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ALLEVIATING SOIL COMPACTION BY ORGANIC AMENDMENTS ON CROPPING FIELDS IN A PART OF NIGERIA'S SAVANNA REGION

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Abstract

It is well recognised that organic amendments in cropping field, especially on long term, alleviate soil compaction. The extent of such however varies clearly with soil condition, bioclimatic conditions of an area, levels of the amendments themselves, cropping history and land management techniques each of which can vary from an area to another. In this article, a brief report is given of a study conducted to examine the combative effects of long term (1961-1991) organic manure amendments on two key indices of soil compaction (bulk density and total porosity) in Konduga area of Nigeria's Sudano-Sahelian region. This was done by examining soils of 15 farmer-managed plots, and those of uncultivated plots under long-standing, semi-natural vegetation cover. The results obtained reveal that even though the cultivated plots vary in age, of between 5-30 years, as at the time of soil sampling (1991), there are very low spatial variations in mean values of the two soil structural properties of the 15 plots. The properties of the cultivated plots have been maintained at about 100% of the values of the same properties of the uncultivated plots. These results thus suggest that on both short and long term bases, the use of organic manure in soil fertility maintenance in the study area can possibly reverse the degradative trends occasioned by soil compaction.

Introduction

Soil compaction has been estimated to be responsible for the degradation of an area of 83 million hectares worldwide, of which 18 million lies in Africa (Soane and Van Ouwerkerk, 1994). There is also widespread evidence for the prevalence of problems in crop production which are attributable to soil compaction caused by the passage of vehicles, implements and draft animals in both tropical and temperate regions (Low, 1972; Tiarks, et. al., 1974; Adeoti, 1983; Soane and Van Ouwerkerk, 1994). Some notable effects of soil compaction include decreased stand uniformity and plant growth, restricted root growth, reduced soil aeration, water infiltration, internal drainage and effectiveness of underground drainage systems.

Larson, et al. (1994) have argued that beside controlling the level of vehicular and animal traffic on cultivated fields, incorporation of agronomic practices that prevent or alleviate soil compaction might help in overcoming these negative effects. Among such practices are crop rotations which require a minimum traffic, cultivation of crops that produce organic materials for maintenance of soil organic matter or crops with perpetrating and fibrous root systems (Salau, et al., 1992). Other practices include direct incorporation of organic manures on cultivated fields, animal grazing management and liming (Agboola and Obatolu, 1989). Infact, several research workers have demonstrated that organic manure amendment very well serves as an important tool of amending soil structure (Mays, et al., 1973; Sommerfeld and Chang, 1985; Campbell, et al., 1986; Swift and Woomer, 1993).

It needs to be known however that the effectiveness of any practice of combating soil compaction certainly differs with soil condition, bioclimatic conditions of an area, levels of amendment, cropping history and land management techniques, each of which can vary from an area to another. Thus, every soil needs to be examined within its own context. Because of such an intricacy, Van Ouwerkerk and Soane (1994) concluded that there is a pressing need for researchers to adopt a more rigorous approach to the conduct of basic researches

on how different measures perform under different set of soil conditions. It is against this background that a decision was taken to carry out an examination of the extent to which organic amendments help combat soil compaction in cultivated soils of Konduga area of Nigeria's Sudano-Sahelian region. In this area, no previous study has been conducted to evaluate the relative efficiency of organic amendments in combating soil compaction despite the area's long agricultural history and importance. It is expected that a study of this kind can possibly guide us on the appropriateness or otherwise of a given practice in reversing the degradative trends associated with soil compaction in the area. Bulk density is the most fundamental and widely used index for assessing and quantifying the extent of soil compaction in cultivated soils (Campbell, 1994), but since total porosity related directly with bulk density (Adeoti, 1983), the two could be used complimentarily.

Materials and Methods

Site Information

Konduga area (12° 50' - 13° 40' North Latitude and 11° 00' - 11° 38' East Longitude) is located in the transitional zone between Sudan and Sahel savanna ecosystems of Northern Nigeria. The area is underlain by young sedimentary rocks of the Chad formation and it is geomorphologically classed in the Ngadda Catchment Complex of the Katagum dune field. The dominant feature of the relief here are the fixed dune systems of the ancient erg of Hausaland, which are low sand hills of varying height from 10m to 30m, and form most of the upland surfaces where extensive rainfed cultivation takes place. The experimental site for this study is located on one of such hills. The area enjoys a semi-arid climate with distinct wet and dry climatic regimes. Rainfall is highly irregular and unpredictable, so much that drought and crop failures are not uncommon in the area (Oladipo, 1993). Temperature is high for most times of the year, being about 27°C on average. The vegetation of the area, though now greatly modified by human activities, is xeromorphic in character and is dominated by slow-growing thorny species consisting largely of *Acacia seyal, Balanites aegyptica* and *Balliostigma reticulata* (Keay, 1959). The soils of the area are described as typical ALFISOLS (Ustalfs) according to the USDA soil taxonomy (Soil Survey Staff, 1992). The soils are generally sandy to loamy in their surface and are characterised by clay-enriched subsoil. They are low or very low in most nutrient elements, but due to slightness in leaching processes their base saturation percentage is very high (being about 80% on average). The soils are being extensively cultivated, and soil fertility is being maintained by the use of organic manure while the plant and crop residues are burnt on the cultivated fields after the growing season with the hope of returning back to the soil the nutrient elements immobilised in crop tissues. In some cases, however, livestock are allowed to consume part of the residue while the rest is eventually burnt.

Field and Laboratory Methods

The ideal way of comprehensively examining the long term effects of organic amendments on soil compaction is to carry out a time-series examination of the soil condition so as to observe the pattern of temporal changes. In the absence of such a long term monitoring, an inferential approach involving side-by-side comparison of soils under amendment and those without such amendments could alternatively be used provide provide a guide as to the extent to which the amendments are favourably improving soil conditions (Abubakar, 1997). Such an approach could be employed provided that:

(i) they are all located within an area of relatively fairly uniform climatic, geologic and geomorphic characteristics so as to eliminate the inherent differences that might exist in soil condition of the plots prior to the commencement of the cultivation practices;

(ii) they have the same management history, i.e. they must be under the same condition prior to being put into cultivation and that they are cropped with the same crops, in the same way.

In this way, 15 different cultivated plots were selected. The area where they are located has been under long-standing, semi-natural forest reserve until 1961 when it was first opened-up for small-holder farmers. Corn, millet and beans are planted after initial harrowing using tractor. Subsequent ploughing using bullock powered plough, manual grass weeding and use of organic manure made up of dung of cows, donkeys, sheep and goats, at the rate of about 100kg per ha-per annum, in soil fertility maintenance is common. At the end of growing season, part of the crop residue is either eaten up directly on the farmlands by grazing livestock or taken away from the fields and given to domesticated animals while the rest is burnt on the fields with the

hope of returning the nutrients immobilised in the crops back to the soil. At the time of field sampling (June, 1991), the cultivated plots vary in age from 5-30 years. From each plot, a quadrant of 20m by 20m was chosen and using a systematic sampling procedure ten topsoil samples (0-15cm) were collected using bulk density rings thereby making a total of 150 samples from the 15 cultivated plots. From part of the area that is still under forest reserve, 15 quadrants, also of 20m by 20m dimensions, were chosen and the same procedure was followed to collect 150 topsoil samples. The uncultivated plots were chosen to serve as the modification of soil compaction in the cultivated plots under which manure application would be assessed. The area where the plots are located have slope angles of between 1-2 degrees , and since they are more or less located side-by-side one another, it is expected that the effects of variations in geology, climate and geomorphology would be minimal. Thus, the differences in the state of soil compaction of the chosen cultivated and uncultivated plots could be greatly attributed to the difference in the prevailing management practices on the two categories of plots. The collected soil samples were analysed for bulk density, using core method, and from the bulk density values obtained, total porosity was computed using standard procedures as described by Campbell (1994).

Statistical Analysis

Descriptive statistics (mean, standard deviation, standard error of the mean, and coefficient of variation percentage) were computed for each plots' categories, for each of the two structural soil properties. This was after an analysis of variance (ANOVA) had been conducted to test for significant differences in the two structural properties 15 cultivated, and between the 15 uncultivated plots. When the results revealed insignificant difference, the idea of comparing individual age-grade cultivated plots with the uncultivated plots was subsequently dropped. Instead, the data for the 15 cultivated and uncultivated plots were added to find the mean, for each callawy. Furthermore, a student's t-test was used to test for significant difference between the two mean values (i.e. between the cultivated and control plots).

Results and Discussion

Table 1 displays the summary statistics of the soil samples' analyses conducted. A close look at the table reveals that while the bulk density value is higher over the control plots, the total porosity is comparatively lower.

Table 1: Summary results of soil samples' analyses conducted

	Bulk Desnsity		Total Porosity	
Variable	Cplots	Coplots	Cplots	Coplots
Mean	1.08	1.12	48.60	47.30
SD	0.02	0.01	2.51	3.71
SEM +	0.02	0.01	0.36	0.54
CV %	1.92	9.94	5.16	7.84

SD = Standard Deviation, SEM = Standard Error of Mean, CV = Coefficient of Variability, Cplots = Cultivated plots, Coplots = Control plots, N = no. of observations for each plot category (i.e. soil samples per plot categories = 75).

Since the differences between the two means are not statistically significant, it is arguable here that the impact of organic amendments on structural properties of cultivated soils of the study area is so great that it has caused the levels of the two structural soil properties under the cultivated plots to be at comparatively similar levels with the same properties under the uncultivated semi-natural vegetated plots. This could further be observed in Table 2 where it is shown that the value of the two properties for the cultivated plots are about 95% and 103% respectively for the bulk density and total porosity, which are similar to those of the control plots.

Table 2: Analysis of the effects of organic amendments on the two structural soil properties of the cultivated plots

Soil Property	DRM	CST	SGD	% Eq.	% C30
BD	0.04	0.01	NS	96.43	-3.57
TP	-1.30	0.46	NS	102.75	2.75

BD=Bulk density, TP=Total porosity, NS=No significant difference,
DRM = Different between the two means (mean for the control minus mean for the cultivated plots)
CST = Calculated value of 't' using the t-test
SGD = Significance of the difference between the means
% Eq. = Percent equivalence (100 * mean for the cultivated plots/mean for the control plots)
% c30 = Percentage change for 30 years (DRM * 100/mean for the control plots)

Consequently, the changes in the bulk density value of the cultivated plots resulting from 5-30 years of cultivation practices were, courtesy of organic manure amendments, kept at very low rates (about 3.6%), while in the case of total porosity, an increase of about 2.8% was recorded. This result further confirms the role of organic matter in reversing

soil compressibility and comparatability as the reason for these observed trends. In Beltsville area of Madison (USA), Tester (1990) has, also observed how organic amendments results in about 45% reduction bulk density and concomitant increase in water contents following 10 years of organic amendments. According to MacRae and Mehuys (1985) such a concomitant increase could translate into increased plant-available water in a soil. In a recent review, Soane (1990) has furthermore, pointed out that several researchers have demonstrated that as organic matter content of a soil rises, the extent of soil's compressibility and compactability diminishes sharply. Summerfeldt and Chang (1985) have however observed that the decline in soil bulk density due to organic manure amendments depends more on the amount incorporated rather than the technique. The average rate of incorporation of organic manure on cropping fields in the study area (about 100kg per ha/annum) could be considered as being fairly adequate enough to reverse the degradative trends associated with soil compaction.

Conclusion

On the basis of the results obtained here, it could be concluded that even on a short-term basis, organic manure application at the rate of 100kg per ha/annum in the study area could maintain bulk density and total porosity values of cultivated soils at levels comparatively similar with those under semi-natural vegetated soils. It is probable that the structural condition of the soils would further be improved if the rate of application exceeds 100 kg per ha/annum. Beside increasing the rate, one other measure that could also help in this regard is crop residue retention on the cultivated fields, as compost. Tester (1990), has argued that an annual compost of 100 kg/ha would result in adequate yields and substantial modification of soil properties. However, Larson et al., (1994) have argued that such a retention often results in horizontal and vertical non-uniformity in soil structural condition, which may eventually lead to impaired water distribution in the cultivated field.

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