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Full Length Research Paper

Slash and burn effects on microbial soil in Ondo, Nigeria

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This study was carried out to examine the effects of slash and burn on the diversity and abundance of soil microorganisms. Composite soil samples were collected from the study area before burning and two weeks after burning progressively for a period of three (3) months. The bacteria and fungi in the soil samples were isolated and identified. In addition, the pH, soil temperature and soil moisture content of the samples were determined. The results show that the diversity and abundance of the soil microorganisms decreased significantly (p 0.05) within the fourteen and twenty-eight days after burning. However, a significant increase in the abundance and diversity of the microorganism was recorded as from the forty-two days after burning. The soil pH was also observed to increase significantly between the fourteen and twenty eight days after burning. The results further revealed that there was significant (p 0.05) increase in bacteria and fungi abundance after burning. The relationship between soil pH and bacteria was significant, while there was no significant relationship between soil pH and fungi. The relationship between temperature, fungi and bacteria were not significant (R^2 50%). Total microorganism abundance and diversity significantly increased following burning during the current study.

Key words: Bacteria, fungi, mineralization, yield, species, soil.

INTRODUCTION

Slash and burn used to be a viable ecological strategy to sustain agriculture in the tropics. Farmers maintained different plots, resulting in a mosaic of plots under cropping and fallow, allowing natural processes of soil regeneration (Brandy and Weil, 1990; Altieri, 2002), but human activities of none sustainable agricultural practices disrupt this equilibrium.

Slash and burn has long been considered to be the most adapted farming system in the humid forest zone (Brandy and Weil, 1990), especially in areas of low population density. There is a nutrient flux during slash and burn; ash from burned biomass is incorporated into the soil resulting in an increase in soil fertility. Carbon and Nitrogen are largely volatilized but Phosphorus and cations are transferred from the biomass to ash and then into the soil. During subsequent rains, cations may be leached, but generally, soils are enriched by ash after rainfall (Nye and Greenland, 1990, Giardima et al., 2000). Farmers grow crops for a few years, until soil fertility, weed infestation and disease reduce crop yield below an acceptable level (Akobundu, 1987).

In slash and burn farming system, the soil can only fully recover, if left undisturbed for many years during long fallow or in improved fallow system (Ahn, 1979). Fallows in this way help to re-establish the equilibrium that prevailed initially in the soil before the clearing of the forest. Unfortunately, some major external driving forces have led farmers to reduce the fallow period. Increasing population density in forest regions and the subsequent increasing demand for food, fibre and shelter, forced farmers to shorten follow length, hence jeopardizing the sustainability of this farming system (Eyasu and Scones, 1998). The practice of slash and burn has been reported to negatively affect soil quality, thereby compromising the resilience of the system (Lai, 1997).

It is important to understand the impact of slash and burn on soil microorganism, as they are crucial to the stability, regulation and functioning of all forest ecosystems

(Reichle, 1997). Future use of fire in management of forest should be based on a sound knowledge of its potential impact upon components of the community. The examination of species changes following slash and burn is particularly, important for understanding the extent and duration of community alterations. Studies involving higher taxonomic level can however, provide clear indication that it is sensitive or robust taxa for inclusion in future studies. Long-term studies of the soil microorganism's species composition of communities and their response to fire are urgently required.

Soil quality and resilience have a profound impact on productivity and environmental quality. Soil quality refers to the soil capacity to produce economic goods and services and to regulate the environment (Lai, 1997), and its capacity sustain plant and animal productivity, maintain or enhance water quality and promote plant and animal heath. Soil quality is thus an ideal indicator of sustainable land management (Lai, 1997). Soil resilience is the ability of the soil to restore its life support processes and environmental regulatory function after major anthropogenic perturbation, that is, its ability to absorb Agriculture practices are among the largest source of stress and disturbance of the environment. Soil biological processes contribute to soil fertility enhancement by increasing the amount and efficiency of nutrient acquisition and recycling, the regulation of the retention and flow of water and nutrients, and the maintenance of good soil physical structure. Soil biological processes influence ecosystem functioning through nutrient cycling, organic mater transformation, microbial decomposition and nutrient retention.

Through their feeding and nesting activities, soil organism generates and maintains soil chemical, physical and biological characteristic within the ecosystem. Bacteria can directly or indirectly modify soil properties through their feeding activities, burrowing and casting (Ahn, 1979).

Burning removes the vegetation and may release a pulse of nutrient to fertilize the soil. Ash also increases the pH of the soil, a process that makes certain nutrients, (especially phosphorous) more available in the short term. Burning also drives off, temporarily, soil microorganism, pests and established plants along enough for crops to be planted in the ashes. Before artificial fertilezers were available, fire was one of the most widespread methods of fertilization. The aim of this study is therefore, to find the effects of slash and burn on soil microbial diversity and abundance in the tropical rainforest ecosystem in Ondo state, Nigeria.

MATERIALS AND METHODS

The study area

This study was carried out at Obanla natural forest, which Is a portion of the forest left behind during land clearing for the establishment of the Federal University of Technology, Akure (FUTA) Ondo State, Nigeria. The forest was formerly part of Akure Forest Reserve. It is located on Longitude 050 18E and Latitude 070 17 N, along Akure-Ilesha Road. The forest is about 9.34 ha in size, translating into 1.5% of total land mass. Generally, the vegetation zone is the tropical humid lowland forest ecosystem. The ecological zone has been described in details by Nwoboshi (1982), Okojie (1996) and Adekunle (2002).

The soil of the area is well drained and classified as ferruginous soil on crystalline rocks of basement complex. The soil is also classified in terms of soil texture as sandy clay loam. The pH varies between 6.7 and 7.2 indicating a neutral soil reaction. The mean monthly temperature is about 28°C. The precipitation is heavy and it varies between 1500 and 2500 mm per annum. The mean monthly relative humidity is about 74%. The fairly moderated daily temperature is as a result of cloudiness and heavy precipitation.

Method of soil collection

In the forest habitat, one hectare (100 × 100 m) land area was centrally established. This was further divided into 25 sample plots of 20 × 20 m where five plots were randomly selected (12.5% sampling intensity). In each of the selected plots, soil samples were collected at a depth of 0 - 10 cm from five points before and two weeks after burning. The soil samples were taken to the laboratory, where isolation of microorganisms was carried out.

Bacteria isolation, identification and counting

The standard procedures for determining the total number of soil microbes were adopted for bacteria and fungi (Alexander, 1997). Suspension of the soil samples was prepared with sterile water and a serial dilution of five factors was made for accurate counting. Then 1 ml of the appropriate dilution was carefully transferred to sterilized petri dishes containing sterile molten nutrient agar at about 37°C. This was mixed and allowed to solidify. It was then incubated for 24 h. The bacteria that grew into colonies were sub-cultured to obtain pure culture for easy identification. Identification was done according to Bergey's manual of determinative bacteriology.

Fungi culturing involved serial dilution of the suspension using molten malt extract agar. This was kept in an incubator at 30°C for 5 days. Fungi that grew were sub-cultured to obtain pure culture for easy identification and they were identified with the criteria of Rhode and Hartman (1980).

Soil pH determination

The soil pH was determined with the aid of glass electrode pH meter in the soil solution of 0.01 mol L^{-1} calcium chloride.

Soil moisture content determination

The oven dry method was used to determine the moisture content of the soil samples. 100 g was weighed and placed in an oven maintained at 105 ± 2°C for a period of 24 h. Thereafter, the soil samples were removed from the oven, and allowed to cool in a desiccators containing silica gel and then reweighed. The samples were returned into the oven to dry for another 30 min and allowed to cool again in the desiccators. Oven drying and cooling were repeated until constant weight was obtained. The moisture content was then calculated using the formula:

MC= (Mn - Mo)/Mn × 100

Where: MC = Moisture Content, Mn = Weight of soil with moisture (wet weight), Mo = Weight of soil without moisture (oven dry weight)

Methods of data analysis

The data on bacteria and fungi count obtained were subjected to repeated analysis of variance (ANOVA) . Regression was done to find out the type of relationship between soil pH, bacteria and fungi count; between soil moisture content, bacteria and fungi count and the one existing between soil temperature, bacteria and fungi in the study area. SPSS statistical package was employed to analyze the data

RESULTS

Effects of slash and burn on bacteria diversity and abundance in the study area

The diversity of bacterial obtained in the study is presented in Table 1. The results revealed that *Bacillus cereus, Proteus vulgaris, Clostidium sporogenes, Aeromana hydrophylla* and *Vibro anguillarum,* were encountered in both the burn and un-burnt plots which implies that they are resistance to burning.

The species and the relative abundance of bacteria obtained in this study are presented in the Table 2. The counts are expressed as Colony Forming Unit per gram (cfu/g) with factor of 10^6. This shows that burning drastically reduced the abundance of bacteria. However, the abundance of bacteria increases from fifty-six days after burning until it reaches eighty-four days after burning. (It increases from 1.48×10^6 to 3.02×10^6 in plot 1, from 1.21×10^6 to 2.78×10^6 in plot 2, from 2.17×10^6 to 2.48×10^6 in plot 3 and $2.64 \times 10^{6\ to}$ 2.74×10^6 in plot 4).

Table 3 shows that burning has devastating effect on diversity of fungi. Only species that were resistant to fire survived the fire incidence, these species include; *Rhizopus stolonifer, Candida albidum* and *Trichoderma uridea*. However, the diversity began to increase from 6 weeks after burning. It was observed that at 42 days after burning, species that were not present before burning were introduced, which makes the number (diversity) of fungi species to be more than what was obtained before burning.

Mean fungi abundance obtained in the study area is presented in the Table 4. The ANOVA for the bacterial count shows that there were significant differences in the bacterial count in the study area due to burning (Table 5). The mean separation shows that abundance of bacterial was significantly higher (p 0.05) at 12th weeks after burning, followed by 10th and 8th weeks after burning respectively (Table 6).

Soil pH analysis

It was observed that the pH of the soil samples significantly increased 2 weeks after burning (Tables 7 and 8) and this could be as a result of the ash added to the soil from burnt biomass. The soil pH was high at 4th (5.16) and 6th weeks after burning (5.15). But there were reductions from the 8th week after burning.

The ANOVA Table (Table 9) shows that there was significant difference in the fungi count in the study area due to burning. The result of the mean separation shows that the abundance of Fungi was significantly (p 0.045) higher at 8th weeks after burning, followed by 6th and 12th weeks after burning (Table 10).

A summary of the results of the regression analysis between soil pH and bacterial is presented in Table 11. The correlation co-efficient shows that the value of R is positive in the study area, suggesting that there was significant correlation between soil pH and the number of bacterial. This implies that, an increase in the pH increases the diversity and abundance of bacteria in the study area. Also, the regression analysis between soil pH and fungi shows a positive and significant correlation. However, the regression analysis between soil temperature and fungi in the study area shows that the value of R^2 is positive, suggesting that there is significant correlation between the soil temperature and fungi. Likewise, the regression analysis between soil temperature and bacteria shows that the value of R is also positive, suggesting that there is significant correlation between the soil temperature and bacteria abundance.

The implication of this observation is that most species of soil microbes are poorly adapted to survive the period of high temperature. But the regression analysis between soil moisture content, bacteria and fungi in the study habitat, shows a negative relationship, suggesting that there was no significant correlation between the soil moisture content and the soil microbes in the study area. The implication of this is that as the soil temperature increases, the soil moisture content reduces, and this tends to affect the physical, biological and the chemical processes in the soil.

DISCUSSION

The results show that the abundance of soil micro-organism significantly increased in the study area forty-two days after burning (Tables 1 and 2). This suggests that many soil organisms survived during burning by moving down the soil profile. These are the true soil organisms with suitable morphological attributes, such as size and shape, for fast movement through inter-ped spaces.

Burning has great effect on diversity of bacteria. Only species that are resistance to burning survived the effects of burning, these species include *Bacillus cereus, Proteus vulgaris* and *Clostridium sporogenes*. The diver-sity increases as from the 6th week after burning. It was also observed that the 8th, 10th and 12th weeks after burning witnessed an increase in bacteria diversity. This could

Table 1. Bacteria diversity in the study area.

S/N	Name	Before burning	14 days after burning	28 days after burning	42 days after burning	56 days after burning	70 days after burning	84 days after burning
1	*Actinomyces* spp	+	-	+	+	-	+	+
2	*B. cereus*	+	+	+	+	+	+	+
3	*Streptococcus feacalis*	+	-	-	-	-	+	+
4	*Escherichia coli*	+	+	+	-	-	-	-
5	*P. vulgaris*	+	+	+	+	+	+	+
6	*Micrococcus leutus*	+	-	+	-	-	-	-
7	*Salmonella* spp.	+	-	-	-	-	-	-
8	*C. sporogenes*	+	+	-	+	+	+	+
9	*Micrococcus lactis*	+	-	-	-	+	+	+
10	*Pseudomonas aeniginosa*	-	-	+	+	-	+	+
11	*Klebsiella scleromalacia*	+	-	-	+	+	+	+
12	*Aeromonas hydrophyila*	+	+	-	+	+	+	+
13	*V. anguillarum*	+	+	+	-	+	+	+
14	*Shigella dysentenae*	+	-	-	-	+	+	-
15	*Bacillus subtilis*	-	+	-	-	+	-	+
16	*Aerococcus viridians*	+	+	+	+	+	-	-
17	*Streptococcu lactis*	+	-	-	+	+	+	+
18	*Branbamella catlarhelis*	-	-	-	+	-	-	-
19	*Rhizobium japomicum*	-	-	-	-	+	-	+
20	*Bacillus megaterium*	-	-	-	-	+	-	+
21	*Azotobacter* spp.	-	-	-	-	+	-	+
22	*Erwinia herbicola*	-	-	-	-	+	+	+
23	*Alcaligenes feacalis*	-	-	-	-	+	+	+
24	*Erwinia amylovora*	-	-	-	-	-	+	+
25	*Streptomyces* spp.	-	-	-	+	-	+	+
	Total	15	8	8	11	16	16	17

Key: + = Present; – =Absent.

Table 2. Bacteria abundance (CFU/g) in the study area.

S/N	Soil sample	Mean of burnt plot over time	Unburnt plot over time
1	Before burning	1.88×10^6	2.34×10^6
2	14 days after burning	1.37×10^6	2.42×10^6
3	28 days after burning	1.45×10^6	1.96×10^6
4	42 days after burning	1.75×10^6	1.44×10^6
5	56 days after burning	1.93×10^6	2.75×10^6
6	70 days after burning	1.93×10^6	2.68×10^6
7	84 days after burning	2.76×10^6	3.11×10^6

be as a result of an increase in the soil pH after burning, which reflected changes in chemical properties of the soil such as the cation exchange capacity, which now favour some species of microorganisms that were in the habitat before burning. The chemical composition of soil often determined the abundance and distribution of microorganism. Similar observation was made by Seasted (1980), who reported that, burning, causes the mineralization of litter and vegetation, with an increase in a number of nutrients including nitrogen, phosphate, potassium, calcium, sodium and magnesium. Fungi diversity increased greatly in the 56^{th}, 70^{th} and 84^{th} days after burning.

The regression analysis shows that the effect of soil pH

Table 3. Fungi diversity in the study area.

S/N	Name	Before burning	14 days after burning	28 days after burning	42 days after burning	56 days after burning	70 days after burning	84 day after burning
1	*Actinomyces* sp.	-	+	-	+	+	-	+
2	*Aspergillus flavus*	+	-	-	+	-	+	-
3	*Aspergillus fumigatus*	-	-	-	+	+	+	+
4	*Aspergillus niger*	+	-	-	+	+	+	+
5	*A. rapens*	-	-	-	+	+	-	-
6	*Aureobasidim pathulana*	-	-	-	+	+	-	+
7	*Botrytis cinrrea*	-		-	+	+	+	+
8	*Candida albidum*	+	+	-	+	+	+	+
9	*Chrysospium* sp.	-	-	-	+	+	+	+
10	*Gonatobotrys simplex*	+	-	-	+	+	+	+
11	*Mucur mucedo*	+	-	-	+	+	+	-
12	*Mycotypha* sp.	-	-	-	-	+	-	-
13	*Neurospora crazza*	-	-	-	+	+	+	+
14	*Peniciluma italicum*	+	-	-	+	-	+	-
15	*Rhizopus nigricans*	+	-	-	+	+	+	+
16	*R. stolonifer*	+	+	-	+	+	+	+
17	*Starchybotrys* sp.	-	-	-	-	+	-	+
18	*Trichoderm uridea*	+	+	+	+	+	+	+
19	*Umbelopsis* sp.	-	-	-	-	+	-	-
20	*Varicospium elodeae*	-	-	-	+	+	+	+
21	*Wardomyces anomalis*	+	-	-	-	+	+	+
	Total	10	4	1	16	18	15	16

Key: += Present, - = Absent.

Table 4. Fungi abundance in the study area.

S/N	Soil sample	Mean burnt plot over time	Unburnt plot over time
1	Before burning	0.41×10^4	1.21×10^4
2	14 days after burning	2.45×10^4	0.91×10^4
3	28 days after burning	0.01×10^4	0.04×10^4
4	42 days after burning	0.11×10^4	0.25×10^4
5	56 days after burning	0.08×10^4	1.11×10^4
6	70 days after burning	0.13×10^4	0.07×10^4
7	84 days after burning	0.14×10^4	1.24×10^4

Table 5. ANOVA table showing the influence of burning on bacterial count.

Source of variation	SS	DF	MS	F	F-Calculated
Days after burning and un-burn treatment	0.346348	6	0.024096	* 2.44	2.39
Within group	0.67468	28			
Total	1.021029	34			

* = Denotes significant ($p > 0.05$).

on bacteria abundance and diversity gave a positive correlation in the study area, which implies that there is significant positive interaction between the soil pH and bacteria counts in the plots. This means that the higher the soil pH, the higher the species of bacteria present and vice-versa. The fungi diversity shows that *T. Uridea,*

Table 6. Mean separation of influence of burning on bacterial count.

Sources of variation	Mean
2nd week after burning	6.11[b]
Before burning	6.26[a]
4th weeks after burning	6.15[b]
6th weeks after burning	6.23[ab]
8th weeks after burning	6.28[a]
10th weeks after burning	6.30[a]
12th weeks after burning	6.39[a]

*Figures with the same alphabet are not significantly different from each other.

Table 7. ANOVA table showing the influence of burning on soil pH.

Source of variation	SS	DF	MS	F	F-calculated
Days after burning and un-burn treatment	3.42970	6	0.571618	*6.72	2.44
Within group	2.37952	28	0.084983		
Total	5.809229	34			

* = Denotes significant (p > 0.05).

Table 8. Mean separation of influence of burning on soil pH.

Sources of variation	Mean
Before burning	5.00[d]
14 days after burning	5.73[a]
28 days after burning	5.16[b]
42 days after burning	5.15[c]
56 days after burning	5.14[bc]
70 days after burning	5.14[bc]
84 days after burning	4.50[f]

*Figures with the same alphabets are not significantly different from each other.

Table 9. ANOVA table showing the influence of burning on fungi count.

Source of variation	SS	DF	MS	F	SIG
Days after burning and un-burn treatment	2.480573	6	0.413429	*2.52	F-calculated
Within group	4.250107	28	0.184787		
Total	6.73068	34			

*Denotes significant (p> 0.05)

R. stolonizer and *C. albidum* were present before and after burning.

The regression analysis shows that there is no significant correlation between the soil pH and fungi count in the study habitat, as negative correlation was recorded. This is also supported by the works of Smith et al. (1994), who reported that soil fungi have a broader pH tolerance, but they might multiply at lower pH values. Also, the regression analysis between the soil temperature and the microorganisms shows that there was strong correlation between the soil temperature and the microbes. The implication of this is that most species of microbes are poorly adapted to survive the period of high temperature, particularly in moist forest environment, but could only

Table 10. Mean separation of influences of burning on the fungi count.

Sources of variation	Mean
Before burning	2.96×10^{4de}
14 days after burning	2.90×10^{4e}
28 days after burning	2.30×10^{4f}
42 days after burning	3.18×10^{4b}
56 days after burning	3.23×10^{4a}
70 days after burning	2.98×10^{4d}
84 days after burning	3.05×10^{4c}

*Variation in Alphabet shows significant differences.

Table 11. Summary of regression analysis.

S\N	Regression type	Regression equation	R	R^2	Not significant
1	Between soil pH and bacteria	-0.3866X + 7.591	0.4134	0.7719	0.488
2	Between soil pH and fungi	-0.0234X + 5.3318	0.0731	0.0053	0.907
3	Between soil temperature and bacteria	0.3395X + 31.695	0.0686	0.631	0.913
4	Between soil temperature and fungi	-5.07342X + 64.833	0.3490	0.533	0.565
5	Between soil moisture content and bacteria	-12.1163X + 113.3511	0.8435	0.2115	0.073
6	Between soil moisture content and Fungi	-3 .3714X + 45.5143	0.6904	0.4767	0.197

NS= Not significant.

survive within narrow ranges of climatic or microclimatic variation. According to Alexander (1997), microbial processes are influenced markedly by soil temperature change. Temperature also greatly affects physical, biological and chemical processes in the soil. The regression analysis between soil moisture content and the microorganisms shows that there is negative correlation. This is supported by the works of Whelan et al. (1980), who reported that low moisture content levels and high temperature decreases the prevalence of dormant forms of microorganisms. Survival of some microorganisms subsequent to burning could be due to a variety of biotic and edaphic factors. Important biotic components include food source (plant or prey), competition, predation (including parasites) and the relationship with other species. Edaphic factors that are important to soil organisms include weather (precipitation, insolation, temperature and wind), microclimate (soil temperature, humidity), chemical (nutrients) and physical soil properties (soil texture and structure). Post burning activation of dormant microorganisms and hatching of eggs may significantly contribute to increase in microorganism's abundance after burning. Many microorganisms survive unfavourable conditions by entering a dormant or resistant state (diapause or aestivation) in which development is arrested, as reported by Huhta (2001). He further noted that the activation of these states is controlled by external stimuli such as temperature, humidity, and/or photoperiod which bring about an alteration in hormonal levels of the organisms.

Increased abundance of some species of microorganisms after burning in this study may also have been affected by the periodic litter fall in the natural forest. Litter fall is characterized by periodic increase coinciding with bark fall. Plant re-growth and accumulation of litter after burning represents an increase in resources with time after burning, and may differ from the pre- burning resources in terms of quality and quantity. Atlas (1984), reported that the speed of reinvasion by soil microorganisms after burning, was associated with the accumulation of leaf litter under tree and with the regeneration of herbs and shrubs in exposed areas. An increased growth of fungi was recorded after the burning.

The decrease in the soil microorganisms 2 and 4 weeks after burning coincided with the onset of high temperature and increased exposure of the study area to climatic extremes that was created artificially by setting the study area on fire. Most soil inhabitants are poorly adapted to survive the periods of low moisture and high temperatures, particularly, in moist forest environments. Many soil microorganisms have poor control of water loss because they lack an impermeable cuticle particularly, some fungi species like *Aspergillus rapens, Umbelopsis* spp., *Starchybotrys* spp. and *mycotypha* spp. (Vanwansen et al., 1998) which were present in the study area. Future use of fire in management of forest should be based on a sound knowledge of its potential impact upon components of the community. Both short and long

term studies of the soil microorganism's species composition of communities, and their response to fire, are urgently required.

CONCLUSIONS AND RECOMMENDATION

1. Microorganism (bacteria and fungi) abundance increases from forty-two days after burning.
2. An increase in soil pH values increases the diversity and abundance of bacteria.
3. Agroforestry farmer should ensure they slash and burn their farmland forty-two days before planting in other to enable the soil to fully regain their microorganisms and fertility back.

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