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Properties and sustainable management of the inland wetland soils for efficient rice production in Southern Guinea Savanna zone of Nigeria

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ABSTRACT

A pedological study was carried out on some inland wetland soils of Obukiyo, Oju Local Government Area of Benue State, Nigeria to identify their properties and suggest sustainable management practices for the soils. The grid method of soil survey was employed in the field to investigate the morphological and physicochemical properties of the soils. Four soil units were identified on the field based on soil colour, texture, structure, surface properties, topography and water level. Two pits were sunk in each soil unit, described and sampled for laboratory analysis. The soil units were deep (160cm to 190cm) and somewhat well to very poorly drained. The soils were fine texture and slightly to moderately acid and slightly alkaline in reaction (pH 4.1-7.8). The percentage sand fraction ranged between 35.12% and 79.75%, silt, 0.00% and 36.56% and clay 19.76% and 58.46%. They had low to moderate organic carbon (0.30%-2.25%), total N (0.01%-0.42%) available P (213 mg/kg-6.515mgkg^{-1}), total exchangeable bases (3.61cmolkg– 8.26cmolkg), E.A (0.62cmolkg^{-1} – 3.63cmolkg^{-1}) CEC (3.75cmolkg^{-1}-8.34cmolkg^{-1}), ECEC (5.70cmolkg^{-1}-10.33cmolkg^{-1}) and high base saturation of 53% to 93%. Based on the physicochemical properties, management practices such as; minimal tillage, application of organic and inorganic fertilizers, application of lime to reduce acidity in unit 1 and integrated planting time management with water control were recommended for units II, III and IV.

1.0 Introduction

Properties of soil are the qualities/characteristics which play an important part in the behaviour of soils and what they can be used for (Lal *et al*., 2004). Properties of soils constitute mineral particles, organic matter, water and air. Soil properties include the physical, chemical and biological characteristics of the soil. The physical properties of the soil are those responsible for the transport of air, heat, water and solutes through the soil. Several physical properties such as soil structure, texture, colour, depth, consistency, density, porosity, permeability, infiltration, shrinking-swelling rate, water holding capacity, susceptibility to erosion, soil inclusion (concretions, nodules, stones, minerals, animals activities, ironstones, gravels), horizon and soil temperature can and do change with management. The major physical properties are texture, structure, consistency/strength, colour, permeability and temperature (Pimental, 2005). They affect the amount of water, air and nutrients available for plant growth and development. Good knowledge of soil physical properties helps in the efficient and effective management of soil. The general soil chemical properties often required in most basic soil surveys include organic carbon, total nitrogen, available phosphorous, exchangeable base (Ca, Ma, K and Na), soil pH, cation exchange capacity (CEC), electrical conductivity (EC), exchange acidity (extractable aluminium) and base saturation (BS) (Ufot, 2012). Good knowledge about soil resources and proper management will guarantee sustainable crop production and soil productivity (Idoga and Ogbu, 2012).

Soil management concerns all operations, practices and treatment used to protect soil and enhance its performance.

It includes soil conservation, soil amendment and optimal soil health (Humberto and Ratan, 2010). In agriculture, some amount of soil management is needed both in non-organic and organic types to prevent agricultural land from becoming poor and unproductive over decades. Organic farming, stresses optimal soil management because it uses soil health as the exclusive source of its fertilization and pest control (Eden and Ndon, 2017). The goal of soil management is to protect the soil and enhance its performance so that the farmer can farm profitably and preserve environmental qualities for decades to come (Hail *et al.*, 2006).

There is more concern to wetland management because of the increasing desire to return wetland to a more natural wetting and drying cycle to improve wetland health and hydrophilic plant productivity (Hail *et al.*, 2006).

In the lower portions of a soil landscape, the inland wetland soils are abundant in rural communities adjoining river basins or flood plains. The soils and the land where they occur are often described as marginal, because of waterlogging conditions and the arduous task of developing the wetlands. The soils are potentially productive and of great agricultural value (Ogban and Babalola, 2003, 2009b) because they are relatively more fertile than the surrounding upland soils. Being the lowest member of the toposequence or watershed, water supply is adequate and usually, the soil can be cultivated throughout the year with negligible soil erosion. Several research works have been conducted on properties of soils for rice production (Ogbu *et al*., 2020, Idoga and Azagaku, 2005, Ahukaemere *et al*., 2016, Edem and Ndon, 2017, Idoga, 2005, Ogban, *et al.,* 2012 and Usman *et al*., 2017) but majorities of these research works do not give prime attention to the management of the identified properties. It is against this backdrop that this research work was initiated to serves as baseline data, hence provide information on soil properties and management practices for rice production. Therefore this study is to identify the soil properties and recommend possible management practices of the wetland soils for sustainable rice production.

2.0 Materials and Methods

2.1 Study Area

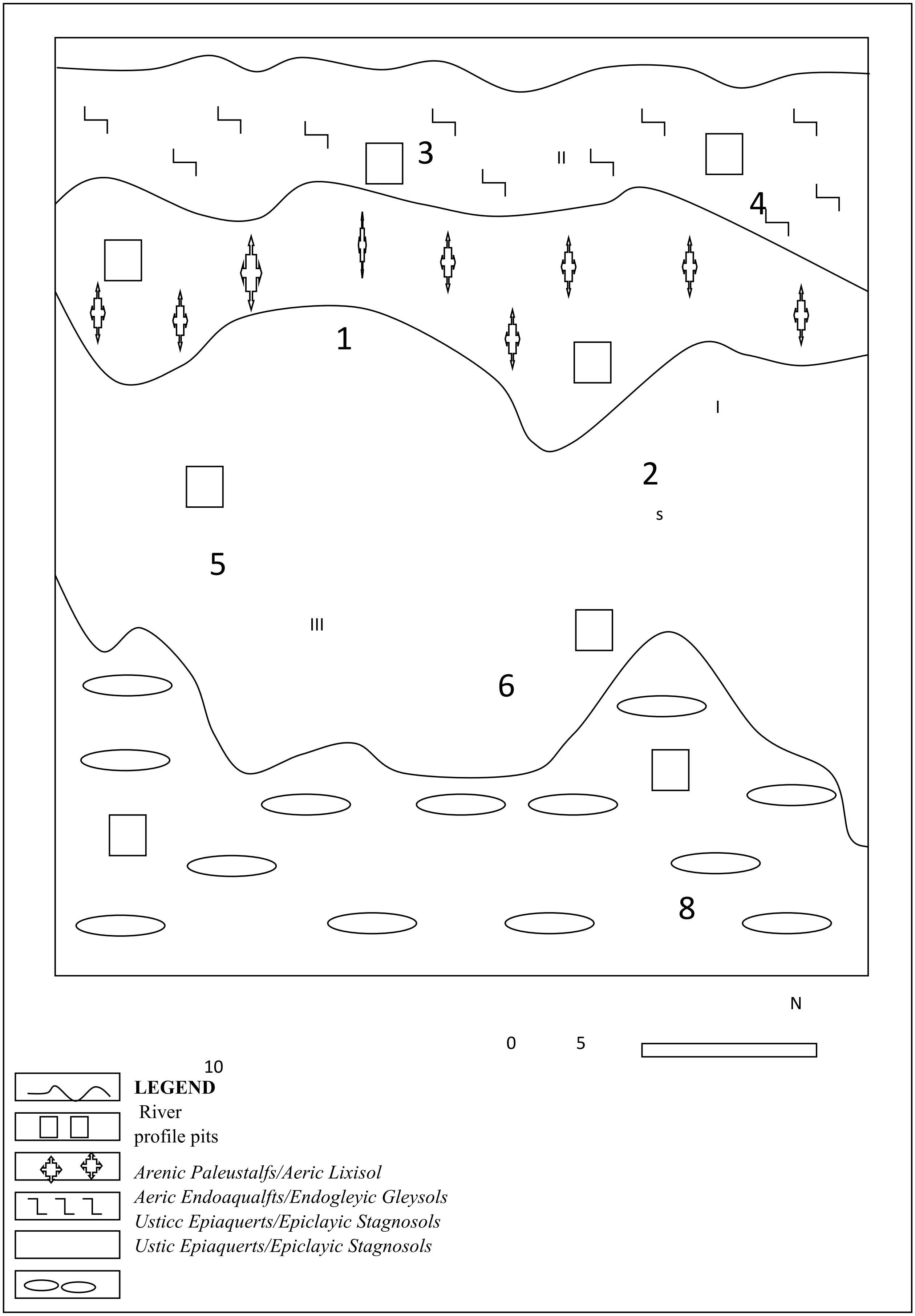
The study area, Obukiyo lies about 2 km South-East of Oju Local Government Headquarters with an average height of about 65m above mean sea level. The area lies between latitude 06.52'N and 06.56'N and longitude 07.37' and 07.45'E. The study site covers about 600 hectares of land. The area falls within the humid tropical climate. The rainy seasons start from April and last till October while the dry season covers the months of November to March. The mean annual rainfall is about 1100mm falling between April and October. The mean monthly maximum temperature is 34^0c. The area was named after the river Obukiyo which rises from Andibilla Plateau. The soils were derived from sedimentary rocks of shale (claystone). The sediment was transported from the upland, Andibilla Plateau by water and deposited on the lowland and gradually weathered into the predominantly clay soil of the area.

2.2 Field and Laboratory Studies

The area was soil surveyed using the grid method. Auger point investigations were carried out at 100m intervals along traverses cut at 100m apart on the baseline. Based on these investigations, four soil units were identified and two profile pits were sunk in each (fig.1). The pits were described according to the guideline for soil profile description (SSS, 2014) and the samples were collected and taken to the laboratory for physicochemical analysis. The air-dried, crushed and sieved (d<2mm) samples were analyzed for particle size distribution, pH, organic carbon, CEC, exchangeable bases (Ca, Mg, K and Na), total nitrogen and available P.

PSD was determined by the Bouyoucos hydrometer method (Day, 1965). Soil pH was determined by electrometric methods as described by IITA (2015). Walkley- black method as described by Nelson and Sommers (1982) was employed for organic matter content. Total nitrogen was determined using the modified macro-Kjeldahl method as described by IITA (2015). Bray No.1 method was used for extractable P. For exchangeable bases, Ca and Mg were determined by AAS while K and Na were done by flame photometer. CEC was determined by IITA (2015) procedures while B.S was calculated by summation method.

The soils were deep ranging in depth from 160 cm to 190 cm. Unit I soils were well-drained with high sand fraction (42.4-74.40 %) at the surface A and AP horizons (Table 1). The high sand fraction is a property of most savannah soils and is mainly due to the nature of the parent materials, constant weathering of rocks and the downward movement of clay through the soil mass (Esu, 2005, Ethan, 2006). It also indicates an Aeolian source as the parent materials of the upper horizons and the possible occurrences of soil erosion that carried away the finer fraction in the surface horizons. The soil of units II, III and IV were poorly drained as indicated by the presence of mottles in the surface horizons and gleyed lower horizons. The poor drainage could be due to the accumulation of surface water as a result of the digressional landscape as well as the high clay fraction of the soils. Soils of unit III and IV had gilgai micro-relief in some places with cracks >2 cm. The soils were well developed, having strong to moderate coarse and medium subangular blocky structures. The good structural development could have been influenced by the high clay content of the soils. The massive lower horizons of some pedons could be due to the weight of the overlying horizons (Idoga and Ogbu, 2012). The soil textures were predominantly sandy clay loam especially at surface A and Ap horizons, while the subsurface horizons were sandy clay and clay in some places. The relatively high clay content (19.76%-58.26%) could be due to the alluvial parent materials as well as the nature of the underlying geology. The relative differences in clay content among the soil units could be due to slight variations in topography. The clay fraction was inconsistent in distribution pattern within profiles 1, 2, 4 and 7 but increased with depth in profiles 3, 5, 6 and 8. Though in all, the clay content was higher in the lower horizons than the upper A and Ap horizons. This is in agreement with the view that clay content generally increases with depth due to some pedogenic processes such as lessivage, eluviation, and illuviation as well as the contribution of the underlying geology through weathering (Idoga, 2002, Ugwu *et al*, 2001). The percentage silt fraction ranged from 0.0% to 36.56% with an inconsistent distribution pattern with depth. This may be attributed to the differences in relief and the rate of deposition of accumulated materials brought down from the upper slope by fluvial processes into the depressional lowland. The silt content was high (15.84% to 36.56%) in profiles 3 and 4. This is contrary to the popular opinion on tropical soils having low silt of less than 15% (Young, 1976). The very low silt content (0.0%-8.54%) of profiles 1, 2, 5, 6, 7 and 8


3
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LEGEND
River
profile pits
Arenic Paleustalfs/Aeric Lixisol
Aeric Endoaqualfts/Endogleyic Gleysols
Usticc Epiaquerts/Epiclayic Stagnosols
Ustic Epiaquerts/Epiclayic Stagnosols

may be due to excessive washing away of the soil particles by water erosion and runoff. The soils had various colours in their surface A and Ap horizons. Soils of profiles 1 and 7 had predominantly dark brown (10 YR 3/3, 10YR 4/3 and 7.5 YR 4/3, moist) colour in their A and Ap horizons. This could be attributed to the presence of relatively high O.M which is the main colouring agent in the topsoil (Ufot, 2012, Brandy and Weil, 2014).

2.3 Soil Chemical properties

The soils of the area were rated as strongly acidic to slightly alkaline in reaction with pH values ranging from 4.1 to 7.8 in H_2O (Table 2). It was lowest (4.1) in the surface horizon of profile 4 and highest (7.8) in the surface horizon of profile 6. It was inconsistently distributed down the profiles. Profiles 1, 2 and 6 had high pH values on the surface than the subsoil as a result of nutrient bicycling and high percentage base saturation at the surface horizon (Idoga and Azagaku, 2005). This could also be accounted for by the direct deposition of crop and vegetable residues on the soil surface and their subsequent decomposition to release basic cations to the soil. Idoga and Ogbu, 2012 attribute the reduction in soil pH with depth to frequent crop harvesting and leaching of bases. The percentage of organic carbon of the soil was low to moderately high for savannah soils and the values ranged from 0.30% to 2.25%. The high value may be attributed to the incorporation of plant and animals residues into the soil. The low soil temperature resulting from poor drainage could also encourage O.M accumulation among the poorly drained soils of Obukiyo. The low amount of O.C of profiles 1,2,5 and 8 is probably due to continuous cropping, bush burning, high erosive rate, grazing, harvested crop residues without replacement and very poor management activities. TN ranged between 0.01% and 0.42%. The high amount of O.C and TN in some subsoil is an indication of the young or immature nature of the soil profile due to the seasonal deposit of materials. The low level of N in the soils may be attributed to release from plant tissues, gaseous loss, surface runoff, leaching, climatic factors, vegetation, human activities, initial soil pH and low activities of symbiotic and non-symbiotic N-fixing bacterias. Loss of N through denitrification and volatilization may also contribute to the low level of N in the area. Available P values were very low with values ranging from 1.213Mg/Kg to 6.515Mg/Kg. This may be attributed to the low pH level which fixed the P and makes it unavailable. It may also be attributed to the low amount of O.C, continue cropping, crop removal, erosion of P-carrying particles, P dissolved in surface runoff and leaching due to the coarse nature of the soils. The exchangeable bases were low as a result of the nature of the underlying parent materials, the intensity of weathering, leaching, low activity clay, low O.M, erosion and lateral translocation of bases. Ca was the most dominant cation with values ranging between $1.38cmolKg^{-1}$ and $4.94cmolKg^{-1}$ in the exchange complex. It may be linked to the occurrence of exchange sites that have a specific affinity to Ca or maybe because Ca is least easily lost from the exchange site or has high displacement ability over other in cation exchange reactions. The Mg values ranged between $0.82cmolKg^{-1}$ and $2.64cmolKg^{-1}$ while that of K and Na ranged from $0.35cmolKg^{-1}$ to $1.86cmolKg^{-1}$ and $0.29cmolKg^{-1}$ and $0.98cmolKg^{-1}$ respectively. These values confirmed the predominance of Ca follow by Mg over K and Na as observed by Idoga, 1985, and Ogunkunle, 1989. The CEC of the soils were low to medium with values ranging between $3.75cmolKg^{-1}$ and $8.34cmolKg^{-1}$. The low CEC values indicated that the soils had a low potential for retaining plant nutrients. It may also be attributed to the nature of clay minerals (kaolinite) and the low O.C level of the soils. The B.S values (53% to 98%) were moderately high to very high. The high B.S is probably associated with the presence of weathered minerals which release nutrients into the soil and their alluvial nature. A general correlation exists between the B.S and its pH. As the B.S is reduced owing to the loss in drainage of Ca and other metallic constituents, the pH also is lowered in a more or less definite proportion (Table 2).

2.4 Sustainable Management of the Inland Wetland

A living soil is a fertile soil whose productivity should be sustained. The study reviewed that the soils were coarse to moderate in structure, sandy clay loamy surface texture, poorly drained exception of unit 1 which had low fertility status as a result of their low N, P organic carbon CEC and exchangeable bases. They had a favourable pH range (4.1-7.8) for rice production.

Chemical clearing but not clean clearing of the soil to prevent long exposure of the soil to direct sunlight which will reduce the loss of volatile N and other nutrient elements from the soil surface, more so that the soils were low in fertility status is very important.

The area also had variable terrain characteristics. The landform is undulating with slope, often varying from 1-2 % hence the negative impact of wrong tillage practices and intensive rainfall will result in loss of surface soils and soil nutrients. Minimum tillage has proven effective in curtailing soils nutrient loss. The farming system is rainfed and the erratic rainfall due to climatic variability must be addressed to increase the agronomic efficiency of inputs for increased crop yield by local farmers. The soils also had variable surface texture and were moderate to slightly acidic. Management practice that reduces soil acidity such as the introduction of derivates from limestone and organic residues to increase the yield of rice significantly should be encouraged. Moreover, heterogeneity of the soil is such that with a hectare of soils two to three soil units may encounter drainage and environmental or climatic problems that may need different management practices for sustainable use. The physical, chemical, biological and morphological properties of unit 1 were quite different from that of units III and IV of the same area. Also, soils of unit II with endo-saturation and high water level required different management practice from unit III and IV with api-saturation, though all were poorly drained with exception of unit 1 that is highly sandy and well-drained. In this situation, integrated time management coupled with water level control and fertilizer application should be considered in unit II soils. Planting should be done in June/July to allow fertilizer application during the short rainfall break in July ending and early August when the water force will be low and the channels can be controlled. April/May or May/June early planting in this unit is dangerous as most of the rice like FARO 44, an early maturing variety will mature within the peak of raining season (August/September) and get submerged in water. Also, FARO 37 with high lodging ability should be avoided in this unit. Units I, III and IV can be cultivated around May/June as the water channels can be controlled for fertilizer application, weeding and harvesting. Climatic change /variation deceived most farmers into early or late farming as the case may be. When the rain commences early, some farmers cultivated so early or too late when the revise hold, making the crops face drought or flood problems. Apart from the issue of draught rice sub-

Table 1 Morphological description of the soils of Obukiyo area of Oju local government area

Horizon	Depth (cm)	Munsel Colour (Moist)	Mottling	Mottling deails	Texture	Structure	Con-sistence	Inclusion	Boundary
		Unit I Pedon 1: Arenic Paleustalfs/Aeric Lixisols							
A	0-40	7.5YR4/3	-		Sandy clay loam	3MSBK	SSW	Few Medium Roots	cs
B	40-60	7.5YR6/4	-		Sandy loam	2MSBK	SSW	Few Fine Roots	ds
BC	60-110	5YR6/6	-		Sandy loam	2MSBK	SSW	Few Fine Roots	ds
C	110-120	5YR7/6	-		Sandy clay loam	2MSBK	SSW	Few Fine Roots/ hard coherent rock at 170cm	-
		Unit I Pedon 2: Arenic Paleustalfs/Aeric Lixisols							
Ap	0-28	10YR5/3	-		Sandy clay loam	3CSBK	SSW	Medium Common Roots	ds
A	28-76	10YR4/2	-		Sandy clay loam	3CSBK	SSW	Few fine roots	cs
AB	76-105	10YR4/6	-		Sandy loam	2MSBK	SSW	Few fine roots	gs
B	105-115	7.5YR6/4			Sandy Clay loam	2MSBK	SSW	Few fine roots	ds
Bt_1	115-180	5YR 5/4			Sandy Clay loan	2MSBK	VSW	Few Fine roots/ hard coherent rock at 180cm	-
		Unit II Pedon 3: Aeric Endoaqualfs/Endogleyic Gleysols							
Ap	0-20	10YR5/6	2.5YR5/6 F3P		sandy clay loam	3CCr	SSW	Many coarse roots	cs
Bt_1	20-80	2.5YR5/2	10R5/6 M2P		Clay loam	2MSBK	VSW	Many coarse roots	ds
Bt_2	80-110	2.5YR4/3	10YR7/6 F2D		Clay loam	2MSBK	VSW	Common medium roots	ds
Bt_3	110-180	2.5YR5/4	10YR5/2 F2D		Clay loam	2MSBK	VSW	Few medium roots	-
		Unit II Pedon 4: Aeric Endoaqualfs/Endogleyic Gleysols							
Ap	0-24	10YR8/6	10YR3/2 C2D		Clay loam	3CCr	VSW	Many coarse roots	ds
Bt_1	24-86	5YR5/3	10YR3/3 F2P		Sandy clay loam	2MSBK	VSW	Few fine roots	ds
Bt_2	86-118	2.5Y4/3	5YR4/3 M2P		Clay loam	2MSBK	VSW	Few fine roots	ds
Bt_3	118-190	2.5Y5/6	5YR7/1 M3P		Sandy clay loam	2MSBK	VSW	Few fine roots	-
		Unit III Pedon 5: Ustic Epiaquerts/Epiclayic Stagnosols							
Ap	0-30	10YR5/6	10YR5/2	FIF	Sandy clay	3CSBK	SSW	Many medium roots	cs
AB	30-60	10YR5/8	10YR5/2 E2D		Sandy clay	3MSBK	VSW	Common fine roots	cs
B	60-75	10YR6/4	2.5Y7/6 C2P		Sandy clay	2MSBK	VSW	Few fine roots	ds
Bt_1	75-115	7.5YR5/4	5YR5/3 C2D		Sandy clay	2MSBK	VSW	Few fine roots	ds
Bt_2	115-150	7.5YR7/4	5YR7/1 C2P		Sandy clay	2MSBK	VSW	Few fine roots	ds
Btn	150-180	7.5YR5/6	2.5Y7/2 C2D		Sandy clay	2MSBK	VSW	-	-
		Unit III Pedon 6: Ustic Epiaquerts/Epiclayic Stagnosols							
Ap	0-20	10YR5/4	10YR6/8 C2P		Sandy clay	3CSBK	SSW	Many fine ro	cs
B	20-50	2.5Y4/4	7.5YR6/3 F1D		Clay	3MSBK	VSW	Common fine roots	ds
Bt_1	50-100	2.5Y5/6	5YR5/4 C2D		Clay	2MSBK	VSW	Few fine roots	ds
Bt_2	100-160	2.5Y5/4	7.5YR7/1 M3P		Clay	2MSBK	VSW	Few fine roots	ds
Btn	160-180	2.5Y6/0	10YR4/2 M3P		Clay	2MSBK	VSW	Few medium con-cretions	-
		Unit IV Pedon 7: Ustic Epiaquerts/Epiclayic Stagnosols							
Ap	0-34	10YR3/3	10YR5/6 F1D		Sandy clay	3CSBK	SW	Many coarse roots	cs
B	34-74	10YR4/3	10YR6/6 F1D		Sandy clay	3CSBK	VSW	Many coarse roots	ds
Bt_1	74-98	7.5YR5/4	10YR5/4 F2D		Sandy clay	2MSBK	VSW	Few coarse roots	ds
Bt_2	98-133	5YR6/3	10YR4/2 M2P		Sandy clay	2MSBK	SPW	Few fine roots	ds
Bt_3	133-180	2.5Y5/2	5YR4/2 M3P		Sandy clay	2MSBK	SPW	Few fine roots	-
		Unit IV Pedon 8: : Ustic Epiaquerts/Epiclayic Stagnosols							
Ap	0-56	10YR3/4	5YR3/2 F1D		Sandy clay	3CCr	VSW	Many medium roots	cs
Bt_1	56-96	10YR4/4	2.5YR6/2 F1D		Sandy clay	3CSBK	VSW	Common medium roots	cs
Bt_2	96-126	7.5YR5/0	5YR5/2 C2P		Sandy clay	3CSBK	SPW	Few fine roots	ds
Bt_3	126-160	5YR4/8	5YR5/2 C2D		Sandy clay	2MSBK	PW	Few fine roots	-

Mottling Details:
F1F=Few fine faint, C2D=Few Common medium distinct, M3P=Many coarse prominent, C3P=Common coarse prominent
Texture
S= Sandy, C= Clay, SL= Sandy loam, SCL= Sandy clay loam, SC= Sandy clay

Structure
3CCr = Strong coarse crumbs, 2CCr = Moderate coarse crumb, 2MCr = Moderate medium crumb, 2MSBK = Moderate medium subangular blocky, 2MFBK = Moderate fine subangular blocky, 3CSBK = Strong coarse subangular blocky, 3MSBK = Strong medium subangular blocky
Consistence
SSW = Slightly sticky wet, VSW = Very sticky wet, VPW = Very sticky wet, SW = Sticky wet, nSW = Non-sticky wet, Npw = Non-plastic wet
Inclusion
C2F= Common medium faint, M2d= Many medium distinct, F1f= Few fine faint, C3d= Common coarse distinct
Boundary
ds = diffuse smooth, gs = gradual smooth, cs = clear smooth, as = abrupt smooth

Table 2: Physical and chemical properties of inland wetland soils of obukiyo of Oju local government area

Horizon	**Depth (cm)**	**Particle size dist.**			**Texture**	**pH H2O**	**Org. C**	**Total N**	**Avail. P**	**Exchangeable Bases**				**TEB**	**EA**	**CEC**	**BS**
		Sand (%)	Silt	Clay			(%)		Mg/kg	Ca	Mg	K	Na	Cmol kg^{-1}			(%)
Unit I Pedon 1: Arenic Paleustalfs/Aeric Lixisols																	
A	0-40	70.40	7.84	21.76	SCL	7.2	1.30	0.05	3.36	1.97	1.66	0.98	0.64	5.25	0.76	5.36	87
B	40-60	72.40	7.84	19.76	SL	6.8	0.30	0.06	1.62	2.68	2.38	0.64	0.48	6.80	1.10	6.29	85
BC	60-110	79.76	0.00	20.24	SL	6.8	0.60	0.05	3.52	3.70	2.62	0.72	0.48	7.52	2.07	7.53	78
C	110-120	71.12	5.54	23.04	SCL	6.0	0.71	0.06	3.56	3.73	1.08	0.54	0.37	5.72	2.02	5.72	74
Unit I Pedon 2: Arenic Paleustalfs/Aeric Lixisols																	
Ap	0-28	74.40	4.56	2I.04	SCL	6.1	1.19	0.05	3.27	1.69	1.38	0.82	0.79	4.68	1.02	4.78	82
A	28-76	70.40	6.84	22.76	SCL	6.5	0.32	0.06	1.56	2.47	1.86	0.54	0.46	5.33	1.07	5.35	83
AB	76-105	72.40	8.54	19.06	SL	5.6	1.54	0.05	2.46	3.93	2.41	0.54	0.48	7.36	2.16	7.47	77
B	105-115	69.12	4.84	26.04	SCL	5.7	1.30	0.08	4.67	2.01	1.76	0.64	0.93	5.34	2.18	5.35	71
Bt_1	115-180	62.40	5.56	32.04	SCL	5.6	0.40	0.42	4.47	1.38	2.43	0.35	0.29	4.45	2.62	4.58	63
Unit II Pedon 3: Aeric Endoaqualfs/Endogleyic Gleysols																	
Ap	0-20	50.40	28.56	21.04	SCL	4.8	2.00	0.05	3.41	2.05	2.03	0.84	0.44	5.35	3.05	5.38	64
Bt_1	20-80	43.12	27.84	29.04	CL	4.4	1.52	0.05	3.13	1.93	1.75	0.72	0.54	4.94	3.61	4.98	58
Bt_2	80-110	43.12	27.84	29.04	CL	5.6	1.50	0.04	1.45	2.07	2.04	0.75	0.54	5.60	0.76	5.73	88
Bt_3	110-180	42.42	24.54	33.04	CL	5.1	1.26	0.04	2.77	2.13	1.84	0.69	0.43	5.09	0.68	5.12	88
Unit II Pedon 4: Aeric Endoaqualf/Endogleyic Gleyols																	
Ap	0-24	42.40	24.56	33.04	CL	4.1	2.00	0.05	2.10	2.60	2.34	0.82	0.53	6.29	3.62	6.34	63
Bt_1	24-86	48.40	20.56	31.04	SCL	4.6	1.42	0.05	1.93	1.98	0.96	0.76	0.58	4.28	3.68	4.39	54
Bt_2	86-118	40.40	24.56	35.04	CL	5.0	2.13	0.06	3.73	3.36	2.73	0.52	0.64	7.25	0.77	7.34	90
Bt_3	118-190	74.40	0.56	25.04	SCL	5.0	0.40	0.08	2.84	2.69	2.48	0.73	0.64	6.54	0.68	6.72	91
Unit III Pedon 5: Ustic Epiaquerts/Epiclayic Stagnosols																	
Ap	0-30	58.40	3.54	38.06	SC	5.7	1.38	0.06	1.42	1.99	0.84	0.76	0.58	4.17	3.63	4.37	53
AB	30-60	60.24	0.44	39.32	SC	7.5	0.88	0.11	1.52	1.98	1.42	0.82	0.58	4.80	2.62	4.85	65
B	60-75	53.04	6.36	40.60	SC	6.7	0.74	0.05	1.44	1.98	2.64	1.03	0.94	7.59	0.71	7.68	91
Bt_1	75-115	51.68	7.20	41.12	SC	7.0	0.97	0.06	1.26	2.99	2.32	0.94	0.82	7.07	2.24	7.07	76
Bt_2	115-150	56.40	1.50	42.10	SC	6.0	1.97	0.06	1.21	1.82	0.98	0.73	0.64	4.17	2.02	4.28	67
Btn	150-180	55.68	0.78	43.54	SC	6.3	1.56	0.04	1.26	3.38	2.41	0.84	0.58	7.21	0.76	7.22	90
Unit III Pedon 6: Ustic Epiaquerts/Epiclayic Stagnosols																	
Ap	0-20	56.40	2.62	40.98	SC	7.8	1.74	0.09	1.41	2.68	2.55	1.86	0.98	8.07	0.62	8.19	93
B	20-50	43.12	2.59	54.29	C	5.4	0.86	0.07	1.82	4.94	1.83	0.87	0.62	8.26	1.77	8.28	82
Bt_1	50-100	42.12	3.22	54.66	C	6.0	0.74	0.07	1.33	3.93	2.34	1.04	0.94	8.25	2.08	8.34	80
Bt_2	100-160	40.40	2.89	56.71	C	5.6	1.26	0.14	2.19	3.24	2.38	0.82	0.62	7.06	2.04	7.16	78
Btn	160-180	39.12	2.62	58.26	C	7.7	0.78	0.01	1.50	2.98	1.87	0.98	0.96	6.52	0.63	6.58	91
Unit IV Pedon 7: Ustic Epiaquerts/Epiclayic Stagnosols																	
Ap	0-34	58.40	2.60	39.00	SC	5.4	2.25	0.05	3.36	1.82	1.34	0.86	0.77	4.79	1.82	4.89	72
B	34-74	59.68	0.32	40.00	SC	6.5	1.02	0.05	1.57	2.94	1.86	0.93	0.56	6.29	1.74	6.29	78
Bt_1	74-98	61.12	1.65	37.23	SC	6.2	0.36	0.04	2.14	3.67	2.48	0.89	0.03	7.97	0.75	7.98	91
Bt_2	98-133	59.70	1.14	39.70	SC	5.8	1.59	0.06	6.51	2.47	1.65	0.42	0.84	5.38	2.11	5.49	72
Bt_3	133-180	35.12	7.45	39.43	SC	5.7	1.73	0.06	1.97	1.64	1.34	0.64	0.53	4.15	2.19	4.26	65
Unit IV Pedon 8: Ustic Epiaquerts/Epiclayic Stagnosols																	
Ap	0-56	57.40	2.40	40.20	SC	5.5	1.45	0.07	2.33	2.34	1.86	0.95	0.82	5.97	2.18	5.98	73
Bt_1	56-96	53.12	2.34	44.59	SC	4.9	1.45	0.06	1.66	2.78	2.02	0.41	0.36	5.55	3.02	5.67	65
Bt_2	96-126	53.40	0.61	45.99	SC	6.1	0.48	0.04	1.94	3.37	2.62	0.82	0.72	7.53	0.76	7.33	91
Bt_3	126-160	52.12	2.62	45.26	SC	5.8	0.46	0.06	2.48	3.43	2.14	1.58	0.42	7.57	2.22	7.69	77

mergence during rain-break or heavy flood, integrated time and water management is also very important for pest and diseases control. Finch birds and rodents attacked and destroy the early yielded varieties and reduced their yields.

Intensively managed soils based on soil testing are necessary to cope with the heterogeneity of soils for sustainable crop production (Soil Survey Report, 2012). Hence soil sampling and management practice should be done in the context of the complexity of soil variability.

The low organic matter has to be substantially increased through effective crop residue management with increased use of leguminous plants as well as judicious use of organic fertilizers. Application of chemical fertilizer will ameliorate exchangeable base limitation but the use of ammonium sulphate fertilizer should be avoided to prevent erosion, leaching and increase in the level of acidity of the soils. Most especially in unit II that is slightly acid in reaction (pH of 4.85-5.13).

Post-harvest incorporation of plant residue into the soil instead of the usual burning of crop residue to stimulate the emergence of a new flush for grazing will stabilize the soil aggregate. The FrameWork for Evaluating Sustainable Land Management (FESLM) as proposed by Smyth and Dumanski (1993) can be adopted in the sustainable management of these inland wetland soils.

Most Obukiyo rice farmers did not believe in irrigation, weeding and fertilizer application on the wetland but the unit I rice farmers requires irrigation if the natural drought period of August rainfall break is long. Rice requires water throughout the growing period. Also, fertilizer application is needed to improve the soil fertility status as they were very low. Though N content may be increased during flooding, through N-fixations by blue-green algae, rainfed N, human and domestic animal urea and possible movement of N from the fallow area but not enough for the plant growth and development as most of it got lost through harvesting and burning, NH_4 volatilization, drainage into rivers by flowing water, denitrification and leaching of $N0_3$ beyond rice use.

3.0 Summary and conclusion

Soils vary considerably in chemical, physical and morphological properties and these influence their agricultural potentials. The knowledge of soil properties is very important in management of the soil. The physico-chemical, biological and morphological features of the soils reviewed that, they had argillic horizons deep, well drained to poorly drained, slightly to moderately acid, slightly alkaline, high sand fraction (unit I) and clay fractions (units II, III and IV), low to moderate organic carbon, TN, available p, exchangeable bases, EA, ECEC and high BS. The sedimentary soils were observed to be low in fertility and more variable in soil properties. Hence appropriate management practices such as organic and inorganic fertilizer application, liming, erosion control, weeding, avoidance of bush burning and heavy cattle grazing and integrated time management with water level control were recommended.

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