Full Length Research Article

NJBAS

Available online at http://www.ajol.info/index.php/njbas/index
Nigerian Journal of Basic and Applied Science (June, 2016), 24(1): 25-34
DOI: http://dx.doi.org/10.4314/njbas.v24i1.5
ISSN 0794-5698

Soil Suitability Classification of Tomas Irrigation Scheme for Irrigated Rice Production in Kano State, Nigeria

[1,2]S.L. Yau, B.A. Raji, [1]W.B Malgwi, [1]E.O. Uyovbisere and *[3]E.A. Manasseh
[1]Dept of Soil Science, Institute for Agricultural Research, Ahmadu Bello University, P.M.B 1044, Samaru, Zaria, Nigeria
[2]Kano State college of Arts Science and Remedial studies P.M.B 3145 Kano, Nigeria
[3]National Agricultural Seeds council, North-West Region, Zaria, Nigeria
[*Corresponding email: manasseh2ng@gmail.com; ☎: +2348035932220]

ABSTRACT: The need for sustainable rice production in Nigeria cannot be over-emphasized. Since rice can be grown both under rain-fed and irrigated conditions, the need for soil suitability evaluation becomes very necessary in order for supply to meet up with demand. Six land qualities viz; climate, soil physical properties, drainage, fertility status, workability and erosion were matched with irrigated rice land use requirements. The current suitability evaluation of Tomas irrigation scheme for irrigated rice, using the nonparametric method indicates that all the mapping units fall into the marginally suitable (S3fs) class, with low fertility status and coarse sandy texture as major limitations. The parametric method reveals that all the mapping units had an index of current productivity (IPC) of 5.63 (N2) which is permanently not suitable. Tomas irrigation scheme was found to be potentially moderately suitable (S2) for irrigated rice production using non-parametric method after the soil fertility status was amended.
Keywords: Rice, irrigation, Suitability and Sustainability.

INTRODUCTION

Land evaluation, as defined by Van Diepen *et al.* (1991) and Rossiter (1996), is the process of making predictions of land performance over time based on specific types of uses, while land suitability evaluation can be defined as assessment or predictions of land quality for specific use. These predictions are then used as a guide in the strategic land use decision making. The process of land suitability evaluation includes , identification, selection and description of land use type, relevant to the area under consideration, others are mapping and description of the different types of land that occur in the area and the assessment of the suitability of the different types of land for the selected land use types (FAO, 1976). Rossiter (1995) stated that the modern era of land evaluation began with the publication of the FAO framework for land evaluation (1976), and subsequent guidelines for land evaluation of general kinds of land use (FAO, 1985 and 1991) and (Sys *et al*., 1991).

Land suitability assessment or evaluation is similar to choosing an appropriate location, except that, the goal is not to isolate the best alternative, but to map a suitability index of the entire study area (Joerin and Theriault, 2001). Due to large number of attributes and various criteria involved in decision making, land evaluation has been identified as multi criteria evaluation method (Rashmidevi *et al*., 2009). Land suitability evaluation therefore, requires specialists of different disciplines like soil scientists, agro ecologists, socio economists and planners.

The suitability assessment is based on a description of land characteristic and land qualities (Dent and Young, 1981). Examples include soil texture, slope, annual rainfall and distance to markets. Land characteristics are important, and if employed directly in the evaluation they are highly correlated with other characteristics. In addition, they may have different effects on land use. Land qualities can be expressed in a positive (e.g. water availability, erosion resistance), or negative way (e.g. erosion risks). Only those land qualities relevant to land use alternatives under consideration needs to be determined. Land qualities can sometimes be measured or estimated directly. In most cases, however, they are based on a combination of land characteristics. For example, land characteristics that determine water availability as a land quality can be measured. Relevant land characteristics include soil texture and structure, organic matter content and rainfall. On the basis of these land characteristics, the water availability we can assess (Dent and Young, 1981).

According to FAO (1976) general framework for land suitability evaluation, the land suitability classification consists of assessing and grouping the land types in suitability orders and suitability classes according to their capacity. There are two orders represented by symbols "S" and "N". The suitability orders "S" represent a suitable land on which sustained use of the kind under consideration is expected to yield benefits which justify the inputs, without unacceptable risk of damage to land resources. On the other hand, the suitability order" N" represents not suitable land which has qualities that preclude sustained use of the kind under consideration (FAO, 1976). Land suitability classes reflect degree of suitability. These are numbered consistently using Arabic numbers in sequence of decreasing degrees of suitability within the order. The product of soil evaluation is a map, which partitions the landscapes in to suitable and unsuitable areas for a particular land use of interest (Shalaby *et al*., 2006). This will ultimately pave a way for suitable land use planning and sustainable development (Sharififar, 2012).

Some evaluation systems group the suitability classes into series or levels of importance (order, class, subclass, type etc.), and are thus hierarchical systems. Other systems have one category, and these are frequently parametric (Hussaini, 2011). The simple or hierarchical system compares the plant requirements with its corresponding qualitative land and climatic characteristics and the most limiting characteristics defines land suitability class, while in parametric method, land and climatic characteristics are defined using different ratings (Behzad *et al*.,2009). Sys *et al*. (1991), described a land having ratings of >75% as very suitable class, 50 to 75%, moderately suitable class, 25 to 50%, as marginally suitable, and <25% not suitable class.

Irrigated rice production is promising by giving much higher yield than the wet season rice under the same input and management levels. This necessitates the physical evaluation of the Tomas soils to identify specific areas that can support economic rice production, so that our domestic rice production may meet up with demand in order to guard against rice importation. Therefore the objective of this study was to evaluate the suitability of Tomas irrigation scheme to irrigated rice production.

MATERIALS AND METHODS

The study area was located within old Dambatta and new Makoda Local Government Areas, in the western part of Kano State, east of Kano-Daura road. It is situated approximately between latitudes 12^{o} 18\` and $12^{o}$ 25\`N, longitudes 8^{o} 32\` and $8^{o}$ 38\`E. The Babbaruga Dam across Tomas River is just upstream of the existing road and bridge, while the potential area for irrigation stretches on either bank of the Tomas River (MANR, 1978). This area lies in sub humid tropical zone with a distinct rainy season lasting from May to September. The area has a seasonal climate which is largely determined by inter tropical discontinuity zone (IDZ). The IDZ is a meeting point of the maritime from the south west and the dry tropical continental air mass or the north easterly winds harmattan (Malgwi, 2001), during which there is no rain. The rainy season normally begins in May and ends in October. The seasonal distribution of mean monthly rainfall and the annual rainfall for 11 years (2003- 2013) was 1,260.33mm (Table 1). The data show that, the peak rainfall months in the area were July, August and September. The seasonal variation in temperatures shows an increase from January (29.5^{O}C) to May (38.22^{O}C). As a result of rains, there was a decrease in temperature to (30.28^{O}C) in August, because of cooling effect. And then there was a slight increase after the rains in November (33.15^{O}C), followed by decrease due to effect of the cool dry dusty harmattan.

Exploratory survey was carried out in identifying and confirming the different mapping units produced by the Ministry of Agriculture and Natural Resources (MANR, 1978), Kano. The soil mapping units were produced at the scale of 1:25,000 which was digitized and georeferenced for further analysis. Four different soil mapping units Ballauda (Ba), Sansan (Sn), Tomas (To) and Ladi (La) were identified and confirmed (Figure 1). Intensive field work was later carried out by siting and digging profile pits in each soil mapping unit, where two profile pits were dug on each mapping unit. Both undisturbed and bulk soil samples from pedogenic horizons from each of the mapping units were collected for laboratory analysis of soil physical and chemical properties using standard procedures.

Six chosen land qualities with their associated characteristics were considered in this study (Table 2). They include climate(C), drainage (D), nutrient availability/ fertility status (F), soil physical properties (S), workability (W) and erosional hazards (e). These were matched with the crop requirement for irrigated rice (Table 3). For the non parametric, the soils were classified by matching their characteristics with the crop requirements (FAO, 1976), using the Liebig's most limiting procedure, while for the parametric method, the current suitability was computed using the linear method, where (IPC) of Ogunkule (1993) was employed.

IPC=A×B/100×S/100×C/100…F/100

Where, IPC is index of current productivity, A the overall least rating characteristics and B, C… were the least rating characteristics for each land quality group.

The parametric land evaluation consists of numerical ratings of different limitation levels of land characteristics according to a numerous scale between the maximum (100 to 75%) and minimum (12.5 to 0%).

Statistical analysis

Descriptive statistics was employed for analyses where ranges and means were used.

Table 1: A long term average summary of climatic data of Kano area (2003-2013)

Month	Temperature (^oC)		Mean rainfall	Relative humidity	Evaporation	Sunshine hours
	Max	Min	(mm)	(%)	(mm)	
Jan	29.5	13.63	0.00	27.82	9.3	6.72
Feb	34.09	17.62	0.00	23.45	11.24	7.6
March	36.87	20.38	0.00	20.89	13.12	7.28
Apr	39.57	24.64	26.44	35.96	12.74	7.44
May	38.22	25.48	84.11	53.07	9.94	7.29
June	34.79	23.72	195.41	64.78	6.37	5.54
July	31.61	22.2	335.4	74.55	3.79	6.14
Aug	30.28	21.78	379.63	80.25	2.6	5.79
Sept	32.3	22.33	195.15	73.74	3.65	7.18
Oct	33.85	21.16	24.19	52.21	6.41	8.34
Nov	33.15	16.69	0.00	31.1	9.02	8.41
Dec	28.88	13.55	0.00	32.34	8.57	8.05
Total			1,260.33			

Source: Nimet Forecast office, Malam Aminu Kano International Airport (MAKIA), Kano 2013.

RESULTS AND DISCUSSION

The soils in Ballauda (Ba), Sansan (Sn), Tomas (To) and Ladi (La) mapping units were well drained and deep, except in pedon Ba1 in Ballauda series which was imperfectly to well drained and water table was encountered at depth 114cm. The parent material was colluvial, loessial and alluvial or a mixture of these, over basement complex. These soils were located on a gently sloping plain of level or nearly level slope of 0-2%. The surface thickness of soils in mapping unit Ba and Sn ranged from 10-35cm, with reddish brown to strong brown colours (7.5YR4/6, moist) and of sandy loam to loamy sand texture. The colour obtained for the surface horizons may be due to the oxidation of iron II to iron III in sand sized fractions (Hassan, 2010). Strong brown to yellowish red (7.5 YR 4/6 moist) colours were observed in the subsurface horizons, indicating the presence of oxidized iron in well drained uplands especially in the tropics (Brady and Weil, 2005). The dark grayish brown colour of the subsurface horizon especially in pedon Ba1 was an indication of anaerobic condition showing gleization (Raji, 1995 and Hassan, 2010).

The physical properties of the soils indicate that gravel content of the pedons in all mapping units was negligible or none at all, which suggests the aeolian and or colluvial origin of the parent material (Esu, 1982). Sand was the dorminant particle size fraction in both surface and subsurface horizons in all mapping units. The available water holding capacity indicates that, almost all the soils have low capacity to retain enough moisture for plant growth, with the exception of some horizons in mapping unit Ba1, which was within the range of 9.5 to 12.5%, considered adequate for plant growth by FAO, (1979).

The soil pH (water) of all mapping units ranged from (4.7 to 6.6), indicating extremely acidic to neutral soil reaction. Total N and available P values for the mapping units were rated low to medium (Chude *et al*., 2004), while the Cation Exchange Capacity CEC values were rated very low to moderate. The low values of CEC of the pedons may be attributed to some of the exchange sites being occupied by ferric ions (Coleman and Thomas, 1964). Higher values were obtained at sub surface horizons.

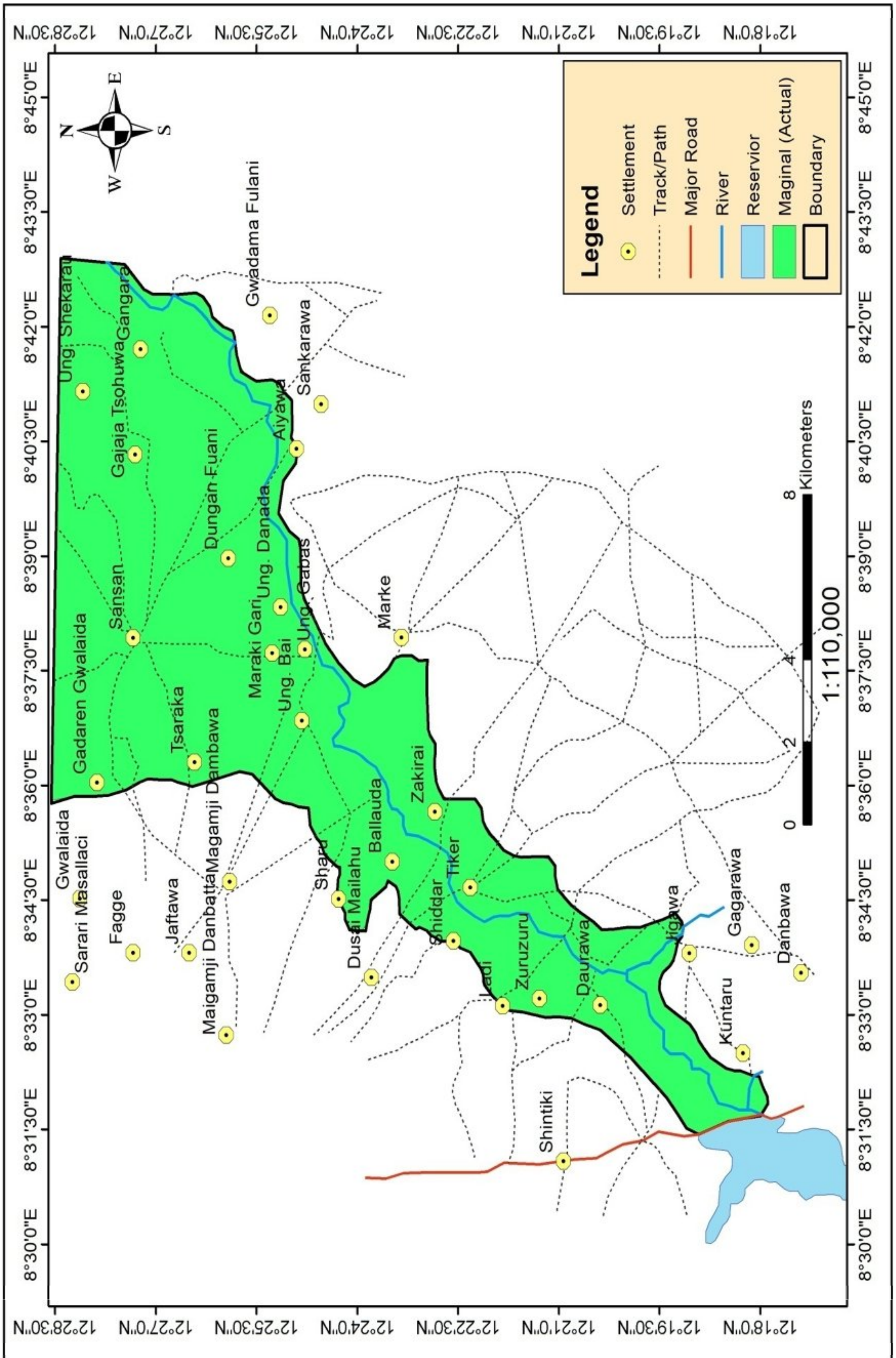

Figure 1: Soil suitability map of Tomas irrigation scheme

Table 2: Land use requirement for suitability classification for irrigated rice

Land qualities/ characteristics	Unit	S1	S2	S3	N1	N2
Climate (c)						
Solar radiation	Sunshine hrs/day	> 478	478-358	358-239	239-120	Any
Mean annual temperature	0C	22-25	20-22	18-20	16-18	< 16
Relative humidity	%	70-75	65-70	60-65	<60	
Soil physical properties (s)						
Texture (clay)	%	LC	SCL	SL	S	S
Drainage (d)						
Wetness		WD-MD	PD	VPD	ED	__
Workability (w)						
Soil depth	(cm)	65-70	50-65	35-50	30-35	< 30
Slope	%	0 -2	2-4	4-6	6-10	> 10
Surface stoniness		None	None to slightly gravel	Slightly stony	Stony	___
Erosion (e)		None	None to slight	Eroded	Well eroded	___
pH		5.5-7.5	5.2-5.5	<5.2	>7.5	Any
Fertility status (f)						
Total N	gkg^{-1}	>2.0	1.5-2.0	1.0-1.5	0.5-1.0	<0.5
CEC ($Cmol/kg^{-1}$)	($Cmol/kg^{-1}$)	12.0-16.0	8.0-12.0	5.0-8.0	<5.0	
Organic C	gkg^{-1}	>2.0	2.0-1.5	1.2-1.5	1.0-1.2	<1.0
Available P	$mgkg^{-1}$	15-20	8-15	5-8	3-5	< 3
Exchangeable K	($Cmol/kg^{-1}$)	0.3-0.5	0.2-0.3	0.1-0.2	< 0.1	__
Micro nutrient						
Fe	$mgkg^{-1}$	3.5-4.5	2.5-3.5	1.5-2.5	1.0-1.5	< 1.0
Zn	$mgkg^{-1}$	1.5-2.0	1.0-1.5	0.8-1.0	0.6-0.8	< 0.6
Mn	$mgkg^{-1}$	1.0-1.5	0.8-1.0	0.6-0.8	0.5-0.6	< 0.5

SOURCES: FAO (1953), Sys *et al*., (1991, 1993); De Datta (1989) and Udoh *et al*., (2011)
KEYS: LC = loamy clay, SCL = Sandy clay loam, SL = sandy loam, S = sand, MD = moderately drained, WD=well drained, PD = poorly drained, VPD = very poorly drained, ED = excessively drained. S1= highly suitable, S2=moderately suitable, S3= Marginally suitable.

Soil Suitability Class S3 (current)

Soils of Ballauda (Ba), Sansan (Sn), Ladi (La) and Tomas (To) mapping units all belong to this suitability class. These soils have no limitation with regards to climate, workability, erosion, soil pH and drainage, there by classifying them in to (S1) highly suitable class. Indicating that, these soils were found to be optimum for irrigated rice production. However, these soils possess major limitations in terms of soil fertility (f) which was inherently low, and soil texture (s) which ranged from sandy loam to loamy sand with negligible percentage of clay. This rated all the mapping units in to S3 (marginal) and makes them sub-optimum for irrigated rice production. Using Liebig's law, the current/actual suitability of Ballauda (Ba), Sansan (Sn),Ladi (La) and Tomas mapping units are classified in to (S3) suitability, which means the soils are ' marginally' suitable for irrigated rice production with the same limitations to give the suitability subclass (S3fs) (Table 3). They have limitations which are severe for sustained application of irrigated rice production, and so will reduce productivity or benefits or increased required inputs that the expenditure will be marginally justified.

Soil suitability class S2 (potential)

To ameliorate these limitations, there is need for more attention in adopting farming practices that encourage conservation of organic matter, supplement the soil N level with external sources of N for optimum rice production due to the importance of N (Davide, 1964), annual incorporation of rice residues instead of burning, and application of full doses/rates of P for crops annually to these mapping units to obtain optimum rice yield. This will ultimately help in improving the nutrient holding capacity of these soils, by making them retain more moisture, a condition favourable for irrigated rice production, since rice requires high amount of moisture to survive (IRRI, 1980). If these limitations are ameliorated and taken care of in the evaluation procedure, the potential suitability of all the mapping units could be raised to S2 'moderately suitable' class. This is a class with moderate limitation but projected benefits are subjected to increased inputs well above those required for the highly suitable lands.

The results of suitability assessment for irrigated rice are shown in Tables 3 and 4 using the nonparametric and parametric method. By the nonparametric method, all the pedons were found to be marginally suitable (S3) for irrigated rice production for actual (current) aggregate suitability. While the potential aggregate suitability for all the pedons were moderately (S2) suitable for irrigated rice production after the major correctable (nutrient) limitations were amended.

The parametric method in (Table 5) indicate that, all the mapping units had an index of current productivity (IPC) of 5.63 (N2), and hence classified as permanently not suitable for irrigated rice production. The major limitations were mainly nutrient availability or soil fertility (F) like low levels of available macro- nutrients, organic carbon and low cation exchange capacity. However, the evaluation of potential suitability by index of potential productivity (IPp) of Tomas using the parametric linear model (without considering the levels of organic C, macro and micro- nutrients which were regarded as temporary limitations), indicate that all the mapping units were permanently not suitable 9.0(N2) and 11.25(N2), with the exception of pedon Ba1 which was currently not suitable 20.5(N1) (table 5). Using the non-parametric method, Tomas irrigation scheme was found to be more favourable to irrigated rice production than the parametric method, and none of the soils was found to be highly suitable (SI) for optimum irrigated rice production.

Table 3: Land d suitability classification and ratings for the different soil mpping units

Mapping unit	Representa tive soil pedons	Climate (c)	Soil physical properties (s) Texture	Drainage wetness	Workability	Erosion	pH	Fertility status (f) macro-nutrients.	Fertility status(f) micro-nutrients. (Fe, Mn, Zn, Cu)	Class	Subclass
		a) Solar radiation b) mean temp. c) Relative humidity			a). slope b). soil depth c) stoniness			a). Total (N) b). CEC c). Organic C d). Available P			
Ba	Ba_1, Ba_2	S_1	S_3	S_1	S_1	S_1	S_1	S_3	S_1	S_3	S_3 fs
Ba	Ba_1, Ba_2	S_1	S_3	S_1	S_1	S_1	S_1	S_3	S_1	S_3	S_3 fs
Ba	Ba_1, Ba_2	S_1	S_3	S_1	S_1	S_1	S_1	S_3	S_1	S_3	S_3 fs
Ba	Ba_1, Ba_2	S_1	S_3	S_1	S_1	S_1	S_1	S_3	S_1	S_3	S_3 fs

Key: Fs= fertility and texture limitations, S1= highly suitable, S2=moderately suitable, S3= Marginally suitable,Ba=Ballauda, Sn= Sansan, To=Tomas and La= Ladi
CEC = Cation Exchange Capacity

Table 4: Actual and potential suitability ratings of soil mapping units

Soil and Climatic characteristics	Ballauda (Ba)	Sansan (Sn)	Tomas (To)	Ladi (La)
Climate (C)		S1	S1	S1
Mean annual temperature (^oC)	S1	S1	S1	S1
Solar radiation	S1	S1	S1	S1
Relative humidity	S1	S1	S1	S1
Soil physical properties(S)				
Texture	S3	S3	S3	S3
Drainage (d)				
Wetness	S2	S2	S2	S2
Workability(W)				
Slope(%)	S1	S1	S1	S1
Soil depth(cm)	S1	S1	S1	S1
Stoniness	S1	S1	S1	S1
Erosional hazards(e)	S1	S1	S1	S1
Fertility status(F)				
Macro-nutrients, CEC and pH.	S3	S3	S3	S3
Micro-nutrients (Fe,Mn,Zn and Cu)	S1	S1	S1	S1
Aggregate Suitability(Actual)	**S3**	**S3**	**S3**	**S3**
Aggregate Suitability(potential)	**S2**	**S2**	**S2**	**S2**

Key:S1 = highlysuitable, S2 = moderately suitable, S3 = Marginallysuitab

Table 5: Soil suitability class scores and ratings of the soil pedons according to severity of limitations

Land quality/ characteristics	Ba1	Ba2	Sn1	Sn2	To1	To2	La1	La2
Climate (C)								
Solar radiation	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Mean annual temp.	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Relative humidity	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Soil physical properties(S)								
soil texture	45(S3)	45(S3)	45(S3)	45(S3)	45(S3)	45(S3)	45(S3)	45(S3)
Drainage								
Wetness	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Workability (W)								
Slope	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Soil depth	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Surface stoniness	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Erosion (e)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Fertility status (F)								
pH	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Base Saturation Percentage	45(S3)	45(S3)	25(S3)	45(S3)	35(S3)	90(S1)	100(S1)	50(S2)
Micro-nutrients								
Total N	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)
CEC	45(S3)	20(N1)	45(S3)	20(N1)	20(N1)	20(N1)	20(N1)	20(N1)
Organic C	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)	12.5(N2)
Available P	20(N1)	12.5(N2)	45(S3)	45(S3)	20(N1)	45(S3)	70(S2)	45(S3)
K	20(N1)	20(N1)	20(N1)	20(N1)	20(N1)	20(N1)	45(S3)	20(N1)
Micro-nutrients								
Fe	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Mn	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Zn	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)	100(S1)
Actual suitability	5.63(N2)	5.63(N2)	5.63(N2)	5.63(N2)	5.63(N2)	5.63(N2)	5.63(N2)	5.63(N2)
Potential suitability	20.25(N1)	9.0(N2)	11.25(N2)	9.0(N2)	9.0(N2)	9.0(N2)	9.0(N2)	9.0(N2)

Key: ratings S1=(100-75) ,S2= (74-50),S3= (49-12.5), N1= (24-12.5) and N2=(12.5-0), Ba=Ballauda, Sn= Sansan, To=Tomas and La= Ladi

CONCLUSION

The suitability class of the soils revealed permanently not suitable using parametric method (IPC) of 5.63 (N2). But using non parametric, all the pedons were marginally suitable (S3) with major limitations of nutrients availability and texture (S3fs) for irrigated rice production. The nonparametric method was found to be more favourable to irrigated rice production than the parametric method. The management option to be employed in order to correct the major limitations and improve the suitability of the soils of Tomas irrigation scheme for sustainable irrigated rice production include residue mulching and organic manuring, returning all crop residues and incorporating them in to the soil after harvest. In addition, inorganic fertilizer application at appropriate rates is recommended.

REFERENCES

Behzad,M., Albaji,M. Papan, P., Boroomand,S.,Nasab, .A., Naseri, A., and Bavi, A. (2009). Qualitative evaluation of land suitability for principal crops in the Gargar Region,Khuzestan province,south west Iran. *Asian Journal of Plant Sciences,* **8:** 28-34.

Brady, N.C. and Weil, R.C. (2005). *The Nature and Properties of Soils,* 13th Edition. Pearson Printice-Hall Inc. India. 881 pp.

Chude, V.O., Malgwi, W.B., Amapu, I.Y., Ano, O.A. (2004). Manual on soil fertility assessment. Federal Fertilizer Department (FFD), in Collaboration with National Special Programme for Food Security, Abuja, Nigeria.

Coleman, N.T. and Thomas, G.W. (1964). Buffer curves of acid clays as affected by the presence of ferric iron and aluminium. *Soil Science Society of American* Proceedings, **28:** 187-190.

Daniel, M.B. (1985). Post Irrigation Assessment of Soil Nutrient Status in the Tomas River Project Area. Kano State.

Davide, J.G. (1964). The time and methods of phosphate fertilizer application. Proceedings Symposium mineral nutrition for rice plant.255-268. John Hopkins Press, Baltimore, Maryland.

Dent, D. and Young, A. (1981), Soil Survey and Land Evaluation George Allen and Unwin, London.

Esu, I.E. (1982). Evaluation of soils for irrigation in the Kaduna Area of Nigeria. Unpublished Ph.D thesis ABU Zaria, Nigeria. 305 pp.

FAO, (1976). Frame work for Land Evaluation FAO Soils Bulletin No. 32 FAO, Rome

FAO, (1985). Guidelines Land Evaluation for Irrigated Agriculture. FAO soil Bull. 55, Rome, 290 pp.

FAO, (1991). Land Use Planning Applications. Proceedings of the FAO Expert Consultations, 1990.

Hassan, A.M. (2010). Micromorphological and Mineralogical Evaluation of Ultisols developed over different parent materials in Northern Guinea Savannah, Nigeria. Unpublished Ph.D thesis. ABU Zaria, Nigeria.193pp

Hussaini, G.M. (2011). Land suitability evaluation for some selected land use types in the Institute for Agricultural Research Farm, Zaria, Nigeria. Unpublished Msc thesis, ABU Zaria, Nigeria.123pp.

IRRI. (1980): Annual Report for 1979. Los Banos, Phillipines.

Joerin, F., Theriault, M. Musy, A. (2001). Using GIS and outranking multicriteria analysis for land use suitability assessment. *International Journal of Geographical Information Sciences,* **15(2):** 153-174.

Malgwi, W.B. (2001). Characterization of salt affected soils in some selected locations in the north western zone of Nigeria. Unpublished Ph.D. Thesis Ahmadu Bello University Zaria, 230pp.

MANR, (1978). Ministry of Agriculture And Natural Resources, Kano State. Progress Report No.1 Tomas Irrigation Project. Associated Consulting Engineers (ACE) Ltd.

Nguyen, N.C. (2004). Ket qua buoc dau nghien cuu giam ngheo theo Phuong phap cung tham gia o xa Binh Thanh, huyen Huong Tra,tinh Thua Thien Hue (Some primary results of participatory poverty assessment of binh thanh commune,huong tra district,thua thien hue province): *Science Journal of Hue University*, **23:** 88-94.

Ogunkule, A.O. (1993). Soil in land suitability evaluation: An example with oil palm in Nigeria. *Soil Use and Management,* **9(1):** 35-40

Raji, B.A. (1995). Pedogenesis of ancient dune soils in the Sokoto sedimentary basin, North Western Nigeria, PhD thesis ABU Zaria, Nigeria. 194pp.

Rashmidevi, T.V., Eldho, T.I. and Jana, R. (2009). A GIS- integrated fuzzy rule-based inference system for land suitability evaluation in agricultural watershed. *Agricultural Systems*, **101(1-2):** 101-109.

Rossiter, D.G. (1995). Economic land evaluation: Why and how. *Soil Use and Management,* **11(3):** 32-140.

Rossiter, D.G. (1996). A Theoretical Framework for Land Evaluation . *Geoderma,* **72:** 165-190.

Shalaby, A., Ouma, Y.O. and Tateishi, R. (2006). Land suitability assessment for perennial crops using remote sensing and Geographic information systems: A case study in northwestern Egypt. *Archives of Agronomy and Soil Science,* **52(3):** 243-261.

Sharififar, A. (2012). Assesment of different methods of soil suitability classification for wheat cultivation. *Journal of Agrobiology,* **29(2):** 47-54.

Udoh, B.T., Ogunkule, A.O. and Olaleye, A.O. (2006). Land suitability evaluation for banana/plantain *(musa spp*) cultivation in Akwa Ibom State of Nigeria. *Journal of Research in Agriculture,* **3(3):** 1-6.

Van Diepen, C.A., Van Keulen, H., Wolf, J. and Berkhout, J.A.A. (1991). Land Evaluation from Intuition to Quantification. *Advances in Soil Science,* **15:** 139-204.