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DIVERSITY AND EVOLUTION OF THE CULTIVATION OF LATE YAMS KOKORO, DIOSCOREA ROTUNDATA POIR (DIOSCOREACEAE) IN YAM PRODUCTION AREAS IN BENIN

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ABSTRACT

Yam is an important food crop in maintaining food and nutrition security in Benin. For this reason, the late Kokoro yams remain less documented in terms of their specific diversity, their geographical distribution and their evolutionary trajectories. The study assessed the diversity, uses and evolutionary dynamics of late Kokoro yams in the main production areas of Benin. It was conducted in 43 villages in the departments of Borgou, Atacora, Donga and Collines. Data were collected through individual interviews and group discussions and included 376 respondents. A total of 166 cultivars were recorded, including 71 in Donga, 59 in Borgou, 21 in Atacora and 15 in Collines. The average Shannon diversity index was 3.4 bits, with a maximum value in the Borgou (3.8 bits). Kokoro made up 37.62% of the yams produced and more than 80% of the crops were intended for self-consumption, especially during the lean season. Seeds were mainly from intra-Community trade and inheritance. Between 2012 and 2025, 61% of cultivars disappeared, with Borgou being the most affected with 72.32% of losses. This erosion is mainly due to sensitivity to poor soils, unavailability of seeds, low yield, diseases, pests and poor culinary or technological quality. Sixty-six elite cultivars were identified according to agronomic, technological and culinary criteria. Their classification revealed groups combining productivity, post-harvest conservation, drought tolerance and poor soil suitability. These results highlight the urgent need for integrated conservation, characterization and participatory improvement strategies to sustainably preserve this national plant genetic diversity.

Keywords: Constraint, Diversity index, Dioscorea rotundata, Late varieties, Evolutionary dynamics

1 INTRODUCTION

Food and nutrition security remains a major challenge for countries in sub-Saharan Africa, where high levels of chronic food insecurity and high vulnerability of rural household's dependent on traditional rain-fed agriculture persist [1, 2]. This agriculture, highly dependent on climatic conditions, is directly affected by climate change, including rainfall variability and declining yields [3, 4]. Thus, agricultural system resilience is a strategic lever for ensuring a sustainable food supply and preserving cultivated genetic resources. Yam (*Dioscorea* spp.) is an essential food security crop in sub-Saharan Africa, particularly in West and Central Africa, where it is a reliable source of calories, income, and cultural identity for millions of rural households [5, 6]. In West Africa alone, more than 300 million people depend on yam as a staple food [6, 7]. In addition to its high carbohydrate content, yam provides essential micronutrients and is an integral part of ceremonies, festivals and local economies [8, 9]. The region produces more than 90% of global yam production [10, 11].

In Benin, yam is not only a major food crop, but also a socio-cultural and economic pillar, involved in extensive fallow-based production systems and regional market economies [12,13].

Its production was estimated at 3 150 248 tons from 2020 to 2021 [14, 15], with an estimated annual per capita consumption of more than 150 kg [16]. However, the increase in production observed in recent decades is mainly based on the extension of cultivated areas rather than a significant increase in productivity [17]. This extensive dynamic puts increased pressure on agricultural land and contributes to the erosion of genetic diversity [18]. The late yams known as Kokoro, belonging to the *D. cayenensis/rotundata* complex, are distinguished by their long cycle, their good postharvest conservation ability, their adaptation to soil and climate constraints and their decisive role in food security during the lean season. However, the varietal dynamics of yams remain strongly influenced by seed exchanges between producers, culinary preferences, and market opportunities, factors that may accelerate the disappearance of some local cultivars [13].

In this context, Kokoro late yams, although essential for food stability, remain insufficiently documented in terms of their specific diversity, current geographical distribution, and evolutionary trajectories. Updating knowledge is essential to guide national strategies for conservation and varietal improvement. The conservation and sustainable use of late-stage Kokoro yams in Benin is hampered by a lack of up-to-date scientific information on their diversity, spatial structure and evolution dynamics. While several studies have characterized the overall diversity of yams in Benin [19,20]. few recent studies have specifically focused on late forms of the *D. cayenensis D. rotundata* complex. Rapid changes in agrarian systems, intensification of cultivation, increased climate variability, fragmentation of farms could lead to genetic homogenization and irreversible loss of locally adapted cultivars. Regional analyses indicate that varietal loss rates can reach levels of concern when traditional seed management systems are disrupted [21]. Furthermore, advances in yam genomics [22,23] now offer robust tools for identifying elite lineages and better understanding domestication and evolution processes. However, the effectiveness of these approaches depends on a comprehensive and up-to-date inventory of available in situ resources.

The present study aims to inventory and collect the varietal diversity of the late Kokoro yams of the *D. cayenensis D. rotundata* complex cultivated in Benin, to analyze their geographical distribution and to evaluate their evolutionary dynamics from 2012 to 2026.

2 MATERIAL

2.1 Presentation of the study area

The study was conducted in four departments (Fig. 1) representing the main areas of yam diversity in Benin, namely Collines (Center), Borgou (North-East), Atacora and Donga (North-West), as defined by [19]. These areas have sub-equatorial to Sudanese-Guinean climates, with annual precipitation ranging from 800 to 1,200 mm and average temperatures ranging from 25°C to 28°C, occasionally reaching 40°C [24]. The soils are mainly tropical ferruginous, ferralitic and locally hydromorphic. Agriculture is the main economic activity, yam (*Dioscorea rotundata* Poir) being one of the main food crops.

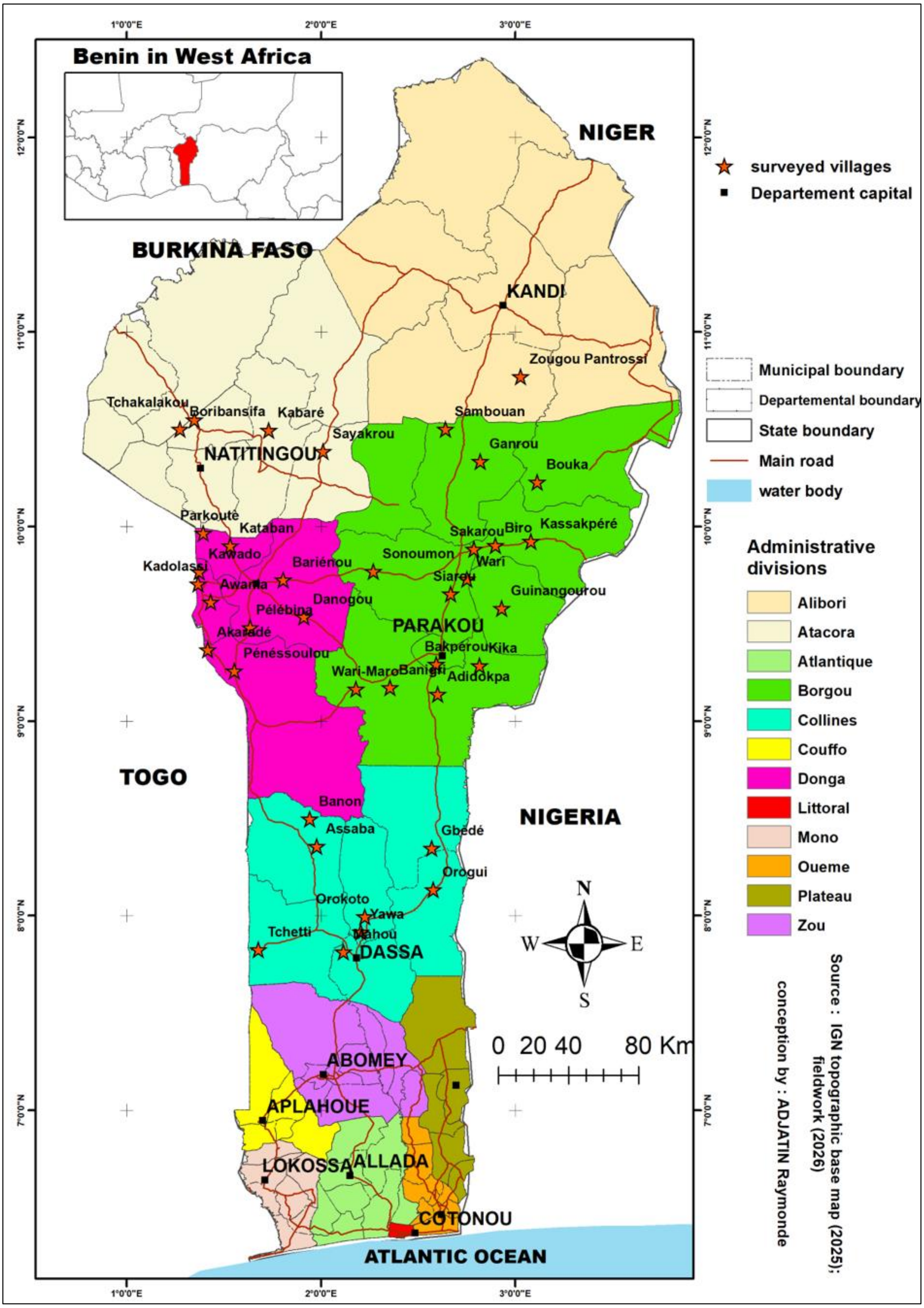

Figure 1: Map showing villages surveyed

3 METHODS

3.1 Selection of prospected localities

The villages were chosen based on the 2012 survey data on yams produced in Benin, covering the entire production area, with the main criteria being the importance of yam production in the locality (unpublished data) and the motivation to cover the entire production area. A total of 43 villages were sampled and surveyed (Table 1). The number of localities selected for the different yam production departments surveyed depends not only on the total number of localities producing the late yam varieties, but also on the accessibility of these localities.

Table 1: List of localities, prospected communes and ethnic groups

N°	Localities	Municipalities	Ethnicities	NO.	Localities	Municipalities	Ethnicities
1	Akaradè	Bassila	Kotokoli	23	Sayakrou	Péhunco	Bariba
2	Alfa kpara	Djougou	Yom	24	Kabaré	Kouandé	Bariba
3	Awanla	Ouaké	Lokpa	25	Tchakalaku	Toucountouna	Wama
4	Barienou	Djougou	Yom	26	Boribansifa	Toucountouna	Wama
5	Danogou	Copargo	Taneka	27	Kokokou	Toucountouna	Nateni
6	Dendougou	Djougou	Yom	28	Wanranrou	Bembereke	Bariba
7	Kadolasi	Ouaké	Lokpa	29	Sombouan	Bembereke	Peuhl/Bariba
8	Kataban	Copargo	Taneka	30	Bouca	Bembereke	Bariba
9	Kawado	Ouaké	Lokpa	31	Ganro	Bembereke	Bariba
10	Pelebina	Djougou	Yom	32	Zugu Pantrosi	Gogounou	Gando/Bariba
11	Penessoulou	Bassila	Thus	33	Kassakperé	Nikki	Bariba
12	Parkoutè	Copargo	Sola	34	Biro	Nikki	Bariba
13	Tigninou	Copargo	Taneka	35	Sirarou	N'Dali	Bariba
14	Yarakeou	Djougou	Koura	36	Wari	N'Dali	Bariba
15	Gbédé	Ouèssè	Nagot and Peuhl	37	Sakarou	N'Dali	Bariba
16	Ouogui	Savè	Nagot (Ifè and Icha)	38	Sonnoumon	N'Dali	Bariba
17	Yawa	Glazoué	Idaatcha	39	Adidokparou	Tchaourou	Bariba
18	Orokoto	Glazoué	Idaatcha	40	Banigri	Tchaourou	Bariba
19	Mawou	Dassa-zoumé	Nagot (Idahatcha)	41	Kika	Tchaourou	Bariba
20	Cheti	Savalou	Nagot (Ifè)	42	Guinagourou	Father	Bariba
21	Assabah	Bantè	Nagot (Ifè and Icha)	43	Bakperu	Parakou	Bariba
22	Banon	Bantè	Nagot (Ifè and Icha)				

3.2 Data collection

Data were collected using two participatory research techniques as described by [25], including individual interviews and group discussions. These discussions were made possible thanks to the support of the village chiefs or local authorities of the yam producers' associations. Individual interviews were conducted using the transect method [26], which consisted of a random selection of respondents. Various data were collected during this phase and included socio-demographic data, yam production data, the origins and methods of seed production, their perception of the evolution of Kokoro production, and the medicinal and/or cultural uses of yams and Kokoro in particular. The group interviews were conducted with a minimum of 30 growers, each presenting a sample of Kokoro cultivars produced or known. This type of interview allows the collection of data to study the extent and distribution of cultivars in different villages as described by [25], to identify elite cultivars on the one hand and cultivars threatened with extinction. In addition, the criteria for preference or peasant selection of Kokoro cultivars at the village or socio-cultural group level were documented and allowed the outcome of the discussions to assess the quality of the three products (cossette, wassa-

wassa and amala) from each cultivar identified, taking into account three levels of appreciation (bad, good and very good).

3.3 Statistical data processing and analysis

All data collected were entered using the Excel 2016 spreadsheet. An analysis of the descriptive statistics was carried out on the quantitative data using SPSS version 21 statistical software. From the focus groups database, summary tables and Figures were produced using the Excel 2016 spreadsheet. Also, the cultivar loss rate (CLR) by villages between 2012 and 2026 and the Shannon Diversity Index (H) were calculated respectively from the formulae:

$$\mathrm{CLR} = \frac{Ni - Na}{\mathrm{Ni}} * 100$$

Where Na represents the number of cultivars recorded in 2026 and Ni the number recorded in 2012,

$$\mathrm{H} = -\sum_{\boldsymbol{i}=1}^{\boldsymbol{b}} \frac{\boldsymbol{n_i}}{\boldsymbol{n}} \boldsymbol{log}_2 \frac{\boldsymbol{n_i}}{\boldsymbol{n}},$$

With $\mathbf{n_i}$ the number of times cultivar i is counted, n the total number of cultivars counted in a municipality, and **b** the number of cultivars counted in a given area.

The relative importance of the different constraints (IMC) related to the production of Kokoro that were identified was determined through a descending ranking of the values obtained according to the formula:

IMC= (NTV +CP +CM) /3

Where NTV is the total number of villages where a constraint was cited; CP, the number of villages where the constraint is considered the main constraint; and CM, the number of villages where the constraint is classified as a major constraint (1 to 5).

The same method was adopted to determine the relative importance of the criteria for preference or peasant selection of cultivars. The statistical software SPSS version 21 was used for descriptive analysis of the recorded quantitative data.

To assess the degree of similarity between the identified elite cultivars, a complete disjunctive table was constructed with the identified cultivars considered as individuals and the agronomic evaluation parameters considered as variables and coded 1 when performing or 0 otherwise. A similarity matrix was thus obtained, and thanks to which a multivariate analysis was carried out with R version 4.4.2 and a similarity dendrogram was obtained.

4 RESULTS

4.1 Socio-demographic characteristics of respondents

All the surveyed yam growers were men. More were adults (77.93%) and had received no formal education (57.45%). Their farming experience ranged from 10 to 20 years. The respondents belonged to 17 ethnic groups, with the Bariba (40.16%), Lokpa (7.98%), and Yom (7.98%) collectively accounting for more than half of the surveyed population. Bariba farmers were the most represented ethnic group across all the study areas and constituted the largest proportion of the surveyed producers. (Table 2).

Table 2: Sociodemographic characteristics of surveyed producers

Number of respondents	Atacora	Borgou	Collines	Donga	Study area
	49	146	49	132	376
Profiles of respondents (%)					
Gender					
Men	100	100	100	100	100
Women	0	0	0	0	0
Ages					
Youth (<30)	16.33	6.16	2.04	9.09	7.98
Adults (30 to 60)	65.31	72.60	97.96	81.06	77.93
Old (>60)	18.37	21.23	0.00	9.85	7.20
Sociocultural groups					
Kotokoli				8.33	2.93
Thus				5.3	1.86
Peuhl		6.16	22.24	1.16	5.85
Taneka				21.97	7.71
Sola			2.04	7.56	2.93
Ditamari			4.08	1.16	1.06
Yom				22.73	7.98
Bariba	36.73	89.73	2.04	0.76	40.16
Koura				7.56	2.66
Lokpa				22.73	7.98
Yoruba		0.68			0.27
Gando	2.04	3.42			1.6
Wama	42.86				5.59
Nateni	18.37				2.39
Idaatcha			30.61		3.99
Mahi			4.08		0.53
Nagot			44.90		5.85
Level of education					
Uneducated	65.31	53.42	63.27	56.82	57.45
Primary	4.08	26.03	22.45	15.15	18.88
Secondary	26.53	17.12	14.29	26.52	21.28
Superior	4.08	3.42	0.00	1.51	2.39
Number of years of experience					
[0, 10[	24.49	19.86	4.08	15.15	16.76
[10, 20[	28.57	26.71	12.24	34.85	27.93
[20, 30[	22.45	26.71	44.90	20.45	26.33
[30, 40[	14.29	19.86	36.73	20.45	21.54
[40.50]	10.20	6.85	2.04	9.09	8.24

4.2 Uses of late-maturing Kokoro yam cultivars in the study area

Late-maturing Kokoro yams are of considerable importance to farmers across the surveyed production areas, accounting for 37.62% of total yam production. Their contribution was highest in Donga (42.17%), followed by Borgou (37.20%), Atacora (36.73%), and Collines (27.31%). These cultivars play an important role in household food security because of their good storability, which allows farmers to consume them during the lean season. This role was reported by 72.00% of farmers in Donga, 26.71% in Borgou, 22.44% in Atacora, and 18.37% in Collines. Unlike early-maturing yam varieties, whose harvests are largely marketed, more than 80% of Kokoro production is intended for household consumption by smallholder farmers.

Kokoro cultivars were also reported to have medicinal, cultural, and culinary uses. Such uses were more frequently documented in Donga and Borgou than in Collines. The cultivars Bakanou, Assina, Vabissi, Banioueré, and Kokogbarou are traditionally used to treat bedwetting, whereas Portchakabim is used to facilitate childbirth. Keqzema is reportedly used to treat visual disorders, while Banioueré and Kokogbarou are used against internal and external haemorrhoids and colds. Kplé-kplé is used to treat dysentery, Griha to alleviate body swelling, and Womakou to relieve headaches. In culinary practices, Kokoro yam is also used to reduce excess salt in sauces.

4.3 Production areas of Kokoro cultivars in the study area

The area cultivated with Kokoro cultivars ranged from 0.125 to 6 ha, with an overall mean of 0.70 ± 0.584 ha. Farmers in Collines and Donga cultivated the largest mean areas, whereas the smallest mean area was recorded in Borgou. However, the largest individual Kokoro field, covering 6 ha, was recorded for a farmer in Sayakrou, Atacora, while the smallest field was recorded in Collines. Among the surveyed municipalities, the largest mean areas under Kokoro cultivation were recorded in Pehunco (1.011 ± 0.674 ha) and Savè (1.00 ± 0.443 ha). In contrast, the smallest mean cultivated area was observed in Bassila (0.57 ± 0.25 ha) (Table 3).

Table 3: Kokoro production areas in the study area

Agroecological zones	Minimum	Maximum	Average (Standard Deviation)
Atacora	0.125	6.000	0.714 (0.443)
Borgou	0.125	4.000	0.585 (0.833)
Collines	0.50	1.50	0.811 (0.304)
Donga	0.125	2.500	0.733 (0.383)
Study area	0.125	6	0.700 (0.584)

4.4 Origins and methods of seed production of Kokoro cultivars produced in the study area

Most farmers (73.14%) obtained Kokoro planting materials through exchanges with relatives or fellow farmers within their villages, whereas 26.86% sourced them from outside their production areas. In Atacora, all surveyed farmers reported that exchanges with relatives or other farmers from neighbouring villages within the same production zone constituted their sole source of planting materials. In contrast, in Collines, 93.88% of the planting materials originated from northern Benin or neighbouring countries, particularly Nigeria and Togo (Table 4). The main modes of acquisition were inheritance (53.19%), purchase (26.86%), and donation (19.68%) (Table 5).

Table 4: Origins and Seed Proportions of Kokoro Cultivars in the Study Area

Departments	Number of respondents	Origins of Kokoro seeds			
		1	Percentages	2	Percentages
Atacora	49	Village	100%	Nigeria and others	0%
Borgou	146	Village	97.95%	Nigeria and others	2.05%
Donga	132	Village	97.71%	Nigeria and others	2.29%
Collines	49	Villages	6.12%	North and neighboring countries	93.88%
Study area	**376**	**Villages**	**73.14%**	**Nigeria, Togo, and/or North Benin**	**26.86%**

Borgou had the highest percentage of farmers who had inherited Kokoro planting materials (71.92%), particularly in the municipalities of Tchaourou, Nikki, Bembéréké, and Pèrèrè. In Collines, 93.88% of the surveyed farmers purchased their planting materials from markets. Market purchase was the only reported acquisition method in five of the six municipalities surveyed in this department. Donations were most frequently reported in Donga, where 45.04% of farmers obtained planting materials through this channel. The highest proportion was recorded in the municipality of Copargo, where 64.10% of the surveyed farmers received Kokoro planting materials as gifts.

Table 5: Seed production methods and proportions in the study area

Departments	Methods of obtaining seeds					
	Inheritance	**Percentages**	**Gift**	**Percentages**	**Purchase**	**Percentages**
Atacora	29	59.18%	7	14.29%	13	26.53%
Borgou	105	71.92%	8	5.48%	33	22.60%
Donga	64	48.50%	59	44.70%	9	6.80%
Collines	03	6.12%	0	0%	46	93.88%
Study area	**201**	**53.45%**	**74**	**19.68%**	**101**	**26.86%**

4.5 Constraints affecting the production of Kokoro cultivars in the study area

A total of 17 constraints affecting the production of Kokoro yam cultivars were identified across the study area. Based on their relative importance, climate change was ranked the most significant constraint (BMI = 27.33), whereas the low economic value of the cultivars was ranked last (BMI = 0.33). The major constraints reported by farmers were climate change, declining soil fertility, transhumance, limited access to farmland, and the scarcity of planting materials (Table 6). Although these constraints were consistently reported across the four departments, their relative rankings varied among production areas. These production constraints influenced farmers' decisions about which cultivars to maintain or grow. Fourteen farmer-preference criteria were identified and grouped into four categories: agronomic criteria (8), culinary and technological criteria (3), economic criteria (1), and social criteria (2). Among the agronomic traits, high productivity was the most important selection criterion for farmers in Collines and Donga. In Atacora and Borgou, the sustained availability of planting materials was the primary criterion, followed by adaptation to poor soils, particularly in Atacora. Regarding culinary and technological attributes, the taste of boiled or roasted yam was a major selection criterion in Atacora and Donga, whereas the quality of pounded yam was more highly valued in Borgou and Collines. Market value was also an important consideration in farmers' selection decisions. In contrast, social criteria were given relatively little importance by farmers in Borgou and Donga (Table 7).

Table 6: Production constraints for Kokoro cultivars and order of importance in the study area

Constraints	Number of villages			Average	Rank
	NTV	**CP**	**CM**		
Climate change	40	6	36	27.33	1
Soil infertility	41	17	21	26.33	2
Transhumance	39	7	31	25.67	3
Unavailability of land	32	4	29	21.67	4
Unavailability of seeds	29	2	12	14.33	5
Painful cultivation practices	18	3	13	11.33	6
Flights of crops	19	2	9	10.00	7
Diseases and pests	18	0	3	7.00	8
Tuber rot in Collines and/or post-harvest loss	15	0	5	6.67	9
High cost of seeds	11	1	5	5.67	10
Weed Sensitivity (Striga)	6	0	3	3.00	11

Traditional cultural considerations	5	0	1	2.00	12
Fall of leaves before tuberization	3	1	1	1.67	13
Rural exodus	2	1	1	1.33	14
Lack of suitable varieties	1	0	1	0.67	15
Field Encroachment	1	0	0	0.33	16
Low economic value of early varieties	1	0	0	0.33	17

Table 7: Categories of preference criteria and their variability across the study area

Categories	Criteria of preferences	Percentages in study area (%)	Variability by agro-ecological zone			
			Atacora	Borgou	Colines	Donga
Agronomic (49.78%)	Good productivity	16.97	9.70	13.35	37.12	18.93
	Good conservation	8.80	7.27	9.95	-	9.37
	Availability of seeds	12.66	20.00	15.57	-	9.37
	Resistance to diseases and pests	1.32	1.82	1.19	-	0.94
	Tolerance of poor soils	5.36	19.39	5.54	-	1.86
	Tolerance to the effects of climate change	2.46	4.24	4.43	-	0.94
	Not requiring a specific production condition	0.18	-	-	-	0.38
	Tolerance of any type of soil	2.02	-	5.57	-	0.38
Culinary and technological (34.30%)	Good taste	15.13	9.70	12.30	17.13	18.13
	Good yam crushed	15.74	7.88	15.54	21.91	17.60
	Good cossette	3.43	8.48	5.41	-	0.94
Economic (15.66%)	Good market value	15.66	11.52	10.00	23.84	19.74
Social (0.26%)	Cultural or traditional value of the cultivar	0.18	-	-	-	0.94
	Free from cultural and/or traditional considerations	0.09	-	0.27	-	-

4.6 Evolutionary dynamics of Kokoro cultivars in the study area from 2012 to 2025

The assessment of changes in Kokoro cultivar diversity between 2012 and 2025 revealed an overall loss of 61% of the cultivars previously grown in the study area. Borgou recorded the highest rate of cultivar loss (72.32%), followed by Donga (55.55%), Collines (54.24%), and Atacora (41.33%) (Table 8). Overall, 65% of the surveyed localities lost more than half of their Kokoro cultivars during the study period, whereas only 39.53% retained at least 50% of their initial cultivar diversity. Seventeen localities showed the greatest capacity for maintaining Kokoro cultivar diversity. These included Akaradè, Danogou, Kataban, Pélébina, Pénéssoulou, and Tigninou in Donga; Ganro, Zougou Pantrosi, and Sakarou in Borgou; Sayakrou, Tchakalakou, and Kokokou in Atacora; and Gbédé, Mawou, Yawa, Orokoto, and Ouogui in Collines. Fig. 2 illustrates the general decline in Kokoro cultivar diversity across the study area, with no municipality remaining unaffected. However, the magnitude of cultivar loss varied more markedly among individual localities than among municipalities or departments, indicating that cultivar conservation dynamics were primarily determined at the local level.

Table 8: Evolutionary dynamics of Kokoro cultivars between 2012 and 2025 in the study area

Agroecological zones	Kokoro cultivars in 2012	Kokoro cultivars in 2025	Proportion of survivors	Proportion of losses (%)
Atacora	75	44	58.67	41.33
Borgou	289	80	27.68	72.32
Collines	59	27	45.76	54.241
Donga	268	117	44.49	55.51
Study area	686	268	39.07	60.93

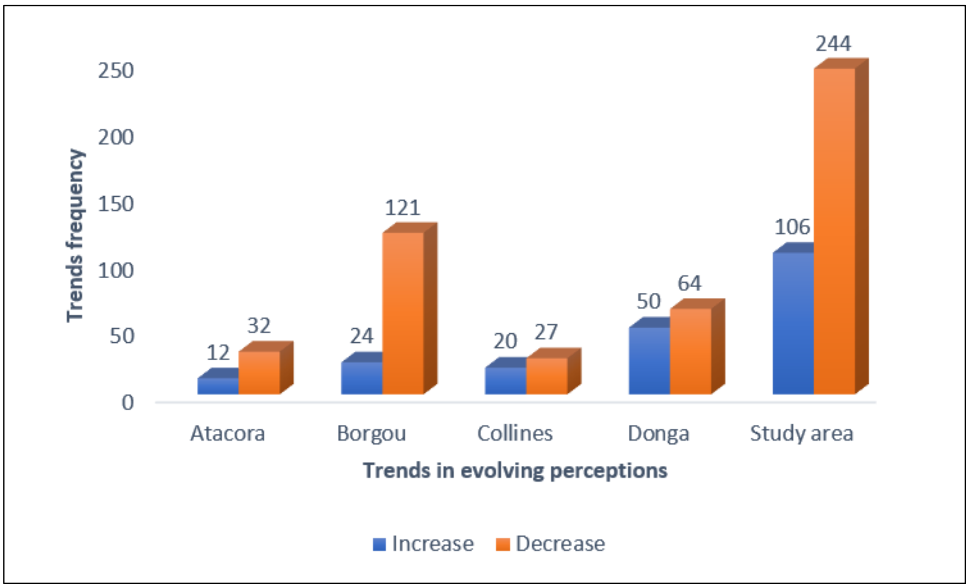

Figure 2: Individual perception of the respondents on the evolutionary dynamics of Kokoro in the study area

4.7 Distribution and extent of Kokoro cultivars in the study area

Subject to possible synonymy, an average of six Kokoro cultivars was grown per village in the study area. Of these, two cultivars were cultivated by many farmers over large areas, two by few farmers over small areas, one by many farmers over small areas, and one by few farmers over large areas (Table 9). The average loss of Kokoro cultivar diversity across the study area was estimated at 60.93%. Analysis of the distribution and cultivation extent of the recorded cultivars revealed that a substantial proportion was threatened with disappearance. Cultivars grown by only a few farmers, regardless of whether they occupied large or small areas, were considered particularly vulnerable. This finding was consistent with the analysis of cultivar dynamics, which indicated that 61% of the Kokoro cultivars grown in the surveyed localities disappeared between 2012 and 2025. Borgou was the most affected department, with a cultivar loss rate of 72.32%, whereas Atacora recorded the lowest loss rate at 41.33%. Only three villages, representing 7% of all the surveyed villages, recorded no loss of Kokoro cultivar diversity during the study period (Table 9).

Table 9: Distribution, extent and loss rate of cultivars

Departments	Localities	Number of cultivars per locality	Distribution and Extended				Cultivar Loss Rate (CPR) %
			++	+-	-+	- -	
Borgou	Wanranrou	2	2	-	-	-	88.24
	Sombouan	2	2	-	-	-	80.00
	Bouca	6	3	1	-	2	70.00
	Ganro	9	3	3	1	2	47.06
	Zugu pantrosi	9	6	-	3	-	25.00
	Biro	6	2	1	-	3	73.91
	Kassakperé	4	2	-	-	2	71.43
	Sakarou	12	2	4	1	5	20.00
	Wari	2	2	-	-	-	89.47
	Sirarou	3	2	-	-	1	83.33
	Sonnoumon	5	3	2	-	-	73.68
	Adidokparou	7	2	1	1	3	56.25
	Banigri	2	1	-	-	1	91.67
	Kika	2	1	-	-	1	89.47
	Guinagourou	6	1	3	-	2	73.91
	Bakperu	3	2	1	-	-	86.96
Average		**5**	**2.25**	**1**	**0.4**	**1.4**	**72.32**
Donga	Penessoulou	7	2	2	1	2	0.00
	Kawado	7	3	1	1	2	58.82
	Barienou	5	1	2	1	1	70.59
	Pelebina	12	3	3	2	4	20.00
	Danogou	10	4	2	1	3	41.18
	Yarakeou	8	4	1	2	1	60.00
	Tigninou	12	3	3	3	3	14.29
	Alfa kpara	9	3	1	2	3	70.27
	Kadolasi	6	1	2	2	1	73.68
	Awanla	6	3	1	1	1	68.42
	Akaradè	8	5	1	1	1	27.27
	Dendougou	10	3	4	1	2	64.29
	Kataban	14	4	2	3	5	26.32
	Parkoutè	2	2	-	-	-	91.30
Average		**6.3**	**2.93**	**1.79**	**1.50**	**2.07**	**55.51**
Atacora	Sayakrou	18	4	1	1	12	14.29
	Kabaré	7	3	-	-	4	68.18
	Tchakalaku	8	3	2	-	3	20.00
	Boribansifa	4	1	2	-	1	60.00

	Kokokou	7	2	-	-	5	41.67
Average		**8.8**	**2.6**	**1**	**0.2**	**5**	**41.33**
Collines	Banon	2	-	-	-	2	60.00
	Assaba	3	-	2	1	-	81.25
	Gbédé	6	3	-	1	2	25.00
	Mawou	3	-	-	2	1	0.00
	Yawa	3	-	2	-	1	50.00
	Orokoto	3	-	2	-	1	0.00
	Cheti	2	-	-	2	-	77.78
	Ouogui	5	2	1	1	1	44.44
Average		**3.4**	**0.63**	**0.88**	**0.88**	**1.00**	**54.24**
Study area	Average	6.233	2.209	1.233	0.814	1.953	60.93

4.8 Reasons for loss of Kokoro cultivars

A total of 17 reasons for the loss or abandonment of Kokoro cultivars were identified across the study area. These included eight agronomic, three technological, three culinary, one economic, and two sociocultural factors. Among the agronomic factors, the most frequently reported were poor adaptation to infertile soils (58.14%), limited availability of planting materials (46.51%), low yield (30.23%), and susceptibility to diseases and pests (20.93%). Poor quality of dried yam chips was the main technological reason for cultivar abandonment, accounting for 25.58% of responses. This constraint was specifically reported by farmers in Donga. Poor culinary quality, cited by 23.26% of respondents, was the primary culinary reason for abandoning Kokoro cultivars in all departments except Collines. From an economic perspective, low market value was the only factor reported and accounted for 6.98% of responses. Theft was also frequently mentioned across the surveyed departments, with a reported frequency of 62%, indicating that it constitutes an important concern for Kokoro producers. In Atacora, all surveyed farmers cited poor adaptation to infertile soils and the scarcity of planting materials. These two factors were therefore identified as the main drivers of Kokoro cultivar loss in the department (Table 10).

Table 10: Reasons for loss of Kokoro diversity in the study area

Categories	Reasons	Proportions (% of villages)				
		Study area	Donga	Borgou	Atacora	Center
Agronomic	Low yield	30.23	50	31.25	-	37.5
	Unavailability of seeds	46.51	28.57	56.25	100	25
	Genetic abnormality	2.33	7.14	-	-	-
	Sensitivity to the effects of climate change	4.65	-	12.25	-	-
	Susceptibility to disease and/or pest attacks	20.93	21.43	18.75	60	-
	Sensitivity to poor soils	58.14	64.29	37.5	100	100
	Special conditions of production	11.63	28.57	6.25	-	-
	Small size of tubers	2.33	-	6.25	-	-
Technological	Poor quality of cossette	25.58	78.57	-	-	-
	Poor quality of Amala	18.60	57.14	-	-	-
	Poor quality of Wassa wassa	18.60	57.14	-	-	-

Culinary	Bad yam crushed	11.63	21.43	12.5	-	-
	Poor organoleptic quality	2.32	-	6.25	-	-
	Poor culinary quality	23.26	42.86	12.5	40	-
Economic	Economic importance of early varieties	9.31	14.29	6.25	20	12.5
Cultural and / or traditional reasons	Traditional and/or cultural considerations	2.33	-	6.25	-	-
	Theft	62	55.72	72.11	45.22	42.25

4.9 Farmer-managed diversity of Kokoro cultivars in the study area

Subject to possible synonymy or homonymy and pending confirmation through agromorphological and molecular characterization, 166 Kokoro cultivars were recorded across the study area. Of these, 71 were identified in Donga, 59 in Borgou, 21 in Atacora, and 15 in Collines. Twenty-six cultivars were widely distributed throughout the study area (Fig. 3). Bani-Ourè was the most widespread cultivar, occurring in nine villages, followed by Kokogbanou and Portchakabim, each recorded in six villages, and Assina, identified in four villages. The remaining representative cultivars were recorded in two or three villages, reflecting the different pathways through which farmers acquired planting materials. Cultivar richness ranged from 2 to 18 per surveyed locality, with an overall mean of 6 ± 3.66 cultivars. Atacora recorded the highest local cultivar richness, whereas the lowest values were observed in Borgou, Donga, and Collines. Among the sociocultural groups, Bariba farmers maintained the greatest diversity, with 105 cultivars, followed by the Yom with 67, the Lokpa with 29, and the Nagot with 27 cultivars (Fig. 4). The Shannon diversity index averaged 3.4 bits across the study area, ranging from 2.1 bits in Atacora to 3.8 bits in Borgou (Table 11). Based on cultivar distribution and cultivation extent, 66 cultivars, representing 39.76% of the total diversity, were classified as elite. Donga contained the highest number of elite cultivars (41), whereas Collines recorded the lowest number (5).

Table 11: Study area and diversity area diversity parameters

Areas of diversity	Number of Villages Prospected	Number of culture units sampled	(H, bit)	Number of cultivars identified
Atacora	5	44	2.1	21
Borgou	16	80	3.8	59
Collines	8	27	2.4	15
Donga	14	117	3.7	71
Study area	43	268	3.4	166

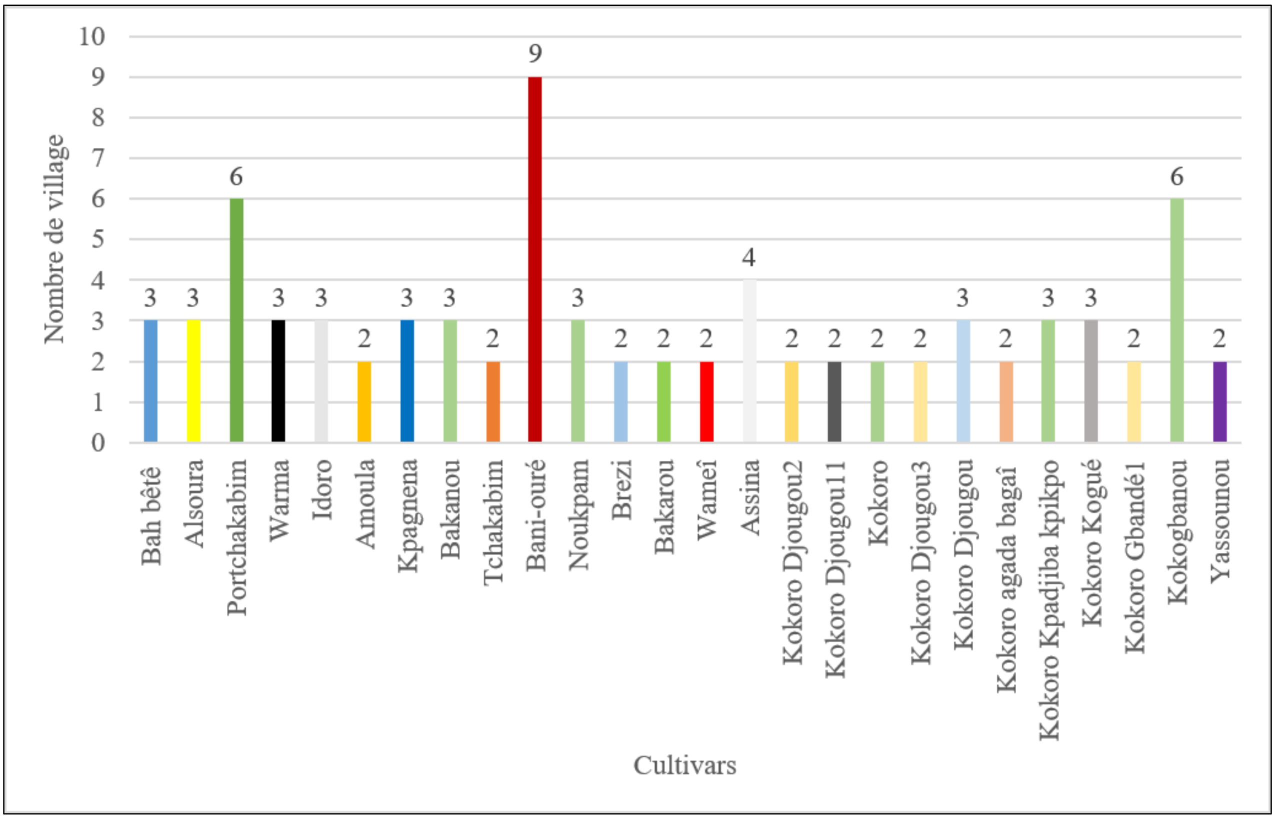

Figure 3: Representativeness of the 26 predominant cultivars in the study area

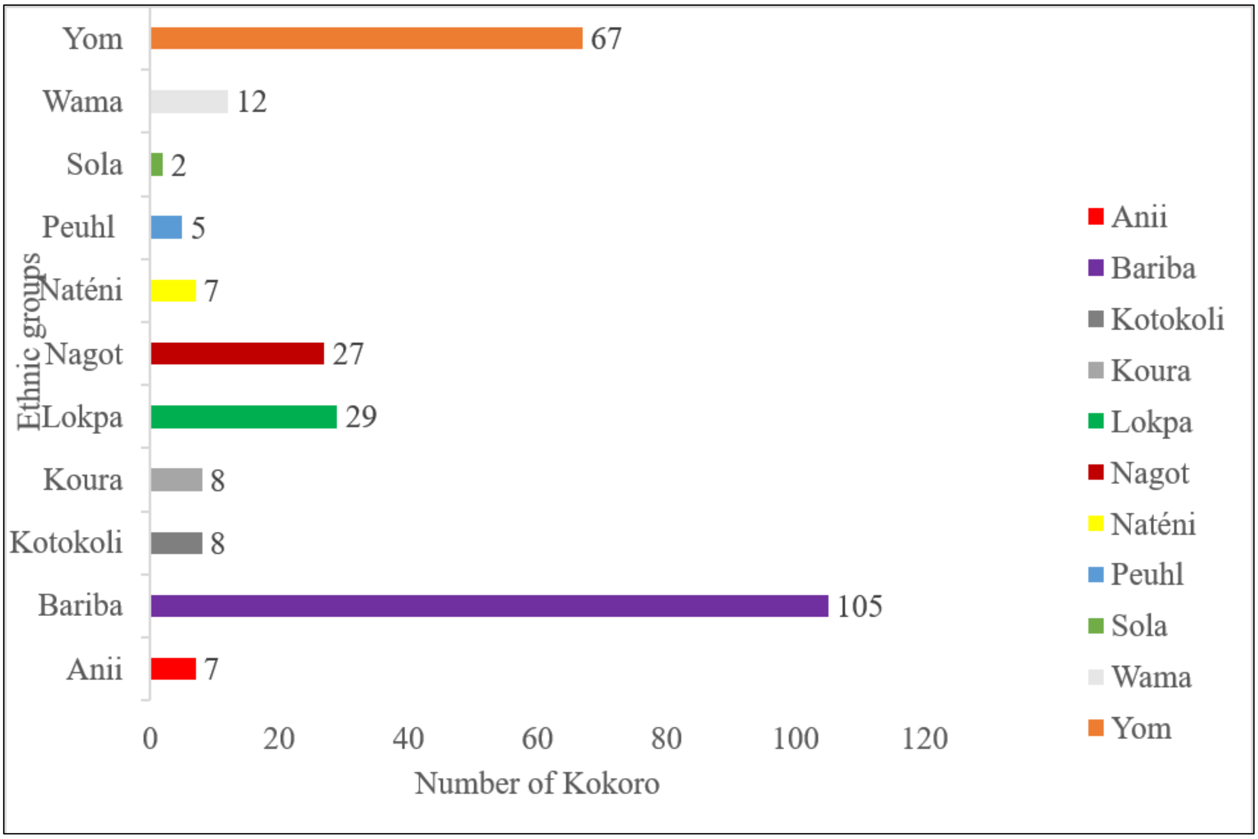

Figure 4: Variability in number of cultivars by ethnic group

Based on six agronomic, two technological, and one culinary criterion commonly used by farmers to assess cultivar performance, the 66 elite Kokoro cultivars were classified into three major groups comprising 24 distinct units (Fig. 5). Group 1 consisted of a single unit represented by the cultivar Assinanga, which was primarily distinguished by the quality of its pounded yam, taste, and dried yam chips. Group 2 comprised 15 units containing 50 cultivars and was divided into two subgroups. The first subgroup included cultivars valued for the quality of their pounded yam, taste, and dried chips, such as Kouli Kouli, Tambissi, and Agoua. The second subgroup consisted of cultivars characterized by good post-harvest storability, adaptation to poor soils, high productivity, ease of sprouting, resistance to storage insects, and drought tolerance. Representative cultivars included Bakanou, Chouhou, and Alassina Maley. Group 3 comprised eight units containing nine cultivars, including Babètè, Koumèni, and Goroko. These cultivars were mainly characterized by high productivity, good post-harvest storability, and tolerance to poor soils. However, they generally exhibited poor technological and culinary qualities (Table 12; Fig. 5). Twelve units contained cultivars specifically adapted to the environmental and soil conditions of a single production area, including seven units adapted to Donga, five to Borgou, and one to Atacora. Overall, 16 of the 24 units were suitable for the environmental and soil conditions of Donga, making it the most favorable production area for the identified elite cultivars. Borgou ranked second, with 13 suitable units, whereas Collines was the least favorable area, with only four suitable units (Table 12).

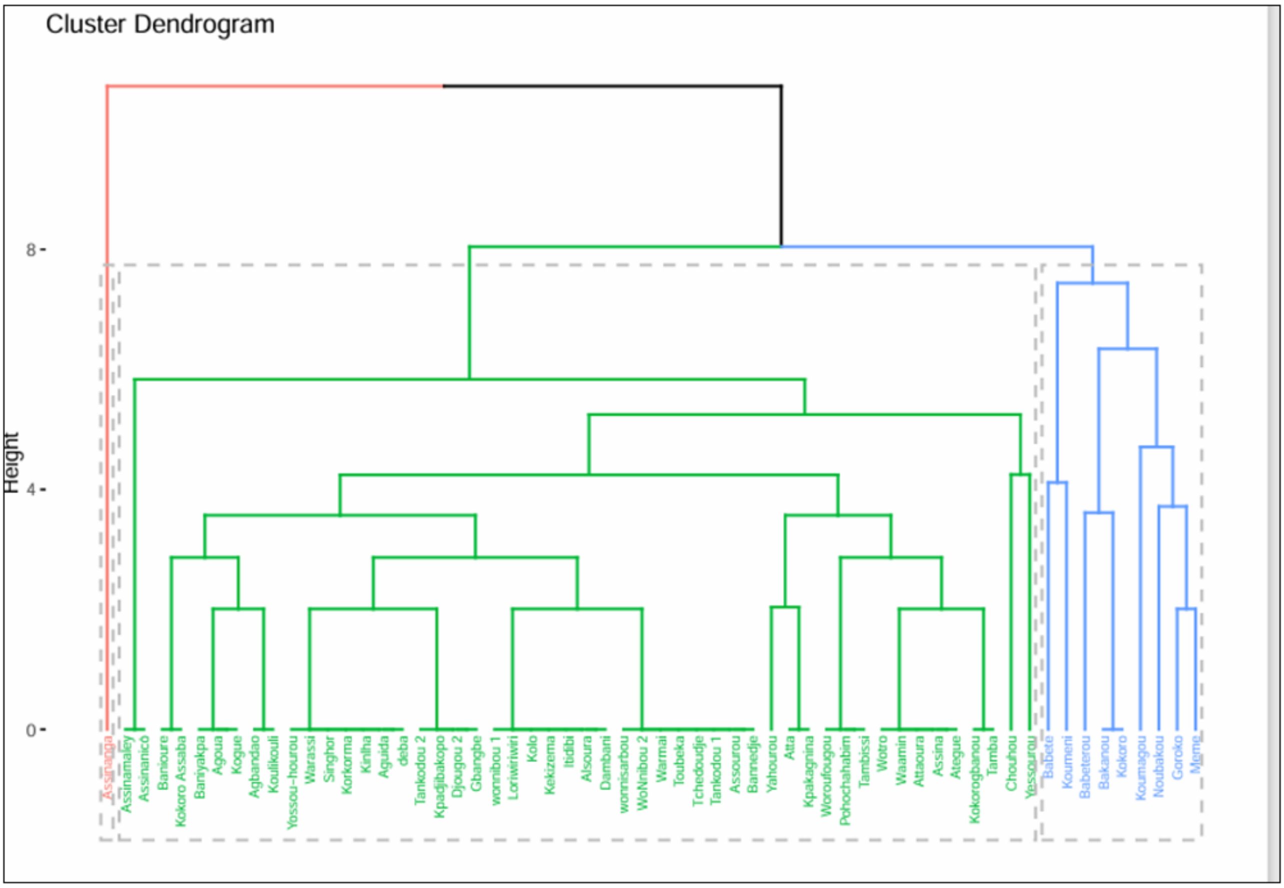

Figure 5: Classification of elite Kokoro cultivars by method

Table 12: Units, number of cultivars, favorable areas and characteristics

Units	Number of cultivars	Cultivars by department (Unit)				
		Atacora	Borgou	Collines	Donga	Characteristics
1	1				Assinaga	Good crushed yam, good taste and good productivity
2	2				Assinamaley, Assinanicô	Poor soil tolerance, good post-harvest conservation, good crushed yam, good taste, good

						productivity, good cossette quality, drought tolerance and ease of germination
3	2		Baniuré	Kokoro Assaba		Tolerance of poor soils, good post-harvest conservation, good crushed yam, good taste and good productivity
4	3		Baniyakpa	Agoua, Kogoué		Good post-harvest conservation, good crushed yam, good taste, good productivity
5	2	Koulikouli			Agbandao	Good post-harvest conservation, good crushed yam, good taste and good productivity
6			Yossou-hourou, Singhor, deba	Aguida,	Warassi, Kinlha, Korkorma	Good post-harvest conservation, good crushed yam, good taste, good productivity, good cossette quality and drought tolerant
7	4		Tankouandou2,	Kpadjibakopo, Djougou2, Gbangbé		Good post-harvest conservation, good crushed yam, good taste, good productivity, good quality of cossette and drought tolerant
8	7	Wounibou1, Dambani			Loriwiriwiri, Kolo, Kekizema, Itidibi, Alsoura	Tolerance of poor soils, good post-harvest conservation, good crushed yam, good taste, good productivity and good quality of cossette
9	8	Wonnisarbou, Wonnibou2, Warmai, Toubeka	Tankouandou1		Assourou, Bannedje	Tolerance of poor soils, good post-harvest conservation, good crushed yam, good taste, good productivity, good quality of cossette and drought tolerant
10	1	Yahourou				Good post-harvest conservation, good crushed yam and good taste

11	2				Atta, Kpakagnina	Tolerance of poor soils, good post-harvest conservation, good crushed yam, good taste
12	3		Woroufougou		Pohochahabim, Tambissi	Good post-harvest conservation, good crushed yam and good taste and good quality of cossette
13	5				Wotro, Waamin, Attaoura, Assina, Atèguè	Poor soil tolerance, good post-harvest conservation, good crushed yam, good taste and good quality of cossette
14	2		Kokorogbanou		Tamba	Tolerance of poor soils, good post-harvest conservation, good crushed yam, good taste, good quality of cossette and drought tolerant
15	1		Chouhou			Good post-harvest conservation, good taste, good productivity and drought tolerant
16	1		Yessourou			Good post-harvest conservation, good crushed yam, good productivity and drought tolerant
17	1				Babetes	Poor soil tolerance, good post-harvest conservation, good productivity, drought tolerant, easy germination and resistant to storage insects
18	1				Koumeni	Tolerance of poor soils, good post-harvest conservation, good productivity and ease of germination
19	1	Babeterou				Poor soil tolerance, good post-harvest conservation, good productivity, good taste, resistant to storage insects and drought tolerant
20	2		Kokoro		Bakanou	Poor soil tolerance, good post-harvest

						conservation, good crushed yam, good productivity, good taste, good cossette quality, drought tolerant and resistant to storage insects
21	1		Koumagou			Tolerance of poor soils, good post-harvest conservation and resistant to storage insects
22	1				Noubakou	Tolerance of poor soils, good post-harvest conservation and good quality of pods
23	1		Goroko			Poor soil tolerance, good post-harvest conservation, good productivity and drought tolerant
24	1				Meme	Tolerance of poor soils, good post-harvest conservation, good productivity

5 DISCUSSION

5.1 Socio-demographic profile and socio-cultural anchoring of Kokoro production

Kokoro yam production is embedded in a strongly gendered social organization. The exclusive participation of men observed among the surveyed farmers is consistent with findings from Benin and Nigeria, where yam cultivation, particularly that of Dioscorea rotundata, is traditionally associated with land ownership, physical labour, and demanding field operations [19]. Women are generally more involved in post-harvest handling, processing, and marketing activities, thereby contributing substantially to the economic development of the yam value chain [20,76].

The predominance of experienced adult farmers suggests that Kokoro production relies on well-established systems of intergenerational knowledge transmission. In traditional farming systems, such continuity promotes farmer-led selection and the dynamic on-farm conservation of plant genetic resources [28]. However, the limited participation of young people raises concerns about the long-term sustainability of these cultivars, particularly in a context characterized by changing rural economies, urban migration, and increasing mobility among younger generations [23,29].

The diversity of sociocultural groups involved in Kokoro production, with a predominance of Bariba farmers, further confirms the close relationship between cultural and varietal diversity. Culinary preferences, ritual functions, local naming systems, and farmer selection criteria differ among sociocultural groups and may contribute to the differentiation and maintenance of locally adapted cultivars [30]. Borgou, historically recognized as an important production area for the *D. cayenensis–rotundata* complex, therefore remains central to the diversification and circulation of Kokoro cultivars [31].

Late-maturing Kokoro yams contribute substantially to local production and are primarily intended for household consumption. Their good post-harvest storability extends food availability during the lean season, which is an important attribute of late-maturing yam cultivars [5,32]. The medicinal, cultural, and culinary uses reported by farmers further demonstrate the multifunctionality of Kokoro cultivars and reinforce their value as both food resources and elements of local biocultural heritage [20,33].

5.2 Production constraints and varietal erosion rates of Kokoro cultivars from 2012 to 2026

Climate change, identified by farmers as the most important production constraint, reflects the sensitivity of yam cultivation to rainfall variability, increasing temperatures, and prolonged dry periods. Previous studies have shown that seasonal climatic fluctuations can significantly affect yam growth, tuber initiation, bulking, and final productivity in West African production systems [5,34]. Soil fertility decline and increasing pressure on agricultural land, which have already been reported in northern Benin, may further reduce farmers' ability to maintain cultivars with high soil fertility requirements [23].

These constraints influence farmers' cultivar-selection decisions. The predominance of agronomic criteria, followed by culinary and technological attributes, indicates that producers seek cultivars that combine high yield, environmental adaptation, storability, and desirable food-quality characteristics [35]. The relatively low importance assigned to strictly social criteria may indicate a gradual shift towards production-oriented and market-related considerations. Nevertheless, culinary quality remains important because most Kokoro production is intended for household consumption.

The loss of approximately 61% of the cultivars reportedly grown between 2012 and 2026 indicates severe varietal erosion and potentially substantial loss of locally managed genetic diversity. Although Borgou remains one of the areas with the greatest cultivar richness, it recorded the highest rate of cultivar disappearance. This apparent contradiction may reflect a process of varietal homogenization driven by the preferential adoption of a limited number of high-performing cultivars and the progressive abandonment of rare or less productive materials [22,29].

In contrast, some localities in Atacora showed greater resilience in maintaining cultivar diversity. This pattern may be associated with the continued exchange of planting materials within communities, lower levels of agricultural intensification, and the persistence of traditional seed-management networks [28]. The widespread loss of cultivars across most surveyed villages nevertheless demonstrates that the phenomenon is systemic rather than restricted to a few production areas. These findings highlight the need for urgent on-farm conservation measures, community-based multiplication of planting materials, and targeted collection of threatened cultivars.

5.3 Distribution, extent and structure of diversity

The distribution pattern observed in the study area, characterized by a small number of widely cultivated cultivars and a large proportion of rare cultivars, is typical of farmer-managed crop diversity systems [35]. Widely distributed cultivars are generally maintained because of their agronomic performance, adaptability, culinary quality, or market value. In contrast, cultivars grown by only a few farmers or over limited areas are particularly vulnerable to local disappearance [23]. Soil degradation and the specific constraints associated with yam planting materials, which are bulky, perishable, expensive to store, and difficult to transport, may limit the capacity of farmers to renew or reintroduce lost cultivars [5]. Technological and sensory characteristics also influence cultivar maintenance. In particular, aptitude for processing into dried yam chips, storability, taste, and suitability for preparing pounded yam are important determinants of farmers' decisions to conserve or abandon particular cultivars [35,32]. Despite the observed erosion, the identification of 166 farmer-named cultivars indicates that considerable diversity is still maintained in the study area. Donga and Borgou recorded the highest cultivar richness, confirming their historical importance in the cultivation, diversification, and circulation of Kokoro yams. The mean Shannon diversity index of 3.4 bits also suggests a relatively high level of cultivar diversity, as commonly observed in traditional farming systems where farmers continue to manage multiple cultivars for different purposes [36].

The classification of elite cultivars into distinct groups based on agronomic, technological, and culinary criteria demonstrates the strategic manner in which farmers manage diversity to cope with climatic, edaphic, food-security, and economic risks [23]. Some cultivars are valued primarily for productivity, drought tolerance, adaptation to poor soils, or post-harvest storability, whereas others are maintained for their culinary and processing qualities. This functional complementarity contributes to the resilience of local production systems. The identified elite cultivars therefore constitute valuable materials for participatory breeding, conservation, and genetic-resource characterization programmes. Agromorphological and molecular analyses will be essential to verify cultivar identities, clarify genetic relationships, identify possible cases of synonymy and homonymy, and determine the actual extent of genetic diversity represented by farmer-named cultivars [22,6].

6 CONCLUSION

This study allowed to take stock of the production of Kokoro cultivars across the different yam production areas in Benin. In short, the peasant diversity of the Kokoro remains substantial but vulnerable. Maintaining it requires strengthening local seed systems, supporting in situ conservation and integrating peasant knowledge into contemporary scientific approaches.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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