Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

Geographic Information System (GIS) Approach in Suitability Study of Asu River Group Soils of Old Ohaozara - Southeastern Nigeria for Rice production

Obasi S. N.*[1] and Obasi C. C.[2]

[1]Department of Crop and Soil Science, National Open University of Nigeria, Faculty of Agricultural Sciences, Kaduna.

[2]Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka

ARTICLE INFO

Article history:
Received February 15, 2022
Received in revised form March 2, 2022
Accepted March 20, 2022
Available online April 18, 2022

Keywords:

Digital Elevation Model
Soil Suitability
Asu River Group
Old Ohaozara

Corresponding Author's E-mail Address:

nobasi@noun.edu.ng 08034499155

https://doi.org/10.36265/njss.2022.320108

ISSN– Online **2736-1411**

Print **2736-142X**

ABSTRACT

This research work was carried out in Ivo Local Government Area, Old Ohaozara, Southern Ebonyi State, Southeastern Nigeria. Using Digital Elevation Model (DEM) which is a component Geographic Information System (GIS). Yearly precipitation and relative humidity scored 95% in all the investigated pedons which included Upland, Lowland, and Irrigated soils placing them in Suitability class 1 (S1) while mean temperature scored 85% in all pedons of Old Ohozara soils. The Suitability Aggregate scores and suitability classification of three Rice Soils of Ivo Local GA in Old Ohaozara indicated that the upland, lowland and irrigated pedons were all (potentially and currently) marginally suitable (S3) except upland pedons 2 and 3 that were currently not suitable- N1 using a parametric method of evaluation. Non-parametric evaluation of soils of Old Ohaozara suggests that all pedons were (potentially and currently), marginally suitable. Old Ohaozara uplands currently and potentially had limitations of wetness for pedons 1 and 2, wetness and fertility for pedon 3. Lowland and irrigated soils of the region currently and potentially had limitations of fertility and toxicity in all pedons except lowland pedon 3 with only fertility limitation. The DEM revealed that the upland terrain here graded from 45.3 – 53.7 m, the lowland region had terrain ranging from 35.0 – 45.7 m while the irrigated region ranged from 53.8 – 68.6 m above sea level in their elevations. The downslope soils dominating the lowland soils with lower terrain which are relatively plain will likely favour the rice cultivation more than the upland and irrigated zones. This is due to the economic feasibility of the lowland soils for the poor farmers which constitute a majority in the study area.

1.0. Introduction

Rice is not only the staple food for nearly half of the world's population, it's also their key source of energy and protein, major means of sustenance, survival, and employment for people living mostly in rural areas (FAO 2003). Rice has taken the second position in agricultural production in most countries in the Asian continent and is one out of three of the energy sources of more than a quarter of the world population living in Africa and Latin America (FAO, 1995). Rice is a key cereal crop in Africa's most populous nation of Nigeria and an important staple food in many homes (Obasi *et al.,* 2015). Old Ohaozara and indeed the state of Ebonyi in Southeastern Nigeria have made a significant impact on rice farming (Obasi and Obasi 2020).

The task of meeting the food insecurity challenge and not encroaching on the ecological wealth of future generations is being given topmost attention by researchers, planners, and scientists. There is therefore an immediate demand to group the land resources with the present land use for sustainability while conserving our fragile agro-ecology (FAO 1993).

The FAO structure for land evaluation explained land evaluation as the means of examining the land productivity when used for a particular purpose. Such purposes may include the implementation and explanation of surveys and study of landforms, soils, vegetation, climate, and other parts of the land to discover and compare some promising kinds of land use, using certain yardsticks related to the purpose of the evaluation (FAO, 1976). Land evaluation reveals to the farmer the suitability of land for a particular uses and its limitations. This can only be made possible by grouping land characteristics and qualities with the needs of the expected use (Udoh *et al*., 2011, Obasi *et al.,* 2016).

The digital elevation model (DEM) also known as Digital Terrain Model (DTM) as a component of a geographic information system (GIS), can be used in the management of large volumes of spatial data thereby giving useful information in solving some compound and complicated location specific and hydrological problems (Dengiz 2013). The system is fashioned to permit users to accumulate, contend, examine, and capture huge magnitudes of spatially referenced data collected from an assortment of sources (Aronoff 1991). Currently, further computer packages, which include decision backup systems, geographic information systems, and remote sensing (RS), lend to the quick and efficiency of the overall preparation operations and allow access to a quantum number of useful information rapidly (Hinton 1996).

A few GIS-related works have been carried out in Southeastern Nigeria namely; Onweremadu (2006), applying GIS in studying different soil groups, diverse uses of land, and environmentally related challenges faced in southeastern Nigeria as well as some soil parameters (Onweremadu *et al.,* 2011). Also, Obasi *et al.* (2011) used the GIS approach to study the suitability of soils of Afikpo in southern Ebonyi.

Ivo Local Government Area of Ebonyi State was carved out of Old Ohaozara LGA in the Southern Ebonyi State comprising major villages such as Ishiagu, Akaeze, Amagu, and Obiagu. The soils of the region have been known to be derived from the Asu River group parent material (Ofomata, 1975). Although this location is made up of some relatively high terrains, lowland and irrigated rainfed rice farming soils are evident. However, the use of irrigation as well as employing upland regions for rice production can be enhanced to increase the production of rice in the area. Digital Terrain Model (DEM) study being a computer-assisted application will guide farmers and prospective investors in rice farming in the study region to know the elevation characteristics of the studied soils by revealing locations where rice can be farmed with reduced inputs and increasing profitability. The major objective of this study is to apply Digital Elevation Model (DEM) in the suitability study of selected soils of Ivo L.G.A., Old Ohaozara Southeastern Nigeria for rice production.

2.0 Materials and Methods

2.1 Study area

The study location was at Ivo L.G.A. in Old Ohaozara, while the two major studied locations were Ishiagu and Akaeze which lie within the latitudes 5° 50′ 30′′ and 5° 57′ 30 N and longitudes 7° 34′ 30′′ and 7° 43′ 30′′ E. The region of the study falls within the tropical rainforest part of southeastern Nigeria. Rainfall lasts from March and ends around November with peak occurrence within June-September. The dry season usually lasts for about three months majorly between December to February. Predominant terrain is mostly lowlands and somewhat plains with a physiographic feature of ruffling relief below 100 m above sea level with a range of 1900 – 2400 mm mean annual rainfall. It has a mean annual rainfall of 1800 - 2300 mm. The originally dense rainforest vegetation of southeastern Nigeria has evolved to derive savannah vegetation emanating from intense anthropogenic activities such as excessive farming, burning of bushes, and hunting. The major rivers draining the Ivo rice soils were the Ivo river, Asu, and Ikwoo rivers while settlements near lowland terrains were Amagu, Akaeze, Ishiagu, Obiagu, and Kpohokpo (Ahukaemere *et al.,* 2018; Ahukaemere and Obasi, 2018).

2.2 Fieldwork

The study area was identified and the study was carried out in Ivo Local Government Area of Old Ohaozara having been guided by a reconnaissance visit. Three major rice farming soils under the categories of lowland, upland, and local irrigated rice production (*Sawah* Technology) were employed for the study. The local irrigation *sawah* technology had been previously practiced near the Federal College of Agriculture Ishiagu. Three profile pits were dug in each of the identified rice cropping land use giving tose to a total of 9 pedons in the study location. The dug pedons were carefully analyzed and described in-situ before sampling from the different horizons for further laboratory analysis.

Table 1: Study locations and coordinates

Locations	Pedons	Latitudes (N)	Longitudes (E)	Elevations (m)
Upland	1	5°54’18”	7°43’28”	47
	2	5°53’08”	7°43’28”	55
	3	5°54’18”	7°42’08”	49
Lowland	1	5°54’22”	7°43’29”	45
	2	5°52’26”	7°41’20”	45
	3	5°54’18”	7°43’28”	46
Irrigated	1	5°53’16”	7°34’00”	65
	2	5°57’02”	7°34’05”	60
	3	5°52’02”	7°34’40”	65

2.3 Laboratory Analysis

The properties analyzed include soil mechanical analysis using the hydrometer method (Gee and Bauder, 1986). The bulk density was carried out according to Blake and Hartge (1986). Soil pH was determined in a 1:1 soil/water ratio using a digital pH meter. Exchangeable acidity was determined by the 1N KCl method. Exchangeable bases; (Ca, Mg, K and Na) were determined using the NH4OAc method of saturation (IITA, 1979). Ca and Mg in solution were measured using Atomic Absorption Spectrophotometer (AAS), while K and Na were measured using a Flame Emission Photometer reading. Organic carbon was determined by the Nelson and Sommers (1982) method. Total nitrogen was determined using Bremner and Ulvaney (1982) technique. Available phosphorus was extracted by Bray No 1 method (Bray and Kurtz, 1945). Base saturation, effective cation exchangeable capacity were all determined by calculation

2.4 Land evaluation procedure

The 9 profiles sunk in the three rice cropping land uses were used for the suitability evaluation study adopting the conventional (non-parametric) methods and the parametric method for rice. In the non-parametric also called the conventional method (FAO, 1976), pedons properties were initially dropped in the suitability classes that match their land characteristics (Table 2), with the growing needs of rice also called agronomic requirements. By the parametric method according to Ogunkunle, (1993), every limiting characteristic was identified and classified accordingly as shown in Table 4. The index of productivity (IP) (actual and potential) was then calculated using the equation

IP = A/10 √BCD…F

A is the overall least rating of all soil characteristics considered, while B, C, and D….F is the least characteristic rating in each land quality group (Udoh *et al.*, 2011). About 5 land quality groups were employed for this study and only a member of each of the 5 land quality groups was applied in the calculation because there exists a strong affinity and relationship with members of the same group. For instance, texture and structure in group "s" (Ogunkunle, 1993). Table 2 reveals 5 land quality groups used in the study including climate (c), soil physical characteristic (s), wetness (w), fertility status (f), and toxicity (t).

2.4.1 Potential Index of Productivity (IPp)

While calculating the Potential Index of Productivity (IPp) soil parameters that do not alter easily like soil organic matter, soil acidity, CEC, and base saturation were adopted to be in the "f" group while the chemical parameters which easily change or altered such as exchangeable K, Ca and available P were not used for the calculation.

2.4.2 Current Index of Productivity (IPc)

The Current Index of Productivity (IPc) combines the easily changed chemical parameters such as exchangeable K, Ca, and available P and those used for IPp for the calculation of the IPc.

Table 2: Factor ratings of land use requirements for wetland rice

Land Qualities Factor Ratings	Land Characteristics	Units %	S1 100-85	S2 84-60	S3 59-40	N1 39-20	N2 19-0
Climate (c)							
	Annual Rainfall	Mm	>1400	1200-1400	950-1100	850-900	<850
	Solar radiation	Cal.cm-2.day-1	>300	300-200	200-100	<100	Any
	*Temperature	^{o}C	25 -30	30 – 32	32 – 35	>35	Any
	*Relative Humidity	%	85 – 80	80 – 75	75 – 60	>85<60	Any
Growing Periods							
	LPG+	Days	120-180	70-120	<70	<70	<70
Soil physical Condition							
	Soil Depth	Cm	> 20	10-20	5-10	<5	any
	Clay	%	40-25	25-15	15-5	≤5	any
Wetness (w)							
	Drainage	-	1-3	1-3	3	any	any
	S.W.D	Cm	10-20	20-40	40-60	>60; <10	any
	F.D	Months	4	3-4	2-3	<2;>4	any
	G.W.T	Cm	0-15	15-30	30-60	>60	any
Fertility Status (f)							
	pH	-	5.5-7.5	5.2-5.5	≤5.2;≥8.2	≤5.2;≥8.2	Any
	Total N	%	> 0.2	0.1-0.2	0.05-0.1	<0.05	any
	Organic C	%	2-3	1-2	3-4	>4;<1	any
	P (Bray)	mg.kg-1	> 20	15-20	10-15	<10	any
	P (Olsen)	mg.kg-1	> 10	7.5-10	5-7.5	<5	any
	K	cmol.kg-1	> 0.2	0.1-0.2	<0.1	<0.1	any
	Ca	cmol.kg-1	10-15	5-10	1-5	<1; >5	Any
	Mg	cmol.kg-1	2-5	1-2	<1	<1;>5	Any
	CEC	cmol.kg-1	>16	10-16	5-10	<5	any
	- Base saturation	%	>50	35-50	<35	<35	any
Toxicity (t)							
	Active- Fe	%	<0.75	0.75-1.0	1-1.25	<1.25	any

Ogunkunle, 1993, *Rathnayake et al., 2016
Key: S.W. D= Surface Water Depth, F. D= Flooding Duration, G. W. T= Ground Water Table
1= Imperfect, 2= Moderate; Poor, 3= Good, 4= Very Poor, LPG= Length of Growing Periods

2.5 Generation of the digital elevation model (DEM)

In this research, the DEM was achieved using the contour lines of the topographic map of the study areas. Ground Truthing was carried out using Global Positioning System (GPS) to record the coordinates of different rice cropping land uses in the study area. Digital Elevation Model (DEM) was therefore derived using point data which have the x, y, and z coordinates laid out in a regular grid arrangement. The point data grids were brought into surfer 21.0 software to produce the 3D DEM (Acker *et al,* 2003). This was able to give us topographic information about the study.

3.0 Results and Discussion

3.1 Suitability Evaluation

The land qualities/ Characteristics of Ivo rice soils in Ebonyi south were as displayed in Table 3, while Table 4 displays their suitability class scores. When climatic requirements for rice (Table 2) were grouped with the land quality (precipitation, temperature, and relative humidity) of the location in Ivo, Old Ohaozara, relative humidity, and precipitation achieved 95% in all the pedons (Upland, Lowland, and Irrigated) placing them in Suitability class 1 (S1) whereas average temperature scored 85% in all investigated pedons of Old Ohaozara soils. Rathnayake *et al.,* (2016) reported that a combination of temperature and relative humidity are among the most dominant governing factors in rice farming due to their Spatio-temporal variations. Morita *et al.,* (2004) noted that extreme temperature affects virtually all the growth levels of rice, ranging from germination to maturity and harvest while Ferrall *et al.,* (2006) suggested that flowering (anthesis and fertilization) and booting (microsporogenesis) are known to be the growth points mostly affected by temperature in rice production. High temperatures beyond the optimum may cause floret sterility thereby decreasing rice yield (Nakagawa *et al.,* 2003). When the temperature goes beyond 35 ^{o}C, which is the threshold maximum temperature in rice, it ultimately leads to spikelet sterility (Matsui et al., 1997). A temperature of 19 ^{o}C or less usually experienced at nights hours is adjudged to be the critical low temperature for leading to the formation of sterile grains in rice (Abeysiriwardena *et al.,* 2002). Relative humidity serves a prominent position in rice production, spikelet fertility is usually severely affected under higher relative humidity and increased temperature, especially at the flowering stage (Yan *et al.,* 2010). Abeysiriwardena *et al.,* (2002) recorded that when the relative humidity of 85-90% combines with a day/night temperature of 35/30 ^{o}C at the heading stage result in almost total grain sterility in rice. Weerakoon *et al.,* (2008) stated that spikelet fertility was not usually retarded by high humidity, because at low temperature, fertility was high. Summarily higher maximum and higher minimum temperatures with high relative humidity reduce rice yields due to spikelet sterility (Peng *et al.,* 2004).

The soil physical condition of Ivo in Ebonyi south as assessed using soil depth and clay content was optimum as soil depth and clay scored 95% (S1). The wetness of Old Ohaozara soils indicated that drainage and flood duration were marginal (S3) in upland soils of Old Ohaozara and optimum in lowland and irrigated soils counterpart (S1).

Fertility evaluation revealed that soil pH was optimum in all investigated pedons of upland, lowland, and irrigated pedons investigated scoring 95% (S1). Total nitrogen is moderate in Ivo upland pedons 1, 2, 3, and lowland pedon 2, scoring 85% (S2), optimum in irrigated pedons 1, 2, and 3 scoring 95% (S1), and marginal in lowland pedons 1 and 3 (S3). Organic C was moderate in all upland and lowland pedons of Old Ohaozara scoring 85% (S2) while it was optimum in all irrigated pedons scoring 95% (S1). Available P was optimum in upland pedon 1, lowland pedon 2, and irrigated pedons 1 and 2 as they scored 95% (S1) while all other pedons indicated a moderately suitable condition having scored 85% (S2). K was also moderate in Ivo upland pedons 1, 2, 3, lowland pedon 3, and irrigated pedon1 as all scored 85% (S2) while it was marginal 60% (S3) in lowland pedons 1, 2 and irrigated pedons 2 and 3.

Table 3: Land Qualities/Characteristics of Ivo rice Soils

Land Qualities/ Land Characteristics	**Unit**	**Upland** Pedon 1	Pedon 2	Pedon 3	**Lowland** Pedon 1	Pedon 2	Pedon 3	**Irrigated** Pedon 1	Pedon 2	Pedon 3
Climate (c)										
Annual Rainfall	mm	2000	2000	2000	2000	2000	2000	2000	2000	2000
Mean Temperature	^{o}C	26-28	26-28	26-28	26-28	26-28	26-28	26-28	26-28	26-28
Relative Humidity	%	80	80	80	80	80	80	80	80	80
Soil physical Characteristics (s)										
Soil Depth	cm	102	105	97	103	100	104	88	79	67
Clay	%	43.91	41.2	32.6	29.4	30.9	28.4	20.5	14.5	6.5
Silt	%	21.5	26.0	20.1	42.9	40.7	36.9	42.2	43.5	46.8
Sand	%	34.6	32.8	47.3	27.7	28.3	34.7	37.3	42.0	46.6
Wetness (w)										
Drainage		3	3	3	2	2	2	1	1	1
Flood Duration	months	2-3	2-3	2-3	4-5	4-5	4-5	4-5	4-5	4-5
G.W.T	cm	NE	NE	NE	103	100	104	88	79	67
Fertility (f)										
pH	-	5.76	5.89	5.91	5.95	5.94	6.03	5.53	5.56	6.09
Total N	%	0.10	0.10	0.13	0.09	0.10	0.08	0.39	0.24	0.22
Organic C	%	1.15	1.19	1.55	1.06	1.11	0.99	4.52	4.42	4.99
Avail. P	mg.kg-1	15.04	12.65	13.42	14.94	17.62	14.94	16.01	15.69	12.13
K	cmol.kg-1	0.17	0.16	0.12	0.06	0.07	0.10	0.10	0.06	0.04
Ca	cmol.kg-1	8.00	6.55	4.14	2.61	5.06	5.59	5.07	6.09	6.56
Mg	cmol.kg-1	1.02	0.78	0.79	0.79	1.13	0.99	0.80	0.75	1.05
ECEC	cmol.kg-1	10.36	8.56	6.51	4.25	7.09	7.44	6.89	7.95	8.45
Base Saturation	%	88.51	86.55	82.92	83.69	88.42	89.91	86.33	86.57	90.96
Toxicity (t)										
Active Fe	mg.kg-1	75.48	46.34	67.25	279.1	126.4	102.9	244.9	283.3	224.7
Fe	%	0.75	0.46	0.67	2.79	1.26	1.02	2.45	2.83	2.24
Al Saturation	%	8.80	11.70	11.89	9.84	7.26	5.68	8.63	8.56	4.33

Key: Drainage 1 = Imperfectly Drained, 2 = Moderately Drained, 3 = Well Drained, NE = Not encountered, ECEC = effective cation exchange capacity

Calcium was marginal in upland pedon 3 and lowland pedon 1 scoring 60% (S3) while all other investigated pedons in these three cropping land uses were moderate in Ca content as it scored 85% (S2). Mg was marginal in all investigated pedons as it scored 60% (S3) in all investigated soils of Old Ohaozara except upland pedon 1, lowland pedon2, and irrigated pedon3 where it indicated a moderate distribution S2 (85%). Base saturation was optimum in all investigated pedons of upland, lowland, and irrigated soils of Ebonyi south rice soils S1 (95%). The toxicity challenge of rice soils of Old Ohaozara indicated that active Fe was not a problem for the upland soils scoring 95% (S1), while lowland pedon 3 was moderate (S2). Lowland pedons 1, 2 and irrigated pedons 1, 2, and 3 were marginal in their Fe concentration having scored 60% (S3). Al was optimum in all pedons (S1) except in upland pedons 2 and 3 where it was moderate as it scores 85% S2.

Table 4: Suitability Class Scores of Ivo Rice Soils

Land Qualities/ Land Characteristics	Upland			Lowland			Irrigated		
	Pedon 1	Pedon 2	Pedon 3	Pedon 1	Pedon 2	Pedon 3	Pedon 1	Pedon 2	Pedon 3
Climate (c)									
Annual Rainfall	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Mean Temperature	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
Relative Humidity	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Soil physical Characteristics (s)									
Soil Depth	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Clay	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S2(85)	S2(85)
Wetness (w)									
Drainage	S3(60)	S3(60)	S3(60)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Flood Duration	S3(60)	S3(60)	S3(60)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Fertility (f)									
pH	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Total N	S2(85)	S2(85)	S2(85)	S3(60)	S2(85)	S3(60)	S1(95)	S1(95)	S1(95)
Organic C	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S1(95)	S1(95)	S1(95)
Avail. P	S1(95)	S2(85)	S2(85)	S2(85)	S1(95)	S2(85)	S1(95)	S1(95)	S2(85)
K	S2(85)	S2(85)	S2(85)	S3(60)	S3(60)	S2(85)	S2(85)	S3(60)	S3(60)
Ca	S2(85)	S2(85)	S3(60)	S3(60)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
Mg	S2(85)	S3(60)	S3(60)	S3(60)	S2(85)	S3(60)	S3(60)	S3(60)	S2(85)
Base Saturation	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Toxicity (t)									
Active Fe	S1(95)	S1(95)	S1(95)	S3(60)	S3(60)	S2(85)	S3(60)	S3(60)	S3(60)
Al Saturation	S1(95)	S2(85)	S2(85)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)

Table 5: Suitability Aggregate scores and suitability classification of three Rice Soils of Ivo LGA

Ebonyi North	Pedons	Parametric Potential	Current	Non-Parametric Potential	Current
Upland	1	S3(39.1)	S3(39.1)	S3w	S3w
	2	S3(35.0)	N1(24.1)	S3w	S3w
	3	S3(35.0)	N1(24.1)	S3wf	S3wf
Lowland	1	S3(39.1)	S3(27.6)	S3ft	S3ft
	2	S3(39.1)	S3(27.6)	S3ft	S3ft
	3	S3(44.5)	S3(39.1)	S3f	S3f
Irrigated	1	S3(39.1)	S3(27.6)	S3ft	S3ft
	2	S3(39.1)	S3(27.6)	S3ft	S3ft
	3	S3(39.1)	S3(27.6)	S3ft	S3ft

Aggregate suitability class score: 100-75 = S1; 74 – 50 = S2; 49 – 25 = S3; 24 – 15 = N1; 14 – 0 = N2; f = Fertility limitation; t = toxicity; w = wetness (water table) limitation

The Suitability Aggregate scores and suitability classification of three Rice Soils of Ivo LGA in Old Ohaozara were as shown in table 5 indicating that the upland, lowland, and irrigated pedons were all (potentially and currently) marginally suitable (S3) except upland pedons 2 and 3 that were currently not suitable- N1 (24.1%) using a parametric method of evaluation. The parametric evaluation suggests that potentially the best soil in all investigated soils of Ivo in Old Ohaozara was located where lowland pedon 3 was sited – S3 (44.5%), followed by the locations of upland pedon 1, lowland pedons 1, 2, irrigated pedons 1, 2 and 3 – S3 (39.1). Also, currently, the best rice soils were found in upland pedon1 and lowland pedon 3 – S3 (39.1%) followed by lowland pedons 1, 2, irrigated pedons 1, 2, and 3 – S3 (27.6%). Non-parametric evaluation of soils of Old Ohaozara suggests that all pedons were (potentially and currently), marginally suitable. Old Ohaozara uplands currently and potentially had limitations of wetness for pedons 1 and 2, wetness and fertility for pedon 3. Lowland and irrigated soils of the region currently and potentially had limitations of fertility and toxicity in all pedons except lowland pedon 3 with only fertility limitation.

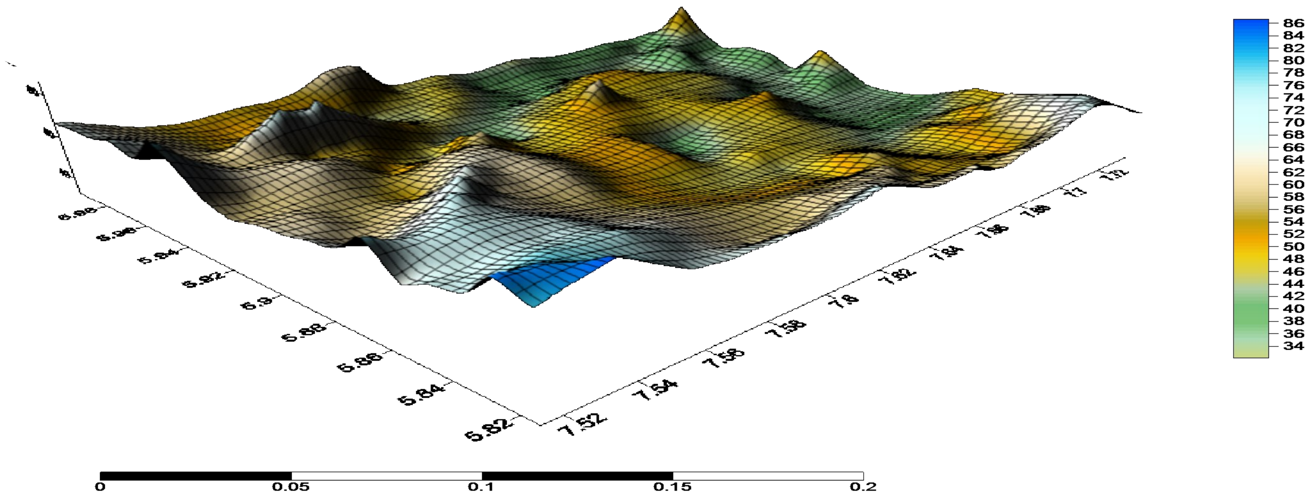

Fig. 1: 3D Surface Analysis of Ivo LGA, Old Ohaozara

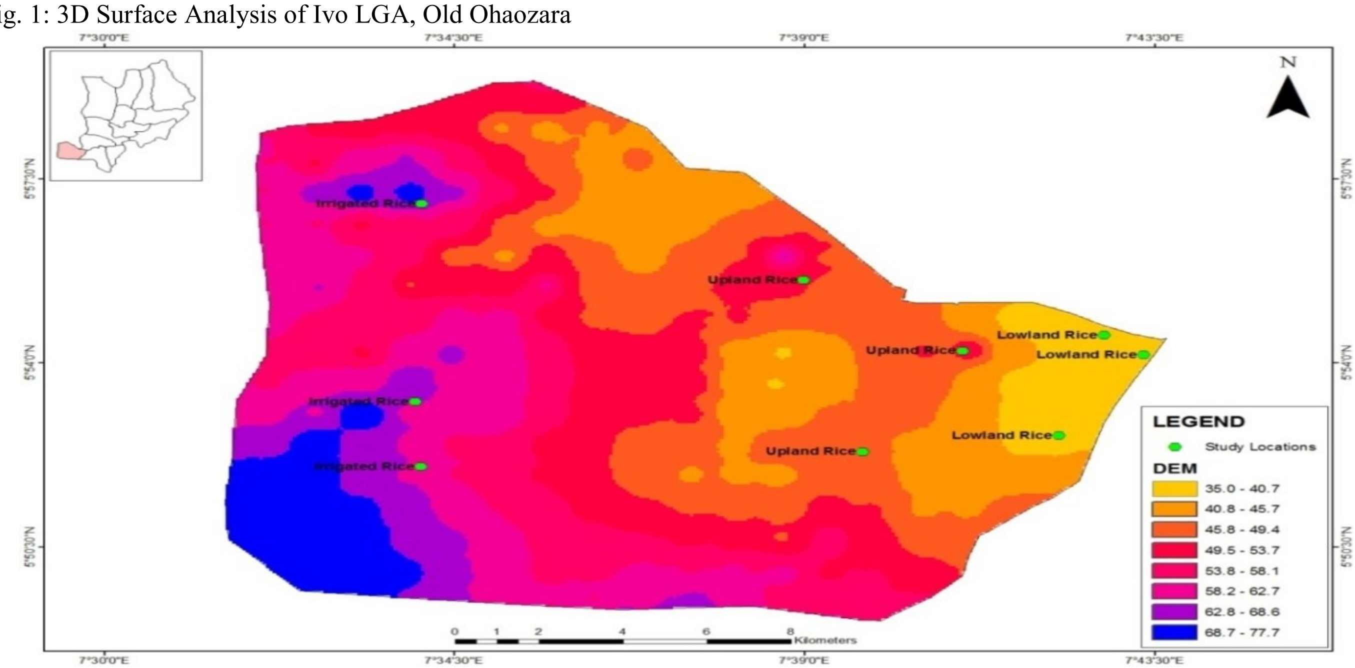

Fig. 2: 2D DEM and study locations in Ivo L.G.A. Old Ohaozara

The 3D, 2D surface analysis (DEM) and study location of, Ivo L.G.A Old Ohaozara were as shown in Figs.1 - 2. These revealed a relatively stable terrain for rice cultivation may have been identified in this region in Ebonyi south soils. The upland elevation here ranged from 45.3 – 53.7 m, the lowland region had elevations ranging from 35.0 – 45.7 m while the irrigated region ranged from 53.8 – 68.6 m above sea level in their elevations. The lowland soils having low terrains or near flat slopes will likely favour rice cultivation when compared to the upland and irrigated soils. Also, the nature of the elevation suggests that the majority of the soils lie within the uplands with only a few inland valleys. The valleys are naturally favoured as materials transported by drainage such as clay particles alongside nutrients from the surrounding uplands are moved down thereby enhancing the fertility of the lowlands. Most rice farmers within the Ivo rice farming region have ultimately adopted lowland rice farming. Rainfed lowland rice farming has proven to be easier for the poor farmers who are still struggling with inputs such as fertilizers, herbicides, etc let alone the luxury of installation of irrigation facilities needed in the higher terrains. Although irrigated rice farming is still not popular in Ivo, Old Ohaozara soils except near the Federal College of Agriculture Ishiagu where irrigated rice farming is practiced under *Sawah* Technology. The major rivers draining the Ivo rice soils were the Ivo river, Asu, and Ikwoo rivers while settlements near lowland terrains were Amagu, Ishiagu, Obiagu, and Kpohokpo.

4.0 Conclusion

The upland, lowland, and irrigated pedons were all (potentially and currently) marginally suitable (S3) except upland pedons 2 and 3 that were currently not suitable- N1 (24.1%) using a parametric method of evaluation. However, using non – a parametric method of evaluation, Old

Ohaozara uplands currently and potentially had limitations of wetness for pedons 1 and 2, wetness and fertility for pedon 3. Lowland and irrigated soils of the region currently and potentially had limitations of fertility and toxicity in all pedons except lowland pedon 3 with only fertility limitation. The upland elevation here ranged from 45.3 – 53.7 m, the lowland region had elevations ranging from 35.0 – 45.7 m while the irrigated region ranged from 53.8 – 68.6 m above sea level in their elevations. Most farmers in the region have adopted lowland rice farming as that would be more economically feasible for them to practice.

References

Abeysiriwardena, D.S. De. Z., Ohba, K. and Maruyama, A. (2002). Influence of temperature and relative humidity on grain sterility in rice. Journal of the National Science Foundation of Sri Lanka. 30, 33 - 41.

Ahukaemere, C.M., Ndukwu, B.N., Obasi S. N., Osujieke, D.N and Ewelike, C. (2018). Morpho-genetic Characteristics and Classification of Soils Derived from Asu River Group and Asata Nkporo Shale in Ebonyi State, South-east Nigeria. *Federal University Wukari Journal of Agriculture and Life Sciences. Vol. 3(1): 121 – 131.*

Ahukaemere C.M., Obasi S. N. (2018). Potentials of Soils derived from Asu River Group and

Asata Nkporo Shale for arable Crop Production in Ebonyi State, Nigeria. *Bulgarian Journal of Soil Science. Volume 3, Issue 1. www. Bsss.bg. pp 48 - 62*

Aronoff S. (1991) Geographic Information System. A Management Perspective. WLD Publications, Ottawa, ON, Canada.

Blake, G. R. and Hartge, K. H. 1986. Bulk density. In: Klute (eds.) Methods of soils analysis Part 1: Physical and Mineralogical Methods. 2nd Ed. ASA, SSSA. Madison, WI pp. 377-382.

Bowles, J. E. 1992. Engineering properties of soils and their measurement (4th ed.) McGraw Hill publishers Boston USA 241p.

Bray, R. H, and Kurtz, L. T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Science, 59: 39-34.*

Bremner, J. M. and Mulvaney, C. S. 1982. Nitrogen-total. In: Methods of Soil Analysis, Part 2, Ed. A.L. P.G Miller and D.R. Keeney (eds.) American Society of Agron. Madison WI, pp 593-624

Dengiz, O. (2013) Land suitability assessment for rice cultivation based on GIS modeling. Turk J of Agric & Forestry 37: 326-334 © TÜBİTAK doi:10.3906/tar-1206-51

FAO (2003) Rice Irrigation in the Near East: Current Situation and Prospects for Improvement. FAO Regional Office for the Near East, Cairo, Egypt.

FAO (Food and Agriculture Organization), 1995. *World Rice Information*, issue No.1. FAO, Rome, Italy.

FAO, (Food and Agriculture Organisation). 1976. A framework for Land Evaluation. FAO Soils Bull. 32: FAO Rome. 87.

Farrell, T.C., Fox, K.M., Williams, R.L. and Fukai, S. (2006). Genotypic variation for cold tolerance during reproductive development in rice: screening with cold air and cold water. Field Crops Research. 98, 178 - 194.

Gee, G.W. and Bauder, J. W. 1986. In particle-size Analysis. Part 1: Physical and Microbiological properties. (2nd edition). Agronomy series No 9. ASA, ASSA Madison, W.I. USA.

Hinton JC (1996) GIS and RS integration for environmental applications. Intern J Geo Info Sys 10: 877–890.

IITA. 1979. International Institute of Tropical Agriculture. Selected methods for soil and plant analysis. IITA manual series No1. Ibadan, Nigeria.

Matsui, T., Namuko, O. S., Ziska, L.H. and Horie, T. (1997). Effect of high temperature and CO2 concentration on spikelet sterility in indica rice. Field Crops Research. 51, 213 - 219.

Morita, S. Shiratsuchi, H., Takahashi, J., and Furta, K. (2004). Effect of high temperature on ripening in rice plants: analysis of the effect of high night and high day temperatures applied to the panicle and other parts of the plant. Japanese Journal of Crop Science. 73, 77-83.

Nakagawa, H, Horie, T. and Matsui, T. (2003). Effects of climate change on rice production and adaptive technologies. In: Shah, F., Huang, J., Cui, K., Nie, L., Shah, T., and Wang, K. (Eds.) Climate change and agriculture paper. Impact of high-temperature stress on rice plants and its traits related to tolerance. (2011). Journal of Agricultural Science. Cambridge University Press. pp 1-12.

Obasi, S. N., Onweremadu, E. U., Imadojemu, P. E. (2011). Suitability of Soils of Afikpo, Southeastern Nigeria: A Geographical Information System (GIS) Approach. *Nig. J. Soil and Env. Res*. Vol. 9: 2011, 59 – 64

Obasi, S. N., Onweremadu, E. U., Egbuche, C. T. and Iwuanyanwu, U. P. (2015). Characterization and Classification of Selected Rice Soils of Tropical Rainforest Region, Southeastern Nigeria. J. of Agriculture, Forestry and Fisheries 4 (3): 46- 50.

Obasi, S. N., Onweremadu, E. U., Udoh, B. T., Osujieke, D. N. and Imadojemu, P. E. (2016) Application of Digital Elevation Model (DEM) In Suitability Evaluation of Selected Soils of Ikwo – Southeastern Nigeria For Rice Production. Nigerian Journal of Agriculture, Food and Environment. 12(3):182-188

Obasi S. N and Obasi C.C. (2020) Fertility capability classification of soils supporting rice production in Ebonyi State, southeastern Nigeria. NJSS 30 (2), Pp 113-122.

Ofomata, G.E.K. (1975) Hydrology. In: G.E.K. Ofomata (ed.) Nigeria in maps. Eastern States, Benin City: Ethiope Publishing House. Pp.13-15.

Ogunkule, A. O. 1993. Variation of some soil properties along with two topo sequences on quartzite schist and banded gneiss in Southwestern Nigeria. *Geo-journal,* 30 (40): 399-402

Onweremadu, E. U., Okon, M. A., Ihem, E. E., Okuwa, J. O., Udoh B. T., and Imadojemu, P. 2011. Soil exchangeable calcium mapping in Central Southeastern

Nigeria using geographic information systems. Niger. J. Agric. Food and Environ. 7(2): 24-29.

Onweremadu, E. U. 2006. Application of Geographic Information Systems in soils, lands use, and environmental problems of Southeastern Nigeria. A Ph.D. Thesis of the Department of Soil Science, UNN.330 pp.

Peng, S.B., Huang, J.L., Sheehy, J.E., Laza, R.C., Visperas, R.M., Zhong, X.H., Centeno, G.S., Khush, G.S., and Cassman, K.G. (2004). Rice yields decline with higher night temperatures from global warming. Proc. Natl. Academy of Science. 101, 9971 - 9975.

Rathnayake et al. 388 Weerakoon, W.M.W., Maruyama, A. and Ohba, K. (2008). Impact of humidity on temperature-induced grain sterility in rice (Oryza sativa L). Journal of Agronomy and Crop Science. 194, 135 - 140.

Rathnayake W.M.U.K., R.P. De Silva and N.D.K. Dayawansa (2016). Assessment of the Suitability of Temperature and Relative Humidity for Rice Cultivation in Rainfed Lowland Paddy Fields in Kurunegala District. Tropical Agricultural Research Vol. 27 (4): 370– 388 (2016)

Udoh, B. T., Henry, H. B. and Akpan U. S. (2011). Suitability evaluation of alluvial soils for rice and cocoa cultivation in an acid sand area of southeastern Nigeria. Journal of innovative research in engineering and science. (pp. 148-161).

Yan, C., Ding, Y., Wang, Q., Liy, Z., Li, G., Muhammad, I. and Wang, S. (2010). The impact of relative humidity, genotypes, and fertilizer application rates on panicle, leaf temperature, fertility, and seed setting of rice. Journal of Agricultural Science. Cambridge. 148, 329 – 339.