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Impact of Bush Burning on Nutrient Cycling in the Federal Capital Territory Abuja, Nigeria

Edicha Jibril A.

Abstract

The paper examined the pattern of distribution of nutrients on soils subjected to regular burning with that of un-burnt soils for about five years in Abuja, the federal capital territory. Both transact line and quadrant techniques were employed to collect soil samples at a depth of 0.15 cm in both burnt and un-burnt plots which were analyzed for texture, pH, C.E.C, available phosphorus, soil organic carbon and exchangeable Ca, mg and K. The student t-test was employed in order to compare the value of soil properties in both burnt and un-burnt plots. From the analysis, there is a significant difference in soil organic carbon, total nitrogen, soil pH, exchangeable bases and cation exchange capacity amongst soils subjected to regular burning and that of the soils that were not burnt for a period of about five years. It is significant at both 0.01 and 0.05 levels.

1.0 Introduction

Wild fire has long had an impact on ecosystem structure and function. The direct transformation of living and dead organic matter in vegetation and soils to charred organic matter and ash is a clear change wrought by fire (Raymond et al 2006).

The ecological effect of specific fire on soils and vegetation referred to as both "fire severity" and "burn severity" can be more subtle and depends on the degree of combustion of living and dead organic matter, nature of the soil and the impact of the fire's heat on the physical and chemical properties of the soil (Neary *et al.*, 2005). Remote sensing is a tool applicable to the characterization of the direct impact of fire on vegetation and soil properties, both of which are important to the understanding of burn severity and post fire ecosystem process.

In areas of complete combustion, vegetation growth and successional processes begin a new without the shade cast by overstory and understory vegetation. In conifer forests that are subject to incomplete combustion, scorched needles on trees cast shade and affect post-fire species dynamics (Roire, 1983). Once dropped, these needles contribute to the soil nutrient pools and can reduce erosion (Pannkuk and Robichaud, 2003). Lightly scorched and un-burnt forest areas act as seed sources for vegetation re-growth.

Soils are also altered by fire in complex ways. The deposition of ash and charred materials from the combustion of living and dead organic matter increases available nitrogen and phosphorus for uptake by vegetation and micro-biota (Debano *et al.*, 1998 and Knoepp *et al.*, 2005).

However, an underlying soil of calcareous nature can immobilize P, making it unavailable for plant growth (Knoepp *et al.*, 2005).

The plentiful cations in the ash residue for example K, Ca and mg, increase the cation exchange between soils and plants, yet ash deposits are easily removed by water and wind erosion. Soils with clay minerals can better retain the cations with some forms of clay having greater affinity for cations, such as montmorillonite compared to others, such as kaolinite (Knoepp *et al.,* 2005 and Grim, 1968). In areas greatly heated by the fire, soil structure can be destroyed and water infiltration rates reduced, producing rapid run off and hills slope erosion (Debano *et al.*, 1998). The type of clays in soils have been shown to have large impact on erosion, with soils containing clays in the smectite family being associated with less rainfall infiltration and higher rates of soil loss (Ben-Hur and Agassi, 1997 and Reichert *et al.,* 1994). In soils heated by fire, iron bearing materials in the soil can be oxidized, imparting a reddish colour to the soil. This oxidization is often used as a qualitative indicator of burn severity in soils (Neary *et al.*, 2005).

Hyperspectral remote sensing data have been shown to be capable of detecting carbonate clay and iron bearing minerals in soils (Chabrillat et al 2002 and Clark *et al.*, 2003a), though no studies targeted at detecting specific soil mineral following wild land fires with hyperspectral data are known to have been conducted with respect to fire. Hypersectral remote sensing data have been used in estimating "burn severity" (Van Wagtendok *et al.*, 2004) and tracking vegetation re-growth (Riano *et al.*, 2002).

Moore (1960) had reported that in the Nigerian savanna, mild fires at the beginning of the dry period resulted in increases in cation exchange capacity, in available phosphorus, in exchangeable Ca, mg and K and in percentage base saturation. However, hot fires coming late in the dry season were found to reduce the cation exchange capacity and exchangeable Ca and potassium, while available phosphorus and the exchange capacity remained unchanged and the base saturation only slightly increased. Edwards (1942) also reported that in Kenya the base exchange capacity of regularly burned grass land decreased probably as a result of reduction in the humus content of the soil. Cook (1939) had reported a small reduction in total nitrogen of the upper 38mm of soil resulting from regular burning of Themeda grassland in southern African. The result here is quite contradictory although in many cases it seems that there is a definite increase in nitrogen following burning. Moore (1960) studied the situation in derived savanna in Nigeria. In plots protected from burning he found nitrogen to be the lowest. Essentially, the focus of this study is to examine the beneficial effect of burning on soils in Kubwa, Abuja with a view to determining the desirability or otherwise of retaining the slash and burn practices of agricultural system.

2.0 **Materials and Methods**

2.1 Site Descriptions

The soil samples were taken in Kubwa in Bwari Area Council of the Federal Capital Territory, Abuja which lies between latitude 8^0 25' and 6^0 45' and 7^0 39' east of the Greenwich meridian.

The vegetation in the study area is dominated by herbaceous plant which are occasionally interspersed with shrubs. The grass elements include species of Andropogon gayanus, Andropogon pseudapricus, imperieta cyclindrica and loudieta arundinacea while the tree elements include parkia biglobosia, daniellia oliver and butyrospermum paradoxium. The local soil is mainly luvisols which is a product of down-wash from hills. The soil is associated with interfluves.

2.2 Experimental Design

The experiment was arranged in a transect line technique in which soil samples were taken from a transect of about 105m at an interval of 40 meter each in the case of the plot that was subjected to regular burning while a quadrant approach was considered for the plot that was not burnt for the period of about 5 years. A plot size of about 20 by 20m was considered. This approach was adopted because an un-burnt plot was not common and the only visible plot was obviously very small in size. Two soil samples were taken from the plots that were regularly burnt while three soil sample were taken from un-burnt plot at a depth of 0-15cm because beyond this level, the soil is difficult to dig.

2.3 Sampling Procedures

The following analytical procedure were employed to analyze the soil samples collected from the field, the soil texture was analysed using pipette method, organic matter by walkly-black and nitrogen by using macro Kjeldahl method. Available phosphorus was determined using Bray No. I method, cation exchange capacity was determined using ammonium acetate extraction method. The exchangeable bases were extracted from the soil samples using ammonium concentration of Ca and mg were determined using atomic absorption spectrophotometry while those of K and Na were determined using flame emission method and finally soil pH was determined using electrometric method as described by Kellman 1979.

2.4 Statistical Analysis

All data were subjected to student t-test in order to determine the mean difference between soils subjected to regularly burning to that of un-burnt plot for five years. Significance was determined at both 0.01 and 0.05 levels.

4.0 Results and Discussion

This section discuses the results of soil physico-chemical analysis collected from both burnt plots and un-burnt plots.

From the data in Table.1, the total sand fraction remains very high in all the plots ranging from 66% to 80%. The silt content in each of the plot is less than 15%. Meanwhile, the clay content is relatively higher than that of the silt content. However, the clay contents in samples 1 and 2 on soils of un-burnt plot is higher than the rest samples. The clay content in the sample plots ranges from 14 to 22%.

The soil reaction is an understanding of chemical characteristics of soil solution. It is measured in terms of activity of the hydrogen ion concentration expressed by the term pH. It shows that soil pH in $CaCl_2$ solution ranges from 6.50 to 8.30 indicating that using pH scale, it fluctuates between neutrality, slightly alkaline to moderately alkaline. Soils on plots 1 and 3 in un-burnt plots are slightly alkaline while soil on plot number 2 is relatively neutral. These soils samples tend towards alkalinity probably because of the abundant presence of calcium which tends to counter balance the hydrogen ions that may lead to soil acidity. Also, the amount of organic matter present is low amongst the

Table 1: **Result of soils analysis from both burnt and un-burnt plots**

Sam-ple	Particle size distribution Corrected in 20°C%				pH Ratio 1:25		(%)			(mol/kg)					
No.	Clay	Silt	Sand	Textual Class	H_20	0.01m $CaCl_2$	SOC	TN	AP	Va	Mg	K	NA	H + al	CEC
1	18	10	72	Sandy Loam	7.60	7.30	0.81	0.14	42.00	2.05	1.84	0.24	2.35	0.20	8.20
2	22	12	66	Sandy Clay loam	7.00	6.50	0.69	0.12	11.38	4.42	2.12	0.11	2.52	0.20	12.30
3	14	6	80	Loamy sand	7.40	7.10	1.80	0.18	11.38	29.50	1.94	0.16	2.26	0.10	35.60
4	14	10	76	Loamy sand	7.80	7.60	1.49	0.19	91.00	11.60	2.86	1.89	1.65	0.10	20.20
5	16	14	70	Sandy loam	8.50	8.30	1.32	0.16	28.00	20.00	3.80	2.56	2.17	0.10	29.60

Source: Laboratory analysis, 2007.
Note: samples 1,2,and 3 represent soils on un-burnt plots while samples 4 and 5 represent soils on burnt plots.

sample plots hence the tendency to produce humic acid from organic decomposition is low hence the probability for the existence of acidity is equally low. Furthermore, the rate of microbial activity is low hence the production of carbonic acid is also low and this may equally affect the pH of the soil. In the same vein, plot numbers 4 and 5 are relatively alkaline.

Furthermore, using water solution as reflected in table.1, the results generally indicate the soil pH is relatively alkaline in nature. From this result, burning seems to affect the soil pH. However, the time lag between the burning and when the samples were collected may be taken into consideration. Also, nutrient cations replace H^+ to raise the pH and this reduction in acidity is perhaps the single most change caused by burning.

The relatively high pH values obtained in all the sample plots conformed with the report of Parker and Muller (1982) that the savanna soil have relatively high pH.

The distribution of soil organic carbon in the sample plots is relatively low as shown in Table.1. SOC in plots 1 and 2 are quite low. They are 0.81 and 0.69 percent respectively while plot number 3 in an un-burnt soil plot is higher (1.08%). Soil organic carbon seems to be low probably because the litter accumulation is generally low in savanna ecosystem hence low carbon accumulation. Also because of the slow rate of litter accumulation, the microbial activities is also low or may be non-existence and hence may be responsible for the low amount of soil carbon.

However, in sample number 3 of un-burnt soil sample plot, soil organic carbon is put at 1.08% (Table.1). This may not be unconnected to the fact that though the sample has remained un-burnt for years but the plot is being subjected to cultivation sometimes hence there was probability for litter accumulation from the plant residues as well as the accumulation of organic manure to the site. Furthermore, the relatively increase in carbon inputs may be due to litter and from a greater abundance of herbaceous roots at shallow depth.

Also, sample number 4 and 5 in burnt plots, as shown in Table 1, indicate that SOC are 1.49 and 1.32 percent respectively. This relatively higher value for SOC may be due to the accumulation of organic ashes after burning which are usually released at once. In addition, burning results in accelerated organic matter decomposition (mainly as a result of site exposure) with attendant decline in soil nitrogen content. Also, after burning biological activities in the soil may be impaired which could trigger anaerobic activities hence increase in organic carbon.

From table.1, it can be easily deduced that the result does not agree with the works of Belsky *et al.*, (1989) who reported that organic matter accounts for 90 to 98% of soil nitrogen and phosphorus.

Samples 1 and 2 are generally low in nitrogen content, 0.14% and 0.12% respectively while sample number 3 has 0.18%. On the other hand, soils on plots 4 and 5 have 0.19% and 0.16% respectively. Esu (1991) set low, medium and high fertility category limits with total N as <0.15, 0.15 – 0.20 and 0.20% respectively. The result of the data analysis have confirmed the generally low total N in the savanna soils (Jone and Wild, 1975; Kowan and Kassam, 1978). The result obtained here with respect to total nitrogen seems to support the report of Cook (1939) in Themeda grassland of South Africa.

Fire has been reported to increase site nutrient losses as compared to other forms of forest clearing (Ewel *et al.,* 1981, Kyuma *et al.,* 1985). These increases are partly attributed to losses in the burning process itself, but also to dramatic increases in surface erosion after burning (Wiersum, 1984). However, there are studies showing dramatic but short term increases in inorganic N and soil pH after burning (Ellingston *et al.,* 2000)

From table. 1 above, there is a relatively/ rapidly release (flush) of nutrients such as Ca, mg, K and P from the ash to the soil after burning which probably explain why soils on plots that are burnt regularly have a higher value than un-burnt plot in some instances. Though, the value obtained may be site-specific and vary according to factors such as soil types and topography, as reported by Jordan (1985) for a site in the Amazon and Tillphitak *et al.*, (1985) from a site in Thailand. Changes in soil physical characteristics as an effect of burning vary greatly, from negligible to dramatic (Bruijnzeel. 1998), depending on soil types, intensity of the fire and weather condition.

However, from table.1, the soil samples from un-burnt plots with respect to available Na are 2.35 Cmol/kg, 2.52 Cmol/kg, and 2.26 Cmol/kg respectively while those of burnt plots are 1.65 Cmol/kg and 2.17 Cmol/kg respectively. The relatively higher values for un-burnt plots may not be unconnected to the fact that when plots are burnt the mineral is subjected to volatilization hence the relatively low value.

Furthermore, referring to table.1, the cation exchange capacity (C.E.C) which is defined as the capacity of the soil to hold cations and exchange for the anions is relatively higher on soil plots subjected to burning regularly than un-burnt plots. The values are 20.26 Cmol/kg and 29.60 Cmol/kg respectively for burnt plots while the values for un-burnt plots are 8.20 Cmol/kg, 12.30 Cml/kg and 35.60 Cmol/kg respectively. The highest value noted in an un-burnt soil plot number 3 may be linked to the application of either organic or inorganic fertilizer in the plot since the said plot was subjected to cultivation. During burning, a substantial amount of cations are released from the ashes in exchange for the anion which account for the higher value of C.E.C under soil plots that are burnt regularly.

Finally, Table. II represents the mean properties of the 0-15cm layer of soil of both burnt and un-burnt plots.

The result from the table. II above shows that there is significant variation in the nutri-

Table 2 : **The Mean Properties of the 0-15cm layer of soil of both burnt and un-burnt plots**

Soil Property	Un-burnt Soil	Burnt Soil
Sand (%)	73.0	73.0
Silt (%)	9.3	12.0
Clay (%)	18.0	15.0
Soil organic carbon (%)	0.65	1.5
Total nitrogen (%)	1.46	0.2
Available phosphorus (PPM)	21.6	59.5
Exchangeable calcium (Cmol/kg)	12.0	15.8
Exchangeable magnesium (Cmol/kg)	2.0	3.3
Exchangeable potassium (Cmol/kg)	0.2	2.2
Exchangeable sodium (Cmol/kg)	2.4	1.9
Cation exchange capacity (Cmol/kg)	18.7	24.9
Extractable H+ Al (Cmol/kg)	0.0	0.1
pH	6.9	8.0

ent status of soils in an un-burnt plots with that of burnt plots using student t-test. It is significant at 0.05 and 0.01 alpha levels. The calculated t value is put at 5 while the theoretical t values at the respective alpha levels are 0.01 = 2.492 and 0.05 = 1.711

Consequently, Ho hypothesis is rejected so that the H_1 hypothesis is accepted, which says that there is a difference/significant in nutrients in plots subjected to regular burning and those not burnt for sometimes for a period of five years.

Conclusion

Sand fraction remains the dominant component soil in all plots and it rang from 66 to 80%. The soil pH tends towards alkalinity which is not unconnected to the fact that the nutrient cations replace H^+ to raise the pH and this diminishes the acidity of the soil which is perhaps the single most change caused by burning. Furthermore, the cation exchange capacity (C.E.C) is relatively higher on soil plots subjected to regular burning compared to that of un-burnt plots which is due to significant release of cation from ashes in exchange for the anion during burning. Finally, there is a significant variation in the nutrients of soils subjected to regular burning compare to that of un-burnt plots. It is significant at both 0.05 and 0.01 alpha levels.

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Edicha Jibril A.
Department of Geography
University of Abuja, Abuja Nigeria.
P.M.B 117, Garki.
E-mail edijib@yahoo.Com