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# Comparative Analysis of Soil Elements Mining by Water Erosion and Bush Burning

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## Abstract

Soil samples taken from soil affected and unaffected by bush burning and water erosion sites were subjected to standard laboratory analysis. The results showed bush burning and water erosion are capable of mining and replenishing soil elements from-and- to the soil at different quantities. Comparatively, eroded soil has most soil elements removal and burnt site has the most soil elements replenished. Burning decreased the soils' pH by (1.3%), carbon was removed from the soil by (37%), organic matter (35%) and nitrogen (35%). Similarly water erosion mined carbon at (64%), organic matter (64.1%) and nitrogen (63%) from the soil at greater percentages except pH (21.6%), which was increased. The basic cations exchange of $Na^+$ (9.5%), $K^+$ (52.9%), $Ca^{++}$ (42.2%) and $Mg^{++}$ (31.8%) were replenished on burnt site. While $Na^+$ (26%), $K^+$ (28%), $Ca^{++}$ (50%), $Mg^{++}$ (32%) were mined from the soil by water erosion. Also heavy metals of $Pb^{++}$, $Ni^+$, $Fe^{++}$, and $V^+$ were added to the soil by both burning and water erosion. The student parametric t- test and F-test analyzed on soil elements data at P= 0.05 significant levels revealed non-significance variation in mean and variance between the soil elements of pH, OC, OM,, ON, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $P4^-$, $Al_4^+$, $Pb^{3+}$, $Fe^{2+}$, $Ni^+$ and $V^+$ for both sites. This suggests similarity among all soil elements inherently found in soil of same environment of deposition and geochemical sources.

**Key word**: soil elements, mining, erosion, bush burning, organic matter

## 2.0 Introduction

The yields of plants depend on the physical and chemical properties condition of the soil, which in turn is influence the soil elements availability. Any factor that affects these properties also affects the soil elements. On one hand negative effect means depletion in soil elements availability in the soil, which is regarded as infertile and consequently, the soil can no longer support plant growth. On the other hand positive effect contributes to the fertility of the soil and is regarded as fertile, which is ideal and favourable for growing of plants.

Organic matter has significant effects on both the physical and chemical properties of the soil and its total health properties. It has impact on the soil structure; moisture holding capacity, diversity and soil organism activities. Both have positive and negative effect on nutrient availability to plants. A positive relationship between organic matter and porosity of the soil is brought by increase in the soil faunal activities. In addition, it also influences the effect of chemical amendments, fertilizers, pesticides and herbicides in the soil.

The soil element is an important attributes defining the fertility of soil. No wonder early human settlements were concentrated are characterized by fertile soils. As the fertility of the soil declines, so does the human settlements that depend on it. Infertility in soil is brought by degradation; according to Barrow (1922) land degradation is the decline in the quality and utility of land. It often manifests in various ways; washing away of soil elements, exposure of subsurface and roots of plants and trees. Also included in this definition are silt deposition in lowland areas, gully and inter-rill erosion, water-logging and soil compactions are forms of land degradation (Lai, 1988).

Archeologists have demonstrated that land degradation was responsible for extinction of Harappan Civilization in Western India, Mesopotamia in West Asia, the ancient Kingdom of Babylon in Far East Asia and the Mayan culture in Central America (Olson, 1981). The UNEP in 1986 estimated that land degradation over the millennia would have caused over two billion hectares of productive land to be unproductive. Developing countries in Africa often have low yields returns farms because of inability to procure fertilizers to boost infertile soils caused by degradation. Onyegoche (1980) asserted that land degradation has contributed to the lost of greater than 35 million tones of soils yearly in Nigeria. Dike (1995) reported that in south central Nigeria about 2-3 million tones of soil are lost annually.

Bush burning is land degradation process which affect the quality of the soil negatively and positively (Ohwoghere-Asuma, 2012). It is often carried out intentionally and indiscriminately by farmers and arsonists in developing country, like Nigeria. Bush burning increases soil temperature, enhances soil erosion by exposing it to agent of denudations, hinders the capability of the soil to retain water and enhances the breakdown of organic nitrogen into mobile nitrate which are subsequently leached from the top soil. Also, recovering of burnt soil from some of these negative effects often take long time to achieve.

Erosion degrades lands by removing the topmost layers of the soil which provide the support for plants and re-deposited elsewhere, where the slope is less steep. Erosion is a geologic process and is often driven by surface run-off. Mostly affected by erosion are the fine grains constituent of the soil, which are easily transported by low energy flowing water. The fine grains constituent of soil usually accommodate the organic matters formed from the decomposition of plants remains. Water erosion occurs naturally or accelerated by anthropogenic means such as deforestation and indiscriminate bush burning which subsequently expose the soil to water erosion.

Consequently, these two forms of soil degradation have the ability of either adding or removing soil elements to and from the soil. Removal of these soil elements is referred to as nutrient mining.

The devastating effects of soil elements mining by erosion and bush burning are worth quantifying in order to assess the degree of degradation of soil caused by these two forms of degradation. The objective of this paper is to investigate comparatively using both the parametric student t- and F-tests to determine the impacts of bush burning and erosion on soil elements mining and replenishing from soil samples collected from Ughelli and Abraka, Delta state, Nigeria (Fig.1).

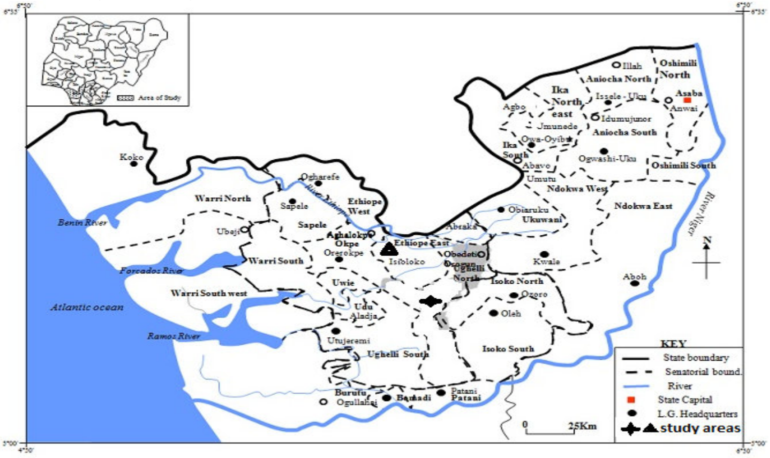

*Fig1: Map of Delta state showing the study areas and sample locations*

## 2.1 Material and Methods

Hand auger was used to collect soil samples from locations affected and not affected by both bush burning and erosion from depth ranging from 0- 20cm. Soil particle size distributions was determined by Bouyoucos (1962) method, pH was determined by the Beckman zeromatic pH meter, a procedure described by (Peech, 1965), in which 0.1N potassium chloride and distilled water were mixed with soil in the ratio of 1:2:5, organic carbon was determined by the Allison (1965) method and total nitrogen by the Kjeldahl method (Bremna, 1965). Exchangeable bases were determined by the method of Jackson (1958) and exchangeable acidity by the titrimetric methods using potassium chloride solution (Mclean, 1965). Soil cation exchange capacity was determined by the ammonium acetate method (Jackson.1958).While available phosphorus was determined by the method prescribed Bray and Kurtz, (1945). Heavy metals of iron, lead, vanadium and nickel were determined by atomic absorption spectrophometer (AAS).

### 2.1.1 Statistical Analysis

The data were analyzed using the SPSS 16 software. In order to assess the homogeneity between the chemical parameters from burnt and water erosion soil sites, the parametric student t- and F-tests were used. A probability of $p < 0.05$ (two paired tail) was used to establish the statistical significance for the data.

## 2.2 Results and Discussion

The summarized results of the laboratory analysis are presented in Tables 1 and 2. The physical and chemical characteristics of all the soil samples analyzed are similar in every aspect. Texture ranges from fine through medium to coarse grained soils (Figures 2 and 3).This suggests soils derived from parent materials or the geologic processes that influenced their formation. They are regarded as unconsolidated coastal plain sand, deltaic plain, Sombreiro and meander belt of the Deltaic sequence of the Niger Delta (Akamigbo and Asadu, 1986).They are also characterized by relatively low quantity of silts and clays. The low content of silts and clays of the soils suggests soil that must have been impacted by leaching, water erosion and the source of the parent materials, which is consistent with those of (Akamigbo, 1984 and Sanchez, 1976).

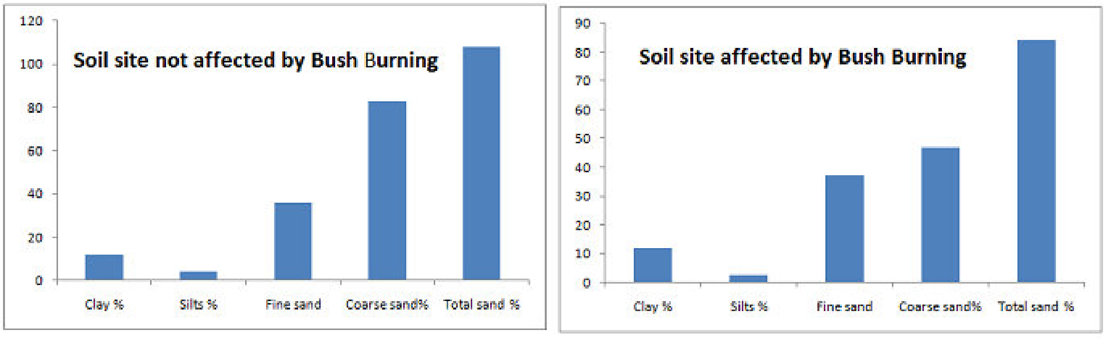

*Fig 2: Grain size distribution from soils sites affected and unaffected by Bush Burning*

The pH of the soil and that of its solution tends to affect the ability of the soil to either retain or release chemical properties of soil. Unlike water, soil has two pH values; the pH of the soil matrix known as ($pH_{KCl}$) and the soil water matrix ($pH_{H2O}$). The ($pH_{KCl}$) is often regarded as the pH of the soil because it takes into account all the physical and chemical characteristics (McBean and Rovers, 1998). Consequently, the $pH_{KCl}$ is used in the study as the pH of the soil. The $pH_{KCl}$ of both unaffected and affected soils ranges from 3.6 to 5.2, an indication of acidic soils.

Both the pH of soil matrix water ($pH_{H2O}$) and the soil matrix ($pH_{KCl}$) are lower than those obtained by Odu et al., (1985) as a standard for the purpose of agriculture. The acidic nature may have been influenced by leaching of soil elements responsible for bases of soil by heavy rainfall which characterized the study area, a characteristics which is common to most rainforest soils of the tropics.

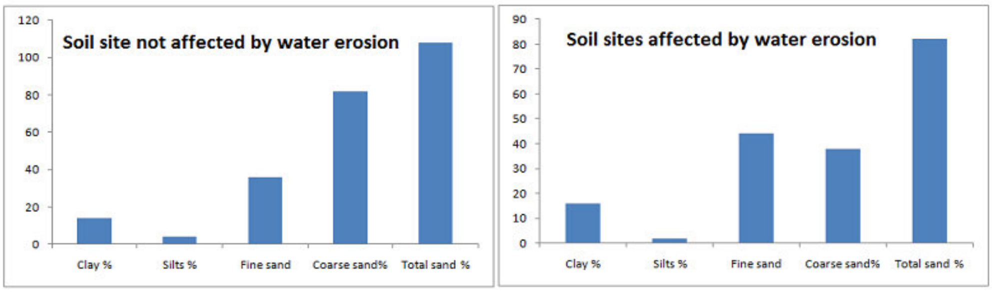

*Fig 3: Grain size distribution from soil sites unaffected and affected by water erosion*

The analysis also revealed low exchangeable cation, which indicates the inherent property of soils derived from local parent material. This is consistent with Akamigbo (1990); Akamigbo and Asadu (1986), who demonstrated that the exchangeable cation and the acidity of soils are greatly controlled by the parent material from which the soils are derived. Heavy rainfall that characterized the areas may have promoted high level of leaching, which is probably responsible for the low exchangeable cation observed in the study. Leaching has contributed to the removal of the more mobile elements responsible for the alkalinity of the soil leaving behind those that are less mobile. This phenomenon has resulted in soil rich in aluminum ($Al^{+++}$) and hydrogen ($H^+$) cations, which are responsible for the acidity of soils.

*Table 1: Soil elements in soils unaffected and affected by bush burning*

| *Variable= 7* | *Unaffected by bush burning* | | | | *Affected by bush burning* | | | |
|---|---|---|---|---|---|---|---|---|
| *Parameter* | *Min* | *Max* | *Mean* | *SD* | *Min* | *Max* | *Mean* | *SD* |
| *pH* | 4.4 | 4.8 | 4.62 | 0.188452 | 4.4 | 4.7 | 4.52 | 0.130384 |
| *O.M* | 0.32 | 1.32 | 0.606 | 0.42153 | 0.24 | 0.81 | 0.394 | 0.236601 |
| *O.C* | 0.55 | 2.27 | 1.042 | 0.725004 | 0.41 | 1.33 | 0.664 | 0.380039 |
| *O.N* | 0.04 | 0.38 | 0.1196 | 0.149924 | 0.009 | 0.81 | 0.3718 | 0.382428 |
| $Na^+$ | 0.03 | 0.07 | 0.042 | 0.016801 | 0.03 | 0.05 | 0.038 | 0.008367 |
| $K^+$ | 0.04 | 0.07 | 0.052 | 0.012781 | 0.02 | 0.04 | 0.032 | 0.008367 |
| $Ca^{2+}$ | 0.02 | 0.35 | 0.162 | 0.145172 | 0.3 | 0.9 | 0.64 | 0.240832 |
| $Mg^{2+}$ | 0.1 | 0.5 | 0.3 | 0.160357 | 0.2 | 0.8 | 0.598 | 0.281105 |
| $P_4^-$ | 1.3 | 1.2 | 2.2 | 1.5 | 1.3 | 1.4 | 1.38 | 0.044721 |
| $Pb^{3+}$, | 0 | 0 | 5.38 | 1.788 | 0 | 5.38 | 2.192 | 3.294286 |
| $Fe^{2+}$ | 0 | 0 | 26 | 10.2 | 0 | 31 | 12.2 | 16.70928 |
| $Ni^+$ | 0 | 0 | 188.5 | 73.4 | 0 | 194.3 | 73.96 | 101.4918 |
| $V^+$ | 0 | 0 | 9.17 | 3.362 | 0 | 12.7 | 6.106 | 5.787018 |

The chemical properties of the soil are lower than the critical levels required for agricultural purpose (Odu et al., (1985).This suggests that the soils are generally poor and cannot be regarded as fertile soils. The reason for unfavorable chemical properties may be probably attributed to geologic processes and the local parent material they are formed from (Enwezor et al., 1981). In addition, the organic matter, carbon and nitrogen contents in the soil are relatively low. The low value of these organic soil elements is attributable to increase process of mineralization of the soil elements by temperature, leaching and burning in accordance with the findings of Sims (1990).

*Table 2: Soil elements in soils unaffected and affected by water erosion*

| ***Unaffected by water erosion*** | | | | | ***Variable= 7 Affected by water erosion*** | | | |
|---|---|---|---|---|---|---|---|---|
| ***Parameter*** | ***Min*** | ***Max*** | ***Mean*** | ***SD*** | ***Min*** | ***Max*** | ***Mean*** | ***SD*** |
| ***pH*** | 3.7 | 4.7 | 3.98 | 0.40865 | 5 | 5.2 | 5.12 | 0.083666 |
| ***O.M*** | 0.5 | 1.28 | 0.676 | 0.33834 | 0.2 | 0.32 | 0.242 | 0.054955 |
| ***O.C*** | 0.86 | 2.2 | 1.164 | 0.58024 | 0.34 | 0.55 | 0.414 | 0.095812 |
| ***O.N*** | 0.046 | 0.096 | 0.0572 | 0.02174 | 0.016 | 0.026 | 0.0208 | 0.004817 |
| $Na^+$ | 0.04 | 0.09 | 0.064 | 0.02302 | 0.04 | 0.08 | 0.056 | 0.015166 |
| $K^+$ | 0.06 | 0.8 | 0.214 | 0.32768 | 0.05 | 0.07 | 0.054 | 0.008944 |
| $Ca^{2+}$ | 0.8 | 1.1 | 1 | 0.12247 | 0.4 | 0.6 | 0.5 | 0.070711 |
| $Mg^{2+}$ | 0.1 | 0.4 | 0.18 | 0.13038 | 0.1 | 0.2 | 0.14 | 0.054772 |
| $P_4^-$ | 1.7 | 5 | 2.46 | 1.42407 | 1.3 | 2.5 | 1.82 | 0.622093 |
| $Pb^{3+}$, | 0 | 5.33 | 2.132 | 2.91936 | 0 | 7.11 | 2.488 | 3.464473 |
| $Fe^{2+}$ | 0 | 177 | 41 | 76.9870 | 0 | 40 | 13.6 | 19.09974 |
| $Ni^+$ | 0 | 177.9 | 71.04 | 97.2757 | 0 | 191.4 | 74.22 | 101.7141 |
| $V^+$ | 0 | 6.62 | 1.324 | 2.96055 | 0 | 10.1 | 3.5 | 4.886717 |

*All except pH are in mg/kg*

The apparent cation exchange capacity (ACEC) and the effective exchangeable capacity (ECEC) are also low. Soils of this kind are referred to as low activity clay (LAC) soils (King and Juo, 1981). Akamigbo and Igwe (1990) described this type of soils that are low in ACEC and ECEC as soils which are made of the 1:1 lattice clay minerals (kaolinites), which is normal property of lateritic soils (Bašić et al., 2003). This is also consistent with Enwezor et al., (1981), who also attributed soils low in CEC to the actual type of clay minerals present in them.

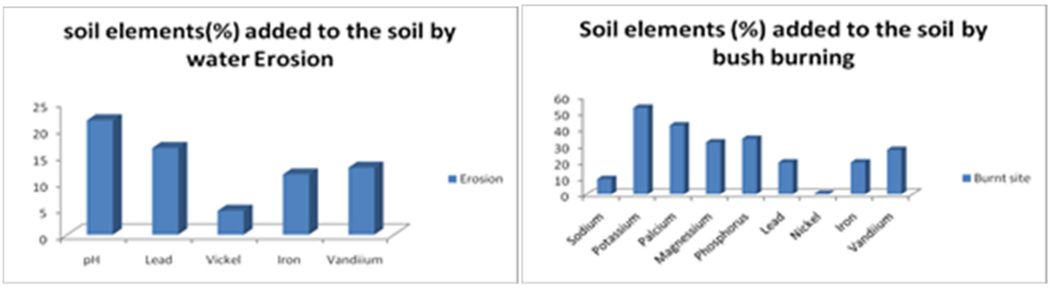

*Figure 4: Soil elements replenished by water erosion and Bush Burning*

The soil content in terms of plant available phosphorus is low. One of the reasons for this is high degree of weathering, as suggested by Enwezor et al. (1977), but the other one is so known “acidic fixation” of phosphorus in soils with low $pH_{KCl}$ enriched by $Al^{+++}$ ions as usually in laterites (Bašić et al., 2003). It also forms insoluble inorganic complexes of iron and calcium as the soil becomes more acidic and consequently, it is increasingly unavailable to plants as result of its solubility. In addition, phosphorus of organic materials is often released by process of mineralization involving soil organisms, which is a major characteristic of tropical soils and this process is often very rapid in soils with high moisture content, temperature and in well-drained similar to those of the study areas.

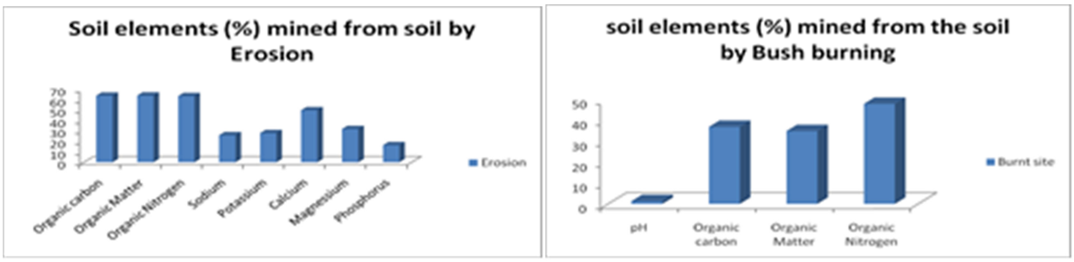

*Fig.5: Percentage of soil elements mined from the soil by water erosion and bush burning*

The concentration of heavy metals in soils analyzed (Fe, Ni, V, and Pb) is showed in tables 1 and 2. The high acidity ($pH_{KCl}$ value that range from 3.7 to 5.2) nature of the soils investigated favourable for the concentration of heavy metals in soil. This is in consistent with the observation of Pilchard et al., (2003) and Tiexeira et al.,(2010), they demonstrated that heavy metals have the tendency to accumulate in the surface of soil horizons rich in organic matter in acid medium with pH < 6.The heavy metals detected in the analysis may have originated from decomposition of organic matter, they occurred in association with organic matter in the undamaged soil or they may be formed from same geochemical processes with organic matter. It is observed however, that the value of the concentration of heavy metals is less compared to the concentration given by Aubert and Pinta (1977), which is the tolerable or critical level for agricultural purposes. According to them the critical level is the total content (extracted in aqua regia); lead 100-400mg/kg, 50-100 mg/kg for vanadium and 100 mg/kg for nickel and 20,000-60,000 mg/kg for iron.

*Table 3; Results of t and F- tests of bush burning and water erosion*

| | O.C | O.M | O.N | $Na^+$ | $K^+$ | $Ca^{+++}$ | $Mg^{++}$ | $P^-$ | $Pb^{3+}$ | $Fe^{++}$ | $Ni^+$ | $V^+$ | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t-test | 0.075726 | 0.072868 | 0.0383235 | 0.014126253 | 0.00007 | 0.18546394 | 0.00256423 | 0.005366 | 0.586838 | 0.79915452 | 0.9917i78 | 0.3873 | 4.99E-15 |
| F-test | 0.00697911 | 0.001189 | 1.818E-12 | 0.286379 | 0.11609 | 0.006317 | 0.0021633 | 7.1467E-07 | 0.728808 | 0.6436196 | 0.991716 | 0.6487 | 0.8038 |

The degree of impacts of bush burning and water erosion in terms of percentage of the undamaged soils is presented in figures 4 and 5.The burning of agricultural residue has contributed to the loss and improved in the fertility of soil. It tends to increase the temperature of the top three inches of the topsoil to such a degree that carbon and nitrogen equilibrium in the soil is destabilized. Consequently, carbon dioxide is lost to the atmosphere, nitrogen is converted to nitrate and fauna and bacteria are killed. This is reflected in the reduction in the values of carbon by 37%, organic matter by 35.5%, nitrogen by 48.8%, pH by 1.3%, silts by 30%, and coarse sand by 13.04% by bush burning (Figures 4 and 5). Conversely, the values of sodium content was increased by 9.5%, potassium 52.9%, calcium 42.2% magnesium 31.8%, phosphorus 34%, lead 19.6% , iron 19.6%, nickel 0.54%, vanadium 27.3%, clay 16.6% and fine sand 29.1% (Figures 4 and 5). The increment recorded in calcium, magnesium, sodium, potassium and available phosphorus in the soil may have emanated from the ashes produced by the burning of cut trees and grasses during land preparation for cultivation (Levine, 1991).

Water erosion as a form of soil damage and land degradation is often responsible for decline and increase in the availability of minerals required for the productivity of agricultural produces as presented figures 4 and 5. The analysis of the soils, both affected and unaffected by erosion revealed that erosion may be responsible for the reduction in carbon content by 64.2%, organic matter by 64.1%, nitrogen by 63.6%, sodium by 26%, potassium by 28%, calcium by 50%, magnesium by 32%, phosphorus by 36%, clay by 6.45%, silts by 14.2% and fine sand by 31.17% (Figures 4 and 5).The observed reduction by water erosion is probably adduced to soil particles and nutrients erosion as well as leaching as demonstrated by Lal (1988). In addition, erosion has the pH of the soil increased by 21.6%, lead by 16.4%, iron by 11.44%, nickel by 12.7%, and vanadium by 12.7% and coarse sand by 18.54 % ( Figures 4 and 5). It is an indication that erosion has caused the reduction of the acidity and same time increasing the alkalinity of the soil. The increase in coarse sand due to erosion may results in enhanced permeability, which is detrimental to the plants, as major soil elements will be leached from the root zone especially as the study areas characterized by high rainfall.

The results of statistical analysis are depicted in Table 3. The t and F-tests results revealed non-significance variation in mean and variance between the soil elements of pH, OC, OM,, ON, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $P4^-$, $Al_4^+$, $Pb^{3+}$, $Fe^{2+}$, $Ni^+$ and $V^+$ from the sites affected by bush burning and water erosion. This is an indication of the homogeneity of soil elements which are main constituent of soils and are controlled by the parent materials and same homogenous geochemical sources. These soil elements are found inherently in soils and they are merely re-introduced back into and removed from the soil by bush burning and water erosion. Soil elements, as nutrients are absorbed by plants and, on burning they are released into the soils; water erosion on the other hand simply removed and re-deposits them, hence no significance variation was observed by t- and F-tests as the process of land degradation is only responsible for the decline or increase of soil elements in the soil.

## 2.3 Conclusion

Regardless of the quantity of soil elements in the soil, it has been shown in the study that both water erosion and bush burning are capable of mining organic matters, associated nitrogen and carbon from the top soil of every soil. The burning of farmland before cultivation has the tendency of releasing oxides of carbon and nitrogen into the atmosphere, thereby increasing the amount of greenhouse gases and consequently contributing to climate change.

In spite of the mining of organic matters from the soil by bush burning, the low exchangeable bases are supplemented by bushing burning as seen from the increased in the exchangeable bases in the study. However, water erosion has further worsened the low exchangeable bases by causing mining of them from the soil that resulted in increased in acidity.

Water erosion has impacted more negatively on the quality of the soils than bush burning, which has some positive impact on the soil elements as seen in the released of exchangeable bases into the soils. Nevertheless both water erosion and bush burning as forms of soil degradation has caused increased in the quantity of heavy metals in the affected sites.

The non-significance variation of mean and variance obtained from student t- test and F-tests is due to homogeneity of soil elements which probably have originated from same geologic parent materials and geochemical sources. These forms of land degradation only remove and redeposit soils elements, even the supplemented amount are those soil elements absorbed by plants which were returned into the soil by the burning of plant residues. In spite of some of the advantages recorded in the paper, bush burning should be discourage in all entirety and grasses should be cultivated in sloppy land to prevent erosion of soils.

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