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Determinant of groundnut (*Arachis hypogaea* L.) yield improvement in the farmers' cropping systems in Benin

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Groundnut is an important crop in the farmers' cropping systems of Benin and one of the selected crops to be promoted by Benin Government. The aim of the present study is to analyze the traditional groundnut cropping systems in Benin. Farmers' socio-economic characteristics, cropping practices, farmers' perceptions of climate change manifestations on groundnut were information collected using an open ended questionnaire. In total, 382 farmers in three agro-ecological zones (AEZ) of Benin Republic were selected according to 121 farmers in the cotton zone of the northern Benin (AEZ 2), 159 farmers in the cotton zone of central Benin (AEZ 5) and 102 farmers in the "*terre de barre*" zone (AEZ 6) in the south. Descriptive statistics and multiple regression analysis were used to analyze data collected. Groundnut cultivation is mainly carried out by women in the AEZ 2, while in the two other AEZ, men are strengthly involved in the production. In the AEZ 5 and 6, groundnut is becoming nowadays a cash crop. Groundnut cultivation occupied less than 10% of the area owned by farmers in the AEZ 2 while it occupied more than half of the total area in the AEZ 5 and 6. Pod blank, pod attack by the termites were the main farmers' perceptions of the climate change effect on groundnut cultivation which is related to soil drought. In general, the sex of the farmers, supply of mineral fertilizer, crop rotation, crop residues management and supply of household waste have a significant and positive effects on the groundnut yield level. The study suggested that, balanced plant nutrition could be a challenge for enhancing groundnut production in Benin.

Key words: Source of income, farmer perception, soil fertility, climate change, crop nutritional balance, crop residues management.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the most widely grown oilseeds in the world, especialy in the tropical regions (Shiyam, 2010; Fonceca, 2010) and contributes to 12% of the world oil production (Schilling,

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2003). Production of groundnut is estimated at 47 million tonnes; 65.1% of this production comes from China and India (Faostat, 2017). African countries' production is dominated by Nigeria and Senegal (2,420,000 and 915,000 tonnes, respectively) (Freud et al., 1997; Faostat, 2017). Due to its high nutritional value, groundnut contributes to the national food security and provides income to farmers (Abbasi et al., 2010; Couto et al., 2011; Noba et al., 2014). The crop residus especially the shell are often used as livestock feed or as fuel (Schilling, 2001; Singh et al., 2010; Ahmad et al., 2007). Like most of the leguminous, it is used for soil fertility resplenishment due to its potential as biological nitrogen fixation source and it can also be used as green manure to improve nitrogen balance in the cropping systems (Smaling et al., 2008).

In Benin, groundnut production has increased in the recent years with about 153,762 ha of area cultivated and 134,229 tonnes of pods produced in 2013 (MAEP, 2014). Despite all the potential of this crop as an alternative to cotton (main cash crop of Benin), production is hampered by several constraints such as, decrease of soil fertility, erratic rainfall and shorter of the length of the growing seasons, weed infestation, high susceptibility to pests and diseases, soil mining due to non fertilizer supply (FAO, 2004; Kumar, 2012) leading to low yield (600 to 800 $kg.ha^{-1}$) (MAEP, 2014). In general, due to poor land management practice there is a continuous degradation of soil fertility (Didagbé et al., 2014; Didagbe et al., 2015). Given the importance of this crop, it is necessary to improve cropping system by developing appropriate fertilizer dose in order to enhance yield and reduce soil mining. This requires an in-depth knowledge of the current cropping systems in order to design appropriate crop and soil management practices.

The purpose of the present study is to characterize groundnut cropping systems in Benin for adequate crop and soil management practices. Specifically, the present study aims to i) determine the socio-economic profil of the groundnut producers in the different agroecological zones of Benin, ii) analyze variation of land management and cropping practices for groundnut production in the different agroecological zones of Benin and iii) finally identify the determinants of yield improvement in the different agroecological zones of Benin for setting sustainable land management practices.

MATERIALS AND METHODS

Study area

The work was carried out in three agro-ecological zones (AEZ) in Benin (Figure 1): the northern cotton zone (Banikora and Kandi) (AEZ 2), the centre cotton zone (Glazoué, Ouessè and Kétou) (AEZ 5) and the "*terre de barre* zone" in the south (Agbangnizou) (AEZ 6). The AEZ 2 was characterized by a Sudano-Sahelian climate with an annual average rainfall of 850 mm. There were two distinct seasons (a rainy season from May to October and a dry season from November to April). The Ferric and Plintic Luvisols (FAO, 2006) were the dominant soil types. In this area, cotton is the main cash crop. Leguminous mainly groundnuts, cowpeas and soybeans are also grown. The AEZ 5 was characterized by a Sudano-Guinean climate with two rainy seasons from April to July and October to November. The annual rainfall varies from 600 to 1400 mm over 80 to 110 days. The Ferric and Plintic Luvisol are also dominant soil types in the area. Black and hydromorphic soils are also found in the valleys of the rivers that cross the area. Cereals and leguminous are widely grown. The Sudano-Guinean zone on "*terre de barre*" (AEZ 6) located in the southern Benin has sub-equatorial rainy season. The cropping systems are based mainly on slash and burn agriculture, maize, cassava, groundnut and cowpea are predominant crops in the cropping systems and soil types are Acrisols (FAO, 2006). The rainfall pattern is highly erratic, leading to changes in the annual production cycles.

Sampling method

The sample size was obtained using the normal approximation of the binomial distribution (Dagnelie, 1998).

$$N = ((U_{1-\alpha/2})^2 \times p\ (1-p))/d^2$$

Where $U_{1-\alpha/2}$ = value of the normal random variable for the probability value of 1-α/2, α is the risk of error. For α = 5%, the probability 1-α/2 = 0.975 with $U_{1-\alpha/2}$= 1.96. p = the proportion of people involved in groundnut production in the study area and the margin of estimation error; in this study we used 5% value of p. Based on the p-values from the results of the exploratory phase, a total of 382 groundnut producers were surveyed, according to 121 in the AEZ 2, 159 in the AEZ 5 and 102 in the AEZ 6. In each locality, the respondents were identified using a simple random sampling technique.

Data collection methods and tools used

The study was carried out from September 2017 to October 2017 during groundnut growth period. An open ended questionnaire was used for data collection. Both quantitative and qualitative information was collected. Three students native from each area were recruited for the survey. Data on socio-economic characteristics of groundnut producers, cropping systems, and groundnut production constraints were collected. Finally, farmers' perceptions on the effect of the cropping practices on soil fertility were also collected.

Data processing and analysis

The Excel office 2013 spreadsheet was used for data processing. Software R version 3.5.2 was used for statistical analysis. Descriptive statistics especially for quantitative variables were computed. Hierarchical clustering was used to link groundnut cropping systems to the most efficient soil fertility management practices. This was followed by a multiple factor analysis to describe the different types of systems. The yield data were subjected to one-way analysis of variance AEZ used as the factor. Mean differences were done using Student Newman-Keuls test. Analyse of the determinants of land of crop management practices that affect the most groundnut yields was done using ordinal logistic regression. A Mapping Factor Analysis was carried out to analyse farmers' perceptions on the effects of climate change on groundnut yield.

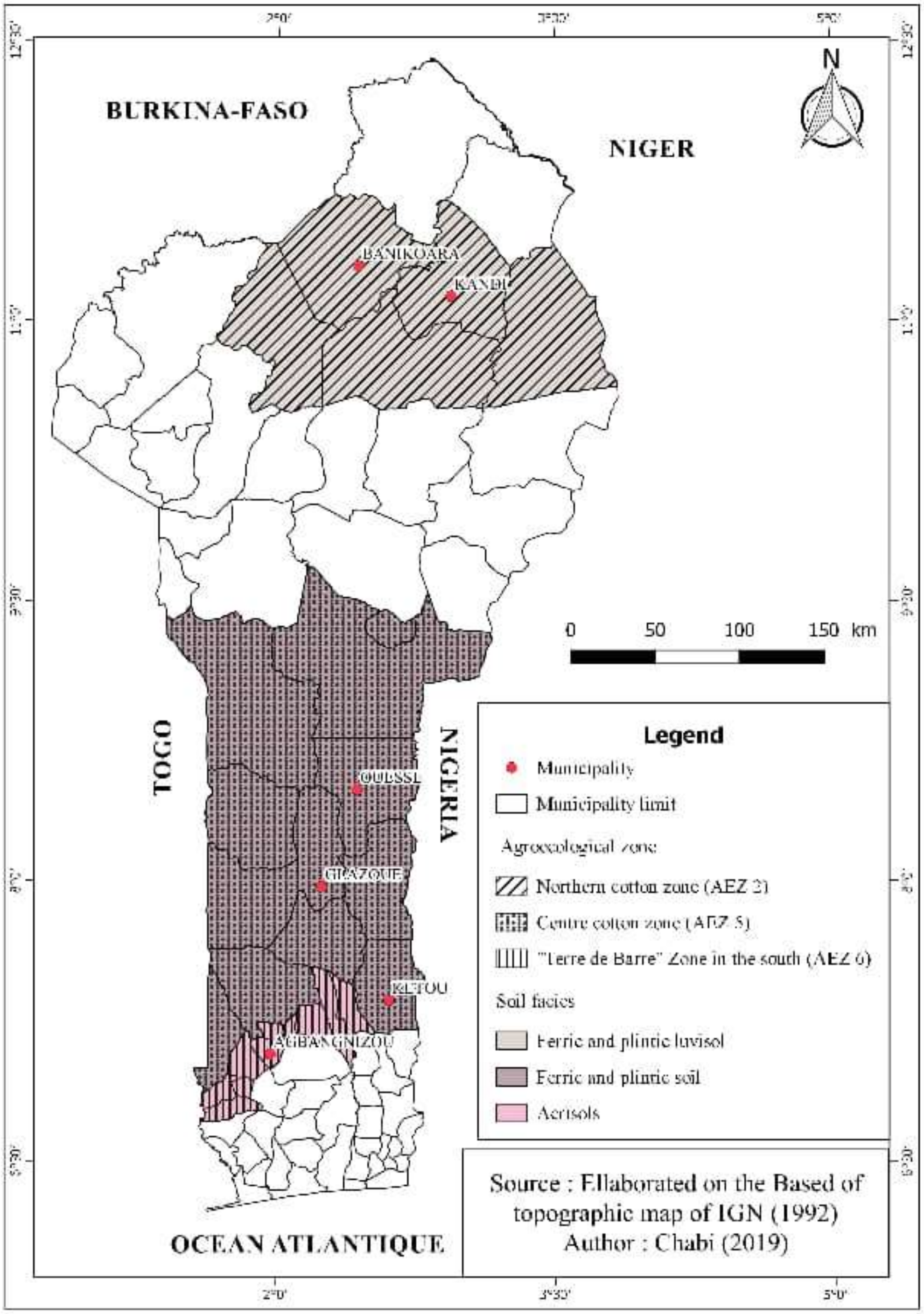

Figure 1. Localization of the surveyed areas in the study.

RESULTS

Socio-economic characteristics of the groundnut producers

In Table 1 the socio-economic characteristics of the respondents in the three AEZ are presented. In general, it is noticed a strong involvement of the men in groundnut production in the AEZ 5 and 6 while in the AEZ 2 women are much more involded. The age of the majority of the respondents (over 50%) range between 30 and 60 years old. More than 60% of the respondents have low

Table 1. Socio-economic characteristics of the groundnut producers in the three agro-ecological zones of Benin.

Variable	Modality	Frequency of respondents (%)		
		AEZ 2	AEZ 5	AEZ 6
Sex	Female	27.1	13.2	2
	Male	72.8	86.8	98
Age (years)	< 30	37.7	37.7	5.88
	30 - 60	56.3	61.2	88.2
	≥ 60	7.9	1	5.9
Educational level	None	90.7	60.46	91.2
	Primary	0.6	6.9	4.9
	Secondary	8.6	13.1	2.9
	University	0	0	0.9
Experience in groundnut production (years)	< 10	36.4	74.4	2.9
	10-20	26.5	37.9	97.1
	≥ 20	38.4	4.6	0
Duration (years) of land use	< 10	29.8	5.4	0
	10-20	33.1	89.9	77.4
	≥ 20	47.7	15.5	22.5
Area (ha) allocated for groundnut cultivation	< 10	82.9	4.6	19.6
	10 -75	15.1	91.5	61.7
	≥ 75	2	3.6	18.6
Reason for the groundnut cultivation	Self consumption	40	10.2	8
	Processing	23.7	1.6	0
	Sale	36.3	88.2	92
Contribution of groundnut to the household income	Very important	25.1	85.6	14.6
	Important	45.2	14.3	35.4
	Less important	29.7	0.1	50

AEZ 2 = Northern cotton agro-ecological zone; AEZ 5 = Centre cotton agro-ecological zone; AEZ 6 = Sudano-Guinean zone on “*terre de barre*”.

education level. Experience in groundnut production ranges between 10 and 20 years in the AEZ 6, while some farmers in the AEZ 2 have more than 20 years old in groundnut production and less than 10 years in the AEZ 5.

Land use duration ranges betwen 10 to 20 years for the majority of farmers in the AEZ 5 and 6, against over 20 years (47.7% of the respondents) in the AEZ 2. The area allocated for groundnut cultivation is less than 10% of the total area owned by the majority of farmers in the AEZ 2, whereas, in the AEZ 5 and 6, it occupied between 10 and 75% of the total area. Autoconsumption is the main reason mentioned by farmers for groundnut cultivation in the AEZ 2 while it is becoming a cash crop in the AEZ 5 and 6 and market driven product with an important contribution to the household income.

Criteria used by farmers to select land for groundnut cultivation

Four criteria are used by farmers in the three AEZ to select land for groundnut cultivation (Figure 2) which included: soil characteristics (light soils without stones, good workability are preferred), yield level of the previous crop grown on the land, soils with high biological activity (presence of insect galleries, earthworm terricules, etc.) and soil with presence of striga (mentioned by farmers in

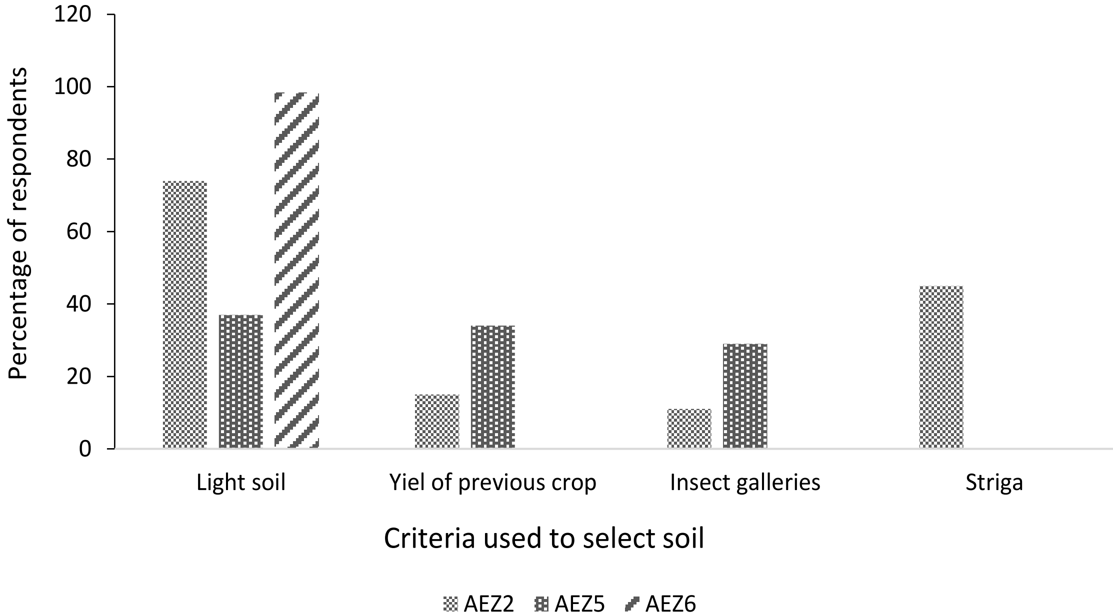

Figure 2. Criteria used by farmers to select appropriate land for groundnut cultivation in the three agro-ecological zones in Benin. AEZ 2 = Northern cotton agro-ecological zone; AEZ 5 = Centre cotton agro-ecological zone; AEZ 6 = Sudano-Guinean zone on "*terre de barre*"

the AEZ 2). Light soils easy to plough and well drained are an important criterion used by farmers in the study area (90% of the respondents). In addition to this criterion, the presence of insect galleries and striga are also used by 45% of farmers in the AEZ 2 and 29% of farmers in the AEZ 5 to select land for groundnut cultivation. Farmers (40% of the respondents) reported that, the presence of insect galleries reflects non compact soil, permeable and favourable for groundnut cultivation in most of the case.

Cropping practices adopted by farmers and groundnut yields in the three agro-ecological zones

Farmers' cropping practices for groundnut cultivation in the three AEZ are in the Table 2. Two ploughing modes are used in the area. Hundred percent of the respondents affirmed that flat ploughing practiced in the AEZ 2 often using cattle traction and ridging. Local varieties are widely used by most of the farmers' according to 80% of the respondents in the three AEZ. The seeds are mostly collected from the previous harvest. The improved varieties are used only in the AEZ 2 by 21% of the farmers. These improved varieties are introduced by traders. Each farmer can provide during the market days. Monocropping of groundnut is developed in the study area. Seeds are sown in rows in the AEZ 2, while in the AEZ 5 sowing method widely practiced, consisted of installing two seeding hills on the ridges side by side. The spacing depends on the biomass of the variety as mentioned by farmers in the AEZ 2. In the three AEZ, mostly cereal crops are rotated with groundnut. Maize is the most commonly cereal used in this rotation system according to 56% of the respondents. Rotation of groundnut with leguminous crops in the area was not observed. The results of the analysis of variance show significant difference ($P < 0.05$) among the three AEZ in terms of groundnut seed yields (Figure 3). Pods yields are significantly higher in the AEZ 2 compared to the two other zones. In all of the AEZ, pods yield is lower than 1 $t.ha^{-1}$.

Soil fertility management practices for groundnut cultivation

Soil fertility management practices for groundnut production in the three AEZ are presented in Figure 4. Crop rotation is mentioned by at least 50% of the respondents in each AEZ. Groundnut monocropping was developed in the AEZ 2. In opposite, farmers in the AEZ 5 and AEZ 6 practiced intercropping of groundnut with cereal crops (88.37 and 100% of the respondents, repectively). Supply of mineral fertilizer for groundnut production is not common in the AEZ 2, whereas, it is adopted by few farmers according to 14% of the respondents in the AEZ 5 and 6. In that case, fertilizers used were NPKSB (14-23-14-5-1) and urea. Doses applied were less than 50 kg ha^{-1}. Supply of household

Table 2. Groundnut producers' cropping practices in the three agro-ecological zones.

Practices	Modality	Percentage of respondents (%)		
		AEZ 2	AEZ 5	AEZ 6
Tillage	Flat plowing	100	0	0
	Ridge	0	100	100
Varieties used	Locale	78.2	95	100
	Improved	21.8	5	0
Sowing	Single seeding	100	6.3	45.8
	Twin seedings	0	94.7	54.2
Crops rotated with groundnut	Cereal	77.4	97.6	100
	Cotton	22.6	2,3	0
Weed management	Manual	22.3	100	100
	Herbicide	77.7	0	0

AEZ 2 = Northern cotton agro-ecological zone; AEZ 5 = Centre cotton agro-ecological zone; AEZ 6 = Sudano-Guinean zone on "*terre de barre*".

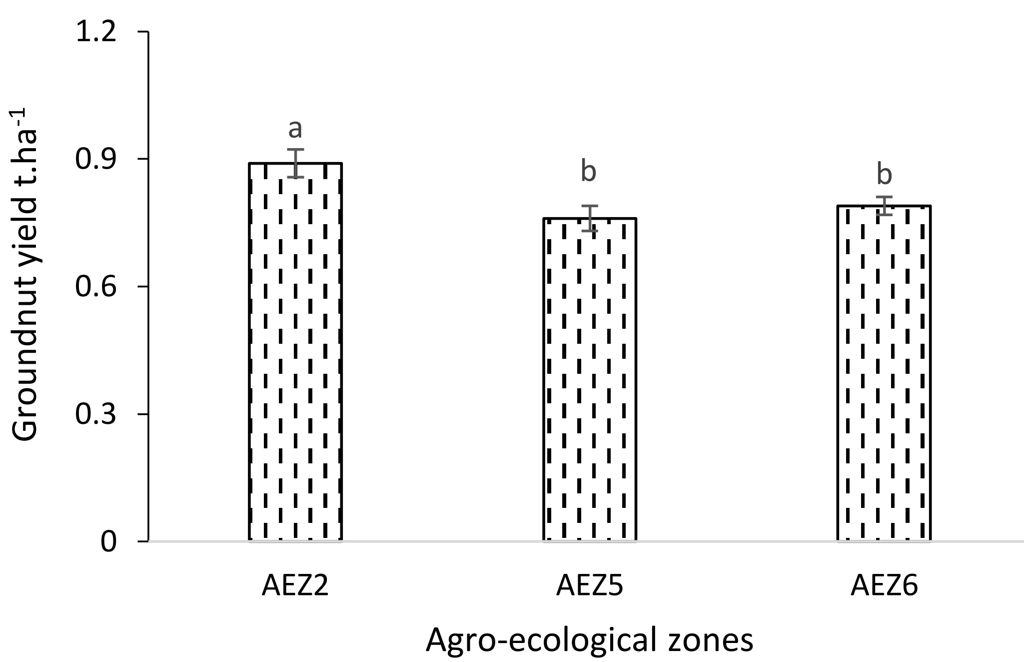

Figure 3. Groundnut seed yield variation among the different AEZ. Barre with the same alphabetic letters are not significantly different regarding groundnut seed yield; AEZ 2 = Northern cotton agro-ecological zone; AEZ 5 = Centre cotton agro-ecological zone; AEZ 6 = Sudano-Guinean zone on "*terre de barre*".

waste as organic manure to sustain soil fertility for groundnut production was observed in the AEZ 6 (18.2% of the respondents). The practices consisted of dumping the waste in the plots before ploughing. The waste was also spread during groundnut development phase. Ninety percent of farmers declared ths the use of organic manure is important in the AEZ 2, but it is marginal in the AEZ 5 and 6 (1.5 and 10.8% respectively). Organic

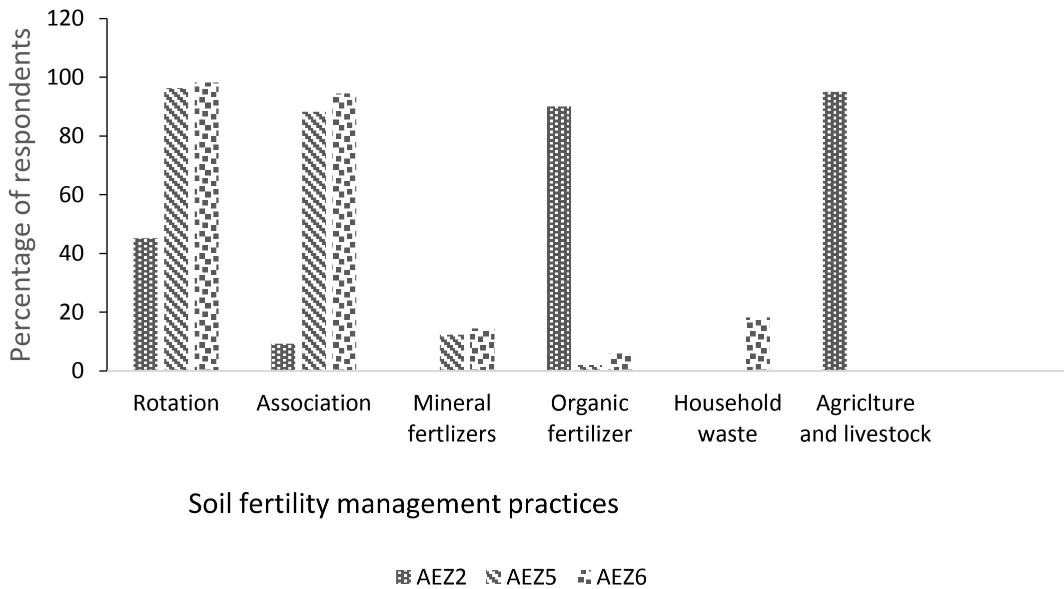

Figure 4. Soil fertility management practices for groundnut production in the three agro-ecological zones. AEZ 2 = Northern cotton agro-ecological zone; AEZ 5 = Centre cotton agro-ecological zone; AEZ 6 = Sudano-Guinean zone on "*terre de barre*".

manure used in the AEZ 2 was cow dung. In fact, integration of agriculture and livestock was only observed in the AEZ 2. In this farming system, livestocks were either parked directly on the plots or the excreta were collected and spread on the plots before ploughing. As a result of this integration in the AEZ 2, all of the respondents used crop residues especially groundnut haulms to feed livestock. Crop residues are also used as organic manure in the other two AEZ. Only 15.5% of the respondents in the AEZ 5 incorporated their crops residues in the soil before ploughing. In contrast, the majority of farmers in the AEZ 5 and 6 burnt their crop residues in the fields during land preparation for sowing.

In total, 6 groundnut cropping systems are generated (Figure 5) based on the characteristics of the cropping systems and soil fertility management practices with a determination coefficient R^2 of 0.50. The results of the multiple factor analysis carried out revealed that the first two axes explained 61.35% of the information related to the different systems. The first system was characterized by farmers who burnt crop residues in their field, practicing intercropping, crop rotation and applied mineral fertilizers. The Class 2 comprised group of farmers applying household waste as organic manure and practicing intercropping of groundnut with other crops residues especially maize. The third group of farmers comprised those practicing crop rotation and burning crop residues. The fourth group is farmers who did not practice intercropping and burn crop residues. The practice of crop rotation and avoiding intercropping of groundnut with cereal crop, the use of animal manure and integration of livestock and crop in the farming system characterized the Class 5. The sixth system comprised farmers that did not practice crop rotation but intercropped groundnuts with cereal crops and apply organic manure for soil fertility resplenishment. Farmers in this group use crop residues to feed the animals.

Farmer perceptions of the effects of climate change on groundnut productivity

The evidence of the effects of climate change on groundnut productivity was assessed (Figure 6). Farmers in the AEZ 2 mentionned that the presence of empty pods linked to leaf stunting and pods attack by termites were manifestations of climatic disturbance. While those in the AEZ 6 emphasized on poor pod filling and stunting of plants. Chlorosis remains the most appropriate manifestation for producers in the AEZ 5.

Derterminants of cropping practices for groundnut yield improvement

The results of the ordinal logistic regression used to assess the determinants of cropping practices that affect yield improvement are presented in Table 3. Variables used in the model are: supply of mineral fertilizers and organic manure, crop rotation, intercropping, crop residues management and supply of household waste. Thus, intercropping, supply of organic manure and integration of crop and livestock were practices that did not affect significantly groundnut productivity. However,

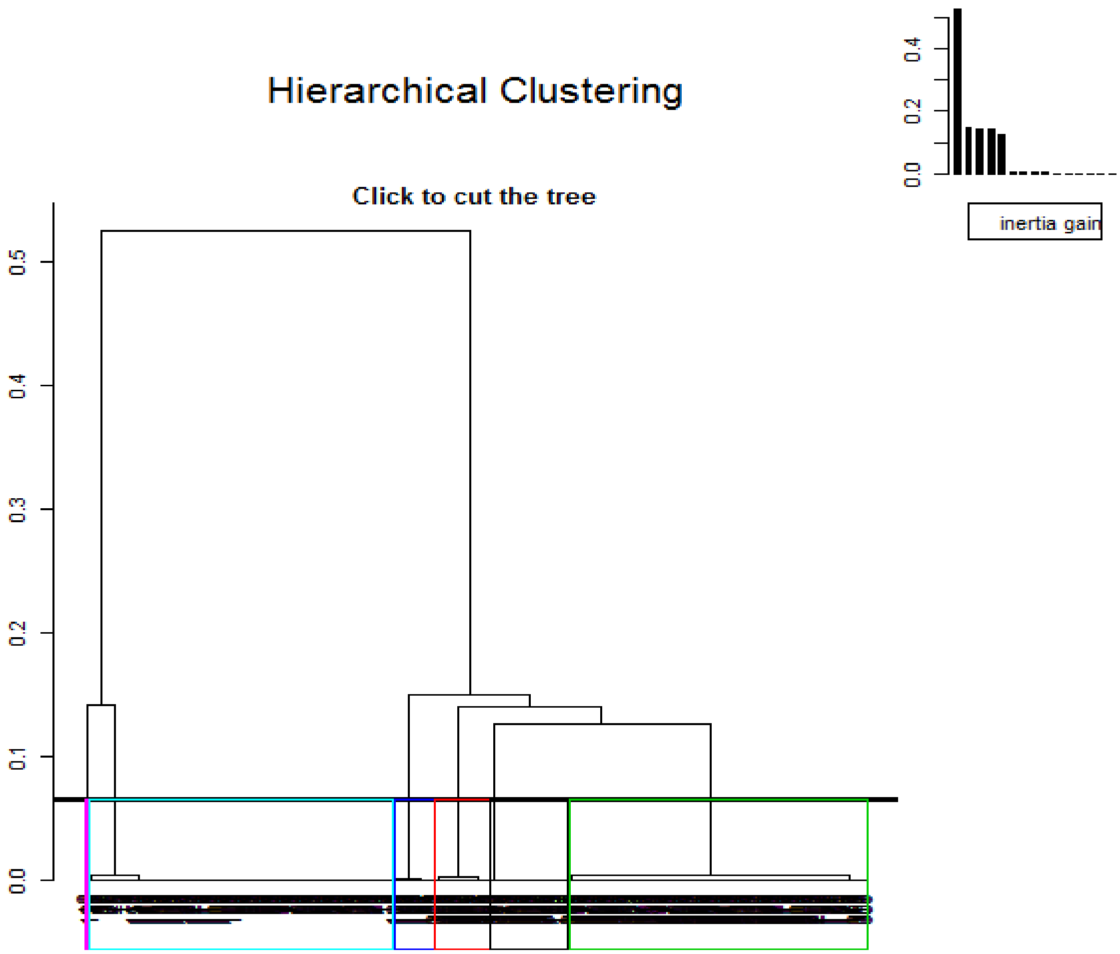

Figure 5. Soil fertility management practices dendrogram.

supply of mineral manure, crop rotation, crop residues management and the use of household waste had significant and positive effects on the groundnut yield level. Considering the socio-economic characteristics of the farmers and their cropping practices, it is observed that, the sex of the farmer affect positively groundnut yield while soil quality affects negatively the yield (Table 4). But, supply of mineral fertilizers, organic manure and household waste as soil fertitily management strategies in the one hand and farmers' age, its level of education and land use duration on the other hand did not affect significantly groundnut yield improvement.

DISCUSSION

Groundnut producers' socio-economic characteristics and cropping pratices

It is shown by our results that men were more involved in groundnut production than women. This may be due to the fact that women do not really have access to land according to the custom. In many part of Africa, the customary rules restrict land ownership right to women (Saïdou et al., 2007; Loko et al.., 2013). The strong involvement of women in groundnut production in the AEZ 2 could be explained by the fact that, groundnut was not a crop of choice for men; they were more interested in cotton production. But the plots were often donated by the husband. The age of the farmers varies between 18 and 80 years. This implies that, this population was young enough, vigorous and had enough physical energy to support the development of groundnut cultivation if they were attracted. Younger segments of the population had access to long-term portions of land, so this justifies their passion for annual crops, including groundnuts (Balogoun et al., 2014). Groundnut cultivation was practiced by a young segment of the population and thus represented labour force for groundnut production. Similar results were reported by Dogbe et al. (2013) in Ghana and concluded that leguminous production has promising future if these relatively young farmers could be motivated to remain in the sector.

The area allocated to groundnut cultivation and its

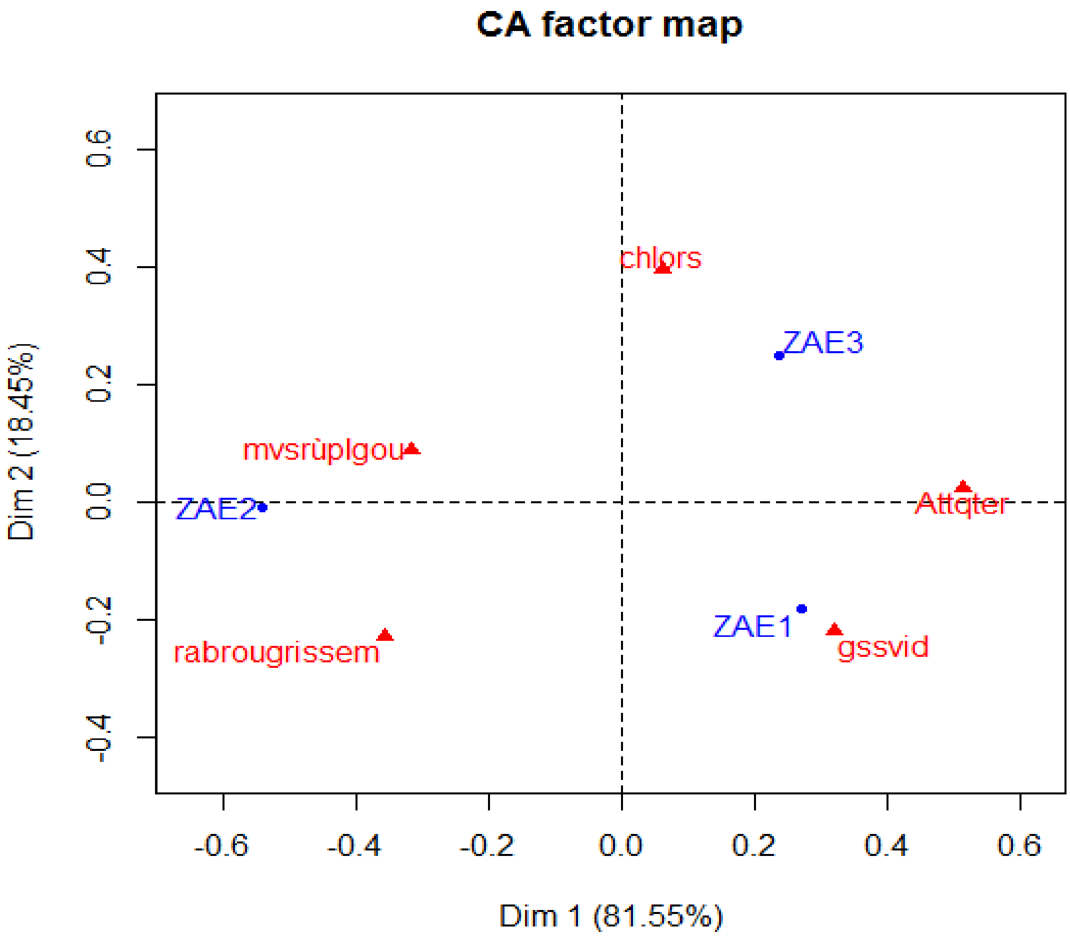

Figure 6: Farmers' perceptions on the effects of climate change on groundnut productivity. AEZ 2 = Northern cotton agro-ecological zone; AEZ 5 = Centre cotton agro-ecological zone; AEZ 6 = Sudano-Guinean zone on "*terre de barre*".Chlors = chlorosis of leaves; Attquer = pod attack by termites; stunting = stunting of plants; gssvid = empty pods; mvsrùplgou = poor pod filling.

Table 3. Determinants of groundnut yield improvement based on the cropping pratices using ordinal polychotomic logistic regression analysis.

Predictor	Coefficients	Standard error coefficients	Z value	Probability
Constante (1)	-5.1	2.8	1.8	0.05 ns
Constante (2)	-4.7	2.8	1.7	0.01*
Crop rotation	1.8	1.5	1.2	0.03*
Intercropping	-0.7	0.4	1.7	0.04*
Organic manure	-0.9	0.6	1.4	0.02*
Mineral fertilizer	0.05	0.4	0.1	0.03*
Crop residues management	1.7	0.5	3.4	0.001***
Household waste	1.9	0.8	2.4	0,02*
Integration of crop and livestock	-1.4	0.9	1.4	0,16 ns

ns = $p > 0.05$; * = $p < 0.05$ and *** = $p < 0.001$.

contribution to household income was very high in the AEZ 5. This could be explained by the fact that, groundnut crop was adopted earlier in this area and it is almost a cash crop for farmers (Naitormbaide, 2007; Didagbe, 2015). Shiyam (2010) also reported that groundnut is now gaining popularity as a high economic

Table 4. Determinants of groundnut yield improvement based on socio-economic characteristics of the farmers and cropping practices using ordinal polychotomic logistic regression analysis.

Predictor	Coefficients	Standard error coefficients	Z value	Probability
Constante (1)	-0.7	0.6	-1.2	0.04*
Constante (2)	1.6	0.6	2.5	0.02*
Sex	1.4	0.3	4.3	0.00***
Age	0.01	0.01	0.9	0.3 ns
Educationel level	-0.3	0.2	-1.3	0.2 ns
Experience in groundnut production	0.01	0.01	0.7	0.5 ns
Purpose of groundnut cultivation	-0.2	0.2	-0.9	0.4 ns
Duration of land use	-0.01	0.02	-0.6	0.6 ns
Organic manure	1.3	0.9	1.5	0.1 ns
Mineral fertilizer	0.5	0.4	1.1	0.3 ns
Household waste	0.3	0.5	1.2	0.9 ns
Integration of crop and livestock	-0.5	0.9	-0.6	0.6 ns
Soil quality	-0.8	0.2	-4.2	0.00***

ns = $p > 0.05$; * = $p < 0.05$ and *** = $p < 0.001$.

and cash crop for peasant households in the southern Nigeria.

In the three AEZ, mostly cereal crops were rotated with groundnut. Maize was the most commonly cereal used in this rotation sytem. In fact, farmers already noticed that groundnut has a fertilizing effect on subsequent cereal crop. On the one hand, the rotational system is based upon on the scientific evidence that leguminous crops planted in the first year will leave some nitrogen in the soil which will subsequently be fixed by the cereal crop in the next season and therefore will increase the potential yield of the cereal crop in that season unlike the continuous cereal system (Kabuli et al*.,* 2005; Nyemba and Dakora, 2010; Ngwira et al*.,* 2012). This practice was also a strategy for crop diversification in order to enhance food security (Ngwira et al*.,* 2012).

Intercropping of groundnut with cereal crops was soil fertility management pratice observed in the area. The main cereal crop involded is the maize. Several studies (Dagbenonbakin 2005; Li et al., 2006; Dahmardeh et al., 2010; Undie et al., 2012; Matusso et al., 2014) reported this common cropping pratices as a soil fertility management pratices with many advantages. Inter-cropping, was an old and commonly used cropping practice which aims to match efficiently crop demands to the available growth resources and labor (Lithourgidis et al., 2011). Moreover, intercropping improves soil fertility through biological nitrogen fixation with the use of leguminous, increases soil conservation through greater ground cover than sole cropping, and provides better lodging resistance for crops susceptible to lodging than when grown in monoculture. Intercropping provides insurance against crop failure or against unstable market prices for a given commodity, especially in areas subject to extreme weather conditions such as frost, drought, and flood (Tsubo et al*.,* 2005; Lithourgidis et al*.,* 2011). From this point of view, intercropping provides high insurance against crop failure and overall provides greater financial stability for farmers (Onduru and Du Preez, 2007). Thus, if a single crop may often fail because of adverse conditions, farmers reduce their risk for total crop failure by growing more than one crop in their field (Clawson, 1985).

Determinants of groundnut yield improvement

In general sandy texture of the soil was the most important criteria for groundnut cultivation. According to the groundnut producers' perception, this soil type facilitates root development and thus allows good pod production and also facilitates harvesting. This finding corroborates Schilling (2001) who reported that groundnut cultivation should be done on soils that are loose or loosened enough to allow the penetration of gynophores and then the removal of mature pods. In addition, groundnut requires well drained and aerated soils because the respiratory exchanges during pods setting are high. Fine textured soil, loose and permeable soils, especially sandy soils, were the most suitable.

Supply of mineral fertilizers, crop rotation, crop residues management and supply of household waste were the common soil fertility management practices noticed in tha area. Crop rotation is practiced by the majority of the farmers. In fact according to the perception of the farmers, growing groundnuts in rotation improves soil fertility and thus increases the yield of the subsequent crops. Bado (2002) showed that in a rotation system where sorghum is planted after groundnut, the yield is generally high. Most of the farmers burn their crop residues in the fields when preparing the land and few of them incorporate them in the soil when ploughing the land. The majority of the farmers did not know about the usefulness of incorporating crop residues in the soil when ploughing and when they are left in the field after harvesting, the herders' cattles destroye their crops when feading these crop residue. This is the reason for burning these crop residues.

In the AEZ 2 close to the sahelian zone, groundnut leaves are dried and used as animal feed during the dry season (Revoredo and Fletcher, 2002). According to Sossa et al*.* (2014), the return of crop residues is still a constraint for farmers noway. Several constraints including the status of the land, the low technical capacity of producers and the lack of financial resources to purchase inputs can interfere with the acceptability and adoption of crop residues management for soil fertility replenishment (Scopel et al., 2013).

Supply of mineral fertilizers remains low among groundnut producers. This practice is essential for sustainable groundnut production (Pacharne et al*.*, 2016; Abbas et al*.,* 2018). The overall soil fertility management strategies developed previously can be considered as low external input for sustainable agriculture as they did not require mineral fertilizer. Such practices could result in severe mineral nutrient deficiency in the soil in the rainfed agriculture where erosion is important. This was probably one of the major factors responsible for low groundnut yield in the traditional cropping system (Veeramani and Subrahmaniyan, 2012). According to Dagbenonbakin (2005); Bajrang et al. (2013) an adequate integrated nutrient management based on farm yard manure and macronutrients supply is important to improve the pod yield and quality of oil. Developing appropriate fertilizer doses in the different AEZ could contribute to improve groundnut yield at farmers' field level.

Some indicators are used to assess soil fertility level before taking decision for improvement. Such observations were also mentioned by Saïdou et al. (2004); M'Biandoun et al*.* (2006) and Akpo et al. (2016). Important indicators used by farmers are much more similar with those mentioned by several autors in West Africa such as the occurrence and abundance of certain types of weeds (Saïdou et al., 2004; Akpo et al*.*, 2016), vegetation height and plant leaves color as green mean fertile soil, intensive biological activity (presence of earthworm casts, termites gallery, presence of insects etc.) and yield of previous crop.

The groundnut seed yields noticed vary from one agro-ecological zone to another and are mainly influenced by the producers' sex and soil quality. This result could be explained by the fact that, soil fertility management practices vary from one zone to another and also by the fact that, the cropping systems were not uniform in the study area *f.i* land preparation for growing groundnut varied from flat ploughing to ridging which may affect soil fertility level therefore groundnut yield. In the study area, as mentioned by Saïdou et al*.* (2004) and Akpo et al*.* (2016) poor soils were mostly lease to the women. In such situation they do not have other choice to grow groundnut in opposite with men who mostly exploit lately cleaned land for groundnut production before maize cultivation as observed in crop rotation system. Climate variability observed nowadays could also explain groundnut seed yield variability among the three AEZ as mentioned by Bello et al*.* (2016). These climate factors varied from one AEZ to another with different rainfall regime and temperature. Annual rainfall amount was less in the AEZ 2 compared with those in the AEZ 5 and 6 which known more rainfall. The main concern now is rainfall distribution during the growing season. All of these climatic factors could affect drastically crop yield. In the case of groundnut yield improvement, it has to be taken into account in the process.

Finally, the supply of mineral fertilizer to groundnut did not affect significantly the seed yields. This could be explained by the types, method or doses of fertilizer input applied and the type of soils. Mostly in Benin, only fertilizer for cotton crop (NPK-SB 14-23-14-5-1) is widely available in the market. There is no specific fertilizer for food crops such as maize, leguminous and tuber crops (Dagbenonbakin 2005; Dagbenonbakin et al*.,* 2015; Saïdou et al., 2018). Also, the extension services do not take care of this crop as it is considered as traditional crop and they emphasized only on cotton the main cash crop promoted by the government. This calling was for the development of specific fertilizer formula emphasizing on both macro and micronutrients for balanced groundnut plant nutrition and for enhancing production in the three AEZ.

Conclusion

Groundnut cultivation is an important economic activity for farmers of the AEZ studied. It contributed to the household income generation and played an important role in the cropping systems. Our result shows that groundnut cropping system varied from one AEZ to another. Results of this study point out that, supply of organic manure, crop rotation, crop residues management and supply of household waste had significant and positive effects on groundnut yield level. Furhtermore, the sex of the farmers affect significantly and positively groundnut yields while soil quality affects negatively the yield. Therefore, it is concluded from the present study that, soil fertility management strategies planned by farmers considering their sexes and their additional sources of income are factors determining groundnut cultivation or not.

Nevertheless, our result did not show significant groundnut seed variability among the AEZ when mineral fertilizer is applied. This was explained by the type of soils, the quality, dose and farmer management practices among the zones. We suggest the development of specific fertilizer formula emphasizing on both macro and micronutrients for balancing groundnut plant nutrition and for enhancing its production in the three AEZ.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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