

LAND SUITABILITY EVALUATION FOR SOILS OF RABAH FLOODPLAIN, SOKOTO STATE USING GIS BASED TECHNOLOGY FOR IRRIGATED RICE PRODUCTION

I.B Buji,¹ N.B. Eniolorunda,² E.A. Manasseh,³ M.J. Magaji,⁴
N.G. Hayatu,⁵ I. Adamu,¹ and M.B. Sharu⁶

¹Department of Soil Science, University of Maiduguri, Borno State

²Department of Geography, Usmanu Danfodiyo University, Sokoto, Nigeria

³National Agricultural Seeds Council, North-West Region, Samaru, Zaria

⁴Department of Soil Science, Bayero University Kano.

⁵Department of Soil Science, Usmanu Danfodiyo University, Sokoto, Nigeria

1. Abstract

In the face of a growing human population, there is decline in rice yield in the Sokoto floodplains reportedly due to soil fertility disturbance. For sustainable livelihoods and food security, information on land quality of the area is of importance. Thus, land suitability assessment was conducted in this study. A fixed grid pattern was set out to cover the site, and using a hand-held GPS receiver, auger observations were made at every 100m interval, following which soil boundary were demarcated. For each soil identified, two standard profiles were sunk to 2m (except where impenetrable layer or water table was encountered) and studied. Soil samples were collected from each genetic horizon, bagged and taken to the laboratory for processing and analysis. Soil properties were interpolated within the ArcGIS 10.2.2 software using the Inverse Distance Weighted (IDW) technique. About 84% of the area has nutrient availability index (NAI) of S1 and S2, due largely to suspected fertilizer application. Areas of high NAI (S1) are those largely of high suitability (S1) in the input nutrients in the order of $K > N > P > Zn$. Soil Quality Index (SQI) is largely of medium to low quality as most of the factors are largely characterised by S2 and S3 ratings. Percentage coverage of suitability is in the order of: S2 (44.70%) > S3 (31%) > S1 (24.30%). The area is more endowed in NAI than in SQI, and therefore of moderate suitability for rice production. Thus, farmers should adopt measures that can improve soil texture, soil water retention and boost soil organic matter.

Keywords: Land suitability, soil quality, nutrient availability, rice, Sokoto

2. INTRODUCTION

With an estimated population of 200 million, Nigeria's cumulative agricultural imports stood at N1trillion per year (FAO, 2021) prior to the year 2015. Out of this volume of imports, about 3million metric tonnes of rice (*Oryza sativa L.*) worth about US\$500 million was imported every year (Omoigui, et al., 2020), making the country the highest importer in Africa and second highest in the world after China (Abubakar et al., 2019). According to USDA's (2019) Production, Supply and Distribution Database, Nigeria produced about 5.8 million metric tonnes of milled rice in 2019 but had to import about 2 million metric tonnes more to augment for the shortfall in supply. This underscores the fact that local production of rice – a food which is perhaps the most important in Nigeria - is insufficient. The potential land area for rice production in Nigeria is between 4.6 and 4.9 million ha. Out of this, only about 1.7million ha (35%) is grown with rice (Nwilene et al., 2010). Realizing the potentiality for self-reliance in rice production, and coupled with the negative impact of importation on foreign reserve together with the needs to grow jobs and economy and to attain sustainability in local production for food security, the current country's administration placed a ban on importation of rice and some agricultural products.

Nigeria covers 923,768km² of landmass out of which 24,000km² (2.6%) is occupied by wetlands (Agbasi & Odiaka, 2016). Although the Sokoto-Rima basin floodplain where the study area is located constitutes a small proportion of the country's total wetlands, settlements surrounding the floodplains are inhabited by rural majority, whose livelihoods depend on agriculture, cultivating mainly rice and other moisture sensitive and highly valued crops (Swindell, 1986; Ojo et al., 2009; Iliya & Baba, 2013). The Boserupian theory posits that population pressure is the basis for agricultural expansion and that when population increases, farmers will begin to cultivate unused land, but as population keeps increasing, a threshold of land saturation where expansion is substituted by intensification is reached (Reenberg et al., 2008; Keita & Zhang, 2010). Due to accelerated population growth in the study area, the floodplains are highly fragmented and intensively cultivated, such that an average farmer holds less than 1ha of land (Nwilene et al., 2010). Consequently in the last two decades, there have been reported cases of decline in farm productivity in the floodplain in spite of availability of factors of production (Ojo et al., 2009; Eniolorunda, 2016), and many studies have alluded fertility disturbance to the decline, largely resulting from overuse which is likely a consequence of land fragmentation.

As human population increases, the need to expand areas of land under cultivation or resort to intensification for sustainable livelihoods and food security

becomes imperative (Reenberg et al. 2008; Keita & Zhang, 2010). To achieve the above, there is a need for proper allocation of land to uses that will maximize returns with minimal or no compromise to the environment. Land evaluation provides information on the constraints and opportunities for the sustenance of land and therefore guides decisions on optimal utilizations of resources, whose knowledge is an essential prerequisite for land use planning and development. Moreover, such an analysis allows identification of the main limiting factors for the agricultural production and enables decision makers such as land users, land use planners, and agricultural support services to develop a crop management able to overcome such constraints, increasing the productivity (Bandyopadhyay et al., 2009). It is in the light of the foregoing that this study aimed at evaluating the suitability of the soil for rice cultivation in the study area as a step towards sustainable production and food security. The objectives are to assess the nutrient availability and quality of the soil.

3. STUDY AREA

The study was carried out in Rabah District, Rabah Local Government Area of Sokoto State. The study area (Figure 1) occupies a land area of 450 ha. It is situated about 50km east of Sokoto Metropolis, between latitudes $13^{\circ} 5' 45''$ and $13^{\circ} 8' 45''$ N and longitudes $5^{\circ} 28.5' 45''$ and $5^{\circ} 33.5' 45''$ E. It is located within the Sokoto River floodplain which is a tributary of the Rima River, located within Rima Basin. The Basin is generally characterized by gently rolling landscape forming monotonous marine lowland with altitudes ranging between 217- 410m above sea level (ASL) (Ifabiyi & Eniolorunda, 2012).

The study area is located on *Dange* formation which is a marine deposit of coastal or estuarine origin, deposited below sea level and underlain by basement complex (Sombroek & Zonneveld, 1971). The formation is mainly of shale and clay. In the late-Tertiary and Quaternary periods, erosion processes became active thereby creating the river systems. The Sokoto river has alluvial deposits all along its course of about 18m in thickness.

The soils in the floodplains are Fluvisols based on FAO taxonomy, the equivalents of which are Entisols in USDA classification. The soils that developed on *Dange* sediments are generally of low fertility with clay minerals of low activity. The deposits of the floodplain soils are enriched with huge manure inputs from local herd dungs kept in the villages or from the direct droppings by the nomadic cattle that graze on the uncultivated floodplain land areas especially in the dry season (Swindell, 1986).

The study area is located in the semi-arid area with prolonged dry season (Adeniyi, 1993; Umar, 2013). Rainfall is highly seasonal and controlled by the irregular movement of the Inter-Tropical Discontinuity (ITD). Rainfall is experienced during the relatively short but intense localized thunderstorms cover small areas. Annual rainfall stands around 600mm, making the area one of the acute climate change impacted areas in Nigeria (Odjugo, 2010). The peak of the hot season records 44⁰C (Ifabiyi & Eniolorunda, 2012), while mean annual minimum and maximum temperatures are 21.5⁰C and 34.9⁰C respectively (Umar, 2013). The insufficient rainfall and high evapotranspiration during the dry season restrict crop cultivation to the floodplain (Adeniyi, 1993).

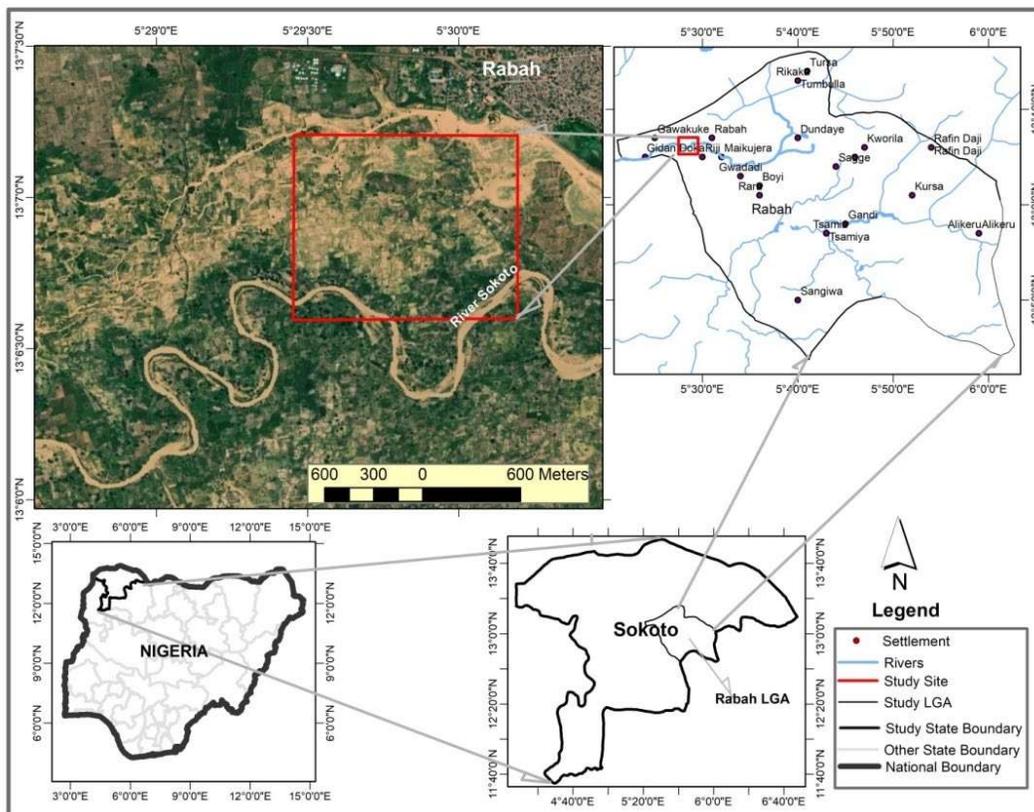


Figure 1. Study area.

The study area is located in the Sudan Savannah consisting of scattered trees such as *Acacia nilotica* (Egyptian mimosa) (Gàbààrúúwáá), *Parkia clappertoniana* (locust tree) (Dóòráwà), *Borassus aethiopum* (deleb palm) (Gígínýà). The vegetation is mainly of short shrubs and grasses, with grasses averagely measuring below 1m. Bush burning, fuel-wood extraction and

uncontrolled grazing are largely responsible for land degradation in the upland, thereby restricting dry season cropping to the floodplains (Adeniyi, 1993).

The study area is drained by River Sokoto which forms a tributary to River Rima. It is an alluvial floodplain on a relatively low-lying area where high level of deposition is experienced. The floodplain is characterized by high groundwater recharge and sinuous river channels, engendering recurrent flooding (Ifabiyi & Eniolorunda, 2012). The water table approaches the ground surface, and water quality for irrigation is good to excellent (FAO, 1969). Availability of drinking water during the long dry season and high soil water retention which makes possible the extension of the growing season beyond the end of the rains explain the locations of observed settlements near the floodplain (Adams, 1986; Swindell, 1986). Also significant is the historical fact that this river became the core of the Sokoto caliphate in the 19th century which saw old settlements expanding and many new ones created, leading to the development of intensive cultivation in areas which formerly relied on bush-fallowing and herding (Swindell, 1986). Population expansion and consequent intensification of cultivation engendered cultivation of moisture loving crops such as rice, onion, among others (Swindell, 1986).

MATERIALS AND METHODS

3.1 Data Collection

A reconnaissance was conducted in and around the study area for acquaintance with the physiography. A detailed soil survey at a scale of 1:10,000 was conducted using the method prescribed by Hildebrand (1966). A series of parallel traverse lines (100m*100m) on a fixed grid pattern (Figure 2) was set out and observations were made at every 100m interval along the baseline to identify the kind of soils in the area using a Dutch auger. Geographic coordinate was recorded at each observation point using a handheld Global Positioning System (GPS) (Garmin GPSMAP78s). At each interval, the soil properties examined were mainly profile characteristics, which include colour, texture, consistence, effective soil depth, surface stoniness, mottling, structure, cementation, concretion, rock fragments, presence of iron-manganese, and slope.

Based on the observed variation during auger examination, soils were delineated; areas with similar kinds of soil were classified as one mapping unit while those with dissimilarities were further examined for accurate location of the boundary between them. For each of the soils identified, two standard profiles were sunk to a depth of 2.0m, except where impenetrable layer or water table was encountered (Figure 3).

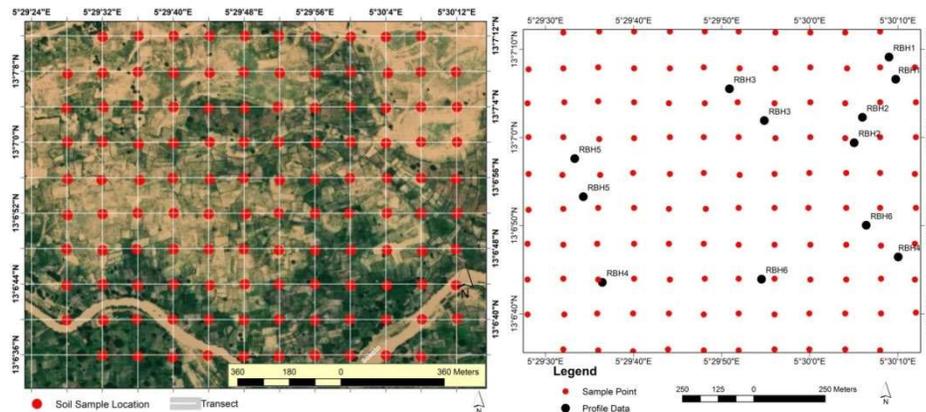


Figure 2: Soil sample locations along transects.

Figure 3: Profile locations

Each profile was demarcated into different horizons, the depths of which were individually measured and described in accordance with the description procedures of soil survey division (Soil Survey Staff, 2006). Bulk soil samples were collected and bagged in well labelled plastic containers from each identified genetic horizon, starting from the lowest to the topmost horizons to avoid contamination. Similarly, undisturbed core samples were collected at each horizon for determination of bulk density and saturated hydraulic conductivity. The samples were taken to the laboratory for processing and analysis.

3.1.1 Slope data

Slope was derived from the 30m resolution Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) covering the study area. The DEM was subjected to standard pre-processing algorithms after which the slope data was extracted from it within the ArcGIS 10.2.2 environment (Eniolorunda & Budah, 2019).

3.1.2 Drainage data

Drainage data was derived from the soil textural and classes based on the rating derived from Kihoro et al. (2013).

3.1.3 Laboratory test

The soil samples collected from the field (pedons) were air dried and gently crushed with porcelain pestle and mortar, and passed through a 2 mm sieve. The physical and chemical properties of the soils were determined using the standard laboratory procedures.

3.1.4 Particle size distributions

Particle size distribution was determined using the principles of Bouyoucos Hydrometer method (Gee & Or, 2002). Sand, silt and clay were determined by dispersing the soil samples in 5 % Calgon (sodium hexametaphosphate) solution. The dispersed samples were shaken on a reciprocating shaker after which particle size distribution was determined with the aid of Bouyoucos hydrometer at progressive time intervals of 40 seconds and 2 hours respectively. The textural classes were extrapolated using the USDA textural triangle.

3.1.5 Saturated hydraulic conductivity (Ksat)

The Saturated hydraulic conductivity (Ksat) of the soil for each sample was determined using the falling head permeameter method similar to that described by Klute & Dirksen (1986). It involved obtaining undisturbed core samples from the field and soaking them with ordinary water to saturation. A PVC core ring similar in height and size to that of the undisturbed core sample were glued together using masking tape. A constant water head of 5cm was then maintained for ten minutes and saturated hydraulic conductivity was computed as:

$$K_{sat} = \frac{aL}{At} \text{Log} \frac{H_0}{H_1}$$

Where: H_0 = Initial Hydraulic head; H_1 = Final Hydraulic head; a = Cross sectional area of the standing PVC pipe (πr^2); L = length of the soil sample; A = Cross sectional area of the water (πr^2); t = Time (sec)

3.1.6 Soil reaction (pH)

Soil pH was determined potentiometrically in water and in CaCl_2 . In water, 10 g of soil samples to 10 ml of distilled water were added (ratio 1:1) while pH in CaCl_2 was determined at a ratio of 1:2 soil to solvent and the readings were taken using the glass electrode pH meter, buffered at pH 7 (Agbenin, 1995).

3.1.7 Total Nitrogen (N)

The micro-Kjeldhal method (Bremner, 1996) was used to determine total nitrogen. The soil was digested by the addition of 1 tablet of mercury catalyst and conc. Hydrogen sulphate and heated cautiously on a digestion stand. H_3BO_3 indicator and NaOH were used in the distillation of the carefully transferred digest. Ammonium Nitrate, the distillate was then determined by titrating with standard hydrogen sulphate until a green to pink colour was reached.

3.1.8 Available Phosphorus (P)

Available phosphorus was determined using the Bray 1 method (Bray & Kurtz, 1965). 1N Ammonium fluoride (NH_4F) and 0.5 N conc. Hydrochloric acid

was used as the extracting solution which was followed by the addition of ammonium molybdate solution ($(\text{NH}_4)_6\text{MO}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$) and stannous chloride ($\text{SnCl}_2\cdot\text{H}_2\text{O}$). Transmittance was measured with a spectrophotometer and standard curve prepared within the range of 0-1ppm P.

3.1.9 Exchangeable Potassium (K)

Exchangeable cations were extracted with 1N, NH_4OAc solution (pH 7). The extract was then read for K using flame photometer (Black, 1965).

3.1.10 Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) of the soils was determined with 1M ammonium acetate (NH_4OAc), buffered at pH 7.0 (Chapman, 1965; Rhodes, 1982.). The excess acetate was removed by repeated washing with alcohol. The adsorbed ammonium ions displaced with 10 % sodium chloride (pH 2.5) and determined by the Kjeldhal procedure.

3.1.11 Zinc

Zinc (Zn) with other micronutrients was leached with 0.1N HCl, using the method of Juo (1979) and determined using the Atomic Absorption Spectrophotometer (AAS).

3.1.12 Exchangeable Sodium Percentage (ESP)

The exchangeable sodium percentage was calculated as the proportion of the CEC (NH_4OAc) occupied by exchangeable sodium as follows:

$$\text{ESP} = \frac{\text{Exchangeable sodium}}{\text{CEC } (\text{NH}_4\text{OAc})}$$

4. DATA ANALYSIS

Measured variables in the data set were analysed using descriptive statistics (range, means, standard deviation and coefficient of variation) within the IBM SPSS 21 statistical package.

4.1 Land Suitability Requirements for Rice

In evaluating the suitability of the study area for rice cultivation, assessment of land quality is key; this requires rating and combining different land characteristics (Dengiz, 2013). Thus, two indices are used for answering the objectives of the study: Nutrient Availability Index (NAI) and Soil Quality Index (SQI). Nutrient availability is evaluated by observations and tests which are used to predict the response of plants and management of nutrients (Fageria & Baligar, 2005), while the ability of soil to support plant growth and crop productivity is termed soil quality. The requirements for the calculation of the indexes are as explained in Equations 1 and 2 and as contained in Tables 1, 2 and 3.

$$NAI = N * P * K * Zn \dots\dots\dots Equation 1$$

Where: NAI = Nutrient Availability Index, N = Nitrogen, P = Phosphorus, K = Potassium, Zn = Zinc

$$SQI = R * T * F * G * S * H \dots\dots\dots Equation 2$$

Where: SQI = Soil Quality Index, R = Drainage, T = Texture, F = Slope, G = Hydraulic Conductivity, S = Salinity Hazard (Exchangeable Sodium Percentage, ESP), H = Soil Reaction.

Table 1: Factor ratings for NAI for rice cultivation

Factor	Unit	Low (S3)	Medium (S2)	High (S1)
N	%	<0.15	0.15-0.20	>0.20
P	ppm	<10	10-20	>20
K	ppm	0.01-0.30	0.31-0.6	0.61-0.73
Zn	ppm	<1.00	1.00-5.00	>5.00

Adapted from Dengiz (2013)

Table 2: Factor SQI ratings for rice cultivation

Suitability	Drainage (R)	Texture (T)	Slope (F) (%)	Soil PH (H)	Hydraulic Conductivity (G) (cm h ⁻¹)	Sodicity ESP* (dS m ⁻¹)
Very low	Highly Excessive	Sand	60-100	< 4.0	Very Slow 0-0.125	Very High >16
Low	Excessively Drained	Sandy Loam	30-60	> 8.4	Slow 0.125-0.5	High 10-16
Moderately low	Very poorly drained	Silt Loam	15-30	4.0 - 5.0	Moderate 0.51-1.20	Moderate High 6-10
Moderate	Well Drained	Loam	8-15	7.8 - 8.4	Rapid 1.21-2.50	Slight 6-10
Moderately high	Moderately Well Drained	Silty Clay	5-8	5.1 - 5.5	High 2.50-4.0	Very Slight 4 - 6

High	Poorly Drained	Clay Loam	2-5	7.4 - 7.8	Very Rapid	>4.0	Moderate Low	2 - 4
Very high	Imperfectly Drained	Clay	0-2	5.6 - 7.3			None	<2

* ESP = Exchangeable Sodium Percentage

Adapted from(Kihoro, Bosco, & Murage, 2013)

Table 2 shows the SQI ratings. However, to harmonise the factors at S1, S2 and S3 suitability levels, corresponding to High, Moderate and Low, Table 2 is recalibrated into Table 3. Based on FAO (1983), high suitability (S1) has insignificant limitations, while moderate suitability (S2) has moderate limitations. Marginal suitability (S3) has major limitations. Areas not suitable (N) have severe limitations which are not visible based on the rating scale in Table 2.

Table 3: Recalibrated SQI ratings for rice cultivation

Suitability	Drainage (R)	Texture (T)	Slope (F) (%)	Soil PH (H)	Hydraulic Conductivity (G) (cm h ⁻¹)		Sodicity ESP* (dS m ⁻¹)	
Low	Highly Excessive, Excessively Drained, Very poorly drained	Sand , Sandy Loam, Silt Loam	60-100, 30-60, 15-30	< 4.0, > 8.4, 4.0 - 5.0	Very Slow, Slow, Moderately Slow	0-0.125 0.125- 0.5 0.51- 1.20	Very High, High, Moderate High	>16, 10-16 6-10
Moderate	Well Drained	Loam	8-15	7.8 - 8.4	Rapid	1.21- 2.50	Slight	6-10
High	Moderately Well Drained, Poorly Drained, Imperfectly Drained	Silty Clay, Clay Loam, Clay	5-8, 2-5, 0-2	5.1 - 5.5, 7.4 - 7.8, 5.6 - 7.3	High, Very Rapid	2.50- 4.0, >4.0	Very Slight, Moderate Low, None	4 - 6, 2 - 4, <2

Modified from Kihoro et al. (2013)

4.2 Point Interpolation of Criteria

Results of the soil physical and chemical properties of the profile obtained from the laboratory were tied to geographic coordinates of the locations and imported into the ArcGIS 10.2.2 software to generate a point map of profiles.

Inverse Distance Weighted (IDW) method was used to interpolate each of the soil properties to generate a thematic layer thereof. Its usage in this study stems from its popularity, simplicity of computation and geographical principles by which it operates (Eniolorunda & Budah, 2018). Geographically, close objects are more related than those distant apart. Thus, the IDW interpolation method works on the assumption that values of nearby known points have more influence (weight) than those farther away in determining the estimated value of a point (Ozsoy, Aksoy, Dirim, & Tumsavas, 2012).

According to Ozsoy et al. (2012), IDW is denoted as:

$$f(x, y) = \frac{[\sum_{i=1}^N w(di) Zi]}{[\sum_{i=1}^N w(di)]} \dots \dots \dots \text{Equation 3}$$

Where $f(x,y)$ is the interpolated value at point (x,y) ; $w(di)$ is the weighting function; Zi is the data value at point I ; and di is the distance from point (x,y) .

4.3 Classification of Criteria

All the criteria maps were later calibrated to a common scale based on FAO standard ratings. Rating of each thematic layer was based on Tables 1 and 3, resulting in high, moderate and low suitability classes, corresponding to S1, S2 and S3 respectively.

4.4 Multi-Criteria Evaluation

The thematic layers were combined into a single map using Weighted Overlay – a Multiple Criteria Evaluation (MCE) method that overlays several raster layers using a common measurement scale and weighing each according to its importance. In this case, each layer was given a weight according to their influence on rice production as provided by Saaty (1980). The weight influence of each soil parameter is by hierarchy, and it is a percentage of the total number of layers. Ratings were subsequently carried out to determine the final suitability map.

4.5 Result

4.5.1 Nutrient Availability Index (NAI)

The inputs for the computation of NAI are Nitrogen, Phosphorous, Potassium and Zinc which are presented in Figure 4. Figure 5 describes the NAI in the study area. Table 4 shows that areas of high nutrient availability (S1) constitute 37.34% of the study area (54.85ha), while S2 covers 46.72% (68.64ha) of the area. Areas of low nutrient availability (S3) constitute approximately 16% (23.42ha). From the above, there appears to be a generally moderate nutrient availability. However, this could be attributed to the fact that NPK fertilizers are

used in large quantities in the study area, thus raising the levels of nutrients (Eniolorunda, 2016). Brady & Weil (2013) submitted that the application of fertilizer usually results in much concentration of elements within the soil. It should be pointed out here that nutrient availability may not necessarily determining crop performance as nutrient acquisition by plants from a given soil also depends on other factors as soil physical conditions, crop or plant genus, species, or even variety (Jungk, 2002). In many soils, nutrient availability is inadequate for crop growth unless fertilized.

In order to evaluate the contributions of the input nutrients to the formation of NAI classes, a cross-tabulation was carried out between the NAI map and each of the input elements to produced Figure 6 and Table 5. For each of the maps in Figure 6, the first column of the legend (left) represents the NAI classes, while the second (right) represents the classes of the input nutrient. It shows how the classes contributed to the formation of the NAI classes.

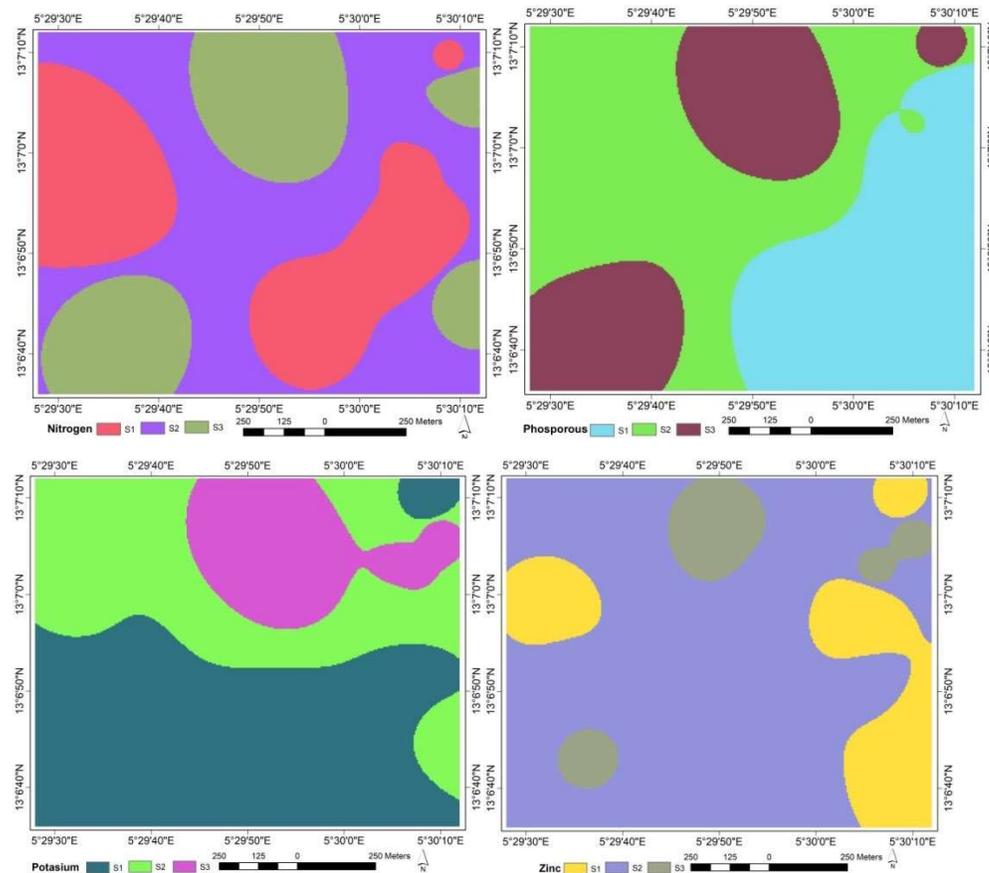


Figure 4: Inputs to NAI

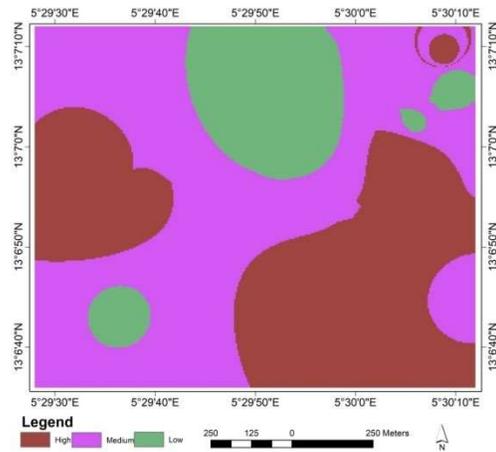


Figure 5: NAI Rating

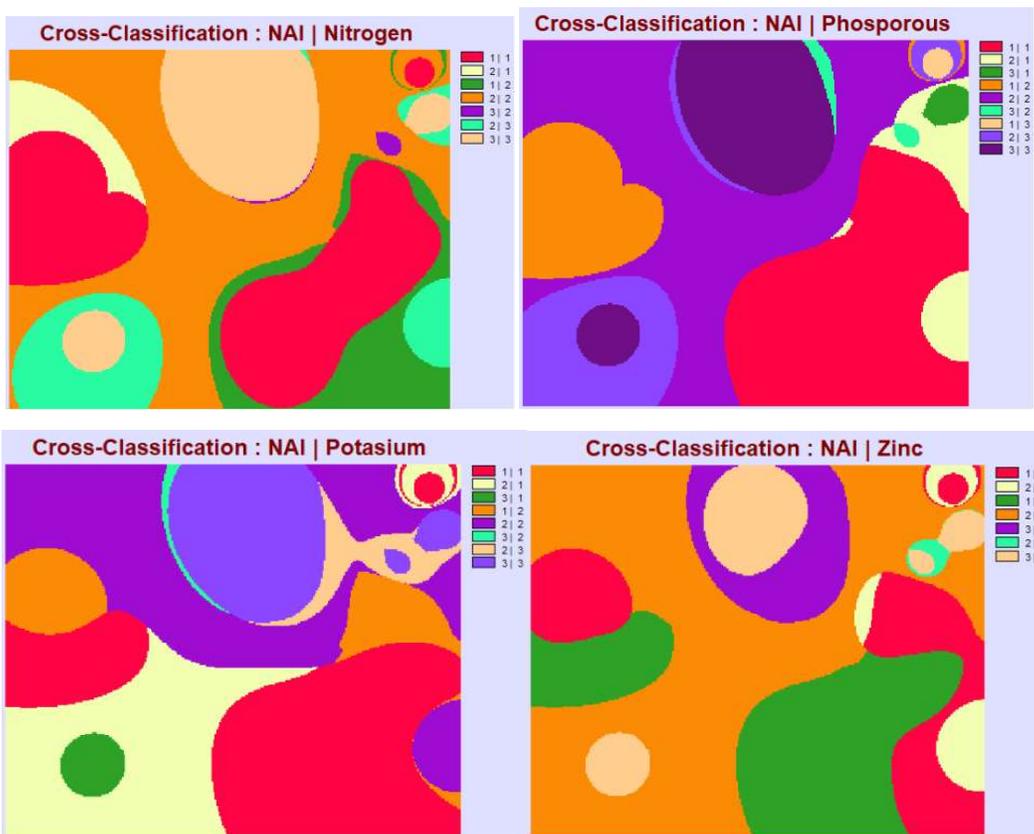


Figure 6: Cross-Tabulation Maps between NAI | Input Elements

Table 4: NAI Rating

S/No	Rating	Area (Ha)	Percentage (%)
1	S1	54.85	37.34
2	S2	68.64	46.72
3	S3	23.42	15.94
Total		146.92	100.00

A legend unit with both sides having same number shows a contribution of same suitability from the input factor to the cognate class in the output NAI (e.g. 1|1, 2|2, etc.). Table 5 further shows the proportions of each of the nutrients contributing to the NAI. The diagonals in Table 5 represent the proportions of classes in the nutrient contributions to same classes in the NAI (i.e. S1 in Nitrogen contributing to S1 in NAI). From Table 5, the magnitudes of input nutrient contributions to NAI are in the orders of K>N>P>Zn, Zn>N >P> K and N>P> K>Zn for S1, S2 and S3 respectively, indicating that areas of high NAI (S1) are those largely of high suitability (S1) in the input nutrients in the order of K>N>P>Zn.

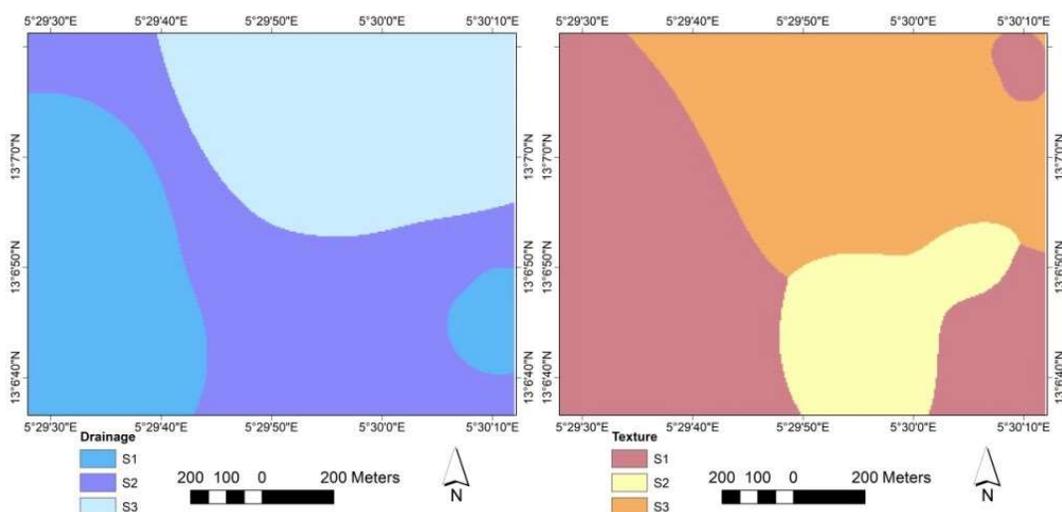
Table 5: Cross-Tab between NAI | Input Elements

Nutrient	Suitability	NAI			
		S1	S2	S3	Total
Nitrogen	S1	0.27	0.04	0.00	0.31
	S2	0.10	0.33	0.00	0.43
	S3	0.00	0.10	0.16	0.26
	Total	0.37	0.47	0.16	1.00
Phosphorous	S1	0.26	0.05	0.01	0.32
	S2	0.10	0.31	0.01	0.43
	S3	0.00	0.10	0.14	0.25
	Total	0.37	0.47	0.16	1.00
Potassium	S1	0.29	0.19	0.02	0.50
	S2	0.08	0.24	0.01	0.33
	S3	0.00	0.03	0.13	0.17

	Total	<u>0.37</u>	<u>0.47</u>	<u>0.16</u>	<u>1.00</u>
Zinc	S1	0.15	0.03	0.00	0.18
	S2	0.23	0.43	0.08	0.73
	S3	0.00	0.00	0.08	0.09
	Total	<u>0.37</u>	<u>0.47</u>	<u>0.16</u>	<u>1.00</u>

4.5.2 Soil Quality Index

The inputs to SQI are drainage, texture, slope, hydraulic conductivity, exchangeable sodium percentage and pH (Figure 7). The SQI (Figure 8) shows that areas of high rating (S1) constitute 16.46% (24.19 ha), while areas of moderate rating form 37.82% (55.56), representing the class with the widest coverage. Areas of low rating have the highest coverage (45.72% - 67.17ha). It boils down to the fact that soil in the area is largely of medium to low quality. This is not unexpected as most of the input factors to the SQI computation are largely characterised by S2 and S3 ratings. The implication is that average to low SQI is in turn capable of counteracting nutrient availability. Although the opposite is the case for NAI in this study where the observed NAI is found to be generally medium, the obtained value in this study can be attributed to high rate of NPK fertilizer application. A medium to low SQI will neutralize a medium to high NAI, thus rendering the soil largely low in terms of suitability for rice cultivation in the study area. The use of a SQI can provide an early assessment of soil degradation processes and help land managers to implement soil conservation practices (María, Sione, Germán, Lado, & Paz, 2017).



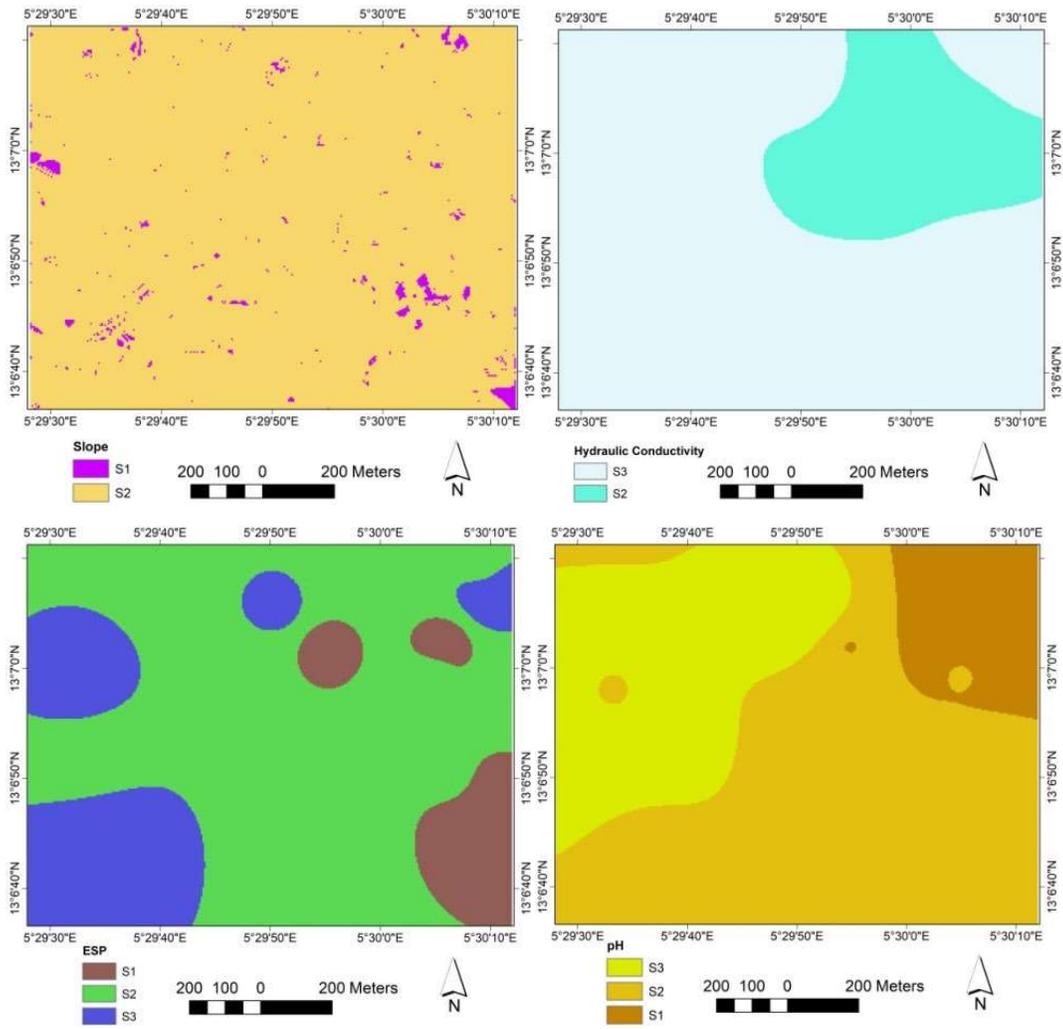


Figure 7: SQI Inputs

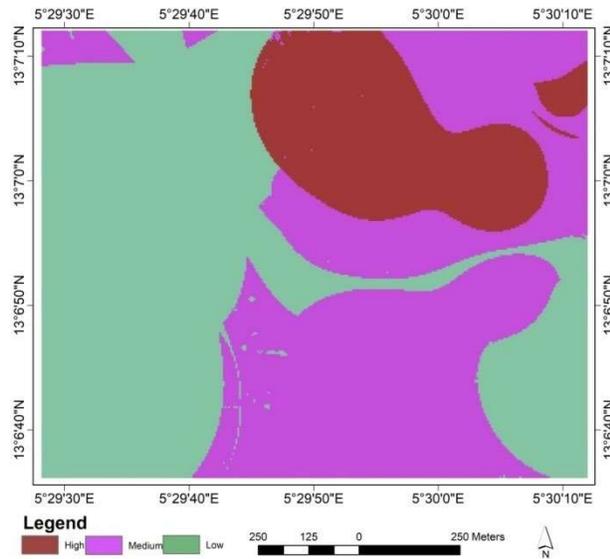


Figure 8: SQI of the study area

Table 6: SQI Rating

S/No	Rating	Area (Ha)	Percentage (%)
1	S1	24.19	16.46
2	S2	55.56	37.82
3	S3	67.17	45.72
Total		146.9171	100

4.5.3 Land suitability evaluation

The suitability classes produced for the study area are: highly suitable (S1), moderately suitable (S2) and marginally suitable (S3) (Figure 9). In the rating of factor inputs, none was found unsuitable; hence, all the classes obtained in the mapping process are suitable in one way or the other. From Table 7, S1 covers 24.30% (35.70ha), while S2 constitutes the largest coverage (44.70% - 65.67ha). Exactly 31% (45.55ha) is marginally suitable (S3). Figure 9 further shows that the eastern part is characterized by S1 and S2, while the western part is characterized by S2 and S3. The reason for this observation can be found in both the NAI and SQI, where the eastern half is less characterised by low ratings of the input factors. Field work indicates that the eastern side is wetter due to water availability. The result of the cross-tabulation between the suitability map and

each of the NAI and SQI (Table 8) further shows that S1s contributed 27% from both the NAI and SQI to the derivation of the suitability map, while S2s contributed about 43%; S3 contributed approximately 31%. These contributions later yielded 25%, 44% and 31% for S1, S2 and S3 respectively in the suitability map.

When viewed differently, Table 8 shows that NAI contributed more of S1 and S2 (84%) to the product suitability pattern, while the SQI contributed more of S2 and S3 (83%). Thus, the study area is more favoured in terms of nutrient availability than it is in soil quality.

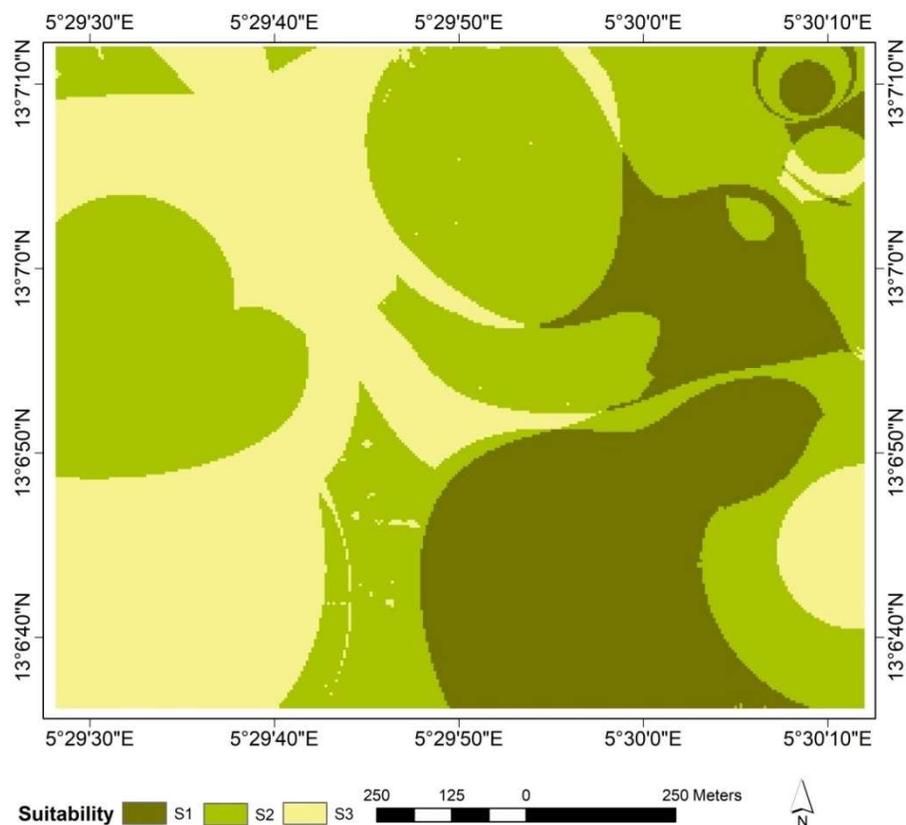


Figure 9: Land Suitability Pattern

Table 7: Land Suitability Distribution

S/No	Suitability	Area (Ha)	Percentage (%)
1	S1	35.70	24.30
2	S2	65.67	44.70
3	S3	45.55	31.00
Total	146.92	146.92	100

Table 8: Cross-tabulation between suitability map and NAI and SQI

Nutrient	Suitability	Land Evaluation Map			
		S1	S2	S3	Total
NAI	S1	0.21	0.16	0.00	0.37
	S2	0.03	0.17	0.26	0.47
	S3	0.00	0.11	0.05	0.16
	Total	0.25	0.44	0.31	1.00
SQI	S1	0.06	0.11	0.00	0.17
	S2	0.19	0.17	0.01	0.38
	S3	0.00	0.16	0.30	0.45
	Total	0.25	0.44	0.31	1.00

5. CONCLUSION AND RECOMMENDATIONS

The study shows that 25% of the study area is of high suitability (S1), while 44% is medium; 31% is of low suitability. No portion of the study area is unsuitable. From the foregoing, it can be assumed that the cultivation of areas under S1 and S3 would produce a counterbalancing yield almost or equal to the productivity of S2 (as if both classes were S2). Thus, the study area can be said to be of moderate land suitability. It is also obvious that NAI contributed 84% in S1 and S2 to the formation of the suitability pattern, while SQI contributed 83% of S2 and S3, making the area more in need of improvement in soil quality than nutrient. Farmers are advised to work more on improving the physical conditions

of the soil in addition to fertilizer application. Such measures must improve soil water retention and boost soil organic matter. Farmers should be trained by extension workers on pre-farming soil analysis to determine the status of the farmland in terms of fertility and quality. This study should be expanded holistically by government in both spatial and content scopes upon which vital decisions can be made for sustainable rice production in the floodplains of the basin.

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