ANALYSIS OF SOIL PHYSICAL PROPERTIES AND SATURATED HYDRUALIC CONDUCTIVITY LEVELS OF VALLEY BOTTOM LAND ON THE BASEMENT COMPLEX.

INYANG[1*] E. P. , SHITTU[2] K. A. AND AKINBOLA[3] G. E.
[1]*Department of Physics University of Calabar, Nigeria*
[2]*Department of Soil Science and Land Resources Management, Obafemi Awolowo University, Ile-Ife, Nigeria*
[3]*Department of Agronomy, University of Ibadan, Ibadan, Nigeria.*
inyang.ephraim@gmail.com +234 8060671660

ISSN: 2141 – 3290
www.wojast.com

ABSTRACT

The soils studied comprise four series namely; Adio, Jago, Matako and Oshun series. Particle size analysis, textural classes, bulk density and saturated hydraulic conductivity were measured. Interestingly, the results showed that the soils texture ranged between loamy sand to sand down the profile for all the soil series. Bulk density increased with soil depth and averaged 1.78, 1.79, 1.87 and 1.71 g/cm^3 in Adio, Jago, Matako and Oshun series respectively. Water tables were < 75 cm, < 80 cm, < 120 cm, < 50 cm in Adio, Jago, Matako, and Oshun series, respectively. Saturated hydraulic conducting (Ks) decreased sharply with depth in the four soil series considered. The inland valleys ranged texturally from loamy sand to sandy loam and would be very suitable for vegetable production because of their densely packed structures and lower bulk density at the top-soil.

INTRODUCTION

One of the most serious problem affecting soil systems and their productivity today in the tropical and developing country like Nigeria is the in effective and unplanned use of scarce land. This in a way has affected agricultural productivity. Biazin *et al* (2011) argued that African agriculture has the lowest rate of productivity increase in the world. The primary and most effective land conservation method is appropriate allocation of lands for uses for which they are most suitable. This became very imperative owing to the fact that abuses of land management should attract land use restrictions, (Horn *et al*. 2000; Horn *et al*. 2005). Although these management practices have been a subject of increasing interest in other regions of the World (Kodesova *et al.* 2011, Pagaliai *et al* 2004,,Lother *et al.* 2013; Van; Alvarez and Steinbach 2009, Hemmat *et al*. 2010). Nigeria is not particular about land management as individual uses any available land.

Unfortunately, the expansion of development and uncontrolled increase in population and demand for land for various uses (Akinbola, 1993, Inyang *et al.* 2012). Inland valley soils have high agricultural potential because of their high inherent fertility, reduced or non-existence erosion threat, availability of water even during the dry season (Akinbola, 2001). There is a positive correlation between soil physical properties and related crop yields (Alvarez and Steinbach (2009) therefore knowledge of soil physical properties is important because structure, bulk density and texture influence root development (De Kimpe and Mehuys, 1979).

Sustainable wetland management requires basic understanding of the resources to be managed (Okusami, 1997). The soil of the inland valley is greatly influenced by seasonal or perennial high ground water which affects soil as a growing medium for plants, land use possibilities and soil formation (Van Diepen, 1985). Soil wetness, may be attributed to rainfall or impeded hydraulic conductivity or low permeability/drainage. In soils influenced by a fluctuating water table, hydraulic conductivity directly affects the rate of recession of the water table, together with the rainfall. It is an important parameter in design and functional efficiency of the drainage system (Edminster, 1957).

The soil of valley bottom land is unique in their characteristics. These attributes are greatly influenced by the dynamic nature of the ground water table and parent materials of the land (Akinbola, 2001). The intensive use of wetlands soil for agriculture purpose is bound to produce some adverse environmental impact, Salau, 1992, Oliver and Berdowski (1997). However, a detailed study and assessment of land for relevant utilization types may release them for agricultural uses.

This study was conducted to assess the physical properties and saturated hydraulic conductivity levels of valley bottom land on the basement complex of a typical tropical forest.

METHODS

Study site description

The study was done on an area situated in the central part of the University of Ibadan, South western Nigeria. The co-ordinates of the location range from latitude 7^0 15'N to 7^0 3^{0}'N and longitude 3^0 45'E and 4^0 1'E. The valley is saucer shaped at the eastern part resulting from the convergence of three slopes, and open v-shaped at western part. It covers an approximate area of about 2 ha.

Ibadan, the capital city of Oyo State is characterized by hot humid tropical climate like the rest of the southwestern Nigeria with two distinct seasons in a year (rainy and dry season) as influenced by the movement of the Inter-Tropical Discontinuity (ITD). The valley understudy is typically swampy in most part of the western end while the eastern end has drier edges which are well drained. Tree such as Oil palm, Mango, Flamboyant and Obeche trees are found growing randomly on the land. The stream sides are dominated by the elephant grass while guinea grass, sedges and spear grass dominated the drier part of the land. Banana and Plantain trees are found now at the eastern part of the valley while some few stands are scattered on other parts of the valley.

Field Study and Soil Sampling

A reconnaissance survey of the land was first done to know the major biophysical features of the land in terms of land terrain, topography, evidence of erosion, drainage, and pattern of cultivation. The soils that were identified by Okusami (1986) as Jago series (JAS-1), Matako series (MAS-2), Adio Series (ADS-3) and Oshun Series (OSH-4), were sampled at different soil depths.

A total of four profile pits were dug with each soil series having one profile pit. Depth of profile pit was measured with a tape, soil texture by hand feel, soil boundaries by visual observation. Upon description, soil sample from each horizon of the profile were collected for particle size analysis. Also, undisturbed core samples were collected for the determination of bulk density and saturated hydraulic conductivity.

Analysis of Physical Properties of Soil

Soil samples brought from field were air dried and sieved through a 2 mm sieve for particle size analysis. Particle size analysis was performed according to Bouyoucos (1962) and the method by Kohn (Hartge and Horn, 1992). Also, Soil Taxonomy (Soil Survey Staff, 1975) was used to designate the textural classes. Bulk density was measured using core method (Blake, 1965).

Determination of Saturated Hydraulic Conductivity of Soil

Saturated hydraulic conductivity was determined using the modified Klute (1965) constant head method. The undisturbed core samples collected in duplicates from each horizon were slowly saturated for 48 hours and saturated hydraulic conductivity was measured. The following relationship was used in calculating: $K = \frac{Q}{At}\frac{dz}{dh}$

Where: K = Saturated hydraulic conductivity (cm/hr); Q = the steady state volume flow from the entire soil column (cm^3); A = cross sectional area (cm^2); t = the time interval (hr); dz = length of sample (cm); dh = hydraulic head change (cm).

RESULTS AND DISCUSSION

The results of the physical properties (Table 1) and analysis of the particle size distribution of soils from the valley bottom ranges between sandy loam to loamy sand. Only pedon JAS-2 had a sandy texture for the sub-surface horizons. The sub-surface horizons for others varied between sandy loam to loamy sand.

With the exception of Osh-4 that had total sand contents that increased with an increase soil depth, the sandy status of the soil ranged between 560.6 g/kg to 835.3g/kg for soil depth that falls between 0-50 cm, the other soil series had their total sand content fluctuated with depth.

Table 1: Particle size distribution and texture of the sampled soils

Soil Series	Soil Depth (cm)	Fine sand g/kg	Coarse sand g/kg	Total sand g/kg	Silt g/kg	Clay g/kg	Silt/Clay g/kg	Texture
ADIO	0-17	300.0	574.5	874.5	78.4	86.3	0.91	Sand
	17-30	109.8	705.9	815.7	117.6	66.7	1.76	Loamy sand
	30-50	168.6	627.5	756.1	117.6	86.3	1.36	Loam sand
	50-75	139.2	754.9	894.1	39.2	66.7	0.59	Sand
JAGO	0-23	145.1	690.2	835.3	117.6	47.1	2.50	Loamy sand
	23-35	113.7	819.6	933.3	19.6	47.1	0.42	Sand
	35-50	58.8	854.9	913.7	39.2	47.1	0.83	Sand
	50-80	33.3	900.0	933.3	19.6	47.1	0.42	Sand
MATAKO	0-12	96.1	73.9	913.7	117.6	47.1	2.5	Loamy sand
	12-42	135.3	739.2	933.3	39.2	86.3	0.45	Sand
	42-75	64.7	770.6	835.3	78.4	86.3	0.91	Sandy loam
	75-120	74.5	682.4	756.5	58.8	184.3	0.32	Sandy loam
OSHUN	0-10	186.3	374.5	560.6	333.3	105.9	3.15	Sandy loam
	10-20	333.4	443.1	776.9	117.6	105.9	1.11	Loamy sand
	20-50	200.0	635.3	835.3	98.0	66.7	1.47	Loamy sand.

The surface horizon for all the pedons considered had a total sand fraction ranging between 560.6 g/kg and 87.45 g/kg with an average of 776.4 g/kg while sub-soil horizon had value between 756.1 g/kg and 933.3g/kg with an average of 847.7 g/kg. All the soils can be described as light texture soils because of their predominated sand related texture, this texture account for the high permeability of the inland valleys. The result of the texture obtained in this study is contrary to what Brinkman *et al*., (1986) observed that inland valley soil could have texture ranging from sand to clay soil but the latter predominate. The clay content in ADS – 1 was irregularly distributed while that of Osh-4 decreased in clay content with increase in soil depth. The clay content in MAS-2 increased with increase in clay content. This is an indication of clay migration by lessivage to produce illuviation. The clay content for all the pedons considered were generally low and ranged between 47.1 g/kg and 183.0 g/kg. This may be due to the position the inland valley land occupies in the topography. This observation was also noted by Fagbami *et. al*., (1982). Average silt/clay ratio for all the soil series were 2.27 and 0.88 for top-soil and sub-soil respectively, this means that this kind of top-soil has higher susceptibility to erosion, Wischmeier, 1969).

The results of bulk density and saturated hydraulic conductivity of the soil samples are given in Table 2. The bulk density ranged between 1.33 g/cm^3 and 1.54 g/cm^3 with mean of 1.54 g/cm^3. Sub-soil horizon values ranged between 1.60 g/cm^3 and 2.10 g/cm^3 with mean value of 1.89

g/cm^3. It is apparent that the bulk density of the surface horizons is ideal for agronomic practice (Ahn, 1993). Similar findings have been reported by Jewitt *et. al.*, (1979), who stated that the bulk density of wet land soils vary between 1.0 g/cm^3 to 2.0 g/cm^3 and increase with depth. Result from all the profiles showed a general trend of an increase in bulk density with soil depth. This may partly be ascribed to organic matter content in the surface layer and partly due to cultivation which is usually carried out on the surface layer.

All the soils sampled, except surface layers of Adio series (1.54 g/cm^3) and Oshun series (1.33 g/cm^3) that had critical values that fall below the 1.63 g/cm^3 have problems of high bulk density that can pose hindrance to root penetration, De-Geus (1973). Ahnn (1993), observed that more favourable are the results of the tropical horizon that are lower than 1.6 g/cm^3 since soil with values of 1.6g/cm^3 to 1.8g/cm^3 indicate poor aeration and water movement will be too low for optimum root growth.

Table 2: Bulk Density and Saturated hydraulic conductivity of the Soils

Soil Series	Depth (cm)	Bulk-Density (g/cm^3)	Saturated hydraulic conductivity (cm/h)
ADIO	0-17	1.54	35.47
	17-30	1.65	26.75
	30-50	1.86	14.34
	50-75	2.06	5.23
JAGO	0-23	1.60	45.64
	23-35	1.81	48.55
	35-50	1.81	27.24
	50-80	1.94	98.11
MATAKO	0-12	1.67	22.26
	12-42	2.01	15.06
	42-75	2.10	2.42
	75-120	1.70	3.53
OSHUN	0-10	1.33	312.45
	10-20	1.71	32.46
	20-50	2.09	5.94

Saturated hydraulic conductivity of top-soil for the four soil series ranged between 22.26 cm/h and 312.45 cm/h with an average of 103.96 cm/h. while sub-soil horizons had values that ranged between 2.42 cm/h and 98.11 cm/h with mean of 25.42 cm/h (Table 2). The reason for higher mean saturated hydraulic conductivity of top soil when compared with sub-soil levels might be due to the stable granular structure of the former. Similar observations had earlier been reported by Nyle *et al*., (1999). Soils with stable granular structure are known to conduct water much more rapidly than those with unstable structure units, which break down upon being wetted. Except JAS – 2 that had fluctuating saturated hydraulic conductivity, all other soils series had values that decreased with increase in soil depth.

CONCLUSION AND RECOMMENDATION

Proper soil management required a pre tillage experiments to ascertain the proper use of the scarce land in the tropics where there is an ever uncontrolled population expansion**.** This study has revealed a water table of <75, <80, <120, <150 cm in Adio, Jago and Matako and Oshun series respectively. The soil texture ranged between loamy sand and sandy loam down the profile for all the soil series where the bulk density increased with soil depth and averages of 1.78, 1.79, 1.87 and 1.71 g/cm^3 in Adio, Jago, Matako and Oshun series respectively. Saturated hydraulic conductivity (ks) was higher on the surface soil layer and decreased sharply with depth. The inland valleys ranged texturally from loamy sand to sandy loam and would be very suitable for vegetable production because of their densely packed structures and lower bulk density at the top- soil. Following their physiography, soils of this nature will be suitable for dry season farming since on their irrigation those probable problems are of moisture retention or soil erodibility would be reduced to minimal.

REFERENCES

Ahn, P. M. (1993). *Tropical Soil and Fertilizer Use.* Longman and scientific technica, UK

Akamigbo, F.O.R. 2001.Survey, Classification and land use of wetland soil in Nigeria. Management of wetland soils for sustainable agriculture and environment. Proceeding of the 27th Annual Conference of the Soil Science Society of Nigeria. Pp. 7

Akinbola, G .E. (2001).Characterization and Classification of some valley bottom soil on basement complex of Southwestern Nigeria. *Proceeding of the 27th Annual Conference of the Soil Science Society of Nigeria*.Pp.103-127.

Akinbola, G. E. (1993). *Changes in Land Use Patterns, Soil Characterization and Potential for Agriculture in Ibadan area*. Ph.D. Thesis, University of Ibadan.

Alvarez R. and Steinbach H.S. (2009). A review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crops yield in the Argentine. *Soil and Tillage Research* 104 1-15.

Biazin B. Geert S., Melesse T., Abdu A., Leo S. (2012). Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa – A review: *Physics and Chemistry of the Earth*: 10.1016/j.pce.2011.08.015

Blake,G.R. 1965. Bulk density. In: *Method of Soil Analysis, C.A Blake (ed)*. Agronomy 9.Amer. Soc. Agron. Madison Wis. 374-390

Bouyoucus, G. J. (1962). Hydrometer method improved for making particles size analysis of soils. *Agronomy Journal* 27:738 -741

Brinkman, R and Blockhuis, W. A. (1986). *The Wetlands and Rice in Sub-Saharan African,* IITA, Nigeria, 31-42.

De Geus, J. G. (1973). *Fertilizer Guide for the Tropics and Sub-tropics*. Centre d' Etude de L'Azote, Zurich.

De Kimpe, C. R. and Mehuys G.R. (1979). Physical properties of gheysolic soil in the of Quebec. *Can. J. Soil Sc.* 59:69-78

Edminster, T.W. (1957). Surface drainage. In: Drainage of Agricultural lands. *Agron. Monogr.* 7: 374-385.

Fagbami, A. A. and Ajayi, F. O. (1982).Valley bottom soils of the sub-humid tropical South Western Nigeria on basement complex characteristics and classification. *Soil Science and Plant nutrition*, 36 (2): 179-194.

Hartge, K.H., Horn, R., (1992). Die physikalische Untersuchung von Bo¨den, Enke Verlag, 177.

Hemmat A., Aghilinategh N., Rezainejad Y., Sadeghi M. (2010). Long-term impacts of municipal solid waste compost, sewage sludge and farmyard manure application on organic carbon, bulk density and consistency limits of a calcareous soil in central Iran. *Soil and Tillage Research,* (108), 43-50

Horn R., Fleige H., Richter F.H., Czyz E.A., Dexter A. E. Diaz-Pereira , E. Dumitru , R. Enarche, F. Mayol , Rajkai K. D. de la Rosa , Simota C. (2005). SIDASS project Part 5: Prediction of mechanical strength of arable soils and its effects on physical properties at various map scales. *Soil and Tillage Research*. (82), 47-56

Horn, R., Van den Akker, J.J.H., Arvidsson, J., (2000). Subsoil compaction_distribution, processes and consequences. *Advances in Geoecology*, 32. Catena Publications

Inyang E P, Oketayo, O. O. and Obiajunwa E. I. (2012). Proton induced X-ray emission analysis of soils with various length of fallow: The effect on soil total elemental composition. *Soil and Tillage Res.*, http://dx.doi.org/10.1016/j.still.2012.03.014

Jewit, T. N; Law, R. D. and Virgo, K. J. (1979). *Outlook on Agriculture*. (10). 23.

Klute, A. 1965. Laboratory measurement of hydraulic conductivity of saturated soil. In Method of Soil Analysis, C. A. Blake (ed). Part 1 .Am. Soc. Agron. (9): 210-221

Kodesova R., Jirku V. Kodes V., Muhlhanselova,N, Zigova A. (2011). Soil structure and soil management. *Soil and Tillage Research* (90): 162-170

Nyle, C. B. and Weil, R. 1999. The Nature and Properties of Soils. (12), 192-194.

Okusami T.A. 1986. Properties of some hydromorphic soils in West Africa. In: *The Wetlands and Rice in Sub-sahara Africa.* (AST. Ju and J.A. Lower (ed)), Ibadan. 182p.

Okusami, T. A. and R. H. Rust (1992). Occurrence of Characteristics and Classification of some Hydromorphic Soil from South Nigeria. In: *Correlation Meeting (viii ISCOM):Characterization, Classification and Utilization of Wet Soils*. USDA Soil Conservation Service. National Soil Survey Centre. Lincoln .N.E

Okusami, T. A. (1997). The characterization, classification and evaluation of acid soil on upper coastal plains of Lagos state, Nigeria. *Ife Journal of Agriculture*. (19), 92. 134-143

Oliver, J. and Berdowski, J. (1997) .Global green house emission inventories per Sector. In *Change: Research and Policy Newsletter on Global Change from the Netherland.* May-June 1997/1.

Pagaliai M, Vigonozzi, N., Pellegrini S. (2004). Soil structure and effect of management practices. *Soil and Tillage Research* (79), 131–143

Salau, A. T. (1992). *Global Environmental Change: A Research Agenda for Africa* CODESRIA Working Paper 2/1992.

Lothar Mueller, Graham Shepherd, Uwe Schindler, Bruce C. Ball, Lars J. Munkholm, Volker Hennings, Elena Smolentseva, Olga Rukhovic, Sergey Lukin, Chunsheng Hu. (2013). Evaluation of soil structure in the framework of an overall soil quality rating. *Soil and Tillage Research*. (127), 74-84

Soil Survey Staff (1975). Soil taxonomy. A basic system of soil classification for making and interpreting soil survey :In *USDA. Agric. Hand Book* 436, 179-200

Umoh, G. S. and Adegeye, A. J. (1999). Environmental conservation and food self- sufficiency. A study of wetland farming in Niger-Delta, Nigeria. *Poverty Alleviation and Food Security in Nigeria.* 192p.

Van Diapien, C.A. (1985). Wetland soils of the world, their characteristics and distribution in the FAO/UNESCO approach, In: *Wetland Soils: Characterization, Classification and Utilization.* Int. rice Res. Inst (IRRI), Los Banos, Philippines, pp. 141-170.

Wischmeier, W. H.(1969) .Relation of soil properties to its erodibility, *Soil Sc. Soc. Amer. Proc*. 33:131-136.