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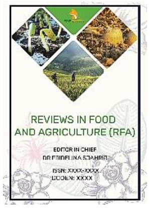

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RESEARCH ARTICLE

QUALITY AND SUITABILITY OF SOILS OF NORTHERN EBONYI, SOUTHEASTERN NIGERIA FOR RICE PRODUCTION

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ABSTRACT

This study was carried out in Abakaliki region, Ebonyi state of southeastern Nigeria and aimed at studying the quality and suitability of soil used for rice cultivation in the area between 2015 to 2017. This purpose was necessary due to the dwindling yield of rice in northern Ebonyi, southeastern Nigeria leading to increased hunger in the country and daunting the efforts of the government to achieve her goal of food security by the year 2025. Soils were delineated into upland, lowland and irrigated as different rice farming land uses with three profile pits dug in each location amounting to a total of nine (9) profile pits for the study. Soil quality indicators employed were; climate, soil physical condition, wetness, fertility and toxicity. An index of productivity equation was used to calculate the suitability status of each of the studied locations. The three pedons of upland rice soils were not suitable (N1) for rice production, while pedons 1 of the lowland and 2 of the irrigated were marginally suitable (S3) while others in these locations were not suitable (NI). The major challenges faced by these soils were basically of wetness, fertility and toxicity. All other soils at the lowland and irrigated soils were not suitable (NI). Practices that will conserve the fertility status of these soils should be adopted such as rotational farming, accumulation of organic materials on the soils and avoidance of burning of rice husks. This is necessary as fallow practice does not exist anymore due to demographic pressure and population growth in southern Nigeria.

KEYWORDS

Suitability, Fertility, Pedons, Rice Farming, Soil Productivity

1. INTRODUCTION

Soil quality refers to how well soil performs its function. Healthy, high-quality soil is productive, has a strong soil structure, and is biologically active. Soil health and soil quality are phrases used interchangeably to describe soils that are not only productive but also have desirable physical and biological properties. Soil quality refers to the ability of a specific type of soil to function in order to sustain plant productivity, maintain or improve water and air quality, and support human health and habitation. The process of evaluating the performance of land when used for specific purposes, according to the FAO framework for land quality and suitability evaluation, entails the execution and interpretation of surveys, as well as the study of land forms, soils, vegetation, climate, and other aspects of land in order to identify and compare promising land use in terms applicable to the evaluation's goals (FAO 1976; Obasi and Obasi, 2022).

The farmer is informed of the limitations of his land's suitability for particular purposes by a land suitability review. This is accomplished by aligning the traits and attributes of the land with the needs of the intended usage (Obasi et al., 2021). Esu pointed out that one of the solutions for achieving both food security and a sustainable environment is to thoroughly research soil through procedures of characterisation and land evaluation for various land utilization types (Esu, 2004). Land suitability assessment for cereals like rice may have been documented, but despite the significance of evaluating sustainable land management and for increased crop production, much work remains to be done, according to who noted that the works that are currently available have geographic and ecological biases (Aondoakaa and Agbakwuru, 2012).

A group researchers recognized drainage, texture, soil depth, nutrient retention (pH, cation exchange capacity), alkalinity, erosion risk, and flood/inundation as the most crucial soil properties in evaluating land quality and suitability (Obasi et al., 2021). Several authors have used the soil attribute extensively to monitor land degradation because it is significant for the overall performance of the land and plays a significant role in assessing land quality (Senjobi and Ogunkunle, 2011). In the opinion of one method for ensuring food security and a sustainable environment is to conduce detailed soil research using soil characterization and land appraisal techniques for various land exploitation types (Esu, 2004). Despite this, specific soil suitability studies, such as rice production suitability assessment, have not been properly documented, and those that have been done so far exhibit location and ecological bias (Aondoakaa and Agbakwuru, 2012). Despite the fact that land evaluation is critical for sustainable land management and increased crop production. Furthermore, some current studies provide a holistic approach to land evaluation and are not crop-specific (Rossiter, 1996; George, 1997; Adeleye, 2002; Soil Survey Staff, 2003).

According to some study, researchers used the FAO Framework in conjunction with the parametric Riquier index to define the suitability

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classes (S1, S2, S3, N1 and N2) for land quality (Eze, 2014; Aguilar and Ortiz, 1992). However, in a more recent study, assessed the suitability of rice soils in Southern and Eastern Nigeria, respectively, using parametric and nonparametric methods (Udoh et al., 2011; Obasi et al., 2021). The study used five land quality groups, and due to the high correlation among group members, only one parameter from each of the five land quality groups was used in the computation (Ogunkunle, 1993). The five categories for land quality were climate (c), soil physical characteristics (s), wetness (w), fertility level (f), and toxicity (t). The study's goal is to investigate the quality and suitability of northern Ebonyi soils for rice farming.

2. Materials and Methods

2.1 Location

The research was conducted on soils in Abakaliki Local Government, Ebonyi State, Nigeria, between latitudes 06° 15' 46'' and 06° 16' 45'' N and longitudes 08° 11' 43'' and 08° 12' 46'' E. The climate is humid tropical, with rainforest and savannah flora, low-lying and undulating slopes, and a distinctive physiographic differentiation of heavily steeped slopes that are typically less than or greater than 100 m above sea level (Orajaka 1975). Lowland rice agriculture is common in the interior valleys at the foot of the toposequences. Rainfall is bimodal, beginning in April and ending in November, with a break in August, though this has been altered due to weather variations and climate change. The minimum and maximum rainfalls are 1700mm and 2000mm, with a mean rainfall of 1800mm (Nwite et al., 2014). The minimum temperature is 27°C and maximum temperature is 31°C, with relative humidity of 60% and 80% during dry and rainy seasons respectively (MAN, 2010; Nnabuihe et al., 2022).

Table 1: Geographic Coordinates of Locations

Locations	Pedons	Latitudes (N)	Longitudes (E)	Elevations (m)
Upland	1	6°15'8"	8°11'45"	53
	2	6°15'10"	8°11'46"	55
	3	6°15'8"	8°11'46"	58
Lowland	1	6°15'5"	8°11'43"	55
	2	6°15'4"	8°14'44"	54
	3	6°15'5"	8°11'46"	54
Irrigated	1	6°15'8"	8°11'48"	55
	2	6°15'9"	8°11'49"	55
	3	6°15'5"	8°11'43"	55

Agriculture is a significant socioeconomic activity in the state, with key crops including rice (Oryza sativa), cassava (Manihot esculentus), maize (Zea mays), yam (Dioscorea spp), cocoyam (Colocasia spp), and others. The geology and geomorphology are Oligocene-Miocene Coastal Plain Sands (Benin formation), modified by river alluvium deposition. Due to recurrent water logging, these soils have considerable mottling of gray and red color (Onweremadu et al., 2007). The vegetation ranges from mangrove swamp on the coast to rainforest in the interior, and it is a mosaic of secondary forests and savannah, as anthropogenic activities have diminished the density of these trees (Chukwu et al., 2009).

2.2 Field Work

The research was conducted in the Abakaliki area of northern Ebonyi state. The area is primarily a rice growing zone. Lowland, highland, and local irrigated rice farming are among the rice land use types described (Sawah Technology). Sawah irrigation is a process in which bunds are built around rice farms with inlets to manage the water that enters the farm for irrigation reasons. However, because there is no irrigation facility in the area, it is only done during the rainy season. Three pedons were sunk in each of the land use classes, for a total of nine pedons. The description of Pedons was carried out in accordance with FAO recommendations (FAO, 2006). Using horizon differentiation, samples were gathered from pedons. Soil potentials will be studied and evaluated after samples were carefully labeled and delivered for analysis of soil attributes.

2.3 Laboratory Soil Analysis

In essence, experiments in soil quality and fertility assessment in Nigerian soils play a critical role in advancing agricultural productivity, environmental conservation, and overall sustainable development by providing actionable information and insights for effective land management. The following analytical procedures were employed to carry out the experiment. Soil mechanical analysis was performed using the hydrometer method (Gee and Bauder, 1986). Bulk density was determined using a digital pH meter in a 1:1 soil/water ratio. Exchangeable acidity was determined using the 1N KCl method. Exchangeable bases (Ca, Mg, K, and Na) were determined using the NH4OAc method of saturation (IITA, 1979). Ca and Mg were measured in solution using an Atomic Absorption Spectrophotometer (AAS), whereas K and Na were measured using a Flame Emission Photometer. The method was used to determine organic carbon (Nelson and Sommers, 1982). Total nitrogen was calculated using the method (Bremner and Mulvaney, 1982). The phosphorus that was available was removed using the Bray No 2 method (Olsen and Sommers 1982). Calculation was used to determine base saturation and effective cation exchangeable capacity.

2.4 Evaluation procedure

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
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

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 (Ogunkunle, 1993).

The conventional (non-parametric) and parametric approaches were used to assess the suitability of soils for rice growing in Ebonyi state's three rice zones. Using the conventional (non-parametric) method, pedons were classified by matching their land features to the agronomic requirements of rice (Table 2) (FAO, 1976). Each limiting attribute was graded using Table 2 utilizing the parametric method (Ogunkunle, 1993). The following equation was used to determine the index of productivity (IP) (actual and potential):

$$IP = A \times \sqrt{(B/100 \times C/100 \times D/100 \times E/100)}.$$

Where A represents the lowest overall characteristic rating while B, C, D, and E represent the lowest characteristic ratings of each land quality group (Udoh et al., 2011). This study used five land quality groups, and only one person from each of the five land quality groups was included in the computation since observed a substantial association among members of the same group (Ogunkunle 1993). Texture and structure, for example, in group "s". Climate (c), soil physical characteristics (s), wetness (w), fertility level (f), and toxicity (t) were the five land quality groups (Table 2). Potential Productivity Index (IPp): In computing the IPp, properties that are not easily altered, such as cation exchange capacity, base saturation, pH, and organic matter, were used as part of the "f" group, while chemical properties that are easily altered, such as exchangeable K, Ca, available P, and Mg:K ratio, were not included (Ogunkunle 1993). Current Productivity Index (IPc): In this scenario, the IPc was calculated using both easily modifiable chemical parameters such as exchangeable K, Ca, accessible P, and Mg:K as well as those utilized for IPp.

3. Results and Discussion

3.1 Digital Elevation Model (DEM)

The Digital Elevation Model (DEM); 2D, 3D Surface analysis and study location (Figures 1 – 2) revealed that Ebonyi North soils in Abakaliki LGA had high lands and few inland valleys for lowland rice cultivation. This is evident by the high altitudes observed in their elevations. There is no doubt that the regions if properly harnessed will likely be more adapted to upland and irrigated rice production. Some of the towns lying within the lowland terrain were Ijibollo, Ete, Ngbabeluzo, Ohachikwe, Okparo and Ofdrekpe. The major rivers draining this region are river Anyim and Ebonyi. There is tendency of impairment with rice cultivation in this terrain as a result of type of rice variety adapted available to farmers – mainly lowland varieties. The DEM shows that in addition to fertility status of the soils, most of the uplands will readily drain off their water received by rainfall thereby leading to moisture stress to the rice crop. Irrigation water is therefore highly advocated in the upland and irrigated rice areas to enhance the productivity of Ebonyi north upland and irrigated rice soils. DEM also show that there is a possibility that some areas naturally well adapted to lowlands rice may not be available since such locations may have been subjected to other land uses.

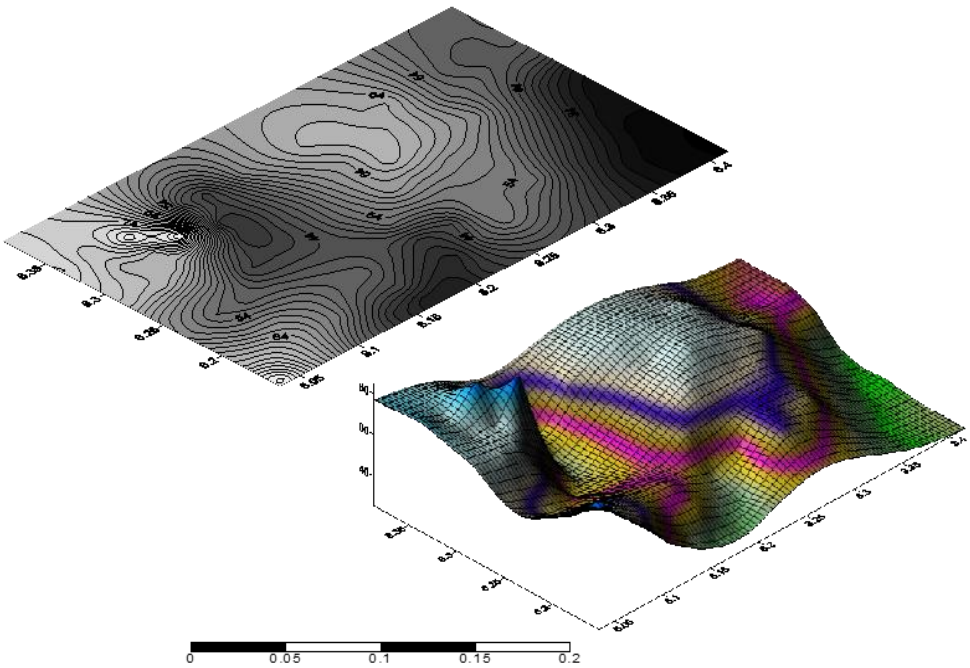

Figure 1: Ebonyi North 3D surface analysis and 2D Elevation Contoured

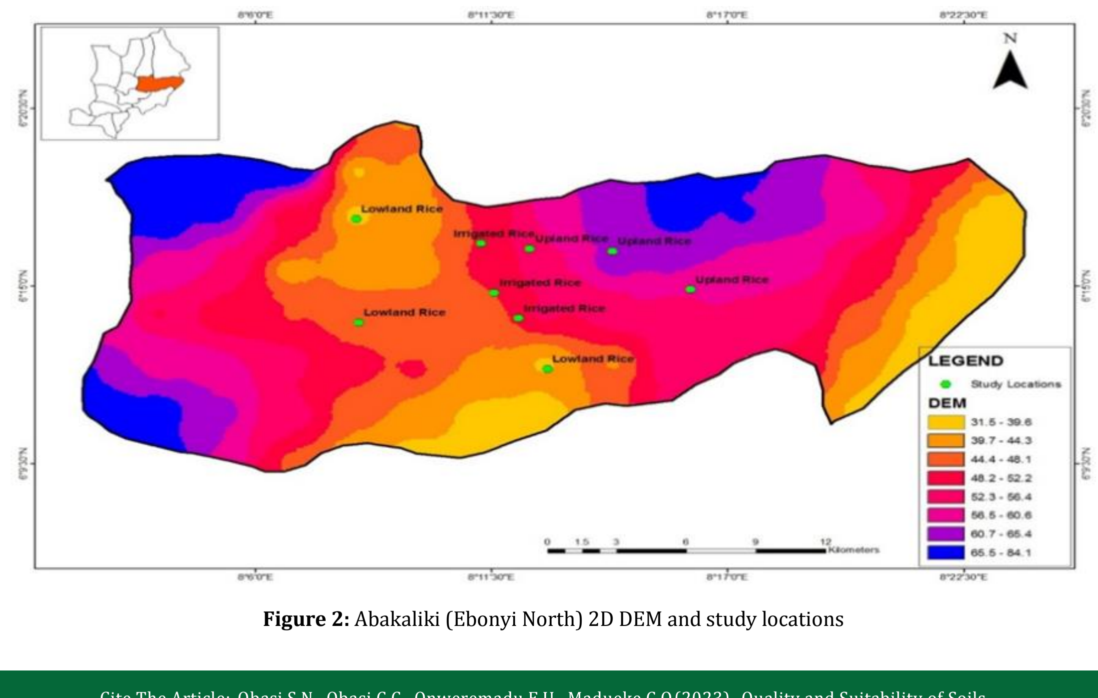

Figure 2: Abakaliki (Ebonyi North) 2D DEM and study locations

3.2 Soil Physical Properties

Table 3 presents the land qualities/characteristics of Ebonyi north soils, while Table 4 shows their suitability class ratings. When the climatic requirements for rice (Table 2) were matched with the land quality (rainfall, temperature, and relative humidity) of the study area in Ebonyi north, annual rainfall and relative humidity scored 95% in all Ebonyi northern pedons (Upland, Lowland, and Irrigated), placing them in Suitability class 1 (S1), while mean temperature scored 85% in all Ebonyi north soils. The soil physical characteristics considered for rice production were soil depth and clay contents. There was optimum soil depth in Ebonyi north with respect to rice cultivation thereby placing the soils on S1 (95 %) while clay content was also optimum scoring 85% and S2. Under wetness, drainage and flood duration were considered. The drainage of Abakaliki soils placed the uplands in suitability class 3 being marginally suitable as pedons scored 60%. Drainage of lowland and irrigated soils was optimum as it scored 85% (S2).

3.3 Soil Fertility Properties

The fertility status of Ebonyi north soils suggests that pH was marginally optimum scoring 60% and S3. Total nitrogen was near optimum with score of 85 % (S2) in upland pedon 1 and all the pedons of lowland and irrigated soils while pedons 2 and 3 of the uplands scored 60 % (S3) being marginally suitable. Organic C was near optimum as it was 85% and S2 in all pedons of the three cropping land uses except uplands pedons 2 and 3 and pedon 2 of the irrigated paddy soils that were marginally suitable with S3 and 60%. K, Ca and Mg were all marginally optimum as they scored 60% and S3 in all investigated soils of Ebonyi north. The ECEC distribution in Ebonyi north soils indicated that only pedon1 of upland, lowland and irrigated soils were marginally suitable scoring 60% (S3) while all other pedons were not suitable scoring 40% (N1). Base saturation was nearly optimum as upland pedons 1 and 3 and irrigated pedon 3 scored 85% (S2) while all other pedons scored 95% (S1) in Ebonyi north agro-ecological zone. The toxicity state of Ebonyi north soils indicated that upland pedons 1 and 3, lowland pedons 1 and irrigated pedons 2 and 3 were optimum (95%) with respect to active Fe toxicity, lowland pedon 3 and irrigated pedon 1 were marginally suitable (60%) while upland pedon 2 and lowland pedon 2 were not suitable (40 %). Al saturation posseses a lighter challenge as upland pedons 1 and 3 and irrigated pedon 1 were marginally suitable (60%) while all other pedons were nearly optimum (60%) in Ebonyi north soils.

Table 3: Land Qualities/Characteristics of Ebonyi North rice Soils

Land Qualities/Land Characteristics	Unit	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	Mm	1500	1500	1500	1500	1500	1500	1500	1500	1500
Mean Temperature	°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	104	115	107	98	103	112	106	112	109
Clay	%	18.5	18.9	11.1	20.0	19.5	20.5	20.9	18.1	13.7
Silt	%	48.9	44.2	34.3	45.6	43.9	44.6	46.3	49.9	44.7
Sand	%	32.7	37.0	54.5	33.9	36.5	34.9	31.3	31.3	41.7
Wetness (w)										
Drainage		2	2	2	2	2	2	2	2	2
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	97	101	110	106	112	109
Fertility (f)										
pH	-	3.99	4.32	4.98	4.42	4.70	4.43	4.28	4.24	4.68
Total N	%	0.11	0.08	0.08	0.10	0.11	0.09	0.09	0.07	0.10
Organic C	%	1.32	0.92	0.93	1.14	1.21	1.07	1.00	0.87	1.21
Avail. P	mg.kg-1	10.4	8.4	8.5	9.2	12.3	8.1	7.9	9.8	7.7
K	cmol.kg-1	0.06	0.08	0.06	0.06	0.07	0.06	0.09	0.06	0.05
Ca	cmol.kg-1	1.31	1.49	1.21	3.05	1.98	1.38	1.80	1.15	1.37
Mg	cmol.kg-1	0.91	0.54	0.28	0.74	0.48	0.63	0.70	0.30	0.22
ECEC	cmol.kg-1	5.01	4.17	3.77	5.62	4.35	4.36	5.34	3.16	3.94
Base Saturation	%	46.6	53.5	42.5	60.6	58.7	50.0	51.1	52.4	43.2
Toxicity (t)										
Active Fe	mg.kg-1	74.0	154.2	69.0	40.0	201.2	129.1	140.4	73.5	74.2
Fe	%	0.74	1.54	0.69	0.40	2.01	1.29	1.40	0.73	0.74
Al Saturation	%	32.64	25.9	28.6	20.8	18.9	25.1	32.7	25.2	21.5

Key: Drainage 1 = Imperfectly Drained, 2 = Moderately Drained, 3 = Well Drained, NE = Not encountered

Table 4: Suitability Class Scores of Abakaliki 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	S2(85)	S2(85)	S3(60)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S3(60)
Wetness (w)									
Drainage	S3(60)	S3(60)	S3(60)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
Flood Duration	S3(60)	S3(60)	S3(60)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Fertility (f)									
pH	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
Total N	S2(85)	S3(60)	S3(60)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
Organic C	S2(85)	S3(60)	S3(60)	S2(85)	S2(85)	S2(85)	S2(85)	S3(60)	S2(85)
Avail. P	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
K	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
Ca	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
Mg	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
ECEC	S3(60)	N1(40)	N1(40)	S3(60)	N1(40)	N1(40)	S3(60)	N1(40)	N1(40)
Base Saturation	S2(85)	S1(95)	S2(85)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S2(85)
Toxicity (t)									
Active Fe	S1(95)	N1(40)	S1(95)	S1(95)	N1(40)	S3(60)	S3(60)	S1(95)	S1(95)
Al Saturation	S3(60)	S2(85)	S3(60)	S2(85)	S2(85)	S2(85)	S3(60)	S2(85)	S2(85)

3.4 Soil Suitability

Table 5 shows the suitability aggregate scores and suitability classification of the study location using parametric and non-parametric suitability evaluation procedures. Ebonyi north upland pedons 1, 2 and 3 were potentially and currently not suitable by parametric evaluation. Potentially, upland pedons 1 – 3 were not suitable (N1) having scored less than 25 in the aggregate suitability class scores as suggested by Ogunkunle (1993) being minimum suitability requirement for rice cultivation. Currently, Ebonyi north upland pedons 1, 2 and 3 were not suitable. Pedon 1 was N1 (15.6), pedon 2, N2 (6.9) and pedon 3 was N2 (7.3).

Ebonyi north lowland pedon 1 was marginally suitable S3 (31.3) potentially and currently using parametric evaluation. Lowland pedons 2 and 3 were potentially not suitable; N1 (14.7) and N1 (22.1) for pedons 2 and 3 respectively. Currently Ebonyi north lowland pedons 2 and 3 were not suitable- N2 (12.4) and N1 (14.7) respectively using parametric evaluation. Under irrigated rice soils all pedons were potentially and currently not suitable – N1 except pedon 2 that was potentially marginally suitable S3 (31.3). Using non – parametric method of evaluation, all the pedons of the three cropping land uses were potentially and currently marginally suitable (S3). Ebonyi north upland soils had limitations of wetness, fertility and toxicity, the lowlands had fertility limitation in the pedon 1, fertility and toxicity limitations in pedons 2 and 3. The irrigated soils of Ebonyi north had limitations of fertility and toxicity in pedon1, fertility in pedons 2 and 3 all currently and potentially using non-parametric method of evaluation.

Table 5: Suitability Aggregate scores and suitability classification of Abakaliki, Ebonyi State					
		Parametric		Non-Parametric	
Ebonyi North	Pedons	Potential	Current	Potential	Current
Upland	1	N1(15.6)	N1(15.6)	S3wft	S3wft
	2	N1(15.6)	N2(6.9)	S3 wft	S3wft
	3	N1(15.6)	N2(7.3)	S3wft	S3wft
Lowland	1	S3(31.3)	S3(31.3)	S3f	S3f
	2	N2(14.7)	N2(12.4)	S3ft	S3ft
	3	N1(22.1)	N1(14.7)	S3ft	S3ft
Irrigated	1	N1(22.1)	N1(22.1)	S3ft	S3ft
	2	S3(31.3)	N1(20.8)	S3f	S3f
	3	N1(22.1)	N2(14.7)	S3sf	S3sf

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

4. Discussion

These results show that upland soils had serious fertility challenge as well as wetness and toxicity, thereby making them non-suitable both currently and potentially. Lowland and irrigated soils had their limitations restricted to fertility, toxicity and soil physical conditions (s) only identified in pedon 3 of the lowland soils. In Table 4, organic matter (OM) was glaringly low in the upland pedons 2 and 3 as well as irrigated pedon 2. Maintenance of a satisfactory organic matter status in rice soils is highly essential, Onyekwere (2016) reported enhanced mineralization of most of the nitrogen and phosphorous in the soils, if the rice fields were unfertilized. This will lead to immobilization of the inorganic materials formed by the microorganisms with none for crops usage.

Potassium (K), Calcium (Ca), Magnesium (Mg) and ECEC and pH were constraints all investigated soils in the three cropping locations. A decline in the quality and fertility status of these soils can be attributed to their leaching losses caused by heavy rainfall in the area especially the upland soils (Wapongnungsang, 2018). Also, crops constantly take up nutrients from soils with no commensurate additions to replenish such nutrients. Rice husks are usually burned in this rice farming region to make way for easy farming while fallow or shifting cultivation is rarely practiced as a result of demographic pressure and the need to feed the growing population in southeastern Nigeria. Suriyagoda proposed that in order to continue rice production in low input agricultural systems, soil fertility restrictions must be addressed before other technologies and policies may improve productivity (Suriyagoda, 2022). When doing so, soil management options other than applying synthetic fertilizers, such as organic matter addition, crop rotation, and tillage practices, should be prioritized because they are critical to overcoming nutrient limitations.

According to some Asian studies, nitrogen (N) is the most widely limiting nutrient, followed by phosphorus (P), and potassium (K) deficiency is uncommon (Dobermann et al., 2003; Ladha et al., 2003; Shen et al., 2004; Rodenburg et al., 2014; Diallo et al., 2016; Somaweera et al., 2016, 2017). In the present study, potassium (K) appears to be limiting while nitrogen (N) and phosphorus (P) were fairly optimum. Apart from nutrient limitations, constraints related to pH and effective cation exchange capacity (ECEC) were also a challenge in the investigated soils. Soil pH was marginally suitable (S3) in all pedons across different rice land uses while effective cation exchange capacity (ECEC) was only marginally suitable in pedons 1 upland, 1 lowland and 1 irrigated while all other pedons were not suitable (N1).

Many authors have reported similar findings in Asian rice soils (Ladha et al., 2003; Haefele et al., 2004, 2014; Shen et al., 2004; Gami et al., 2009; Saito and Futakuchi, 2009; Rodenburg et al., 2014; Diallo et al., 2016). Nutrient deficit is less common in the sequence of uplands > rainfed lowlands > irrigated lowlands > deepwater/mangrove habitats (Haefele et al., 2014; Nhamo et al., 2014). This is related to nutrient and soil particle transfer from higher to lower portions of the landscape, as well as changes in soil moisture availability. Soils with concerns such as Fe-toxicity, on the other hand, are more common in the lower parts of the landscape and in areas where seepage water collects (Haefele et al., 2014; Rodenburg et al., 2014).

5. Conclusion

These results show that upland soils had serious fertility challenge as well as wetness and toxicity, thereby making them non-suitable both currently and potentially. Lowland and irrigated soils had their limitations restricted to fertility, toxicity and soil physical conditions (s) only identified in pedon 3 of the lowland soils. Equally, organic matter (OM) was glaringly low in the upland pedons 2 and 3 as well as irrigated pedon 2. Potassium (K), Calcium (Ca), Magnesium (Mg) and ECEC and pH were constraints in all investigated soils in the three cropping locations. A decline in the quality and fertility status of these soils can be attributed to their leaching losses caused by heavy rainfall in the area especially the upland soils. The parameters adopted as soil quality indicators were under; climate, soil physical condition, wetness, fertility and toxicity. The research indicated that out of the nine profile pits studied, three in each rice landuse of uplands, lowland and irrigated soils, all upland soils were not suitable (N1). Pedon 1 of the lowland soils was marginally suitable (S3) (potentially and currently) while pedon 2 of the irrigated soils was marginally suitable (S3) (potentially). All other soils at the lowland and irrigated soils were not suitable (NI). Studying soil quality and suitability in northern Ebonyi state, Nigeria is critical in ensuring sustainable agricultural practices, safeguarding the environment, promoting economic development, and addressing various challenges related to land use, climate change, and natural resource management. Practices that will conserve the fertility status of these soils should be adopted such as rotational farming, accumulation of organic materials on the soils and avoidance of burning of rice husks. This is necessary as fallow practice does not exist anymore due to demographic pressure and population growth in southern Nigeria.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

SN Obasi involved in planning and conceptualization of the research work, field work, write up and editing. EU Onweremadu provided supervision and technical support. CC Obasi did the data analysis, interpretation and reviews. CO Madueke provided some information on digital elevation and map productions.

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