Nigeria
Journal of Soil and
Environmental Research

Nig. J. Soil & Env. Res. Vol. 10: 2012, 71 - 78
@ Department of Soil Science,
Faculty of Agriculture,
Ahmadu Bello University, Zaria,
Nigeria

Suitability Evaluation of Soils of Lower River Oshin Floodplain, Kwara State, Nigeria for Rain-Fed Arable Crop Cultivation

Lawal[1], B. A., A. G. Ojanuga[2], S. S. Noma[2], M.K.A. Adeboye[1], A.U. Dikko[2] and A. Singh[3]
[1]Department of Soil Science, Federal University of Technology, Minna.
[2]Department of Soil Science and Agricultural Engineering, Usmanu Danfodiyo University, Sokoto.
[3]Department of Crop Science, Usmanu Danfodiyo University, Sokoto.

ABSTRACT

The rapid population growth of Nigeria and the need to satisfy their food requirements have resulted in the cultivation of floodplains hitherto regarded as marginal lands for rain-fed agriculture. In a bid to generate adequate information that may aid optimal and sustainable exploitation of the soils of lower River Oshin floodplains in Kwara State, Nigeria, the FAO land suitability evaluation (LSE) for rain-fed maize and paddy-rice was used to evaluate the land. The total land area was 788 ha. Three soil units designated as OSH-1, 118 ha, OSH-2, 221 ha and OSH-3, 449 ha were identified. Maize and paddy-rice were the crops commonly cultivated by farmers in the area. The soil units, OSH-2 and OSH-3 had surface texture of sandy loam and bulk densities of 1.22 and 1.13 Mg m^3 that favour good agricultural production. All the soils had medium to high available P, 10 - 40 mg kg^{-1}, organic C, 27.5 35.5 g kg^{-1}, and CEC, 19.14 21.99 cmol kg^{-1} status. None of the soil units rated highly suitable (S1) for both crops. Topography and P-fixation were the limiting factors controlling the choice of OSH-1 and OSH-3 respectively for paddy-rice, while drainage was the controlling factor limiting suitability of all the soil units for maize production. Generally, all the soils have enormous potential for rain-fed cultivation of rice and other arable crops that are intolerant to waterlogged soils, if adequate drainage is provided and problem of P-fixation in OSH-3 is properly managed.

Key words: *Suitability evaluation, agricultural potential, Oshin river floodplain.*

INTRODUCTION

Increasing demand for food in Nigeria as a result of rapid population expansion necessitates a substantial expansion of cultivated areas including the fadama (wetlands/floodplains) otherwise considered as marginal land for rain-fed agriculture (Ojanuga, 2006a). Some plants/crops may grow under different soils and extreme agro-ecological conditions, yet not all can grow on the same soil and under the same environment (Mishra, 2007). Floodplains were reported to be a fragile ecosystems and their conversion to cropland may result to severe ecological and environmental deterioration and degradation (Babalola *et al.*, 2011). Therefore, for optimal and sustainable use, land suitability evaluation will enable farmers to understand the suitability of these fragile ecosystems for the kinds of use intended.

Dwellers of the lower River Oshin floodplain in Kwara State, Nigeria beginning from early 1960's earned their income working under the sugarcane plantation and in the factory of the former Nigerian Sugar Company, Bacita, Kwara State, Nigeria. Closure of the sugar company in 2005 brought about change in socio-economic status of the people. Consequently, people of the study area fell-back to agriculture with resultant clearing of the lower River Oshin floodplains. Change in socio-economic status of the people prompted inventory of soil resources of the area with a view to generating data necessary for suitability assessment of the soil resources for rain-fed maize and paddy rice. The selected crops are popularly grown within the lower Oshin river floodplain and their choice for suitability evaluation represents the interest of farmers.

MATERIALS AND METHODS

Oshin river, a large volume seasonal water body took it source from Ila-Oragun in Osun State and stretches 152 kilometre distance before discharging into a loop of river Niger; approximately eight kilometres east of Jebba, Kwara State, Nigeria. The study site lies within floodplain of the river, covering 778 hectares, and is located between latitudes 9° 04' and 9° 10' N and longitudes 4° 52' and 4° 56' E. The study area was classified as sub-humid Central Niger-Benue Trough agro-ecological zone of Nigeria characterized by extensive flat to very gently undulating lowlands with broad interfluves over very deep weathered Nupe sandstones (Ojanuga, 2006b). It falls within the Southern Guinea Savanna vegetation belt of Nigeria with annual rainfall ranging from 1182 to 1301 mm and a growing season up of 150 days (between midApril and midOctober), while mean annual temperature is 33.5 °C (Ojanuga, 2006b).. The soils of the lowland areas were broadly described as poorly drained grey soils (Dystric Fluvisols) (Ojanuga, 2006b), seasonally flooded and accreted with fresh sediments. The soils are predominantly cropped to rice (Ojanuga, 2006b).

The study involved a semi-detailed soil survey using rigid-grid method (100 m × 100 m) on a 778 ha land. Soil units were mapped out by plotting the data obtained from auger samples. In each soil unit, two modal profile pits were dug and examined according to Soil Survey Staff (1993) and FAO (2006) methods. Bulk soil samples were collected from various identified genetic horizons of profile pit representative of each soil unit and analysed in the laboratory.

Soil Analysis

Bulked soil samples collected were air-dried, gently crushed using a mortar and pestle, and passed through 2 mm-sieve to obtain fine earth separates. The processed soil samples were analysed for some physicochemical properties following procedures outlined by ISRIC/FAO (2002). Briefly, particle size analysis was determined by hydrometer method. Soil pH in 1:1 soil-water suspension was measured with pH meter and organic C by Walkley-Black method. The available Phosphorus (P) was determined according to Bray No. 1 method. Cation exchange capacity (CEC) was by use of neutral ammonium acetate method and base saturation by calculation.

Land evaluation

The land suitability evaluation for maize and paddy rice was carried out using the FAO method (FAO, 1976; FAO, 1983) (Table 1a). Key environmental factors considered in the evaluation were climate (annual rainfall, temperature), topography (slope) and soils. The criteria employed for the evaluation of soils were soil depth, texture, drainage, pH, available P, organic C, CEC and base saturation. The identified soil units were placed in suitability classes by matching their characteristics with requirements of the test crops. The most limiting characteristic dictated overall suitability for each soil unit. The suitability of each factor for respective soil unit was classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) or not suitable (N).

RESULTS AND DISCUSSIONS

Soil Characteristics of the Study Area

Three soil units designated as OSH-1, OSH-2 and OSH-3 were identified on the basis of drainage, relative positions, soil colour, texture and depth. Physicochemical properties of the three soil units are shown in Table 1. The soil chemical indices were rated using the critical limits recommended by Esu (1991) (Table 2). Soil surface texture was sandy clay loam for OSH-1 overlaying clay loam while OSH-2 and 3 have predominantly sandy loam surfaces overlaying sandy loam subsurface. Sand was the dominant fraction which may be attributed to the sedimentary parent materials, Nupe sandstones, from which these soils were developed. Brady and Weil (2010) linked soil texture to nature of parent materials the soils were derived from and also to the rate and nature of some weathering processes. The distribution of sand, silt and clay in profiles of all the soils were irregular and diagnostic of fresh alluvial deposits seasonally received. Averagely, the silt/clay ratios were 0.64, 0.42 and 0.68 for OSH-1, OSH-2 and OSH-3 respectively, suggesting that all the soil units are relatively young. Young parent material usually have silt/clay ratio above 0.25 (Asomoa, 1973). All the soil units were poorly drained, typical of fluvisols. In OSH-1 the poor drainage condition was not only due to its high clay content, 320 g kg^{-1} but also as a result of impervious layer from a depth of 172 cm. The drainage problem of OSH-2 and OSH-3 was associated to seasonal rise in water-table during peak rainy months of August-September in the study area. The soil unit OSH-1 had relatively higher bulk density, > 1.4 Mg m^3, compared to the other soil units, which may be attributed to the high clay particle content, > 280 g kg^1 throughout its profile. The higher the clay content, the higher the bulk density (Brady and Weil, 2002). The other soil units, OSH-2 and OSH-3 have relatively low bulk density of < 1.29 Mg m^3 indicating that they are not compacted. Bulk density values of > 1.75 Mg m^3 for sandy soils and > 1.63 Mg m^3 for silty and clayey soils have been shown to cause hindrance to root penetration (Landon, 1991). Therefore, all the soils have optimal bulk density for plant growth.

Table 1a: Rating of land use requirements for rain-fed maize

Land Characteristics/ diagnostic factor	Factor suitability rating (maize)				Factor suitability rating (paddy rice)			
	Highly suitable (S1)	Moderate suitability (S2)	Marginal suitability (S3)	Not suitable (N)	Highly suitable (S1)	Moderate suitability (S2)	Marginal suitability (S3)	Not suitable (N)
Climate:								
Rainfall (mm)	> 800	700-800	600-700	< 600	800-1200	700 -800	600 -700	< 600
Temperature (^{o}C)	24-30	20-24, 30-32	15-20, 32-35	< 15, > 35	24-28	22-24 30-32	18-22 32-35	< 18 > 35
Land/soil physical properties:								
Slope (%)	0-2	4-8	8-16	>16	< 1	1-2	2-4	> 4
Soil depth (cm)	> 120	75-120	30-75	< 30	> 75	50-75	25-50	< 25
Soil Texture	CL,L	SL,LS	LCS	CS	C,SiC,CL	SC,SiC,SiL	SL,L,SCL	S,LS
Volume of coarse fragments	< 5	5-25	46-70	> 70	< 15	< 35	< 55	< 55
Drainage	Well	Moderately Well	Imperfect	poor, very poor				
Nutrients availability (Topsoil):								
pH	6.0-6.5	5.5-6.0, 6.5-7.0	5.0-5.5, 7.0-8.2	< 5.0, > 8.2	5.0-6.0	6.0-7.0	7.0-8.0	> 8.0
Organic C (g kg^{-1})	> 2.0	1.0-2.0	0.5-1.0	< 0.5	2.0-4.0	1.0-0.2	0.5-1.0	< 0.5, > 5.0
Available P (mg kg^{-1})	> 40	10-40	3-10	< 3	> 40	20-40	10-20	< 10
CEC (cmol kg^{-1})	> 25	13-25	6-12	< 6	> 25	13-25	6-12	< 6
Base Saturation (%)	> 80	40-80	20-40	< 20	> 75	50-75	30-50	< 30

CL = Clay loam, L = loam, SL = sandy loam, LS = loamy sand, LCM= loamy coarse sand, CS = coarse sand
Adopted from FAO (1983)

Table 1: Some physicochemical properties of the soils of lower Oshin River floodplains

Pedon	Horizon	Soil Depth (cm)	Sand	Silt	Clay	Texture	Silt/clay ratio	Bulk Density ($Mg\ m^3$)	pH (H_2O)	Org. C ($g\ kg^{-1}$)	Avail. P ($mg\ kg^{-1}$)	CEC ($cmol_{(+)}\ kg^{-1}$ soil)	(%) BS
			←	($g\ kg^{-1}$ soil)	→								
OSH-1	Ap	0 - 29	500	180	320	Scl	0.56	1.48	5.5	27.5	22	19.14	77.60
	Ctg1	29 - 66	428	211	361	Cl	0.58	1.56	5.7	26.0	5	28.71	74.12
	Ctg2	66 - 172	500	220	280	Scl	0.79	1.50	5.1	22.3	12	25.06	53.57
	R	172+	-	-	-	-	-	-	-	-	-	-	-
OSH-2	Ap	0 - 30	720	90	190	Sl	0.47	1.22	5.9	35.5	40	21.96	63.57
	ACg1	30 - 49	768	51	181	Sl	0.28	1.11	6.3	12.0	17	17.30	53.76
	ACg2	49 - 64	750	80	170	Sl	0.47	1.25	6.4	9.0	12	17.46	54.18
	ACg3	64 - 89	808	41	151	Sl	0.27	1.03	6.4	12.0	12	14.71	42.42
	ACg4	89 - 140	710	110	180	Sl	0.61	1.29	6.7	18.0	7	16.35	51.07
	2C	140 - 152	908	11	81	S	0.14	N.D**	6.6	23.3	5	14.65	45.39
	3C	152 -180	458	221	321	Cl	0.69	N.D	6.9	44.0	7	28.46	71.39
OSH-3	Ap	0 - 42	698	111	191	Sl	0.58	1.13	6.2	28.0	10	21.99	63.62
	Cg1	42 - 65	680	140	180	Sl	0.78	1.05	6.7	22.3	10	17.88	55.26
	Cg2	65 -150	698	121	181	Sl	0.67	1.26	6.1	37.3	5	27.41	70.81

*CEC= cation exchange capacity; (%) BS= percentage base saturation; Avail. P= available phosphorus; Org. C= organic carbon.

The soil reaction was moderate in OSH-1 to slightly acidic in OSH-2 and OSH-3, have surface horizon pH (H_2O) values of 5.5, 5.9 and 6.2 respectively for OSH-1, OSH-2 and OSH-3. The pH values for surface horizon fall within the range of 5.5 6.5 where most essential nutrients are optimally available to plants (Lake, 2000). Organic C content were generally rated high and the values for the topsoil were 15.9 mg kg^{-1} for OSH-1 and OSH-3, and 20.4 mg kg^{-1} for OSH-2. Available P status was rated high for the surface horizons of OSH-1 and OSH-2, and medium for OSH-3. The base saturation was 77.60, 63.57 and 63.62 % for OSH-1, OSH-2 and OSH-3 respectively and rated medium to high. Also, CEC values for the surface horizons of OSH-1, OSH-2 and OSH-3 were 19.14, 21.96 and 21.99 cmol(+) kg^{-1} respectively and was rated high. The soil units were classified as Typic Endoaquepts/ Fluvic Cambisols (Clayic), Aquic Ustifluvents/ Gleyic Fluvisols (Arenic) and Oxyaquic Ustifluvents/ Gleyic Fluvisols (Eutric) (Lawal *et al.*, 2012)

Land suitability classification for maize and paddy-rice

A summary of land qualities/land characteristics of the study site is shown in Table 3 and the assessment ratings resulting from matching of land qualities and the requirements for the test crops are presented in Table 4 using the FAO (1976) suitability ratings (Appendix 1). All the soils have effective soil depth > 100 cm and thus were rated highly suitable (S1) for maize and paddy-rice. On the

Table 2: Critical limits for interpreting fertility levels of Analytical parameters

Parameter	Low	Medium	High
CEC (cmol kg^{-1})	<6	6 - 12	> 12
Org. C (g kg^{-1})	< 10	10 - 15	> 15
Avail. P (mg kg^{-1})	< 10	10 - 20	>20
B.S (%)	<50	50 - 80	> 80

Source: Esu (1991).

Table 3: Land qualities/characteristics of the lower Oshin river floodplains

Parameters	Soil unit		
	OSH-1	**OSH-2**	**OSH-3**
Mean annual rainfall (mm)	1282	1282	1282
Average length of dry season (days)	195	195	195
Temperature °C	33.5	33.5	33.5
Slope (%)	< 3	< 2	< 2
Drainage	Imperfectly drained	Imperfectly drained	Imperfectly drained
Soil depth (cm)	172	140	150
Texture	SCL/CL	SL/SL	SL/SL
Bulk density (Mg m^3)	1.48	1.22	1.13
pH (H_2O)	5.5	5.9	6.2
Available P (mg kg^{-1})	22	40	10
Organic C (g kg^{-1})	27.5	35.5	28.0
CEC (cmol kg^{-1})	19.14	21.96	21.99
% Base saturation	77.60	63.57	63.62

Table 4: Suitability assessment of soils of lower River Oshin floodplain for rain-fed maize and paddy-rice

Soil unit	Soil depth	Soil texture	Topography	Drainage (wetness)	Rainfall	pH	Available P	CEC	Base Saturation	Organic C	Overall suitability class
Paddy rice											
OSH-1	S1	S1	S3	S1	S1	S1	S2	S2	S2	S1	S3t
OSH-2	S1	S2	S1	S1	S1	S1	S1	S2	S2	S1	S2sf
OSH-3	S1	S2	S1	S1	S1	S2	S3	S2	S2	S1	S3f
Maize											
OSH-1	S1	S1	S1	S2	S1	S2	S2	S2	S2	S1	S2w
OSH-2	S1	S2	S1	S2	S1	S2	S2	S2	S2	S1	S2w
OSH-3	S1	S2	S1	S2	S1	S1	S2	S2	S2	S1	S2w

*S1 = highly suitable, S2 = moderately suitable, S3 = marginally suitable.

Limitations (restrictive features): s = soil texture, f = fertility limitation, t = topography, w = wetness/oxygen availability limitation.

CEC = cation exchange capacity.

basis of soil texture, OSH-1 which was sandy clay loam overlaying clay loam was highly suitable (S1) while OSH-2 and OSH-3, both predominantly sandy loam, were moderately suitable (S2) for maize and paddy rice. Both OSH-2 and 3 may require special management practices that will encourage the incorporation of organic residues (Omar, 2011) so as to maintain favourable structure for sustainable maize and paddy-rice cultivation. The slope of < 3 % and below made all the soil units highly suitable (S1) for maize and OSH-2 and OSH-3 moderately suitable (S2) and OSH-1 marginally suitable (S3) for paddy rice. Cultural practices involving raising of bunds (check basin system) in soil units OSH-2 and 3, may enhance their water retention for paddy-rice cultivation. Notwithstanding, slope of < 3 % may favour mechanical operation (Fasina and Adeyanju, 2006). All the soil units were imperfectly drained due to their *aquic* condition which may constitute major limitation (S2) for the growing of maize but highly suitable (S1) for paddy rice. Drainage is required for maize which was known to be non-tolerant to water-logging conditions. Fasina and Adeyanju (2006) reported that constant flooding may constitute the major factor limiting the productive capacity of wetland soils for maize and cassava. Mean annual rainfall for the study area is 1282 mm per annum and usually spread over a period of 190 days with months of May to September usually receiving above 100 mm rainfall per month. Therefore, rainfall was considered suitable (S1) for both crops.

Regarding soil reaction (pH), OSH-1 and OSH-2 were highly suitable (S1) for paddy rice, moderately suitable (S2) for maize, while OSH-3 was highly suitable (S1) for maize and moderately suitable (S2) for paddy rice. OSH-1 and 2 may require application of calcium based fertilizer and organic matter for optimum production of maize. Similar treatment is suggested for OSH-3 for optimum production of paddy-rice. Considering nutrient retention (CEC), all the soil units were moderately suitable (S2) for maize and paddy rice. Furthermore, with regard to available P content, all the soil units were moderately suitable (S2) for maize, but for paddy rice, OSH-2 was highly suitable (S1), OSH-1 moderately suitable (S2) and OSH-3 marginally suitable (S3). In terms of requirement for both test crops, all the soil units were highly suitable (S1) regarding to organic C and moderately suitable in terms of percent base saturation.

CONCLUSION

In terms of nutrient status, all the soil units assessed were rated medium to high and on this basis alone maize and paddy-rice can be cultivated on these soils. However, for optimum performance, maize may require ploughing, harrowing and ridging in addition to field drainage for all the soil units since drainage (soil wetness) was the major limiting factor. In case of paddy-rice, making of checks will enhance water retention especially in OSH-1 where topography was the most limiting factor since rice is a water loving crop. Heavy P-fertilizer application may be needed for sustainable cultivation of rice on OSH-3. The soil texture and by extension fragile soil structures of OSH-2 and 3 will require management practices that will encourage the return of plants/crop residues into these soils. Application of calcium based fertilizer in OSH-1 and OSH-2 may be necessary if they are intended for maize and so do OSH-3 if it is to be used for paddy-rice cultivation.

AKNOWLEDGEMENT

The authors are grateful to the Science and Technology Education Post-Basic (STEP-B) Project, Federal Ministry of Education, for providing fund for the study, out of 2010 Innovators Of Tomorrows (IOT) grant, to the Federal University of Technology, Minna.

REFERENCES

Asomoa, G.K. (1973). Particle-size free iron oxide distribution in some latosols and groundwater laterites of Ghana. *Georderma*. 10:285-297.

Babalola, T.S., T. Oso, A.S. Fasina and K. Godonu (2011). Land evaluation studies of two wetland soils in Nigeria. *International Research Journal of Agricultural Science and Soil Science*, 1(16):193-204.

Brady, N.C. and R. Weil (2002). The Nature and Properties of Soils. 13[th] edition. Singapore, Pearson Education. 976pp.

Esu, I.E. (1991). Detailed Soil Survey of NIHORT Farm at Bunkure, Kano State, Nigeria. Institute for Agricultural Research, Ahmadu Bello University, Zaria.

FAO (1976). A Framework for Land Evaluation. FAO Soil Bulletin 32. Soil Resources Development and Conservation Service Land and Water Development Division Food and Agriculture Organization of the United Nations Rome, Italy. 89pp.

FAO (1983). Guidelines: Land Evaluation for Rain-fed Agriculture. Soil Bulletin No 52, Food and Agriculture Organization, Rome, 237 pp.

FAO (2006). Guidelines for Soil Description. 4[th] edition. Food and Agriculture Organization of the United Nations. 97pp.

Fasina, A.S. and A. Adeyanju (2006). Suitability Classification of Some Granitic Soils of Humid

Southwest Nigeria for Rain-fed Maize, Cassava and Swamp Rice Production. *Nigeria Journal of Soil Science* 16:1-9.

ISRIC/FAO (2002): Procedures for Soil Analysis. Sixth edition L.P. van Reeuwijk.International Soil Reference and Information Centre/Food and Agricultural Organisation.119pp.

Lake, B. (2000). Understanding Soil pH. Leaflet No. 2. Yanco Agricultural Institute, New South Wales. 4 pp.

Landon, J.R. (1991). Booker Tropical Soil Manual. A Handbook for Soil Survey ans Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical Group U.K. Ltd, Essex, England, 474 pp.

Lawal, B.A., A.G. Ojanuga, S.S. Noma, A. Singh, M.K.A. Adeboye and A.J. Odofin (2012). Properties, Classification and Agricultural Potentials of the Soils of Lower Oshin River Floodplains in Kwara State, Nigeria. *Nigerian Journal of Technological Research*, 7: 25-31.

Mishra, A. (2007). Land suitability classification for different crops. An Orissa Review. Retrieved on 14/12/2011.

http://orissa.gov.in/e-magazine/Orissareview/nov-2007/engpdf/Pages65-68.pdf

Ojanuga, A.G. (2006a). Management of Fadama Soils for Food Security and Poverty Alleviation. In: S. Idoga, S.A. Ayuba, A. Ali, O.O. Agbede and S.O. Ojeniyi (eds). Management of Fadama Soils for Environmental Quality, Food Security and Poverty Alleviation in Nigeria. *Proceedings of the 30th Annual Conference of Soils Science Society of Nigeria*.University of Agriculture, Makurdi, Nigeria.Pp10-15.

Ojanuga, A.G. (2006b). Agroecological Zones of Nigeria Manual. FAO/NSPFS, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria. 124pp.

Omar, G. (2011). Assessment of the Fertility Status of some Irrigated Fluvisols in Northern Guinea Savannah of Nigeria. *Savannah Journal of Agriculture*, 6(1):19-31.

Soil Survey Staff (1993). Soil Survey Manual.Soil Conservation Service. United State Department of Agriculture Handbook 18 (Online). Http://soils.usda.govt/technical/manual/contents/index.html