LAND SUITABILITY EVALUATION FOR SESAME (*Sesamum indicum* L.) PRODUCTION IN BEKWARRA LOCAL GOVERNMENT AREA, CROSS RIVER STATE, NIGERIA

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ABSTRACT
Land evaluation involves soil data acquisition, analysis and categorization which puts data in a useful form for public consumption. The current study was to evaluate each soil unit in Bekwarra Local Government Area for the production of sesame. Satellite imagery of Anyikang was obtained from google earth, and the contour map generated in the ArcGIS 10.2.1.3 environment. Four spatial toposequences were identified. Along each of the four toposequences, one profile pit was dug in the crest, middle slope and lower slope positions. A total of 12 profile pits were therefore studied in the 33.32 ha tract of land. The soils were very deep (>150 cm), with soil pH of 4.5 – 6.1, while organic carbon was low to moderate. Currently, 1.19, 14.56 and 17.59 ha of the map extent were classified as moderately, marginally and currently not suitable, respectively for sesame cultivation. Upon proper management, a great proportion of the tract was upgraded. Consequently, potential aggregate suitability resulted in the qualification of 9.51 and 23.81 ha of the map extent as highly and moderately suitable for sesame production. Therefore, a good percentage of land that was currently not suitable or marginally suitable was later upgraded, potentially to highly or moderately suitable because of the removal of limitations due to either sum of basic cations, soil pH or soil organic carbon. The difficult-to-alter properties were suitable for sesame, while the partly limiting properties were easily altered and adjustable. There is therefore ease of upgrading the properties where they are found to be limiting in order to obtain more suitable tracts of land for sesame production.

Keywords: sandstone, southern guinea savanna, sesame, land evaluation, land suitability

INTRODUCTION

Sandstone is sedimentary in origin and often laid down as layers of loose grains compacted and cemented to form rocks. It is brittle and has silica or quartz as a major component. It is clastic in origin and formed by compaction, desiccation and cementation of detrital sediments such as sand, silt, clay and gravels (Esu, 2010).

Sandstone covers about 18 % of the land area of Nigeria and occurs in all major ecological zones (Ogunwale and Ashaye, 1975). Soils formed from sandstone are usually shallow, sandy and stony or gravelly and are generally erodible (Bulktrade, 1989). In Cross River State, the soils are fragile, acid, low in native fertility and have been reported to have been found to dominate Bekwarra, Yakurr (Ofem *et al*. 2020, Ofem *et al*. 2022) and parts of Ogoja. However, the marginal soils are intensively cultivated by farmers (Udoh, 2015) and are often leached of basic cations which result in the low pH, phosphate deficiency and fixation, as well as Al toxicity (Obasi *et al*., 2011). The low fertility condition of the soils has further compounded its management. Therefore, evaluating the soils alongside other land components is necessary as a prerequisite sustainable crop production.

Land suitability is the degree of appropriateness of a tract of land for a specified use. The procedure evaluates the ability of the land to tolerate the production of specified crops in a sustainable way and allows for the identification of limiting factors for agricultural production as well as enables decision makers to develop crop management strategies that can increase land productivity (Rabia, 2012). It is therefore seen as a step ahead of pedological characterization of soils; identifying land limiting properties and prospects, as well as its response to land use, currently and potentially.

Sesame seeds otherwise called 'bene-seed' are one of the highly sought-after cash crops in Nigeria and second to cocoa in terms of export value. Annual exports of sesame from Nigeria are estimated at about USD 459,443,483, and Nigeria is the major supplier of sesame seed to Japan, Turkey, China and India which are the world's largest importers (USAID, 2002; Dream Vista Global Resources Ltd., 2025).

A fundamental knowledge of land use planning is required to meet the farming challenges of the 21st century as well as assist farmers in decision making in order to make recommendations for utilitarian purposes. Knowledge of the properties of these soils will enhance the design of appropriate soil management practices that will boost commercial production of sesame in the study area. Over the years, the consumption of sesame as food has masked its industrial use mainly due to low production of the crop in the study area possibly due to insufficient land evaluation for the purpose (Wacal et al. 2024).

This land suitability evaluation is an avenue to mitigate land degradation which may result from wrong allocation of land resources to land uses. This study is apt as it will identify parcels of land with comparative advantage for sesame production and will result in higher economic return for sesame production in Bekwarra Local Government Area. This study was conceived to evaluate tracts of lands in Bekwarra Local Government Area of Cross River State, Nigeria for suitability for sesame production.

MATERIALS AND METHOD

Location details of the study area

The research was sited in Anyikang - Bekwarra LGA, Cross River State found within longitudes 4^{o}21' and 6^{o}45' E, and latitudes 7^{o}15' and 9^{o}28' N. Vandikyia (Benue State) is found in the north of Bekwarra LGA, in the North-west is Yala LGA, while Obudu LGA is found in the east and in the South is Ogoja LGA in Cross River State (FIG. 1).

With equatorial climatic condition, Bekwarra has a distinct wet season (March – November) and a short period of dry spell in July/ August. The dry season is often in November and early March, but climaxes in December/ January. The annual rainfall has range of 1750 - 2000 mm, while annual relative humidity is within 60 - 70 % and annual temperature is 27 - 28 ^{o}C.

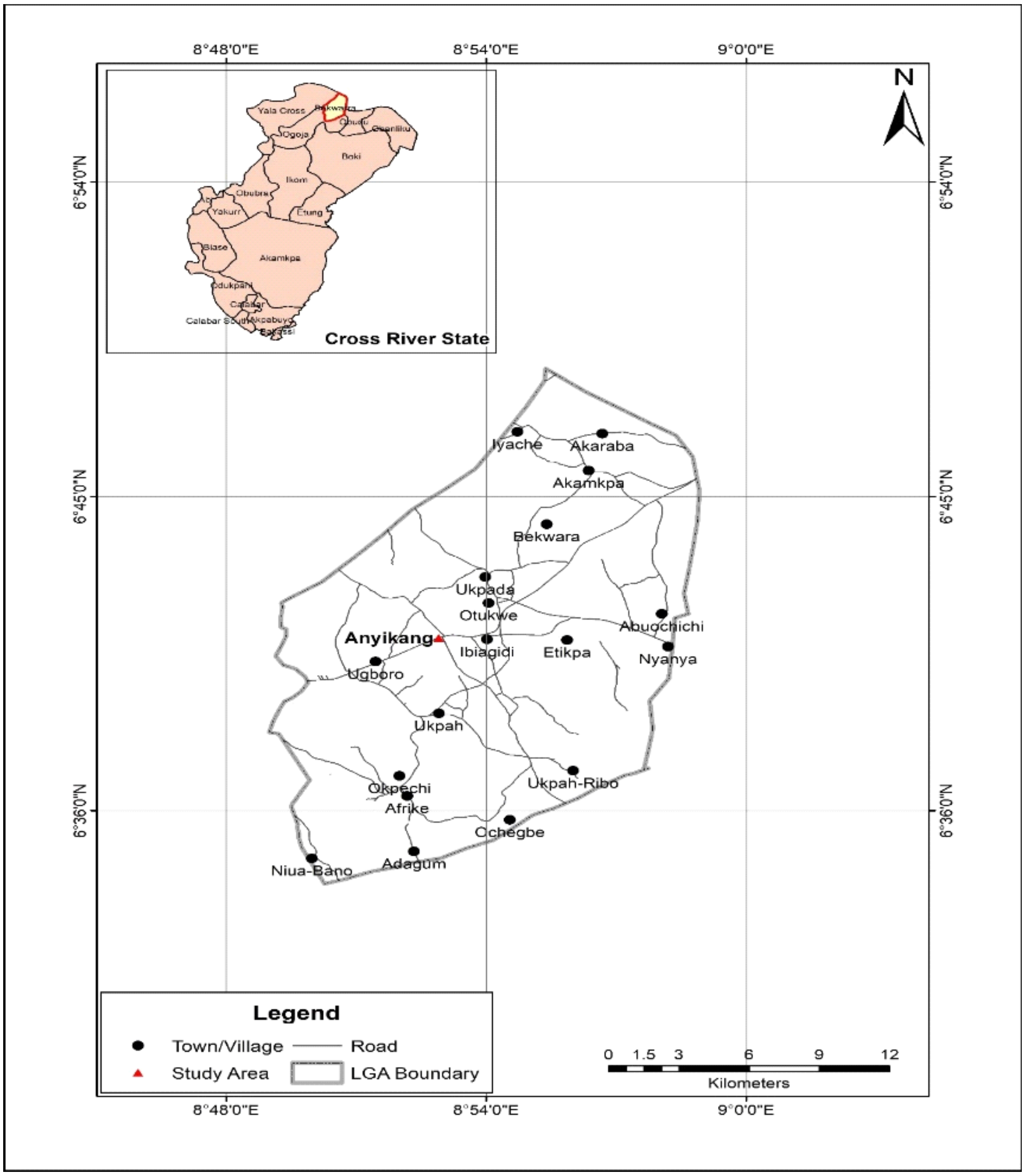

FIG. 1: Map of Bekwarra Local Government Area showing the area of study

The soils are developed on a bed of sedimentary formation of ferruginous fine-grained sandstones developed on acid crystalline rock of granite and gneisses. The vegetation transits the tropical rainforest and Guinea savanna, and is generally described as southern guinea savanna, and characterized by few forest trees, grassland, farmland, shrubs, with pockets of immature forests of the derived savanna zone. Major crops consist of sesame, yam, banana, groundnut, maize, mango, orange, millet, rice, and sorghum.

Field study

The satellite imagery of Anyikang was obtained from google earth (Plate 1) and the contour map generated in the ArcGIS 10.2.1.3 environment which was aided by the coordinates obtained using hand-held GPS device. With this, elevation ranges

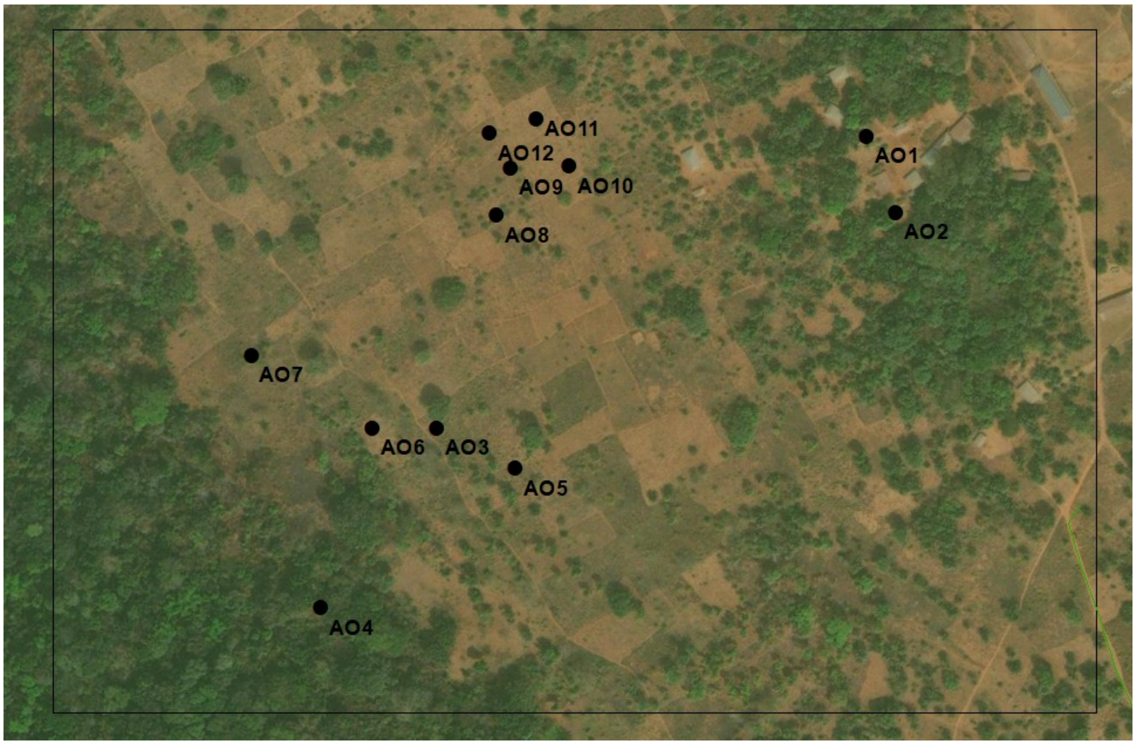

Plate 1: Satellite imagery showing the map extent of Anyikang, Bekwarra LGA

Soil samples for analyses were collected from pedogenic horizons using the bottom – top approach into well-labeled zip-lock bags and transported to the laboratory.

Laboratory studies

Soil samples were air-dried to constant weight, ground with wooden pestle and sieved with 2 mm sieve. Processed soil samples were subjected to physical and chemical analyses using standard procedures as described in Soil Survey Staff (2014). The Bouyoucos hydrometer method was employed to determine particle size distribution from which soil textural classes were determined using the USDA soil textural triangle. Soil pH was determined electrometrically in soil-water ratio of 1:2.5 using a pH meter, whereas soil organic carbon content was determined by the modified Walkley-Black wet digestion and combustion method, while the titrimetric method was employed to determine basic cations (K^+, Ca^{2+}, Mg^{2+}, Na^+) using NH_4OAc as the extractant. Cation exchange capacity (CEC) was obtained by the NH_4OAc displacement method at pH of 7.0. Finally, base saturation was calculated by expressing the sum of exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) as a percentage of CEC.

Procedures for Land suitability evaluation for Sesame production

The procedures for land suitability evaluation are as outlined in Ofem *et al*. (2022). Land requirements and limitations ratings for sesame production were obtained and presented in Table 1. This information were compared to profile data for placement in suitability classes. Ratings indicating adequacy or inadequacy of land qualities for sesame production were used to explain the extent of the limitations, while the most limiting factor was assumed to determine the overall suitability ratings. Thus, the square root method was used to determine the index of productivity. The index of productivity (IP) for each pedon was computed for the parametric method using the equation: IP = Ax √B/100 x C/100… x E/100; Where, A = Overall lowest characteristic rating, B, C…E = the lowest characteristics rating for each land quality group. Since strong correlations exist within climate (c), wetness (w), slope or topography (t), physical soil characteristics (s), soil fertility (f), only one member of each group will be used in the calculation.

RESULTS AND DISCUSSION

Land Suitability Evaluation for Sesame Production in Bekwarra

Land characteristics of the area are corrected to 60.00 cm depth and presented in Table 2. These characteristics in comparison with values in Table 1 gave rise to the suitability classes, scores rating and aggregate suitability rating in Table 3.

Land requirements for sesame

Temperature, rainfall and relative humidity characteristics representing 'c' were optimum for the cultivation of sesame (Table 2) with suitability scores ranging from S1 (90.00) to S1 (100.00) for these climatic factors. Climate did not constitute a limitation for sesame in Bekwarra. The topography (t) of the study area was highly suitable for sesame cultivation with a score of S_1 (90.00 - 95.00), while 'w' characteristics (drainage and flooding) had rating of S_1 (100.00) in all pedons. These characteristics do not constitute a limitation for sesame cultivation as the soils were well-drained and free of flooding. Soil texture was optimum with suitability class score of S_1 (98.00) which was good for plant nutrients and moisture retention with reduced leaching. Similarly, soil depth was optimum for the studied pedons with suitability class scores of S_1 (100.00) as soil depth generally exceeded 60 cm required for sesame production.

Soil fertility

The soils were optimum in terms of apparent cation exchange capacity (ACEC) with a suitability class of S_1 (100.00). However, base saturation witnessed slight variation in suitability; the suitability class scores had range of S_2 (80.00) - S_1 (100.00) in the crest, S_2

TABLE 1
Land use requirements for suitability classes for sesame production (limitation- parametric method of evaluation)

Land Characteristics	Class, degree of limitation and rating scale					
		S1	S2	S3	N1	N2
	0	1	2	3		4
	100-95	95-85	85-60	60-40	40-25	25-0
Climate (c)						
MAR(mm/yr)	1750-2000	2000-2750	2750-4750	>4750	-	-
MAT (°C)	25-24	24-20	20-18	18-16	-	<16
RH (%)	<60	60-65	65-75	75-85	-	>85
Topography (t)						
Slope (%)	0-2	2-4	4-8	8-16	-	>16
Wetness (w)						
Flooding	Fo (No flooding limitation)	- (No flooding limitation)	F1 Slight limitation; no longer than 1-2 mths	F2 Moderate limitation; 2-3mths of flood in every 5-10 yrs	- -	F3+ Severe limitation; Every year, 2-4 mths of flood.
Drainage	Well	Moderate	Imperfect	Poor and aeric	Poor but drainable	Poor, not drainable
Physical characteristics (s)						
Texture	SiCL, CL, L, SL	SiC, SiL, SC	LS, C, Co	C>60, S	-	C, cS
Soil depth (cm)	>100	100-75	75-50	50-30	-	<30
Soil fertility (f)						
ACEC (cmol/kg)	>24	24-16	<16(-)	<16(+)	-	-
BS (%)	>80	80-50	50-35	<35	-	-
SBC	>6.5	6.5-4.0	4.0-2.8	2.8-1.6	<1.6	-
pH (H_2O)	6.3-6.2, 6.3-6.5	6.2-5.8, 6.5-7.0	5.8-5.5, 7.0-7.5	5.5-5.2, 7.5-8.2	<5.2 -	- 8.2
Org. C (%)	>2.0	2.0-1.2	1.2-0.5	<0.5	-	-

Sys *et al*. 1993; F1 = slight, CL = Clay loam, C= clay, SCL= sandy clay loam, S= sand, SiCL= silty clay loam, SL= Sandy loam, lty clay, SiL= Silty loam, SC= Sandy clay, LS= Loamy sand, Co= Cobbly, S= Sand, Cs= very fine clay, S1=highly suitable, lerately suitable, S3=marginally suitable, N1=presently not suitable, N2=permanently not suitable. MAR= mean annual rainfall, Mean annual temperature, RH= Relative humidity, CF= Coarse fragments, ACEC= Apparent CEC, BS= Base saturation, SBC= basic cations, Org. C= organic carbon

(80.00) - S_1 (100.00) in the middle slope and S_2 (83.00) - S_1 (100.00) in the lower slope. Though the soils were not limited due to base saturation for sesame production, the variation suggest varied leaching rates across positions leading to a possible variation in suitability for sesame.

Sum of basic cations (SBC) also fluctuated with landscape positions. In the crest, the suitability class scores range was N_1 (40.00) - S_1(86.00), and N_1 (43.00) - S_2 (70.00) in the middle slope, while the lower slope was S_3 (50.00) - S_2 (80.00). The soils were slightly (S2) to severely limited (N1) in the SBC for sesame production and must be managed by the use of appropriate fertilizers to boost the cation saturation of the soil exchange complex.

Soil pH constituted a major limitation for the cultivation of sesame in most of the studied soils with suitability class scores fluctuating across slope position. In the crest, suitability class was N1(40.00) - S3 (55.00), S3 (45.00) - S2 (80.00) in the middle slope and N1 (40.00) - S2 (70.00) in the lower slope. Pedons that are rated N1 and S3 have very severe to severe limitations and must be limed with appropriate liming materials to ameliorate the acidity conditions for improved sesame production. This portrays soil pH as the most influential characteristic in the area for sesame production and will most likely influence its production according to Liebig's law of minimum.

Soil organic carbon varied with positions for sesame cultivation and constitute slight (S2) to severe (S3) limitations. S3 (55.00) - S2 (75.00) was obtained in the crest, S2 (65.00) - S2 (80.00) in the middle slope, and S3 (58.00) - S1 (90.00) in the lower slope position. Areas with moderate or severe limitations can be managed by the use of composts, animal manure, or return of plant residue to the soil.

TABLE 2: Land characteristics of the area corrected to 60.00 cm depth

Pedon	MAR Mm/year	MAT oC	RH %	Slope %	FL	DR	Texture	Depth Cm	ACEC cmol/kg clay	BS %	SBC* cmol/kg	pH*	OC* %
A01	1750-2000	27-28	60 - 70	1.5	Fo	WD	SL	188	92.5	62.5	3.79	4.8	0.7
A04	1750-2000	27-28	60 – 70	1.5	Fo	WD	SL	190	81.2	74	2.56	5.4	0.5
A07	1750-2000	27-28	60 – 70	1.5	Fo	WD	SL	189	106.1	41	1.57	5.1	0.5
A010	1750-2000	27-28	60 – 70	1.5	Fo	WD	SCL	200	69.8	54.5	2.18	5.4	0.05
A02	1750-2000	27-28	60 – 70	1.5	Fo	WD	SCL	190	90.5	62	3.3	4.9	0.6
AO5	1750-2000	27-28	60 – 70	1.5	Fo	WD	SCL	190	70.8	83	4.8	5.6	0.6
AO8	1750-2000	27-28	60 – 70	1.5	Fo	WD	SCL	186	80	47	1.98	5.3	0.6
AO11	1750-2000	27-28	60 – 70	1.5	Fo	WD	SL	190	80	63	2.47	5.8	0.06
A03	1750-2000	27-28	60 – 70	2.0	Fo	WD	SL	198	84.2	59.5	2.97	4.7	4.7
AO6	1750-2000	27-28	60 – 70	2.0	Fo	WD	SL	194	83.3	73.5	3.15	4.9	4.9
A09	1750-2000	27-28	60 – 70	2.0	Fo	WD	SCL	200	72.9	50.5	2.28	5.6	5.6
AO12	1750-2000	27-28	60 - 70	2.0	Fo	WD	SCL	170	65.9	49.5	2.25	5.3	5.3

FL: Flooding, Fo: No flooding, DR: Drainage, WD: Well drained, RH: Relative humidity, MAT: Mean annual temperature, MAR: Mean annual rainfall, ACEC: Apparent CEC, BS: Base saturation, SBC: Sum of basic cations, OC: Organic carbon, *: chemical properties that are easily altered and masked, SL: Sandy loam, SCL: Sandy clay loam

Aggregate suitability rating of the studied soils for sesame production

Parametric method: Currently, no pedon was highly suitable, one pedon was moderately suitable, while six pedons (AO12, AO9, AO6, AO11, AO2, AO4) were marginally suitable with aggregate suitability rating ranging between 40.1 and 54.9. Furthermore, five pedons (AO1, AO7, AO10, AO8, AO3) were currently not suitable for sesame production with aggregate suitability rating ranging from 35.6 to 39.4 (Table 3). The distribution of these suitability ratings is shown in Figure 2.

Potentially, the pedons were more suitable with AO1, AO4, AO5, AO6, and AO9 rated as highly suitable (S1) with aggregate suitability ratings exceeding 85.00 %. Furthermore, seven

TABLE 3

Land Characteristics and Rating Index for Sesame Production

Pedon	MAR	MAT	RH	Slope	FL	DR	Texture	Depth	ACEC	BS	SBC*	Soil pH*	OC*
A01	S1(98)	S1(100)	S1(90)	S1(95)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S1(89)	S1(86)	N1(40)	S2(75)
A04	S1(98)	S1(100)	S1(90)	S1(95)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S1(100)	S2(65)	S3(55)	S3(55)
A07	S1(98)	S1(100)	S1(90)	S1(95)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S2(80)	N1(40)	N1(40)	S2(70)
A010	S1(98)	S1(100)	S1(90)	S1(95)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S2(80)	N1(40)	S3(50)	S2(60)
A02	S1(98)	S1(100)	S1(90)	S1(95)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S1(85)	S2(70)	S3(45)	S2(70)
A05	S1(98)	S1(100)	S1(90)	S1(95)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S1(100)	S2(70)	S2(70)	S2(80)
A08	S1(98)	S1(100)	S1(90)	S1(95)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S2(80)	S3(43)	S2(68)	S2(68)
A011	S1(98)	S1(100)	S1(90)	S1(95)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S1(85)	S3(60)	S2(80)	S2(65)
A03	S1(98)	S1(100)	S1(90)	S1(90)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S2(83)	S2(65)	N1(40)	S2(68)
A06	S1(98)	S1(100)	S1(90)	S1(90)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S1(100)	S2(80)	S3(45)	S1(90)
A09	S1(98)	S1(100)	S1(90)	S1(90)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S1(100)	S3(50)	S2(70)	S2(68)
A012	S1(98)	S1(100)	S1(90)	S1(90)	S1(100)	S1(100)	S1(98)	S1(100)	S1(100)	S1(85)	S3(50)	S2(68)	S3(58)

N/B: MAR – mean annual rainfall, MAT - mean annual temperature, BS - base saturation, OC - organic carbon, SBC – sum of basic cations; S1 - highly suitable, S2 - moderately suitable, S3 - marginally suitable, N1 - currently not suitable, N2 - permanently not suitable, ACEC – apparent cation exchange capacity, *chemical properties that are easily altered and masked; f – fertility quality, c – climate quality, t – topography, IPc: current index of productivity, IP: potential index of productivity pedons (AO7, AO10, AO2, AO8, AO11, AO3, AO12) were moderately suitable (S2) for sesame production. This indicates an upgrade from the previous one pedon that was moderately suitable, currently. The distribution of these suitability ratings is shown in Figure 3.

Currently, 1.19 ha was classified as moderately suitable (S2), 14.56 ha was marginally suitable (S3) and 17.59 ha was currently not suitable (N1) for sesame cultivation. This suggests that good soil management procedures will be required to upgrade a great proportion of the area. Potential aggregate suitability indicates that, 9.51 ha of the map extent met the requirements for placement into land suitability class S1, while 23.81 ha qualified as S2 for sesame production. This area of coverage was obtained after land management procedures may have been applied. Again, it was observed that a good percentage of soils that were either N1 or S3 were later upgraded, potentially to S1 or S2 mainly because the limiting properties being either sum of basic cations, soil pH or soil organic carbon were easily improved fertility limitations.

When the land was evaluated by the non-parametric approach, it appeared to be more suitable for sesame cultivation potentially and currently more than it was obtained by the parametric method. For instance, currently, the land was either S2 (AO6, AO9, AO12, AO11, AO2, AO5, AO4) or S3 (AO1, AO7, AO10, AO8, AO3). However, by the potential suitability, all the pedons were upgraded to S1 except AO3 and AO12 which qualified as S2 with limitations arising from fertility properties.

According to Ogunkunle (1993), the efficiency of either of parametric and non-parametric land evaluation depends on the relevance of the most limiting characteristic to crop cultivation. According to the author, where the climate, soil physical condition or CEC is identified as the most limiting property, the non-parametric system may be most accurate. If easily amended chemical properties are rather limiting, the parametric method may be a better approach (Ogunkunle, 1993).

This upgrade was made possible after the removal of fertility limitations. Ranking the pedons for sesame cultivation by their scores using the parametric approach (potential suitability) (Table 3) indicated that all the pedons along the second toposequence (AO4, AO5, AO6) were among the first five best pedons studied for sesame cultivation in Bekwarra LGA, presenting them as tracts with great potentials for sesame production, but will require some management measures for further improvement in production capacity.

Summary and conclusion

Satellite imagery of Anyikang was obtained and the contour map generated in the ArcGIS 10.2.1.3 environment. The four spatially located toposequences were identified and one profile pit dug in the crest, middle slope and lower slope positions of each toposequence resulting in a total of 12 profile pits.

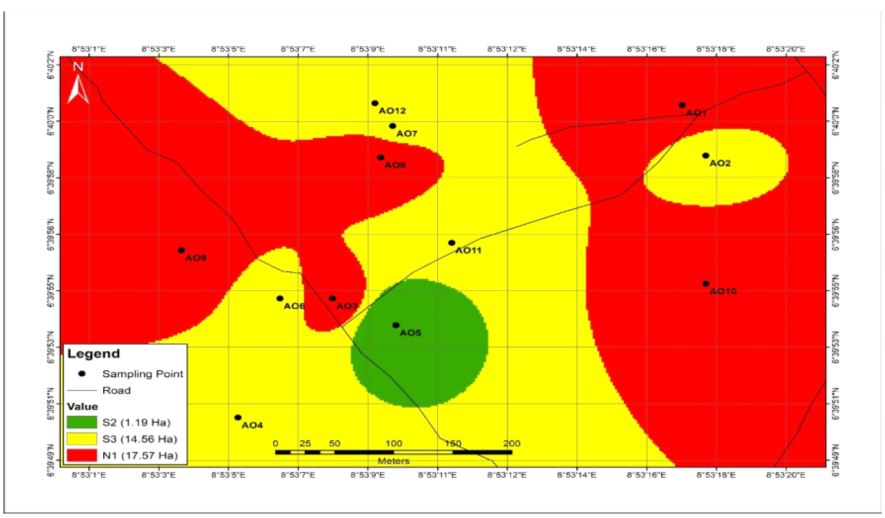

Figure 2: Distribution of current land suitability classes in Anyikang

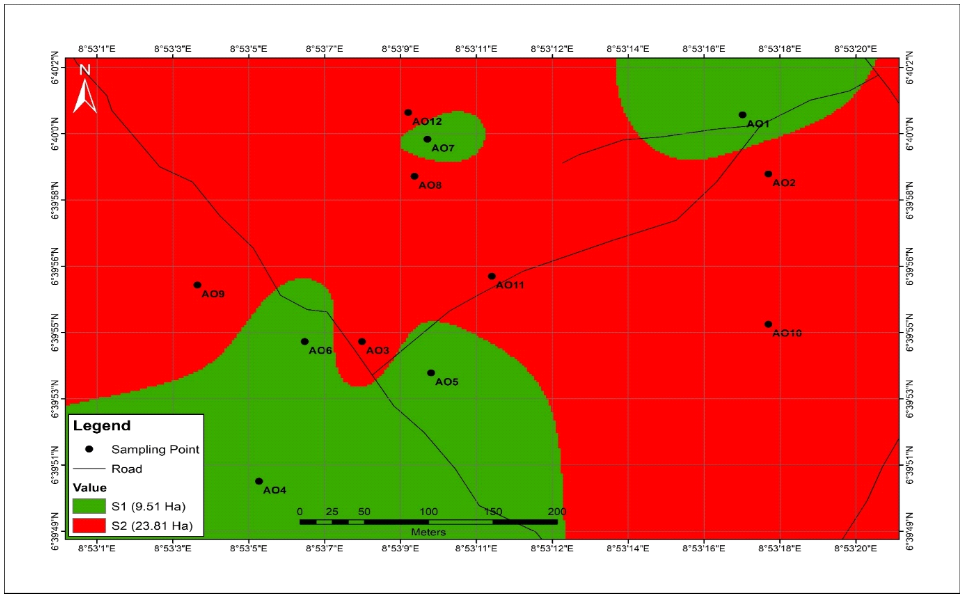

Figure 3: Distribution of potential land suitability classes in Anyikang

The study was to evaluating the tracts of land for the production of sesame. Currently, only a small proportion of the map extent was classified as moderately suitable (S2) for sesame cultivation, while majority of the area was either marginally suitable (S3) or currently not suitable (N1) for sesame cultivation. This suggests that good soil management procedures will be required to upgrade a great proportion of the area. Potential aggregate suitability indicates an improvement in the proportion for highly suitable (S1) and moderately suitable (S2) classes for sesame production. This area of coverage was obtained after land management procedures would have been applied.

In conclusion, a good percentage of the land area that was currently not suitable (N1) or marginally suitable (S3) was later upgraded potentially, to highly (S1) or moderately (S2) suitable mainly because the limiting properties being either sum of basic cations, soil pH or soil organic carbon were easily-removed fertility limitations. Furthermore, ranking the pedons for sesame cultivation by their scores using the potential parametric approach indicated that all the pedons along the second toposequence (AO4, AO5, AO6) were among the first five best pedons studied for sesame cultivation. Therefore, currently, the middle slope soils had higher index of productivity, while potentially, the crest and lower slopes had higher index of productivity and therefore more suitable for sesame production in the Bekwarra area.

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