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Genetic erosion and *in-situ* conservation of peanut (*Arachis hypogaea* L.) in Cameroon

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abstract

Context

Genetic erosion and *in situ* conservation are two strategies for resilience in food security. The main objective of this study was to know the interactions between these two concepts into the farmlands facing climate change threats. A survey of 224 peanut's farmers of 75 localities was represented by two groups; North region (zone 1) with 111 farmers and South region (zone 2) with 113 farmers. 23 variables (questions), were divided in two categories; variables of protection (8 questions) and variables of production (15 questions).

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Factorial analysis of components (FAC) was used to construct *in situ* conservation models for the North and South system of production. The Cramer tests, were used to link genetic erosion and *in situ* conservation. FAC shows that, models of *in situ* conservation are very specific inside each zone. Globally the interaction exists into the farmers because the Cramer value of 0.385 characterizes the presence of genetic erosion, and a quite high level (3) of *in situ* conservation. Facing climate change threats, the practice of genetic erosion to sustain food security inside the farmlands is another good solution. Also, genetic erosion and *in situ* conservation of peanut are the two resilient approaches against food insecurity.

I. Introduction

The Convention on Biodiversity (CBD) (Heinrich, 2002), adds sustainability and resilience (Benton, 2009), facing threats of climate change for food security, Manda et al. (2025). Throughout the ages, men practiced agricultural resilience (Akoa, 2023), and *in situ* conservation (William, 2022) in farmlands Liu et al. (2021), for many reasons; as nutrition, Nila et al. (2019), clothing, cosmetic, Talebmorad et al. (2021), and medical needs (Zhang, 2019). Peanut (*Arachis hypogaea* L.) is originated to South America (Hammons, 1994), and in Cameroon, it introduces in 1928 (Hamasselbé, 2006). *In situ* conservation integrates also storage into high and small farmlands (UNCED, 1992; Maxted et al., 1997ab). The main conservations are the landraces Maxted et al. (2002). Cameroon, has five agro ecological system of food production (DSCE, 2009; figure 1), and for natural conservation which plays and important role in food security. Also, farmers participate actively by selecting peanuts after every harvest, for sowing to the following season Maxted et al. (1997c). Because, peanut plays the third important role, after cocoyam and maize (Hamasselbé, 2008) in Cameroon. And, peanut is very resilient, in land for food security (Nwaga, 2000, Akoa, 2024a), by it good adaptability (Park, 2009; Foncéka, 2010, Akoa, 2024c). The methods of *in situ* conservation (FAO, 2014; Maxted, 2002) by farmers in spite of the absence of storage factories Maxted et al. (1997b) are specific (Nana, 2021) facing climate change's threats (Pachauri & Meyer, 2014; FAO, 2010) to fight against food insecurity. Today, this economical method of conservation (Yébi-Mandjek & Seignobos 2010), is confronted to the genetic erosion (FAO, 2009; Essomba, 1990) enhances by climate change threats (GIEC, 2007). Van de Wouw et al. (2009) define genetic erosion as the loss of variation in crops due to the modernization of agriculture. Nevertheless, many new cultivars introduce by genetic erosion are very attractive by big farmlands in this country (Akoa, 2024b), and contribute also at the resilience process, but using others variables for its sustainability (Akoa, 2024c). The main objective of this study, is to know whether *in situ* conservation and genetic erosion could interacted in food security.

II. Material and methods

II.1. Materials

II.1.1. Survey

Variables of production: Question 1 (Q1) Do you sell the peanuts you produce? Question 2 (Q2) apart from groundnuts, do you grow anything else? Question 3 (Q3) Do you feed animals with the groundnut's tops? Question 4 (Q4) Are groundnuts grown twice a year in your home? Question 5 (Q5) Do you eat the peanuts you harvest? Question 6 (Q6) Do you have two rain cycles? Question 7 (Q7) Is your parcel ten years old? Question 8 (Q8) Does this plot belong to you? Question 9 (Q9) Have you received training for this crop? Question 10 (Q10) Are the crops grown in the off-season? Question 11 (Q11) Do you use the same varieties? Question 12 (Q12) Are you satisfied with the returns? Question 13 (Q13) Do you use an herbicide? Question 14 (Q14) Do you enrich your parcels with NPK? Question 15 (Q15) Do you use sulphide as an input? (Essomba et al., 1990; Hamasselbé, 2006; Ibrahim, 2010).

Variables of protection: Question 1 (Q1) Are your peanut crops still sick? Question 2 (Q2) Do you have training on peanut diseases? Question 3 (Q3) When your parcels are sick, do you treat them? Question 4 (Q4) Do you practice fallow? Question 5 (Q5) Do you make associations of cultures? Question 6 (Q6) Do you use (bio) pesticides? Question 7 (Q7) Do you use breeding seeds? Question 8 (Q8) Do public authorities help you in the event of yield losses due to disease? (FAO, 2015).

II.1.2. Representation of Farmers

A sample of 224 peanut farmers in towns and villages, divided as follows: North localities: 30 farmers from towns; 81 farmers from villages; South localities: 50 farmers from towns; 63 farmers from villages using the map of agro ecological (figure 1). During 2021-2023.

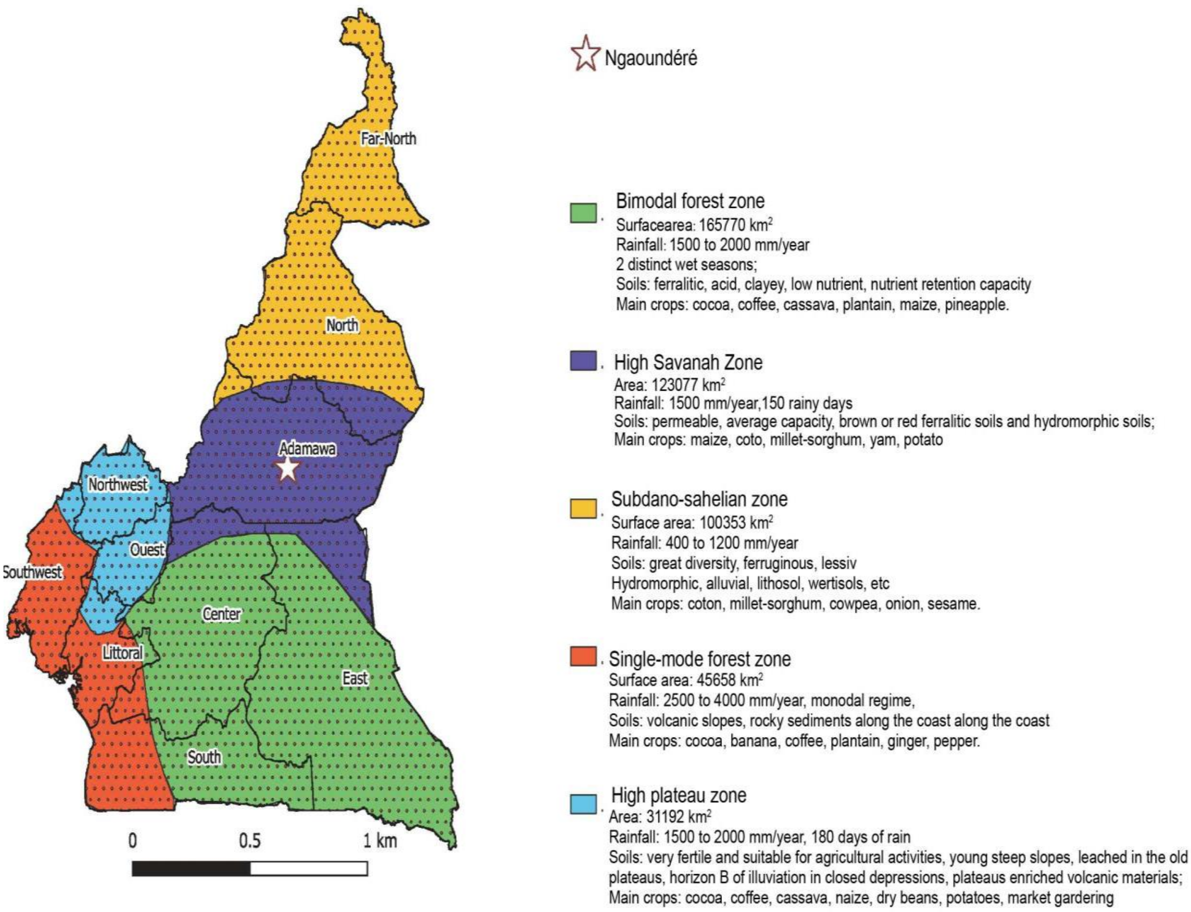

Fig.1. Agro ecological area of Cameroon (DSCE, 2009)

II.2. METHODS

II.2.1. Choice of towns and villages

In the first hand, the first approach was knowledge about peanut (cultivation and utilization). The second approach was *in situ* conservation methods. The third approach was the period of 4 years for production of peanut. All these approaches were according Agricultural Research Institute for Development (ARID) and the technical sheet of Hamasselbé et al. (2003). In the second hand, the designation of farmland as town was assessed at 10 -500 m^2, and village greater than 500 m^2 contrarily to FAO methodology of (Khalil et al., 2017; Akhere & Ndzifon, 2020).

II.2.2. Codification of Farmers

Farmers into North and South region codified as: INVLE1. I: Inhabitant (farmer), N: North, VLE 1: City's Farmer number 1. ISVLE 7; I: Inhabitant, S: South, VLE7: City's Farmer number 7 or; ISVAG 42: I: Individual; S: South, VAG; village's Farmer number 42) Hamasselbé et al. (2003). Zone 1 is North zone grouping three regions: Adamawa, north and far north. Zone 2 is South zone grouping seven regions: Center, East, West, Littoral, South, South-West, North West (NPCCA, 2015).

II.2.3. Data analysis

Factorial analyzes of components (fac) Pressac & Mell, 2017 was used to construct all models of *in situ* conservation in the North and South also for the global system of production. Cramer (1946) value (1) test scale, was used to compare level of genetic erosion and *in situ* conservation intensity

$$\text{(i)} \qquad V = \sqrt{\Phi^2/\min\,(k-1, r-1)}$$

Φ^2: coefficient phi; K: number of raw; r: number of lignes

Genetic erosion and genetic erosion of Cramer scale ranging from 1 to 6, for each value obtained. Most the V value is closed to 1, most the risk of genetic erosion is lower, and high is *in situ* conversation. Inversely, more the V value is closed to 0, most the risk of genetic erosion is high and *in situ* conservation is weak. Summarily, peanut's conservation is inversely proportional to genetic erosion (table I). Software R program, version 4.2.3 (R Core Team, 2023).

Table I: Cramer's value adaptation scale to peanut genetic erosion and conservation

Cramer's test (V)	Interpretation	Scale	Genetic erosion characteristic	Intensity of conservation
between 0 et 0.05	Absence of link	6	Very high	None existant
between 0.05 et 0.1	very weak	5	High	Little existing
between 0.1 et 0.2	Weak	4	Quite high	Existing
between 0.2 et 0.4	moderate	3	Existing	Quite high
between 0.4 et 0.8	High	2	Little existing	High
between 0.8 et 1	Collinear	1	None existant	Very high

III. Results and discussion

III.1. Results

III.1.1. Models for *in situ* conservation of peanut

III.1.1.1. Models for North and South towns

The farmers from north and south cities are represented at 61.69% in the fac. The different colors represent the levels of representations with respect to the square cosine (cos2) of the variables of the farmers and of the modalities of the questions. Farmers from north towns, INCT18 and INCT7 are correlated to the *in-situ* conservation model of peanuts of variable Q15 by the use of sulfur. The farmers from south cities, ISCT39 and ISCT33 are correlated to *in-situ* conservation model of peanuts for the variable Q6, linked to the two cycles of the rainy seasons. The farmers from the south city ISCT23 are correlated to the *in-situ* conservation model of peanuts by variables Q4 and Q10 related to the practice of peanut cultivation twice a year and in the off-season. Variable Q14 which represents the enrichment in NPK does not characterize the farmers of the cities of the South and is an extreme variable and little correlated to the individuals of the cities of the south ISCT32 and ISCT27 which, on the other hand, are not very correlated to the related conservation model (figure2).

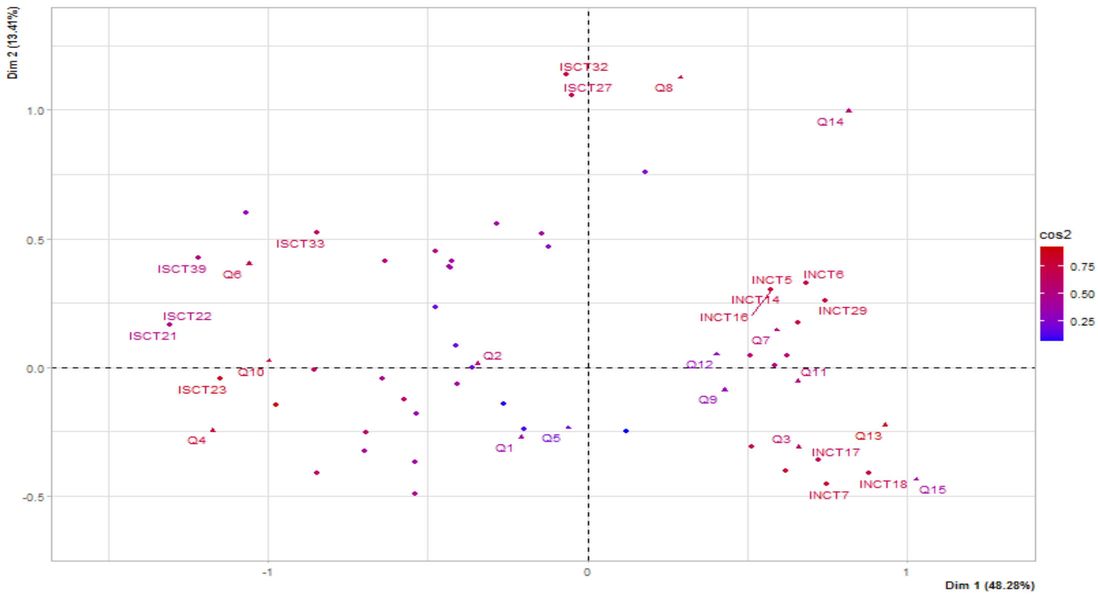

Fig.2. Model for *in situ* conservation for peanut in North and South towns

III.1.1.2. Models for North and South villages

The farmers of the north and South villages are represented at 61.61% in the fac. The different colors represent the levels of representations with respect to the square cosine (cos2) of the variables of the farmers and of the modalities of the questions. The farmers from south villages ISVAG15, ISVAG55, ISVAG25 are correlated to the *in-situ* conservation model of peanuts for variables Q4 and Q6 relating to the double cultivation of groundnuts following the two rainy seasons. Variable Q10, is linked to off-season agriculture is an uncommon practice among individuals in south villages (figure 3).

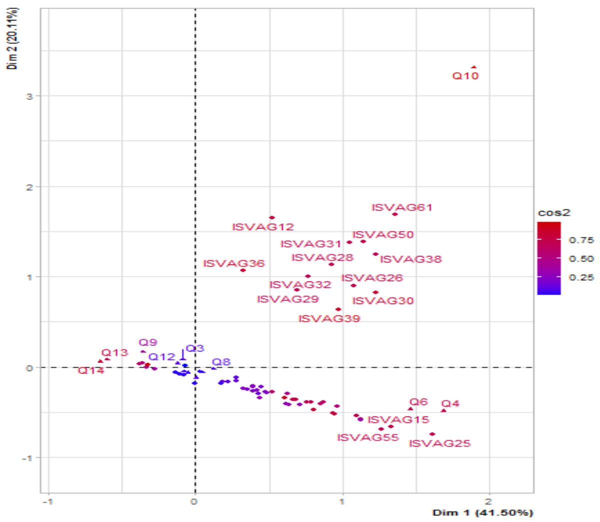

Fig.3. Model for *in situ* conservation for North and South villages

III.1.1.3. General model of *in-situ* conservation for zone1

The farmers from the north zone including the farmers from towns and villages are represented at 85.84% in the fac. The different colors represent the levels of representations with respect to the square cosine (cos2) of the variables of the farmers and of the modalities of the questions. The models of *in situ* conservation of groundnuts which characterize this north zone are the variables Q1, Q8, Q14, Q15, respectively relating to the marketing of groundnuts, the ownership of arable land, the enrichment in NPK, and the use of sulfur. The farmers from north towns, INCT26 and INCT28 have the same model of *in situ* conservation as the farmers from villages, INVAG (49, 36, 58, and 71 (figure 4).

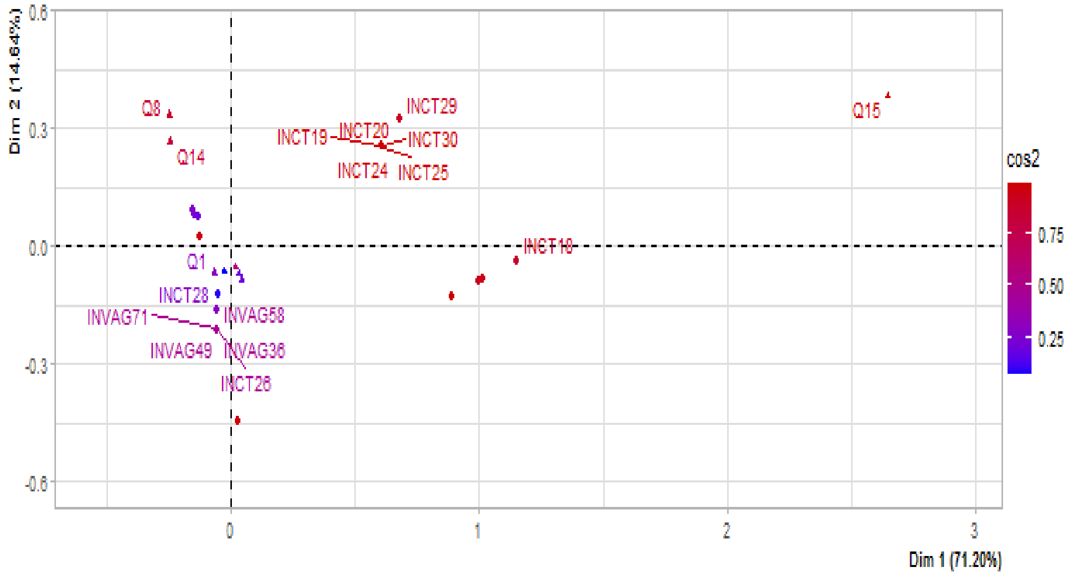

Fig.4. General model of *in-situ* conservation for zone1

III.1.1.4. General model of *in-situ* conservation for zone2

The farmers from towns and villages in the south zone are represented at 33.35% in the fac. The different colors represent the levels of representations with respect to the square cosine (cos2) of the variables of the farmers and of the modalities of the questions. The *in-situ* conservation models for peanuts from farmers in this south zone are the variables Q3, Q10, Q12, Q13, and Q14. These variables of *in-situ* conservation in the south refer respectively to livestock feed, off-season agriculture, yield satisfaction, herbicide use, and NPK. *In situ* conservation models for peanuts Q14 and Q13 diverge from conservation variables in the south (figure, 5).

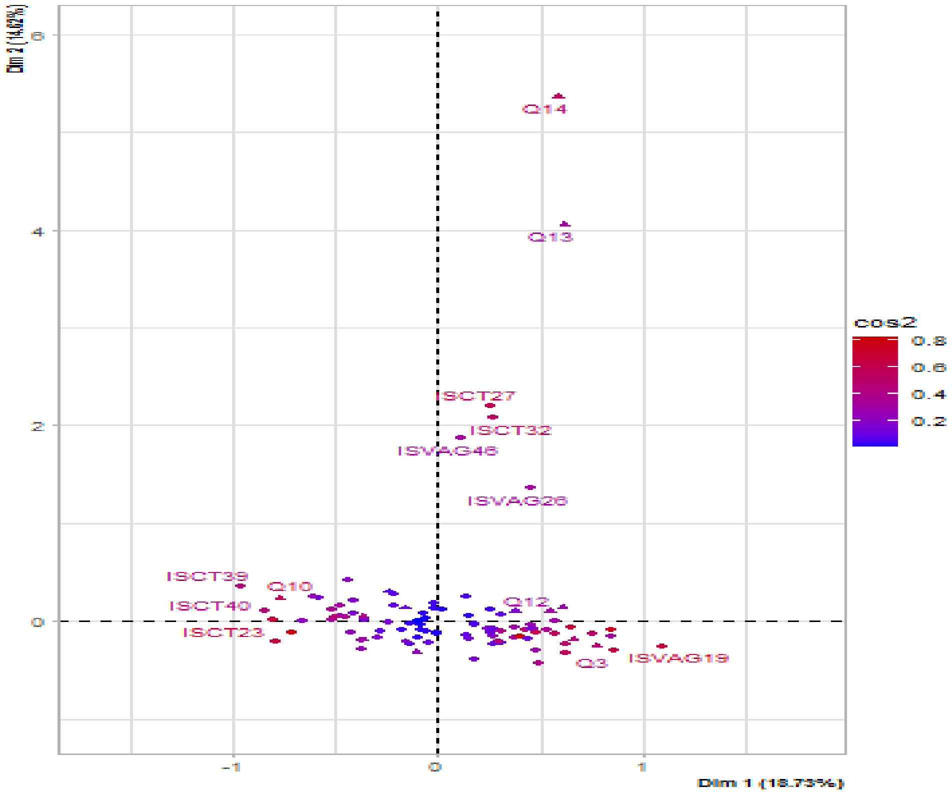

Fig.5. General model of *in-situ* conservation for zone2

III.1.1.5. General system of *in situ* conservation for 224 farmers

Three general patterns of production in groundnut cultivation are represented in dimensions 1 and 2 at 45.26%. The south region contains a single, but hybrid cropping pattern combining town and village techniques, while the north region contains two pure cropping patterns, one for towns and one for villages (figure 6).

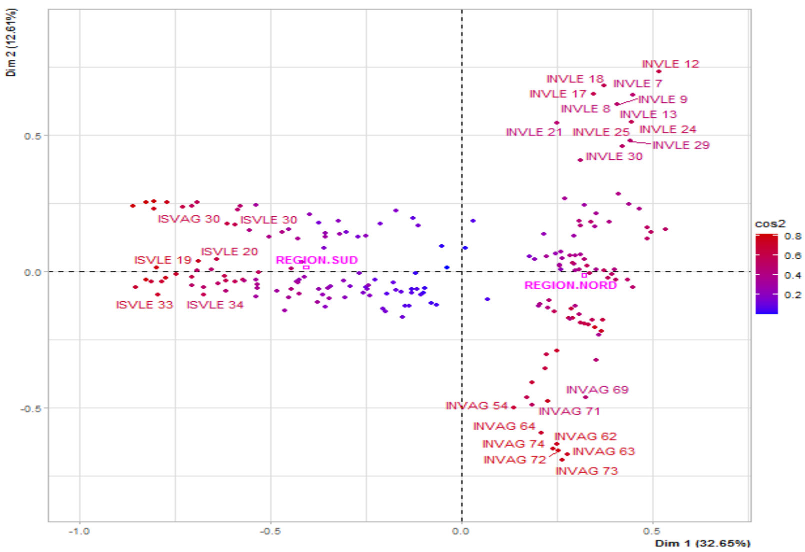

Fig.6. General system of *in situ* conservation for 224 farmers

III.1.2. Models of variables for *in situ* conservation

III.1.2.1. Model of variables for production in zone 1 and 2

The peanut production model variables for zones 1 and 2 is represented at 55.62% in the fac. The different colors represent the levels of representation with respect to the cosine squared (cos2) of the variables of the farmers and the modalities of the questions. *In situ* conservation models of the south region are negatively correlated to variables Q3, Q7, Q8, Q9, Q11, Q12, Q13, Q14, Q15 which represent the *in situ* conservation variables of the north, but *in situ* conservation of the peanut is done by the conservation models of the variables Q1, Q2, Q4, Q5, Q6, Q10 (figure 7).

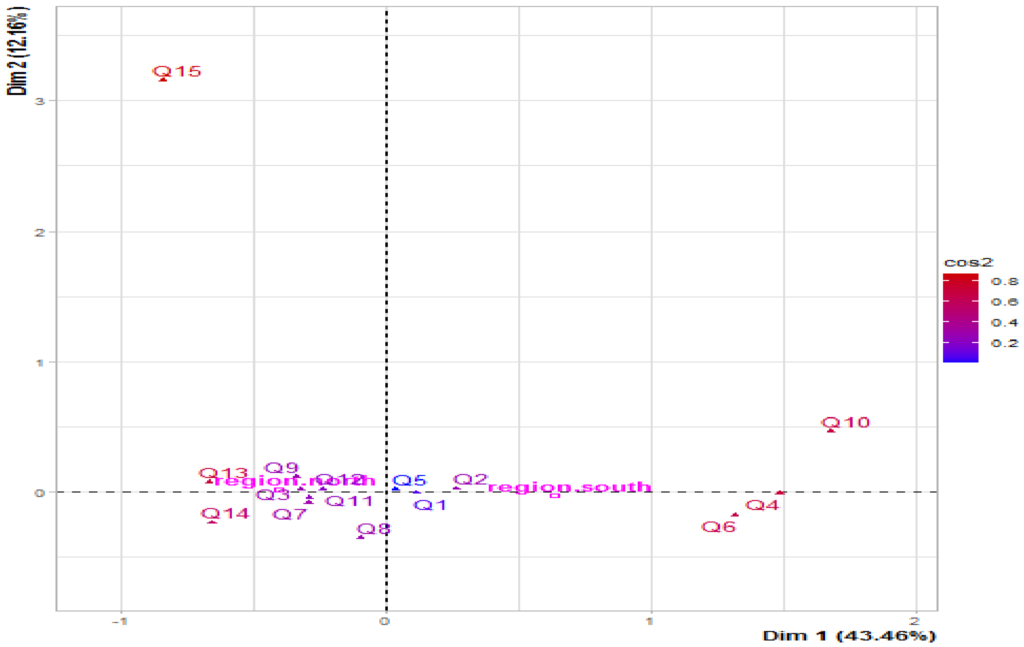

Fig. 7. Model of variables for production in zone 1 and 2

III.1.2.2. Model of variables for protection in zone 1 and 2

The variables which characterize best the north region for protection are question 2 (Q2) do you have any training on peanut diseases? Question 3 (Q3) when your plots are diseased do you treat them? Question 6 (Q6) do you use pesticides? Question 8 (Q8) Does the government help you in case of yield losses due to disease? These variables are strongly correlated. The variables which characterize best the south region for protection are the variables related to questions 4 and 5 respectively: Question 4 (Q4) do you practice fallow? Question 5 (Q5) do you do crop associations? (Figure 8).

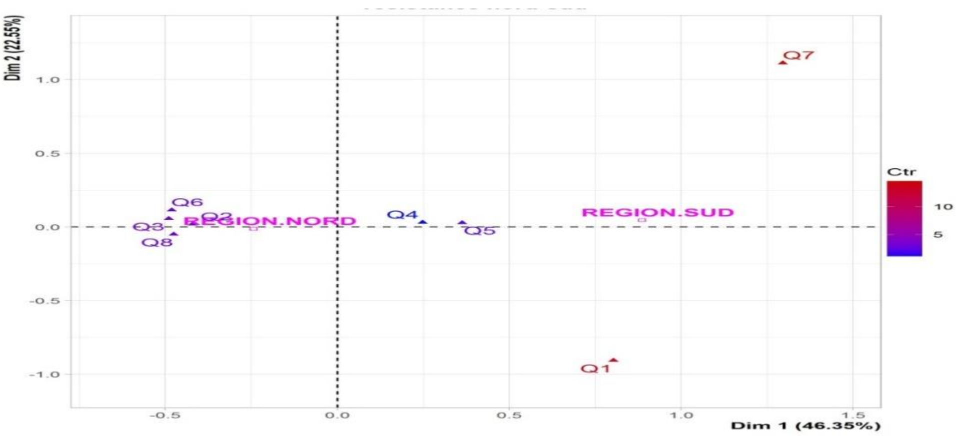

Fig.8. Model of variables for protection in zone 1 and 2

III.1.2.4. General variables of production for 224 farmers

The north region is strongly correlated to the variables Q7, Q8, Q9, Q13, Q14, Q21, Q3, and negatively correlated to the variables Q17, Q6, Q4, Q10, which represents the characteristic variables of the south region (figure 9).

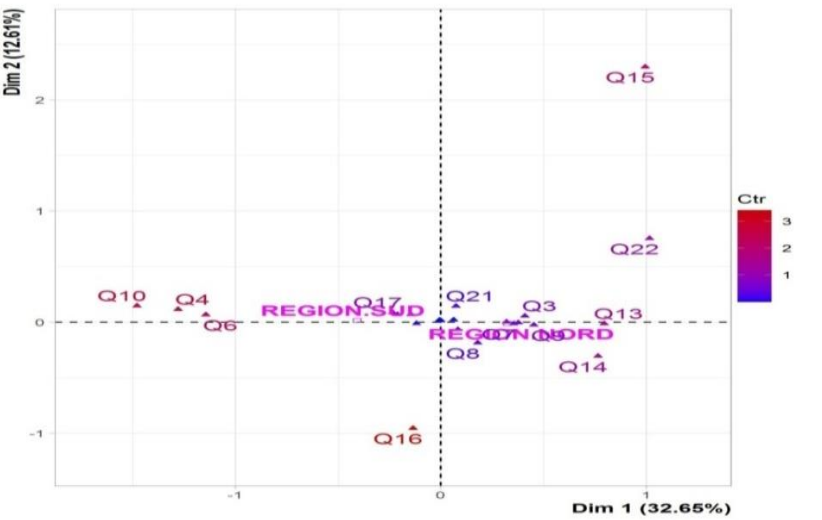

Fig. 9. General variables of production for 224 farmers

III.1.3. Intensity of peanut conservation

III.1.3.1. North and south cities

The 100% of the intensities of the connections of the towns of the south and the north are reached in dimension 14. The connection is almost average between the farmers of the towns of the north and the south and the variables, in the first dimension (0.43) and almost zero in dimension 13 (0.01), the first two dimensions have a value of 61.69%. Cramer's test gives a value of 0.445 (2) which corresponds to a little existence of genetic erosion and high level of *in situ* conservation of peanut (table II).

Table II. Dimension of Cramer values in north and south towns

	Eigen value	% of variance	cumulative % of variance
dim 1	0.43	48.28	48.28
dim 2	0.12	13.41	61.69
dim 3	0.07	7.71	69.40
dim 4	0.06	6.45	75.85
dim 5	0.05	5.36	81.21
dim 6	0.04	4.57	85.78
dim 7	0.03	3.51	89.29
dim 8	0.02	2.53	91.82
dim 9	0.02	2.39	94.21
dim 10	0.02	1.81	96.02
dim 11	0.01	1.64	97.66
dim 12	0.01	1.17	98.82
dim 13	0.01	0.75	99.58
dim 14	0.00	0.42	100.00
V of Cramer	0.445 (2)		

Dim = dimension

III.1.3.2. North and south villages

The 100% of the intensities of the links of the villages of the south and the north are reached in dimension 13. The dependence between the conservation variables and the individuals of the villages of the north and the south is weak in the first dimension (0.25) and is almost independent (0.01) at the 11th dimension. The first two dimensions have a cumulative value of 61.60%. Cramer's test gives a value of 0.3 (3), this value corresponds to an existence of genetic erosion and a quite high level of peanut conservation (table III).

Table III. Dimension of fac values of north and south villages

	Eigen value	% of variance	cumulative % of variance
dim 1	0.25	41.50	41.50
dim 2	0.12	20.11	61.60
dim 3	0.06	9.91	71.51
dim 4	0.05	7.76	79.27
dim 5	0.03	4.54	83.81
dim 6	0.02	3.87	87.68
dim 7	0.02	3.36	91.04
dim 8	0.02	3.26	94.29

dim 9	0.01	1.95	96.24
dim 10	0.01	1.74	97.98
dim 11	0.01	1.41	99.39
dim 12	0.00	0.39	99.78
dim 13	0.00	0.22	100.00
V of Cramer	0.3 (3)		

III.1.3.3. Intensity of peanut conservation in zone1

The 100% of the intensities of the links in the north zone are reached at dimension 7. The links between the variables and the individuals of zone 1 are independent (0.09) at the first dimension and almost zero at the third dimension and (0.01). The first dimension has a cumulative value of 71.20%. Cramer's test gives a value of 0.06 (5), this value corresponds to a high genetic erosion and a little existing level of peanut conservation (table IV).

Table IV. Dimension of fac values of zone1

	Eigen value	% of variance	cumulative % of variance
dim 1	0.09	71.20	71.20
dim 2	0.02	14.64	85.85
dim 3	0.01	5.43	91.28
dim 4	0.00	3.07	94.35
dim 5	0.00	2.63	96.98
dim 6	0.00	1.78	98.76
Dim7	0.00	1.24	100.00
V of Cramer	0.06 (5)		

III.1.3.4. Intensity of conservation in zone 2

The 100% of the intensities of the connections in the south zone are reached at dimension 13. The connections between the individuals of the south and the conservation variables in dimension 1 are weak (0.20) and almost zero at the 3rd dimension (0.02). The first dimension has a cumulative value of 18.73%. Cramer's test gives a value of 0.545 (2), which corresponds to a little existence of genetic erosion and a high level of peanut conservation (table V).

Table V. Specific values of the conservation of the inhabitants of zone 2

	Eigen value	% of variance	cumulative % of variance
dim 1	0.20	18.73	18.73
dim 2	0.16	14.62	33.35
dim 3	0.16	14.33	47.68
dim 4	0.12	11.39	59.07
dim 5	0.11	10.35	69.42
dim 6	0.07	6.80	76.22
dim 7	0.06	5.67	81.89
dim 8	0.05	4.39	86.28
dim 9	0.04	3.67	89.95
dim 10	0.04	3.39	93.34
dim 11	0.03	2.55	95.89
dim 12	0.03	2.40	98.29
dim 13	0.02	1.71	100.00
V of Cramer	0.545 (2)		

III.1.3.5. Intensity of conservation for 224 farmers

100% of the intensities of the bonds in zone 1 and 2 are reached at dimension 14. The intensity of the bonds between the farmers and conservation variables on the general level vary between 0.34 and 0.01 from the first to the 14th dimension. The first dimension has a cumulative value of 43.46%. Cramer's test gives a value of 0.385(3). This value corresponds to an existence of genetic erosion and a quite high level of peanut conservation (table VI).

Table VI. Specific values of the conservation of the inhabitants of zone 1 and 2

	Eigen value	% of variance	cumulative % of variance
dim 1	0.34	43.46	43.46
dim 2	0.09	12.16	55.62
dim 3	0.08	10.16	65.77
dim 4	0.06	7.52	73.29
dim 5	0.04	5.51	78.81
dim 6	0.03	4.21	83.02
dim 7	0.03	4.00	87.01
dim 8	0.02	2.96	89.98
dim 9	0.02	2.82	92.79
dim 10	0.02	2.11	94.90
dim 11	0.01	1.79	96.69
dim 12	0.01	1.446	98.15
dim 13	0.01	1.12	99.27
dim 14	0.01	0.73	100.00
V of Cramer	0.385 (3)		

Table VII. Summary of assessments

North and South villages also zone 2 are the same scale intensity (2) and same characteristics of genetic erosion and *in situ* conservation intensity. Zone 1 has a little existing *in situ* conservation and high genetic erosion.

Sites	Cramer's value	Scale intensity	Characteristic of genetic erosion	*In situ* conservation intensity
North and South towns	0.3	3	Existing	Quite high
North and South villages	0.445	2	Little existing	High
Zone 1	0.06	5	High	Little existing
Zone 2	0.545	2	Little existing	High
Zone 1 and 2	0.385	3	Existing	Quite high

III.2. Discussions

Protection and production model and global system of production

The representation of the fac contradicts the results of Khalil et al. (2017) basing on the standard work of the FAO which demonstrates that there would be an uniformity of production by area of less than 2 ha, while figure 2 demonstrates a variability of farmers. This variability of farmlands could explained by the fact that it is a supply capacity at different time periods of seedlings' demand both in markets and households. Supply and demand can thus be in balance to explain price stability in the markets and remain within the purchasing power threshold of populations. And according to (Aryal, 2021), these results in the small farmlands in urban areas are for fighting against food shortages. In large areas, 61.61% (figure 3) average of farmlands correlate to some variables of production in south villages. The best representation would be strongly correlated to Q10 variable which represents an off-season crop. Thus, it is the off-season which mainly characterizes the production of the big farmers into the south. This could be explained by the fact that, irrigation methods would not be developed to support off-season agriculture. These results confirms the work of (Akhere & Ndzifon, 2020) on the production strategies of farmers in Bamenda in times of drought.

The cultures of the south zone take place both in the growing season and in the off-season, certainly by the use of swamps. This allows a continuous supply of this agricultural speculation in the south markets, in the absence of supply from the groundnut basin from the north. This could be explained by the fact that the issues and structures present in the two peanut production system areas don't meet the same objectives. Indeed, zone 1 or north zone is considered as the national peanut basin and the availability of seedling is more encouraged than in zone 2. The presence of non-governmental organizations and research institutions are more important and benefit more from the funds of research for the satisfaction of demand and even of technological innovation. These results are confirmed by (Yébi-Mandjek & Seignobos, 2010) and also by Hamasselbé et al. (2003) on intensive farming in the Sudano-Sahelian zone of north Cameroon. Similarly, the mixed model of conservation (figure 9) confirms this result.

Among these 224 peanut producers, there are two main peanut systems (figure 6). The system in the south region, which has a strong representation of certain farmlands, has a certain heterogeneity by combining a big-area of farmlands (ISVAG 30). This could be explained by the fact that the agricultural system that he would practice would be similar to the small farmers. The second conservation system with three variants namely a homogeneous agricultural system of towns and villages and a mixed agriculture. These results contradict the works of Essomba et al. (1990), who present peanut production with four systems.

In situ conservation intensity and genetic erosion

The Cramer's test gives a value of 0.445 (2), which corresponds to a little existence of genetic erosion and a high level of conservation of peanut in north and south cities. Cramer's test gives a value of 0.3 (3). This value could explained by an existence of genetic erosion and a quite high level of peanut conservation in north and south villages. Because in towns, the conservation of seeds is very ease, and the intensity reflects the level of attachment that small farmers have with the family seedling from previous harvests. Thus, small farmers (towns) produce for self-consumption due to low household demand. These results corroborate the work of (Hamasselbé, 2008) on the revaluation of groundnut production threatened with genetic erosion in agricultural competition; as well as those obtained by the same author (Hamasselbé,

2006) on the place of groundnut consumption in the north Cameroon, faced with an increase in demand for food security.

The genetic erosion of villages (0.3) for Cramer test gives 3 and therefore exists, but peanut conservation is quite high. This could be explained by the fact that confidence in the new seedling cannot be a guarantee of sufficient productivity. Because in developed countries there would be losses in yields following a genetic erosion of around 30% due to uncontrolled pathogens (Dong & Pamela, 2019), and on the other hand, the search for biological uniformity in yields and resistance to diseases could not be tested in large areas, who do not have research structures for carrying out trials Betdogo et al. (2015). Nevertheless, big farmers still test new seedlings, with the aim of improving yields; while small farmers don't take this risk, and keep the seedlings from previous crops. The big farmers are informated about research's results and also oriented productions to commercialization, while the small farmers are oriented to self-consumption, and therefore only seek their subsistence. These two kings of *in situ* conservation by both big and small farmers corroborate the work of (Nana, 2021) on biodiversity conservation in Central Africa, when he speaks of mixed conservation.

IV. Conclusion

In situ conservation intensity and genetic erosion interactions exist in farmlands. This strategy could be used in peanuts production system, facing climate change threats. *in situ* conservation is very diversified and it is inversely proportional to genetic erosion. Two approaches for measuring *in situ* conservation was made by utilizing factorial analysis components (FAC) and Cramer's value adaptation scale test. In sum, Cramer test value of 0.385 characterizes the presence of genetic erosion, and a quite high level (3) of *in situ* conservation. All pillars of food security are presented, but it is duo to the utilization of chemicals products for sustaining production into the main basin of peanuts. Facing climate change threats, the practice of genetic erosion to sustain food security inside the farmlands is another solution. Also, genetic erosion and *in situ* conservation of peanut are the two resilient approaches against food insecurity.

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Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest

Ethical approval: This article does not contain any study with human participants or animals performed by any of the authors.

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