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Assessment of Tyre Burning Impact on Forest Soil Mineral Nutrients in Arakanga Forest Reserve, Southwestern Nigeria

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Abstract

Soil nutrients are needed for healthy forest growth. Forest soils were assessed at two different sites and depths (0-30cm and 30-60cm) within Arakanga Forest Reserve (AFR) to determine the effects of tyre burning on the mineral nutrient concentration of the soil. The two sites include the tyre burning part of the reserve (Site 1) and control site (Site 2). The AFR is a forest reserve in Ogun state, Nigeria that falls under the purview of a peri-urban forest. A 4x2 factorial experiment was laid out in a Randomized Complete Block Design (RCBD). Soil samples were randomly collected in each site at different depths and taken to the laboratory for further analysis. The trend for macro-nutrients in Sites 1 and 2 was as follows K>Mg>Na>Ca. Site 1 had a higher Sodium and Calcium at 0-30cm depth though there was no significant difference ($p \geq 0.05$) in their concentration between depths and sites. Potassium and Magnesium at both depths and sites varied significantly ($p \geq 0.05$). The order of concentration of micro-nutrients in Sites 1 and 2 include; Fe>Zn>Mn>Cu and Zn>Fe>Cu>Mn respectively. Copper, Iron, Zinc and Manganese concentrations were higher at 0-30cm depth in Site 1. Soil properties such as Organic Carbon, Organic matter, Total Nitrogen and Available Phosphorus were higher at 0-30cm; Bulk density and porosity were higher at 30-60cm depth and also varied between sites. Proper protection of the forest reserve from scavengers who illegally burn tyres to extract tiny steel wires should be enforced to sustain healthy forest growth.

Keywords: mineral nutrient, tyre burning, soil depth, forest growth

1.0 Introduction

Soil is a vital natural resource and its condition is fundamental for sustainable forest and agricultural production. The capacity of soil to function within ecosystem boundaries to sustain biological activity, maintain environmental quality, and promote plant and animal health is important (Doran and Zeiss, 2000). Soils function to provide ecosystem services that include increased soil water retention and availability, soil aggregation, nutrient cycling and storage, and microbial diversity and function. Rebecca (1992) stated that soil is a major source of nutrients needed by plants for growth. The three main nutrients are nitrogen (N), phosphorus (P) and potassium (K). Together they make up the trio known as NPK. Other important nutrients are calcium, magnesium and sulphur.

Plants also need small quantities of iron, manganese, zinc, copper, boron and molybdenum, known as trace elements because only traces are needed by plants. The role these nutrients play in plant growth is complex, and this document provides only a brief outline (Rebecca, 1992). Soil properties can be generally categorized as stable or dynamic. Stable soil properties are influenced by soil-forming factors such as climate, organisms, parent material, and topography, which change little with management practices (Romig, *et al*., 1995). Dynamic properties can change with land use and management practices over the course of a short time, generally within a human lifespan, and includes soil organic matter (SOM), bulk density and pH (Thapa, 2021).

Tyres are an attractive chemical commodity, construction material and solid fuel, due to their high energy density (Giere*et al*., 2004). Tyres consist mainly of styrene-butadiene, polybutadiene, bromated butyl rubber, carbon black, extender oils, nylon, and steel wire. Tyres are among the planet's fastest-growing non-biodegradable wastes due to the intense development of vehicles (Wang *et al*., 2019). The storage and reuse of tyres require attention to their potential environmental impact, including leaching and open-air burning which release hazardous smoke and pyrolytic oil into the environment (Pedram*et al*., 2017). Moreover, heavy metals such as zinc (Zn), Cu, Cr, are also reported to be present in the tyres (Rhodes *et al*., 2012; Lai *et al*., 2017; Nadal *et al*., 2016). Only around 25% of the discarded tyres are reused, while the remaining ones end up in landfills or illegal dumps and most times are eventually burnt.

When tyres are burnt, their firesare reported to generate large amounts of hazardous trace elements, toxic, mutagenic and carcinogenic compounds, such as volatile organics, polycyclic aromatic hydrocarbons, heavy metals, particulates and other products of incomplete combustion (Rhodes *et al*., 2012; Wang *et al*., 2007). As a result, significant environmental hazard is generated, and pollution of not only the atmosphere but also the surrounding soil and the groundwater is likely to occur (Chrysikou*et al.,* 2008). In countries like Nigeria, without tyre reuse and management programs, the frequency of tyre fires is suggested to be much greater (Shakya*et al.,* 2008). Soil and vegetation exhibit an integral relationship, the impact of tyre burning on forest soils which will in turn affect forest ecosystem biodiversity has received relatively little attention.

Arakanga Forest Reserve is a forest reserve and is located in Nigeria. It is planted mainly with exotic tree species such as *Tectonagrandis*(Teak) and *Gmelinaarborea*(Gmelina). However, illegal car tyre-burning activities have been observed within some parts of the reserve which has attracted public concern over potential contamination of the reserve. Therefore, this study aimed to assess the impacts of tyre burning on the concentration of soil mineral nutrients in the study area and determine the distribution of mineral nutrients at two different depths in Arakanga Forest Reserve.

2.0 Materials and Methods

2.1 Study Area Description

This research was carried out within the Arakanga Forest Reserve in Abeokuta, Ogun State Nigeria. It lies within latitudes 7° and 7°5′ N and longitudes 3°3′ and 3°37′E. Arakanga Forest Reserve (AFR) is one of nine (9) forest reserves in the Ogun state that falls under the purview of a peri-urban forest (Figure 1). AFR is about 2.3km² long and makes up both the high forest and savanna vegetation (Adekunle*et al*., 2013; Awojuola, 2001). The soils in the area are dominated by clayey loam developed on underlying granite. The dominant tree species in the reserve are *Gmelinaarborea* and *Tectonagrandis.*

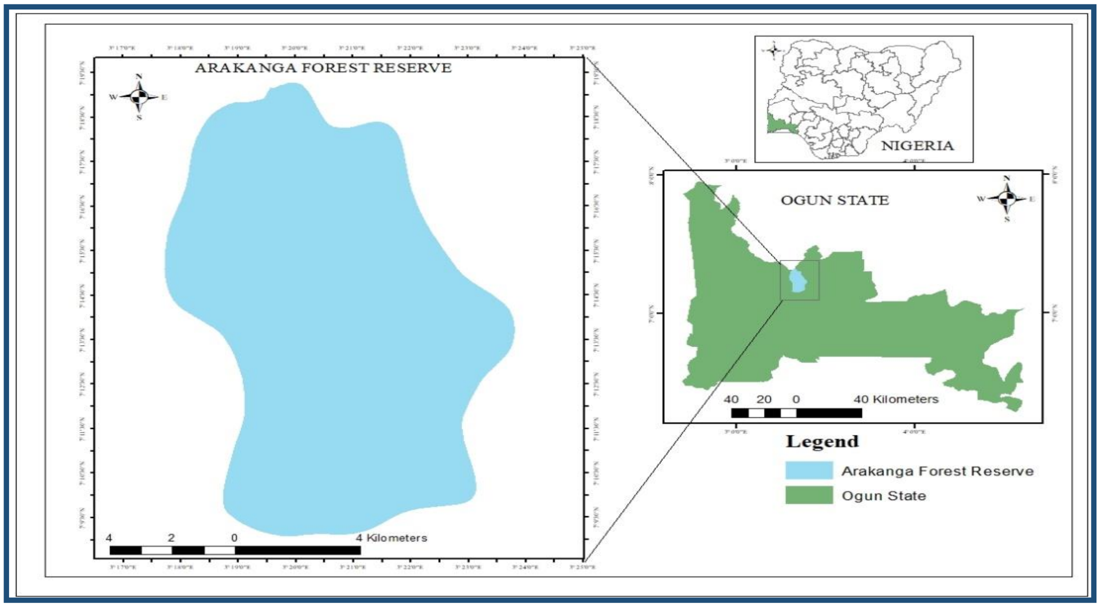

Figure 1: ***Map of Arakanga Forest Reserve in Ogun State***

2.2 Sample collection

Two different sites were identified within the reserve which include tyre burning part of the reserve (Site 1) and the unaffected site (Site 2) where no burning of tyres occurs. The study was a 4x2 factorial experiment laid out in Randomized Complete Block Design (RCBD) with factor 1 as two different sites (tyre burning area and undisturbed area) and factor 2 was soil samples collected from two soil depths (0-30cm and 30-60cm).

A total of twenty soil samples randomly collected at each site and depth were taken to the laboratory for analysis. Soil pH was determined in 0.01M Cacl$_2$ by using a soil collection solution ratio of 1:2.5 by means of a Philip analogue pH meter. The soil pH was determined using the pH meter (Black, 1965). The organic carbon content of the soil was determined by the wet oxidation method of Walkley-Black as described by Allison (1965). The total Nitrogen content of the soil was determined by the Micro Kjeldahl procedure Bremner (1965). C; N was computed as ratio of N; C. Available Phosphorus (P) was extracted by the Bray 1 method. The P concentration in the extract was determined colorimetrically by using the Spectronic 20 and absorption was read-off as described by Bray and Kurts (1945) and modified by Murphy and Riley (1962). Exchangeable K, Ca and Mg were extracted using ammonium acetate, K was determined on flame photometer and Ca and Mg by Atomic Absorption Spectrophotometer

(AAS).

2.3 Data analysis

Data collected were analysed using Statistical Analysis System (SAS) procedures and software (SAS, 2003). The means were separated by the Duncan's Multiple Range Test (Duncan, 1995) at 5% probability.

3.0 Results

3.1 Soil properties comparison between the two sites

The result of the soil properties with respect to the burnt area and unaffected soil of the study area (site 1 and site 2) at two different depths (0 – 30 cm and 30 – 60 cm) is shown in Table 1. Site 1 had constant higher values of pH, Organic Carbon, Total Nitrogen, Organic Matter, Available Phosphorus, Bulk Density and Porosity(6.66, 37.40 g/kg, 2.78 g/kg, 64.61 g/kg, 16.10 g/kg and 29.00) across all the chemical soil properties (pH, Organic Carbon, Total Nitrogen, Organic matter, Available Phosphorus and porosity) except Bulk density compared to unaffected soil type

3.2 Interaction between sites and depths on soil properties in the study area

As shown in Table 2, higher pH value (7.03; 6.60) was recorded at 30-60cm and 0-30cm in site 1 and 2 respectively. Also, pH at 0-30 cm was significantly ($p > 0.05$) higher in Site 1 than that of Site 2. Reverse is the case at depth 30-60 cm between the two sites. Soil properties such as Organic carbon, Organic matter, Total nitrogen, Available Phosphorus, Bulk density and porosity were significantly difference ($p > 0.05$) between depths across sites.

Table 1: Effect of soil type (Site 1 and Site 2) on soil properties of the study

area

Soil type	pH	Organic Carbon (g/kg)	Total Nitrogen (g/kg)	Organic Matter (g/kg)	Available Phosphorus (g/kg)	Bulk Density (g/cm^3)	Porosity
				Site 1			
Depth (cm)							
0-30	6.66±0.16^{a}	37.40±9.98^{a}	2.78±0.10^{a}	64.61±17.21^{a}	16.10±0.88^{a}	1.87±0.00^{b}	29.00±0.00^{a}
30-60	6.55±0.21^{a}	29.18±10.85^{a}	2.20±0.15^{b}	17.71±3.84^{b}	12.49±0.78^{b}	1.82±0.02^{b}	30.5±0.67^{a}
				Site 2			
0-30	6.45±0.00^{b}	35.38±10.92^{a}	2.62±0.17^{a}	61.01±18.84^{a}	16.05±0.90^{a}	2.00±0.05^{a}	24.5±2.01^{b}
30-60	6.33±0.12^{b}	27.08±11.45^{a}	2.04±0.08^{b}	14.09±2.37^{b}	12.44±0.35^{b}	1.95±0.07^{a}	26.00±2.68^{b}

Means followed by the same letter (s) written the same column are not significantly different at 5% level of probability using DMRT.

Table 2: Interaction between soil type and depths on soil properties in the study area

Soil type	pH	Organic Carbon (g/kg)	Total Nitrogen (g/kg)	Organic Matter (g/kg)	Available Phosphorus (g/kg)	Bulk Density (g/cm^3)	Porosity
				Site 1			
Depth (cm)							
0-30	6.30±0.00^{c}	59.80±0.20^{a}	3.02±0.00^{a}	103.09±0.35^{a}	17.96±0.66^{a}	1.87±0.00^{b}	29.00±0.00^{b}
30-60	7.03±0.03^{a}	15.16±0.46^{b}	2.54±0.01^{b}	26.14±0.79^{b}	14.25±0.01^{b}	1.87±0.00^{b}	29.00±0.00^{b}
				Site 2			
0-30	6.60±0.00^{b}	10.97±1.03^{b}	2.22±0.00^{c}	18.91±1.78^{c}	14.14±0.01^{b}	2.13±0.05^{a}	20.00±0.00^{c}
30-60	6.06±0.03^{d}	43.19±19.81^{ab}	1.86±0.00^{d}	9.28±1.38^{d}	10.74±0.00^{c}	1.77±0.03^{c}	32.00±0.00^{a}

Values of the same superscripts vertically are not significantly different ($p<0.05$)

3.3 Comparison of macro-nutrients within and between sites in the study area

The concentration of macro-nutrients with regard to depth in the two sites is provided in Table 3. The concentration of macro-nutrients (Na, K, Ca and Mg) varied significantly ($p > 0.05$) between depths (0-30 and 30-60 cm) across sites respectively. However, there were no significant variations between macro-nutrient concentrations within depths.

Table 3: Comparison of macro-nutrients between depths and sites in the study area

Macro-nutrients (Cmol/Kg)	Site 1 Depth (cm)		Site 2 Depth (cm)	
	0-30	30-60	0-30	30-60
Na	0.38 ± 0.03^{a}	0.37 ± 0.07^{b}	0.37 ± 0.04^{b}	0.39 ± 0.03^{a}
K	0.53 ± 0.07^{a}	0.51 ± 0.03^{b}	0.52 ± 0.03^{b}	0.54 ± 0.00^{a}
Ca	0.29 ± 0.03^{a}	0.28 ± 0.05^{b}	0.29 ± 0.03^{b}	0.30 ± 0.03^{a}
Mg	0.40 ± 0.02^{a}	0.37 ± 0.05^{b}	0.39 ± 0.05^{b}	0.41 ± 0.00^{a}

Means followed by the same letter(s) within the same column and treatment are not significantly different ($p>0.05$) using DMRT.

3.4 Variation of micro-nutrients within and between sites in the study area

Comparison of micro-nutrients concentration between depths and the two sites within the study area is shown in Table 4. The trend observed in macro-nutrients concentration between depths and sites isobtained here. There were significant variations ($p > 0.05$) in the concentration of micro-nutrients (Cu, Fe, Zn and Mn) between depths (0-30 and 30-60 cm) across sites respectively. Nevertheless, there were no significant variations in macro-nutrients concentration within depths of the same site.

Table 4: Comparison of macro-nutrients between depths and sites in the study area

Macro-nutrients (Cmol/Kg)	**Site 1 Depth (cm)**		**Site 2 Depth (cm)**	
	0-30	30-60	0-30	30-60
Cu	5.21±0.45^{a}	4.66±0.41^{b}	4.93±0.30^{b}	6.22±0.20^{a}
Fe	16.92±2.12^{a}	15.98±1.92^{b}	16.45±1.37^{b}	21.67±0.00^{a}
Zn	16.14±1.03^{a}	14.24±0.86^{b}	15.19±0.70^{b}	18.45±0.03^{a}
Mn	5.71±0.86^{a}	4.49±1.03^{b}	5.10±0.66^{b}	7.63±0.02^{a}

Means followed by the same letter(s) within the same column are not significantly different using DMRT ($p<0.05$)

4.0 Discussions

The soil pH is slightly acidic and near neutral and the values obtained in this study for both depths are similar to those reported by Pantami*et al*., 2010under a similar condition. Organic carbon also decreases down the depths. Higher values recorded at 0-30cm could be as a result of the deposition of leaves and tree branches from pruning on the upper layer of soil. The same trend applies to Organic matter where the top soil contains higher organic matter which corroborates the findings of Tabi*et al*., 2013 and Edem and Alphonsus (2016), who observed an increase in soil SOC in the soil surface after bush burning.Higher available Phosphorus recorded in Site 1 may be attributed to burning. The result is consistent with the finding of Tabi*et al*., (2013) who observed increase in available P was higher immediately after burning than after one year of cropping relative to the unburned forest vegetation. Higher Bulk density at 0-30cm in Site 1 and lower value in Site 2 at 30-60cm may be as a result of the effect of burning on the structure of the particles of the soil as stated by Certini, 2005 in his study.

The result of Total Nitrogen agrees with the result of Maharjan, *et al*., 2015, where its values decreased with depth. Total Nitrogen was higher in tyre burning site (site 1). Soil porosity increases with depth and was higher in Site 1 in the first 30cm depth. The forest tree leaves and other components such as wild animal waste, decomposed dead organisms and plants may have influenced the increase in topsoil Nitrogen, Organic Matter and Carbon. These findings are in consonance with the results of Tabi*et al*., 2013.

The macronutrients (Na, K, Ca and Mg) obtained in Site 1, where the burning of tyres is carried out, decreased down the depths while it increased down the depth in unaffected soil (Site 1). In addition, all the macronutrients examined in this study were higher in the topsoil (0-30cm) in Site 1 and in the subsoil (30-60cm) of Site 2. Higher Sodium concentration in Site 1 may be due to the presence of synthetic sodium carbon butadiene rubber in tyres (Fayzullaev, 2022)and this may damage roots through direct toxicity and prevention of soil from holding sufficient air and water needed for plant growth. Also, Potassium an essential plant nutrient is required in large amounts for proper growth and proper reproduction of plants (Agyarko, *et al*., 2014) but its high concentration in the soil can inhibit Mg uptake which may in turn induce Mg deficiency in plants (Trankner*et al*., 2016). Higher Magnesium in affected soil may be as a result of its concentration on the surface of clay and organic matter particles. An increase of Calcium in the subsoil of Site 2 may not be due to leaching because calcium is present adequately in most soils and is a component of several primary and secondary minerals in the soil.

Potassium (K) was the dominating plant nutrient among others in both Sites 1 and 2. It’s one of the important macronutrients as it contributes to giving plants strong cellular walls, aids in the cell division and is accountable for the activation of different enzymes (Marschne and Marschner, 2012). Its importance cannot be overemphasized, as it serves as one of the important macronutrients in seedling production in forest nursery.

All the micronutrients assessed in this study are higher in Site 1 and relatively low in Site 2. This may be a result of the deposition of heavy metals on the surface of the forest reserve soil after the tyres might have been burnt. In Site 1, Iron was the highest deposited micronutrient, while it was Zinc in Site 2.

Comparison of micronutrients also showed a similar pattern. A higher concentration of micronutrients occurs at 0-30cm depth. The behaviour of micronutrients, such as Fe, Mn, Cu, Zn, and Mo, with respect to fire is not well known but is important to understand its effect on the post-fire recovery of soils and plants (Verma and Jayakumar, 2012). Zinc and Iron are the dominant elements among the micronutrients at 0-30cm depth both in Site 1 and 2, but affected soil seems to have the higher value. This may be as a result of the deposition of metal wires extracted from the tyres after burning since Zinc and Iron are the major composition of tyre. The concentration of Fe and Mn found to be higher in unaffected soil at 0-30cm, could either be due to the uptake of essential nutrients by plants, leaching of exchangeable cations through heavy rainfall, or by erosion or a combination of these factors.

Conclusions and Recommendations

Organic carbon, total nitrogen, organic matter and available phosphorus are higher in affected soil, compared to unaffected soil. Macronutrients and micronutrients were slightly different in concentration between the two depths and sites examined. However, when depths are not taken into consideration, macronutrients (Na, K, Ca and Mg) were higher in Site 1. Site 2 had a higher concentration of Micronutrients (Cu, Fe, Zn and Mn) than Site 1.

The trend for macronutrients in Site 1 was as follows K>Mg>Na>Ca. The same trend was also observed in Site 2. Potassium was the highest macronutrient compared to others. Iron (Fe) was the dominant element with the following trend in Site1 Fe>Zn>Mn>Cu. Site2 possessed a different trend; Zn>Fe>Cu>Mn. This study further showed that macronutrients obtained decrease with depth in affected soil and increase with depth in unaffected soil. A similar pattern was observed in micronutrient results obtained.

Tyre burning is a dangerous practice as it can result inexcessive accumulation of soil nutrients which invariably is able to inhibit the uptake of other nutrients, resulting in deficiencies. High concentrations of basessuch as calcium, magnesium, potassium and sodium are associated with increased soil alkalinity.The excess of micronutrients promotes harmful effects such as induction of oxidative stress,reduction in photosynthetic pigments, alteration in membrane integrity and permeability, inhibition of protein function, interference with absorption and utilization of other mineral elements, stunted growth, and reduced yields. Proper disposal alternatives should be encouraged and tyres should be recycled to serve other useful purposes than disposing them in forestland. Therefore, more research needs to be conducted in the future to further assess the effect of tyre burning within the forest plantation on other soil health parameters.

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