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Parametric and Non-Parametric Suitability Evaluations of Rice Soils of Asu River Group Parent Materials in Ohaozara, Nigeria

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ABSTRACT

The study was carried out in Ohaozara Southern Ebonyi State in Southeastern Nigeria. Study area was identified in a rice soil of about 120 hectares used for FGN/IFAD Value Chain Development program (VCDP). Three profile pits were dug on a transect line of about 100 – 200m apart for suitability evaluation study. The aim of the study was to use parametric and non – parametric suitability evaluation to study the rice soils under Asu River Group parent material. Parametric method is where each limiting characteristic was rated using information provided on factor ratings of land use requirements for wetland ricetable. In Non-parametric method, pedons were placed in suitability classes by matching their land characteristics with the agronomic requirements of rice. The index of productivity (IP) (actual and potential) was calculated using the equation: IP= A x $\sqrt{(B/100 \times C/100 \times D/100 \times E/100)}$. Suitability evaluation results show that climate, soil physical conditions and wetness were optimum S1(95%) and moderately suitable S2(85%) while,fertility and toxicity parameters made the soil marginally suitable S3(60%). Parametric and non – parametric suitability evaluation revealed that the soils were mostly marginally suitable both potentially and currently. Major limitations of the investigated soils bother on fertility and Al toxicity.

1.0 Introduction

Soil is one of the most important natural resources and proper understanding of its properties is necessary for judicious, beneficial and optimal use on sustainable basis (Jagdish, *et al*, 2009). Soil suitability is the categorization of soils into groups at varying levels of generalization according to their morphological, physical, chemical, and mineralogical properties. The soils are intensively utilized in Nigeria without proper management practices to replenish soils fertility due to lack of crop suitability maps. Thishas led to soil degradation and reduced agricultural productivity (Ekwoanya and Ojanuga, 2002).

Land evaluation can tell farmers how suitable their land is in terms of soil limitations, to specified land use and management practices. Land suitability evaluation is the process of making predictions of land performance over time based on specific types of uses. These predictions are then used as a guide in strategic land use decision making. The process of land suitability classification is the assessment and categorized of specific areas of land in terms of their suitability for defined uses (FAO 1976). This assessment is always carried out separately for each category of land use (Iha, 2009).

The most important soil characteristics in land evaluation include drainage, texture, soil depth, nutrient retention (pH, cation exchange capacity), alkalinity, erosion hazard, and flood/inundation. Soil attribute is important for the overall performance of land and play a preponderant role in checking land quality, and has been used extensively by several authors to monitor land degradation (Senjobi , 2007; Senjobi and Ogunkunle, 2011).

In the views of Esu (2004), studying soil in detail through processes of soil characterization and land evaluation for various land utilization types is one of the strategies for achieving food security as well as sustainable environment. However, despite the importance of land evaluation on sustainable management of land and for enhanced crop production, specific soil suitability studies; such as suitability assessment for rice production have not been properly documented; and available ones show locations and ecological bias (Aondoakaa and Agbakwuru, 2012). More so, some of the studies available provide holistic approach on land evaluation and are not crop specific (Rossiter, 1996; George, 1997; Adeleye, 2002; Soil Survey Staff, 2003).

Eze (2014), noted that Aguilar and Ortiz (1992) used the FAO Framework, in combination with the parametric Riquier index to define the suitability classes (S1, S2, S3, N1 and N2) for land capability. However, in a recent study, Udoh *et al*, (2011), used the parametric and the non-parametric methods to evaluate the suitability of the eight pedons for rice and cocoa cultivation in soils developed from alluvial deposit; in which five land quality groups were used for the studyand only a member of each of the five land quality groups was used in the calculation, because of the strong correlation among members of the same group (Ogunkunle, 1993). The five land quality groups were climate (c), soil physical characteristic (s), wetness (w), fertility status (f) and toxicity (t).This study attempts to use parametric and non – parametric evaluation procedures to investigate the suitability of rice soils within the Asu River group parent materials in Ohaozara, Southeastern Nigeria.

2.0 Materials and methods

2.1. Study area

2.1.1 Location

The study area is located near Umunaga – Uburu in Ohaozara Local Government Area of Ebonyi State Southeastern Nigeria, with the Latitude of $6^{o}010899'$ N and Longitude of $7^{o}777467'$ E. The study area falls within the tropical rainforest zone of the southeastern Nigeria and experiences rainfall between March - November with highest intensities occurring between June-September while about

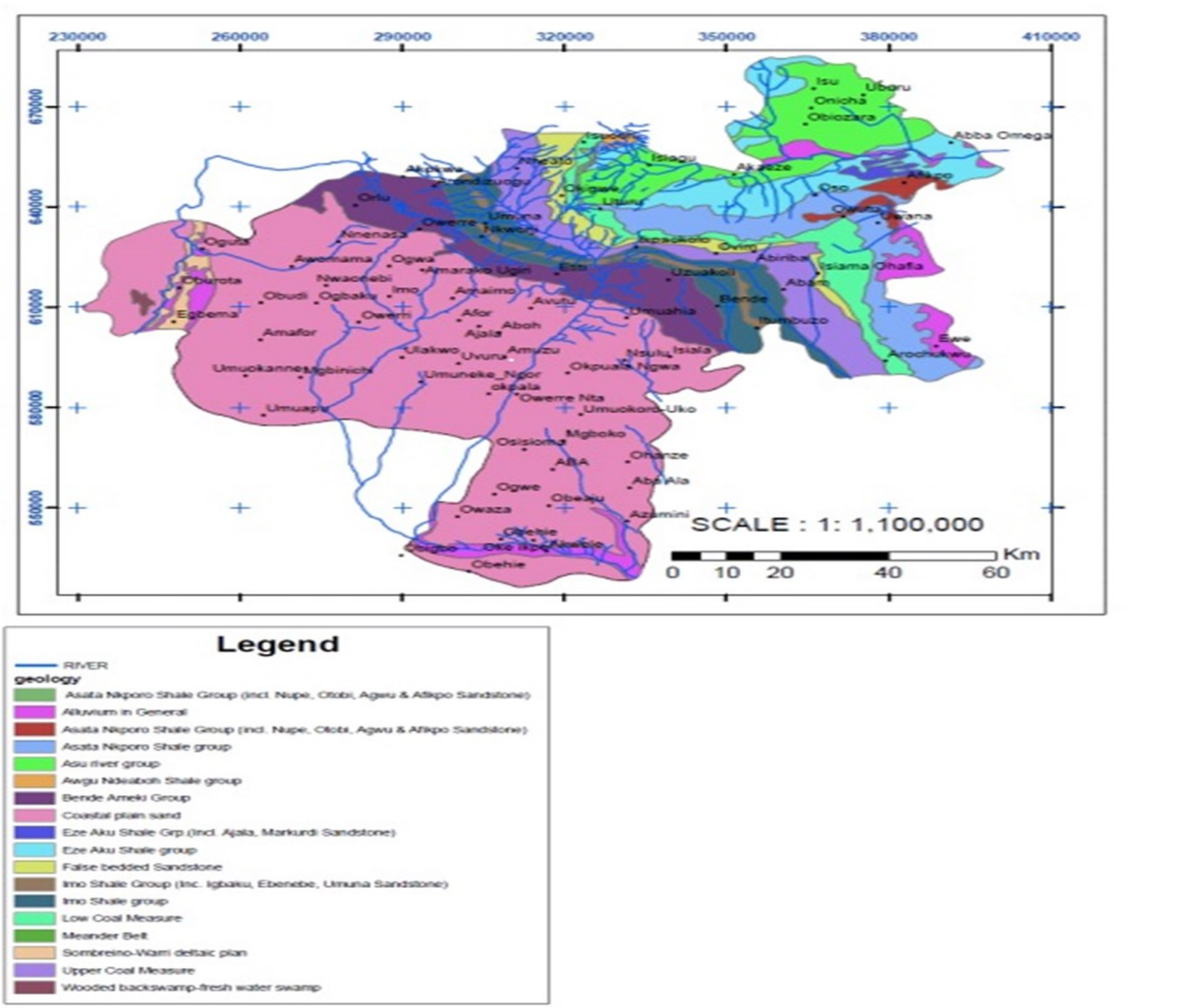

Fig 1: Geological map of old Imo State showing the study area, Ahukaemere *et al.,* 2015

three months of dry season occur from December - February.The area lies within the humid tropics with Ustic moisture regime (Obasi and Obasi, 2020). This concept is one of moisture that is limited but is present at a time when conditions are suitable for plant growth. The soil in moisture control section in ustic moisture regime is dry in some or all parts for 90 or more cumulative days in normal year (Soil Survey Staff, 2003). This location receives a mean annual rainfall of between 2250 mm in the South and 1500 mm in the northern part of the zone, average annual temperature of about 27^{o}C with relative humidity of 85% (Nwakpu, 2003; Ahukaemere and Obasi 2018).

2.1.2 Geology and geomorphology

The Asu River Group is a major stratigraphic unit in the study area, consisting of dark micaceous shale, fine grained and calcareous sandstone bodies.Asu-River group geological formation is lower cretaceous, consisting of Eze-Aku shale formation and Nkporo formation made up of shales, sandstones and siltstones (Obasi *et al.,* 2015). The sediments later became folded given rise to two major structural features, the Abakalili anticlinorium and related Afikposynclinorium (Esu, 2004; Ukaegbu and Akpabio 2009).

2.2 Field work

Reconnaissance study was carried out and the study area identified near Umunaga in Ogbuoma autonomous Community Uburu in Ohaozara Local Government Area of Ebonyi State. The study area was in a FGN/IFAD/ Value Chain Development Programme (VCDP) site having about 120 hectares of land. The study area has been subjected to rice farming over the years due its prevalent lowland nature. Three profile pits were dug at an appreciable interval of 100 – 200 m apart within the study area.

2.3 Laboratory analysis

Soil samples were air dried, pulverized, and sieved through a 2 mm sieve mesh. The properties analyzed include particle size distribution determined by hydrometer method (Gee and Bauder, 1986). Soil pH was determined in a 1:2.5 soil/water ratio using digital pH meter and conductivity meter respectively. Exchangeable acidity was determined by the 1N KCl method. Exchangeable bases; Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na) were determined using NH4OAc saturation method (IITA, 1979). Ca and Mg in solution were determined using Atomic Absorption Spectrophotometer, while K and Na were determined using Flame Emission Photometer. Organic carbon was determined by Walkley and Black dichromate wet oxidation method (Nelson and Sommers,1982). Total nitrogen was determined by micro-kjeldahl technique (Bremner and Mulvaney, 1982). The Effective Cation Exchange Capacity (ECEC) was determined summation method, while the available phosphorus was extracted by Bray II method (Olsen and Sommers 1982). Base saturation was calculated as the sum of all base forming cations, divided by cation exchange capacity and multiplied by 100.

2.4 Evaluation procedure

The non-parametric method as well as the parametric method were used to evaluate the suitability for rice soils of Ohaozara in Southeastern Nigeria.

Non-parametric method (FAO, 1976), pedons was placed in suitability classes by matching their land characteristics with the agronomic requirements of rice (Table 1).

By parametric method (Ogunkunle, 1993) each limiting characteristic was rated as using Table 1. The index of productivity (IP) (actual and potential) was calculated using the equation**:**

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

Where A is the overall lowest characteristic rating and B, C, D and E are the lowest characteristic ratings of each land quality group (Udoh *et al.*, 2011). Five land quality groups was used for this study and only a member of each

Table 1: 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

Ogunkunle, 1993

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

of the five land quality groups was used in the calculation because (Ogunkunle, 1993) noted that there exists a strong correlation among members of the same group. For example, texture and structure in group "s". The five land quality groups were climate (c), soil physical characteristic (s), wetness (w), fertility status (f) and toxicity (t) (Table 1).

2.4.1 Potential Index of Productivity (IPp): In computing the IPp, properties that are not easily altered like cation exchange capacity, base saturation, pH and organic matter were used as part of the "f" group while the easily altered chemical properties like exchangeable K, Ca, available P, Mg:K ratio were not part of the calculation (Ogunkunle, 1993).

2.4.2 Current Index of Productivity (IPc): In this case, both the easily altered chemical properties like exchangeable K, Ca, available P and Mg:K as well as those used for IPp were used for the calculation of the IPc.

3.0 Results and Discussion

The land qualities /land characteristics of Ohaozara were as shown in Table 2. The climatic data indicated that rainfall within the study area was 1800 mm. The table of factor ratings of land requirements for rice (Table 1) shows that temperature was optimum having 95%.Also mean annual temperature and relative humidity also scored 85 and 95% respectively.

Soil physical condition of the study area revealed that pedons 1, 2 and 3 had depth of 110, 124 and 125 cm respectively. This depths recorded were due tohigh-water table at the time of sampling that did not allow further depth determination down the profile . These depths were very good for rice cultivation. All investigated profile pits scored 95% which was highly suitable for rice production. Clay recorded 22.76, 25.76 and 26.76% in pedons 1, 2 and 3 respectively. This clay content was not the optimum clay needed for the rice plant as it scored 85% in the suitability class score which indicated moderately suitable clay content.

There is the possibility that as the water table goes down; the clay concentration at the subsoil will increase. The lower clay content of the upper layer may further indicate

Table 2: Land qualities/characteristics of Ohaozara soils

Land qualities/Land characteristics	**Units %**	**Pedon 1**	**Pedon 2**	**Pedon 3**
Climate				
Annual rainfall	Mm	1800	1800	1800
Mean temperature	^{o}C	26 – 28	26 – 28	26 – 28
Relative humidity	%	80	80	80
Soil physical condition				
Soil depth	Cm	110	124	126
Clay	%	22.76	25.76	26.76
Wetness (w)				
Drainage	-	1	1	1
S.W.D	Cm	10	10	10
F.D	Months	3	3	3
G.W.T	Cm	18	15	15
Fertility status (f)				
pH	-	5.25	5.16	5.14
Total N	%	0.068	0.055	0.044
Organic C	%	0.715	0.571	0.468
P (Olsen)	mg.kg-1	27.68	24.18	20.3
K	cmol.kg-1	0.152	0.079	0.077
Ca	cmol.kg-1	1.79	1.14	1.25
Mg	cmol.kg-1	0.91	0.82	0.82
ECEC	cmol.kg-1	3.713	3.313	3.293
- Base saturation	%	78.65	66.5	66.9
Toxicity				
Al. Saturation	%	44.75	36.6	48.1

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

the degree of leaching the soil has undergone. This is evident of Ultisols, formed by the mineral weathering, translocations of clays to accumulate in an argillic or kandic horizon and leaching of base forming cations from the profile (Bray and Weil, 1999). Idoga and Azagaku, (2005) noted that increase in clay with depth may be the result of eluviations, illuviation processes as well as contribution of the underlying geology through weathering. According to Malgwi*et al*., (2000), lower clay content of the surface horizon could also be due to sorting of soil materials by biological and or agricultural activities, clay migration or surface erosion by runoff or combination of these.Wetness parameters were as recorded in table 2; drainage indicated imperfectly drained, surface water depth was >10cm in the heavily flooded period while flood duration lasts about three months.

The fertility status of the investigated soils was as shown in table 2. Soil pH recorded 5.25, 5.16 and 5.14 in pedons 1, 2 and 3 respectively. The soils of the studied area are generally slightly acidic. The acidic nature of the soils may be due to high intensity rainfall in the area, which leaches basic cations down the profile. Enwezor *et al.,* (1998), stated that leaching of Ca and Mg is largely responsible for acidity development in soils. Also, it may be due to Al saturation of the exchange complex. Acidity (Low pH) of the soils may also be due to the effects of cultivation, erosion and leaching of nutrients or a combination of these. However, soil acidity in the investigated soil was moderately suitable as it scored 85% in the suitability class score as shown in table 3.

Organic carbon, total nitrogen, Ca, Mg and ECEC were all marginally suitable in the investigated rice soilscoring S3 (60%) in the suitability class score as shown in table 3.In all pedons, organic matter contents decreased with soil depth having means below the critical level. The low values of organic matter would encourage a rapid leaching of cations such Ca and Mg into the subsoils from the surface. Thus, the

Table 3: Suitability class scores of studied soil

Land qualities/Land characteristics	Pedon 1	Pedon 2	Pedon 3
Climate			
Annual rainfall	S1 (95)	S1(95)	S1(95)
Mean temperature	S2 (85)	S2(85)	S2(85)
Relative humidity	S1 (95)	S1(95)	S1(95)
Soil physical condition			
Soil depth	S1 (95)	S1(95)	S1(95)
Clay	S2(85)	S1 (95)	S1(95)
Wetness (w)			
Drainage	S1 (95)	S1(95)	S1(95)
S.W.D	S1 (95)	S1(95)	S1(95)
F.D	S2 (85)	S2(85)	S2(85)
G.W.T	S2(85)	S1(95)	S1(95)
Fertility Status (f)			
pH	S2(85)	S2(85)	S2(85)
Total N	S3(60)	S3(60)	S3(60)
Organic C	S3(60)	S3(60)	S3(60)
P (Olsen)	S1 (95)	S1(95)	S1(95)
K	S2(85)	S3(60)	S3(60)
Ca	S3(60)	S3(60)	S3(60)
Mg	S3(60)	S3(60)	S3(60)
ECEC	S3(60)	S3(60)	S3(60)
- Base saturation	S1 (95)	S1(95)	S1(95)
Toxicity			
Al. Saturation	S3(60)	S2(85)	S3(60)

N = Nitrogen, C= carbon, Ca = Calcium K = Potassium, Mg = Magnesium, P = Phosphorus, Fe = Iron, Al = Aluminum, ECEC = Effective cation exchange capacity

soils are very low in ECEC (<4.0 cmol kg-1) and low in total N. This agrees with Hassan (2010) who advocated that any soil which has <4cmol (+) kg^{-1}ECEC is less productive since soils from all pedons possessed low ECEC <4.0cmol (+) kg^{-1}. According to Chikezie *et al.* (2009) and Eze (2014), the environment of eastern Nigeria is characterized by high temperature and relative humidity conditions that favour rapid decomposition and mineralization of organic matter. Therefore, organic matter content has to be substantially increased through effective crop residue management.Base Saturation was however optimum as it scored S1(95%) in the suitability class scores while Al saturation was relatively high,posing a slight toxicity challenge to the rice crops grown in the area. Al saturation toxicity made the soil moderately suitable S2 (85%) in pedon 2 and marginally suitable S3 (60%) in pedons 1 and 3 as revealed by the suitability class score in table 3.

The suitability aggregate scores and suitability classification of the studied soils were represented in Table 4. This reveals the potential and current suitability status of the studied soils using parametric and non-parametric suitability evaluation procedures. Parametrically; pedons 1 and 3 were potentially marginally suitable scoring S3 (36.42) and S3 (35.00) respectively, while pedon 2 was potentially moderately suitable scoring S2 (55.42). Also, parametrically currently, pedons 1 and 2 were marginally suitable scoring S3 (31.32) and S3 (48.45) respectively while pedon 3 was currently not suitable N1(24.7). The non-suitability nature of the soil can improve using appropriate agronomic and soil management practices.The study of Obasi *et al.,* (20216) on selected rice soils indicated that all studied soils were currently not suitable parametrically as all investigated pedons scored N1 (<25) in the aggregate suitability class scores. However, potentially and parametrically, this study agrees with Obasi *et al.,* (2016) who recorded marginally suitable in the 9 pedons studied compared to the current study that recorded moderately suitable in pedon 2 and marginally in the rest.

Table 4: Suitability Aggregate scores and suitability classification

Pedons	Parametric		Non-parametric	
	potential	Current	potential	Current
1	S3(36.42)	S3(31.32)	S3ft	S3ft
2	S2(55.42)	S3(48.45)	S3f	S3f
3	S3(35.00)	N1(24.70)	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

Non – parametrically; all investigated soils were all marginally suitable both potentially and currently. The key limitations of the investigated soils bother on fertility and toxicity for pedons 1 and 3 while pedon 2 had a limiting fertility challenge. The non- parametric results were in agreement with the reports of Obasi *et al.,* (2016)who worked on similar soils of the agro-ecology.

4.0 Conclusion

Climate, Soil physical condition and wetness properties were optimum and sub optimum in their suitability status while fertility and toxicity parameters were moderately and marginally suitable in the studied soils. Parametric and non – parametric suitability evaluation revealed that the soils were mostly marginally suitable both potentially and currently. Major limitations of the investigated soils bother on fertility and Al toxicity.

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