

Research Article

The Implications of Spatial Variations in Geographic Location, Geology and Pedology on Food Security in the Southeast Nigeria

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Abstract: The explanation of the associations and variations in geographic location, pedology and geologic formations for effective policy framework towards sustainability food production in Southeast Nigeria is the central objective of this study. The study area was stratified into five states. Data on textural classes were systematically collected from three states and at eight sampled points using commerce, wetland and non-wet land agricultural areas as indices and analyzed using laboratory and geo-spatial tools. The results indicated that pedologic characteristics of the study area vary with geographic spaces but particle size was dominated by sandy loam. The multivariate analysis of variance, tests of variations, homogeneity, and overlapping variances revealed that variations among geographic space and geologic formations have significant effect on the distribution of pedologic characteristics in the Southeast. Also, the spatial variabilities of geographic location, geology, and pedology in the southeast suggest dynamics in land capability class for crop yields which constitute major issue to agricultural development and the corresponding food security. The dominance of sandy loam soil is an indicator of the prevalence of class A and class B land (soils) while qualitative interview affirmed that most farmers still relied on the natural fertility of the soil for crop production, but the quality and quantity of their produced were often hampered by traditional/small size holdings. To sustain food security for the teeming population, this study recommended for massive evaluation of physicochemical and bio-geochemical properties of soil in the Southeast to provide basis for farmers' choice of crops; creation of more awareness and education of farmers on the type of crops that can yield better under certain pedo-geographic and geologic formations.

Keywords: Geographic Location, Pedology, MANOVA, Food Security, National Development

1. Introduction

1.1. Background

The quest for sustainability in agriculture to foster food security and national development has attracted the attention of various researchers in the 21st century. It is commonly agreed among geographers, land use and environmental resource planners that variations exist in the aerial distributions of distinct geographic phenomena in time and space. The dominance of agricultural activities as accelerated by the availability of expanse of underutilized or misused land (soil) have been identified as one of the most outstanding attributes of the developing economies like Nigeria [1].

It is estimated that approximately 1.2 billion people across the globe live in abject poverty while 160 billion children under the age of five years are malnourished with about 80 percent of the population residing in rural areas of African and Asian continents [2], Hazzel and Wood cited in Duru, Umo and Ojinma, [3]. Also, Nigeria has ranked among the top world hungriest country in 2018 [4]. The identified patterns and issues are indicators of poor agricultural production and the corresponding threats to food security and national development. The scenarios for the state of agricultural development and food security differ considerably among people in localities, and countries across the globe. Similarly, variations in pedology (soil type), geology, and climate of a given geographic space could have significant influence on

the type, quality, and quantity of crop produced by the people through time.

The pedologic attributes of a given geographic area coupled with its geologic formation collectively defined the degree of nutrients enrichment and the land capability for crop yields. Recently, Duru et al [3] observed that a functional and proactive soil management which is often control by the geologic formation are among the major catalyst to a sustainable food production and security for the teeming population across geographic spaces. Accordingly, developing agricultural sector for effective food security and national development entails building capacity for effective soil management through legal, institutional, leadership, partnership, training, and supportive frameworks [5]; depending on the degree of degradation that have set in [3]. The degradable state of soils (land) over space is an aspect of environmental challenges confronting humanity in the 21st century. The persistent population increase and the resultant increase in demand for land to boost crop production and built-up areas can collectively increase pressure and despoliation compounded by the climate change issues.

In Nigeria and southeast region in particular, where the rural economies are based on agriculture and commerce, the desire for food security is further complicated by poverty, misappropriation of geographic space, small size of holdings, low level of education, and abiotic factors such as pedology, climate, geology and local geomorphology [6]. The concept “food security” represents adequate food availability, accessibility, utilization, and stability to the people in a given geographic space (locality, region, or country) over a period of time [7]. The vitality and role of food in humans and allied organisms’ existence justify the need to gear more efforts toward ensuring adequate and sustainable food production and security [8]. For instance, the vulnerability of agricultural sector to climate variability, food production and supply usually posed serious challenges to the people thereby altering the pattern of food security and farmers’ income. Poor and infertile soils often played a de-accelerating role on crop yield per unit of land. Other constraints are pests, diseases, cost of land and cost of crop management practices [9].

The three basic questions that agitate the minds of the researchers in this study are:

- a. What is the dominant pedologic characteristic of the southeast Nigeria?
- b. Are there significant variations among the geographic location, geologic formations, and pedologic (soil) characteristics in the Southeast Nigeria?
- c. Do significant association exist between geographic location and geology, sand, clay, silt characteristics in the Southeast Nigeria?

The highlighted research questions form the focus of this investigation. Each issue will be analyse and discuss accordingly in a section of this study.

1.2. Aim and Objectives of the Study

The effectiveness of agricultural productivity and food security is the outcome of many factors that usually vary

across geographic spaces and time. Therefore, the causal explanation of the associations and variations in geographic locations (spaces), geologic formations and pedologic characteristics for enhance crop production in the southeast Nigeria is the aim of this study. To achieve the aim, the following specific objectives are investigated.

1. To assess the pedologic characteristic in the southeast Nigeria.
2. To determine whether there are significant variations among geographic space, geologic formations and pedologic characteristics in the southeast.
3. To evaluate the proportion of variances between geographic locations, geology, sand, clay, and silt characteristics in the southeast.

1.3. Research Hypothesis

This study is built on a null hypothesis that states thus: there is no significant variation among and between geographic space, geologic formations, and pedologic characteristics in the southeast.

1.4. The Study Area

Southeast Nigeria is located between Latitude 4°38' and 7° 05' North of Equator and Longitude 5°50' and 8°10' East of Greenwich Meridian. It is made up of five States (Abia, Anambra, Ebonyi, Enugu and Imo). The climate of the area grouped as Af (Humid Tropical) climate in the Southern part (comprising Abia, Imo, Anambra States) and Am (wet and dry climates) at the North (Enugu and Ebonyi States) based on Köppen's climatic classification scheme [10]. Similarly, the rainfall distributions vary across geographic space and seasons. The area usually received double rainfall maxima (April to July and August to November) with a mean annual total that ranges between 1,875 mm and over 2,500 mm and often diminishes from the North to the south [11]. The southern part of the region do received higher monthly and annual rainfall amount than the north with some exceptional situations induced by local factors (e.g. topography, hydrology, and land use). The variability in rainfall amount, frequency, density, and intensity offer the area unique conditions for the production varieties of crops such as palm tree, yam, cassava, rice, cashew, plantain, banana, coconut, cocoyam, pineapple, vegetables, rubber, maize, beans, cowpea etc. especially in the villages. The yield per unit of land is mostly determined by the soil natural fertility.

The pedologic attributes of the study area vary across geographic space and in time. In Aba area of Abia State, the soil is dominated purely Ferrallitic soils in nature with deep porous brownish colour. In Oguta area of Imo State, it is Pale brownish loamy Alluvium (classed as hydromorphic soils) due to the proximity to and influence of the Great Oguta Lake. Within the Abakaliki area of Ebonyi State, the soil is reddish brown gravelly and pale clayed soil derived from shale as a result of the ironstone concretions. In the Ikwo area of Ebonyi State, the soil is Pale brownish loamy Alluvium (hydromorphic soil) induced by the Great Cross River.

The geologic formations of the study area also vary across geographic space along with the pedology (Figure 1). For instances, the distributive patterns of the hydromorphic soils in the Aba and Ikwo areas of the southeast Nigeria is influenced by the recent Quaternary Alluvium deposits. Similarly, Ferrallitic soils in Aba area is accelerated by the Coastal Plains Sands of Tertiary Time (Holocene) deposits while the dominant of gravelly ironstone concretions in Abakaliki is associated with Cenozoic era which [12] opines that the Anticlinorium had undergoes some elements of rejuvenation following the prevalence of protracted erosion, weathering, and allied geomorphological processes.

Recent discourse on the variabilities and patterns in the distributions of pedology, geology and climate of the southeast Nigeria suggest differences in land use capability for distinct agricultural and allied practices in the region. The identified variables coupled with the land management/ ownership system may have very strong influence on food production and security

in the area and national development in general [1; 13].

2. Materials and Methods

This study is empirical in nature with emphasis on field survey, laboratory and map analyses. The study area was stratified into five areas based on states. Three States (comprising Abia, Ebonyi, and Imo) were systematically selected using agriculture, commerce, and administration as basic indices to facilitate equal representation. The geographic locations for sample collections were stratified into eight distinct units and eight series of samples systematically collected. The geologic formation was classified into four major groups: the Eze Aku formation (1), Asu River formation (2), Coastal Plains Sands Deposits of the Tertiary Times (3), and recent Quaternary Alluvium deposits (4). The codings were according to their ages of formations from oldest to the youngest (Figure 1).

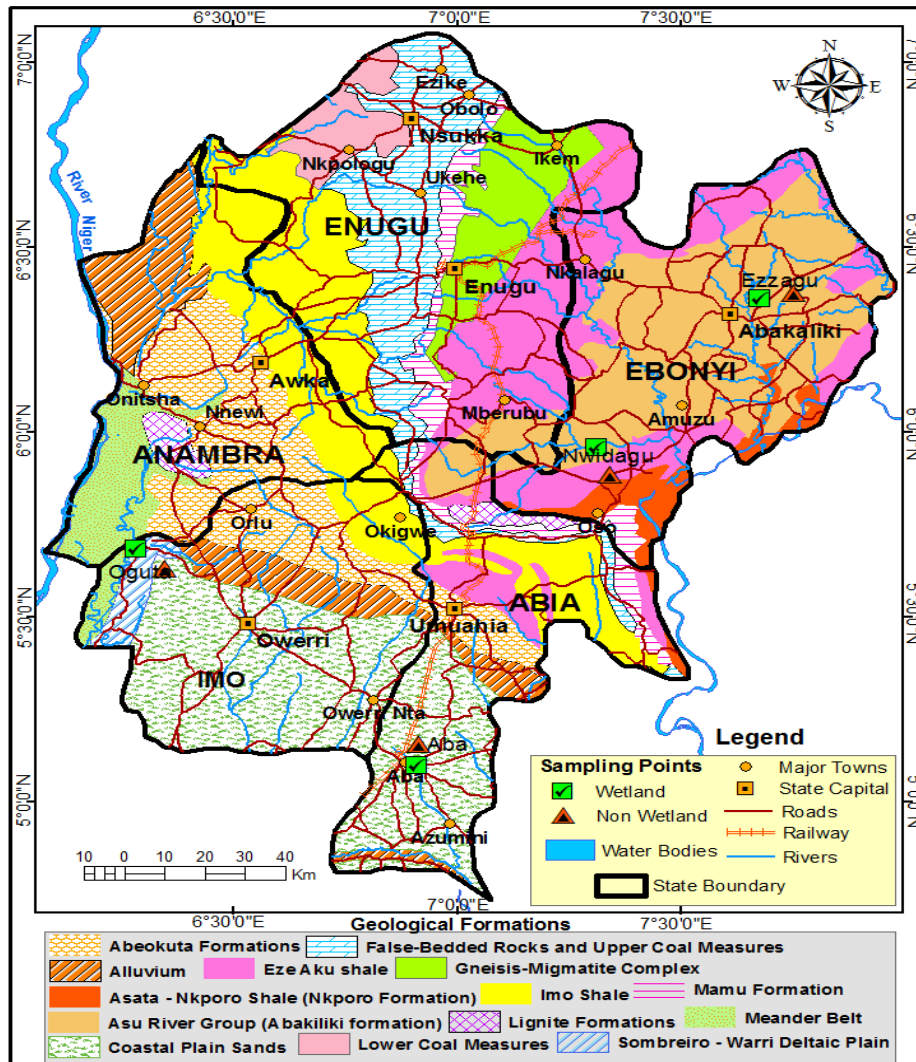


Figure 1. Southeast Nigeria showing Geologic Formations and Sampling Points.

Data on pedological characteristics were generated through direct field survey from wetland and non-wetland agricultural areas. The laboratory analyses used sedimentation (Bouguous

hygrometric) method. Samples for pedological classes were systematically collected using a (6.5×6.5cm) stainless steel soil corer at depths ranging from 0 – 19cm, 20 – 40cm, and 41

– 60cm [13] respectively to determine vertical variability each at wetland and non-wetland agricultural areas of the southeast. A total of 24 samples were collected during the surveys.

The collected soil samples from various points were packaged in the black polythene bags, labelled accordingly, and transported to the laboratory for further treatments and analyses. In the laboratory, samples were given appropriate treatments to ensure standard compliance and quality assurance, oven-dried at the temperature of 110°C for 24 hours to remove organic matters and chunk. The dried particles was homogenized and sieved using 2 mm mesh to eradicate gravel (size > 2 mm), while the pedologic (sand, silt, and clay) characteristics were retained. The analytical procedures and the calculations on their proportion were in

strict compliances to [14; 15; 16] recommendations.

Data generated from geographic locations, geologic formations, and pedologic characteristics were presented on Tables and analyzed using descriptive statistics {mean, standard deviation, and percentages} and multivariate statistics {multivariate analysis of variance (MANOVA), linear regression models}. The descriptive statistics provide the basis for comparisons while the multivariate analyses provide the frame for complex analyses, test of hypothesis, and answering research questions at appropriate degree of freedom (to ascertain the significant at 0.05 confidence level) [10]. The Statistical Packages for Social Sciences (SPSS) model 22.0 IBM, USA was used.

3. Data Analyses and Results

Table 1. Descriptive Evaluation of Pedologic Characteristics of the Southeast Nigeria.

Location	Type of Agriculture	Sand (mean)	Std Dev.	Silt (Mean)	Std Dev.	Clay (Mean)	Std Dev	Sample Size
Abakaliki	1. Non-wetland	45.67	6.4	15.40	1.7	38.93	8.2	3
	2. Wetland	52.33	.6	24.40	1.0	22.60	.0	3
Ikwo	3. Non-wetland	80.67	3.8	6.07	.6	15.27	1.2	3
	4. Wetland	69.67	5.5	15.07	5.7	15.27	1.2	3
Aba	5. Non-wetland	83.00	2.0	1.07	1.2	15.93	2.3	3
	6. Wetland	74.00	4.6	6.07	.6	19.93	4.2	3
Oguta	7. Non-wetland	84.00	1.0	.40	.0	15.60	1.0	3
	8. Wetland	87.00	.0	.40	.0	12.60	.0	3
Total		72.04	15.0	8.62	8.6	19.52	8.6	24

1 & 2 = Abakaliki; 3 & 4 = Ikwo (Ebonyi); 4 & 5 = Aba (Abia); 6 & 7 = Oguta (Imo).

Source: Authors' Analyses (2021).

Table 2. Multivariate Tests ^a of Variations among Geographic location, Geology, and Pedology in the Southeast Nigeria.

Effect	Statistical Test	Value	F	Hypothesis df	Error df	Sig.
Geographic Location	Pillai's Trace	2.073	5.112	21	48	.000
	Wilks' Lambda	.004	11.185	21	40	.000
	Hotelling' Trace	36.323	21.909	21	38	.000
	Roy's Largest Root	31.685	72.422 ^c	7	16	.000

a. Design: Intercept + Geographic location. b. Exact statistic. c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Source: Authors' Analysis (2021).

Table 3. Test of Variations between Subjects in the Southeast Nigeria.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	R Squared	Adjusted R Squared
Corrected Model	Geology	30.000 ^a	7	4.286	8.324	.000	1.00	1.000
	Sand	4964.292 ^b	7	709.185	50.506	.000	.957	.938
	Silt	1625.292 ^c	7	232.185	48.456	.000	.955	.935
	Clay	1496.500 ^d	7	213.786	18.456	.000	.890	.842
Error	Geology	.000	16	.000				
	Sand	224.667	16	14.042				
	Silt	76.667	16	4.792				
	Clay	185.333	16	11.583				

Source: Authors' Analysis (2021).

4. Discussion of Results

4.1. Variations in Pedologic Characteristics

The results of the laboratory analyses of pedologic attributes across geographic location were presented in tables for easy perusal and comparisons. The descriptive analysis

summarize in Table 1 reveals that the mean distributions of pedologic properties vary across geographic locations. At Abakaliki, the mean distribution of sand showed 45.67 percent for the non-wetland agricultural area and a standard deviation of 6.4. The mean distribution of sand for the wetland agricultural area offers 52.33 percent and a standard deviation of 0.6. Also, the mean distribution of silt gave 15.40 percent

for the non-wetland agricultural area and 24.40 percent for the wetland. The clay distribution revealed 38.93 percent for the non-wetland agricultural area and 22.60 percent for wetland agricultural area.

In the Ikwo, the distributions of sand give 80.67 and 69.67 percent for non-wetland and wetland agricultural areas respectively. The silt reveals 6.07 and 15.07 percent for non-wetland and wetland agricultural areas. Similarly, the mean distribution of clay indicates a uniform pattern of 15.27 percent each for the non-wetland and wetland agricultural areas. The standard deviation of the distribution for Ikwo sample unit ranged between 0.6 for silt at the non-wetland and 5.7 for silt at the wetland agricultural areas.

The distribution of sand at Aba showed variations with the higher mean value of 83.00 percent for non-wetland agricultural area and 74.00 percent for the wetland agricultural area. The silt distributions reveal the mean values of 1.07 percent for non-wetland and 6.07 percent for the wetland agricultural areas. Also, the clay distributions offer 15.93 percent for non-wetland and 19.93 percent for the wetland agricultural areas. The standard deviations of the pedologic characteristics at Aba reveal that the highest value of 4.6 percent is associated with sand for the wetland agricultural area while the lowest value of 0.6 is associated with silt for the non-wetland agricultural area.

In Oguta, the mean distributions of sand reveal the value of 84.00 percent in the non-wetland and 87.00 percent for the wetland agricultural areas. Silt indicates a uniform value of 0.40 percent each for the non-wetland and wetland agricultural areas. The clay distribution yields a value of 15.60 percent for the non-wetland and 12.60 percent for wetland agricultural areas. On the other hand, the standard deviation of the distributions vary across space and variables with a value that range between 0.0 recorded at four distinct points for the lowest and the highest the value of 1.0 is recorded consecutively as depicted in Table 1.

The distribution pattern of the pedologic characteristics across geographic space show strong affinity with the geologic formations. For example, the distribution of sand attribute is more prevalent at the Abakaliki, Aba, and Ikwo non-wetland agricultural areas than Oguta that the sand variable is most dominant at the wetland agricultural area. Similarly, the general pattern in the distribution of pedologic characteristics give the mean values of 72.04 percent for sand, 8.62 percent for silt, and 19.52 percent for clay respectively. The classification pedologic characteristics using United Department for Agriculture (USDA) as cited in [10] scheme reveals that the study area is dominated by sandy loam, follows by clay loam classes.

4.2. Effects of Geographic Space, Geology and Pedologic Characteristics

In consideration of research objective two, a General Linear Model (GLM) with option in MANOVA is employed as a surrogate to determine whether there are significant variations among geographic locations, geologic formations, and pedologic characteristics in the Southeast

Nigeria.

The results of the MANOVA model presented on Table 2 are quite intriguing. The assessment of homogeneity among the groups of parameters using Pillai's Trace statistics yields a value of 2.073 which is a good representative statistic. The calculated F value associated with the model offers a positive result of 5.112. A test of significant at $(0.05)_{21/48}$ confidence level gives a Table value of 1.7444. The result of the Pillai's test reveals that there are significant variations among the geographic location, geologic formations, and pedologic characteristics in the southeast. The variations could influence the type, quality and quantity of the regional crop production, food security and national development.

Similarly, Wilks' Lambda is used as a surrogate to determine the multivariate effects of variations in geographic space and geologic formations on the linear combinations of the distribution of pedologic variables in the southeast. The model result presented on Table 2 yields a statistical value of 0.004. The calculated F value using Wilk's Lambda model offers 11.185. A test of significant using the Table value at $(0.05)_{21/40}$ confidence level yields 1.7444. The results sustain that there are significant variations among geographic space, geologic formations and pedologic attributes in the southeast Nigeria (Table 2).

In another perspective, Hotelling's Trace statistic is used as alternative to determine the association since it operate with the highest matrix and the result gives a value of 36.323. The computed F value yields 21.909 while the test of significant at $(0.05)_{21/38}$ confidence level offers 1.7444. The pattern in the results validated the notion that there are significant variations among geographic space, geologic formations, and pedologic characteristics in the southeast Nigeria.

Roy's Largest Root is used as a surrogate to measure the association's strength based on the proportion of overlapping variances among the independent variables and the first linear combination of dependent variables. The result of Roy's model gives a value of 31.685. The calculated F value offers 72.422. A test of significant at $(0.05)_{7/16}$ offers a Table value of 2.6572. Since the calculated F value is higher than the Table value tested at 0.05 confidence level, it is therefore inferred that there are significant variations among geographic space, geologic formations, and pedologic characteristics in the southeast Nigeria. In spite of differences in parameters used, the results corroborated that of [10] in the Kwa Iboe River Basin. This similarity is possibly due to similarities in geologic formations, pedologic characteristics, and historical evolution of landforms in the region. The results presented on Table 2 are clear indicators that the viability of agricultural production in the southeast Nigeria relied on diverse geographic factors. These factors range from natural (climate, soil, geology, topography and natural hazards) to human interferences (land use, farm preparation, management practices, systems of land ownership, and crop varieties).

4.3. Proportion of Variances and Associations between Subjects

In consideration of the null hypothesis that states thus: there

is no significant variation between geographic location, geologic formations, and pedologic characteristics in the southeast Nigeria, MANOVA is used. The effect of variation between subjects as summarize in Table 3 was explored using type three error model as a surrogate to avert the differences associated with sample sizes and cell effects [10].

From Table 3, the results of the type three sums of squares model of variation between subject gave 30.000 and F value of 8.324 for geology; sand yielded a sum of square value 4964.292 and F value of 50.506; silt offers a sum of square value of 1625.292 and F value of 48.456 while clay offers a sum of square value of 185.333 and the F value of 11.583. However, a test of significant at $(0.05)_{7/1}$ confidence level gave a Table value of 2.6572. In consideration of the results, it is therefore inferred that significant association exist between geology and pedologic characteristics (sand, clay and silt) in the Southeast. The result suggested that each subject is crucial in context of nutrients enrichment and land capability for specific set of crops yield across geographic space and in time.

In another perspective, a regression model is employed as a surrogate for the determination of the proportion of variances accounted for on a linear combination of each subject in the series (see Table 3). The results show that the R squared of the model associated with geologic formations yields a perfect positive coefficient of 1.000 that explains 100 percent of the total variance. The R squared value for sand gave a value of 0.957 that accounted for 95.7 percent of the variance in the series. Similarly, silt offered the R squared value of 0.955 that explains 95.5 percent of the proportion of variance in the series. Finally, clay offered R squared value of 0.890 representing 89.0 percent of the proportion variance accounted for in the model. The identified variables revealed strong associations. The regression coefficients and the corresponding proportions of explainable variances corroborated the finding reported in [10], though with strict emphases on fluvial sediment processes in the Kwa Iboe River of Southeastern Nigeria.

5. Implications on Food Security and Regional Agricultural Development

In consideration of the findings based on the quantitative evaluations, it is clear that significant variations exist among geographic locations, geologic formations, and pedologic characteristics in the southeast Nigeria. The implication is that land capabilities for crop (agricultural) production vary with geographic location, geology and pedology. The prevailing geology defined the pedologic features and the pattern of nutrients enrichments. The nutrient enrichments usually played accelerating or de-accelerating role on food production and security which a country depend on for its socio-economic and agricultural development. Therefore, while some areas possess very high quality class, others do not. The variations in quality often requires of appropriate management strategies [3, 17] to boost crop yield per land (soil) for enhance food security, eradicate hunger, and poverty [17].

Similarly, this study also established that significant association exist between geographic space and geology, sand, clay, silt characteristics in the Southeast. This is an indication that while geographic space varies with distant and location, the geologic formation defines the characteristic of pedology and the soil nutrients' endowments in each area. The unity between various variables further suggests the need for land users and managers to choose appropriate crops and strategies that will enable them get the best crop outputs from their farm lands while sustainably maintaining the quality of the land capability for agricultural productivity.

6. Conclusion and Recommendations

The role of agriculture in food security and national development had long been emphasized in Abumere [9] but often constraint by some stringent human and natural factors. The diversities of the geology, climate, and pedology across geographic locations in the southeast suggest variability in soil capability for crop yields. These constitute major issues to agricultural development and the corresponding food security. The dominance of sandy loam soil is an indicator of the prevalence of class A and class B land (soils) which suggest that most farmers still relied on the natural fertility of the soil for crop production, but the quality and quantity of the produced are been hampered by traditional/ small size holdings, limited capital investment and skills.

The quantitative evaluation of distinct parameters showed that variations in geographic space and geology do have significant implication on the pedological characteristics of the southeast Nigeria. This invariably affects the proportion of crop production and food supplies to meet the high demand of especially the low and middle income earners with limited purchasing capacity. Therefore, to secure adequate food availability, accessibility, utilization, and stability as observed in [7] to the teeming populace that are often underfed and malnourished. The identified constraints required adequate attention. To accomplish that, this study makes the following recommendations.

1. Government at various levels should partner the international donor agencies and communities to carry out comprehensive soil capability surveys in order to determine the bio-physical, geo-chemical and pedological properties to provide basis for the farmers' choice of crops. This is necessary given that variations in geographic spaces and geologic formations have strong influence on the pedologic attributes as well as soil nutrients enrichment and crop yield per land. Such valid soil surveys will invariably boost food production and security for national development.
2. More efforts should be directed towards the creation of more awareness and education of farmers and other land (soil) users on the type of crops that can yield better under certain pedologic and geologic formations in the Southeast Nigeria. The awareness and farmers education will be very successful and cheaper, if agricultural extension officers, youth Corpers, teachers and retirees

are actively engaged at the local level.

3. The patterns in funding agriculture through subsidies, loans, and grants by Federal and State governments should be sufficient to meet the receivers' requirements. In case of loans, the terms and conditions need be feasible and affordable to avert indebtedness among rural farmers (poor) and other land users or allied beneficiaries.
4. There is need to emphasize more on grants and subsidies that are appropriate to the situations of (poor) farmers as in the case of World Bank, Food Agriculture Organization, and other multi-national agencies. This justifies a fact that most farmers cannot afford viable insurance services for their farms.

Declaration

The authors declare that there is no conflicting interest in this article

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