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Spatio-temporal assessment of soil microbial biomass carbon around industrial area of Kano metropolis, Nigeria

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ABSTRACT

The soil microbial biomass carbon (MBC) acts as the transformation agent of the organic matter in soil as such the microbial biomass carbon is both a source and sink of some soil nutrients C, N, P, and S contained in the organic matter. The study is aimed at assessing the seasonal variation of soil microbial biomass carbon in contaminated soil. Ten soil samples were collected in contaminated and control locations, the samples were collected using composite sampling techniques in both wet and dry season and then analyzed in the laboratory for microbial biomass carbon using fumigation-extraction methods and pH using pH meter. The results of the analysis were subjected to statistical analyses using SPSS software and Microsoft Excel to undertake a T-test of means and ANOVA at 95% confident limit. The spatial distribution of microbial biomass carbon shows that contaminated locations have the highest mean values of microbial biomass carbon with 0.19 g C/kg and 0.29 gC/kg for Sharada and Bompai contaminated locations, while their control locations recorded low mean values of MBC (0.15 g C/kg and 0.17 g C/kg respectively). The temporal variation of MBC was observed where, high mean values were obtained in wet season which is due to the favorable condition for microbial population growth and activities due to rainfall, temperature and rapid mineralization rate in the wet season.

1. Introduction

Microbial Biomass Carbon is the living part of soil organic matter, excluding plant roots and soil animals more massive than about $5\times10^{3}\mu m^{3}$. It consists of many species of bacteria and fungi, together with relatively larger soil organisms such as yeast, algae, and protozoa (Gregorich *et al.,* 2000). Estimation of soil microbial biomass carbon offers a means of assessing the response of the total microbial population to the changes in soil management practices (Dai *et al.,* 2004). The soil microbial biomass acts as the transformation agent of the organic matter in the soil. As such, the biomass is both a source and sink of the nutrients C, N, P and S contained in the organic matter; it is the center of the majority of biological activity in soil (Lenart-Boron and Piotr, 2014).

Microbial activity includes all the metabolic reactions and exchanges conducted by micro-fauna and micro-flora in soil (Barajas-Aceves, 2005). It plays an essential role in soil productivity and sustainability, as it underpins some fundamental soil properties such as fertility and structure. Microbial biomass carbon and activities are regulated by many soils and environmental factors including soil organic matter quality, physical like temperature and chemical soil characteristics such as soil reaction (pH), presence and activity of plants and animals, and these factors also influence the amount of "available" pollutant to which microbes are exposed (Chander *et al.,* 2001). To correctly understand microbial biomass carbon activity in soil, one must therefore, know about the microbial activities. Investigating the flow of C and N in the soil, from newly deposited plant or other materials to the mineral forms of carbon dioxide and ammonium or nitrate ions clearly shows the central role of the microbial biomass. Soil microbial biomass, which plays an essential role in nutrient cycling and ecosystem sustainability, has been found to be sensitive to soil contamination (Brzezinska, 2006). The study is aimed at assessing the seasonal variation in soil microbial biomass carbon in a contaminated soil around the industrial area of Kano metropolis Nigeria.

2. Materials and Methods

2.1. Description of the Study Area

The study conducted on irrigated land around Sharada industrial area located between latitude 11° 57'N to 11° 59'N and longitude 8° 30' E to 8°32'E (Fig. 1) and situated within Municipal and Kumbotso Local Government Area, and Bompai industrial located between latitude 12° 10' N to 12° 12' N and longitude 8° 33' E to 8°35'E, and fall within Nassarawa, Ungogo and Fagge Local Government Area (Mohammed,

2010). The climate of the area is tropical wet and dry type, (Ayoade, 1983; Adamu, 2014). The rainfall in the area usually start around June, reach its peak around August, last till around October (Tanko, 2004) which favored the activities of soil microbes (Brady and Weil, 1999).

However, the dry season is around January to May and September to December within this period the activities of soil microbes is very low (Mohammed, 2004). The mean annual temperature is about 26^{o}C, but mean monthly values range between 21^{o}C in coolest months (December/January) and 31^{o}C in the hottest months (April/May) and temporal variation from one year to the other is very marginal (Olofin, 1987).The soils of the study locations are ferruginous tropical soils type whose equivalent to nitosols according to Food and Agriculture Organization and they are also equivalent to Ultisol and Alfisol according to United State Department of Agriculture (USDA, 1987). Variety of hydromorphic soils occur in a depression on the low terrace and abandoned parts of the channels which are referred to as fadama soils as observed along rivers on the studied areas (Mohammed, 2004). The residential, commercial and industrial land use types are the dominant land use in the study locations.

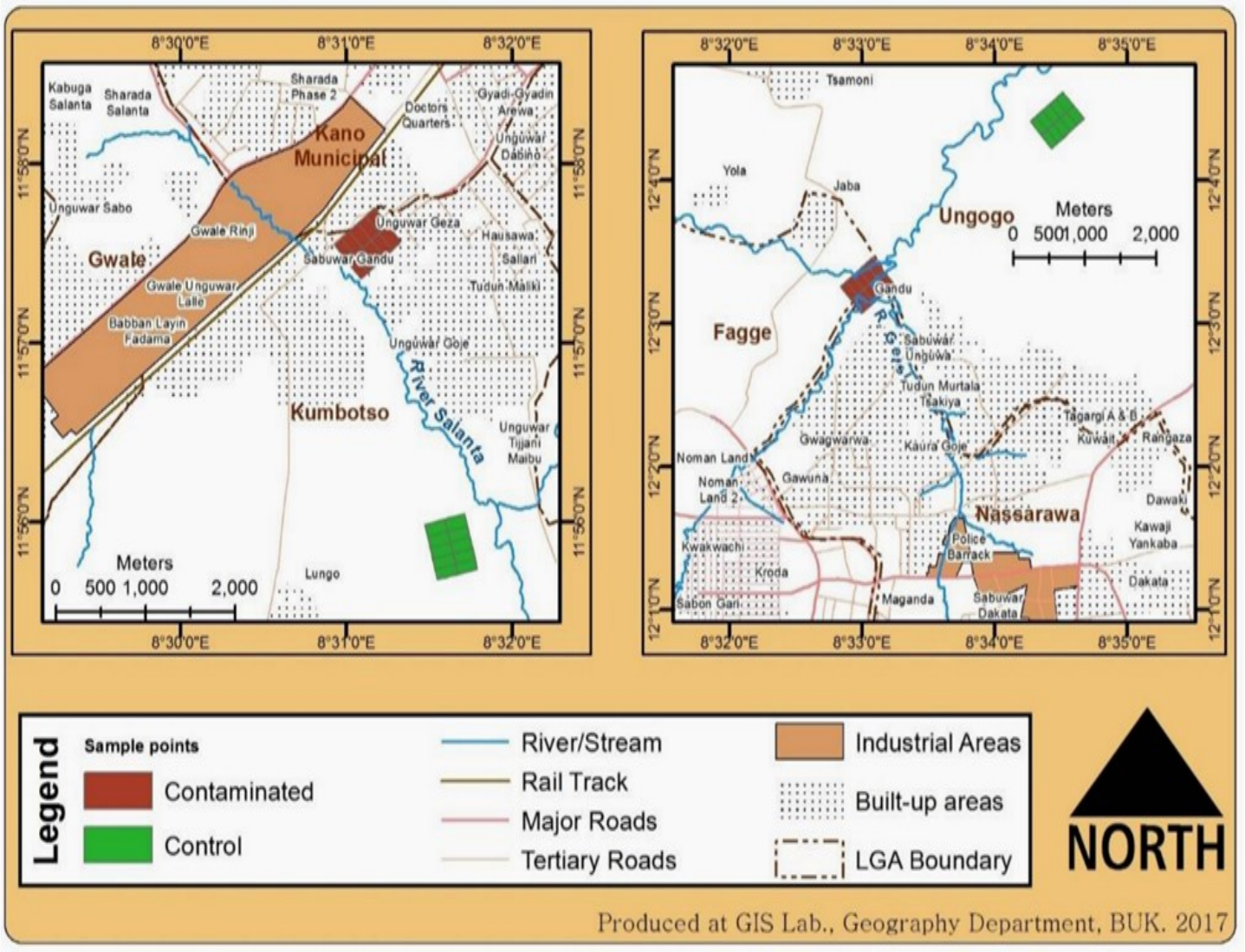

Figure 1. Study Location showing sampling site

According to United State Department of Agriculture (USDA, 1987). Variety of hydromorphic soils occur in a depression on the low terrace and abandoned parts of the channels which are referred to as *fadama* soils as observed along rivers on the studied areas (Mohammed, 2004). The residential, commercial and industrial land use types are the dominant land use in the study locations.

The materials used in this study include global positioning system (GPS) for recording the coordinates of sampled points, soil auger and spade for soil sampling, polythene bags for storing soil samples collected, marker for labeling the samples, pH meter to determine the soil pH, soil thermometer for recording the soil temperature and calorimeter for the determination of microbial biomass carbon.

2.2 Samples collection techniques

Two locations in the study area were selected purposively as Sharada and Bompai because they are the areas where

wastewater are discharged into the stream and used for irrigation. Each location was divided into two different area being adjacent to each other delineated: wastewater affected and control locations. In each area selected one square kilometer was delineated and then divided into ten small square where samples were collected in each small square using point composite sampling techniques from 0 – 15cm depth. The soil samples collected were placed into polythene bags, labeled appropriately, air dried and then taken to the laboratory for further analysis of soil pH and microbial biomass carbon.

2.3 Laboratory Procedures

Determination of Soil Reaction (pH): Weighed 10g of soil sample was placed in a 50 ml beaker, and 25 ml of 1.0 (N) KCl was added, and the suspension was stirred at regular intervals for 1 hour. The pH was measured with the glass electrode by immersing it into the suspension. The suspension was stirred well just before immersing the electrode. The pH meter was switched on at least 15 minutes. The electrode was rinsed with distilled water after each determination, and a blotting paper was used for water removal from its surface. The standardization process was checked after every ten determinations. The soil temperature was recorded using a soil thermometer and expressed in degree Celsius. The microbial biomass carbon was determined by fumigation-extraction methods as described by Vance *et al.* (1987) in the modification described by Nannipieri *et al.* (2003). Thus, 15g of fresh soil sample was placed into two 50ml beakers, and the beakers were placed into two paired desiccators (control and Fumigated). In the fumigated desiccator, the 100ml beaker containing 25ml chloroform (alcohol-free) was placed in the centre of the desiccator, boiling chips were added to the chloroform which assisted in rapid volatilization of the chloroform. The second desiccator contains non-fumigated (control) samples in which the desiccator was closed, and the sealant was uniformly distributed. A vacuum was applied to the fumigated treatment until chloroform boiled. The desiccators were closed and stored in dark condition for 72 hours at room temperature. The desiccators were opened, and the soil samples were transferred into the shaking bottle, 50ml of 0.5M K_2SO_4 were added and shake on a wrist action shaker for 25 minutes, and the suspension was filtered with Whatman paper No. 42 filter paper. The samples were digested, and the microbial biomass carbon was analyzed with a calorimeter.

$$MBC\left(\frac{mgC}{kg}\right) = \frac{EC_F - EC_{UF}}{K_{EC}} \quad \text{.....1}$$

Calculation:

Where: EC_F is the Organic carbon extracted from fumigated soil, EC_{UF} is the Organic carbon extracted from non-fumigated soil and, K_{Ec} is the 2.64 constant (Vance et al.1987).

3. Results and Discussion

3.1. Distribution of microbial biomass carbon, soil pH and temperature

The results of the analyses for soil samples in both dry and wet seasons from four locations for microbial biomass carbon, pH and temperature were presented in Table 1. The microbial biomass carbon of soil is frequently used as an early indicator of changes in soil chemical properties resulting from soil management and environmental stresses in the agricultural ecosystem (Chander *et al.,* 2001). The distribution of microbial biomass carbon, soil pH and temperature in the study locations as shown in Table 1, indicates that contaminated locations have the highest mean values of microbial biomass carbon with 0.19 g C/kg and 0.29g C/kg for Sharada and Bompai contaminated locations respectively, while their control locations measured 0.15 g C/kg and 0.17 g C/kg respectively as shown on. The mean value for microbial biomass carbon are 0.19g C/kg, 0.15 g C/kg, 0.29 g C/kg and 0.17 g C/kg for Sharada contaminated, its control, Bompai contaminated and its control location respectively (Table 1). The high mean values of microbial biomass carbon were found in contaminated locations where temperatures are high as shown in Table 1. This indicates that microbial biomass carbon influenced markedly by soil temperature changes. This is explained by Brady and Weil (1999) that soil microbial activities virtually ceases below 5 ^oC and increase more than double for every 10^oC rise in temperature up to an optimum of about 35^oC to 40 ^oC.

The mean values of temperature in the study locations also found to be higher in wet season where the mean values of microbial biomass carbon, was seen to be higher. This indicates the influence of rainfall (moisture) and temperature on soil microbial biomass carbon. This is explained by Brady and Weil (1999) that the diversity and activity of soil microbes increase with the increase of temperature and soil moisture. This is supported by Saxena and Singh (2013) who are of the view that seasonal variation of microbial biomass carbon was directly related to the availability of moisture and temperature condition of the soil.

2.2. Temporal Variation of microbial biomass carbon in the study location

The mean values of microbial biomass carbon in the soil of the study locations in both dry and wet seasons (Figure 3) which shows that, microbial biomass carbon was found to be higher in wet season in all the study locations than dry season which is probably attributed to the favorable condition for microbial population growth and activities due to rainfall, high temperature and rapid mineralization rate in wet season (Mondal et al., 2015). This shows that microbial biomass carbon responds more to seasonal change and consequently be an early and sensitive indicator of soil quality change. Seasonal variation in soil moisture and temperature have a significant effect on microbial biomass carbon which in turn affect the ability of soil to supply nutrient to plant through organic matter turn over (Boerner, Brinkman and Smith, 2005). The pattern of seasonal variation in microbial biomass carbon, obtained in this study is inconsistent with the result obtained by Guicharnaud, Arnalds and Ian Poton (2010) who is on the opinion that microbial biomass carbon is affected by soil characteristics and an environmental factor which vary with season. Lenart-Boron and Piotr (2014) also observed that microbial biomass carbon increases with increases in soil moisture, temperature, and pH.

Table 1: Spatio-temporal Distribution of MBC, Température and pH in the study Locations

Seasons	Statistics	Microbial biomass carbon (Mg C/Kg)	Temperature (°C)	pH (Kcl)
Sharada Contaminated Location				
Dry	Mean	0.19	24	8.99
	Range	0.17-0.22	23.41-24.73	8.2-10
Wet	Mean	2.66	26	8.3
	Range	2.58-2.74-2	25-28.0	7.4-9.4
Sharada Control Location				
Dry	Mean	0.15	21.45	6.44
	Range	0.1-0.18	21.01-22.03	6.2-6.8
Wet	Mean	3	25.8	6.21
	Range	2.72-3.68	25-27.0	7.01-8.2
Bompai Contaminated Location				
Dry	Mean	0.29	24.74	7.65
	Range	0.18-0.43	24.1-25.52	6.9-8.2
Wet	Mean	3.72	25.55	7.32
	Range	3.68-3.74	24.6-27.0	7.3-9.1
Bompai Control Location				
Dry	Mean	0.17	21.64	7.11
	Range	0.12-0.21	19.84-23.1	6.6-7.4
Wet	Mean	2.75	25.52	7.03
	Range	1.87-3.21	24.0-26.0	6.7-8.5

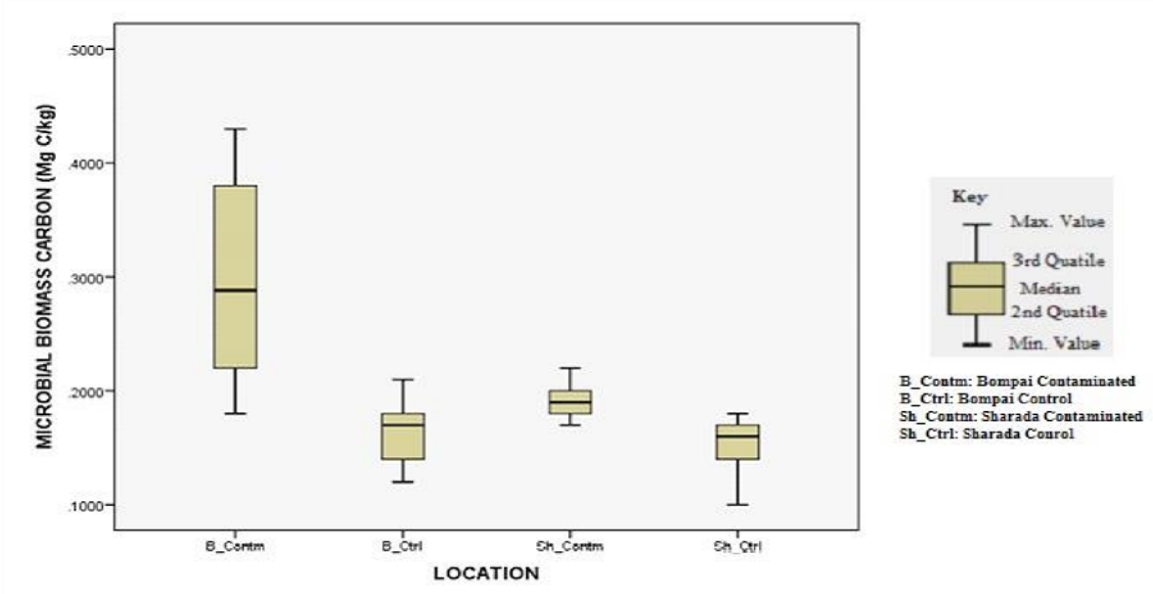

Figure 1: Spatial Distribution of MBC in Study Locations **Source: Fieldwork (2015)**

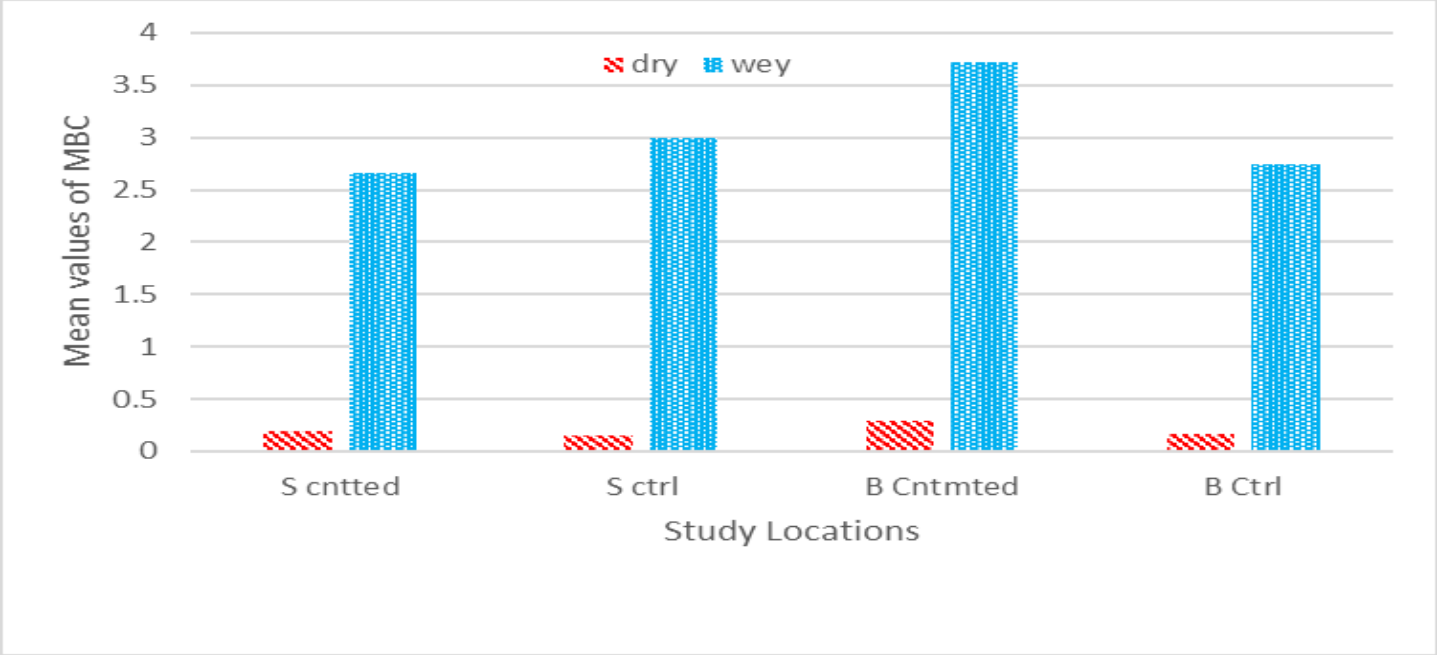

Figure 3: Temporal variation of MBC among the study locations

4. Conclusion

From the findings, it was concluded that significant seasonal variation of microbial biomass carbon among the study location was discovered which is due to high temperature and rainfall effect which facilitated the biochemical reaction in the soil and enhance the population growth and activities of soil microbes. Higher microbial biomass carbon in contaminated locations is due to high pH and temperature in the area which reduced the toxicity effect of the contaminants and enhanced the microbial diversity and activities respectively. The determination of microbial biomass carbon, soil pH and temperature of soil reflect the microbial activities in the soil of Sharada and Bompai areas and could be considered as soil quality indicators.

5. Recommendations

From the findings, rainfall and temperature are the leading causes of seasonal variation of microbial biomass carbon and therefore, on the basis of the results of this study, it was recommended that, appropriate soil management practices should be encouraged like minimum tillage, improve drainage and application of organic fertilizer which enhances the structural stability of the soil, increased water holding capacity of the soil thereby strengthening the population and activities of soil microbes. Also, Further studies are recommended on the contaminants levels for determining soil quality using microbial parameters in order to assess the capability and efficiency of microbial biomass carbon in assessing soil contamination status.

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