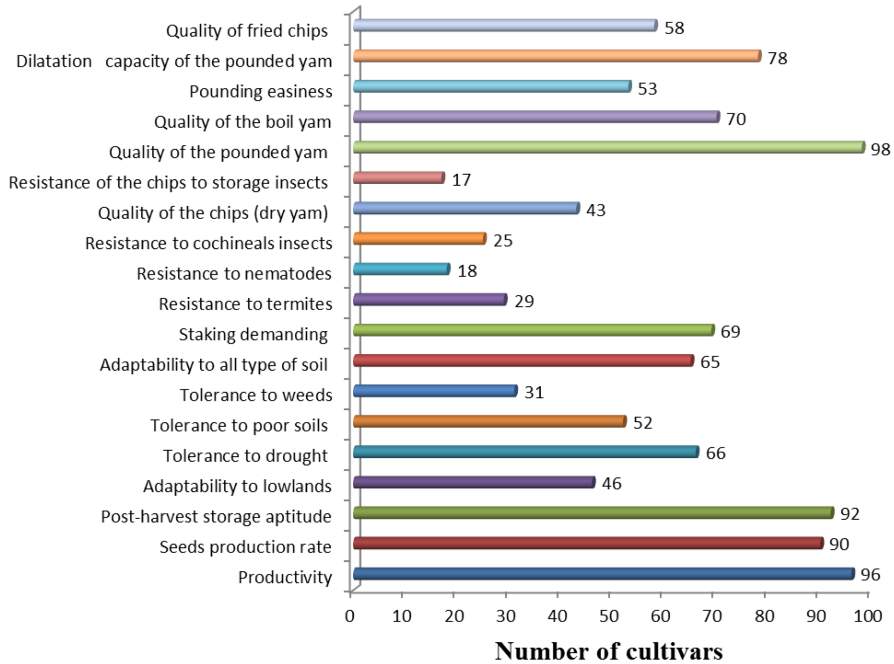

Figure 7. Variability of the number of best performing yam cultivars identified per trait of economic importance through participatory evaluation in Togo.

A) Cultivar **Laboko** with its tuber with pointed tips. tolerant to high soil moisture (lowland yam); very sweet and highly demanded on the market.

B) Cultivar **Kratchi** with details of its very thorny and characteristic stem; tolerant to weeds.

B) Cultivar **N'Kéné** with its wide and opened leaves and the corm of its tuber; resistant to drought.

C) Cultivar **Koukou**, a single- harvest kokoro cultivar with its numerous small sized tubers; tolerant to poor soil and dry chips resistant to storage insects.

Figure 8. Morphological traits of selected performing yam cultivars.

ment, public awareness actions, capacity building for agricultural technicians and leaders of farmers' associations, variety exchanges between villages, diversity fairs and community biodiversity register.
3) Implementation of a participatory varietal selection and breeding programs.
4) Definition of a national programme for *in situ* and *ex situ* conservation of the related wild yam species diversity for their use in breeding programmes

ACKNOWLEDGEMENTS

This study was funded by the Global Crop Diversity Trust (Rome, Italy) and jointly carried out by Institut Togolais des recherches Agricoles (ITRA) and the Laboratory of Agricultural Biodiversity and Tropical Plant Breeding (LAAPT, now BIORAVE) of the University of Abomey-Calavi (UAC). We would like to thank the Director General (Dr Agbobli Comlan Atsu) and the Scientific Director (Dr Labare Kodjo) from ITRA for the technical facilitation. We also thank Dr Dao Balabadi (ITRA) and Mr Edéa Emile (UAC) for designing the maps and Mr Tsatsu Domenyo (ITRA) for his technical assistance. We express our sincere gratitude to all producers, chiefs of village, leaders of farmers' groups and agricultural technicians met for their contribution to the success of the study.

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