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Production System and Constraints of the Kersting's Groundnut [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet] in Togo

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A B S T R A C T

The Kersting's groundnut is an underutilized but essential legume for food and nutritional security in West Africa, particularly in Togo. Despite its importance, its production remains limited due to multiple constraints, including climatic, agronomic, and socio-economic factors. This study aims to identify agricultural practices, production constraints, and the impacts of climate change on this crop to propose suitable solutions. To achieve this, a participatory survey was conducted with 238 producers in 135 villages of the five agro-ecological regions of Togo (Savanes, Kara, Centrale, Plateaux, and Maritime). Data were collected using semi-structured questionnaires, supplemented by field observations and interviews with key stakeholders. Data analysis helped to understand the cultivation system, rank constraints by region, and assess the climatic impacts and varietal preferences of the producers. The results show that the main constraints include difficult harvesting (43% of producers), irregular rainfall (21.7%), and pests (20%). Climate change has led to a general decline in yields (70% of respondents) and a shift in cultivation periods. Producers favor drought-resistant varieties that do not require chemical fertilizers and offer good yields. Furthermore, gender roles significantly influence agricultural practices, with women primarily involved in daily production activities and men playing a key role in strategic decisions, such as plot selection. These findings highlight the importance of promoting improved seeds suited to local conditions, strengthening producers' capacities, and integrating sustainable farming practices to enhance the resilience of this crop in the face of climatic and socio-economic challenges.

Introduction

The Kersting's groundnut is an important legume in tropical regions, particularly in West Africa. Mainly cultivated by small-scale farmers, it plays a crucial role in food security, nutrition, and the local economy (Kouelo *et al.,* 2015). Due to its high protein content, it is an important source of nutrients, especially in areas where access to animal-based products is limited (Dansi *et al.,* 2012; Pasquet *et al.,* 2002). Additionally, this crop fits well into local agricultural systems due to its ability to enrich the soil with nitrogen, thus contributing to the sustainability of farming practices (Akohoue *et al.,* 2020).

However, despite its agronomic and socio-economic potential, the production of the Kersting's groundnut remains marginalized compared to other legumes such as peanuts or cowpeas. Yields remain low and irregular due to multiple factors, including irregular rainfall due to climate change, poor soils, limited availability of improved seeds, pest attacks, and harvest difficulties (Kouassi *et al.,* 2020; Anani *et al.,* 2024). Furthermore, climate change exacerbates these challenges by altering growing cycles and increasing the vulnerability of crops to abiotic and biotic stresses (IPCC, 2021). Moreover, gender-specific roles influence the management of plots and agricultural resources, thereby limiting the overall productivity of this legume (Ky, 2023). The constraints related to this crop are also amplified by social and economic issues. Limited access to quality seeds, poor organization of value chains, and a lack of technical knowledge hinder the intensification and diversification of this crop. Furthermore, gender roles strongly influence agricultural decisions, potentially limiting women's access to the necessary resources to optimize production (Doss *et al.,* 2018).

This study focuses on the Kersting's groundnut cultivation in Togo, a country where it is still grown in a traditional manner and is becoming increasingly rare. There is still no data on its genetic diversity. The study aims to: (i) identify agricultural practices and varietal preferences, (ii) identify production constraints and evaluate solutions adopted by producers to mitigate challenges, and (iii) analyze the impact of climate change and pests on yields and farming practices. The results obtained will better inform agricultural policies and research programs to promote the optimal utilization of this underutilized legume.

Materials and Methods

Study Area

The study was conducted across the five major regions of Togo: Savanes, Kara, Centrale, Plateaux, and Maritime (Figure 1). These regions represent the country's agroecological diversity and encompass the main agricultural systems found nationwide.

(a) The Savanes and Kara regions are part of the dry savanna zone. The climate in these areas is Sudanian-Guinean, characterized by a rainy season from April to November and a dry season from November to March (Agboh et Badjaré, 2007).

(b) The Centrale region represents the humid savanna zone. The soils are mainly vertisols or vertic-type soils. The landscape is composed of three main vegetation types: wooded and shrubby savanna, deciduous and semi-deciduous forest (Togo Mountains), and remnants of gallery forests along rivers and streams (Agboh et Badjaré, 2007).

(c) The Plateaux region, located in the south-central part of Togo, is predominantly a forested zone. It extends along the Atakora mountain range, which includes the mountainous areas of Kuma, Danyi, Akposso-Akebou, as well as Mount Agou and Mount Haïto. The region has a mountain-type climate with a relatively short dry season (about two months). The vegetation consists of Sudanian-Guinean forests alternating with wooded savannas (Agboh et Badjaré, 2007; Atakpama *et al.,* 2022).

(d) The Maritime region (including Grand Lomé), also known as the coastal zone, borders the Atlantic Ocean. It lies between 6°00' and 6°50' north latitude and 0°40' to 1°50' east longitude. The climate is subequatorial and characterized by a bimodal rainfall pattern (Agboh et Badjaré, 2007).

Agriculture is the primary economic activity in all five regions. Major crops include maize, rice, soybean, yam, cassava, common bean, cotton, coffee, and cocoa (Bationo *et al.,* 2012; ARISE IIP, 2022).

Despite its nutritional and agronomic importance, the Kersting's groundnut remains a minor and marginalized crop, typically cultivated on small plots for household consumption or limited local sale.

Sampling Technique and Data Collection

The Kersting's groundnut is rare and does not have an official database on its distribution, so the snowball sampling method described by Biernacki was used (Ayenan and Ofori *et al.,* 2017; Biernacki et Waldorf, 1981; Ayenan and Danquah, *et al.,* 2017). The different villages and producers have been identified throughout the entire territory with the help of ICAT (Institut Supérieur des Métiers de l'Agriculture) agents, village development committees (CVD), and group leaders. Producers were notified the day before and asked to bring a sample of their Kersting's groundnut variety. The main methods used for data collection were semi-structured surveys with focus groups, as well as individual interviews, coupled with field and home observations (Sêmihinva Akpavi, 2010; Seêmihinva Akpavi *et al.,* 2008).

The study's objectives and the work to be done were explained to the producers and their consent was obtained before administering the questionnaires. The interviews were conducted in local language of each sociolinguistic group with the help of translators. In each village, two different questionnaires (group and individual) were administered to the present Kersting's groundnut producers. During the individual questionnaire, information documented was related to socio cultural characteristics of farmers such as age, sex and ethnic groups. The producers were also asked about their farming practices, uses, constraints, varietal preferences, perceptions of climate change impacts, and pest control methods. During the group discussion, traditional knowledge about the cultivation of *Macrotyloma geocarpum* and an inventory of the various factors limiting its production in the study area were the key pieces of information required. Finally, it was possible to visit a few fields in certain villages, which allowed us to observe the cultivated areas, the condition of the crops and the management techniques used.

Data Analysis

Quantitative data were summarized into percentages and averages to describe general trends. Constraints were ranked based on their relative importance using a weighted average score. They were ranked at both the regional level and across the entire study area based on the average of the following three parameters: the total number of villages where the constraint is cited (TNV), the number of villages where the constraint is major or ranked first (MAC), and the number of villages where the constraint is ranked among the five main constraints (PCO). For each of these parameters, a high value indicates the importance of the constraint. Thus, the importance of the constraint (IMC) is determined by the formula described by Kinhoégbè *et al.,* (2020).

$$IMC = (TNV + MAC + PCO) / 3$$

The results were stratified by region to identify local specificities. Tests such as chi-square or ANOVA were used to evaluate the relationships between variables. In addition, a correspondence analysis (CA) was carried out to explore the associations between the five regions of Togo and the crops associated with Kersting's groundnut. This method highlighted specific correspondences between regions and associated crops and visualised the similarities or differences between regions in terms of farming practices (Sarr *et al.,* 2022).

Results and Discussion

Sociodemographic characteristics of Kersting's groundnut producers

From north to south, 135 villages have been identified, and 238 producers have been interviewed during study. The surveyed population is predominantly female (56.7%) and primarily within the adult age group (30 to 60 years), with an average age of 48 years. The average household size is 7 people. The study reveals that nearly half of the producers (47.5%) have not received formal education, and among those who have been educated, the majority have not exceeded the primary level. The experience of the producers ranges from 1 to 51 years, with the majority having less than 5 years of experience. The most experienced producers are primarily found in the Kara and Centrale regions, with a predominance of women among those with more than 20 years of experience (Table 1).

Kersting's groundnut Cultivation System

In the villages, the Kersting's groundnut is cultivated residually by a small number of farmers. The planting period typically ranges from late June to early August, depending on seasonal variations. On average, planting occurs in July (67.65%), after plowing, in furrows or small mounds. A weeding operation is then carried out 5 to 6 weeks later. It is essential to space the plants properly during planting to allow the Kersting's

groundnut to spread correctly. Harvesting takes place in November (68.91%), about 4 to 5 months after planting. Table 2 shows the detailed cultivation schedule for each region.

In addition to residual cultivation of the earth bean, 21% of producers also adopt various intercropping practices, reflecting their strategies for resource optimization and production diversification. The survey results reveal the levels of association in the different regions (Table 3) as well as the most intercropped crops with the Kersting's groundnut by producers (Figure 2). Indeed, correspondence analysis highlights several characteristic associations. The Savannah region stands out clearly along the first dimension (Dim 1) and is only associated with okra (1.96%). The Plateaux region, located at the positive extreme of the second dimension (Dim 2), is closely linked to sorghum (9.80%) and yam (3.92%), indicating that these species are frequently associated with cowpea in this region. The Central and Kara regions are grouped together in the lower left part of the graph, reflecting a greater diversity of associated crops, but with a low presence of millet (3.92%) and little millet 1.96%). These areas are particularly associated with beans 62.75%) and Bambara groundnuts (15.69%).

In addition to intercropping, producers implement crop rotations aimed at maintaining soil fertility and reducing risks associated with pests and diseases. The analysis of rotation practices reveals specific patterns adopted based on local constraints and opportunities. Most producers (84%) plant the Kersting's groundnut first on new land or land that was previously fallow for two main reasons: it requires very fertile soil, and its cultivation does not require chemical fertilizers. However, 16% of producers plant it second, often after crops like sorghum, maize, or Bambara groundnut.

Land Area Dedicated to Kersting's groundnut Production

The areas dedicated to Kersting's groundnut cultivation vary between 0.03 and 2 hectares, with a frequency of 0.06 hectares. It was found that 46% of producers, including 26% of women, cultivate earth beans on an area of 0.06 hectares. However, the area dedicated to Kersting's groundnut cultivation is not correlated with gender ($p>0.05$). Furthermore, 23% of producers cultivate on 0.03 hectares, 21% on 0.12 hectares, and 10% on areas ranging from 0.25 to 2 hectares. The total area of land owned varies from 0.25 hectare to 15 hectares, with a frequency of 2 hectares (± 2).

Gender Involvement in Kersting's groundnut Production

In Kersting's groundnut cultivation, all household members participate in various stages of production. However, the level of involvement varies depending on roles and responsibilities within the family. The level of involvement is defined by physical, material, and decision-making participation in the implementation of agricultural activities. It includes both manual contributions and decisions regarding resources and techniques used. The general observation reveals that men are less involved in the daily activities of Kersting's groundnut cultivation, such as planting and harvesting. In contrast, they play a dominant role in the choice of land and its maintenance. Table 4 presents a detailed analysis of the level of involvement of men and women in the different stages of Kersting's groundnut cultivation, highlighting this division of roles.

Seed System

After examining the differentiated roles of men and women in the production of the earth bean, it is essential to focus on the seed system, a fundamental element in the production chain.

Origin of the First Seeds

Producers mentioned three main sources for their first seeds, as illustrated in Figure 3. These sources are crucial for understanding the dynamics of access to and transmission of seed resources within the communities. Eighty-eight producers (37%) received their first seeds through family inheritance; seventy-nine producers (33%) obtained their seeds from the market; and seventy-one producers (30%) received their first seeds as gifts.

Annual Seed Supply

Producers generally obtain their seeds for each new season from the previous year's harvest. However, in cases of seed shortages, producers turn to other sources of supply. They then purchase seeds from the local market or obtain them from neighboring producers.

Producers' Preference Criteria

In addition to the origin and supply of seeds, producers pay close attention to certain criteria when choosing the varieties of earth beans to cultivate. These criteria play a

key role in their decision-making and significantly influence local agricultural practices. As shown in Table 5, the main criteria preferred by producers are: drought resistance, color, no need for chemical fertilizers, and yield.

Conservation

In addition to the seed system and preference criteria, conservation methods play a crucial role in maintaining seed quality and protecting the seeds from bruchids. Producers store the seeds with or without pods in cans, granaries, gourds, sacks, and canaries. Cans remain the most used container, preferred by 77% of producers. As for the products used, producers mentioned sand, ash, pepper, and market chemicals (Figure 4). It is worth noting that regardless of the conservation technique, the average storage time, according to 44% of producers, is 8 months, that is, until the next season.

However, the production of earth beans is not without challenges. The constraints related to production and conservation are numerous and varied. Based on farmers' responses and perceptions, ten constraints hindering Kersting's groundnut production were identified in Togo (Table 6). The three most significant constraints cited by most farmers were harvesting difficulties, irregular rainfall, and the presence of pests. The challenges faced by producers have been categorized into three groups: the main constraints (Table 6); the impact of pests (Table 7); and the impact of climate change (Figure 5).

Almost all respondents (98%) acknowledged climate change in recent years**,** estimating the duration of this change to be between 1 and 15 years, with an average of 5 years (45%). The main manifestations, according to them, are irregular rainfall, increased temperatures, and drought. As solutions, some producers engage in reforestation (13%), a few perform ceremonies (1%), and the majority (86%) try to adapt to annual seasons. The impacts of climate change on Kersting's groundnut production, according to the producers, are listed in Figure 5.

Sociodemographic Characteristics

The analysis of the demographic and socio-economic data of Kersting's groundnut producers in Togo highlights several key aspects of this agricultural sector. The small number of producers observed in a country where agriculture is the main economic activity reflects the effective decline of this crop in Togo. The predominance of women among producers, with 56.7%, underscores the essential role of women in Kersting's groundnut production. This observation aligns with agricultural practices in Togo, where women play a central role in managing food crops, thus contributing to household food security.

The average age of 48 years reflects a relatively mature agricultural population, with a majority in the 30 to 60-year-old range, which could indicate a certain stability in their commitment to growing earth beans. However, the low representation of young people (under 30) among producers raises concerns about generational renewal, labor availability, and the attractiveness of this crop to younger people.

The educational level, where nearly half of producers have no formal education, could influence agricultural practices and the adoption of new technologies. The low level of formal education often limits access to essential information on best agricultural practices and innovations, which can affect productivity and profitability.

The experience of producers, ranging from 1 to 51 years, shows significant diversity, with a major concentration in the under-5 years category. This trend may reflect a recent entry into Kersting's groundnut production, possibly in response to economic incentives or the search for crop diversification.

The regions of Kara and Centrale, where the most experienced producers are found, benefit from better local knowledge and accumulated expertise, especially with a strong participation of women with over 20 years of experience.

These results highlight the need for targeted support, particularly in training and capacity building, to maximize the production potential of earth beans in Togo. Emphasis could be placed on integrating young people and improving education levels to foster more resilient and innovative agriculture.

Cultivation Systems and Crop Associations

The Kersting's groundnut cultivation system follows a well-defined calendar, with sowing primarily in July, and harvesting between November and December. The agricultural practices involve prior plowing and weeding

5 to 6 weeks after sowing to ensure proper plant development. Careful management of spacing during sowing is critical for maximizing productivity.

Kersting's groundnut are mainly grown in monoculture (79%), but a notable proportion of producers (21%) practice crop association (Table 2). This method is more common in the Kara region (32%) compared to other regions like the Savanes (10%) or Plateaux (3%).

This regional variability in cultivation practices reflects the different adaptation strategies of producers in response to local agro-ecological and socio-economic conditions. Crop associations help diversify income and food sources, as well as optimize the use of available resources.

According to Ayenan's work in 2016, Kersting's groundnut can be associated with cereals and roots (millet, sorghum, maize, yam) (Ayenan et Ezin, 2016); however, in Togo, beans are the most frequently associated crop, followed by Bambara groundnut and sorghum (Figure 2).

These associations address producers' needs in terms of complementing crop cycles, space management, and reducing risks related to climate hazards and market fluctuations. However, crop associations mainly reflect the lack of land for better diversification and thus the producers flourishing.

Crop Rotations

In addition to crop associations, producers implement crop rotations to preserve soil fertility and reduce the risk of pests and diseases. These practices vary depending on local contexts, demonstrating farmers' adaptation to the constraints and opportunities of their environment.

The study revealed that most producers (84%) prioritize earth beans as the first crop on newly prepared soil or after fallow, primarily due to their low fertilizer requirements and preference for very fertile soils. This strategy allows producers to optimize productivity without resorting to expensive inputs.

In contrast, 16% of producers integrate Kersting's groundnut second in the rotation, often preceded by crops such as sorghum, maize, or Bambara groundnut, showing a diversity of practices depending on resources and farm goals.

Areas Dedicated to Kersting's groundnut Production

In this study, areas dedicated to Kersting's groundnut cultivation range from 0.03 to 2 hectares, with an average of 0.06 hectares. Nearly half of producers (46%) cultivate on this area, illustrating a trend of allocating small plots for Kersting's groundnut production. While women represent a significant share (26%) of producers using these small areas, statistical analysis did not reveal a significant correlation between gender and the cultivated area ($p > 0.05$).

These results can be compared with those of Vissoh *et al.,* (2023) who reported similar areas in other West African regions, where earth beans are often grown on small plots due to the crop's demand for fertile soil and its primary use for domestic consumption (Vissoh *et al.,* 2023). However, unlike some studies, such as Dansi *et al.,* in 2012, which observed an increase in cultivated areas in response to growing demand in local markets, our study does not indicate such a trend among Togolese producers (Dansi *et al.,* 2012). The diversity in cultivated areas, with some producers dedicating up to 2 hectares, also reflects the variability of socio-economic contexts and land exploitation strategies. Larger areas are rarer and are often associated with producers who have more access to resources or who aim to maximize production for the market. In conclusion, these results highlight the predominance of small areas in Kersting's groundnut cultivation in Togo, underscoring the need for tailored strategies to support smallholders, particularly in terms of access to soil fertility and resource management.

Gender Implications in Kersting's groundnut Production

Kersting's groundnut production involves all household members, but the level of involvement differs by gender and family roles. As illustrated in Table 3, women are the key players in critical stages of production, including seed selection, crop management, and harvesting.

Their contribution is particularly significant in tasks requiring daily involvement, such as sowing and maintaining plots. Men, on the other hand, are more involved in strategic decisions, such as choosing and preparing plots. This division of labor reflects a traditional work structure, where men handle tasks that require land management, while women are at the heart of agricultural execution.

Table.1 Socio-demographical characteristics of respondents

Variables	Savanes (n=21)	Kara (n=144)	Centrale (n=38)	Plateaux (n= 30)	Maritime (n=5)	Overall
Gender						
Male	47.62	38.19	50.00	60.00	20.00	43.28
Female	52.38	61.81	50.00	40.00	80.00	56.72
Education level (%)						
Illiterate	57.14	48.60	42.11	40.00	60.00	47.48
Primary	28.57	34.00	39.47	30.00	20.00	33.61
Secondary	14.29	16.00	15.79	30.00	20.00	17.65
University	0	1.40	2.63	0.00	0.00	1.26
Ages (Years)						
Average	49.43	50.87	44.21	41.63	45.20	48.39
Range	27-70	25-85	23-73	22-62	39-51	22-85
Growing experience (Years)						
Average	7.33	11.08	7.5	6.10	1.40	9.34
Range	2-20	1-50	1-51	1-20	1-2	1-51
Household size						
Average	6.14	6.79	6.65	6.37	3.80	6.59
Range	3-12	1-14	3-10	1-18	3-5	1-18

Table.2 Cultural calendar and cycle of Kersting's groundnut per region

Parameters	Periods	Regions					Total	%	Chi-square		
		C	K	M	P	S			Value	df	p-Value
Sowing	May		2	1			3	1,26	131.72	32	<0.001
	May-July	1		2	3		6	2,52			
	June	11	27	2	3		43	18,07			
	June-July	3	3		2		8	3,36			
	July	22	105		13	21	161	67,65			
	July-August		1		7		8	3,36			
	August	1	6		2		9	3,78			
Total		38	144	5	30	21	238	100,00			
Haverst	September	1	7				8	3,36	107.57	24	<0.001
	September-October		1		3		4	1,68			
	October	2	7	3			12	5,04			
	October-November	5	4		1		10	4,20			
	November	20	113	2	10	19	164	68,91			
	November-December	6	5		6	2	19	7,98			
	December	4	7		10		21	8,82			
Total		38	144	5	30	21	238	100,00			
Cycle	≤120	28	125	5	17	21	196	82,35	36.565	8	<0.001
	≥150		1		4		5	2,10			
	120-150	10	18		9		37	15,55			
Total		38	144	5	30	21	238	100,00			

C= Centrale; K= Kara; P= Plateaux ; M= Maritime ; S= Savanes

Table.3 Cultivation system practiced

	Percentage of respondents per regions						
Cultural mode	Savanes	Kara	Centrale	Plateaux	Maritime	Overall	
Association	10 (N=2)	32 (N=46)	5 (N=2)	3 (N=1)	0	21 (N=51)	P<0.001
Monoculture	90 (N=19)	68 (N=98)	95 (N=36)	97 (N=29)	100 (N=5)	79 (N=187)	

Table.4 Level of gender involvement in Kersting's groundnut production

Level of involvement	Women	Men
Choice of accessions	+++	++
Choice of plot	++	+++
Maintaining the plot	++	+++
Crop management	+++	++
Harvest	+++	+

+++ = High; ++ = Medium; + = Low

Table.5 Farmers' preference criteria of Kersting's groundnut

Preference criteria	Proportion of citations (%)
Drought resistant	18.71
Attractive colour	17.99
grows without fertiliser	17.27
Good yield	13.67
Used for traditional ceremonies	7.19
Taste	6.47
High market price	5.76
Less risk of rotting	5.04
Treatment for stomach ache	4.32
Lighter than beans	3.60

Table.6 Kersting's groundnut production constraints

Contraints			Overall				Rank per Regions				
	TNV	MAC	PCO	IMC	Rank		Savanes	Kara	Centrale	Plateaux	Maritime
Difficult harvest	43	43	43	43	1		2	1	2	1	6
Rainfall irregularity	23	21	21	21.667	2		1	2	1	3	4
Pests	32	10	18	20.00	3		7	3	4	2	-
Soil poverty	20	17	20	19	4		3	4	3	4	3
Lack of fallow land	15	15	15	15.00	5		5	5	3	4	4
Rarity of seeds	10	8	10	9.33	6		6	6	6	5	1
Storage insects	8	4	8	6.67	7		9	7	8	6	5
Lack of knowledge and poor sales	8	3	8	6.33	8		4	10	5	7	2
Loss of seeds during harvest	4	4	4	4.00	9		8	9	7	-	-
Wilt of leaves	5	1	5	3.6667	10		-	8	7	-	-

Table.7 Evaluation of pests and diseases impact in Kersting's groundnut production

Variables	Responses (%)	Regions					
		SAVANES (n=21)	KARA (n=144)	CENTRALE (n=38)	PLATEAUX (n=30)	MARITIME (n=5)	Overall (n=238)
Damage level* **	Average	4.8	31.9	21.1	3.3	-	23.5
	High	-	5.6	-	-	-	3.4
	Low	14.3	22.9	28.9	20.0	-	22.3
	None	81.0	39.6	50.0	76.7	100	50.8
Control methods* **	Ash	-	9.2	-	-	-	6.8
	Insecticide	-	3.4	-	-	-	2.5
	No action	100	73.6	95.0	100	-	79.7
	Surveillance	-	13.8	5.0	-	-	11.0

***p < 0.001

Figure.1 Map of the study area showing regions and Villages surveyed**.**

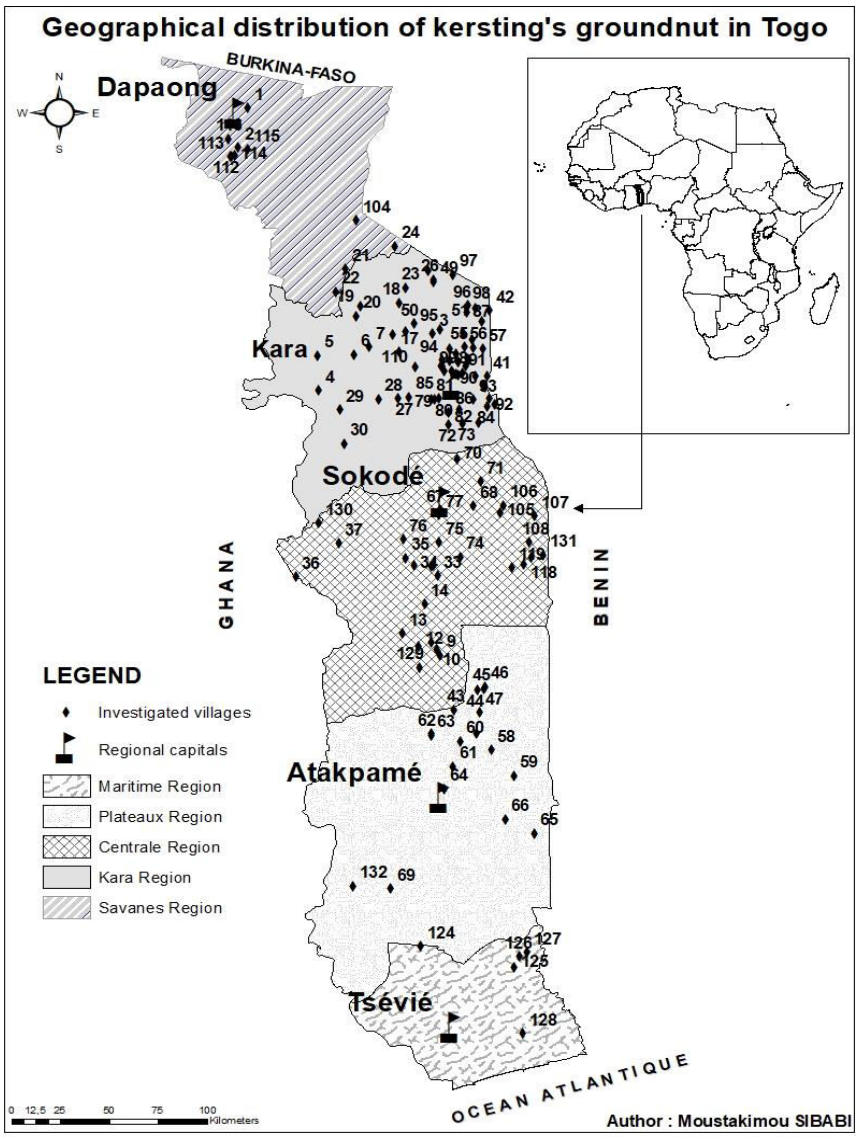


Figure.2 Analysis of the correspondence of crops associated with Kersting's groundnut according to the regions of Togo.

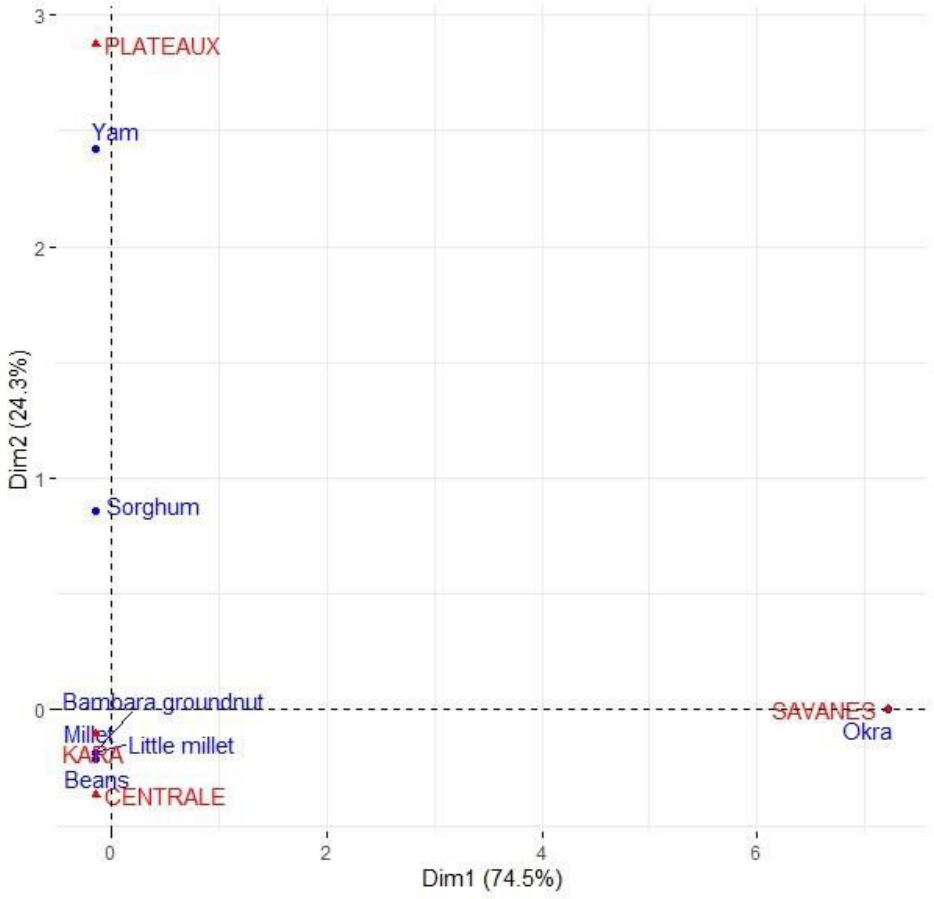


Figure.3 Origins of Kersting's groundnut Seeds.

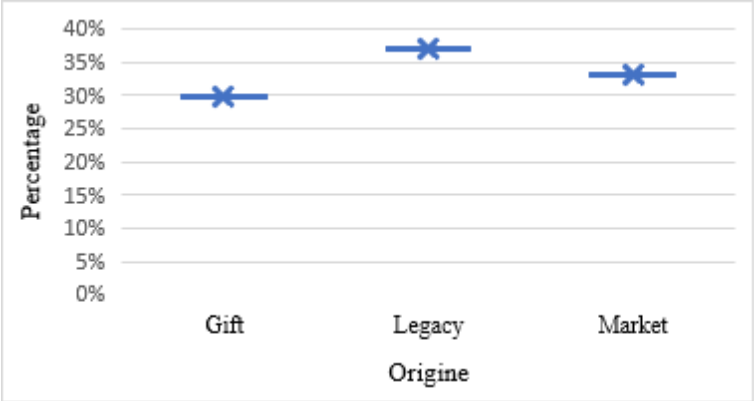


Figure.4 Conservation products used

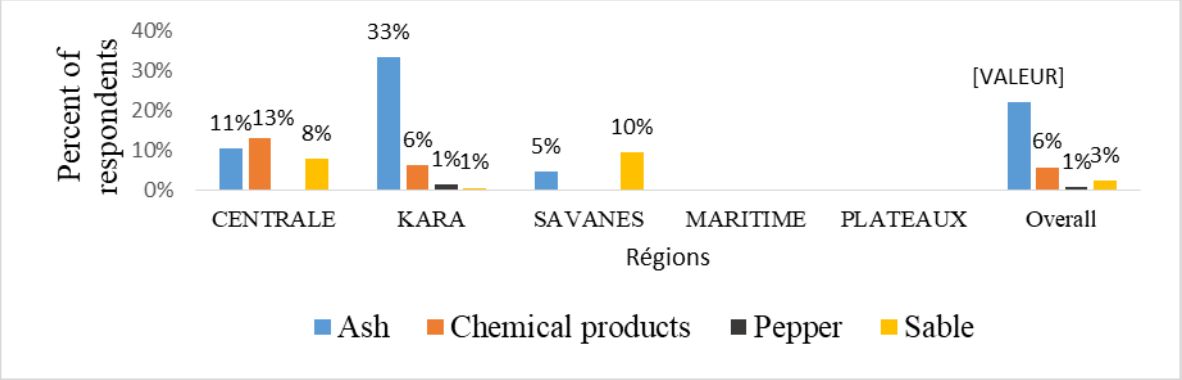
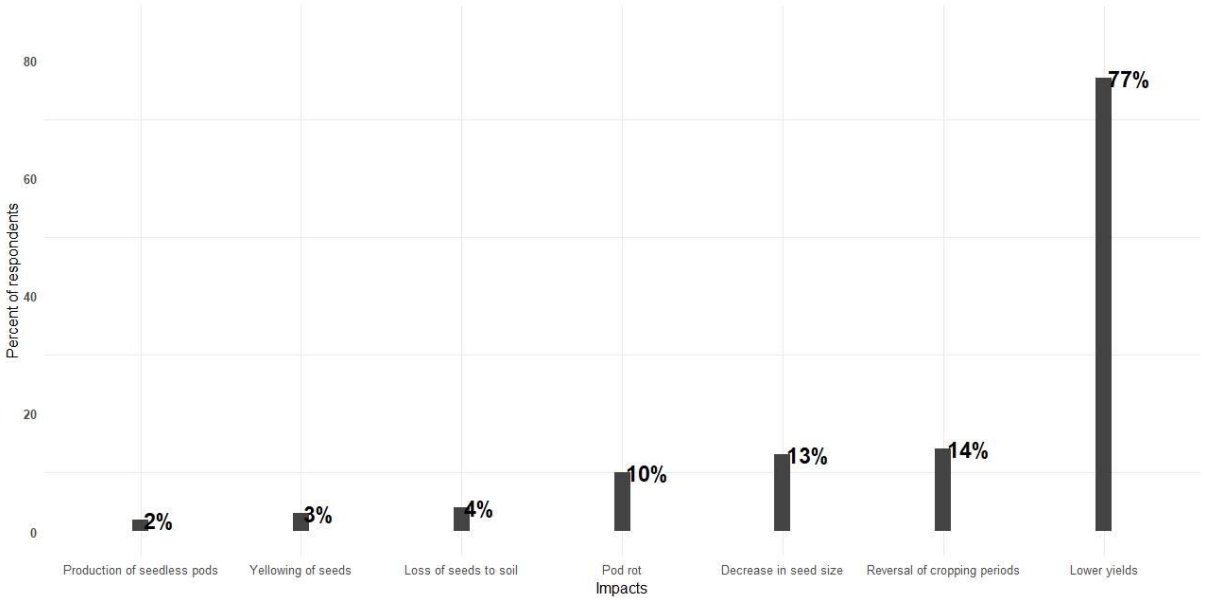


Figure.5 Impacts of climate change on Kersting's groundnut



The findings of this study align with available data on the central role of women in agriculture in West Africa. For instance, in Mali, rural women contribute 55% to the national agro-food production (FAO, 2021). According to the ministry of agriculture, livestock and rural development's gender action plan 2024-2028, in Togo, agriculture involves 96% of rural households, with nearly 54% of the active population engaged, and women play an essential role in agricultural activities. However, men's involvement in resource management is crucial for the viability of production, particularly in land selection and preparation, which directly impacts crop productivity. In summary, while women are central to agricultural operations, a collaborative approach between genders is essential to ensure effective and sustainable resource management. This highlights the importance of policies and programs that support both men and women in their respective roles, while promoting gender equality in the agricultural sector.

Origin of Kersting's groundnut Seeds

The origin of seeds plays a critical role in agricultural production, influencing both crop quality and resilience to climate hazards and pests. Figure 3 shows that Kersting's groundnut seeds primarily come from three sources: gifts (30%), family inheritance (36%), and the market (34%). Seeds from family inheritance are the main source, emphasizing the importance of traditional agricultural practices and the intergenerational transfer of

knowledge. This reliance on inherited seeds may limit the genetic diversity of crops, which is crucial for disease resistance and climate change adaptation.

Market-sourced seeds, while slightly less common, indicate a trend toward small-scale commercialization, mainly in local markets. This form of commercialization reflects a gradual professionalization of agricultural production while remaining embedded in a community context. It allows producers to access local varieties suited to specific agro-ecological conditions but may limit access to improved and certified varieties.

Gifts of seeds, while representing a significant share, highlight networks of solidarity and mutual aid among producers. However, this may also indicate a dependence on gifts due to insufficient resources to acquire seeds in the market.

These results align with studies by Ayenan and Ezin, who observed a similar prevalence of inherited seeds and gifts in other rural areas of West Africa (Ayenan and Ezin, 2016). However, to ensure the sustainability and resilience of Kersting's groundnut production, it is essential to diversify seed sources and promote access to improved varieties through more formal marketing structures. As part of this sustainability effort, farmers generally obtain their seeds for each new season from the previous year's harvest. This practice allows them to maintain continuity in production while reducing costs associated with purchasing seeds.

Farmers' Preference Criteria

The choice of groundnut varieties cultivated is strongly influenced by various criteria that meet the specific needs of farmers and local environmental constraints. As shown in Table 4, the main preference criteria include drought resistance, grain color, the absence of a need for chemical fertilizers, and yield.

- Drought resistance: This criterion is crucial, especially in northern Togo, where climatic conditions are more arid. A variety's ability to withstand drought ensures stable production even during periods of low rainfall, which is essential for household food security.
- Grain color: While primarily an aesthetic criterion, grain color also has commercial importance. Local consumers have specific preferences that influence market demand. A variety with a desirable color can be sold at a higher price, increasing farmers' income.
- Absence of a need for chemical fertilizers: This criterion reflects a preference for varieties that can grow in naturally low-fertility soils. Avoiding chemical fertilizers reduces production costs and promotes environmentally friendly agriculture, which is essential for small-scale farmers with limited resources.
- Yield: Yield remains a fundamental criterion, as it directly determines the amount of produce harvested. Farmers prefer high-yielding varieties to maximize their production on often limited land areas.

These preferences align with previous studies, which have also highlighted the importance of climate resilience and yield in other research on legumes in West Africa (Yovo and Lantomey, 2023). These criteria reflect how agricultural practices adapt to local challenges and emphasize the need to develop and promote groundnut varieties that meet these specific requirements.

Constraints Related to Production and Storage

The results reveal that Kersting's groundnut production faces several major constraints, with notable regional disparities. Harvesting difficulties, identified as the primary constraint across all regions, highlight the labor-intensive nature of this stage, which is mostly done manually. This observation has also been emphasized in the Kersting's groundnut cultivation guide, which underscores the importance of mechanization in groundnut farming. This challenge is a key reason for the lack of interest in groundnut cultivation and the limited production areas. Improving harvesting tools and techniques could help reduce this constraint and improve yields.

Rainfall irregularity, ranked second, illustrates the significant impact of climate on groundnut cultivation, which relies entirely on rainfed agriculture. These findings align with previous studies, which demonstrate that climate change disrupts traditional agricultural cycles in semi-arid regions, including Togo (Yovo and Lantomey, 2023). As illustrated in Figure 5, climate change affects groundnut production mainly through yield reduction (77%), a decrease in pod size (13%) caused by drought, and pod rot (10%) due to excessive rainfall. Better management of sowing calendars and the introduction of drought-resistant varieties could help mitigate these effects.

Additionally, pests, ranked third overall, represent a

major problem for farmers, particularly in the Kara and Centrale regions. These results are in line with those of Agoyi *et al.,* (2020) which report significant losses due to pests under similar conditions (Agoyi *et al.,* 2020). The use of agroecological practices such as intercropping or crop rotation could help minimize these damages.

Finally, poor soil fertility and the lack of fallow land, particularly concerning in the Savanes and Plateaux regions, highlight the need for sustainable soil management strategies. Approaches such as integrating nitrogen-fixing crops (e.g., Bambara groundnut) or using organic amendments could help improve soil fertility.

The regional variations observed, particularly regarding constraints related to rainfall irregularity and pests, reflect local specificities in agricultural practices, climate, and available resources. These differences underscore the importance of a contextual and tailored approach in developing solutions for the groundnut value chain.

Impact of Pests and Diseases on Groundnut Production

The assessment of damage caused by pests and diseases on groundnut production reveals significant regional variations. Overall, 50.8% of surveyed farmers reported no damage, indicating a certain level of crop resilience in some areas, particularly in the Plateaux (76.7%) and Maritime (100%) regions. Conversely, the Kara region exhibits increased vulnerability, with only 39.6% of farmers reporting no damage and a significant proportion (31.9%) reporting moderate damage levels.

Severe damage remains marginal, accounting for 3.4% of overall responses, with a concentration observed in the Kara region (5.6%). Additionally, minor damage is more widespread, affecting 22.3% of farmers, with the Centrale (28.9%) and Kara (22.9%) regions being the most impacted.

Regarding pest and disease control methods adopted by farmers, the majority (79.7%) do not take any measures, likely reflecting a lack of access to resources or appropriate knowledge. However, some specific practices are observed, such as the use of ash (6.8%) and insecticides (2.5%), mainly in the Kara region. Amuti and Larbi (1981) estimate the percentage of weight loss caused by *Callosobruchus maculatus* (F.) at 5.1% for *Macrotyloma geocarpum* under traditional storage conditions over five months (Amuti, 1980). Thus, these methods help combat bruchid beetles for better storage. Field monitoring is also practiced by 11% of farmers, with notable adoption in the Kara (13.8%) and Centrale (5%) regions.

These findings highlight the importance of strengthening farmers' capacities in pest and disease management, focusing on accessible, environmentally sustainable, and locally adapted approaches.

The analysis of the results reveals that Kersting's groundnut production remains an important socio-economic crop despite the numerous constraints that contribute to the reduction of cultivated areas and limit productivity. Among these, difficult harvesting, irregular rainfall, pests, and soil poverty stand out as the main barriers identified by producers. Furthermore, gender roles influence production stages.

Climate change impacts, including reduced yields and shifting cultivation periods, exacerbate producers' vulnerability, requiring tailored solutions. The study also highlights a preference for drought-resistant varieties offering good yields. These criteria represent levers for the selection and diffusion of new varieties suited to local conditions.

To ensure sustainable resilience for this crop and guarantee food security in Togo, it is essential to enhance access to improved seeds, integrate sustainable agricultural practices, and raise producer awareness about resource management techniques. These interventions can be supported by participatory research involving farmers in the development of innovative solutions. This is the focus of our ongoing work on the agromorphological, biochemical, and molecular characterization of *Macrotyloma geocarpum* cultivated in Togo.

Abbreviations

ICAT: Institut de Conseil et d'Appui Technique
CVD: Comités Villageois de Developpement

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Authors' Contributions

KKP and EMB contributed to the study design and field coordination. MS designed the study, collected data, performed analysis, and wrote the manuscript. AT, KA and KKP provided technical support and revised the manuscript critically. KK and AMEH contributed to data collection. All authors read and approved the final manuscript.

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Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate All procedures performed in this study involving human participants were conducted ethically according to local institutional guidelines. The surveys were conducted in collaboration with field agents from the *Institut de Conseil et d'Appui Technique (ICAT)*, under the coordination and institutional coverage of the *Institut Togolais de Recherche Agronomique (ITRA)*. The ICAT agents officially introduced the research team to the local communities and producers. Informed consent was obtained from all individual participants included in the study.

Consent for publish Not applicable.

Competing interests The authors declare that they have no competing interests.

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