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EFFECT OF "SLASH AND BURN" OPERATION ON AGRICULTURAL SOIL QUALITY IN EGBEMA, SOUTHERN NIGERIA

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Abstract
Effect of "slash and burn" operation an agricultural soil quality in Egbema was assessed for 4 months. The soil properties were modified. pH changed from 6.4 to 9.2 (week 4) and 8.9 (week 8) and decreased till 8.1 in wk 16. Soil phosphate, K and Ca increased from 13.2, 0.30 and 3.1mg/g in week 0 after burning to 17.7, 0.68 and 4.9mg/g respectively in week 8 after burning before decreasing gradually though still above the control values. Only nitrate and soil moisture remained low. Microbial populations which were initially adversely affected increased above control levels by week 8. Of all the microbial groups assessed, the most affected were the nitrifying bacteria (NB), followed by the fungi, the phosphate solubilizing bacteria (PSB) before the total hetrotrophic bacteria (THB). All of them recovered above control level on week 8 and remained above control level till week 16. Activities of soil enzymes correlated positively with soil microbial dynamics. Dehydrogenase and alkaline phosophatase activities which were initially adversely affected increased above the control (unburnt soil) values. Acid Phosphatese activity correlated negatively with soil pH values as its activities remained very low. When the soil pH increased in all the parameters assessed the affects of the burning was more on the top soil (0-15cm) then the sub soil (16-30cm). It is adviceable to avoid the operation on already alkaline soil and to supplement soil nitrate at the initial period after burning to help plant and microbial growth.

Introduction

The traditional farming system in most parts of southern Nigeria is the land fallow system. This is characterized by the 'slash and burn' operations before planting. This system involves slashing or cutting the bush and burning the slashed trees and shrubs to clear the farmland for planting of the desired crops. This affects both soil physicochemical and biological properties like other anthropogenic activities (Nwaugo *et al.*, 2008a; Hubta, 2001; Nwaboshi, 1982). In some cases, prescribed burning is carried out to control the activities of certain plants or oven other organisms (Huhta, 2001).

The process of 'slash and burn' has long been accepted as a normal process in rural or non-mechanized agricultural system in the tropics. This process affects the delicately balanced ecological system of the soil, thereby altering the soil biodynamics and other ecological factors. DeBano (2000) and Adeniyi (2010) agrees that the "slash and burn" operation affects the soil nutrients and microbial spectrum. Similarly, Nwaugo *et al.*, (2008b), and Sharma and Kaira (2006) agree that whatever affects the soil properties affect the soil fertility; hence agricultural yields are equally affected.

Sharma and Kaira (2006) and Giardiama *et al.*, (2000) stated the application of ash on soil affects its pH and nutrient content. Mineralization in soil is a biogeochemical process mediated by several organisms through the activities of their

enzymes. Several researchers including Li *et al.*, (2005), Parham *et al.*, (2003), Nwaugo *et al.*, (2006, 2008b) have explained that the assessment of soil quality should include the activities of soil enzymes whose activities cause the biogeochemical transformations experienced in mineralization. This is buttressed by the assertion of Prescott *et al.*, (2002) and Pelczar *et al.*, (2003) that only a very small percentage (3-6%) of soil micro-organisms are culturable. This leaves over 90% of soil organisms unobserved by the traditional microbiological cultural techniques.

The 'slash and burn' operation for farming purposes has been an age long practice especially in the tropics, but the attendant affects on soil microbial dynamics and enzyme activities are not clearly understood. This work therefore was designed to assess the effects of the operation in relation to time.

Material and Methods

The study area is a portion of farm land in Okwuzi-Egbema in Ogba-Egbema Ndani Local Government Area of Rivers State specifically mapped out for the purpose and undisturbed, all through the research. Egbema lies in the rain forest zone of the tropical climatic region of southern Nigeria. The people are mainly farmers and fishermen. However, the presence of several oil prospecting and producing companies have modified the occupational structure of the people.

Sample Collection

Soil preparation: This was done by mapping out two equal portions in the acquired farmland which were only ten meters (10m) apart. While one portion was slash and burnt the other was left untouched as control.

Soil samples were collected from both burnt and unburnt portions at two weeks internals for 16 weeks (test soil) and 8 weeks (control soil). The samples were obtained from two depths of the soil top soil (0-15cm) and sub soil (16-30cm) using soil *auger* according to Pansu and Gautheryrou (2006). The samples were put into sterile plastic containers and taken to the laboratory for analysis within 2-3 hours of collection.

The soil temperature was assessed *in-situ* using mercury in bulb thermometer while the pH was determined using the Jenway HANNA 1910 multipurpose tester (HANNA instruments, Moonsuket Rhodes Island, USA). The soil nitrate and phosphate were determined according Pansu and Gautheryrou (2006) while the moisture content was done by the evaporation method (Li *et al.*, 2005). The soil K and Ca were determined as described by Pansu and Goutherpyrou (2006).

Microbiological Analysis

The soil microbial dynamics was assessed using cultural techniques involving various culture media. While Pikovskaya's media was used to determined the population of phosopahte solubilizing bacteria (PSB), modified mineral salt agar was used for nitrifying bacteria (NB) and nutrient agar was used for total heterotrophic bacteria (THB). Sabouround dextrose agar was used for fungal count. The microbiological loads of the various soil samples were determined aften ten-fold serial dilutions with 0.2ml of the desired dilution inoculated on the prepared culture media using spread plate technique (Chessbrough, 2002). Counting of observed bacterial colonies was done after 24-48 hours incubation at 35^0C, while fungal count was taken after 2-4 days incubation at room temperature. Only bacterial plates with 20-150 colonies were accepted for use in the counts.

Soil Enzyme Activities

The activities of the enzymes in the soil were assessed. These were dehydrogenase, acid phosphate and alkaline phosphate. The activity of the

dehydrogenase was determined by the reduction of Triphenyl Tetrazoluin Chloride (TTC) to Triphenyl Formazon (TPF) as described in Alef and Nannipieri (1995). 5.0g of 2mm sieved soil sample was mixed with 10ml of 0.25% aqueous TTC and incubated in sealed tubes at 25°C for 6 hours. The absorbance at 485nm of the methanol extract of the TPF formed was measured using methanol as blank and the results expressed as mg g-1 6h-1

The activities of both acid and alkaline phosphatases were determined by the spectrophotometric estimation of the P-nitrophenol released by the enzymes after incubating the soil with buffered p-nitrophenol phosphate for 4 hours. The acid phosphatase was incubated at pH of 5.5 and alkaline phosphatase at 11.0 according to Alef and Nanipieri (1995).

Data Analysis

All results obtained were subjected to statistical analysis to test for the significance of the observations made and the values obtained. The statistical tools used were ANOVA and correlation analysis.

Results

Results of the soil physicochemical parameters analyzed are showed on Table 1. The parameters assessed showed two trends, Moisture content and nitrate values were adversely affected while temperature and pH increased significantly ($P \leq 0.05$). Potassium (K) and Calcium (Ca) also significantly ($P \leq 0.05$) increased in values.

Temperature values were highest on 0 weeks (38.7°c) but gradually decreased till week 4 when it returned to the control value of 28.6°C. pH values also rose from 7.6 (0 week) to 9.4 in week 4 and thereafter began to decrease (8.8 week 8 and 8 week 16). The values for K and Ca rose from 0.30mg/g and 3.1 mg/g in 0 week to 0.68 and 4.9mg/g in 8 week respectively before decreasing again (Table 1). Phosphate value also increased from 12.3mg/g in the control to 13.2mg/g at 0 week and continued the increase till 4 week (16.7mg/g) and 8 week 17.7mg/g before decreasing. However, significant decease was observed in the nitrate content as it deceased from 0.34mg/g in the control to 0.15mg/g in 0 week. It gradually increased till its peak in 8 week (0.43) which was above the control but began to decease again. All the parameters had their peak values between week 4 and week 8 which were above the control values but decreased thereafter. Values obtained from the sub soil samples (16-30cm) were below the values from the top soil (0-15cm) except the moisture content which was the reverse.

In the microbial dynamics, all microbial groups had their highest loads by the week 8. They all showed similar trends of drastically decreasing immediately after burning but rapidly increasing thereafter, with their peaks at week 8. The highest increase of each group was between weeks 4 and 8 (Table 2). The most affected group was the nitrifying bacteria, followed by the fungal group and the PSB. The THB was the least affected. All the various groups of micro-organisms had their highest counts in the top soil especially the FC and NB while the least affected by soil depth was the THB.

Soil enzyme activities analyses positively correlated with microbial dynamics. All of them were significantly ($p = 0.05$) adversely affected by he burning, hence decreased in activities but increased significantly thereafter till the peak – (week 8). The most affected was dehydrogenase which decreased from 27.3mg g-1 6h-1 in the control to only 6mg g-1 6h-1 on week 0. Values obtained for alkaline and acid phosphatases showed remarkable differences in rate of recovery after the burning. While alkaline phosphatase which had 3.8 vmol-p-nitro phenol in the control but deceased to 0.30 in 0 week increased to 4.3 in week 8 rapidly, acid phosophatase

only rose to 2.4 in the same week 8 (Table 3). However, the activities began to decrease gradually thereafter. The top soil had higher values than the subsoil.

Discussion

The effect of "slash and burn" operations on soil in traditional farming system in Egbema showed extensive modifications of the soil physiochemical parameters. From the values obtained, while nitrate and moisture content decreased immediately after burning, pH, phosphate, and the alkaline earth metals (Ca, K) increased statistically ($P \leq 0.05$). The soil becomes alkaline. This could be from the ash, which is alkaline and affected the soil in that order. The ash also had high Ca and K content including phosphates, which are all products of the plant materials burnt. On the other hand, nitrate is decompose and evaporated due to the heat of burning, just like the soil moisture. Burnt soil often cakes in relation to the amount of heat applied. These observations agree with Adeniyi (2010), Hubta (2001), DeBano (2000) and Certini (2005).

However, results showed that the depreciated nitrate and soil moisture began to appreciate from week 2 with the other parameters analyzed. The soil pH, phosphate and metals (Ca K) continued to increase in values till week 8 which had the highest values. This observation could be attributed to the gradual solubilization of the burnt materials (ash and other residual components). Adeniyi (2010) reported a similar observation but stated that it continue till week 10. Martinez and Moody (2001), Mataix – Solera and Doerr (2007) and Badia and Marti (2003) also reported this gradual solubilization of materials in fire-affected soil. This work therefore agrees that burning of plant materials on soil affect soil properties which increase above the control values with time.

Observations also showed that these parameters later decreased but remained slightly above the control. This could be attributed to the activities of increased microbial actions.

The effects of slash and burn on soil was observed be more on the top soil (0-15) than the subsoil (16-30cm). All the parameters analyzed showed such trend. This observation could be attributed to the extent of heat involved. 'Slash and burn' operation could be described as prescribed fire/controlled fire which was not too intensive, so could not last long on a spot to affect the soil underneat. Arocena and Opio (2003) and Choromanska and Deluca (2001) stated that prescribed fire only affects top soil changing its properties temporarily. Though there were changes in the properties of the subsoil, such changes were not in the same magnitude with those of the topsoil.

In the microbial spectrum analyzed, the most prevalent was the THB group, followed by the PSB and then the fungal group. The least was the NB. This trend had been reported earlier Nwaugo *et al.*, (2008a), and Pelczar *et al.*, (2002). After the fire, the rate of decrease in population was highest in NB, followed by the fungi and then the PSB. Nwaugo *et al* (2001), Pelczar *et al.*, (2002) and Prescott *et al.*, (2002) and that NB are very sensitive to changes in soil parameters. Again NB are obligate aerobes, hence could not survive the fire which made use of the available oxygen. Fungi and most PSB are also found in the top soil hence were more affected than the THB which could equally be found slightly below the soil surface. Though the microbial populations decreased immediately after the fire, no microbial group was completely eliminated.

Observations also showed rapid recovery from week 2, which got to the peak by week 8 in all the groups. The increase in microbial population could be attributed to

the increase in soil nutrient and environmental factors favouring their proliferation and survival.

The activities of the enzymes in the affected soil followed the pattern of microbial populations. Immediately after the fire, there was a general increase in activities by the three enzymes. However, while the activities of dehydrogenase and alkaline phosphatese increased rapidly and peaked by week 8, acid phosphates had a very slow increase in activity. The slow recovery of acid phosphatese could easily be attributed to the change in pH occasioned by the produced ash. The ash made the soil alkaline which was not condusive for acid phosphatese but favoured alkaline phosphates. Similarly dehydrogenase is produced by all micro organisms, so its activity could increase as long as there is increase in microbial populations. Reverodo and Melo (2007), Nwaugo *et al*., (2010), Li *et al*., (2005) and Boerner and Brinkman (2003) had earlier observed a similar situation. Choromanska and Deluca (2002) who stated that heating modified soil enzyme and microbial activities. The effect of the fire on enzymes is direct since the enzymes are microbial metabolites and whatever affects the microorganisms affects their products. Again, the micro-oganisms and soil enzymes are mainly proteins which are denatured by heat. However results showed that both dehydrogenase and alkaline phosphatase activities rose above the control by week 8 and even at week 16.

In conclusion, "slash and burn" operation in traditional farming system had only transient effects on soil physicochemical and microbiological properties. However, since the soil become alkaline, the process is not appropriate on already alkaline soil as it may become too alkaline for microbial activities and mineralization. Again, a supplementary nitrogen source could be provided to aid plant growth at the initial period after burning.

Table 1: Effect of burning on some soil physicochemical properties

	Test soil										Control soil					
	Wk 0		Wks 3		Wks 4		Wks 8		Wks 16		Wks 0		Wks 4		Wks 8	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Temp^{0}C	38.7	31.7	29.7	28.1	28.1	26.1	28.6	26.4	28.4	26.3	28.2	26.4	28.0	26.3	28.3	26.4
pH	7.6	7.0	8.8	7.4	9.4	7.5	8.9	7.5	8.1	7.2	6.5	6.8	6.4	6.6	6.5	6.7
Moisture %	28.7	20.7	19.7	21.2	21.3	22.1	25.1	6.2	24.3	25.1	21.2	24.7	20.9	33.2	22.1	24.4
Nitrate mg kg	0.15	0.20	0.18	0.22	0.27	0.21	0.43	0.29	0.40	0.31	0.34	0.26	0.36	0.24	0.38	0.26
Phosphate my/ g	13.2	12.6	14.2	13.4	16.7	14.1	17.7	4.3	15.7	13.2	112.3	11.2	12.6	11.3	12.8	11.4
K mg/g	0.20	0.24	0.42	0.29	0.61	0.42	0.68	0.48	0.61	0.47	0.24	0.22	0.26	0.25	0.25	0.23
Ca mg/g	3.1	2.8	3.9	3.2	4.6	3.8	4.9	3.9	4.7	3.6	2.6	2.4	2.8	2.3	2.7	2.4

a = top soil (0 – 15cm)

b = subsoil (16-30cm)

Table 2: Effect of burning on soil bacterial diversity in test soil (cfu/g)

Group of bacteria	Wk 0		Wk 2		Wk 4		Wk 8		Wk 16	
	A	**b**	**a**	**b**	**a**	**b**	**a**	**b**	**A**	**b**
THB	2.1×10^4	2.10×10^3	4.9×10^4	6.3×10^3	3.4×10^6	2.1×10^4	4.7×10^6	2.5×10^5	4.4×10^6	2.2×10^5
PSB	1.2×10^3	1.1×10^2	2.6×10^3	1.7×10^3	3.1×10^5	4.3×10^4	4.4×10^5	4.2×10^4	4.2×10^5	4.0×10^4
NB	1.1×10^2	2.3×10^1	2.4×10^2	7.1×10^1	2.9×10^4	1.2×10^2	3.9×10^4	4.9×10^3	3.4×10^4	4.1×10^3
FC	1.7×10^2	1.4×10^1	3.1×10^3	2.1×10^2	3.1×10^4	2.0×10^3	3.7×10^5	2.7×10^3	3.2×10^5	2.5×10^3

Control soil samples

Group of bacteria	Wk 0		Wk 2		Wk 4	
	A	**b**	**a**	**b**	**A**	**b**
THB	4.3×10^6	2.3×10^5	4.1×10^6	2.1×10^5	4.2×10^6	2.2×10^5
PSB	3.8×10^8	3.7×10^4	3.9×10^5	3.6×10^4	3.8×10^5	3.4×10^4
NB	3.5×10^4	4.4×10^3	3.2×10^4	4.5×10^3	3.4×10^3	3.2×10^3
FC	2.3×10^5	2.1×10^3	2.5×10^5	2.2×10^3	2.4×10^3	2.2×10^3

THB – Total heterotrophic bacteria
PSB – phosphate solubilizing bacteria
NB – Nitrifying bacteria
FC – Fungal count
a – Top soil
b – Sub soil

a=top soil (0 – 15 cm)

b= sub soil (16 – 30cm)

Table 3 Effect of burning on soil dehydrogenase and phosphatase activities (Test soil)

	Wk 0		Wk2		Wks 4		Wks 8		Wks 16	
	A	b	a	b	a	b	a	b	A	b
Dehyd	4.2	3.1	19.3	8.1	24.3	18.2	36.3	20.7	32.4	21.1
Acid P.	0.24	0.12	0.91	0.42	1.2	0.71	2.4	1.9	2.4	1.8
Alk. P.	0.30	0.14	1.73	0.61	2.9	1.7	4.3	2.4	4.1	2.5

Control soil

	Wk 0		Wk2		Wks 4	
	A	b	a	b	a	B
Dehyd	27.3	16.8	29.2	16.9	28.4	16.6
Acid P.	3.4	2.1	3.6	2.0	3.5	2.2
Alk. P.	3.8	2.4	3.9	2.1	3.8	2.2

a – Top soil
b – Sub soil
Dehyd = Dehydrogenase; Acid P. = Acid phosphatase; Alk. P = Alkaline phosphatase.

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