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# Evaluation of Soil Management and Soil Degradation

Anita Sachan[1], Venkat Nagarjun[2]
[1, 2] Department Of Agriculture, National Institute Of Agricultural Extension Management , Rangareddi , Telangana

## ABSTRACT

**Bulk density was significantly increased in all the treatments with highest value (1.65Mg/m ) in bare fallow and lowest value (1.43Mg/m ) in grass. There was no significant decrease in porosity and pore size distribution. Mean weight diameter (MWD) of aggregates and saturated hydraulic conductivity (Ksat ) were significantly increased. The least values for MWD (1.06mm) and for Ksat (25.80cm/hr) and highest for MWD (2.09mm) and for Ksat (49.20cm/hr) were obtained under bare fallow and grass treatments respectively. The percentage aggregate size above 2.0mm was highest in grass and lowest in bare fallow. Calculations showed significant positive correlation (r = 0.50) between organic matter and MWD. There was significant negative correlation (r = -0.60) between organic matter and bulk density and highly significant positive correlation (r = 0.800) between organic matter and saturated hydraulic conductivity.**

***Keywords—*** Cover management, physical properties, organic matter, non-tillage, aggregate stability

## I. INTRODUCTION

Vegetative degradation is regarded as a reduction in the available biomass, and decline in vegetative ground cover. It may result from deforestation and overgrazing. Such degradation is likely to be a major contributory factor to soil degradation particularly with regard to soil erosion and loss of soil organic matter.

The main factor directly or indirectly responsible for soil and land degradation process is water erosion (Spaan, 2005). The severe surface erosion is linked with intensive precipitation, high detachability of surface soil materials and reduced infiltration. This is induced by poor and weak soil structure and by poor cover of vegetation or plant residue in critical periods. Most arable soils of the world suffered from serious problems of degradation due to high rate of runoff erosion. This has posed a great threat to agricultural sustainability as it decreases actual and potential soil productivity (Lal, 1998).

Combating vegetation degradation either through natural grassland or planted crops has the potential to contribute directly to the maintenance and improvement of soil productivity. Vegetation cover protects the soil from intense precipitation of rain and detachability of surface materials. It reduces runoff, conserved the moisture and retains sediment and organic debris. It also allows drainage of excess water due to their semi-permeable nature.

Conventional tillage which creates favorable environment for crop growth, can also damage pore continuity and promote dispersion of clay forming crust and create dense, non-friable clods and aggregates.

There are several research works on the influence of tillage on run-off and soil loss in West Africa (Obi, 1982). However, fewer works have been carried out on zero tillage and selection of crops that will provide maximum cover to the soil as well as economic benefit to the farmers. The use of sorghum (*Sorghum bicolor*) and cocoyam to provide immediate soil cover has not been extensively studied in the Southeastern zone of Nigeria. It has become necessary therefore to provide information in this regard by identifying the management practices that would protect the soil resource and restore lost productivity. The objective of the study is to evaluate the effects of vegetative covers on the physical properties of the soil.

## II. MATERIALS AND METHODS

### Site Description

This study was carried out on fairly steep (5% slope) runoff plots established by Soil Science Department, University of Nigeria Nsukka in 1973. The run off plots measured 20m x 3m and spaced 50cm apart. Asbestos sheets were driven into the soil to a depth of 10cm along the top ends and sides of the plot. The study area is located between latitude $06^{0}$51'N and longitude $07^{0}$ 24'E, and mean elevation of 400m above sea level. The plots were established to monitor the long-term effects of different soil/crop management practices on soil loss and run-off.

The soil is an Ultisol (Acrisol, FAO; sol ferrallitique, French system) belonging to the Nkpologu series. It is deep, porous, and red to brownish red and derived from sandy deposit of false bedded sand stones, classified as typic paleustult.

The area is characterized by a humid tropical climate with wet and dry season (Obi, 1982). The rainfall is bimodally distributed with annual total of about 1750mm.The mean annual temperature is $27^0$C with minimum and maximum of $21^0$C and $31^0$C (UNN meteorological station).

**Land Preparation and Layout**

In early May 2004 experimental plots were selected at the run-off site. Each of these plots had been left fallow, for about 5years. All the plots were carefully cleared using cutlass and local hoes without destroying the structure of the soil. The experimental plots were arranged in a completely randomized design (CRD) with five treatments and three replications. Each treatment plot with an area of 61.8$m^2$ and total area of the experimental site was 0.093ha. Non-tillage practice was applied to all the plots. The treatments include; BF (Bare fallow), CY (Cocoyam), SG (Sorghum), CP (*Centrosema pubescens)* PM (*Panicum maximum)*

**Crop Establishment**

The test crops were Cocoyam (CY) and Sorghum (SG). Cocoyam was planted at the rate of one corn per hole and at a planting distance of 46cm x 46cm with a careful opening of soil by hoe. Sorghum was planted at the rate of 3 seeds per hole and thinned to a stand at 4 weeks after planting (WAP). The planting distance was 75cm x 60cm. *Centrosema pubescens* (CP) and *Panicum, maximum* (PM) were established through seedlings. The bare plots were kept weed-free by means of a hoe.

## III. OBSERVATIONS

**Particle Size Distribution**

Particle size analysis was carried out using the method of hydrometer as described by Gee and Bauder (1986). The pretreatment entailed the dispersion of sample with sodium-hexameta-phosphate. In this method, soil samples were soaked in calgon for 24 hours and later stirred with mechanical agitator before the hydrometer test.

**Mean Weight Diameter**

The distribution of aggregates was estimated by the wet-sieving technique and mean weight diameter (MWD) of the stable aggregates was determined by the method of Kemper and Rosenau (1986).

$$MWD = \sum_{I=1}^{n} x_i w_i$$

Where, MWD is the mean weight diameter of stable aggregates $X_i$, the mean diameter of each sieve fraction (mm) and $W_i$ the proportion of total sample weight in the corresponding size fraction, after deducting the weight of sand (upon dispersion and passing through the same sieve). Higher values of MWD indicate the dominance of less erodible, large aggregates of the soil.

**Soil Moisture Retention**

Water retention at low suctions was determined using the same core sample used for bulk density and porosity. The metal cores used had dimensions of 5.5cm diameter and 5cm height. After saturation for 24 hours the cores were used to measure soil water retention at 0.06 bar using 60cm tension table and then oven dried at $105^0$ C for 24hours.

**Saturated Hydraulic Conductivity**

Saturated hydraulic conductivity, (K) was determined by Klute (1986) method.

**Pore Size Distribution**

Total porosity was determined using undisturbed cores method. Macro porosity and micro porosity were determined from the volumetric water content at field capacity (Plint and Plint, 2002).

**Bulk Density**

The soil dry bulk density was determined using the core method.

**Organic Matter Content**

Organic matter content was determined in duplicate using Walkley and Black's method.

## IV. RESULTS AND DISCUSSION

**Texture and Organic Matter**

The textural analyses of the soils under the different management practices for the two years of study are presented in Table 1. The results show that there was no change in the texture of the soil as a result of various management practices introduced. The soil had predominantly sandy loam texture. The inability of the different management practices to change the texture might be attributed to the fact that texture is a function of parent material (Obi and Anikwe,1999).

There was no significant change in organic matter content of the soil in the first year (2004) of study. In the second year (2005), organic matter content was significantly increased by the different treatments as compared to bare fallow. Increase in organic matter content might be attributed to recycling of plant biomass and organic debris (Zhang et al., 2007). Addition of organic manure and increase in root biomass apparently improves organic matter contents.

**Table 1: Particle size distribution and organic matter content of the top (0-15cm) soil**

| Treatments | Organic matter content g/kg | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|---|
| **2004** | | | | | |
| Bare fallow | 10.3 | 82.8 | 4.9 | 12.3 | SL |
| Cocoyam | 10.9 | 84.1 | 3.9 | 12.0 | SL |
| Sorghum | 11.2 | 82.1 | 5.9 | 12.0 | SL |
| *Centrosema pube scens* | 11.0 | 85.0 | 3.2 | 11.8 | SL |
| *Panicum maximum* | 14.0 | 83.4 | 3.9 | 12.7 | SL |
| LSD (p=0.05) | NS | | | | |
| **2005** | | | | | |
| Bare fallow | 10.5c | 81.4 | 3.6 | 15.0 | SL |
| Cocoyam | 11.8bc | 82.0 | 5.0 | 13.0 | SL |
| Sorghum | 13.2b | 81.3 | 3.7 | 15.0 | SL |
| *Centrosema pubescens* | 12.2b | 82.6 | 4.4 | 13.0 | SL |
| *Panicum maximum* | 14.8a | 82.6 | 3.4 | 14.00 | SL |
| LSD (p=0.05) | 0.152 | | | | |

In the column, values followed by the same letter are significantly differentNS=Non significant

**Bulk Density, Total Porosity and Pore Size Distribution**

Data related to bulk density, porosity, pore size distribution and MWD are presented in table 2.It is apparent from table 2 that in 2004, the differences observed among the treatments with respect to bulk density were not significant. In 2005, the bulk density decreased by the treatments excluding bare fallow and the differences observed were statistically significant.

According to Milton et al., (2006) soils under conservation tillage practices usually exhibit higher soil bulk density and lower total and macro porosity compared to those under conventional tillage practices. This result also agrees with the work of Greenland (1981), which reported increase in bulk density under zero tillage. The highest bulk density (1.65Mg/m ) observed in 2005 under bare fallow may be attributed to rain drop impact and top soil removal by erosion (Mbagwu et al., 1984).

It was observed that there was no significant effect on total porosity and pore size distribution due to treatments. The effect of treatments on the MWD for the first year (2004) was not statistically significant. This may be attributed to low organic matter contents. Significant effect of the treatments (PM, CY, SG, and CP) were observed on bare fallow. The results indicated that the soil under cover treatments exhibited higher stability compared to under bare fallow. This might be attributed to the buildup of organic matter in the soil during the first and second years of the experiment.

**Aggregate Size Distribution**

Aggregate size distribution is shown in Figure 1.

**Table 2: Physical properties of the top (0 – 15cm) soil**

| Treatments | Bulk density ($Mg/m^3$) | Total porosity (%) | Macro-porosity (%) | Micro-porosity (%) | MWD (mm) |
|---|---|---|---|---|---|
| **2004** | | | | | |
| Bare fallow | 1.5 | 45.9 | 11.4 | 34.5 | 1.0 |
| Cocoyam | 1.5 | 47.1 | 18.4 | 28.5 | 1.6 |
| Sorghum | 1.4 | 46.0 | 17.5 | 28.7 | 1.6 |
| *Centrosema pubescens* | 1.5 | 48.4 | 18.1 | 30.3 | 1.7 |
| *Panicum maximum* | 1.4 | 45.8 | 13.0 | 32.8 | 1.8 |
| Mean | 1.5 | 46.6 | 15.7 | 31.0 | 1.6 |
| LSD (p=0.05) | NS | NS | NS | NS | NS |
| **2005** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Bare fallow | 1.6b | 47.1 | 14.0 | 33.0 | 1.0b |
| Cocoyam | 1.5ab | 46.9 | 13.8 | 33.0 | 1.6a |
| Sorghum | 1.5a | 46.0 | 16.6 | 30.1 | 1.7a |
| *Centrosema pubescens* | 1.5a | 45.2 | 16.1 | 29.1 | 1.8a |
| *Panicum maximum* | 1.4a | 44.4 | 9.4 | 35.3 | 2.1a |
| Mean | 1.5 | 45.9 | 14.0 | 32.1 | 1.7 |
| LSD(p= 0.05) | 0.07 | NS | NS | NS | 0.56 |

In each column, values followed by the same letter are not significantly different.NS=Non significant

It was clearly observed that the size range greater than 2.0 mm was lowest (17.0%) for soil under bare fallow compared to the grass (61.6%), cocoyam (41.0%), sorghum (40.0%) and legume (33.2%).The soil under bare fallow has the highest percentage of micro-aggregate (19.8%) whereas grass has the lowest size (10.4%). These small size soil particles can easily be lost with runoff (Zhang et al.; 2007). The poor aggregation in legume could be traced to poor establishment of legume in the first year.

**Saturated Hydraulic Conductivity (Ksat)**

Saturated hydraulic conductivity (Ksat) of the soil under different cover management practices is presented in Table 3. In 2005 there was significant treatment effect.

**Interrelationships Between Organic Matter and Physical Properties**

In the first year there was no significant relationship between organic matter and bulk density, but in the second year organic matter significantly and negatively correlated with bulk density (r = -0.622).This indicates that low organic matter contributed to the increase in bulk density.

Organic matter content had significant positive correlation with MWD of water-stable aggregates in the second year (Table 4) which indicates that organic matter is a major binding agent and addition of organic materials by plant to the soil improved the soil structure. According to (P > 0.05) with Ksat value ranging from 25.80 cm/hr in BF to 49.20 cm/hr in PM. In the first year there were no significant differences in the Ksat values under the various treatments. This is as results of low organic matter contents which is responsible for soil aggregation. Generally, the plots with plant cover tended to show higher hydraulic conductivity values compared to those under bare fallow. The higher Ksat value observed under vegetative cover and no-tillage may be due to channeling and loosening effects of root and soil fauna (Greenland; 1981).

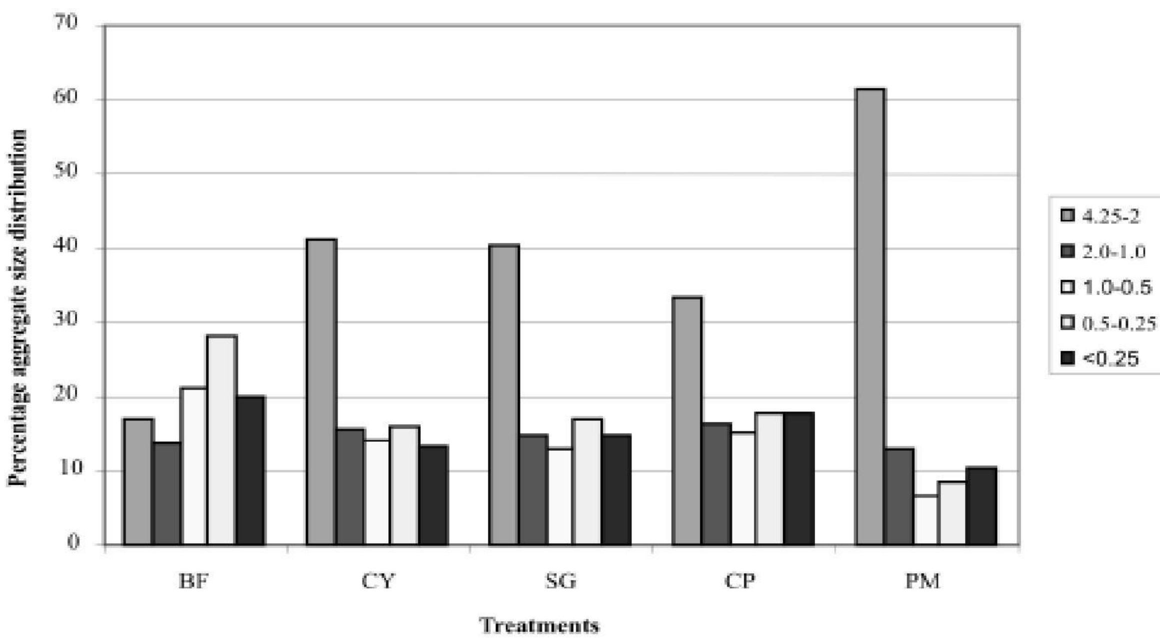


**Fig 1: Aggregate size distribution of the soil after 2 years under different cover management**

**Table 3: Saturated hydraulic conductivity (cm/hr) of the top (15cm) soil**

| **Treatments** | **Saturated hydraulic conductivity** | |
|---|---|---|
| | **2004** | **2005** |
| Bare fallow | 19.3 | 25.8b |
| Cocoyam | 21.8 | 30.7ab |
| Sorghum | 28.7 | 34.4ab |
| *Centrosema pubescens* | 30.3 | 39.8ab |
| *Panicum maximum* | 22.8 | 49.2a |
| LSD (p=0.05) | NS | 17.0 |

In the column, values followed by the same letter are not significantly different. NS=Non significant

Mbagwu et al. (1984), the type of surface active agents which enter the soil was important in maintaining soil aggregate stability.

Organic matter content showed a highly significant positive relationship with saturated hydraulic conductivity in the second year (r = 0.765). The positive relationship between organic matter and hydraulic conductivity implies that organic matter influenced the soil structure, and enhanced better flow of water.

**Table 4: Correlation between organic matter content and soil physical parameters**

| **Parameters** | **r-values (2004)** | **r-values (2005)** |
|---|---|---|
| Organic matter Vs bulk density | - 0.125 | -0.622* |
| Organic matter Vs Mean weight diameter | 0.398 | 0.529* |
| Organic matter Vs saturated hydraulic conductivity | 0.045 | 0.765** |

* = significant at 5% level of probability, ** = significant at 1% level of probability

## V. CONCLUSION

The study clearly indicates that the cover management practice has greatly improved the soil physical properties. This is as a result of increase in organic matter level and aggregate stability. The higher aggregate stability was associated with low bulk density. The significant increase in hydraulic conductivity indicates better infiltration and percolation of water. Therefore, cover management practices should be encouraged in farming system for a sustainable production.

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