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On-farm diversity of sorghum [*Sorghum bicolor* (L.) Moench] and risks of varietal erosion in four regions of Burkina Faso

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Local sorghum varieties managed and cultivated by farmers contribute in a large part in crop production of Burkina Faso. The loss of local sorghum varieties were reported, but very few investigations have been made on it. This study was conducted to assess the status of 739 local sorghum varieties collected in four regions of Burkina Faso and to identify the threats factors of sorghum diversity. A sample of 159 varieties identified as "rare" and described by the cycle length, the uses and disadvantageous characteristics has been submitted to a Multiple Correspondence Analysis (MCA) to determine sorghums groups and characterize them. The results showed a higher varietal richness in the North, East and Centre-East regions compared to the South-West region, with respectively 13.0; 11.7; 10.9 and 6.1 varieties per village. The MCA underlined four main groups of sorghum: custom sorghums, lain period sorghums and tincture sorghums, pharmacopeia sorghums and sweet-stem sorghums; they are characterized by lateness associated to the low grain productivity, earliness associated to the low grain quality, drought sensitivity. For these sorghums groups it appears that the climatic and socio-cultural changes are the main threats factors of sorghum diversity loss. Farmers' associations at regional level and research structures should in common develop suitable initiatives to follow-up and conserve sorghum diversity.

Key words: Sorghum, local varieties, lateness, decline of uses, erosion.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is a subsistence crop for many farmers in the semi-arid tropics in Africa. The cropping systems based on sorghum used manly local varieties which are part of their strategy to reduce the risks in the constraining areas. Teshome et al. (1999b) have defined the local varieties as "variable plant populations adapted to local agro-climatic conditions which are named, selected and maintained by the

traditional farmers to meet their social, economic, cultural and ecological needs".

The grain sorghum is the first food crop in Burkina Faso, with an annual average production of 1.7 million ton, which ranks the country in the fourth highest African producer behind Nigeria, Ethiopia and Sudan (FAOSTAT, 2015). Sorghum is cultivated for human consumption. The production is mainly ensured by local varieties (98%) (MASA, 2014) which are diversified and belong mostly (93%) to the botanical race guinea (Sapin, 1984; Zongo, 1991; Barro-Kondombo et al., 2008). The guinea varieties are rustic, well adapted to low agronomic conditions and climatic uncertainties (Vaksmann et al., 1996; Clerget et al., 2004; Kouressy et al., 2008); moreover their grain quality is well suited to the various local processing.

In Burkina Faso, the variability of rainy season (irregularity, drought, etc.), degradation of soil fertility and insufficiency of arable farmland in some regions are the major constraints of sorghum production (MASA, 2014). Sorghum is grown under rainfed conditions on variable surfaces size often on families' farms. The dominant cropping system is extensive type (60% of households) with low or no use of mineral fertilizers. The growing areas devoted to each variety depend on its socio-economic and cultural importance. Delauney et al. (2008) reported in Burkina Faso that one season to another 70 to 90% of sorghum seeds used by farmers are auto-produced in their own farms.

Many studies have shown a great preference of local sorghum varieties in traditional farming systems in Africa. Farmers are attached to local varieties for different reasons: cultural practices and food preferences (Barnaud et al., 2007; Missihoun et al., 2012; Muui et al., 2013), biophysical, pests and diseases constraints (Teshome et al., 1997; 1999a; Seboka and Hintum, 2006; Mekbib et al., 2009). The diversity of characters allows each farmer to find the variety that suits to his context and his production objectives; that is why, Wood and Lenné (1997) underlined that "local varieties are a key component for traditional cropping systems"; they provide food security and well-being of traditional households (Cavatassi et al., 2005).

The importance and the role of plant genetic resources have been reported by Frankel (1974), Altieri and Merrick (1987), Bellon (1996), Wood and Lenné (1997). The threats in plant genetic resources of cultivated plants are various (Brush, 1986; Mercer and Perales, 2010); their loss will threaten the future generations (FAO, 1996). Burkina Faso like others countries in the world has led sorghum germplasm collections between 1960 and 2010 that are conserved ex-situ (vom Brocke et al., 2014). Some characterizations have been done (Zongo, 1991; Barro- Kondombo et al., 2010), but to date few information have been reported on local sorghum varieties erosion. The objective of this study is to assess the status of the local sorghum diversity grown in four regions of Burkina Faso and to identify the threats factors of diversity loss based on collection and climatic data.

MATERIALS AND METHODS

Collection areas

Local sorghum varieties have been collected in 2009 and 2010 in 73 villages of four regions of Burkina Faso: Centre-East, East, North, and South-West. The sampling areas are located between 9°27' and 14°18' North parallel and between the meridians 3°49' West and 2°20' East. The average annual rainfall varies from 500 mm in the North to 1100 mm in the South-West (Figure 1) (National Direction of Meteorology, 2011). Table 1 gives the agroclimatic variations in the study area.

Germplasm collection

The collection was preceded by a participatory diagnostic in each village. During the interview with farmers the varieties which still grown almost everywhere in the village, those threatened and those lost were inventoried. Each variety was nominated by its local name (vernacular name and synonymous). The farmers group provided the background of each variety: the status (local or improved variety), the origin [inherited from parents, introduced (purchasing, gift, etc.)], the date of the first introduction in the village, the frequency (abundance, rare, etc.), the uses, the local knowledge for each variety, the advantageous and disadvantageous agronomic characteristics and the factors that affect sorghum production and varietal diversity. Each farmer donor indicated how collected variety was managed in his farm. The varieties were collected according to their local names in each village. Fifteen (15) to 39 leaders of household (men, rare women and chief of village) have participated to group discussion in the villages.

Data analysis

Seven hundred and thirty-nine (739) local sorghum varieties were analysed in this study; among this material, 159 rare varieties threatened of loss in 66 villages were used to determine the threats factors of sorghum varietal erosion. Fifteen modalities of three descriptive variables were used in a Multiple Correspondence Analysis (MCA) (Escofier and Pagès, 1998) to establish the groups structure, these are: i) the cycle length (short cycle, intermediate cycle, long cycle); ii) the uses [fresh consumption, lain period sorghums, custom, ordinary consumption (thick porridge, local beer, etc.), consumed as rice, pharmacopeia, tincture, sweet-stem]; iii) the disadvantageous characteristics (unsuitable panicle shape according to farmers opinion, low grain quality, low productivity and sensitivity to drought). The village was setting as an additional variable. The analysis was led with XLSTAT software, version 2015.17.6 (Addinsoft 2015).

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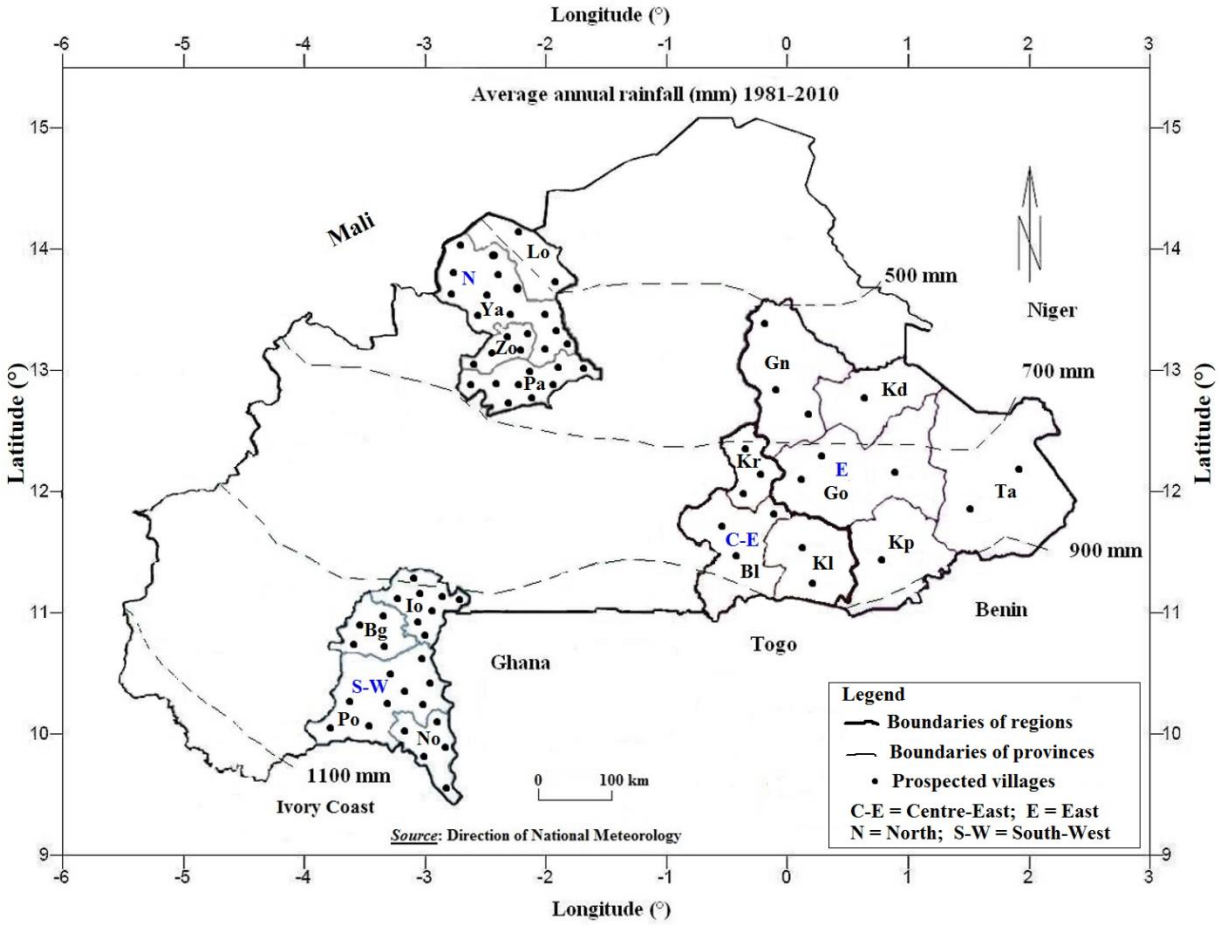

Figure 1. Climatic zones of Burkina Faso and geographical locations of the 73 surveyed villages (National Direction of Meteorology, 2011; Ministry of Territorial Administration, 2010). Centre-East [Boulgou (Bl), Koulpélogo (Kl), Kouritenga (Kr)]; East [Gnagna (Gn), Gourma (Go), Komondjari (Kd), Kompienga (Kp), Tapoa (Ta)]; North [Lorum (Lo), Passoré (Pa), Yatenga (Ya), Zondoma (Zo)]; South-West [Bougouriba (Bg), Ioba (Io), Noumbiel (No), Poni (Po)].

Table 1. Agroclimatic variations in the four regions of study (Source: DGAT, 2006; National Direction of Meteorology, 2011)

Region	Altitude (m)	Land forms	Types of dominant soil	Temperature (°C)	Rainfall (mm)	Rainfall duration (month)
Centre-East	200	Upland, Lowland, Hills	Ferric-lixisol, Vertisol	13-42	700-950	5-6
East	100-200	Upland, Lowland, Hills	Ferric-lixisol, Oxisols	13-43 13-42	500-700 700-950	4 5-6
North	200-400	Upland, Lowland, Hills	Lithosols, Ferric-lixisol	13-43	500-700	4
South-West	300-500	Upland, Lowland, Hills	Oxisols, Ferric-lixisol	13- 41	900-1100	6-7

RESULTS

Varietal diversity described by farmers

Sorghum varieties were classified by farmers in short-cycle, intermediate and long cycle in correspondence to the duration of rainy season in each growing area. In the North region, the long cycle varieties are those whose maturity occurs after four months of cultivation and six months and more in the other three regions. The varietal

diversity managed by farmers can be grouped in three groups: i) food sorghums [varieties with grain consumed fresh, lain period varieties, varieties for ordinary consumption (thick porridge, local beer, etc.), sweet-stem varieties, varieties use like the “rice” with small grain mostly belong to the botanical race guinea-margaritiferum traditionally used in a culinary preparation similar to that of the rice]; ii) custom sorghums (varieties for rites in memory of ancestors); iii) local knowledge sorghums (tincture and pharmacopeia varieties).

If the glume and grain colour are ordinary used to name varieties, these are also designated by the names linked to agronomic characteristics (productivity, particularity of the cycle duration, grain characteristic, etc.). It is found special names for earliest cycle varieties (e.g. I will not sell my goat, the wife will not leave home), for long panicle varieties (horse tail), for varieties with closed glumes (blind sorghum). Other sorghums are designated by their adaptability to the soil type (varieties of lowlands, etc.) and by their resistance to parasitic weeds as striga. It is in this varietal panel that households choose varieties that are suitable to their cropping context, their food preferences and their production objectives.

From one to eight varieties are grown per household. The area devoted to each variety vary from less than 1000 m² to more than 5 ha. The growing areas and usages frequencies provide information on the evolutionary process of each variety at the village scale. A variety is abundant when it is cultivated in almost all farms on large areas and constitutes the essential of the subsistence production in the households. The frequent varieties are grown by a large number of farmers but often on a reduced area. The rare varieties are less found, often owned by one farmer, they are grown in general on small areas. The abundant and frequent varieties represent 45.6% and 32.9% of the collected diversity; they are less threatened by erosion risks compared to rare varieties (21.5%), their characteristics are suitable to farmers food needs, while the rare varieties are often used for specific purposes. Most of varietal diversity is cultivated in remote fields far from home and backyard fields. Nine point two percent (9.2%) to 17.1% of varieties in the villages are sown around the lowlands.

Varietal diversity collected in the villages

From three to eighteen varieties were collected in the 73 surveyed villages. The lowest varietal diversity (3 varieties) was found in the South-West and the highest (18 varieties) in the North (Table 2). On average, the varietal richness is higher in the North, East and Centre-East regions respectively (13.0; 11.7; 10.9 varieties) compared to the South-West region (6.1 varieties). A percentage of 60.6 of varieties would have been inherited from parents and were considered as old because they were grown for at least 30 years in the villages. The oldest varieties are found in the villages of Kampene (province of Poni) and Zabatourla (province of Boulgou); they would have been cultivated at least 89 and 95 years in these villages at collection time. Gnagna, Tapoa and Boulgou provinces would conserve more inherited varieties from parents, with respectively 70.3, 73.3 and 86.1% of their varietal diversity. Varietal introductions were higher in Zondoma and Bougouriba provinces with 52.9 and 77.3% of their current sorghum diversity. Among the introductions it has been found some improved varieties: IRAT 204 (North), Framida and ICSV 1049 (East and Centre-East), Sariaso 1 and Sariaso 2 in the South-West. The three first varieties belong to the botanical race caudatum, and the last two varieties to the botanical race guinea.

Varietal erosion and threats on sorghum diversity

The varietal erosion is almost observed everywhere in the villages. For all the sampling villages, 98 varieties were reported as lost. The circumstances of the losses were not always well elucidated, but would be due to rainfall decrease, to soils poverty, or have been abandoned in favour of maize growing. Seventy-three point five percent (73.5%) of lost varieties were found (Table 3). They are still grown in other villages in the production system often on small areas. The analysis of rainfall data from 1950 to 2010 shows a decreasing trend of rainfall in many sites illustrated here by data from four meteorological stations (Figure 2).

The signs of varietal erosion still exist in the villages. The MCA with the 15 modalities of variables related to cycle length, the usages and the disadvantageous characteristics allowed to structure and characterize the 159 rare varieties threatened of loss. All of the information is carried by six factorial axes.

The first two factorial axes (F1 x F2) explain 78.7% of the total variance (Figure 3). The axis one which carries the greatest part of total information (68.2% of variance) is explained by cycle lateness (24.8%), low grain quality (16.5 %), low productivity (14.6%), cycle earliness (14.2%), consumed fresh grain (9.6%), lain period sorghums (8.8%), custom sorghums (8.3%) and tincture sorghums (2.5%). The axis two is more explained by the sorghums use for pharmacopeia (22.2%), the intermediate cycle (16.0%) and the sweet-stem sorghums (13.1%). The axis three is essentially explain by "sorghums use as rice" (24.6%), panicle shape (18.1%) and ordinary sorghums (11.0%).

Two sorghums groups can be distinguished on axis one of MCA: the custom sorghums characterized by lateness and low productivity; the lain period sorghums and tincture sorghums characterized by their earliness and their low grain quality. Two other groups have been also distinguished on axis two: the pharmacopeia sorghums characterized by their sensitivity to drought and sweet-stem sorghums.

Table 2. Presentation of collected varieties in 2009 and 2010 in the four regions of Burkina Faso.

Study region	Province of collection	Number of collected village	Total number of variety per province		Mean number of variety per village	Range of variety number per village	Percentage of improved varieties identified in the collection area	Age of the oldest variety in the province (year)	Name of the oldest varieties
			Inherited varieties	Introduced varieties					
Centre-East	Boulgou	3	37	6	14.3	[12;16]	0	95	Bouré Naga-zoula
	Koulpélogo	2	9	6	7.5	[7;8]	6.7	82	Belko
	Kouritenga	3	17	12	9.7	[7;14]	0	71	Sonmouï
East	Gnagna	3	26	11	12.3	[9;16]	2.7	72	Tchoadi
	Gourma	3	20	13	11.0	[8;13]	0	65	Zouanviéléga
	Komondjari	1	5	4	9.0	[9]	11.1	56	Kankan-yaré
	Kompienga	1	3	5	8.0	[8]	0	80	Icuari
	Tapoa	2	22	8	15.0	[15]	0	75	Manpuoli, Ibiari-moani, Ikparbinuani, Ku-dimangu
North	Lorum	2	10	6	8.0	[8]	6.3	66	Gnouga
	Passoré	9	72	49	13.4	[8;18]	0.8	83	Kiédogo Bôchimin
	Yatenga	13	112	58	13.1	[8;17]	0.6	78	Balinga
	Zondoma	5	33	37	14.0	[11;17]	0	74	Bonga
South-West	Bougouriba	4	5	17	5.5	[4;10]	0	76	Gnignan
	Ioba	8	35	29	8.0	[4;14]	0	75	Hamana-bilé
	Noumbiel	5	12	7	3.8	[3;5]	0	80	Tchar
	Poni	9	30	23	5.9	[5;9]	1.9	89	Djôsiê-blo
Total		73	448	291	10.1	-		-	

DISCUSSION

Dynamic of varietal diversity

The four regions of this study present a very contrasted environmental profile on the agro-ecological level and agricultural potentialities. The North region is particularly characterized by low availability of arable farmland, low soil fertility, rainfall constraints with recurring cereal deficits (MARHASA, 2015), which is not the case for the three other regions with better environmental conditions.

In Burkina Faso, the priority of farmers in cereal production is to ensure households food security. Each household choose to cultivate the cereals (sorghum, millet, maize) and varieties that suit to the family food preferences and their environmental production context. In the East, Centre-East and North regions, sorghum would be more consumed within households, while it is more intended for commercialization in the South-West, where families' consumption are preferentially focused on maize. Except the custom sorghum found everywhere in the "terroir" and managed by the tradition guarantors, the low varietal richness in the South-West could be explained by the low number of varieties consumed in households, the good characteristics and yield regularity of cultivated varieties that meet farmers' production objectives.

Many studies have shown a link between the level of varietal diversity and the natural and human factors (Brush and Meng, 1998; Seboka and Hintum, 2006). The results of this study are comparable to those of Brush and Perales (2007) who found a low diversity in local maize varieties in high altitude villages (more humid) compared to that of low altitude villages in the Chipas state of Mexico. Mekbib and al. (2009) found in the humid zone in the East of Ethiopia a low diversity in local sorghum (8.3 varieties) compared to the medium rainy zone (11.4 varieties). Barro-Kondombo et al. (2010) also reported a low diversity on local sorghum in the humid zone of Burkina Faso (7.3 varieties per village) compared to the low and medium rainy zones (12.3 to 17.5 varieties). In arid and semi-arid regions of Africa where climate vulnerability (Kouressy et al., 2008; Abdulai et al., 2012) and diverse stress can compromise the harvests it is usual that farmers manage a large diversity to attenuate the risks of bad harvests; this is probably the

Table 3. Situation of lost varieties in the four regions of Burkina Faso.

Region	Province	Reported number of lost varieties	Number of varieties found and still growing in other villages	Number of varieties not found	Name of lost varieties not found
Centre-East	Boulgou	4	3	1	Boukarga
	Koulpélogo	3	3	0	
	Kouritenga	6	5	1	Boukarga
	Gnagna	5	5	0	
East	Gourma	4	3	1	Touguelèpa,
	Komondjari	3	2	1	Soassa
	Kompienga	1	1	0	
	Tapoa	4	2	2	Jualiagamba, Manpaba
North	Lorum	1	1	0	
	Passoré	8	5	3	Wangoussougou, Yiliga, Pazini-yendé
	Yatenga	12	11	1	Rawoumdé
	Zondoma	10	7	3	Réogo, Samkaboudou, Wangoussougou
South-West	Bougouriba	6	2	4	Bordjonguô, Yibi-gnaman, Badjonka, Sokou
	Ioba	13	11	2	Wourzour, Napobsan
	Noumbiel	4	3	1	Danlar
	Poni	14	8	6	Bassa, Bazongo, Djoumwan, Gnêrêkononi, Nigapiêre, Vôvô
Total		98	72	26	

situation in the North more exposed to rainfall constraints and decline (Figure 2). Mercer and Perales (2010) reported that of all the factors influencing the plants diversity, climatic effects are the most important.

Varietal erosion

The structuration of sorghum groups by MCA showed that almost all the information is explained by the first two factorial axes (78.7%) (Figure 3). The analysis of groups characteristics shows that the cycle lateness, low productivity and low grain quality are disadvantageous characteristics for the sorghum groups attached to the axis one. The earliness is an advantageous character. For the lain period sorghums characterized by earliness, their growing on small areas would not mean necessarily an erosion risks because these varieties are essential, even vital; they allow to offset the cereal deficits of the end of rainy season. The evidence is that most early sorghum are among inherited varieties. Vom Brocke et al. (2010) showed that all of the many farmers' selection criteria of sorghum in Burkina Faso, the earliness of cycle, the grain quality (hard grain) and yield (grain and flour) were the most important.

Drought sensitivity is a handicap for pharmacopeia sorghums on axis two. Pharmacopeia sorghums, sweet-stem sorghums, tincture sorghums and "rice sorghums" not numerous in the varietal panel grown in the villages appear also to be affected by socio-cultural changes in food habits and usages. Nowadays, the use of pharmacopeia sorghums in healthcare tends to decline, also sorghums use like rice are simply replaced by "*Oryza sativa* and *Oryza glaberrima*".

In Burkina Faso, despite of the increase of maize and cotton area in the East, Centre-East and South-West regions, the area devoted to sorghum remained quasi stable or slightly increased from 1 to 18% during the four years (2010-2014) followed the collection (MARHASA, 2015); the South-West region has increased its areas of 18% showing a general interest in sorghum. However, in general the decisions of farmers' (selection, production objectives, etc.) may change the dynamics of diversity and even contribute to its loss (Teshome et al., 1997; Tunstall et al., 2001). Local varieties may be abandoned at the village level when they no longer meet to farmers' production objectives (Missihoun et al., 2012a; Dossou-Aminon et al., 2014), but can be desired again later. If this is the case, the research office may contribute to find

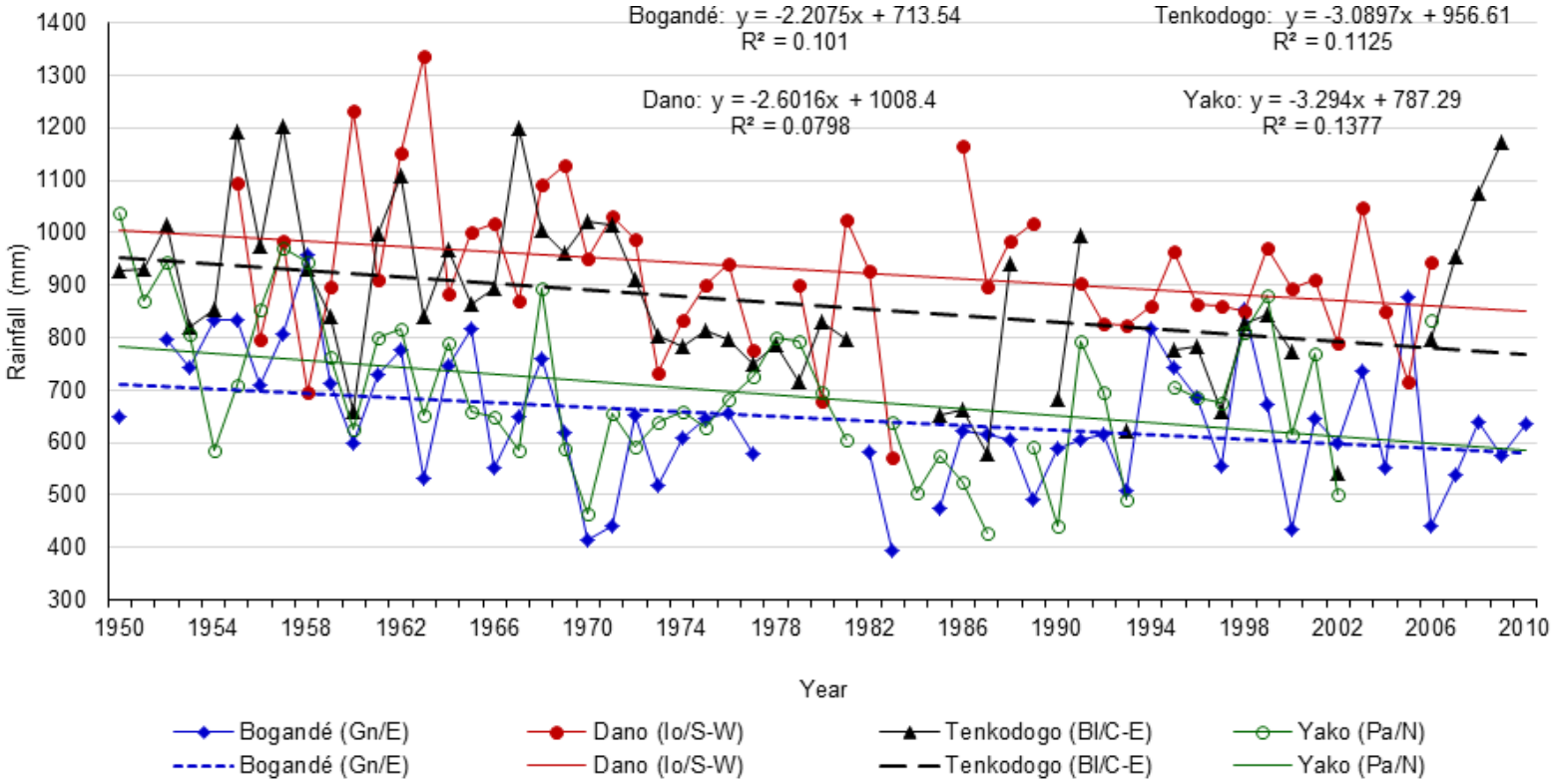

Figure 2. Evolution and trends of average rainfall (1950-2010) of four studies regions: Bogandé (East), Dano (South-West), Tenkodogo (Centre-East), Yako (North) stations (Source: National Direction of Meteorology, 2015)

some of them, either into other prospected villages as shown in our study or in its germplasm collections maintained ex-situ as the case in Burkina Faso where Flagnon (SCHV 159) and Gnossiconi (SCHV 162) (CNS, 2014), two local varieties of the North-West region lost a long time ago and sought-after by farmers, have been successfully reintroduced (vom Brocke et al., 2014.) because they were kept respectively since 1962 and 1969 in the gene bank of INERA Saria research station. A local variety named Soassa like that lost in Komondjari and not found in the sampled villages was also found in the Saria gene bank. This variety of long cycle and almost completely closed glumes was collected in the Tamasogo village of Ganzourgou province (Burkina Faso) and introduced in 1965.

In this context of varietal erosion, the taking into account of local sorghum diversity in the breeding programs is prior for its safeguard but not enough to save interest genes. Common actions involving farmers and research should be undertaken to avoid varietal erosion. As underlined Ramanatha Rao and Hodgkin (2002), "phytogenetic resource conservation merits far greater attention than it is now receiving".

Conclusion

This study on local sorghum variety in the four regions of Burkina Faso has shown that the diversity cultivated in the villages is dominated

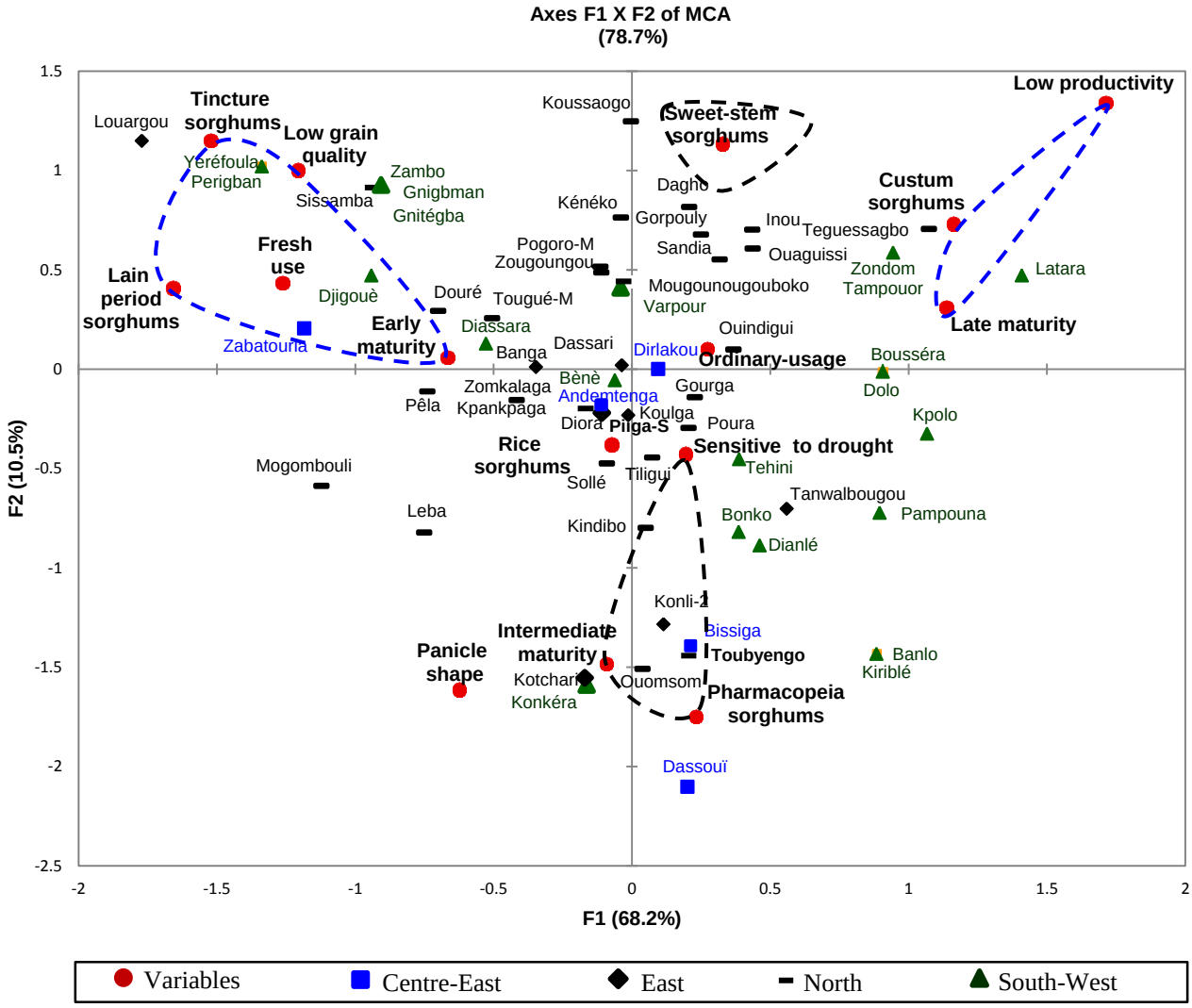

Figure 3. Graphical representation of the 15 modalities of descriptive variables for 159 rare varieties of the four study regions in Burkina Faso.

(60.6%) by inherited varieties from parents. Twenty six point five percent of lost varieties were not found in the sampled areas. The erosion threats exist at different levels. Among sorghums groups structured by MCA, pharmacopeia sorghums, sweet-stem sorghums, tincture sorghums and "rice sorghums" are more threatened by their low number in the varietal diversity grown and their low uses in the villages linked to socio-cultural changes. The tradition is transmitted from generation to generation, it is not evident that the young generation for diverse reasons (modification of production objectives, etc.) could maintain custom sorghums and local knowledge. None disposition exists at the regional level to safeguard diversity. It would be necessity to develop some efficient mechanisms to follow up sorghum diversity in order to avoid losing genes that could be useful for agriculture of the future.

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