Nigerian Journal of Soil Science 24 (2014) 134 – 146

Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

FERTILITY MANAGEMENT EFFECTS ON SOIL PHYSICAL AND CHEMICAL PROPERTIES UNDER LONG-TERM MAIZE CROPPING IN AN ALFISOL IN NORTHERN GUINEA SAVANNA ZONE

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ABSTRACT

Long - term productivity and sustainability of agro-ecosystems has been of great concern in agriculture for decades, hence development of various new approaches designed to maintain and protect soil resources in the Nigeria Northern Guinea Savanna. Intensive cultivation of land requires continuous application of inorganic fertilizers, especially N fertilizers and organic amendments to maintain soil fertility and productivity. Effect of long-term management practices and input factors were evaluated in this study in an Alfisol at Samaru, Zaria. Changes in soil quality were assessed by measuring appropriate physical and chemical indicators from 2006 to 2008 Rain-fed cropping seasons. Soils were sampled at 0-10 cm (surface) and 10-30 cm (subsurface) and analyzed for chemical and physical properties. Data obtained were analyzed using the SAS statistical package for ANOVA and means were separated with DMRT at 5% level of probability. The study was established in 1997 and maintained till 2008. The treatments consisted of inorganic-N fertilizer (urea) and manure (cow dung) applied at 90 kg N ha^{-1} (sole or mixed-(45kg N inorganic-N + 45kg N manure).Results showed that application of manure in combination with sole inorganic-N fertilizer at the rate of 90 kg N ha^{-1} increased soil pH value by 1%, soil organic carbon by 68 %, total nitrogen by 51% and available phosphorus by 83 % at the surface compared to sole inorganic-N. Cation exchange capacity (CEC) was significantly improved by 28% at the surface and 67% at the subsurface levels. Furthermore, soil bulk density was significantly reduced by 12%, total porosity was increased by 6 %, available moisture contents at field capacity and permanent wilting point were increased by 60% and 25% respectively compared to sole inorganic-N fertilizer treatments. To sustain soil fertility for optimal crop yields, adoption of a balanced fertilization programme that combines inorganic-N fertilizer with manure is recommended.

Key words: Continuous cropping, manure; inorganic-N fertilizer; soil fertility; maize; Alfisol.

INTRODUCTION

Long - term productivity and sustainability of agro-ecosystems has been of great concern in agricultural production systems for decades, leading to the development of various new approaches to maintain and protect soil resources (Harris and Bezdicek, 1994). The problem is associated with the conservation and maintenance of the amount of soil organic matter, which is a vital component of soil productivity. The amount of organic matter in the soil is a function of the total input of organic amendments contributed by cultural practices (Gregorich et al., 1996). Hence, Soil and fertility management practices, such as continuous cultivation, residue management and fertilization, exert a considerable influence on the level of organic matter deposited in soil over time.The benefits of balanced fertilization using organic manure, crop residues and green manuring in maintaining soil organic matter levels has been widely studied. Soils of the Nigerian Northern Guinea Savanna (NGS) ecological zone are dominated by low-activity clays and are low in soil organic matter (SOM), hence have low buffering capacities (Odunze,2003). However, continuous intensive cultivation with application of sole urea fertilizer, could alter the soil physical and chemical properties by decreasing the pH and reducing the content of exchange bases which may lead to soil degradation (Odunze et al., 2012).

As a result of these problems and the increasing level of soil degradation, the use of sole urea fertilizer has been greatly minimized in crop production practices at present (Vanlauwe *et al.,* 2001; Odunze *et al.,* 2012). This has led to the development of integrated soil fertility management strategies through research efforts by combining organic and inorganic amendments to enhance crop production to a sustainable level. The combination of organic and inorganic amendments would reduce the amounts of synthetic fertilizers needed, and the amounts of nutrients contained in the synthetic fertilizers may be more efficiently utilized (Vanlauwe *et al.*, 2002). A combination of organic and synthetic amendments has been reported to improve crop yield and soil fertility levels (Palm *et al.,* 1997; Vanlauwe *et al.,* 2002; Odunze *et al.*, 2012).

The study therefore was aimed at evaluating the comparative effects of long-term application of organic manure and inorganic fertilizers on the physico-chemical properties of the soil, which are factors that are directly related to soil productivity.

MATERIALS AND METHODS

Experimental field Characteristics

The field trial was a long- term experiment established in 1997 at the Institute for Agricultural Research (IAR) Samaru, Zaria, in the Northern Guinea Savanna ecological zone of Nigeria. The field is located at longitude $11^{\cdot}16^{o}$N and latitude $7^{\cdot}64^{o}$E at 683 m above sea level. The soil was silty loam in texture having 47% sand, 43% silt, and 10% clay, pH 5.20 (H_20); organic carbon, total nitrogen, available phosphorus and CEC (5.37, 0.45, 11 gkg^{-1} and 2.73 cmol kg^{-1} respectively (at the commencement of trial in 1997 (Ogunwole *et al.,* 2010). The top soil was sandy loam in texture with 54% sand, 32% silt, and 14% clay,and the subsoil was clay loam with 42% sand, 29% silt,29% clay at the beginning of this study in 2006 (Eche, 2011). It was a leached tropical ferruginous soil, classified as Typic Haplustalf in the USDA system (USDA, 1998). Mean annual rainfall (1997-2007) was 1084.65mm and fell within the months of May- October, while the average annual temperature was 26.36^{o}C (IAR Meterological station, 2007).

The treatments consisted of inorganic-N fertilizer (urea) and manure (cow dung) applied at the rate of 90 kg N ha^{-1} (sole or mixed- 45kg N inorganic-N + 45kgN manure).The treatments were arranged in a randomized complete block design with three replicates. Plot size was 36 m^2 (6m by 6m). The manure was incorporated into the furrows about 10cm deep below the original soil surface a week before planting. Each experimental plot consisted of 8 ridges with the four inner ridges used as net plots while the two outer ridges were used as the sampling plots. The maize variety used as test crop throughout the study period (1997-2008) was Oba Super II, which is a long duration (110-120 days), drought tolerant, and N efficient hybrid (Heuberger, 1998). At 2 weeks after planting (WAP), the first dose of inorganic-N fertilizer was split – applied (⅓) for plots requiring inorganic-N fertilizer treatment. The remaining two third (⅔) of the inorganic-N fertilizer was applied in 5 WAP. In 2003, nutrient omission trial was conducted and results obtained confirmed possible limitations of Zn, K, S, and Mg. From 2004 to 2006, a yearly blanket application of 180 kg $MgSO_4$ $ha^{-1}$and 3 kg $ZnSO_4$ ha^{-1} (corresponding to 3 kg Zn, 18 kg Mg, and 25 kg S ha^{-1}) were made to all plots and K application rate was also increased from 30 – 50 kg K ha^{-1}.

Soil Sampling and Chemical Analysis

Eight disturbed Soil samples were taken on a diagonal transect of each plot from depths of 0 – 10 and 10 – 30 cm respectively. The samples were bulked to form a composite sample per plot and per depth and sub-samples taken for chemical analyses. Samples were taken at tarselling (reproductive) stage of the maize crop,which is the critical stage of maize growth and taken once to determine the soil conditions at optimum period of nutrient uptake by the crop.

Soil pH was determined both in water and 0.01M $CaCl_2$ solution at a soil to solution ratio of 1:2.5. Organic C was determined by the dichromate oxidation method (Nelson and Sommers, 1982).Total and inorganic N (NO_3-N, NH_4-N) were determined by the Kjeldahl method (Bremner and Mulvaney, 1982; Okalebo *et al*., 2002). Available P was extracted by the Bray-1 -method (Bray and Kurtz, 1945). Exchangeable bases and cation exchange capacity were determined by the methods described by Kundsen *et al*. (1982).

Measurements of Soil Physical Properties

Eight undisturbed soil samples were taken on a diagonal transect of each plot from depths of 0 – 10 and 10 – 30 cm respectively for soil physical property determination.Bulk density (BD) was determined by core method and moisture content by the gravimetric method using undisturbed soil cores (Blake and Hartge, 1986), while total porosity (f) was calculated from the bulk density of the soil.

Statistical Analysis

Preliminary and group contrast data obtained for rain-fed cropping season (June-September/October) of each year were analysed by standard ANOVA procedures and also pooled over two years of cropping maize. The analysis of variance was performed using the GLM Proc. of SAS (SAS, 1999) and treatment means were compared using Duncan's Multiple Range Test (Duncan, 1955) at 5% level of probability. Principal component analysis (PCA) was carried out to identify the soil properties that most importantly explained variability in maize grain yield (Litchter *et al*., 2008; Hinojosa *et al*., 2004: Wander and Bollero, 1999).

RESULTS

Soil Chemical Properties

Result of soil pH (Table 1) showed a slight pH decrease at the subsoil (10-30cm depth) compared to the surface soil (0-10cm depth). The pH values ranged from 5.30 – 5.44 in the surface soils and from 5.10 – 5.25 in the subsurface soils. Application of manure alone (pH5.46- surface, 5.25-subsurface) at the rate of 90 kg N ha^{-1} increased pH value by 2% at the surface and 1% at the subsurface levels while application of mixed manure and inorganic-N fertilizer (pH 5.44-surface, 5.20-subsurface) increased pH by 1.4 % at the surface and 1.2 % at the subsurface compared to sole inorganic-N (pH 5.37-surface, 5.14-surbsurface).

Result obtained for soil organic carbon (SOC) showed a general decline in the soil for all treatments (Table 1). The SOC contents in the sole inorganic-N fertilizer plots ranged from 1.03 to 2.43 g kg^{-1} with C: N ratio of 2 to 3.Treatments involving manure gave higher OC (OC 4.09 g kg^{-1}, C: N ratio 6). Application of mixed manure and inorganic-N fertilizer (OC 4.09 g kg^{-1}) at the rate of 90 kg N ha^{-1} increased SOC by 42 % at the surface and

76 % at the subsurface compared to sole inorganic-N fertilizer application.

The total nitrogen (TN) content of the soils was generally low for all treatments (Table 1). Treatments involving manure incorporation alone statistically ($p<0.5$) gave the highest level of TN (0.57 g kg^{-1}),followed by manure mixed with inorganic-N (0.53 g kg^{-1}), at 90 kg N ha^{-1}. Application of manure mixed with inorganic-N fertilizer increased TN by 51% at the surface and 73 % at the subsurface levels compared to sole urea at the rate of 90 kg N ha^{-1}.

Available phosphorus (AP) was observed to decrease generally with depth (Table 1). The AP contents at the 0-10cm depth were higher in treatments involving manure, although the values were in the moderate range (10-19 mg kg^{-1}). Application of mixed manure and inorganic-N at the rate of 90 kg N ha^{-1} increased AP by 83 % at the surface and 70% at the subsurface levels.

Results for cation exchange capacity (CEC) showed higher CEC values at 10-30 cm depth compared to the 0-10 cm depth (Table 1). The high CEC values obtained in the mixed manure and inorganic-N treated plot compared to sole inorganic-N at 90 kg N ha^{-1} showed improvement by 28 % and 67% at the 0-10 and 10-30 cm depths respectively.

Soil physical properties

The results obtained for the bulk densities showed higher bulk density at 10-30 cm depth compared to 0-10 cm depth (Table 2). The soil bulk density values obtained for the incorporation of animal manures were lower (<1.45 g cm^{-3}) compared to the values for sole inorganic-N fertilizer (>1.52 g cm^{-3}).

Total porosity values obtained were lower at the subsoil (10-30 cm) than at the top soil (0-10 cm). The incorporation of manure as a soil amendment increased total porosity at both depths compared to sole inorganic-N fertilizer.

Soil moisture content at -33 kPa was lower at the 0-10 cm depth compared to the 10-30 cm depth. Higher moisture retention was observed with the treatments involving animal manure at 0-10 cm depth compared to the 10-30 cm depth.

Saturated hydraulic conductivity (Ks) of the various treatments was also affected though high variability in the results obtained.

In summary, inorganic-N fertilizer in combination with manure at 90 kg N ha^{-1}at the 0-10cm depth, significantly reduced soil bulk density by 12 % (1.36 g cm^{-3}), improved total porosity by 8% (50 %), available moisture contents at field capacity by 60% (0.2 kPa) and permanent wilting point by 25% (0.10 kPa) compared to sole inorganic-N fertilizer treatments (1.54g cm^{-3}, 46%, 0.10 kPa and 0.08 kPa).

Principal Component Analysis of Soil Chemical Properties

Table 3 shows the results of Principal Component Analysis (PCA), which was performed separately to determine which chemical properties were most useful in accounting for the variation among fertility treatments.The factor loadings of chemical properties on the PCA showed the following overall ordination: P>CEC>TN>0C. Available P (AP) and CEC were the most important variables for PC1 and; cumulatively explained 49% of the total variation within the soil fertility treatments (Table 3).

Principal Component Analysis of Soil Physical Properties

The PCA output for the physical parameters is summarized in Table 4. Only PCs with eigen values >1 that explained at least 5% of the total variance were retained for interpretation. Sixty-one percent of the variance (proportion) was explained by PC1 and was dominated by soil moisture retention at field moisture capacity (FMC), permanent wilting point (PWP) and total porosity (TP); with a negative loading for soil bulk density (BD). The PC2 was dominated by saturated hydraulic conductivity (SHC) and explained an additional 19 % of the total variance while PC3 explained a further 12 % of the total variance. The factor loadings of soil physical parameters on PCA therefore showed the following ordination: TP> soil moisture (FMC) > soil moisture (PWP) > SHC.

DISCUSSION

The low pH values obtained at the 10-30 cm depth could be due to reduced organic matter content at this depth (Eche, 2011). The earlier application of 180 kg $MgSO_4$ and 3 kg $ZnSO_4$ from 2004 to 2006 could have left strong residual acidity in the soil. This is because the presence of sulphate ions could contribute to soil acidity. The application of manure alone or in combination with sole inorganic-N fertilizer increased pH value by 1% unit at the surface and 0.2% at the subsurface levels compared to sole inorganic-N. Perhaps, the organic manure at decomposition mitigated soil acidity even at the immediate subsoil level (10-30 cm).

The relatively low soil organic carbon (SOC) in the sole inorganic-N fertilizeris largely due to non- addition of organic matter to the soil as well as the high rate of organic mineralization in the Nigerian NGS. Because of the high diurnal temperature, the rate of decomposition is rapid which depletes residual carbon in the soil. The higher levels of SOC obtained in the treatments involving manure incorporation (sole or mixed) could be due to the fact that the manure may have provided more C as an energy source for microbes, while the introduced manure was undergoing rapid mineralization due to its narrow C: N ratio. The general decline in SOC could be due to incidence of rapid mineralization of OM in the NGS soils and also due to the effects of runoff and erosion.

The generally low TN for all treatments may be due to plant uptake, runoff and leaching effects. The higher TN content in manure treated plots was due to the production of good biomass. The significantly ($p<0.05$) generally lower TN in the sole inorganic-N fertilizer treated plots could be due to the rapid growth of maize and consequently, higher uptake of N to the detriment of the microorganisms, since the N in the inorganic-N fertilizer is in soluble form and readily available to the plant. This result agrees with the findings of Adeboye (2006). The higher TN obtained from manure showed narrow C: N ratios indicating higher rate of decomposition of organic materials which is common with most Savanna Soils (Tarawali *et al*., 2001) and soil quality improvement (Ogunwole, 2005).

Available phosphorus (AP) was observed to decrease generally with depth. This could be due to the fact that P is not mobile in soil. Manure have been observed to release considerable amounts of organic acids into the soil thereby resulting in the hydrolysis of organic P; hence, improving P-nutrition for plant and microorganisms (Rao *et al*., 2002; Li *et al*., 2003,2004). This could be the reason for the higher P levels obtained in the manure treatments compared to inorganic-N fertilizer treatment.

Higher CEC values at 10-30 cm depth showed that nutrients like Ca and Mg may have illuviated into the subsoils (10-30 cm depth) and influenced CEC at that depth.This agrees with the findings of Odunze and Kureh (2006) who observed that the organic colloidal fractions were low in soils of the Samaru area indicating that nutrients in these soils were susceptible to leaching. Results obtained from this study showing CEC values in the range of 3 - 12 cmol kg^{-1} for both soil depths, suggests a dominance of low activity clays (sesquioxides and kaolinite clays) and organic colloidal fractions (Odunze and Kureh, 2006). The high CEC values obtained in the manure treated plots (mixed) compared to sole inorganic-N at 90 kg N ha^{-1} showed that the potential of the soil to exchange cations had been improved by 28% and 67% at the 0-10 and 10-30 cm depths respectively, showing that the soil quality has been upgraded.

Soil physical properties

Lower soil bulk density at the 0-10 cm depth appeared to be due to incorporation of manure which contributed to improved soil physical conditions compared to sole inorganic-N treatment. This agrees with the findings of Ogunwole (2005), who found that soil quality increases with low bulk density, aggregate strength and residue cover. Evanylo and McGuinn (2000) observed similar trend and suggested that bulk density values of 1.55 to <1.65 g cm^{-3} can affect root growth and development in silt loams, while soil bulk density of $\leq$ 1.40 g cm^{-3} were ideal for optimum root growth.

The higher total porosity values obtained from treatments involving incorporation of animal manures could be due to their increased organic carbon inputs and the abundant root biomass which supported the stability of their microaggregates. This agrees with the findings of Ogunwole et al., (2010) who reported improved microaggregate stability under long - term incorporation of legume residue.

The higher soil moisture retention observed in the manure treated plots indicated better conditions for plant water and nutrient uptake, leading to good crop growth and development, and this enables the plant to withstand period of drought. This would result in higher crop yield in the manure-amended soils compared to the sole inorganic-N fertilizer treatments. Vanlauwe *et al*., (2001) observed large numbers of maize plants being barren in sole urea treatments due to stress resulting from low soil water and N availability.

Saturated hydraulic conductivity (Ks) of the various treatments was affected though there was high variability in the results obtained due to difficulties in obtaining representative undisturbed core samples. This may result to lateral movement of roots and water when water cannot percolate down as a result of hard pan or laterite pan (Ogunwole, 2005). The presence of roots and other macro pore channels coupled with the fact that laboratory measurements were on undisturbed smaller diameter soil cores, could be additional reasons for such variability. This finding agrees with the work of Abdulkadir, (2006) who observed high variability in Ks due to difficulty in obtaining representative undisturbed core samples. As a result of the wide differences in the results obtained, the Ks values determined using laboratory analysis of soil core samples cannot be expected to give reliable results.

This improved physical quality attributes enhanced soil pH, organic carbon, total nitrogen, available phosphorus and CEC. The higher SOC in the manure treated plots could be attributed to greater soil water holding capacity, nutrients availability in plants, improvement of soil physical properties and the efficiency of fertilizer nutrients by organic amendments (Benbi *et al*., 1998).

The findings of the PCA of soil chemical properties supported the ANOVA results (Table 1), and showed that the soil chemical parameters that dictate variability include AP and CEC and these captured about 49% of the variability. However, AP was strongly related given that the study soil is mostly strongly acidic (pH 5.1 – 5.6) and P will be more readily available under acid condition.

Principal components analysis of soil physical properties indicated that the plant available water (soil moisture retention at FMC and PWP) was the physical parameter that best influenced variability on field and this captured about 61% of the variability. These results were consistent with Harris *et al*. (1996) and Ogunwole, (2005) who found that soil quality decreases with increasing bulk density and increases with aggregate strength and residue cover.

CONCLUSIONS

Results of this study indicate that combined application of inorganic-N fertilizer with manure had a profound effect on cation exchange capacity, bulk density, total porosity and soil moisture content at the soil surface. Under this treatment the soils were acidic both at surface and subsurface layers and had low OC and TN contents. Also, bulk density (1.36g cm^{-3}), total porosity (49 %), available moisture contents (0.16 kPa and 0.10 kPa respectively) of the soils were improved upon relative to the inorganic-N fertilizer treatments (1.54g cm^{-3}, 45 %, 0.10 kPa and 0.08 kPa respectively).In conclusion therefore, combined application of inorganic-N fertilizer with manure was found to restore and maintain soil fertility in the long-term trial for sustainable soil productivity at Samaru, NGS ecological zone of Nigeria.

ACKNOWLEDGEMENTS

The authors acknowledge the partial financial support of the University Board of Research, Ahmadu Bello University, Zaria. Thanks are expressed to Mallam Ilu and Mr Anthony Ibitoye both of the Department of Soil Science for their technical support.

Table 1: Soil Chemical Properties at 0-10 cm and 10-30cm depths at tarselling stage comparing S (sole manure or sole inorganic-N) and M (mixed manure and inorganic-N) at 90 kg N ha^{-1}

Treatment	pH10	OC10	TN10	AP10	CEC10	pH30	OC30	TN30	AP30	CEC30
Manure	5.43a	3.35a	0.58a	18.97a	5.96a	5.21a	1.49a	0.45a	7.38a	10.66a
Inorganic-N	5.33b	1.03b	0.33b	5.92b	3.41b	5.13b	0.70b	0.20b	1.50b	4.88b
Control	5.30b	0.20b	0.10c	1.00c	1.73c	5.10b	0.40b	0.05c	0.75c	2.79c
SED	0.031	0.058	0.046	0.143	0.428	0.048	0.079	0.047	0.189	0.526
Significance *	*	*	*	*		*	*	*	*	*
SI-90	5.37b	2.43c	0.35c	8.25b	3.57b	5.14b	1.17b	0.23c	3.33b	5.52b
Mixed- 90	5.44a	3.45b	0.53b	15.06a	4.57a	5.20a	2.06a	0.40a	5.66a	9.22a
SM- 90	5.46a	4..09a	0.57a	18.82a	5.94a	5.25a	1.25b	0.38b	5.07a	10.70a
SED	0.034	0.058	0.058	0.175	0.295	0.036	0.053	0.053	0.186	0.632
Significance	*	*	*	*	*	*	*	*	*	*
Contrast										
SI-90 vs M-90	*	*	*	*	*	*	*	*	*	*
SM- 90 vs M-90	NS	*	*	NS	NS	NS	*	*	NS	NS
SI-90 vs SM-90	*	*	*	*	*	*	NS	*	*	*

Table 2: Soil Physical Properties comparing site and mixed organic and inorganic fertilizers.

Treatment	BD_{10} (gcm^{-3})	TP_{10} (%)	SHC_{10} (cm sec^{-1})	Soil Moisture content (kPa) -33	-1500	BD_{30} (gcm^{-3})	TP_{30} (%)	SHC_{30} (cm sec^{-1})	Soil Moisture content(kPa) -33	-1500
Manure	1.25b	53.40a	8.43bc	0.20a	0.12a	1.50c	43.95a	27.96a	0.12bc	0.09a
Inoganic-N	1.54a	44.41c	4.79c	0.10b	0.07bc	1.67b	37.52b	18.99ab	0.15a	0.06b
Control	1.56a	41.13c	14.33a	0.08c	0.06c	1.75a	23.27c	10.30b	0.09c	0.04c
SED	0.006	0.006	0.011	0.005	0.006	0.006	0.006	0.006	0.006	0.006
Significance	*	*	*	*	*	*	*	*	*	*
SI-90	1.54a	45.83c	4.79b	0.10b	0.08b	1.58a	39.45b	10.30c	0.13a	0.06a
M-90	1.36c	49.53b	12.78a	0.16a	0.10ab	1.58a	44.32a	27.91a	0.13a	0.07a
SM-90	1.27b	53.40a	4.89c	0.18a	0.12a	1.57a	42.91ab	14.34b	0.14a	0.08a
SED	0.013	0.006	0.010	0.005	0.006	0.005	1.344	0.006	0.006	0.006
Significance	*	*	*	*	*	NS	*	*	NS	NS
Contrast										
SI-90 vs M-90	*	*	*	*	NS	NS	*	*	NS	NS
SM-90 vs M-90	*	*	*	NS	*	NS	NS	*	NS	NS
SI-90 vs SM-90	*	*	*	*	*	NS	NS	*	NS	NS

Means in the same column followed by the same letter(s) are not significantly different at $p<0.05$; SED: standard error difference; NS: Not significant; SI-90&SM-90:sole inorganic-N and sole manureat 90kg N ha^{-1} respectively; BD: bulk density; TP: total porosity; SHC: saturated hydraulic conductivity; M90: mixed inorganic & manure; *: Significant at 5% level of probability; 10 & 30: 0-10 cm and 10-30 cm depths.

Table 3: Principal Components Analysis of soil chemical properties

	Principal Component			
Measurements	PC1	PC2	PC3	PC4
Eigen values	12.80	4.32	2.24	1.56
% Contribution	49.23	16.57	8.61	6.00
Cumulative Percent	49.23	65.80	74.41	80.41
Chemical Parameters	Rotated Score of six retained eigen vectors			
PH 1	0.443	0.319	-0.167	**0.701**
OC1	**0.690**	0.172	**-0.546**	0.197
TN1	**0.825**	0.424	0.086	-0172
Av.P1	**0.923**	-0.024	-0.056	0.038
Ca1	**0.889**	-0.107	-0.021	0.158
Mg1	**0.589**	-0.251	0.348	-0.182
K1	**0.752**	0.238	-0.299	0.138
Na1	0.485	**-0.665**	0.338	0.325
CEC1	**0.913**	-0.149	0.048	0.111
PH2	0.004	**0.502**	-0.041	**0.613**
OC2	**0.598**	0.181	**-0.531**	-0.333
TN2	**0.811**	0.351	-0.208	-0.156
Av. P2	**0.874**	0.052	-0.437	0.022
Ca2	**0.924**	-0.275	-0.056	0.090
Mg2	**0.828**	-0.466	-0.125	0.056
K2	**0.923**	-0.003	-0.060	0.029
Na2	**0.723**	**-0.528**	0.287	0.157
CEC2	**0.918**	-0.316	-0.069	0.084

Values in bold (>0.500) represents chosen parameters that explains variation with the treatments; 1&2: 0-10 & 10-30 cm soil depths respectively.

Table 4: Principal Components Analysis of soil physical properties

	Principal component		
Measurements	PC1	PC2	PC3
Eigen values	6.12	1.89	1.15
% contribution	61.18	18.89	11.47
Cumulative percent	61.18	80.07	91.54
Physical Parameters	Rotated Scores of three retained eigen vectors		
BD 1	**-0.812**	-0.134	0.498
TP 1	**0.967**	0.095	-0.109
-33a	**0.964**	0.207	0.013
-1500a	**0.939**	-0.106	-0.081
SHC 1	-0.099	**0.825**	**0.511**
BD 2	**-0.876**	0.000	0.055
TP 2	**0.797**	-0.397	0.300
-33b	0.106	-0.787	**0.577**
-1500b	**0.913**	-0.212	0.091
SHC2	**0.677**	**0.553**	0.428

Note: 1 and a: 0-10cm depth; 2 and b: 10-30cm depth; Values in bold (>0.500) represents chosen parameters that explains variation with the treatments.

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