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SOILS AND URBAN LAND USE PLANNING: A CASE STUDY OF MAKURDI URBAN CENTRE, BENUE STATE OF NIGERIA

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ABSTRACT

Frequent cases of human displacement, loss of properties and sometimes lives caused by seasonal floods in Makurdi Urban Centre in recent times necessitated a pedological investigation on the soils of the town. Six soil profile pits were sunk in selected areas of Makurdi, two in the high lying area of Makurdi North Bank and four others in the low lying areas of the South Bank settlement. The investigation revealed that the soils of North Bank were well drained with sandy loam surface texture underlain by sandy clay loam subsurface, while those of the low lying South Bank were poorly to very poorly drained with predominantly Sandy Clay Loam surface textures underlain with clay loam to clay subsurfaces. The bulk density values of the well-drained soils were higher (1.50gmcm^{-3}) than those of the poorly drained soils (1.38gmcm^{-3}) at their subsurface horizons. The very poor drainage of the South Bank signifies that water table remains above soil surface for some periods of most years. The chemical properties of the soils revealed that the low-lying soils of Makurdi South Bank were rich in plant nutrients, having high organic carbon (2.2 – 2.58%), total nitrogen (0.28 – 0.31%), available phosphorus (9.00 – 12.8mgkg^{-1}), exchangeable bases (6.06 – 8.89cmolkg^{-1}), cation exchange capacity (7.06 – 10.15cmolkg^{-1}), base saturation (75-94%) and pH (6.48 – 6.85). The well drained upland soils of North Bank classified as Typic Paleustalfs/Eutric Luvisols while those of South Bank classified as Typic Endoqualfs, Arenic Endoqualfs/Gleyic Luvisols and Arenic Endoaquent//Eutric Gleysol. The high fertility status coupled with the aquic soil moisture regime qualify the low-lying soils as unique agricultural soils, capable of supporting both rainfed and dry season croppings. These soils are recommended for urban agriculture, especially dry season vegetable farming and aquaculture. The application of these soils for residential and industrial uses with yearly tales of woes should be discouraged.

Key words: Soils, urban Land use planning.

INTRODUCTION

Land is an important economic factor of production. It is the basic resource for human needs of food, shelter and clothing (Brady, 1990). The increasing sophistication of man's life has added to these basic needs of man, an insatiable list of wants including recreation, tourism and transportation to mention but a few. Unfortunately however, land is fixed: it is limited in extent and so cannot meet the increasing demand for it. The ever increasing population has further worsened the demand and supply crisis in land leading to very unhealthy competition.

Unhealthy competition for land is most noticeable with urbanization. In Nigeria rural areas, agriculture and simple shelter are the major uses of land. In the urban areas, sophisticated residential buildings, commercial centres, recreational centres (stadia, public squares, hotels), transportation (roads, motor parks, airports) and to a lesser extent agriculture in the urban fringes are the major uses of land. Until 1976 when Benue state was created, its capital, Makurdi consisted of isolated settlements on isolated elevated lands in the predominantly low lying area, South of River Benue Bank. The settlements are Wadata and High Level (name coined from height of elevation). The surrounding low lying areas were left to either rice or sugarcane production or as natural drains (Idoga, 2006). Since the creation of Benue State in 1976, there has been tremendous influx of people of diverse interest into Makurdi with consequent high demand for land for residential and commercial purposes as well as industrial and recreational facilities. This process gave birth to new settlements such as Nyima layout, Wurukum Extension, Logo, Modern Market, Welfare quarters, industrial layout and many others, most of which are in low land landscape.

These extended settlement areas have been facing the challenges of seasonal floods with associated collapse of buildings, destruction of properties and sometime loss of lives. To revert this ugly trend calls for rational approach to land use. Unfortunately land use planning and land use policy are seriously lacking in Nigeria (Ojanuga, 2004), not to mention urban land use planning. The situation in Makurdi is worsened by the lack of soil information. Soil is an integral part of land which tends to have an over bearing influence on the potentials of land. The objective of this work was to characterize and classify the soils of the flood prone areas of Makurdi South Bank visa vis the elevated area of North Bank for land use recommendations that would bring about sustainable environment.

MATERIALS AND METHODS

The fast growing town of Makurdi is located between latitudes 7°40´ and 7°50´ N and longitudes 8°25´ and 8°40´ E. The town is dissected by River Benue into two major settlements – the North and South Bank settlements referring to the northern and southern banks of the river. The North Bank settlement is generally a well-drained elevated land rising up to about 30m above mean sea level while the South Bank settlement is mainly low lying with an elevation of about 18m above mean sea level, except for few isolated elevated areas like High Level and Wadata. The dominant slope gradient of the North Bank area towards River Benue is about 3–5% (gently sloping) while that of the south bank is about 0–2%(nearly level). The mean annual rainfall for Makurdi varies between 1100mm and 1300mm falling between April and October. The rainfall distribution pattern has been uni-modal in recent years with the single peak in August (Idoga, 2005).

Six soil profile pits , two in the elevated North Bank area and four in the low-lying area of South Bank were sited. The profile pits were distributed according to identified soil problems or lack of them in the study area. The two pits in the North Bank were on nearly level topography (0–2%) and on gently sloping topography (3–5%) each representing areas of slight to moderate erosion problems. In the South Bank settlement, the areas selected included Industrial Layout, Modern Market Area, Zone 4 Police Headquarters area,and welfare quarters representing areas of deep floods and cracking soils. The pits were dug to required soil depth (200cm) except where limitations of hard pan or ground water table were encountered. The profile pits were described according to the guidelines of Soil Survey Staff (1998). Soil samples (including core samples) were collected from identified horizons for laboratory analysis. The soils were analyzed for particle size distribution and bulk density using the Bouyocous hydrometer method as described by Gee and Bander (1986) and by the core sample method using a metal sampler as described by Blake and Hartge (1986) respectively. The routine methods of soil analysis as described by IITA (1979) were employed for the determination of soil pH, organic Carbon, Total N, available P, CEC and exchangeable bases. Base Saturation was calculated using the sum of bases and CEC.

RESULTS AND DISCUSSION

Table 1 shows the morphological description of the soils of Makurdi urban centre. The dominant subsurface colour hue of the North Bank area (profiles 1 and 2) was 5YR which is indicative of good drainage. This implies that the soils are not prone to flooding as rain water is drained out as quickly as it falls. Profile 1 is located on nearly level topography with little or no evidence of soil erosion while profile 2 was on a moderately sloping land with moderate sheet and rill erosion. These soils could be said to be moderately suitable for urban development as they impose constraints of moderate erosion risks. Soil erosion is evident in the North Bank settlement particularly in the moderately sloping area as the foundations of most houses are exposed.

Among the lowlying soils of South Bank area, the dominant sub-surface soil colour hues were 2.5Y and 5Y which are indicators of poor drainage resulting from floods or high water table or both due to the low lying positions of the soils. The standing water at the depth of 100-120cm of soil surface (profiles 3,5 and 6) could be indicative of the presence of impervious layers which might be responsible for the endosaturation and the gray colouration. Such soils are highly prone to flash floods. The situation has been worsened in recent years by the unimodal rainfall pattern in Makurdi with August being the single peak. The resultant effect is the yearly displacement of many families in Wurukum, Logo, Modern Market Area, and Zone 4 Police Headquarters between the months of July and September. The high surface and ground water weakens the foundation of houses over the years leading to their eventual collapse. This may explain why areas liable to flash floods are not recommended for any form of buildings (Jassen, 1987). In the Industrial Layout, flash floods have been reported to have silted up some factories to the extent that the state government spent about 25 million naira in clearing the sediments in 2003 (Idoga and Ejembi 2005). The low land position and the very poor drainage conditions of the soils are also responsible for the frequent evacuation of sewage tanks. This is not only expensive, but also hazardous to health as sewage disposal vehicles are not readily available. In addition to the physical damage of buildings, flash floods are also associated with certain diseases. Available medical records from Federal Medical Centre Makurdi indicate that malaria, typhoid, schistosomiasis and trypanosomiasis are common diseases of these depressional areas, because they serve as breeding sites for their vectors.

The soils of the Modern market area exhibited cracks that were less than 2cm wide and 50cm deep (table 1) which is an indication that they have vertic properties (shrinking and swelling). These soil properties are known to be associated with vertical cracks in buildings. Such cracks are common features in most houses in the area, to the extent that some of the houses are rendered inhabitable because of the fear of imminent collapse. This singular property of the soil is responsible for the high cost of buildings in this area as special foundations and all round lintels are required. In Welfare Quarters area, the soil depth is limited by ground water table (95cm). This is not a good soil condition for housing development as the fluctuating water table weakens the foundations of houses. This is evident in the peeling off of paint coats close to the ground level.

The physical and chemical properties of the soils are presented in table 2. The soil bulk density values show an increasing trend with depth in all the profiles. The low-lying soils of South Bank have lower soil bulk density values (1.15gmcm^{-3}) particularly in the thick A horizons than the well-drained soils of North Bank (1.25 gmcm^{-3}). The reason for this difference could be due to the higher organic matter content of lowland soils. Again, the increase in bulk density values with depth is more pronounced in the well-drained North Bank soils. The lower values of the lower horizons of the lowland soils could be due to the influence of ground water (Foth, 1972). Load bearing capacity of a soil is influenced by the soil bulk density. The higher the soil bulk density values, the higher the load bearing capacity. The implications of these differences are that the well-drained soils have higher ability to support foundations of houses. For the depressional soils, deep and solid foundtions are a must to avoid sinking. The deeper the foundation, the higher the cost.

The chemical characteristics of the soils indicate that the carbon content indicate that the depressional soils have higher organic carbon content (2.28%), nitrogen (0.3%) and phosphorus (12.8%); higher pH (6.8) and higher base saturation (>80%) than the well-drained soils of North Bank. The high fertility status of these soils coupled with aquic soil moisture regime qualify them as unique agricultural soils capable of supporting both rainy and dry seasons' croppings, and therefore should better be utilized as such rather than residential and industrial uses with yearly tales of woes.

Soil Classification

All the profiles studied, with the exception of profile 6, had argillic horizons and high base saturation. They were therefore classified as Alfisols. Profile 6 qualified as Entisol because of limited soil profile development. Profiles 3 – 6 had aquic soil moisture regime and therefore were classified as Aqualfs (3-5) and Aquent (6). Profiles 1 and 2 were qualified as Ustalfs because of the ustic soil moisture regime, and Typic Paleustalfs due to their clay distribution patterns. The FAO/UNESCO soil legend equivalent is Eutric Luvisol. Profile 3 qualified as Arenic Endoaqualf because of endo-saturation and the high sand fraction of the upper horizon, while profiles 4 and 5 were classified as Typic Endoaqualfs. The FAO/UNESCO equivalent of these profiles are Gleyic Luvisols. Profile 6 was classified as Arenic Endoaquent/Eutric Gleysol.

Recommended Land Uses

Land use recommendations are based on the principle of land matching which involves comparison of soil characteristics with the intended land use requirements. The soils of the South Bank area have characteristics that are more amenable to agriculture and nature conservation / natural drains than to urban development. This is because of their higher fertility status (organic C, total N, available P, pH, and base saturation). In addition these soils have aquic soil moisture regime which makes them unique agricultural soils as they can support both wet and dry season farming. On the basis of their characteristics, most low-lying soils of South Bank Area are not appropriately utilized as at now with the resultant environmental issues of flood and diseases. The recommended agricultural uses or nature conservation is based on existing ecological conditions and the low level of technology of the people. Again, this recommendation will fit into the increasingly popular "Urban Agriculture", supplying fresh vegetables and other nutritious food to urban dwellers where poor roads and weak supply chains make it difficult to transport highly perishable produce from rural areas (Spore, 2012). Urban agriculture in this case is not limited to keeping few animals and backyard gardens, but also aquaculture and dry season vegetable farming due to the existing favourable soil conditions The increasing number of fish ponds in private houses in South Bank give credence to this recommendation. Rice-based cropping system with rice as the wet season crop and vegetables/cassava/sweet potato as the dry season crops, may be recommended for these soils. In this way the soils are not just put to productive uses, but also serve as natural drains. These soils provide unique opportunities for green areas as advocated for metropolitan centres. If the low-lying soils of the South Bank must be put to urban development, Government must ensure correct land scaping with well laid out drainage channels to avoid excessive floods. This recommendation is based on the poverty and technological levels of the people so that land allotees are not differentially disadvantaged. The recommendation also helps to ensure environmental safety and sustainability. The present practice of allocating land in its natural form without landscaping should be discouraged.

From the soil characteristics, the more elevated soils of North Bank are more amenable to urban development than the low-lying soils of the South Bank for reasons of good drainage and higher bulk density. The only constraint is in the area of soil erosion due to moderate sloping topography particularly where profile 2 is located. This constraint may be overcome by adequate drainage construction and land leveling. Unfortunately, government had not shown interest in the development of the North Bank area until recently. With Government acquisition of land for housing development in addition to private organizations efforts in the provision of houses, it is believed that pipe borne water and good road network will be extended to the area just as the case of electricity some years back.

CONCLUSION AND RECOMMENDATIONS

The frequent cases of flooding in Makurdi Urban Area in recent years is traceable to inappropriate urban land use planning without due regards to soil information. Soil-landscape relationship is an underlying factor in soil drainage and consequent flooding. The South Bank Area of Makurdi Town is low-lying with high water table and higher clay content such that water infiltration and percolation are restricted. The resultant effect is that water is not lost as fast as it is gained through rainfall and overland flow from the upland leading to devastating floods that have caused havoc to the environment, properties and sometimes lives. This ugly trend could have been averted through soil survey and subsequent urban land use planning.

The following recommendations are made from the study for environmental sustainability.

- The wetland soils of South Bank area especially those that experience episaturation endosaturation are more amenable to agriculture and nature conservation and should be used as such – urban agriculture and natural drains.
- Landscaping should be encouraged if urban development must be carried out in the wetland soils.
- Urban development should be encouraged in the well-drained upland areas of the town.
- Further urban development of the South Bank should be discouraged to allow for appropriate urban land use planning based on soil survey data

Table 1: Morphological Properties of some selected soils of Makurdi Urban Area.

Horizon	Depth (cm)	Matrix Colour	Mottles	Textures	Structure	Inclusions	Boundary	Remarks
Profile 1	Typic Paleustalf/ Eutric Luvisol							
A	0 –12	7.5YR ¾	–	ls	1fgr	cfr	Gs	–
B	12 –25	7.5YR 4/6	–	sl	1fsbk	cfr	Gs	–
Bt_1	25 –56	5YR 4/6	–	scl	2msbk	ffr	Ds	–
Bt_2	56 –98	5YR 5/6	–	scl	3msbk	ffr	gs	–
Bt_3	98 – 165	5YR 5/8	–	sc	3csbk	–	–	Hard clay pan.
Profile 2	Typic Paleustalf/ Eutric Luvisol							
A	0 –8	7.5YR 4/4	–	ls	1fcr	–	gs	–
AB	8 –36	7.5YR 4/6	–	sl	1fsbk	–	gs	–
Bt_1	36 –64	5YR 4/6	–	scl	2msbk	–	gs	–
Bt_2	64 –108	5YR 5/6	–	scl	3msbk	–	gs	–
Bt_3	108 – 168	5YR 5/8	–	sc	3csbk	–	–	Hard clay pan.
Profile 3	Arenic Endoqualf/ Gleyic Luvisol							
A	0 –28	10YR 2/2	10YR 5/8 cif	sl	2fcr	mfr	gs	–
Bt_1	28 –46	10YR 5/6	7.5YR 5/8 c2d	scl	2msbk	cfr	gw	–
Bt_2	46 –81	2.5Y 6/4	7.5YR 4/6 c2d	scl	2msbk	cfr	gs	–
Bc	81 – 118	2.5Y 7/4	7.5YR 4/6 c3d	sc	3csbk	–	–	Water table.
Profile 4	Typic Endoaqualf/ Gleyic Luvisol							
A	0 –30	10YR 2/1	–	scl	3msbk	mfr	as	Cracks
Bt_1	30 –55	10YR 2/3	–	cl	3csbk	ffr	gs	–
Bt_2	55 –85	5Y 4/2	–	c	3csbk	–	gs	–
Bt_3	85 –97	5Y 7/1	–	c	3csbk	–	–	–
Profile 5	Typic Endoaqualf/ Gleyic Luvisol							
Ap	0 –28	10YR 2/3	10YR 5/8 cif	sl	2fcr	mfr	gs	–
Bt_1	28 –43	10YR 5/6	7.5YR 5/8	scl	2msbk	ffr	gw	–
Bt_2	43 –80	2.5Y 6/4	7.5YR 4/6	scl	2msbk	ffr	gs	–
Bt_3	80 – 110	2.5Y 7/4	7.5YR 4/6	sc	–	–	–	Water table.
Profile 6	Arenic Endoaquent/Eutric Gleysol							
A	0 – 16	10YR ¾	–	sl	1fgr	Cfr	gs	–
AB	16 – 40	10YR 5/4	–	s	1fgr	Ffr	gs	–
C_1	40 –76	2.5Y 4/2	–	s	1fgr	–	gs	–
C_2	76 – 106	2.5Y 7/4	–	s	1fgr	–	–	Water table.

Textures: Is = Loamy Sand: Sl = Sandy loam; S = Sand; Scl = Sandy clay loam, Sc = Sandy clay; C = clay Structures: Ifgr = Weak fine granules; Ifcs = Weak fine crumbs; 2fcs = moderate fine crumbs; IfSbk = Weak fine subangular blocky; 2msbk = moderate medium subangular blocky; 3msbk Strong medium subangular blocky; 3csbk = Strong coarse subangular blocky.
Inclusions: ffr = few fine roots; Cfr = common fine roots; mfr = Many fine roots.
Boundary: gs = gradual smooth; gw = gradual wavy; ds = difuse smooth; as, abrupt smooth.

Table 2: Physical and Chemical Characteristics of some selected soils of Makurdi Urban Area.

Horizon	Depth	Particle Size Distribution (%) Sand	Silt	Clay	Bulk density ($gmcm^{-3}$)	pH (H_2O)	Org. C (%)	Total N (%)	Avail. P ($mgKg^{-1}$)	Exchangeable Bases ($CmolKg^{-1}$) Ca	Mg	K	Na	CEC ($CmolKg^{-1}$)	B.S (%)
Profile 1	**Typic Paleustalf/ Eutric Luvisol**														
A	0 –12	80	13	7	1.20	6.20	0.90	0.10	6.50	2.68	1.84	0.12	0.09	6.34	75
B	12 –25	77	12	11	1.25	5.95	0.75	0.08	5.50	2.40	1.86	0.10	0.08	6.30	70
Bt_1	25 –56	70	10	20	1.35	5.80	0.50	0.05	4.00	2.36	1.94	0.14	0.09	6.68	68
Bt_2	56 –98	64	12	24	1.42	5.45	0.30	0.03	3.10	2.36	2.00	0.11	0.11	7.12	64
Bt_3	98 –165	58	12	30	1.45	5.40	0.30	0,03	3.20	2.48	1.88	0.12	0.10	7.48	61
Profile 2	**Typic Paleustalf/ Eutric Luvisol**														
A	0 –8	78	12	10	1.25	5.90	0.80	0.09	6.00	2.50	1.76	0.11	0.09	5.82	77
AB	8 –36	75	13	12	1.28	5.86	0.60	0.05	5.11	2.16	1.96	0.14	0.11	5.60	78
Bt_1	36 –64	69	11	20	1.38	5.67	0.40	0.03	3.46	1.86	2.04	0.13	0.10	6.04	68
Bt_2	64 –108	60	12	28	1.45	5.80	0.30	0.03	3.00	1.90	1.88	0.12	0.11	6.14	65
Bt_3	108 –168	56	11	33	1.50	5.84	0.30	0.03	3.20	2.08	1.68	0.12	0.12	6.24	64
Profile 3	**Arenic Endoqualf/ Gleyic Luvisol**														
A	0 –28	77	14	9	1.15	6.21	1.64	0.18	9.20	4.28	2.40	0.14	0.11	7.80	87
Bt_1	28 –46	70	11	19	1.20	6.00	0.82	0.09	7.68	3.84	2.58	0.11	0.10	8.01	83
Bt_2	46 –81	62	12	26	1.22	5.84	0.50	0.06	6.88	3.20	2.12	0.12	0.12	8.68	64
Bc	81 –118	57	13	30	1.24	6.05	0.30	0.05	6.94	3.60	2.46	0.14	0.12	9.10	69
Profile 4	**Typic Endoaqualf/ Gleyic Luvisol**														
A	0 –30	58	13	29	1.29	5.72	1.65	0.18	12.80	4.68	2.58	0.20	0.12	8.20	92
Bt_1	30 –55	51	16	33	1.34	5.62	0.90	0.10	8.00	3.40	2.89	0.21	0.12	8.36	79
Bt_2	55 –85	41	16	43	1.35	5.42	0.50	0.05	6.50	2.80	2.90	0.11	0.10	8.88	67
Bt_3	85 –97	40	15	45	1.38	5.27	0.40	0.05	6.00	2.76	2.00	0.21	0.09	9.21	55
Profile 5	**Typic Endoaqualf/ Gleyic Luvisol**														
Ap	0 –28	70	19	11	1.25	6.30	1.25	0.15	9.80	3.42	2.14	0.18	0.12	6.88	85
Bt_1	28 –43	65	20	15	1.28	6.05	0.65	0.07	8,60	3.26	2.26	0.16	0.12	6.78	86
Bt_2	43 –80	61	17	22	1.29	5.90	0.50	0.05	7.20	2.92	1.90	0.14	0.11	6.94	73
Bt_3	80 –110	57	12	31	1.29	5.98	0.03	0.03	6.80	3.08	1.98	0.16	0.12	7.06	76
Profile 6	**Arenic Endoaquent/Eutric Gleysol**														
A	0 –16	83	10	7	1.10	5.75	0.84	0.08	5.20	1.20	0.87	0.11	0.11	3.68	62
AB	16 –40	85	9	6	1.15	5.40	0.50	0.04	3.20	0.86	0.70	0.12	0.12	3.20	55
C_1	40 –76	88	7	5	1.18	5.20	0.30	0.03	3.00	0.84	0.64	0.10	0.10	2.86	58
C_2	76 – 106	90	6	4	1.20	5.25	0.10	0.01	1.86	0.78	0.60	0.10	0.10	2.56	61

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