The Effects of Landuse on the Infiltration Capacity of Coastal Plain Soils of Calabar– Nigeria

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Abstract

The effects of different landuses, viz forest, farmland and grassland were evaluated in coastal plain soils prone to shearing, erosion and leaching. Infiltration was measured under field conditions using cylinder infiltrometers (Hills, 1970) in rainy season. Equilibrium infiltration rate was reached on each landuse after (180mins). The values obtained were 17.4, 12.0 and 9.6 (cm/hrs^{-1}) for forest, grassland and farmland respectively. Soil samples analysed revealed mean values of 84.9, 8.8 and 6.3 percent for sand, silt and clay. *The preponderance of sand fractions in soils was found to be responsible for poor water retention capacity of affected soils. Saturated hydraulic conductivity (Ks) values estimated indicated a sharp decline in clay deposits in soils layers which naturally stabilizes water movement into soil profile. Conservation measures involving mulching, liming, cover cropping and afforestation to improve soil structure and infiltration capacity are recommended.*

Key words: Infiltration capacity, Coastal plain soils, Surface run-off, Monothological sedimentary characteristics

1. Introduction

Infiltration is the movement of water into the immediate soil surface. It is an important component in watershed modeling for the prediction of surface runoff. For a given soil, the land use pattern play a vital role in determining the infiltration characteristic and is of particular interest to soil scientist , hydrologist, agronomist, geographers and agricultural engineers (Suresh, 2008).

The two essential parameters used in characterizing infiltration of water into soil profile are the rate and the cumulative amount. Measurement and numerical solutions have shown that the infiltration rate in a uniform, initially dry soil when rainfall does not limit infiltration, decrease with time and approaches an asymptotic minimum rate (Saiko and Zonn, 2003). Available data in literature showed that there are variations in the infiltration rates of tropical soils including soils of the study area. According to Antigha and Essien (2007), these variations are due to high rainfall, land use type, and the influence of vegetation. Observably, the dynamics of soil characteristics in relation to this changing infiltration rate may act in different proportion as either assets or constraints to the quality of land resources.

Several researchers have studied the contributions of soil physical parameters as particle size distribution, bulk density, total porosity and saturated hydraulic conductivity (Ks), when compared with infiltration behaviour (Melvis., 2001) Shukla, 2003, Zhan and Charles, 2004; Antigha and Essien 2007). However, there have been no studies on isolating the effects of different landuse practices on the infiltration characteristics of coastal plain sandy soils. Isolation of the effects of land use treatments will enable an assessment of infiltration capacity under different landuses in a given watershed. Such effects are realizable by the two terms of sorptivity, S and the A, parameter of the Philips equation (Philips, 1957b).

2. Study area

The study area is Calabar, Nigeria. It lies between longitude $8^0$15 and $8^0$25' E and Latitude $04^0$15' and 04^0 56' N. The experimental sites were located at Ikot Edem Odo, Obufa Esuk and University of Calabar research forest. The area experiences annual average rainfall of between 2000-3500 mm , with relative humidity of 80 to 100 per cent and vapour pressure of 29 milibars throughout the year (NAA 2006). The relief is low lying, within elevation of 17.6m above sea level. The geology of the study environment comprise of sedimentary deposits of fluvio marine origin, and composed of sand, silt, clay and alluvial materials. Species of mangrove are the dominant vegetation of the coastal and riverine ecosystem. Greater concentration of these is found along banks of the "Great Kwa" river that drains the landscape.(Fig.1).

The existing tracts of natural forest is made up of woody and non-woody plants, including massive trees, shrubs, herbs, climbers and abundant biological diversity. However, the resource richness is constantly facing extinction arising from human activities as farming, logging, urbanization and construction work.

3. Method of study

Three major landuses were identified for this study viz, forest, farmland and grassland near the Great Kwa river watershed. Infiltration measurements were carried out in rainy season using cylinder infiltrometers on soils of the different landuses. A metal tube was driven into the ground to a depth of 10cm with a sledge hammer to avoid lateral flow of water. Care was taken to prevent damage to soil structure in the process.

A constant ponding level of 5 cm was maintained in the metal tube (ring) throughout experimental runs. With the aid of a timer, readings were taken at intervals. The readings continued until a steady state of equilibrium (usually 180 minutes) was reached.

Soil samples were collected using short cylindrical iron cores of about 5cm long and 3cm in diameter for bulk density, particle size distribution, total porosity and particle density determination. The soil samples were labeled and taken to laboratory for analysis.

Saturated hydraulic conductivity (Ks) values of each landuse was estimated by the clay content based soil component method of the EPIC (Erosion induced productivity loss index calculator) model developed by William, Jones and Dyke (1984).

4. Computation of saturated hydraulic conductivity (Ks)

Saturated hydraulic conductivity of soils was estimated by the clay content based soil component method of EPIC (Erosion Induced Productivity loss Index Calculator) Model developed by William, Jones and Dyke (1984).

The equation is given as:

$$Ks = \frac{12.7\,(100\text{-CLA})}{100 - \text{CLA} + \exp(11.45\text{-}0.097)(100\text{-CLA})} + 0.25$$

Ks is the saturated hydraulic conductivity in Cmh^{-1} while CLA is the percentage clay in the soil layer.

5. Result and discussion

Tables 1, 2 and 3 show the equilibrium infiltration rate of soils after a period of three hours (180mins) of field measurements. It is evident that, of the three landuses; forest, farmland and grassland, forest recorded the highest infiltration value of 17.4cm/hr. The high infiltration rate under this landuse is due to the addition of organic matter and biological activities on the one hand and the loosening of surface soil arising from lateral spread of roots on the other. Forest also has dense vegetal cover, that exert significant influence on infiltration. Sharma (2000) observed that the presence of a dense vegetal cover on the surface increases infiltration as soils under such landuses , have higher water absorption capacity in the event of heavy storm than other landuses.

Infiltration rate in farmland reached steady state after 90 minutes. Tillage practices involving the use of hoes and diggers contributed in altering the soil structure. The cultural practice, very often affects soil pores as the migration of fine colloidal materials or inwash down the profile become inevitable in the process. The colloidal particles in turn usually swell and cause pore surface sealing. This reduces the sizes of voids and lowers infiltration with time (Tami and Leong, 2004).

Grassland and forest landuses attained equilibrium infiltration rates at 120minutes despite variations in final values of 12cm/hr^{-}1 and 17.4cm/hr^{-1} recorded. This implies that, grassland is less porous than forest. The improvement in the infiltration rate under grassland is premised on the presence of adventious root system which creates miniature channels that conduct water and moderate its flow down the soil profile.

Table 4 indicates the particle size characteristics of soils of the study sites. The textual analysis revealed that the soils are predominately sandy loan with negligible quantity of clay in soil layers. The range in textual characteristics indicates 7.2, 4.7 and 7 per cent of sand silt and clay confirming the preponderance of sand deposits in soil layers of landuses. Inferentially, the region has a monothological sedimentary characteristics.

Antigha and Essien (2007) maintained that soils of this category lack cohesion, facilitates shearing and tend to have excessive infiltration that encourage leaching.

Table 5 presents values of saturated hydraulic conductivity in soil layers of landuses. Since infiltration is a surface phenomenon, the contribution of landuse treatment was calculated with only the Ks of the top soil layer (0-15cm).

The Ks of the predominant sand loam soils exhibited high values because most of the clay content had been washed down through leaching and excess infiltration from the surface beyond the hydrological zone of soils.

Studies have shown that, clay content in soil layers stabilizes infiltration rate of soils (Glenn, Delmar, Williams and Richard (1995). Thus, variations in clay content of soils in different landuse of forest (5.0), grassland (5.7) and (6.3) farmland, per cent as indicated in the table above accounts for their water holding capacity over time. Generally, a decline in colloidal clay particle in soil layer marks a degradation of affected landuse with obvious consequence on poor infiltration rate, erosivity, leaching and reduction in land potential for productive use by man.

6. Conclusion

The study demonstrated the effects of landuse in coastal plain soil susceptible to erosion and leaching. Infiltration rates measured showed that of the three land uses of forest, farmland and grassland, farmland suppressed infiltration; grassland showed marginal improvement while forest had the highest value. Clay content estimation using clay base equation revealed a decline of (Ks) factor in stabilizing soil water movement.

Hence, soils here are porous and lack the potential to maximally support plant growth , unless treatment administration measures are evolved.

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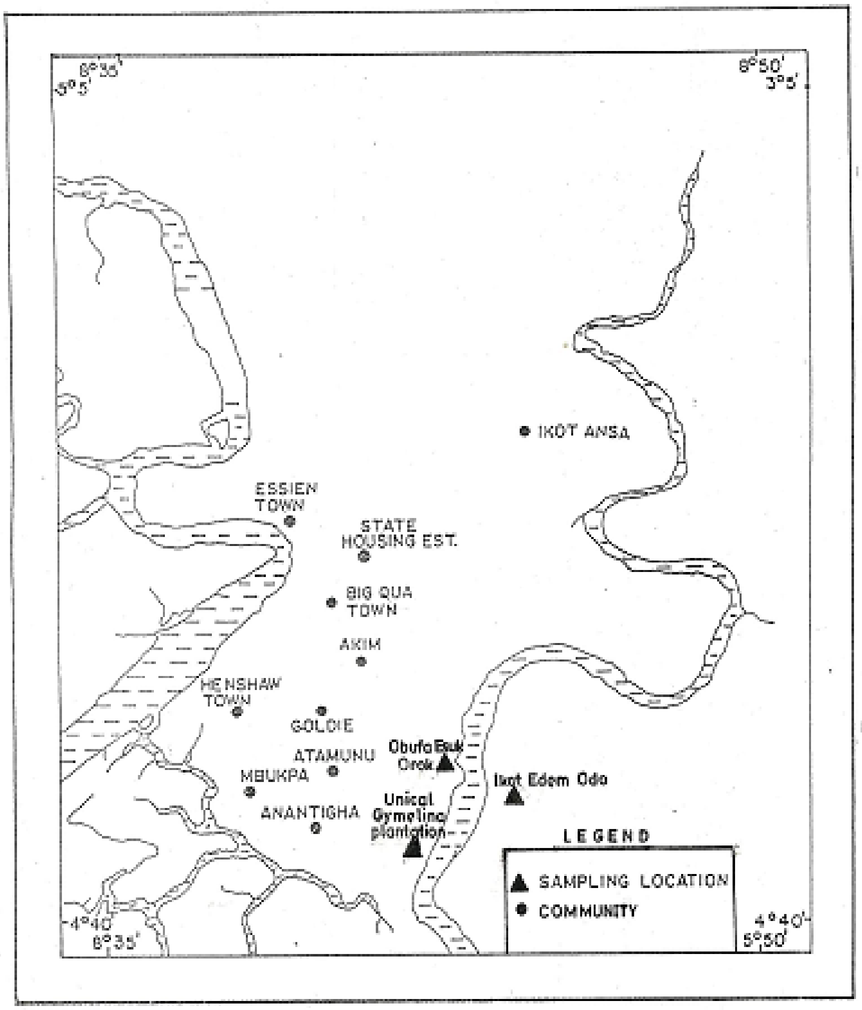

Fig. 1: Map of the study area showing sampling locations

Source: Fieldwork, 2011

Table 1, Equilibrium infiltration rate of grassland

Interval Mins	Cumulative time(mins)	Cumulative Intake(Cm)	Cm mins	Cm/hr^{-1}
0	0	0	-	-
5	5	1.6	0.32	19.2
5	10	3.4	0.34	20.4
5	15	5.0	0.33	19.8
5	20	6.6	0.33	19.8
5	25	8.0	0.32	19.8
5	30	9.4	0.31	18.6
10	40	12.0	0.30	18.0
10	50	14.0	0.28	16.8
10	60	16.0	0.27	16.2
15	75	18.8	0.25	15.0
15	90	21.2	0.24	14.0
30	120	23.7	0.20	12.0
30	150	32.6	0.20	12.0
30	180	36.0	0.20	12.0

Fieldwork 2011

Table 2, Equilibrium infiltration rate of forest

Interval Mins	Cumulative time(Mins)	Cumulative intake(cm)	Cm mins	Cm/hr^{-1}
0	0	0	-	-
5	5	1.8	0.36	21.6
5	10	3.2	0.32	19.2
5	15	5.2	0.35	20.8
5	20	7.0	0.35	20.8
5	25	8.8	0.35	20.8
5	30	10.2	0.34	20.4
10	40	12.8	0.32	19.2
10	50	16.8	0.33	19.8
10	60	18.8	0.31	18.8
15	75	23.0	0.31	18.8
15	90	27.2	0.30	18.8
30	120	35.2	0.29	17.4
30	150	42.8	0.29	17.4
30	180	52.2	0.29	17.4

Fieldwork, 2011

Table 3 : Equilibrium infiltration rate of farmland

Interval Mins	Cumulative time(Mins)	Cumulative intake(cm)	Cm mins	Cm/hr^{-1}
0	0	0	-	-
5	5	1.2	0.24	14.4
5	10	2.0	0.20	12.0
5	15	2.5	0.17	10.2
5	20	4.0	0.20	12.0
5	25	4.5	0.18	11.0
5	30	5.5	0.18	11.0
10	40	7.2	0.18	11.0
10	50	8.8	0.18	11.0
10	60	10.6	0.18	11.0
15	75	11.6	0.15	10.0
15	90	14.8	0.16	9.6
30	120	18.6	0.16	9.6
30	150	24.4	0.16	9.6
30	180	28.8	0.16	9.6

Fieldwork, 2011

Table 4 Physical properties of soils from different experimental sites

Landuse	Sand %	Silt %	Clay %	Particle density Mgm^{-3}	Bulk density mgm^{-3}	Total porosity%
Forest	83.3	11.0	5.7	2.3	1.5	35
Grassland	87.3	7.7	5.0	2.5	1.5	4.0
Farmland	80.1	6.3	5.2	2.0	1.49	36

Fieldwork, 2011

Tabe: 5 Values of Ks in soil layers in different landuses

Landuse	Clay in soil layer %	Ks (Cmh^{-1})
Forest	5.0	36.0
Grassland	57	35.0
Farmland	6.3	32.1

Fieldwork, 2011.