IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 8, Issue 2 Ver. I (Feb. 2015), PP 71-75
www.iosrjournals.org

Physical properties and management of forested steep lands being converted to farm lands: the case of Oban Hills, Cross River State, Nigeria.

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Abstract: *Soil samples were collected from fifteen profiles located from the top of Oban hills to the valley bottom in southeastern Nigeria. Standard laboratory methods were used to analyse the samples. The predominant top and subsoil textures were gravelly sandy loam and gravelly sandy clay loam respectively. The particle size distribution of the steep land soils ranged from 34 to 82%, 6 to 36% and 6 to 42% for sand, silt and clay respectively.*

The bulk density results range from 0.67 to 1.87g/cm^3 with the mean of 1.38g/cm^3 for top soils while it was 0.74 to 2.16g/cm^3 with the mean of 2.02g/cm^3 for sub soils. Top soils porosity values ranged from 29.43 to 74.72% with mean of 47.93% whereas subsoil range from 12.08 to 38% with the mean of 22.54%. The values of saturated hydraulic conductivity ranged from 7.56 to 103.87cm/hr. with mean of 34.42cm/hr. and 0.74 to 42.83cm/hr. with mean of 10.13cm/hr. for the top and sub soils respectively. The possession of sandy loam top soil texture will confer moderately rapid infiltration rate to them. The top soil bulk density values were adequate as they were mostly below 1.6g/cm^3. The porosity of the soil inferred from bulk density could be classified as good while the hydraulic conductivity as high. The present physical attributes of these soils coupled with high organic carbon top soil value enhance rapid infiltration. To maintain the productivity of these steep lands, slash and burn land use must not be utilized, zero tillage must be promoted and it will be better to adopt a land use that keeps the soils under a permanent cover e.g. forestry or perennial crop plantation. These will guarantee near natural soil conditions and prevent the development of rill or gully erosion.
Key words: *Bulk density, porosity, hydraulic conductivity, erosion, steep land.*

I. Introduction

Steep lands are susceptible to erosion when cleared of natural vegetation hence, are lands not suitable for cultivation. Soil erosion by wind and water is responsible for about 85% of the causes of land degradation the world over (Mbagwu and Obi, 2003). Soil fertility depletion is majorly caused by soil erosion (SOWA, 2006), this is particularly serious on steep lands as it is difficult to retain nutrients on deforested eroding slopes. That is why vine growing in many semi arid regions worldwide plays an important role (in preventing erosion) as a permanent plant cover (Hacisalihoglu, 2007). According to Sanders (1998) new lands to be brought under cultivation are slopping and susceptible to erosion. People choose to use them because the best (flat) lands are already in use either as settlement or competing for use as industrial areas as urbanization and development increases. This is particularly true of the highly populated Asian and African countries. The activities of mankind through agriculture or road construction could accelerate soil erosion. In Nigeria the widespread use of marginal (steep) lands for farming has led to increased land degradation particularly accelerated erosion. Soil erosion problems usually increase with the soil (vegetative) cover removed. When a clean-tilled field is cultivated, the aggregate stability of such soils readily decreases (NRCS, 2011). Soil erosion significantly affects soil quality, quantity, water and therefore its productivity (Chude, 2005). Soil erosion affects soil fertility and productivity in four major ways:

a. It reduces plant available water by changing the water holding characteristics of the root zone (Rhoton, 1990).
b. It degrades soil structure following the loss of soil organic carbon which leads to surface sealing and crusting (Lal, 1987).
c. Loss of plant nutrients through overland flow.
d. Increased problem of soil variability which impact crop productivity (Farnestock *et al.*, 1995).

The problem of erosion does not only end in declining farmers yields. Erosion from sloping lands cause serious problems downstream, silting of dams and streams, frequent flooding, damage to irrigation and hydro-electric schemes, silting of navigable rivers and harbours (Sanders, 1998). Erosion potential and infiltration capacity could be predicted from aggregate stability (Lal, 1981). This is because soil erodibility increases as aggregate stability decreases (Kemper and Rosenau, 1986). Aggregate stability plays an important role in erodibility, organic matter protection and therefore the productive potential of a soil (Burt, 2011). The objective of this study was to undertake an inventory of some soil physical properties for evaluation and offer advice on its management. This will act as a guide in the future when farmers would have deforested most of the steep lands of Oban hills as it is currently going on.

II. Materials And Methods

This study was carried out at the Oban hills which lie between latitudes $5^0$18' and 5^0 22' north and longitudes $8^0$18' and $8^0$40' east. It was specifically sited at where the highest ranges of the hills are found, the Aking/Osomba hills in Akamkpa Local Government Area of Cross River State, Nigeria. Three toposequences were selected for this study on three mountain ranges. A profile pit was dug at each of the following positions: crest (plateau), shoulder slope (sub plateau), back slope (mid slope), foot slope (lower slope), and toe slope (valley bottom). From these toposequences, fifteen profiles were sampled. Each profile was dug to a maximum depth of 2m except where there was an obstruction.

Core sample were collected from different horizons for determining the bulk density and hydraulic conductivity. In addition, soil samples were collected from each horizon for laboratory study (Klute, 2002). Apart from samples used for bulk density and hydraulic conductivity determinations, samples brought from the field were air-dried, ground and passed through a 2 mm-sized sieve. The fine earth fraction was used for the following analysis; particle size distribution using Bouyoucos hydrometer method. The soil textures were determined using USDA textural triangle. Metal rings (100 cm^3) were used to collect undisturbed core samples from different horizons, oven dried to constant weight at 105^0C and the bulk density calculated. The total porosity was calculated using the bulk density results and particle density assumed to be 2.65 g/m^3 for most mineral soils. The saturated hydraulic conductivity (Ks) of the soil was determined using the constant head method and the Darcy equation (Klute, 2002) as explained below;

$Ks = VL/[At(H_2 – H_1)]$……………………….(1)

Where V = volume of water flowing through sample of cross sectional area, A, in time, t and $(H_2 – H_1)$ = hydraulic head difference imposed across the sample length, L. The wet sieving technique was used to determine the aggregate stability (Akagra and Cassel, 1986) of one toposequence (profile 6) of the soils (because of logistics).

III. Results And Discussion

Particle size distribution. Sand fractions in the soils decreased with profile depth ranging from 34 to 82%. Only four horizons had sand contents less than fifty percent indicating high sand contents of the soils. The silt contents of the soils fluctuated with depth ranging from 6 to 36%. Clay distribution of the soils increased with increased profile depth with the range from 6 to 42% (Table 1).

The textures of Oban hill soils were mainly gravelly sandy loam, sandy clay loam and to a lesser extent loamy sand. The top soils were mostly sandy loam while the subsurface horizons were mostly gravelly sandy clay loam. However, there were few occurrences of sandy clay and sandy loam subsurface horizons. The dominance of sand fraction in the texture of these soils is expected following the geology of Oban hills which is basement complex, principally made up of granites, schists and gneisses. The dominance of sandy loam textures in the surface soils implies they will have moderately rapid infiltration while the subsurface soils would be moderate to moderately slow (Landon, 1991). The possession of clay related sub soils indicates the soils are stable (Quansah, 1981).

Bulk density. The values of bulk density of Oban hills soils increased with increase in profile depth. The range was from 0.67 to 1.78 g/cm^3 and 1.64 to 2.33 g/cm^3 for top and subsurface horizons respectively (Table 1). These top soil values fell within the range associated with sands and sandy loam (1.20 to 1.80g/cm^3). The means obtained here are similar to those of Honduras steep lands (Thurow and Smith, 1998); and agree with those quoted for uncultivated lands (Landon, 1991). Bulk density values lower than 1.0g/cm^3 in the top soils obtained here had been explained by Prichett (1979) who stated that this is possible in soils high in organic carbon. The mean bulk density values for subsoil horizons are characteristic of the type that restricts root penetration i.e. above 1.75g/cm^3 for sands (De Geus, 1973). However, it should be noted that root restriction varies with soil types. In clay soils root restriction is expected between bulk density values of 1.46 and 1.63 g/cm^3 (De Gues, 1973). However, bean roots has been restricted in (70% clay) soils at 1.1 g/cm^3, maize at 1.2 $g/cm^3$and wheat at 1.3 g/cm^3 (Cassel and Lal, 1992). The

Table 1: Summary of Physical Properties of the Soils of Oban Hills.

Profile		Clay %	Silt %	Sand %	% gravel	Bulk den. (g/cm^3)	Porosity %	Hydrau. Cond. Cm/hr	Wet Stable Aggregate (%)
	Range	18 – 30	20 – 24	46 – 62	14.93-26.29	0.84-2.19	17.34-68.30	5.66-15	N D*
1.	Mean	23.33	22.00	54.66	19.71	1.66	37.23	13.09	“
	S.D	6.11	2.00	7.02	5.88	0.72	27.25	7.25	“
									“
	Range	14-22	20-24	54-54	6.39-39.38	1.02-2.11	20.38-61.51	8.85-65.47	“
2.	Mean	17.33	22.66	60.00	24.23	1.74	34.21	27.71	“
	S.D	4.16	2.30	5.29	19.65	0.62	23.64	82.68	“
									“
	Range	10-24	14-36	54-70	18.64-33.93	1.36-2.08	21.51-48.68	10.62-16.35	N D
3.	Mean	16.66	24.00	59.63	26.36	1.80	32.07	13.16	“
	S.D	7.03	11.13	9.23	7.64	0.38	14.55	2.91	“
									“
	Range	6-22	10-14	64.82	6.13-47.15	1.61-2.13	19.16-39.25	11.06-56.63	“
4.	Mean	16.66	12.00	71.33	13.11	1.90	28.17	26.98	“
	S.D	9.23	2.00	9.45	21.92	0.26	10.05	25.69	“
									“
	Range	6-30	6-14	64-80	3.21-19.35	1.78-2.33	12.08-32.83	7.56-10.18	“
5.	Mean	19.33	10.00	70.66	8.84	2.14	18.99	8.50	“
	S.D	12.22	4.00	8.32	9.10	0.31	11.98	1.45	“
									“
	Range	24-36	14-22	42-62	6.07-41.17	0.67-2.03	23.42-74.70	5.31-8.04	60.85-65.45
6.	Mean	29.33	16.66	54.00	23.62	1.49	43.90	6.47	62.76
	S.D	6.11	4.61	10.58	17.55	0.72	27.17	1.40	30.69
	Range	18-24	16-18	58-66	5.70-3.63	1.34-2.32	12.45-49.43	0.74-18.96	60.20-64.7
7.	Mean	22.00	16.50	61.50	18.56	1.90	27.26	7.53	63.34
	S.D	2.82	1.00	3.41	12.35	0.41	15.77	8.21	32.42
	Range	22-24	14-26	50.54	16.29-42.46	1.27-2.15	18.87-52.08	1.57-53.70	50.71-75.49
8.	Mean	22.50	20.00	57.50	34.19	1.88	28.87	27.54	68.34
	S.D	1.00	5.88	6.60	12.04	0.41	15.74	30.89	33.05
	Range	20-32	10-16	52-66	11.13-46.76	1.66-2.20	16.98-37.36	2.29-37.27	37.70-67.12
9.	Mean	26.66	13.33	60.00	30.26	1.95	26.41	34.35	54.36
	S.D	6.11	3.05	7.21	17.96	0.27	10.27	46.16	18.90
	Range	10-30	10-20	60.70	22.51-57.44	1.31-2.30	13.21-50.57	4.09-103.89	26.59-50.55
10.	Mean	20.66	13.83	66.00	39.63	1.89	28.55	42.10	38.65
	S.D	10.06	5.77	5.29	17.61	0.51	19.55	53.96	20.32
	Range	26-42	8-24	34-56	11.41-46.47	1.55-1.89	33.58-41.51	0.81-11.80	N D
11	Mean	33.00	19.50	47.50	30.80	1.72	37.73	4.90	“
	S.D	7.39	7.72	13.98	15.92	0.14	3.81	4.82	“
									“
	Range	10-22	16-26	52-74	16.45-45.79	1.64-1.72	35.85-38.11	1.45-19.91	“
12	Mean	17.33	22.00	60.66	29.14	1.67	36.85	11.36	“
	S.D	6.42	5.29	11.71	14.40	0.03	1.15	9.30	“
	Range	12-12	12-12	76-76	23.62-23.62	1.35-1.35	49.06-49.06	34.55	“
13	Mean	12.0	12.0	76.00	23.62	1.35	49.06	34.55	“
	S.D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	“
	Range	14-30	12-16	58-70	45.82-49.22	1.87-2.15	18.87-29.43	22.12-58.99	“
14	Mean	22.00	14.00	64.00	47.52	2.01	24.15	40.55	“
	S.D	11.31	2.22	8.48	2.40	0.19	7.46	26.07	“
	Range	14-32	12-16	64-70	4.69-17.93	1.37-2.16	18.49-48.30	6.755-23.96	“
15.	Mean	18.00	14.00	68.00	9.12	1.79	32.46	15.54	“
	S.D	4.00	2.00	3.46	7.62	0.39	14.99	8.61	“

N.D Not determined

high bulk density obtained for these soils may be associated with the high gravel contents (Biswas and Mukherjee,
1994).

Total porosity. Values of total porosity of Oban steep lands decreased with increase in soil depth. The values ranged from 29.43 to 74.72% with means of 47.93% and from 12.08 to 40.38% with mean of 22.54% for surface and subsurface horizons respectively (Table 1). Harrod (1975) reported that soil total porosity ranged from 30 to 70% while Hillel (1982) stated 30 to 60%. However Kachinskii (1970) classified soil porosity as follows, greater than 50%, best soils; 45-50%, good soils; 40-44%, satisfactory soils; less than 40% unsatisfactory soils and less than 30% poor soils. Based on these, the soils of Oban steep lands could be classified as good for the top soils and poor for sub soils.

Hydraulic conductivity. The saturated hydraulic conductivities of the soils decreased with increased soil depth. The conductivity values ranged from 7.56 to 103.87 cm/hr. with a mean of 34.42 cm/hr.; and 0.74 to 42.83 cm/hr. with a mean of 10.13 cm/hr. for top and subsurface soils respectively (Table 1). The surface horizons of these steep lands by their conductivity values are classified as having very rapid conductivity class characterized by sandy textures. The subsurface characteristics were classified as rapid characteristic of sandy loam textures (Landon, 1991). Both the surface and subsurface horizons had high conductivity mean values. This is because, the mean conductivity value of these top soils (34.42 cm/hr.) is higher than 12.5 cm/hr. classified by FAO (1963) as very rapid while the subsoil mean value (10.13 cm/hr.) is also classified as rapid by FAO (1963).

Water stable aggregate. The water stable aggregate (WSA) generally increased for each profile as we move from top to bottom except for the lower slope where the reverse was the case. This could have arisen from the type of material deposited. Little of such result was observed at the toe slope (valley bottom). From the mean results, the water stable aggregate increased from the crest to the middle slope and thereafter decreased. The mean results show wet stable aggregates to be generally above 50 % except for the valley bottom profile (Table 1). The wet stable aggregate mean results from the crest to middle slope was between 62.76 % - 68.34 %. These mean wet stable aggregate results are very encouraging being generally above 50 % considering the fact that the higher the value, the better the aggregate stability. This higher percentage points to the stability of the aggregates. This guarantees adequate pore spaces, high infiltration rates and space for root growth (NRCS, 2011).

Management of the soils. The physical properties of these steep land soils have favourable characteristics for crop production and forestry. This is what attracts farmers to engage in slash and burn practices in order to cultivate these steep hill slopes. For land closer to settlements, arable and permanent tree crops should be cultivated. Adoption of arable crops should be practiced using the no-till system of cultivation. Lands further from settlements and especially on steeply sloping hills will be suitable in the forested land use that it is presently under. Permanent tree crops like oil palm (*Elaies guineensis*), Cocoa (*Theobroma cacao*) and rubber (*Havea brasiliensis*) have high productive potentials in these soils. This is recommended to maintain a permanent soil cover on the hill slopes. With a vegetative soil cover better infiltration conditions will be maintained. The planting of vetiver strips across hill slopes at about ten metres interval on arable farms is an absolute necessity. This will conserve soil and stop it from being moved from upland to down slope.

IV. Conclusion.

A walk through these forested steep lands showed there were no areas with observed rills or gullies though there were areas with gradient up to 45%. The absence of gullies may not be unconnected with these very rapid rates of the hydraulic conductivities, high wet stable aggregate values and low surface bulk densities. Also, Essoka, Ibanga and Amalu (2009) stated that these soils have high organic matter in their surface horizons. All these attributes would have contributed to keep these soils in place despite their very high gradients. It is therefore recommended, as farmers are extending their fields into these steep lands, steps be taken to convince them to adopt the above management practices that will maintain these natural or near natural conditions (properties). This will conserve soil and maintain their productivity.

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