

Erodibility of Slash-and-Burn Soils along a Toposequence in Relation to Four Determinant Soil Characteristics

Edem I. Dennis* Uduak C. Udo-Inyang and Ifiok. R. Inim
Department of Soil Science University of Uyo, Nigeria
* E-mail of the corresponding author: dennis.edem@gmail.com +234-8027031426

Abstract

Good crop yields are normally obtained in the first year after slash-and-burn farming system in south-eastern Nigeria, but decline rapidly thereafter. The suitability of land for slash-and-burn agriculture depends partly on its sensitivity to erosion. Erodibility of slash-and-burn soils, in relation to four determinant soil characteristics was studied to assess the effect of burning on some selected properties and erodibility of the soil. Soils from 0 to 0.15m and 0.15 to 0.30 m depths were collected before and after burning the plots, from three geomorphic surfaces of upper slope, middle slope, and valley bottom. Results obtained showed an increase in bulk density after burning and a corresponding decrease in total porosity. Soil pH and nutrient content increased significantly after burning, but soil organic carbon (SOC) and exchangeable acidity decreased with burning. Soil permeability was moderately slow in all the landscape positions. Erodibility increased significantly after burning by 20, 14 and 18 % in the upper slope (US), middle slope (MS), and valley bottom (VB) respectively. Soil pH was one of the soil characteristics that mostly determine soil erodibility (β =-0.693*). We do not know the composition or the amount of ash added to the soil and so the changes in soil properties cannot be related quantitatively to ash input.
Keywords: erodibility, toposequence, slash and burn agriculture, susceptibility, permeability

1. Introduction

Up to a century or so ago, shifting cultivation had no very serious effect on the farmland of the tropics, since the soil and vegetation were given adequate time to regenerate after a period of cropping. The method of land clearing is the traditional slash and burn (Onofiok, 1992). This method according to Babalola (2000) has been an integral part of shifting cultivation and widely practiced by over 90% of farmers in South eastern Nigeria. Burning aid in clearing bush debris and reduction of weed infestation that would have been competing with crops for sunlight, water and soil nutrients as reported by Babalola (2000). The ash deposits after burning increase the pH of the soil, and help to fertilize the soil. This is done by immediate release of the mineral nutrients e.g. Mg, Ca and Available P, for crop use (Niemeyer et al, 2005). Brye (2006), reported that increased soil temperature after burning, stimulate biological activities, and increase organic matter mineralization to enhance nutrient availability with increase susceptibility of the soil to erosion.

Erosion is a gravity driven process that moves solids (sediment, rock and other particles) in the natural environment or their source and deposits them elsewhere it usually occurs due to transport by wind, water or ice, and other materials under the force of gravity, or by living organisms, such as burrowing animals; in the case of bio-erosion, (Montgomery, 2008). Erosion is a natural process, but it has increased dramatically by human land use practices, especially industrial agriculture, deforestation and urban sprawl.

Soil erodibility is an indicator of a soils susceptibility to raindrop impact, runoff and other erosive processes, thus is based on the physical characteristics of the soil (Laflen et al, 1991). Different soils respond differently to the impact of kinetic energy from raindrops or the shear stress exerted by moving fluid susceptibility of soil to erosion is an integrated response of soils, inherent properties, properties of the eroding fluid and their interaction with climate. Their responses depend on their mechanical makeup and chemical composition. Because of differences in inherent properties, soil exhibit different degrees of susceptibility (soil erodibility) to the forces generated by erosion agent (Lal, 1987).

. Soil characteristics that affect the resistance of a soil to erosion include texture, structure, permeability and organic matter (Onofiok, 1992).

Burning has been identified as one of the soil degrading practices that result in soil structural degradation (Hubbert et al, 2006) and exposes the soil surface to climatic element of rainfall, destroys soil structure, and alters soil firmamental characteristics such as texture, mineralogy and cation exchange capacity (Kettering et al, 2000). Hence exposed soil surfaces by burning will tend to be more erodible than the original soils because of their poor structure and low organic matter content due to high mineralization. A centimeter of soil degraded or lost takes a thousand years to regenerate; the need for soil conservation is therefore eminent especially for this region where rainfall is about 2500-4000 mm per annum (Montgomery, 2008). Burning increases fertility of soil in the short term, but the damage caused on this free gift of nature is irreparable. Against this background, a study was conducted to assess the effect of slash-and-burn method of land clearing on some selected soil properties and the erodibility of burnt plots down the slope.

2. Materials and Methods

*2.1**Study Area***

The study was conducted at the University of Uyo Teaching and Research Farm Use_Offot Uyo, Akwa Ibom State, South Eastern Nigeria. The area is located between latitude $4^0 30^1$ and $5^0 31^1$N and longitude $7^0 31^1$ and $8^0 20$E and altitude 65m from the sea level. The area is divided into two distinct seasons; the wet or rainy and dry seasons. The wet or rainy season begins from April and lasts till October. It is characterized by heavy rainfall of about 2500-4000 mm per annum. The rainfall intensity is very high and there is evidence of high leaching and erosion menace associated with slope and rainfall factors in the area. The rainfall is bimodal with peaks in July and September and a relative moisture stressed period in August known as "August break". The dry season starts from November and last still March. It is characterized by high temperature with a mean annual temperature of 28^0C. The highest temperature is experienced between Januarys through March, the period described by Enwezor et al. (1990) as overhead passage of the sun. Relative humidity is between 70 % and 80 %. The landscape is generally undulating to steep hills, while the vegetation is mainly; the tropical rainforest. The soils are derived from sandy parent materials which are weathered with low activity of clay (Udo and Sobulo, 1981). The soils have low content of organic matter, cation exchange capacity, base saturation and low pH. The soil in the area is formed on coastal plain sands parent materials and has been described as typic paleudult (Loganathan and Sutton, 1986). The predominant land use is continuous croping, forest and permanent plantation. The original vegetation was replaced by *Panicumm maximum Chromolaena odorata, Cynodon plectostacyus, Imperata cylindnca*.

2.2 Field Studies

A plot of land measuring 40 x 18m and with slope of 9 % was cleared for the study at University of Uyo Teaching and Research Farm, Use Offot.

A total of six plots each measuring 40 x 3 m with a landscape position described as the upper slope (US), middle slope (MS) and valley bottom VB) were cleared with machete and pegged. The experiment involved two treatment, (burnt and unburnt plots) replicated six times on three landscape positions. Progressively, fire was set into three out of six plots.

2.3 Soil Sampling

Six mini-profile pits, (45 cm depth) were dug, at the centre of each sub plots, described and sampled according to FAO/UNESCO (1990). Composite soil and auger samples were taken in the burnt and controlled plot. Auger samples were also collected at the two depth of 0-0.15 m and 0.15-0.30 m in the upper slope, middle slope and valley bottom. Core sample were obtained for saturated hydraulic conductivity and bulk density determinations. The soil samples were secured in a core, and one end of the sample was covered by a piece of a cheese cloth fastened with a rubber band and properly labeled. The bulk sample were collected and secured in a polythene bag and properly labeled before taken to the laboratory for analyses.

2.4 Laboratory analysis

The particle size distribution was determined using the Bouyoucos hydrometer method as described by Klute (1986) after dispersing the soil particles with hexametaphosphate solution. The textural class of the soil was determined using the textural triangle. Saturated hydraulic conductivity: The samples collected from each plot were placed in a basin of water and allowed to saturate by capillarity for 24 hour prior to the installation of a constant head permeameter. The saturated core sample was placed in a funnel, resting on a tripod stand after the constant head cylinder was placed on top of it and fastened together using a masking tape. A constant head of water was constantly maintains throughout the period of the experiment. The flux of water passing through the soil column was collected in a measuring cylinder and readings were taken accurately until equilibrium discharge was attended in each of the samples.

2.5 Calculations

The saturated hydraulic conductivity was calculating using the formula:

$$Ks = \frac{QL}{At\Delta H} \quad (cmhr^{-1)}) \qquad (1)$$

Where Ks = saturated hydraulic conductivity ($cmhr^{-1}$), Q= effluent discharged (cm^3)
A = πr^2 = cross sectional area of the core cylinder (cm^2), π = Pie = 3.14, r = Radius of the cone
L = Length of the soil column (cm), ΔH = hydraulic head difference between top and bottom of the cylinder (cm).
Bulk density: The core samples were over dried to a constant weight at 105^0C. The bulk density was calculated using the mass - volume relationship: BD = Ms/Vt (2)

Where; BD = Bulk Density (g/cm^3),Ms = Mass of oven dry soil (g), Vt = Total volume of soil, (cm), (solid + pore spaces); The total volume of the soil was calculated from the internal diameter of the cylinder.
Total porosity was calculated from particle and bulk density relationship using the formular as described by Vomocil (1965) as cited by Edem (2007). St = [1 - Δb/Δp] x 100 (3)

Where , St = percent total porosity, Δb = Bulk density (gcm^{-3}), Δp = Particle density (m^3m^{-3}) , assumed to be $2.65m^3m^{-3}$ for mineral soil, while Permeability (Ks) was computed from values of hydraulic conductivity: (Ks) using the equation. $Kp = ks\,\eta\,/\rho g$. (4)

Where; Kp =Permeability (cm^2), Ks = saturated conductivity (cmh^{-1}), η = fluid viscosity ($gcm^{-1}\,s^{-1}$), ρ = fluid density (gcm^{-3}), g = acceleration of gravity (cms^{-2}). The permeability class were determined according to O'Neal (1952) and coded as stipulated by Wischmeir and Smith (1978).
The soil-erodibility factor (K) was computed using the nomograph in Renard et al (1997) and the equation.

$$100K = 2.1M^{1.14}\,(10^{-4})\ 12\text{–}a) + 3.25(b\text{-}2) + 2.5\ (c\text{-}3) \qquad (5)$$

Where, M = (% silt + % very fine sand) (100 -% clay) a = % Organic matter, b = structure code (from 1to 6), c = profile permeability class (from 1 to 6), K = Soil erodibility.

2.6 Chemical analysis

Soil pH was determined in 1:2:5 soil to water ratio using the glass electrode pH meter.
While the exchangeable bases (Ca^{2+}, K^+, Mg^{2+} and Na^+), were extracted using IMNH_4OAC (Thomas, 1982). Calcium and Magnesium were determined by EDTA titration, while potassium and sodium were determined using flame photometer. Effective cation exchange capacity (ECEC) was determined by IITA (1979) summation method i.e. sum total of exchangeable bases (TEB) and exchange acidity (EA).

$$ECEC = \text{Exchangeable } Ca^{+} + Mg^{2+} + K + Na^{+} + EA \qquad (6)$$

The exchangeable acidity was extracted with normal potassium chloride solution. The total acidity and the exchangeable aluminum were determined by titration as described as Juo (1973) , whereas Organic carbon was determined using wet oxidation method of Walkley black as modified by Nelson and Sommers (1996), and Total nitrogen was determined by Kjeldahl digestion method as described by Bremmer (1996).
Available phosphorus was estimated with Bray P-1 method of Bray and Kurtz (1945) and P concentration in the extracts was determined by the blue colour method of Murphy and Riley (1962).

2.7 Statistical Analysis

Data obtained from laboratory analysis and determinations were fitted into a randomized complete block design (RCBD) of SPSS statistical package version 18 for analysis of variance (ANOVA). Where a significant F-test was observed, treatment means were separated using Fisher's least significant different (LSD) ($P<0.05$).Pearson correlation analysis was employed to test the relationship between soil properties as affected by burning.

3. Results and Discussion

3.1. Particle-size distribution and soil texture

Results show that fine sand fraction was greater than the coarse sand in burnt and unburnt plot except in the middle slope of the burnt subsoil (0.15-0.30 m) where the coarse sand was 520.3gkg^{-1} while fine sand was 290.0 gkg^{-1} (Table 3.1). Very fine sand increased with depth in all the plots examined except in the valley bottom of the unburnt plots, where it was 11.2 gkg^{-1} in the top soil (0-0.15 m) and 10.7 gkg^{-1} in the subsoil. The soil was preponderance of sand fraction, averaging above 80%. The silt fraction was the least, with values of 37.0 gkg^{-1}, 50.3 gkg^{-1}, 70.3 gkg in the burnt top soil, whereas 23.6 gkg^{-1}, 17.0 gkg^{-1}, 57.0 gkg^{-1} were contain in the burnt sub soil and 43.6 gkg^{-1}, 37.0 gkg^{-1} and 24.6 gkg^{-1} in the unburnt subsoil. High value of sand fraction indicates that the soils were well sorted and the transportability of the sand fraction is low. This implies that the lighter particles of silt and clay and other colloidal material were carried away (Obi and Asiegbu, 1980). The result showed that all the plots were sandy loam texture. The textural class was not affected by slash and burn system, since soil texture is a permanent and natural attribute of the soil (Hillel, 1982).

3.2 Bulk density and porosity

Bulk density increased with burning from 1.35 kg/m^3 to 1.55 kg/m^3 in the upper slope, 1.49 kg/m^3 to 1.35 kg/m^3 in the middle slope, and 1.53 kg/m^3 to 1.57 kg/m^3 in the valley bottom. Giovannini et al. (1998), suggested that the increase in bulk density after slash and burn can be ascribed to the disruption of soil aggregation and loss of organic matter following burning. This is reflected by the dominance of the particle-size distribution by the quartz sand fraction (Table 3.1).

High values of bulk density usually reflect low values to total porosity. Total porosity decreased after slash and burn was practiced. Total porosity reduced from 0.50m3m3 to 0.42 in the upper slope, 0.47 to 0.38 in the middle slope and 0.43 to 0.41 in the valley bottom. Reduction in total porosity has also been reported by Mallik et al. (1984), Zhang et al (2007). It therefore appears that the reduction in total porosity was perhaps due to ash deposits in larger pores. The ash deposited might have probably reduced the large pore density and constantly increased the small density (Tucker, 2003).

3.3 Saturated hydraulic conductivity (Ks)

Saturated hydraulic conductivity was generally high, and very rapid in terms of conductivity class (Table 1). Ks varied widely in the burnt and unburnt plots and highest in the upper slope(US) of the burnt plot being 22.1cm/hr and the least is 13.4 cm/hr in the MS of the unburnt plot. The textural characteristics, organic matter content and structure appeared to have been responsible for high Ks values. Saturated hydraulic conductivity reduced significantly after burning, except in the upper slope, where Ks was 22.1 cm/hr for burnt plot and 16.4 cm/hr for unburnt plot. Babalola and Obi (1981) and Ogban et al (1998) have reported similar results for soils derived from coastal plan sand parent materials. The implication is that rainwater as well as colloidal material could easily be removed from the root zone, and could adversely affect nutrient conservation in the soils.

3.4 Soil pH

The pH of the soil increased after slash and burn was practiced, significant increase was observed in the middle slope and valley bottom of both the top soil and the subsoil these is due to the ash deposit after burning, which tends to act as liming material and hence increase the soil pH (Table 2). Govannini et al. (1988) had made similar observation while working on effect of heating on some physical and chemical parameters related to soil aggregation and erodibility.

3.5 Total nitrogen

Total N values were very low in the burnt and unburnt plots, while organic content in both plot were high, these might be due to the vitalization process. Thus even though the total amount of nitrogen on a site decreases, the amount of available nitrogen to plants may actually increase or decrease, depending on the site (Adriano, 1986).

3.6 Available phosphorus

Phosphorus, which is one of the most limiting elements in Nigerian soil, increased from 88.30 $mgkg^{-1}$, 91.43 $mgkg^{-1}$ and 01.40 $mgkg^{-1}$ to 95.40 $mgkg^{-1}$, 113.50 $mgkg^{-1}$ and 133.60 $mgkg^{-1}$ in the upper slope, middle slope, and valley bottom respectively in burnt top soil. Available also increased after burning in the subsoil (Table 3.2) and many times higher than the critical level of 15-25 $mgkg^{-1}$ stipulated for soils of this zone (Ibia and Udo, 1993) the implication of this high level of P is that this soil will not need P fertilizers for a number of cropping (Effiong et al., 2006).

3.7 Exchangeable bases

Ca and Mg contents were moderately high except in the middle slope of the burnt top soil with value of 2.56 $cmolkg^{-1}$. With critical levels of 4.0 cmol kg^{-1} for calcium and 0.5 $cmolkg^{-1}$ for Mg, the soil said to be rich in magnesium content and relatively low in Ca, despite burning tends to increase exchangeable bases, only magnesium content increase significantly after burning with the highest value observed in the upper slope of the burnt soil to be 2.10 $cmolkg^{-1}$. The increase in magnesium is of importance because some of the magnesium will be made available for plant use and magnesium is known to improve plant growth. Potassium contents after burning increase in all the three landscape position and in both the top and subsoil, with highest values observed at the MS and VB of the burnt subsoil to be 0.09cmol kg^{-1} Tisdale et al (2003), reported that the availability of K^+ and Na^+ may increase or decrease due to burning. Low Na content is significant because high content of Na^+ can destroy soil structure and can be dangerous to plant.

3.8Exchange acidity

Exchange acidity decreased after burning, decreasing from 2.12 $cmolkg^{-1}$, 2.0 $cmolkg^{-1}$, 2.14 $cmolkg^{-1}$ in the US, MS, and VB of the unburnt topsoil respectively to 1.76 $cmolkh^{-1}$, 1.65 $cmolkg^{-1}$, 1.48 $cmolkg^{-1}$ in the US, MS, and VB of the burnt topsoil. Similarly there was a significant decrease in the subsoil after burning. The decrease in the exchange acidity indicates direct benefit of the ash deposits after burning, which acts as liming material to the soil. This is because Al toxicity is probably the most important growth limiting factor in acid soil. When slash and burn is practiced, the activity of Al^{3+} is reduced by precipitation as $Al(OH)^3$ (Tisdale et al, 2003) the ash deposits raises the soil pH while greatly reducing the level of extractable Al. Not only is Al^{3+} toxic to plants, but increasing Al^{3+} in the solution also restricts the plant uptake of Ca and Mg. Also the removal of H^+ toxicity, which damages root membranes and is detrimental to the growth of beneficial bacteria is very important

3.9 Effective cation exchange capacity (ECEC) and percentage base saturation

The ECEC of the soil increased variable in the subsoil after burning, but decreased in the top soil. These shows that the availability of exchangeable cations in the soil has increased in the subsoil, and since cation exchange is pH dependent, the increase in the pH value after the soil was burn might be responsible for increase in the ECEC content of the soil. Percentage base saturation in the soil increase from 71.90 %, 70.60 % and 73.83 % in the US, MS and VB respectively to 74.89 %, 72.31 % and 81.5 % in the US, MS, VB respectively in the top soil after burning, percentage base saturation also increase in the subsoil. These might be due to increase in pH, because soil pH and fertility level increase with increase in base saturation (Edem, 2007). The high percentage of base saturation will provide basic cations to growing plants. This also shows that at pH 7 or higher, soil are essentially 100 percent basic cation saturated (Edem, 2007).

4 Erodibility determinant factors in burnt and unburnt soil

4.1. Permeability

The permeability rating (Renard et al, 1997) was moderately slow in both burnt and unburnt plots (Table 3) and permeability code was 4. Permeability is the ability of porous media to transmit fluids (Hillel, 1971). The results showed that fluid would be unimpeded, as shown by the high values of Ks. The high values of saturated hydraulic conductivity are the reasons why the soils are generally well drained (SLUS-AK, 1989) and can suffer severe moisture deficit during short dry spell, but residue mulches can bind, reduce inter-particle pore-space and saturated Ks (Ogban et al, 1998). Organic matter is known to hold a large amount of available water. This will likely lower permeability hence resistance of the porous medium to fluid flow.

4.2 Soil structure

The structure of the soil was characterized by well formed distinct peds that were moderately durable with fine granular structure, coded 2. After burning, it was characterized by poorly formed peds of very fine granular with structure code of 2. The topsoil was affected by the heat following burning, with changes in structural stability from moderately fine granular in the US to weak fine granular and weak fine crumb (single grain crumb) in the MS. There was no significant structural change in the VB of the topsoil. The same structural effect of topsoil VB was true for the subsoil, except in the MS were the granular type was reduced to single grain crumb. Wuest et al (2005) found a reduction in structural stability following burning. Nevertheless, the decrease in structural stability resulting from burning suggests that the vulnerability of soil surface to rainfall impact cannot be undermined.

4.3 Organic carbon

Organic carbon content decrease after burning except where it increased from 16.61 gkg^{-1} to 23.83 gkg^{-1}, in the top soil and 15.86 gkg^{-1} to 22.63 gkg^{-1} in the subsoil. The increase in organic carbon has been reported by Brye (2006) who submitted that increased soil temperatures after burning, stimulate biological activity; increase organic matter mineralization to enhance nutrient availability.

4.4 Erodibility factor (K)

The soil-erodibility factor (K) was determined using the nomograph in Renard et al, (1997). K ranged from 0.22-0.283 $t.ha.h.ha^{-1}$ in the burnt plot and 0.155-0.216 $t.ha.h.ha^{-1}$ in the unburnt plot (Table 3). The K values were generally higher in the burnt plot and may be attributed to low silt, clay, low organic matter contents, and weaker structure. High K values may also be accounted for by the coarse sand fraction. Although, Obi and Asiegbu (1980) had reported that the transportability of coarse sand is low downstream. Lal (1983) had observed that erodibility of soils decreased with coarse sand content because a protective desert-like pavement develops on the surface. Ntakwa et. al., (1989) had, however, reported that the nomograph method underestimated the erodibility of a surface light-textured oxic paleustalf in western Nigerian by about 78 % when compared with measured values. Although the soils in the present study were light-textured Psammentic Palecudult (Uyo), the high K values indicates that there is high susceptibility of the soils to erosion especially in the burnt plots. This observation is consistence with Lal (1983), for soils of the humid tropics.

5. Relationship of soil properties in the burnt and unburnt plots

Significant correlation of soil properties of burnt soil as indicated show that fine sand correlated negatively with coarse sand (r = -0.993**) high values of bulk density usually reflect low values of total porosity. (r = -0.986**). Bulk density also had negative significant correlation with Organic carbon and saturated hydraulic conductivity (r = -0.975** and r = -0.986**). Hydraulic conductivity increase with increase in organic carbon and total porosity (r = 0.994*, r = 0.940*). These shows that soil preponderance of macro pores have the capacity for higher conductivity while organic matter helps to maintain the structural stability pores. pH and Calcium correlated positively (r = 0.889*) indicating that at high pH, calcium content increase at the sorption site of the soil . Effiong et al, (2006) reported that high Ca^{2+} saturation indicates a favourable pH for plant growth and microbial activities. Tucker, (2003) had similar results when working on impacts of grassland burning in the uplands on the soils, hydrology and biodiversity**.** Whereas results from the unburnt plot showed that an increase in fine sand lead to increase in coarse sand (r = 0.952*), while very fine sand correlated positively with silt (r = 0.863*). There was a high significant negative correlation (r = -1.000**) between total porosity and hydraulic conductivity. Indicating that a decrease in total porosity brings about increase in the hydraulic conductivity attributable to dominant of aeration pores in the distribution. Calcium had a negative significant correlation with Na (r = -0.856*). This implies that high content of calcium in the pre-burnt soil decreased sodium content. Low clay content increased the erodibility of unburnt soils (r = -0.895*). Obi and Asiegbu (1980) had reported that erodibility of the soil will increase with low values of clay particles.

5.1 Soil properties capable of causing erosion in the study site

Regression results indicated that all the measured soil properties were excluded in the model with exception of total nitrogen, Mg, Ks, silt and very fine sand in the stepwise selection techniques of multiple regression analysis, when measuring the characteristics of the soil that predict erodibility of the bunt plot. The exclusion of those soil properties in the multiple regressions ($p < 0.05$) reduced substantially their significance in determining the erodibility of the study site. As total nitrogen escaped from the soil, erodibility increase (β = -0.742), this is due to the reduction in organic carbon content and subsequent volatilization of N during burning. Erodibility increase when the saturated hydraulic conductivity decreases (β = -0.561). Since soil hydraulic conductivity is a function of the soil water potential, therefore the readiness of the porous medium to allow fluid pass through it, controls the rate of overland flow. As silt and very fine sand increase, erodibility increases (β = 0.106 and 0.115). Soil with high content of silt experienced high erodibility with values of 0.4 t.ha/h.mg.mm and above (Ogban et al, 2000). Very fine sand fraction are easily eroded, and hence increased in the movement of soil. Since very fine sand is small in size (0.2mm) it requires less energy to be eroded down-stream relative to sand fraction > 0.2mm.

But in the pre-burnt plots, the appreciable influence of these properties (clay, ECEC, Ca, BD, and K) on erodibility relates closely to the report of Tucker (2003) on impact of grassland burning in the uplands on soils. He stressed the importance of clay and bulk density and their effects on erodibility. Soils with high clay content have low erodibility (β = -0.895) while those with higher clay content have more stable aggregates because of the strong inter colloidal bonds.

6 Summary and conclusion

Changes in soil properties which occurred following slash-and-burning were slight reductions in acidity and organic carbon content particularly on the surface soil of the middle slope and valley bottom. Surprisingly, the exchangeable K^+ and available P increased in the burnt plot, even when large amounts of nitrogen were mineralized. The system appears to lose very large amounts of nitrate, reflecting both the large amount of N and the heavy rainfall of the area.

There is deterioration in structural stability in the surface soil associated with rapid decomposition of organic matter. Heavy rainfall may lead to the formation of a surface cap and may reduce porosity, hence reduced infiltration capacity and poor stability can lead to erosion. The structural stability of the soil was slightly reduced after burning, but soil permeability was moderately slow both in the burnt and unburnt plot in all the landscapes. Erodibility was high in the soil, ranging from 0.155-0216 $t.ha.h.ha^{-1}$ and increased after burning to 0.22-00.283 $t.ha.h.ha^{-1}$.

Soils in Uyo are fragile and easily eroded, practicing slash and burn method of land clearing increased the erodibility of the soil. On the contrary burning increased the nutrients content and stabilized the pH of soil. With the current increase in demographic pressure on land in South eastern Nigeria, which has led to a continuous and intensive cultivation of land (including very steep and marginal lands), slash-and-burn may hinder a sustainable cropping system and should be discouraged. Here, the collective degenerative effect of burning on these soil properties is enormous in a way that these fragile tropical soil may not be rejuvenated once degraded.

References

Agee, J. K. 1993. *Fire Ecology of Pacific Northwest Forests Island* Press, Washington D.C., 493 PP.

Babalola O. 2000 Soil Management and Conservation in Nigeria. In: Akoroda, M. O. (ed). *Agronomy in Nigeria*. University of Ibadan, Nigeria. Pp 216-222.

Brye, K. R. 2006 *Soil Physiochemical Changes Following 12 years of Annual Burning in a Humid-Sub Tropical Tall-Grass Praise*. Hypothesis. Acta Occotogica 30, 407-413.

Edem S. O. 2007. *Soil: The Dynamic System*. Minders International Publishers pp. 122.

Glovannini, G. Lucchesi. S. Giachetti. M. 1988. Effect of Heating on Some Physical and Chemical Parameters Related to Soil Aggregation and Erodibility. *Soil Sci*. 146, 255-261.

Hillel, O. 1982. *Introduction to Soil Physical* Academy Press Inc.

Ketterings,Q. M. Bigham J.M., Lapeche V. 2000. Changes in Soil Mineralogy and Texture Caused by Slash and Burn Fires in Samatra, Indonesia *soil sci. Soc. Am* 64, 1108-1117.

Ntakwa, P. W., Lai, R and Sharma, R. 1987. An Evaluation of the Universal Soil Loss Equation and Field.

Onofiok, O. E. 1992: *Introduction to Soil Science*, Unpublished Lecture Note. Department of Soil Science, University of Nigeria, Nsukka, Enugu State, Nigeria.

Renard. K. G., G. R Foster, G. A. Weesies, D. K. Mcool, and D. C. Yodar (cords). 1997 *Predicting Erosion by Water*: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE) US department of Agriculture Handbook No. 703, 404 pp.

Wischmeier WH, Smith DD 1978 *Predicting Rainfall Erosion Lossess*. A Guide to Conservation Planning. United States Department of Agricultural Science and Education Administration, Agric. Handbook No. 537. United States Govt. Printers: Washington , DC: 58.

Zhang, G. S. Chan, K. V. Oates, A. Heenan, D. P. Huang, G. B. 2007. Relationship Between Soils Structure and Runoff/Soil Loss After 24years of Conservation of Tillage, *Soil Tillage Res*. 92 122-128.

Ini D.Edem was born on December 22, 1976; bagged B. Agric. Degree (Upper credit) in Soil Science from University of Uyo and MSc Soil Science (Soil physics option) from the premier University, Ibadan and currently a PhD student at University of Ibadan & lecturer, Department of Soil Science University of Uyo, since December, 2004.

Dr. Uduak.C. Udo-inyang was born on October 11965. Obtained 1st degree in soil science from University of Calabar in 1991, MSc. From ABU (Zaria) in 1996 and PhD. 2010 in Agroclimatology. He is a fellow of Traditional Technique for micro-climate improvement of Wagenegin University and working as a Senior lecturer, Department of Soil Science, University of Uyo, Nigeria.

Table I: Mean values of selected soil physical properties of the burnt and unburnt plots

*Parameters		Burnt plot			Unburnt plot		
	Depth (m)	US	MS	VB	US	MS	VB
Coarse sand	0-0.15	408.50	417.0	274.40	277.50	365.80	288.40
(g/kg)	0.15-0.30	222.30	520.30	278.60	283.30	211.50	280.30
Fine sand	0-0.15	147.0	657.0	503.60	522.30	455.30	518.0
(g/kg)	0.15-0.30	591.0	290.0	514.30	504.0	625.0	523.0
Very fine sand	0-0.15	10.4	11.4	11.0	8.5	8.2	11.2
(g/kg)	0.15-0.30	16.0	12.3	16.2	9.5	10.3	10.7
Silt	0-0.15	37.0	50.3	70.3	51.3	43.6	30.3
(g/kg)	0.15-0.30	23.6	17 .0	57.0	43.6	37.0	24.6
Clay	0-0.15	127.0	133.60	140.3	140.3	127.0	153.6
(g/kg)	0.15-0.30	147.0	160.30	147.0	133.6	133.6	160.3
Texture	0-0.15	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand
	0.15-0.30	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand
Bulk Density	0-0.15	1.55	1.65	1.57	1.35	1.49	1.53
Kgm^{-1}	0.15-0.30	1.55	1.65	1.57	1.35	1.49	1.53
Total porosity	0-0.15	42.0	38.0	41.0	50.0	47.0	43.0
m^3m^{-3}	0.15-0.30	42.0	38.0	41.0	50.0	47.0	43.0
Ks	0-0.15	22.10	13.40	19.03	16.40	17.9	20.1
(cmh^{-1})	0.15-0.30	22.10	13.40	19.03	16.40	14.9	20.1
Conductivity Class	0-0.15	Very rapid	Very rapid	Very rapid	Very rapid	Very rapid	Very rapid
	0.15-0.30	Very rapid	Very rapid	Very rapid	Very rapid	Very rapid`	Very rapid

*Each value is a mean of 3 replicates
US = Upper Slope , MS =Middle Slope , VB = Valley Bottom, KS= Saturated Hydraulic Conductivity

Table 2: Mean values of chemical properties of the burnt and unburnt soil

*Parameters		**Burnt plot**			**Unburnt plot**		
	Depth (m)	US	MS	VB	US	MS	VB
pH	0-0.15	6.53	6.61	6.79	6.40	6.20	6.26
	0.15-0.30	6.63	6.68	6.77	6.44	6.31	6.42
Org c	0-0.15	23.80	17.89	22.78	16.61	20.37	24.58
gkg^{-1}	0.15-0.30	22.63	16.46	22.55	15.86	19.69	23.90
TN	0-0.15	0.773	0.593	0.756	0.153	0.630	0.590
gkg^{-1}	0.15-0.30	0.500	0.503	0.480	0.326	0.373	0.316
C/N	0-0.15	30	30	30	109	32	42
	0.15-0.30	45	33	47	49	53	76
AV.P	0-0.15	95.40	113.50	133.60	88.30	91.43	101.40
$mgkg^{-1}$	0.15-0.30	93.60	99.80	97.40	86.50	82.90	94.30
Ca	0-0.15	3.04	2.56	4.48	3.52	3.14	4.02
gkg^{-1}	0.15-0.30	3.36	4.00	4.48	4.44	3.89	3.41
Mg	0-0.15	2.10	1.62	1.90	1.82	1.74	1.92
gKg^{-1}	0.15-0.30	1.60	1.58	1.70	1.52	1.54	1.61
K	0-0.15	0.07	0.08	0.08	0.06	0.05	0.06
gkg^{-1}	0.15-0.30	0.07	0.09	0.09	0.04	0.04	0.06
Na	0-0.15	0.04	0.05	0.05	0.05	0.05	0.04
gkg^{-1}	0.15-0.30	0.03	0.04	0.05	0.03	0.04	0.04
ECEC	0-0.15	7.01	5.96	8.00	7.57	7.05	8.18
gkg^{-1}	0.15-0.30	6.98	7.77	8.36	8.05	7.61	7.20
Bs	0-0.15	4.89	72.31	81.50	71.90	70.60	72.83
%	0.15-0.30	72.49	78.13	75.83	74.90	72.40	71.11
EA	0-0.15	1.76	1.65	1.48	2.12	2.07	2.14
(mol/kg)	0.15-0.30	1.92	1.70	2.02	2.02	2.10	2.08

*Each value is a mean of 3 replicates
TN = Total Nitrogen , C/N = Carbon and Nitrogen Ratio; Av.P = Available Phosphorus; CEC = Effective cation exchange capacity; BS = Base Saturation; EA = Exchange Acidity

Table 3: Erodibility (K) of burnt and unburnt soil using four determinant soil characteristics

Ms = Moderately Slow WFG = Weak Fine Granular

Parameters		Burnt plot			Unburnt plot		
	Depth (m)	US	MS	VB	US	MS	VB
% silt + % very	0-0.15	14.10	16.43	18.30	18.63	12.56	14.50
fine sand	0.15-0.30	18.36	14.0	21.90	13.86	14.0	13.16
% clay	0-0.15	12.70	13.36	14.03	14.00	12.70	15.36
	0.15-0.30	14.70	16.03	14.70	13.36	13.36	16.03
Org C	0-0.15	23.38	17.89	22.78	16.61	20.37	24.58
g/kg	0.15-0.30	22.63	16.46	22.55	15.86	19.69	23.90
Permeability	0-0.15	5.2	3.1	4.4	3.8	4.2	4.7
(cm^2) X 10^{-6}	0.15-0.30	5.2	3.1	4.4	3.8	4.2	4.7
Permeability	0-0.15	ms	ms	ms	ms	ms	ms
Class	0.15-0.30	ms	ms	ms	ms	ms	ms
Permeability	0-0.15	4	4	4	4	4	4
Code	0.15-0.30	4	4	4	4	4	4
	0-0.15	WFG	WFC	MFC	MFG	WFG	MFC
Soil structure	0.15-0.30	MFG	WFG	MMG	MMG	MFG	MMG
Structure code	0-0.15	2	1	1	2	2	2
	0.15-0.30	2	2	2	2	2	2
Erodibility	0-0.15	0.245	0.250	0.234	0.204	0.220	0.199
(t.ha.h/haMJmm)	0.15-0.30	0.247	0.267	0.283	0.216	0.214	0.155

WFC = Weak Fine Crumb MFC = Moderate Fine Crumb
MFG = Moderate Fine Granular MMG =Moderate Medium Granular