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SITE SUITABILITY ANALYSIS FOR CROP MAPPING USING GEOSPATIAL TECHNIQUES IN AKKO LGA, GOMBE STATE

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ABSTRACT

Land suitability analysis is a prerequisite for sustainable agricultural production. This study is aimed at evaluating the current physical land suitability for rice, maize and soya beans in Akko local government area, Gombe state, Nigeria. A GIS and RS technique with a multicriteria evaluation approach are applied for evaluating the physical land suitability for the mentioned crops. To achieve this, fifteen parameters were considered which constitute topographic, climatic and physiochemical factors. The acquired data were spatially processed and analyzed through vector to raster conversion, raster coordinates transformation and resampling, criteria standardization and weighting and; finally integrated to three suitability maps each for the selected crop. The results shows that areas that are highly and moderately suitable for maize, rice and soya beans crops cultivation are ascertained as 53.57%, 21.33% and 49.39% respectively of the total LGA's area; this corresponds to 1,410.12 Km², 549.59 Km² and 1,272.56 Km² respectively. These findings indicate that there are considerable suitable lands with huge potential for optimal yield production for the selected crops in Akko LGA. The findings should be put into use by local and state agricultural extension officers, which will serves as vital tool in directing farmers on what to grow on which land for optimum yield production. Hence, this would enhance crops productivity in a sustainable manner and improve food security for better socio-economic development of Akko LGA and Gombe states at large.

1. BACKGROUND OF THE STUDY

Land suitability refers to the fitness of a given parcel of land for specific uses". Consequently, land suitability assessment is land evaluation which is usually conducted to determine specific land use for a particular location and identify limiting factors for a particular crop production (AbdelRahman, Natarajan, & Hegde, 2016; Mu, 2006). The assessment of land suitability depends on land capability as well as other factors such as land quality, proximity to different accesses, land ownership, customers demand and economic values (Counsel, 1999). Land suitability analysis evaluation according to FAO standards has been applied in many parts of the world, particularly in the developing countries (FAO, 2007b).

The dominant sector of the Nigerian economy is Agriculture. It accounts for about 70% of the economic activities of the country and employs about two-thirds of the Nation's total labour force while accounting for about 45 per cent of the increase in GDP during the period: 1990-2005. Specifically, the agricultural GDP is contributed by crops (84%) (NIRSAL, 2019). Despite the huge potentials, Nigeria's agricultural sector is faced with many challenges prominent among which are absence of appropriate technology and low productivity which cause by lack of suitable data for crop production (Udemezue, 2019). The inhabitants of Akko local government are agrarian that depends on Agriculture for livelihoods. Due to the influx of Internally Displaced Persons (IDPs) and people's impulse to invest in agriculture after back-to-farm campaign in 2016 brought intense demand on agricultural lands. Lack of knowledge and spatial data about where to grow certain crop drastically affect many farmers, which thrown them in great lost (Jibril, *et al.*, 2019).

In order to increase food production and provide food security, crops need to be grown areas where they are best suited; hence land suitability for crop production is inevitable. Land suitability analysis refers to a method of land evaluation which measures the degree of appropriateness of land for a certain use, and that the identification of the main limiting factors of crop production enables decision makers to develop crop management system. Thematic database on soils is vital in crop suitability analysis for optimal utilization of available resources. Establishing appropriate suitability factors considering soil characteristic as well as socio-environmental criteria in the construction of suitability analysis will improves yield production. Careful planning of the use of land resources is based on land evaluation. Remote sensing provides landscape information synoptically, repetitively and objectively. GIS is a powerful tool for geo-environmental analysis and appraisal of natural resources. Remote sensing and GIS are playing a rapidly increasing role in field of land suitability development. Therefore, the study aim at producing suitable spatial data for rice, maize and soya-beans crops in Akko LGA using spatial-multicriteria decision analysis tools to evaluate the suitability of various soil units of the study area.

2 STUDY AREA

Akko LGA is one of the eleven LGAs in Gombe state with Kumo urban area as its administrative centre; it is the most populous LGA and second in land mass after Dukku LGA. The LGA lies between latitude 9° 48′ 18″ and 10° 23′ 56″ North of the Equator, and between of 10° 41′ 04″ and 11° 32′ 20″ East of Greenwich meridian (see Figure 1). It has an approximate land mass of 2,631 Km². Akko LGA experiences a two season climate, rainy and dry seasons. Over the period of three decades (1977-2008), the rainy days within the rainfall season ranges from 29-53 days and spread within six months from April to October with annual average rainfall of 962.55mm. The annual average temperature is 36.2^{0}C; occurring in March to October while from December to February the temperature lowers to 19.7^{0}C. Relative humidity has the same pattern being 94% in August and fell to less than 10% during harmattan in December to February (Jibril, *et al.*, 2019). The LGA has 337,853 inhabitants and is projected to 521,400 people in 2023. About 80% of the populations are agrarian mainly practicing subsistent agriculture; and the crops cultivated in the LGA includes maize, millet, corn, beans, soya beans, sesame, cotton, groundnut, bambranut and vegetables such as tomatoes, pepper, and okra. The soil types within Akko LGA include sandy, sandy loam, loamy clay, and clay which highly support agriculture. The highest elevation 729m above mean see level on Akko escapement in the central areas of the LGA and reduces to 250m in the eastern, western and southern plains. The land form is dissected sufficient streams and rivers which run in all direction except the North.

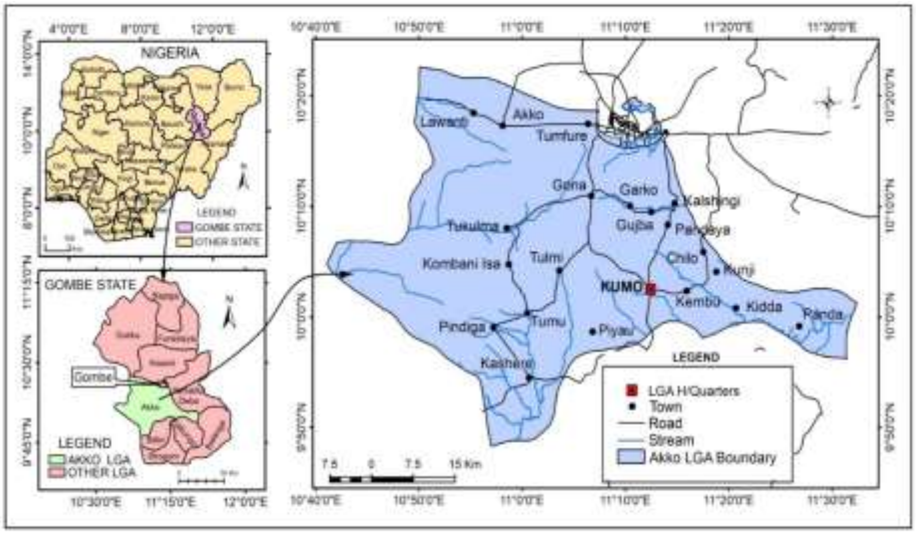

Figure 1: Location of the Study Area.

3. MATERIALS AND METHODS

3.1 Data source

Data employed in this study comprised climatic data (Rainfall and Temperature) retrieved from NASA's Power Data Access Viewer. Digital Elevation Model (DEM) as a topographic data which used for slope generation as well as Landsat-9 satellite imagery are obtained from USGS Earth Explorer. Others are soil physical properties such as: soil texture, soil drainage, soil depth. And soil chemical characteristics such as soil reaction (pH), organic carbon, base saturation, cation exchange capacity (CEC), electrical conductivity (ECe), Exchangeable Sodium Percentage (ESP) downloaded from ISRIC Africa soil database website. Administrative maps and roads are obtained from Gombe state ministry of land and survey.

Table 1: Data and their Sources

SN	Data type	Date	Scale / Resolution	Data uses	Source
1	Soil physical and chemical parameters	2020	250m	Evaluation of soil characteristics for optimum	ISRIC Data Hub
2	Administrative map	2010	Scale: 1:300,000	To determine the extent of the study area.	Ministry of land and survey Gombe
4	Landsat-9 satellite imagery	2023	12 bands / 30m	Generation of Land use/cover map	USGS
5	Digital Elevation Model (DEM)	2017	1 band / 30m resolution	To generate slope map	USGS

6	Metrological data	2012 - 2022	Temperature/ Rainfall /5Km	Determination of environmental Factors too	Power Data Access Viewer
7	Soil type data	1985	250m	To extract diff soil type in the study area	ISRIC Data Hub

3.2 Land Suitability Factors

The factors considered for the evaluation of suitable agricultural lands for maize, rise and soya beans crops comprises topographic, climatic, soil physical and chemical characteristics. These factors were chose from the reviews of the existing literatures such as FAO, (1983), Oluwatosin, (2005), Rota *et al.,* (2006), Mustapha *et al.,* (2011), Abagyeh, (2016), Tashayo *et al.*, (2020), Han *et al.*, (2021) and Vanger *et al.*, (2023).

3.2.1 Topographic Criteria

Elevation, slope and aspects are topographical elements that respectively define the relative height of terrain surface with respect to mean sea level; identifies the steepness degree of a terrain surface; and direction faces by the slope. Rice crop is generally said to thrive well in low altitude, slope less than fifteen degrees to facilitate runoff accumulation and level north facing slope for longer sun illumination (Kihoro *et al.,* 2013). While maize do good on higher altitude, well drain terrain.

3.2.2 Climatic Criteria

Crops are sensitive to temperature fluctuations; optimal temperatures for maize, rice and soya beans crops growth range between 20°C to 35°C. High temperature during flowering can lead to sterility, while low temperatures can delay maturity and reduce yield. The selected crops require abundant rainfall water, particularly during its vegetative and reproductive stages. Adequate rainfall is necessary for optimal growth; the selected crops strive well in a rainfall ranges from 500 to 1200mm.

3.2.3 Soil Physio-Chemical Criteria

Specifically, Soil texture gives the relative proportions of sand, silt, and clay particles. Different crops thrive in different soil textures. Loam, silt and loamy sandy soils moderately hold moisture, which can be good for crops like maize, while clay soils hold moisture better, suitable for crops like rice and soybeans. Maize crop prefer well drain soil and in contrast rice required poor drain soil while soya beans do well on moderately drain soils. Maize, rice and soya beans crops grow well in soils with a pH between 5 and 7 (Gemechu et al., 2020). Maize and rice grow well on soils where organic matter is greater than 5%, while soya beans thrive on soils with > 0.8%. Cation Exchange Capacity (CEC) measures the soil's ability to hold and exchange positively charged ions (cations) like calcium, magnesium, potassium, and ammonium. Soils with higher CEC can retain more nutrients, reducing leaching losses. Exchangeable Sodium Percentage (ESP) by definition, a sodic soil contains high level of sodium relative to the other cations i.e. calcium, magnesium and potassium. A soil considered "sodic" when the exchangeable sodium percentage is greater than or equal to 15% (Agbede, 2009). Another important soil parameter is Base Saturation (BS) A simplify example of base saturation is the combined saturation of the three major cations that have a basic or alkaline reaction (K^+,Ca^{2+},and Mg^{2+}). In general, Tables 2, 3 and 4 gives suitability ratings of different criteria for maize, rice and soya beans crops respectively.

Table 2: Criteria Suitability Rating for Maize

	Rating			
Soil characteristics	S1	S2	S3	N
Precipitation (mm)	> 800	700-800	600-700	<600
Temperature (°C)	24 - 30	20 – 24; 30-32	15 – 20; 32-35	<15; >35
Texture	Sl, SCL	SiCl, CL	Si, SL, SC	Ch, LS, S
Drainage	WD	MWD	ED	VPD
Slope (%)	0.5 - 7	7 – 14	14 - 22; 0 – 0.5	> 22
pH(1:1water)	6.5-7	5.8-6,7-7.5	5.5-5.8	<5.5,>8
CEC mol($^+$)kg^{-1}	> 12	9-12	5-8	< 5
EC (ds/m)	< 1	1 – 2	2 – 4	> 4
ESP (%)	<10	10 – 15	> 15	–
Organic Carbon (gkg^{-1})	>10	10-5	5-2	<2
Base Saturation (%)	>50	50-30	30-20	<20
Soil depth(cm)	>120	50-120	30-50	<30
Total Exc. Bases				
Landuse	Farmlands	Shrubs	Forest / Bare land	Built-up/waterbody

Adopted from: FAO (1983); Mustapha *et al.*, 2011) and Oluwatosin (2005).

Table 3: Criteria Suitability Rating for Rice

Soil characteristics	S1	S2	S3	N
		Rating		
Precipitation (mm)	>1400	1000 – 1400	800 – 1000	<800
Temperature (°C)	22 - 30	20 – 22; 30-34	18 – 20; 34 – 36	<18
Texture	c,sc,sic	L,scl,cl	Hc	S
Slope (%)	0.5 - 7	7 – 14	14 - 22; 0 – 0.5	>22
Drainage	PD,VPD	MWD,SPD	WD	VWD,AD
pH (in water)	5.6 – 7.44	7.4 – 7.8	5.1 – 5.6	<5.1 ; >7.8
CEC(cmol(+)kg^{-1}	>12	9-12	5-8	<5
Org.C(gkg^{-1})	>15	10-15	5-10	<5
Base Saturation (%)	>50	50-35	35-20	<20
Soil Depth(cm)	>100	70-100	40-70	<40
ECe (ds/m)	0-2	2-4	4-6	>6
ESP (%)	0-20	20-30	30-40	>40
Total Exc. Bases				

Table 3: Criteria Suitability Rating for Rice

Adopted from: FAO (1983); Mustapha *et al.*, 2011) and Oluwatosin (2005).

Table 4 gives the suitability rating for optimum soya beans cultivation adopted from Rota et al., (2006) and Vanger *et al.*, (2023).

Table 4: Criteria Suitability Rating for Soya Beans

Soil Characteristics	S1	S2	S3	N
		Rating		
Available P	>30	30-12	12-10	<10
Organic Carbon	>2	1.99-0.68	0.67– 0.14	<0.14
Ph	7-6.0	6.0 – 5.6	5.5 – 5.2	<5.2
BS	>50	50 – 35	35 - 20	<20
Total Exc. Bases	>5	5 – 3.5	3.5 - 2	<2
ECe (Ds/m)	0 – 5	5 - 7	7 - 8	>8
ESP (%)	0 - 8	8 - 15	15 - 20	20 – 35
Texture	Si, SiCL, SiL	SC, L, SCL	LS, LfS, C	S, Cm, Gravel
Soil Depth (cm)	>100	100 - 75	75 - 40	< 40
Slope %	0-3	4 - 8	8-12	>12
Rainfall (mm)	>800	800 -700	700-600	<600
Temperature (°C)	21-33	20	19	>34 <18
Drainage	Well drained	Moderately	Imperfectly	Poorly drained
Land Use	Croplands	Shrubs/Grasses	Forest	Built Up

3.2.4 Standardization of Criteria

Factors were standardized using reclassified tool in order to use a common scale of measurement so that to compare them and integrate them to a single overall suitability feature data set. Each criterion is grouped and rated from 1 to 4 (Table 5), the higher the scale value, the more suitable a location is. During standardization, those criteria express on ratio scale such as rainfall, temperature were reclassified by grouping the range of input values into zones of equal interval, and the suitability values assigned to each class in the 'new values' field. And for those on interval scale such as texture, landuse etc., rank values were assigned to them according to the suitability of each class in the respective factor criteria maps. All the soil characteristics parameters given in Tables 2, 3 and 4 that are responsible for identifying crops lands suitability for maize, rice and soya beans cultivation were standardized to a common scale with respect to Table 5. This was done using "Reclassify Tool" in ArcGIS 10.8.

Table 5: Criterion Suitability Rating

Rating	Description	Suitability
SI	Highly Suitable	4
S2	Moderately Suitable	3
S3	Marginally Suitable	2
N1	Not Suitable	1

3.3 Estimation of Criteria Weight

In reality the factors or criteria considered for suitability evaluation of crops lands are not of equal importance, some have more influence over the others. Therefore, it is imperative to weight the importance or preference of each factor relative to other factor effects on crop produce and growth rate. In the procedure for MCE (Multi-criteria evaluation), it is necessary that the sum of the weights equal to one. In developing a pairwise comparison matrix, all the factors are compared two at a case in terms of their standing related to the declared objective. In developing weights, an individual compares every possible pairing and enters the evaluation into a pairwise comparison matrix (Gbanie et al., 2013). Since the matrix is symmetric, only the lower triangle necessarily to be filled in. The remaining cells are then simply the reciprocals of the lower triangle (Table 4). An online version of AHP priority calculator prepared by Goepel, (2018) was used in calculating criteria weights. Criteria weights had been computed by solving comparison matrix generated from comparison of two criteria at a time using Saaty words scale values of 1 – 9 (Table 6).

Table 6: Saaty Words Scale for Pairwise Comparison

Intensity of importance	Definition
1	Equal importance
2	Equal to moderately importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

Source: Saaty, (1980).

3.5 Weighted Sum Overlay Analysis

The land suitability map for maize, rice and soya beans production in Akko LGA was created using Weighted Sum Overlay Analysis in ArcGIS 10.8 by multiplying each criterion with its weight and then aggregated the results to a single individual crop suitability map index. Each map index is portraying where the respective crop will highly strive best and where it will not. The index maps were then reclassified to six levels of suitability classes commonly used by the Food and Agricultural Organization (FAO, 1976): very highly suitable (S1-0), highly suitable (S1-1), moderately suitable (S2), marginally suitable (S3), temporally unsuitable (N1) and permanently unsuitable (N2).

4. RESULTS

4.1 Soil Characteristics of the Study Area

The study area is delineated in to eight soil units based on their texture, drainage and depth; these units are further coded from AK01 to AK08. Different soil physical and chemical qualities of the soils units were retrieved from ISRIC soil classification database as presented in Table 7.

Table 7: Soil Units Physical and Chemical Qualities

SOIL_UNIT	AK01	AK02	AK03	AK04	AK05	AK06	AK07	AK08
Soil Texture	Sandy	Sandy Loam	Sandy Loam	Sandy Loam	Clay	Loamy Clay	Clay Loam	Loamy Sand
Soil Depth (Cm)	160	115	75	65	102	83	76	56
pH (H_2O)	5.9	7.7	6	7.5	5.8	6.4	6.9	6.2
Ex. Bases (Meq/100g)	0.75	5.64	0	8.4	11.61	3.42	27.29	6.04
CEC $mol^{(+)}kg^{-1}$	3	8	18.5	7	12	9.6	36.6	9.2
Base Saturation	53.5	70	100	100	100	35.6	74.6	65.7
Organic Carbon (gkg^{-1})	0.8	5.2	1.7	3.5	7.6	5.8	6.3	2.9
Bulk Density (g/cm^3)	1.37	1.1	0.9	1.21	1.52	1.38	1.43	1.32
ECe (ds/m)	2.4	1.7	0.8	1.4	0.4	0.3	0.5	1.2
ESP (%)	24	21	13	15	11	4	2	27

Table 7 shows the variability of pH values in Akko LGA. Soils in unit AK01, AK03, AK05, AK06 and AK08 are considered acidic since their values are less than 6.5 pH value (Horneck *et al.*, 2011); while pH values within the range of 6.5 to 7.5 are considered neutral and this category of soils are found in soil unit AK04 and AK07. In other hand alkaline soils are found in unit AK07 which have pH value above 7.5. CEC value in soil unit AK07 is 36.6 $mol^{(+)}kg^{-1}$ falls between 25-40 which is considered high according to Awotundun, (1973). Moderately CEC values are ranged between 12 and 25 and where found in soil unit AK03 and AK05 (18.5 and 12 respectively). Conversely, soil unit AK01, AK02, AK04, AK06 and AK08 have CEC values of 3, 8, 7, 9.6, and 9.2 respectively, all are below 12 $mol^{(+)}kg^{-1}$ and classified as low in terms of CEC contents. Table 2 also shows that organic carbon in all the soil units ranged from 0.8 to 7.6. Awotundun, (1973) placed soil with greater 4% organic carbon as extremely high; therefore soil unit AK02, AK05, AK06 and AK07 are in this category; while organic carbon in other soil units falls in medium category. However, FAO (1983) and Rota et al., (2006) specifies that soils with greater than 2% of organic carbon are highly suitable for growing maize, rice and soya beans. Depth of the soil units varies from 56 to 160 cm. Soil greater than 40 cm are considered suitable for cultivating rice, greater than 30cm for maize (Mustapha *et al.*, 2011); and greater than 75cm for soya beans (Rota et al., 2006). Therefore, soil depth in all the units satisfied this standard for maize and rice cultivation in Akko LGA. Table 2 reveals that soil textures of the study area are sandy (AK01), sandy loam (AK02, 3, 4), clay (AK05), loamy clay (AK06), clay loam (AK07), and loamy sand (AK08). Oluwatosin (2005) and Gemechu *et al.*, (2020) specifies that maize, rice and soya beans can strive well in loamy clay and clay loamy soils and perform moderately in loamy sandy with rice marginally strive in sandy loam soils. All the selected crops perform poorly in sandy soils.

Table 7 portrays that exchangeable sodium percentage (ESP) of the soil units range from 2 to 27%. According to Oluwatosin, (2005) and Mustapha et al., (2011) soils with ESP value less than 10% and from 0 to 20% are considered highly suitable for growing maize and rice respectively; and from 0 to 15% considered highly suitable for soya beans cultivation (Rota et al., 2006). Soil units AK03, 04, 05, 06 and AK07 falls in this category. In other hand, soil unit AK01, 02 and 08 have ESP value of 24, 21 and 27 respectively and are categorize as moderately suitable for growing maize, rice and soya beans. Base saturation in the study area varies from 35.6 to 100.0 %. For optimum yield production of maize, rice and soya beans, BS should be greater than 50% as in all the units considered highly suitable with the exception of unit AK06 with 35.6% which falls in moderately suitable category (Mustapha *et al.*, 2011). Electrical conductivity (ECe) varies from 0.3 to 2.4 ds/m. All ECe values of less than 1 and less than 2 ds/m as in AK03, 05, 06 and 07 are classified as highly suitable for cultivation of maize and rice/soya beans respectively (Oluwatosin, 2005 and Mustapha *et al.*, 2011). Also, rice and soya beans can strive well in soils with ECe from 2 to 6 ds/m as in unit AK01 and poorer in greater than 6 ds/m. While maize can moderately do good in soils with ECe greater than 1 to 4 ds/m as found in units AK0, 02, 04 and 8 and poorly where ECe is greater than 4 ds/m. Also, soya beans strive well on soils with ECe of 0 to 6. Bulk density values of the soil units in Akko LGA ranges from 0.9 to 1.52 g/cm³. Bulk density value of less than 1.2 g/cm³ is considered highly suitable for maize and rice cultivation; thus, soil unit AK02, 03 and 04 falls within this category. Also, all the selected crops can moderately do

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well in soil with bulk density value greater than 1.2 to 1.4 g/cm³. Soil unit that falls within this class includes AK01, 06 and 08 which have 1.37, 1.38 and 1.32 g/cm³ respectively. In contrast, higher bulk densities are found in units AK05 and 07 with 1.52 and 1.43 g/cm³ respectively;

4.2 Standardization of Criteria

Criteria layers by default express crop requirement layers in different units; hence there is need to harmonize them to a common measurement scale so that to be able to be compare and harmonistically overlay one on the other. Figure 2, 3, and 4 shows the fourteen criteria considered for siting suitable lands for maize, rice and soyabeans crops were standardized and rank to a common scale of measurement (see Table 5) in order to be able to be aggregated to a single and an overall crop lands suitability data set.

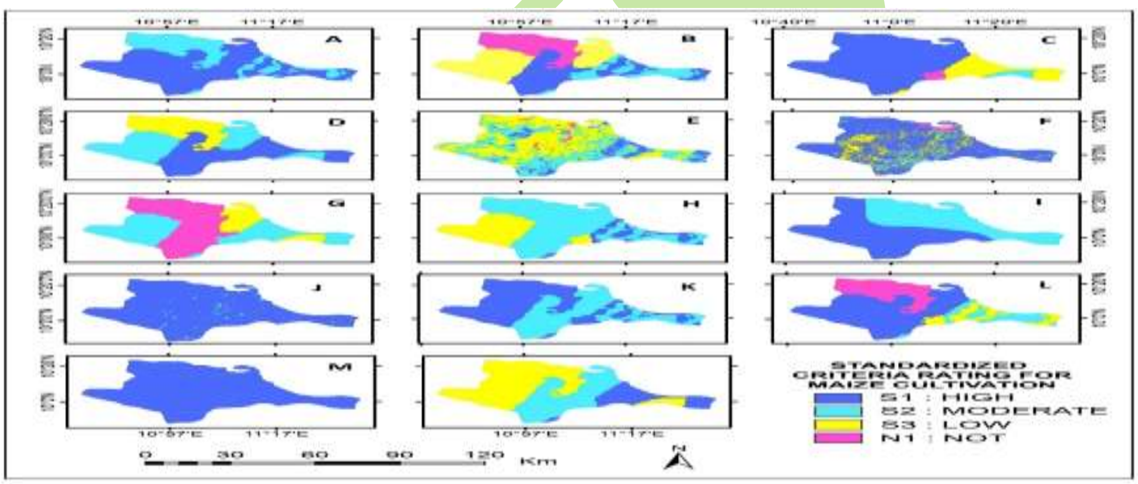

Figure 2: Standardized Criteria Suitable Maize Cultivation: A: Base saturation; B: Cation Exchange Capacity; C: Soil drainage; D: Electrical conductivity Exchangeable Sodium Percentage; E: Total exchangeable bases; F: Landuse; G: Organic Carbon; H: pH; I: Rainfall; J: Slope; K: Soil depth; L: Soil Texture; M: Temperature; N: Exchangeable Sodium Percentage

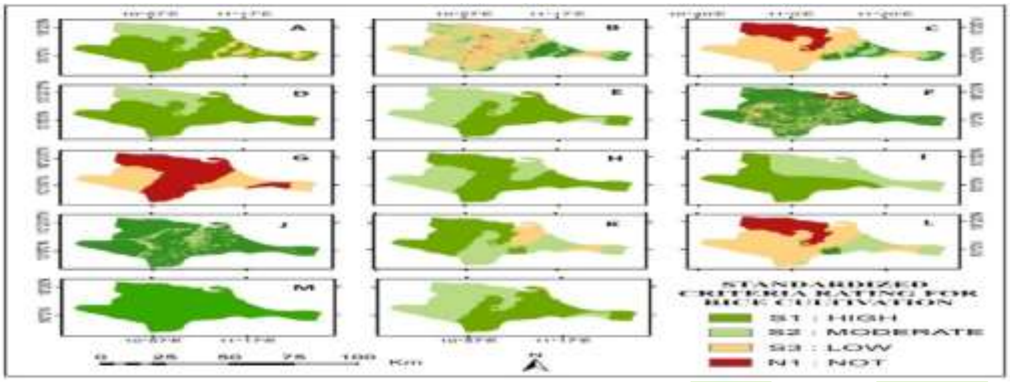

Figure 3: Standardized Criteria Suitable for Rice Cultivation: A: Base saturation; B: Cation Exchange Capacity; C: Soil drainage; D: Electrical conductivity Exchangeable Sodium Percentage; E: Total exchangeable bases; F: Landuse; G: Organic Carbon; H: pH; I: Rainfall; J: Slope; K: Soil depth; L: Soil Texture; M: Temperature; N: Exchangeable Sodium Percentage

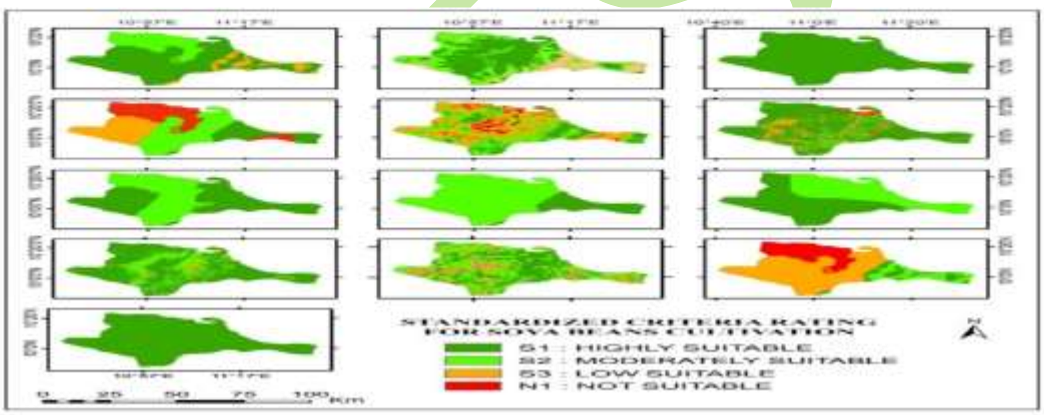

Figure 4: Standardized Criteria for Choosing Suitable Soya Beans Lands: A: Base saturation; B: Soil drainage; C: Electrical conductivity; D: Exchangeable Sodium Percentage; E: Total exchangeable bases; F: Landuse; G: Organic Carbon; H: pH; I: Rainfall; J: Slope; K: Available Phosphorus; L: Soil Texture; M: Temperature.

4.3 Estimation of Criteria Weight

To estimate the criteria weights, an online version of AHP priority calculator prepared by Goepel, 2018 was employed for that purpose. Criteria weights had been computed by solving comparison matrix (Tables 8, 9 and 10) generated from comparison of two

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criteria at a time using Saaty words scale values of 1 – 9 (Table 6).

Table 8: Criteria Pairwise Comparison Matrix and Weights for Maize Crop

	R	Tp	Tx	Dr	pH	CEC	OC	BS	Dp	Sp	EC	ESP	TEB	LU	Weight	Rank
R	1	1	1	1	1	2	1	2	2	1	2	2	1	1	8.6%	4
Tp	1	1	1	1	1	2	1	1	2	1	1	2	1	1	7.8%	6
Tx	1	1	1	1	1	1	2	2	2	1	2	2	1	2	9.0%	2
Dr	1	1	1	1	2	2	2	2	2	1	2	3	1	1	10.0%	1
pH	1	1	1	½	1	2	1	2	2	2	2	3	1	1	8.9%	3
TEB	1/2	1/2	1	½	½	1	1	1	3	3	2	2	1	1	7.6%	7
OC	1	1	1/2	½	1	1	1	2	3	3	2	2	1	1	8.6%	5
BS	1/2	1	1/2	½	½	1	1/2	1	3	3	1	1	1	1	6.6%	9
Dp	1/2	1/2	1/2	½	½	1/3	1/3	1/3	1	1	1	2	1	1	4.5%	13
Sp	1	1	1	1	½	1/3	1/3	1/3	1	1	1	2	1	2	6.1%	10
EC	1/2	1	1/2	½	½	1/2	1/2	1	1	1	1	1	1	2	5.3%	12
ESP	1/2	1/2	1/2	1/3	1/3	1/2	1/2	1	1/2	1/2	1	1	1	1	4.1%	14
CEC	1	1	1	1	1	1	1	1	1	1	1	1	1	2	7.1%	8
LU	1	1	1/2	1	1	1	1	1	1	1/2	1/2	1	½	1	5.8%	11

Number of comparisons = 91
Consistency Ratio CR = 4.4%
Principal eigen value = 14.907
Eigenvector solution: 5 iterations, delta = 5.4E-8

Table 8 reveals the comparison matrix chosen for selecting suitable lands for high maize yield production. It also indicates that the highest rank criterion is Dr: Soil Drainage which score rank 1 and with 10.0% as weight of influence in the overlay model. The second ranked criterion is Tx: Soil Texture, which have 9% weight of influence. Criteria such as pH: Soil Reaction, R: Rainfall, OC: Organic and Tp: Temperature was ranked as 3, 4, 5 and 6 and a corresponding percentage of influence of 8.9%, 8.6%, 8.6% and 7.8% respectively. Similarly, criteria that follow in ranking are Total Exchangeable Bases (TEB), Cation Exchange Capacity (CEC), BS: Base Saturation and Sp: Slope with the weights of 7.6%, 7.1%, 6.6% and 6.1% respectively. Other criteria that follow are LU: Landuse with 5.8% percentage of influence, EC: Electrical Conductivity (5.3%), Dp: Soil Depth (4.5%) and ESP: Exchangeable Sodium Percentage (4.1%).

Table 9: Criteria Pairwise Comparison Matrix and Weights for Rice Crop

	Tx	R	Dr	Sp	TEB	pH	OC	CEC	EC	Dp	BS	LU	Tp	ESP	Weight	Rank
Tx	1	0.5	1	2	2	2	2	3	4	3	4	2	1	3	11.2%	3
R	2	1	1	3	3	3	3	4	4	3	5	3	2	4	16.2%	1
Dr	1	1	1	2	3	3	3	4	4	3	4	2	1	4	13.6%	2
Sp	1/2	1/3	1/5	1	1	2	2	3	3	2	3	2	2	4	9.2%	5
TEB	1/5	1/3	1/3	1	1	2	2	3	4	3	4	1	1	3	8.4%	6
pH	1/2	1/3	1/3	½	1/2	1	1	2	2	2	3	1	0.5	2	5.5%	8
OC	1/2	1/3	1/3	½	1/2	1	1	2	2	2	3	1	0.5	2	5.5%	8
CEC	1/3	1/4	1/4	1/3	1/3	1/2	1/2	1	1	1	2	1/2	1/3	2	3.4%	11
EC	1/4	1/4	1/4	1/3	1/4	1/2	1/2	1	1	1/2	1	1/2	1/3	1	2.8%	12
Dp	1/3	1/3	1/3	½	1/3	1/2	1/2	1	2	1	2	1/2	1/3	2	3.9%	10
BS	1/4	1/5	1/4	1/3	1/4	1/3	1/3	1/2	1	1/5	1	1/2	1/3	1	2.5%	14
LU	1/2	1/3	1/2	½	1	1	1	2	2	2	2	1	1/2	2	5.7%	7
Tp	1	1/2	1/3	0.5	1	2	2	3	3	3	3	2	1	3	9.3%	4
ESP	1/3	1/4	1/4	¼	1/3	1/2	1/2	1/2	1	1/2	1	1/2	1/3	1	2.7%	13

Number of comparisons = 91
Consistency Ratio CR = 2.0%
Principal eigen value = 14.408
Eigenvector solution: 4 iterations, delta = 1.7E-8

Table 9 reveals the comparison matrix chosen for selecting suitable lands for high rice yield production. It also indicates that the highest rank criterion is R: Rainfall which score rank 1 and with 16.1% as weight of influence in the overlay model. The second ranked criterion is Dr: Soil Drainage which has 13.6% weight of influence. Criteria such as Tx: Soil Texture, Tp: Temperature, Sp: Slope and TEB: Total Exchangeable Bases were ranked as 3, 4, 5 and 6 with a corresponding percentage of influence of 11.2%, 9.3%, 9.2% and 8.4% respectively. Similarly, criteria that follow in ranking are LU: Landuse (7), pH: Soil Reaction (8), OC: Organic (8) and Dp: Soil Depth (10) with the weights of 5.7%, 5.5%, 5.5% and 3.9% respectively. Other criteria that follow are CEC: Cation Exchange Capacity with 3.4% percentage of influence, EC: Electrical Conductivity (2.8%), ESP: Exchangeable Sodium Percentage (2.7%) and BS: Base Saturation (2.5%).

Table 10: Criteria Pairwise Comparison Matrix and Weights for Soya Beans Crop

	Tx	R	LU	AP	Tp	Sp	pH	Dr	TEB	OC	EC	ESP	BS	Weight	Rank
Tx	1	1	2	1/2	2	1	1/2	1/2	1/3	2	4	4	3	9.1%	6
R	1	1	2	1	1	2	1	1	1	2	3	3	2	9.9%	4
LU	1/2	1/2	1	1/3	1	1	1/2	1/2	1/2	1	2	3	1	5.6%	10
AP	2	1	3	1	1	1	2	2	2	2	3	3	2	12.5%	1
Tp	1/2	1	1	1	1	1	1	1	2	2	3	3	2	9.2%	5
Sp	1	1/2	1	1	1	1	1/2	1	2	1	2	3	2	8.1%	8
pH	2	1	2	1/2	1	2	1	1/2	2	2	2	3	2	10.1%	3
Dr	2	1	2	1/2	1	1	2	1	2	2	3	4	2	11.1%	2
TEB	3	1	2	1/2	1/2	1/2	1/2	1/2	1	1	2	3	2	8.1%	7
OC	1/2	1/2	1	1/2	1/2	1	1/2	1/2	1	1	2	2	2	5.8%	9
EC	1/4	1/3	1/2	1/3	1/3	1/2	1/2	1/3	1/2	1/2	1	1	1/2	3.2%	12
ESP	1/4	1/3	1/3	1/3	1/3	1/3	1/3	0.25	1/3	1/2	1	1	1/2	2.7%	13
BS	1/3	1/2	1	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	2	1	4.6%	11

Number of comparisons = 78
Consistency Ratio CR = 3.7%
Principal eigen value = 13.697

Table 10 indicates that the highest rank criterion for Soya Beans Crop cultivation is AP: Available Phosphorus which score rank 1 and with 12.5% as weight of influence in the overlay model. The second ranked criterion is Dr: Soil Drainage which has 11.1% weight of influence. Criteria such as pH: Soil Reaction R: Rainfall, Tp: Temperature, and Tx: Soil Texture, as 3, 4, 5 and 6 with a corresponding percentage of influence of 10.1%, 9.9%, 9.2% and 9.1% respectively. Similarly, criteria that follow in ranking are TEB: Total Exchangeable Bases were ranked (7), Sp: Slope, (8), OC: Organic (9) and LU: Landuse (10) with the weights of 8.1%, 8.1%, and 5.8% and 5.6% respectively. Other criteria that follow are BS: Base Saturation with 4.6% percentage of influence, EC: Electrical Conductivity (3.2%) and ESP: Exchangeable Sodium Percentage (2.7%).

4.4 Production of Suitability Maps

In order to determine the suitable land areas for maize, rice and soya beans, the results obtained during criteria standardization and weights generation were considered. The overall suitability classification rating generated from evaluation of soil physiochemical, climatic and socioeconomic requirements were integrated into GIS using ArcGIS's Spatial Overlay Analysis to develop one symbology color interpolation

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for each classification i.e. (highly suitable S1, moderately suitable S2, marginally suitable S3 and not suitable N). By this overlay analysis, the suitability map for maize, rice and soya beans were produced as portrayed in Figure 5, 6, and 7. The area coverage for each suitability class is estimated in Kilometer square as well as their corresponding percentage (Table 11, 12 and 13).

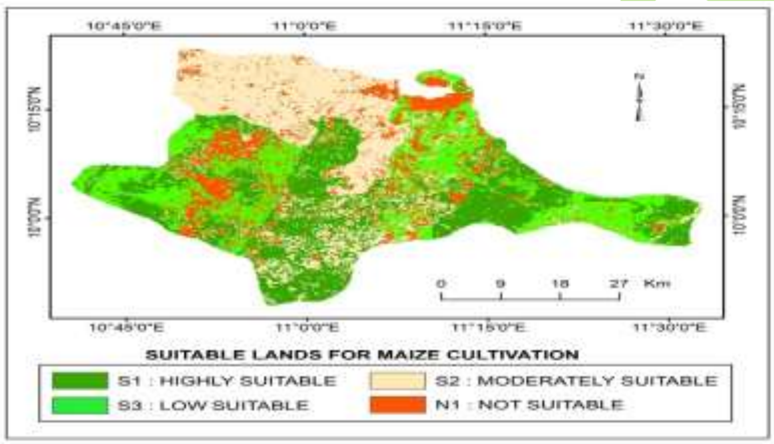

Figure 5: Suitability of Lands for Maize Production

Figure 5 shows the spatial variability of suitability classes for cultivation of maize crop in Akko LGA of Gombe state. Highly suitable (S1) areas for maize crop production are represented in dark green colour; this class covers an area of 770.12 Km² equivalents to 29.89% of the total area Akko LGA (Table 11). Moderately suitable (S2) are represented in light green colour; this class get 23.68% ² equivalents to 610.112 Km² of the LGA lands. Similarly, marginally suitable (S3) lands are denoted in orange colour; the class covers an area equals to 811.182 Km² (31.48 %). The remaining areas which amounted to 385.122 Km² (14.95 %) are considered not suitable (N1) for maize crop production in Akko LGA and are shown in red colours.

Table 11: Statistics of Suitability Classes for Maize Production

SUITABILITY CLASS	CODE	AREA Km²	%
HIGHLY SUITABLE	S1	770.12	29.89
MODERATELY SUITABLE	S2	610.112	23.68
MARGINALLY SUITABLE	S3	811.182	31.48
NOT SUITABLE	N	385.122	14.95
TOTAL		2576.532	100.00

Figure 6 shows the spatial variability of suitability classes for cultivation of rice crop in Akko LGA of Gombe state. Highly suitable (S1) areas for rice crop production are represented in dark green colour. Moderately suitable (S2) are represented in light green colour; while marginally suitable lands (S3) are denoted in orange colour. Not suitable (N1) lands are represented in red colour.

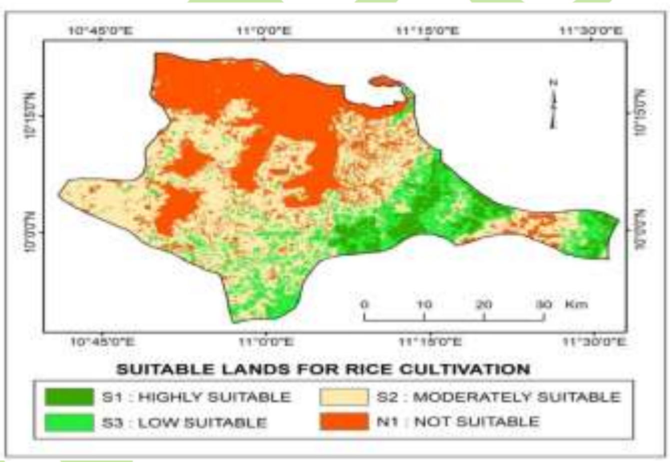

Figure 6: Suitability of Lands for Rice Production

Table 12 shows the statistics of the suitability classes for rice cultivation in Akko LGA and its indicate that S1 class covers an area of 138.59 Km² equivalents to 5.38 % of the total area Akko LGA. S2 class get 15.95% equivalents to 411.00 Km² of the LGA's lands. Similarly, S3 class covers an area equals to 1130.76 Km² corresponding to 43.89 %. The remaining areas which amounted to 896.18 Km² (34.78 %) are considered not suitable for rice crop production in Akko LGA.

Table 12: Statistics of Suitability Classes for Rice Production

SUITABILITY CLASS	CODE	AREA Km²	%
HIGHLY SUITABLE	S1	138.59	5.38
MODERATELY SUITABLE	S2	411.00	15.95
MARGINALLY SUITABLE	S3	1130.76	43.89
NOT SUITABLE	N	896.18	34.78
TOTAL		2576.532	100.00

As in Figure 5 and 6, likewise, Figure 7 displays the spatial variability of suitability classes for cultivation of soya beans crop in Akko LGA of Gombe state. Highly suitable (S1) areas for soya beans crop production are represented in dark green colour. Moderately suitable (S2) are represented in light green colour; while marginally suitable lands (S3) are denoted in orange colour. Not suitable (N1) lands are represented in red colour.

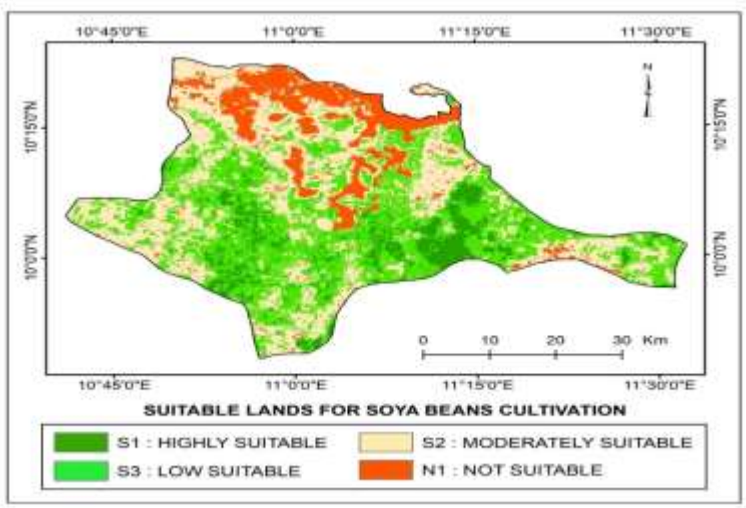

Figure 7: Suitability of Lands for Soya Beans Production

Table 12 shows the statistics of the suitability classes for rice cultivation in Akko LGA and its indicate that S1 class covers an area of 138.59 Km² equivalents to 5.38 % of the total area Akko LGA. S2 class get 15.95% equivalents to 411.00 Km² of the LGA's lands. Similarly, S3 class covers an area equals to 1130.76 Km² corresponding to

43.89 %. The remaining areas which amounted to 896.18 Km² (34.78 %) are considered not suitable for rice crop production in Akko LGA.

Table 13: Statistics of Suitability Classes for soya beans Production

SUITABILITY CLASS	CODE	AREA Km²	%
HIGHLY SUITABLE	S1	247.75	9.62
MODERATELY SUITABLE	S2	1024.81	39.77
MARGINALLY SUITABLE	S3	965.35	37.47
NOT SUITABLE	N	338.63	13.14
TOTAL		2576.532	100.00

CONCLUSION

This research demonstrates that available geospatial data from different sources with varying specifications can be employed to perform land suitability assessment for the production of maize, rice and soya beans crops. The results of AHP evaluations shows that factors such as soil drainage, texture and reaction, rainfall, organic carbon temperature and Total Exchangeable Bases are the most influential criteria for high maize yield production. Similarly, it has shown that the leading parameters considered for optimal rice cultivation are rainfall, soil drainage and texture,temperature, slope and total exchangeable bases. On the other hand, available phosphorus, soil drainage and reaction, rainfall, temperature and soil texture are identified as most important parameters for soya beans cultivation in Akko LGA. The research further identified spatial suitability disparities of lands for the production of the selected crops in Akko LGA. It is found that areas that are highly and moderately suitable for maize, rice and soya beans crops cultivation are ascertained as 53.57%, 21.33% and 49.39% respectively of the total LGA's area; this corresponds to 1,410.12 Km², 549.59 Km² and 1,272.56 Km² respectively. It is recommended that the findings should be put into use by local and state agricultural extension officers, which will serve as vital tool in directing farmers on what to grow on which land for optimum yield production. Hence, this would enhance crops productivity in a sustainable manner and improve food security for better socio-economic development of Akko LGA and Gombe states at large.

REFERENCES:

Abagyeh, S.O.I. (2016). Characterization and IRRIGATION Suitability Ratings of Soils of Mid-Benue Valley Using Okra (Abelmoschus Esculentus) as a test crop. Department of Soil Sciences, Collage of Agronomy, Federeal University of Agriculture Makurdi, Nigeria.

AbdelRahman, M. A. E., Natarajan, A., & Hegde, R. (2016). Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar district, Karnataka, India. The Egyptian Journal of Remote Sensing and Space Science, 19(1), 125–141. doi:10.1016/j.ejrs.2016.02.001

Agbede O.O., (2009), Understanding soil and plant nutrition. ISBN: 978-900-0887-6

Awotundun, E. F. (1973). Soil Analysis: A Manual for the Soil-Water Laboratory. Ministry of Agriculture and Natural Resources, Kano, Nigeria. Pp27-61

Counsel, A. P. (1999). Land capability assessment guidelines. Retrieved from http://apps.actpla.act.gov.au/tplan/planning_register/register_docs/landcapabilitygl5a.pdf

Dorijan, R., Mladen, J., Mateo G. and Ivan, P. (2020). Optimal Soybean (Glycine max L.) Land Suitability Using GIS-Based Multicriteria Analysis and Sentinel-2 Multitemporal Images. Remote Sensing, 12 / 146 3; doi:10.3390/rs12091463.

FAO. (1976). A framework for land evaluation. Rome, Italy: Author.

FAO, (1983). Guidelines: Land Evaluation for Rainfed Agriculture. FAO Soil Bulletin, 52, FAO, Room, 237p

FAO, (2007b). Land evaluation, towards a revised framework. Land and Water Discussion Paper 6. Rome: FAO Electronic publishing division.

FAO, (2006). Guidelines for soil description: FAO, Room. ISBN 92-5-105521-1

Gbanie, S. P., Tengbe, P.B., Momoh, J.S.,Medo, J. and Kabba, V.T.S. (2013). Modelling landfill location using Geographic Information System (GIS) and Multi-criteria decision Analysis (MCDA): A case study of Bo, Southern Sierra Leone. Applied Geography. 36, 3-12. https://doi.org/10.1016/j.apgeog.2012.06013

Gemechu D., Sintayehu L. G., Ashenif M., Alemayehu R., & Sintayehu T. | (2020) GIS and remote sensing-based physical land suitability analysis for major cereal crops in Dabo Hana district, South-West Ethiopia, Cogent Food & Agriculture, 6:1, 1780100, DOI: 10.1080/23311932.2020.1780100

Goepel, K.D. (2018). Implementation of an Online Software Tool for the Analytic Hierarchy Process (AHP-OS). International Journal of the Analytic Hierarchy Process, Vol. 10 Issue 3 2018, pp 469-487, https://doi.org/10.13033/ijahp.v10i3.590

Han, C.; Chen, S.; Yu, Y.; Xu, Z.; Zhu, B.; Xu, X.; Wang, Z. (2021). Evaluation of Agricultural Land Suitability Based on RS, AHP, and MEA: A Case Study in Jilin Province, China. Agriculture, 11, 370. https://doi.org/10.3390/agriculture11040370

Horneck, D.A., Sullivan, D.M., Owen, J.S., Hart, J.M., 2011. Soil Test Interpretation Guide. Oregon State University, Extension Service, USA. Available at [Access date : 06.01.2018]: https://ir.library.oregonstate.edu/downloads/00000020g

Jibril, B. A; Adamu, M. A; John D. M., Ismail, A. A and Isa, W. A. (2019). Site Identification for Recessional Irrigation Farming Around Dadin Kowa Dam Gombe State, Nigeria. FUDMA Journal of Sciences, Vol. 3 No. 3, September, 2019, pp 626 –634

Kihoro J, Bosco NJ, Murage H. Suitability analysis for rice growing sites using a multicriteria evaluation and GIS approach in great Mwea region, Kenya. Springerplus. 2013 Jun 17;2(1):265. doi: 10.1186/2193-1801-2-265. PMID: 23888264; PMCID: PMC3717158.

Mohana, P., Mariappan, N. V. E., & Manoharan, N. (2009). Land suitability analysis for the part of Parambikulam Aliyar command area, Udumalpet Taluk using remote sensing and GIS Techniques. International Journal on Design and Manufacturing T Echnologies, 3(2), 98–102. doi:10.18000/ijodam.70069

Mustafa, A.A. Man Singh, R.N. Ahmed, N. Khanna,M. Sarangi, A. andMishra, A.K. (2011). Land suitability Analysis for different crops. A multicreteria decision making approach using Remote Sensing and GIS. Indian Research Institute New Delhi

NIRSAL (2019). Final Report - Borno State Commodities Value Chain Assessment Report. Available at https://fscluster.org/sites/default/files/documents/ final_report_-Borno_state_commodities_value_chain.

Oluwatosin, G.A. (2005). Land Suitability Assessment in Continental Grits of Northwestern Nigeria for Rainfed Crop Production. West African Journal of Applied Ecology, 7:53–67.

Patil, R.B. and Prasad, j. (2004). Characteristics and classification of some Sal (Shorea robusta) supporting soils in Dindori district of Madhya Pradesh. Jornal of the indian society of soil sciences. 52(2), 119-125

Rota, J.A., Wandahwa, P. and Sigunga, D.O. (2006). Land Evaluation for Soya Beans (Glycine Max, L. Merrill) Production Based on Kriging Soil and Climate Parameters for the Kakamega District, Kenya. Jornal of Agronomy. 5(1): 142-150.

Saaty, T. L. (1980). The Analytic Hierarchy Process. New York : McGraw-Hill

Surajit, B., Mobin, A., and Sristi, S. (2017). Land Suitability Analysis for Agricultural Crop using Remote Sensing and GIS - A Case Study of Purulia District.

Tashayo, B., Honarbakhsh, A., Akbari, M. and Eftekhari, M. (2020). Land suitability assessment for maize farming using a GIS-AHP method for a semi- arid region, Iran. Journal of the Saudi Society of Agricultural Sciences 19, 332–338. https://doi.org/10.1016/j.jssas.2020.03.003

Udemezue JC. (2019) Challenges and Opportunities of Agricultural Sector Among Youths in the Twenty First Century: The Case of Nigeria. Adv Biotechnol Microbiol. 14(5): 555896. DOI: 10.19080/AIBM.2019.14.555896

Vanger N. Maakaven, Kilani M. Olaknule, Bojang. A. and Elisha Ikpe (2023). Suitability Mapping for Optimum Soybeans (Glycine Max (L.) Merr.) Production in Konshisha LGA, Benue State, Nigeria using Satellite Remote Sensing Data. International Journal of Weather, Climate Change and Conservation Research, 9 (2),1-22. doi: https://doi.org/10.37745/ijwcccr.15/vol9n2122.