Assessment of Effect of Charcoal Production on Physicochemical of Soil in Akunnu, Akoko, Ondo State

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Abstract

Charcoal production is the process of converting wood or other organic material into charcoal through the application of heat in absence of oxygen. To investigate the effect of charcoal production on soil properties, soil samples from ten soil sampling points were collected at a depth of 0-15 cm at kiln site and adjacent fields (control). The study revealed that the earth kiln method used by charcoal producers has significantly increased pH of soil (< 5.5) to be acidic. Soil organic matter (OM) and organic carbon (OC) was high at most areas of the site (74.2%), while others fall within the ranges of low to medium. Available macronutrient status for Nitrogen (0.06 % - 0.23 %) falls within moderate to high ranges while (P, K, Ca, Mg) falls within moderate to high ranges (0.22 Cmol/kg –7.15 Cmol/kg), having few points low in these contents. The availability of micronutrients was highly variable. Zinc (Zn) were moderate at almost all areas, iron (Fe) was low (41.9%), while copper (Cu) was moderate and high respectively across the site (0.18 mg/kg – 0.31 mg/kg). Base on this result it was understood that the coarsening particles resulting from charcoal production has implication for nutrient availability resulting in less nutrients available for crops use. Therefore, the study suggest for an improved method of charcoal production should be used, regulation of indiscriminate felling of trees and woodlot should be established in areas of charcoal production.

***Keywords**: Akoko, Charcoal production, physical and chemical properties**,** earth kiln, kiln site*

1. Introduction

Man's use of charcoal extends back as far as human history itself. It was first used more than thirty thousand years ago to make some of the earliest cave paintings. Much later, charcoal played an important role in what might be considered mankind's first technology, the smelting and working of metals. In more recent times, charcoal has remained a technologically important material, primarily as a result of its adsorptive properties. The use of activated charcoal in gas masks during World War I saved many thousands of lives, and today charcoal is used on an enormous scale for the purification of air and water [19]. Charcoal production is a common practice in many parts of the world, especially in developing countries, where it is used as a source of fuel for cooking and heating. biomass energy, especially fuel wood and charcoal, are the most important sources of energy in developing country [3]. it is a fuel that is produced by carbonization of biomass

Charcoal production is done through a method called pyrolysis of biomass. Pyrolysis is defined as the irreversible chemical change brought about by heating biomass in the absence of oxygen. During pyrolysis biomass undergoes a sequence of change and normally yields a black carbonaceous solid called charcoal along with mixture of gases vapors. Generally charcoal production through pyrolysis is maximized in process of low temperature and slow heating rates the so called carbonization [5]. Charcoal is used as a domestic fuel for cooking and heating in many developing countries .It is the most popular barbecue fuel throughout the world its advantages when used as a domestic fuel are that it produces less smoke while burn require little or no preparation before actual use has higher energy content per unit mass can easily transported stored and used when left over after cooking.

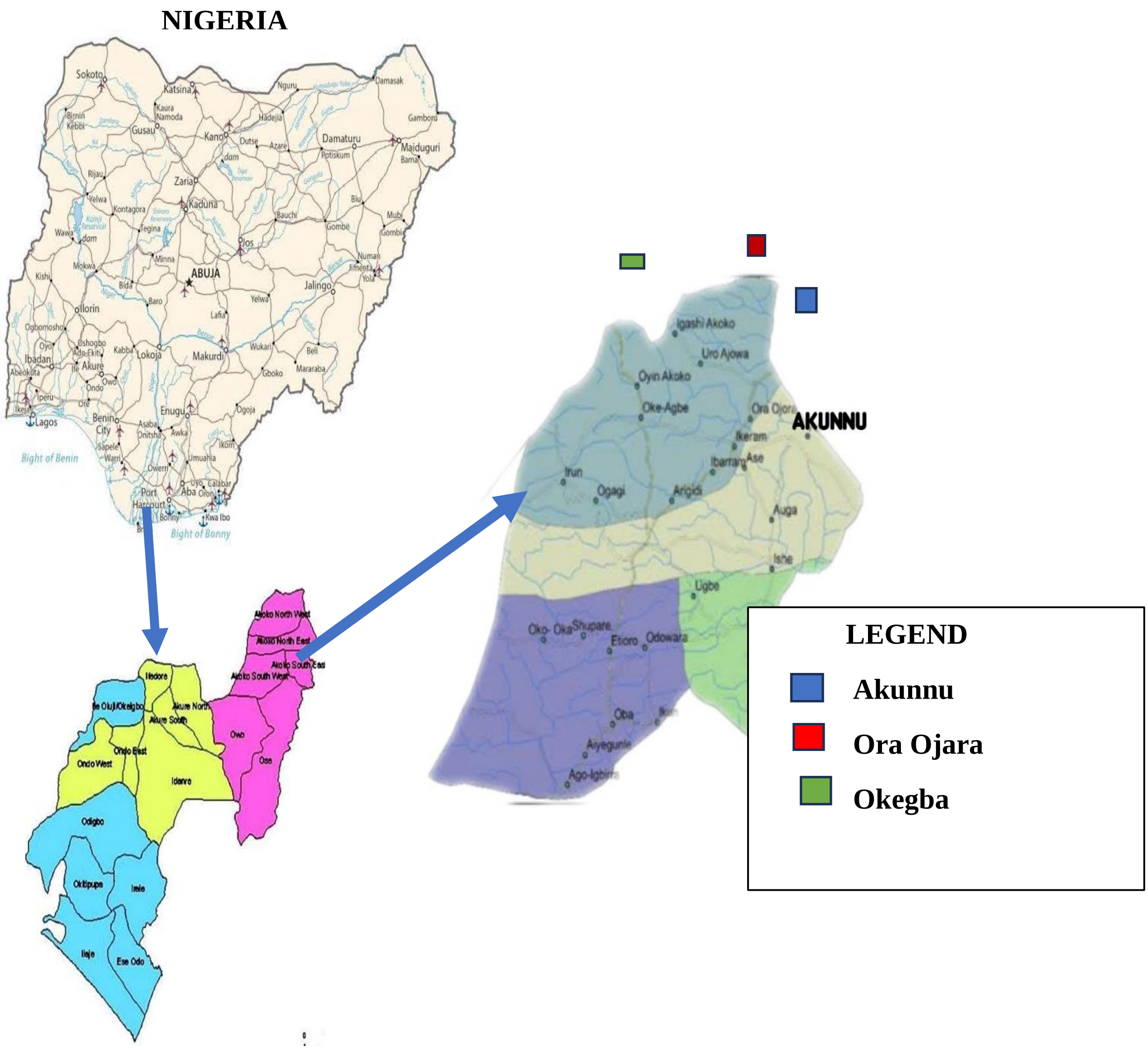
The charcoal production has been known since the Bronze Age and was vital to metallurgical industries until the discovery of the conversion of coal to coke at the beginning of the 18th century when there was increasing scarcity of easily harvested [11] The world largest charcoal producer 'Brazil' with more 12 million metric tons in year 2002 has preserved its charcoal-based industries in large part because it has extensive iron deposit and very few coal mines [22].

In most Africa countries charcoal environmental degradation in rural area [15] in the contrast to the developing countries in Africa and Asia the European and North America countries use large amount of charcoal for barbeque fuel in foundries and forges for extraction and refining of metals especially iron.

The ash produced during charcoal production can alter soil pH, nutrient availability, and water-holding capacity, thereby altering soil fertility and crop productivity. For instance, according to [1], soil pH increased significantly near charcoal production sites in Nigeria, which could lead to reduced nutrient availability and lower crop productivity. [4] reported that the use of charcoal production in Ghana led to soil degradation and loss of soil organic matter, which can reduce soil fertility and productivity over time. Also, a study conducted in Ondo state, Nigeria found that the use of traditional charcoal kilns led to significant soil degradation, while the use of improved kilns reduced the negative impact on soil properties. Therefore, this research study aimed to assess the impacts of charcoal production on physicochemical properties of soil in Akoko north.

2. Materials and Methods

2.1 Description of the Study Area: The study was conducted in Akoko, Akunnu, Ondo State in the year 2023. It is located at about 7°37' north of the equator and 5°56' east of the Meridian. It is situated around 700 km (430 mi) southwest of Abuja and 311 km (193 mi) north of Lagos State. The residential districts in Akoko vary in density, with areas such as Okela, Okegba Okorun, Okoja Iku, and Odeyare having over 200 inhabitants per hectare (81/acre) [9].



ONDO STATE

Figure 2.1: Map of the study area.

2.2 Soil sampling and Analysis: Soil samples was carried out according to the method of [23]. A total of ten composite samples was collected from three different locations. An auger was used to collect the soil samples as shown in Plate 1 and coordinates of these locations were also recorded accordingly with the use of a hand-held GPS (global positioning system). Three composite and replicates samples each was collected from the sampling locations at a depth of 0 to 15 cm, and at a distance interval of 10 m 20 m and 30 m with a control devoid of charcoal activities 100 m meter away. A total of ten soil samples were bulked into composite which were later bagged in a polyethylene bag and labelled as followed: L1, L2, L3, L4, L5, L6, L7, L8, L9. where L = Location and control point accordingly as shown in Plate 2. The samples were transported to the crop, soil and pest management (CSP) laboratory for processing.

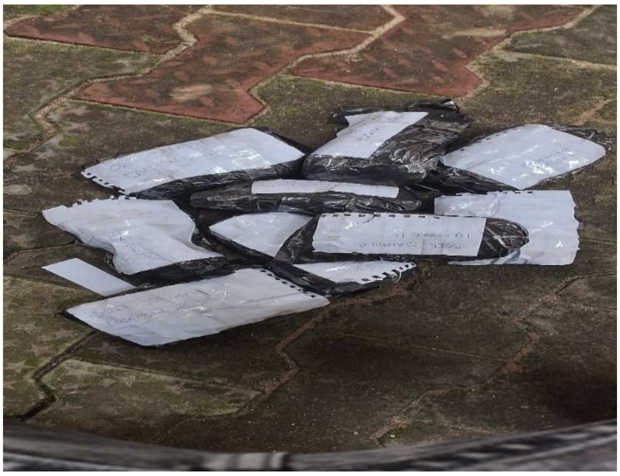


Plate. 1 Collection of soil sample Plate. 2 Bagged Soil Sample

2.3 Method of Soil Testing

Stones and other debris were removed from the soil samples before they were air dried inside the lab at room temperature (20°C to 22°C) on a broadsheet. The drying time of the soil samples varied depending on their moisture content, and thus the samples took 7 days to completely dry. The large boulders were broken down to smaller particle size. Pebbles, plant roots, and other unwanted material were also taken out. Once the soil had completely dried, it was sieved through a 2 mm sieve and the samples were then stored in sterile polyethylene bags for analysis.

2.3.1 *Determination of Physico-chemical Parameter*

The physico- parameter of soil samples were obtained by applying the standard method for analysis of soils according to [27]. A crush part of the air-dried soil sample was completely mixed with water in the ratio of 1:1 by volume and a benchtop 2601 pH/conductivity meter was utilized to determine the pH of the soil. The Physicochemical parameters included: pH, Organic Carbon (OC), Organic Matter (OM), Nitrogen (N), Pottasium (K), Phosphorus (P), Sodium (Na). Calcium (Ca), Magnegium (Mg).

2.3.2 *Determination of Soil Heavy Metals*

Available micronutrients (Fe, Ni, Cr, Zn, and Cu) were extracted by DTPA [27]. The DTPA (diethylenetriaminepentaacetic acid) micronutrient extraction method is a non-equilibrium extraction for determining the potential soil availability of Zn, Cu, Mn, and Fe. Lead, nickel, and cadmium in soils have all been tested using this method. Solution pH, temperature, soil extraction ratio, shaking duration, extraction time, and extractant concentration all have an impact on how many micronutrients and trace metals are removed. ICP-OES analyzes extracts. For Zn, Cu, Mn, and Fe, the method's detection limit is roughly 0.1 mg/kg, and its

typical reproducibility is 10% for Cu and Zn and 15% for Fe and Mn. The DTPA soil test was developed to identify near-neutral and calcareous soils that don't have enough Zn, Fe, Mn, or Cu to support the highest agricultural yields. Diethylenetriaminepentaacetic acid (DTPA), 0.1M triethanolamine, and 0.01M CaCl2 make up the extractant, which has a pH of 7.3. Shaking 10 g of air-dry soil with 20 ml of extractant for two hours constitutes the soil test. After filtering the leachate, Zn, Fe, Mn, and Cu are determined using atomic absorption spectrophotometry in the filtrate.

2.4 Statistical and Geostatistical Analysis

The obtained data were analyzed using descriptive statistics, namely the mean, minimum and maximum; standard deviation (SD); coefficient of variation (CV) on MINITAB 17.0 software. The post-hoc test (turkey test) was used to determine significant difference ($p < 0.05$) in the data; histogram of frequency distribution curve; boxplot graph; Principal component analysis (PCA) with Dendrogram, Scree plot and K-means clustering analysis were used to express the variation in the data. The Pearson's coefficient of correlation of the obtained data was carried out in IBM SPSS Statistics software version 23. Coordinates recorded with global positioning system (GPS) and selected data were used on Golden Software SURFER 18.1 to examine the spatial distribution of soil properties using Kriging Method.

3. Result and Discussion

Table 1: Physicochemical parameter of the soil sample collected from the study Area

Location	pH Mean	OC Mean	OM Mean	N Mean	P Mean	K Mean
1A	4.99	1.07	1.85	0.12	13.77	0.46
	5.00	1.09	1.88	0.13	13.69	0.45
1B	4.90	0.67	1.16	0.10	28.54	0.43
	4.95	0.65	1.12	0.08	28.39	0.42
1C	4.76	0.90	1.55	0.18	19.60	0.45
	4.78	0.92	1.58	0.15	19.68	0.44
2A	4.85	0.90	1.55	0.17	29.40	0.40
	4.86	0.88	1.52	0.20	29.40	0.34
2B	4.87	1.00	1.72	0.10	29.17	0.42
	4.88	1.02	1.75	0.13	29.09	0.40
2C	4.81	0.33	0.56	0.06	26.68	0.34
	4.80	0.90	0.59	0.08	26.60	0.35

3A	4.96	0.52	0.89	0.12	23.96	0.26
	4.94	0.54	0.92	0.11	23.88	0.26
3B	4.92	1.19	2.05	0.23	15.09	0.39
	4.90	1.22	2.10	0.18	15.01	0.40
3C	4.72	1.09	1.88	0.16	24.19	0.47
	4.74	1.11	1.92	0.13	24.11	0.47
Control	4.95	1.52	1.66	0.19	32.75	0.22
	4.99	1.53	1.65	0.21	32.75	0.21

Location	**SAND**	**CLAY**	**SILT**	**Na Mean**	**Ca Mean**	**Mg Mean**
1A	52.80	27.20	20.00	0.56	4.00	2.00
	53.00	26.80	19.60	0.58	4.10	2.00
1B	52.80	23.20	16.00	0.72	7.30	3.30
	52.32	24.00	16.80	0.78	7.00	3.30
1C	56.80	28.00	20.00	0.65	5.20	2.50
	59.00	27.20	19.20	0.60	5.20	2.50
2A	52.80	26.80	19.60	0.43	6.20	3.10
	52.00	27.00	19.40	0.44	6.30	3.20
2B	56.00	30.00	18.60	0.50	7.30	3.10
	56.80	31.00	18.00	0.43	7.00	3.20
2C	56.20	31.20	16.00	0.54	5.70	2.80
	56.90	31.00	16.40	0.59	5.80	2.70
3A	55.20	27.80	20.00	0.35	4.40	2.20
	54.90	28.00	19.90	0.34	4.30	2.30
3B	52.40	31.20	21.60	0.55	6.00	2.60
	55.00	31.60	20.80	0.56	5.80	2.80
3C	48.80	32.00	17.80	0.66	7.00	3.20
	50.00	31.80	18.00	0.68	7.10	3.00
Control	62.50	31.25	24.00	0.92	6.50	1.89
	62.90	31.28	24.08	0.94	6.51	1.84

3.1 Soil pH

The descriptive statistics of soil pH at ten different locations on the study site are presented in Table 4.1. The pH values ranged from 4.72 to 5.00. The average pH values at each location are illustrated in Figure 4.1. Based on the results presented in Table 4.1, a variance analysis was conducted, and it was found that there is no significant difference in pH between locations L4 and L5, L3 and L9, and L7 and L8. The values were similar with the pH value of 4.7–5.7 reported by [31]. However, the pH values at the remaining locations are significantly different from each other, as indicated by the analysis conducted at a significance level of $p < 0.05$. The highest observed pH value of 5.00 was recorded at location L1, while the lowest pH value of 4.72 were observed at location L9. According to [13] pH values below 5.5 is acidic and pH values from 5.5 – 6.5 is slightly acidic, the pH values obtained are therefore acidic. Figure 3.1 visually represents the average pH content at each location

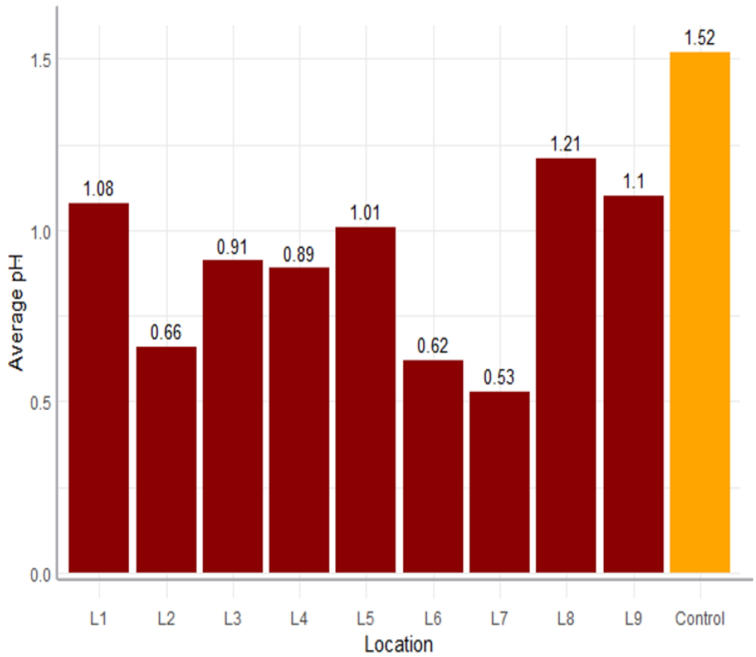


Figure 3.1: A graph showing average pH

3.2 Organic Carbon

The soil organic carbon content of the study area varied from 0.33% to 1.53%. Within this range, there is no significant difference between the organic carbon levels in locations L3 and L4, as indicated in Table 4.2. However, significant differences exist between the organic carbon levels in the remaining locations. The maximum value of organic carbon, 1.53%, was observed at the control location, while the minimum value of 0.33% was recorded at L6. The samples from each location falls under medium and high rating similar to the report by [12] that (< 0.25%) as very low, (0.25 – 0.50%) as low, (0.50 – 0.75%) as medium (> 0.75%) as high and [26] that (< 0.50%) as low, (0.50-1.0%) as medium and (> 1.0%) as high. The organic carbon values obtained are found to be in low and high range. Figure 3.2 visually represents the average organic carbon content at each location.

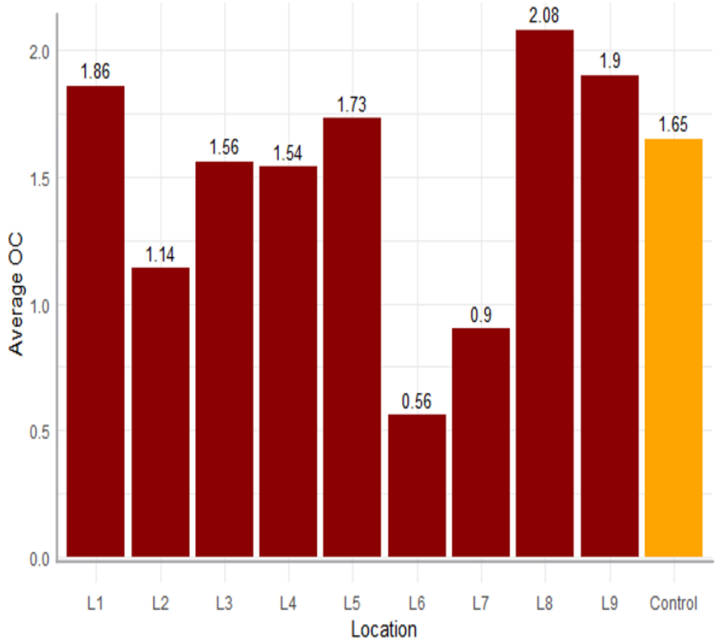


Figure 3.2: A graph showing organic carbon value of soil

3.3 Organic Matter

The organic matter content of the soils in the study area ranges from 0.56% to 2.0%. The maximum value of 2.1% was observed at L8, while the minimum value of 0.56% was recorded at L6. 26.1% are ranged as very low to medium which is in line with the result from [18] that organic matter content (< 1.0%) as very low, (1.0 – 2.0%) as low, (2.0 – 4.0%) as medium and (> 4%) as high. Low content of organic matter in the soil may be a result of reduced presence of decaying organism and low annual precipitation. Figure 3.3 visually represents the average organic matter content at each location

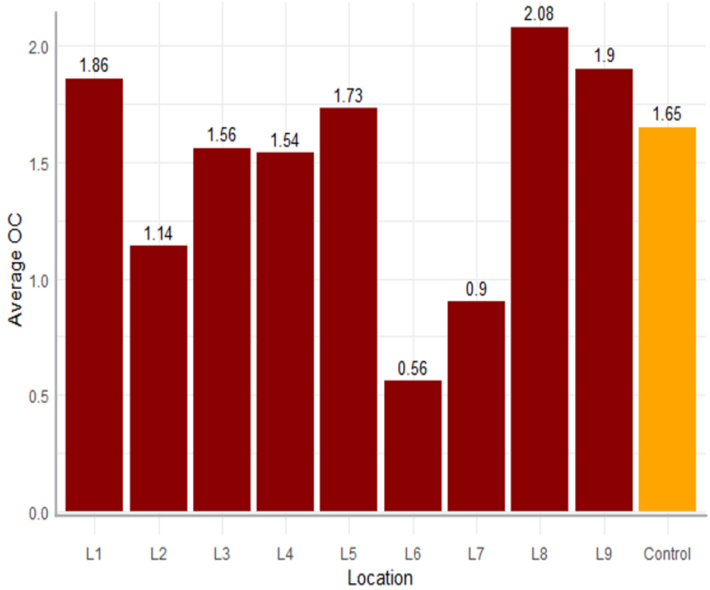


Figure 3.3: A graph showing average Organic Matter (OM)

3.4 Nitrogen

Nitrogen soil content of the study area ranged from 0.06% to 0.23%. The maximum value of 0.23% was observed at location L8, while the minimum value of 0.06% was recorded at location L6. There was no significant difference between the nitrogen contents of locations L2 and L3, L1 and L4, and L6 and L7 and control shows a medium level of nitrogen content and L8 shows a high level which is similar to the ranges reported by [24] that values greater than 0.2% are very high. However, significant differences exist between the nitrogen contents of the remaining locations. Deficiency of nitrogen in L6 is due to less organic matter contents in these soils due to climatic conditions. Figure 3.4 visually represents the average nitrogen content at each location

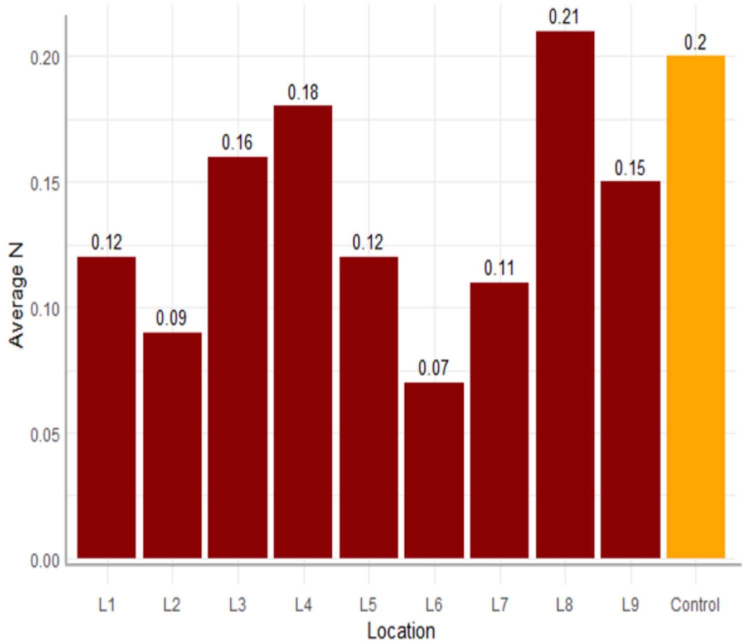


Figure 3.4: A graph showing average Nitrogen (N)

3.5 Sand

Table 4.5 presents the descriptive analysis of the sand content in the samples. The mean values ranged from 49.4% to 62.70%. The maximum value of 62.70% was found at the control, whereas the lowest value of 49.4% was recorded at location L8. The values were observed to be lower when compared with the control which could have been a result of accumulation of organic matter. Notably, there is a significant difference in the sand contents among the various locations as indicated by the analysis conducted at a significance level of $p < 0.05$. Sand content in the locations was found to be within medium to high range which is in line with the report by [21] that sand content (< 20%) as low, (20-50 %) as moderate and (> 50%) as high. Figure 4.5 provides a graphical representation of the average sand content at each location.

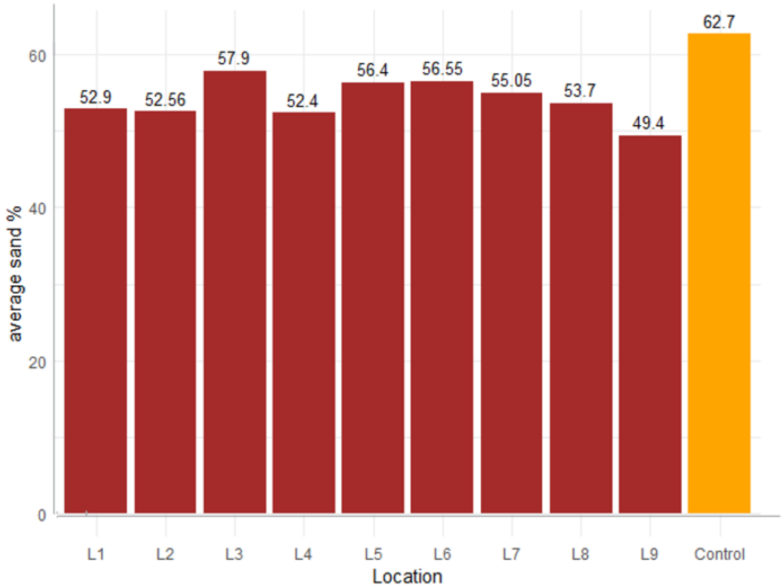


Figure 3.5: A graph showing average content of sand

3.6 Clay

The mean values of the soil samples varied between 23.6% and 31.9%. Among the locations, the highest clay content of 31.9% was observed at location L9, while the lowest clay content of 23.6% was recorded at location L2. Moreover, a statistically significant difference in clay contents was observed across the different locations, as indicated by the analysis carried out at a significance level of $p < 0.05$. [1] also had similar findings in a study in south-western Ethiopia. Clay content in the location is moderate which is similar to the report by [6] that Clay content value (< 25%) as low, (25-60%) as moderate, (> 60%) as high. Figure 4.6 provides a visual representation of the average sand content at each location.

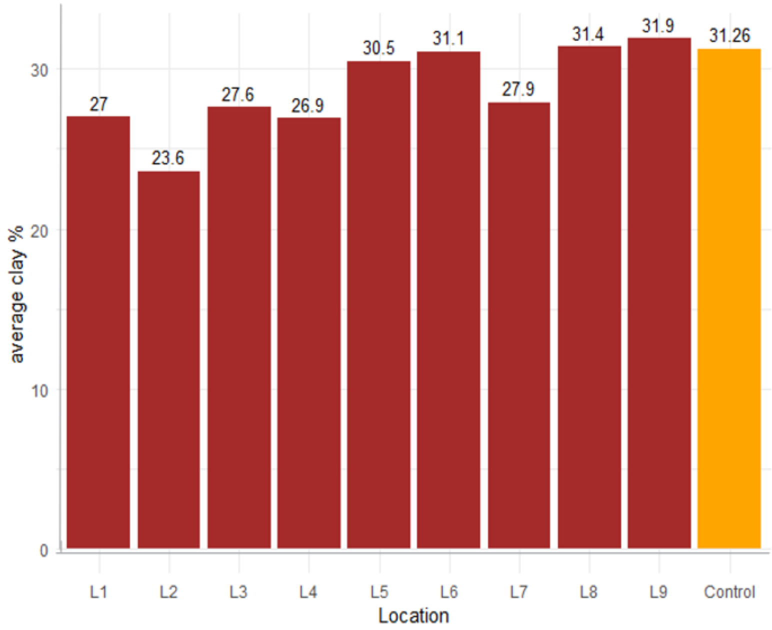


Figure 4.6: A graph showing average content of Clay

3.7 Silt

The results of the descriptive analysis conducted on the silt content in the samples indicates that average values ranged from 16.20% to 24.04%. The highest silt content of 24.04% was observed at the control location, while the lowest silt content of 16.2% was recorded at location L6. Furthermore, a statistically significant difference in silt contents was observed across the various locations, as indicated by the analysis conducted at a significance level of $p < 0.05$. Contrary to the report by [18] who found no significant difference in silt content across various locations. Reasons for the difference in the findings may be due to geographical location, period of sampling and probably composition of the soil itself. Silt content value is found to be in medium range which is in line with the report by [6] that silt content value (< 15%) is low, (15-45%) is medium, (> 45%) is high. Figure 4.7 visually represents the average silt content at each location.

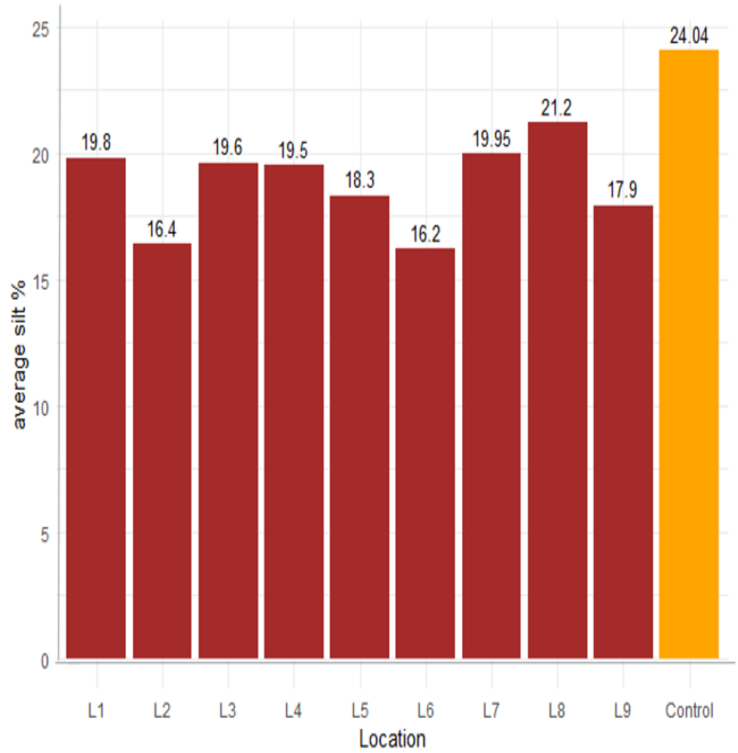


Figure 4.7: A graph showing average content of Silt

3.8 Phosphorous

The descriptive statistics of phosphorus content in different soil samples from ten locations shows that the phosphorus content ranged from 13.73 to 32.75 mg/kg, with an average of 24.29 mg/kg. The maximum phosphorus content of 32.75 mg/kg was observed at the control location, while the minimum value of 13.73 mg/kg was observed at L1. The phosphorus contents of all locations of sampling are high when compared to the ranges (5-15 mg/kg) reported by [3] The value at L1 is low when compared to the respective ranges (15.0 to 20.0 mg/kg) and (20.0 to 24.5 mg/kg) reported by [16]. These are in line with the report of [20]. Phosphorus value in the locations is found to be within the moderate to high range when compared to the report by [29], Phosphorus content value (< 10 mg/kg) as low, (10-20 mg/kg) as moderate, (> 20 mg/kg) as high.

High content of phosphorus at these locations may be a result of high level of organic matter in the soils, while the low content of phosphorus at L1 may be as a result of erosion and leaching during raining seasons at the study area. Figure 3.8 visually represents the average phosphorus content at each location.

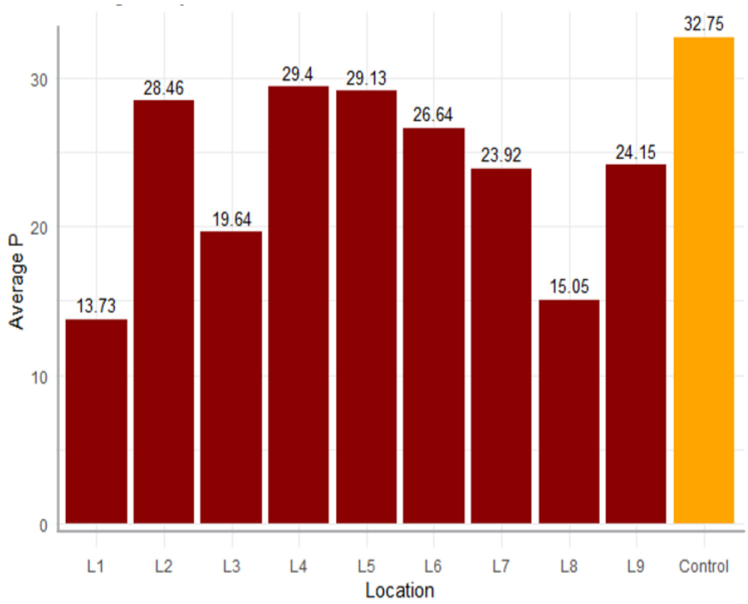


Figure 3.8: A graph showing average Phosphorus

3.9 Potassium

The descriptive statistics of Potassium content in different soil samples from ten locations indicate that potassium content ranged from 0.22 Cmol/kg to 0.47 Cmol/kg. The maximum value of 0.47 Cmol/kg was observed at location L9, while the minimum value of 0.22 Cmol/kg was observed at the control location. Based on the statistical analysis, locations L1, L3, and L9 are not significantly different from each other in terms of potassium content. Similarly, locations L2, L5, and L8 are also not significantly different from each other. Additionally, there is no significant difference between location L4 and L6. Furthermore, the potassium content at the control location is not significantly different from location L7. 16 .4% of the locations has low potassium content (< 0.15 Cmol/kg) and 83.6% falls under the moderate range of (0.15 to 0.30 Cmol/kg) similar to the report by [30]. Figure 3.9 visually represents the average potassium content at each location. Figure 3.9 visually represents the average potassium content at each location

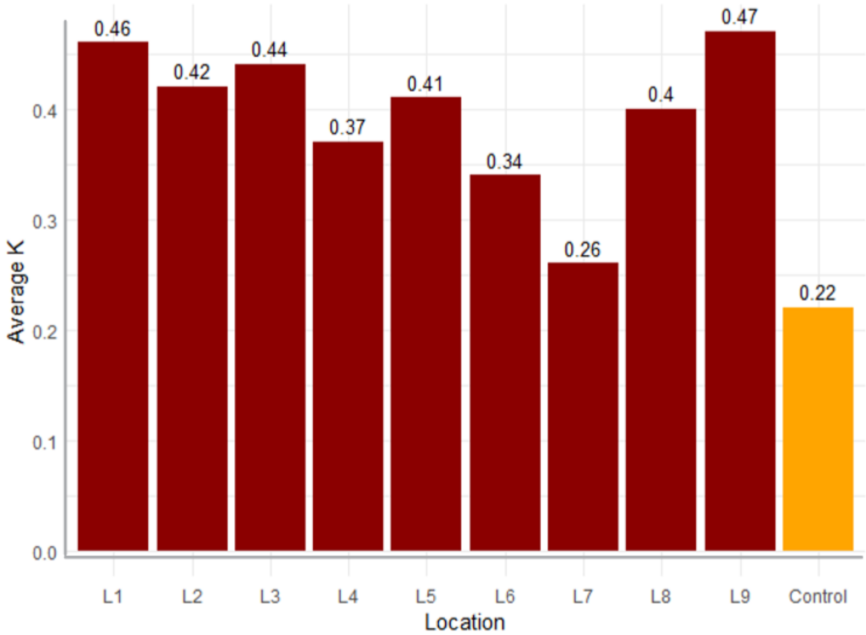


Figure 3.9: A graph showing average Potassium (K)

3.10 Sodium

The sodium content of the soil samples reveals a range from 0.34 to 0.93 Cmol/kg, with an average of 0.59 Cmol/kg. The maximum sodium content of 0.93 Cmol/kg was observed at the control location, while the minimum value of 0.34 Cmol/kg was observed at location L7. The statistical analysis indicates that there is no significant difference in sodium content between locations L1, L6, and L8. These are similar to the ratings reported by [18]. Similarly, no significant difference exists between locations L4 and L5. However, there is a significant difference between the remaining location. Figure 3.10 visually represents the average sodium content at each location.

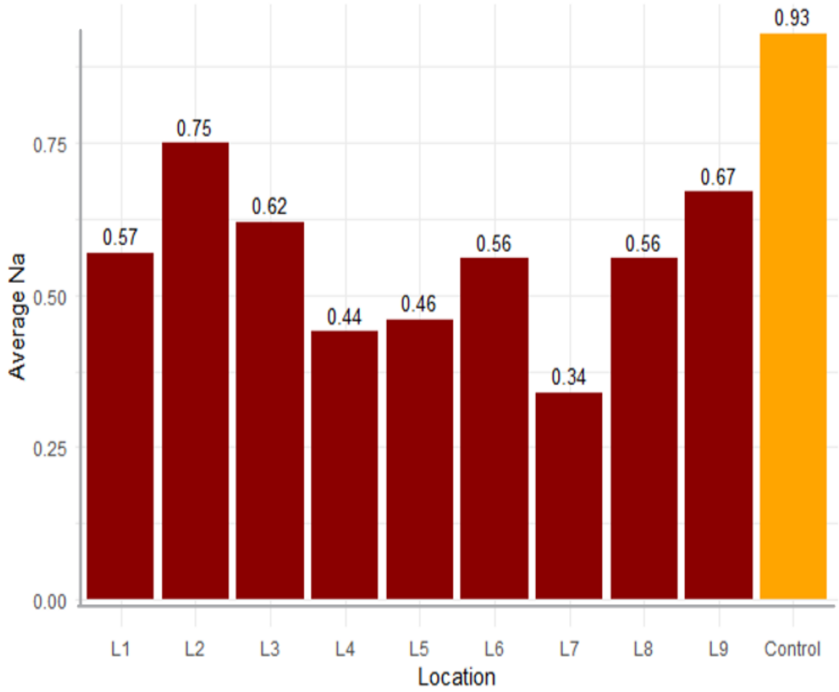


Figure 4.10: A graph showing average Sodium (Na)

3.11 Calcium

The calcium content data of the study area range from 4.05 to 7.15 Cmol/kg, with an average of 6.37 Cmol/kg. The maximum calcium content of 7.15 Cmol/kg was observed at locations L2 and L5, while the minimum value of 4.05 Cmol/kg was observed at location L1. The statistical analysis conducted at a significance level of $p < 0.05$ indicates that there is no significant difference in calcium content between locations L2 and L5. However, a significant difference exists between the remaining location. According to the report by [28], Calcium content value (< 5 Cmol/kg) is low, (5-10 Cmol/kg) is moderate, (> 10 Cmol/kg) is high. Therefore, the calcium content in the locations is found to be within the low to moderate range. Low calcium content is because of the coarse particles of soil as a result of charcoal production. Figure 3.11 visually represents the average calcium content at each location

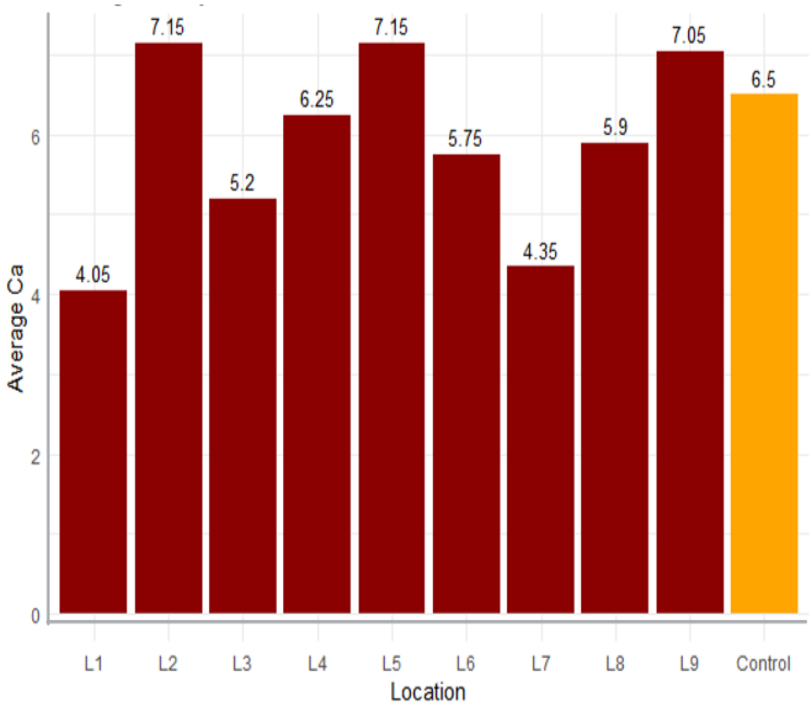


Figure 3.11: A graph showing average calcium

3.12 Magnesium

The magnesium content data range from 1.86 to 3.30 Cmol/kg, with an average of 2.68 Cmol/kg. The maximum magnesium content of 3.30 Cmol/kg was observed at locations L2, while the minimum value of 1.86 Cmol/kg was observed at the control location. All locations magnesium contents are similar in accordance to the report of [17]. The statistical analysis conducted at a significance level of $p < 0.05$ indicates that there is no significant difference in magnesium content between locations L4 and L5. The high magnesium content is as a result of low pH in the study area, this supports the statement reported by [2]. Figure 3.12 visually represents the average magnesium content at each location.

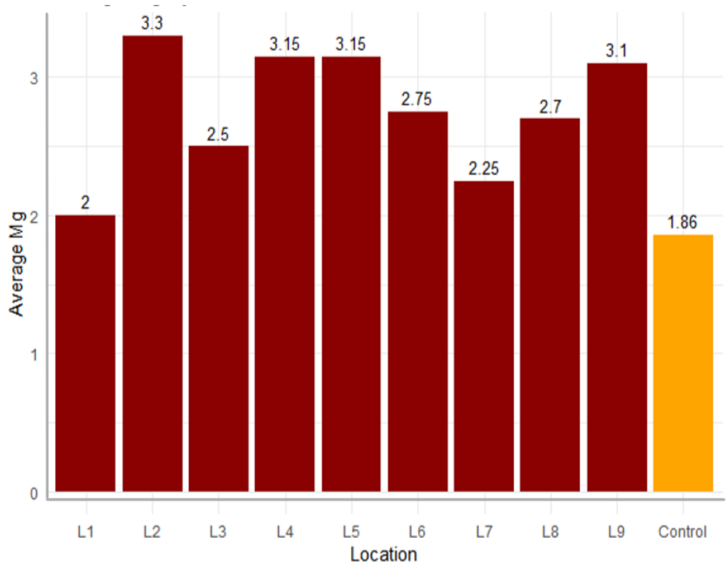


Figure 3.12: A graph showing average magnesium

Table 2: Heavy metal parameter of the soil sample collected from the study Area

Location	Cu Mean	Fe Mean	Zn Mean	Ni Mean	Cr Mean
1A	0.21	0.47	0.67	0.05	0.08
	0.21	0.42	0.67	0.06	0.08
1B	0.25	0.42	0.80	0.07	0.10
	0.25	0.43	0.80	0.07	0.10
1C	0.21	0.49	0.82	0.08	0.09
	0.21	0.50	0.82	0.08	0.09
2A	0.19	0.71	0.62	0.02	0.10
	0.19	0.71	0.63	0.02	0.10
2B	0.21	0.54	0.21	0.01	0.11
	0.21	0.54	0.21	0.01	0.11
2C	0.19	0.53	0.84	0.03	0.08
	0.19	0.53	0.83	0.03	0.08
3A	0.18	0.61	0.72	0.04	0.06
	0.18	0.61	0.73	0.04	0.06
3B	0.31	0.38	0.46	0.06	0.07
	0.31	0.38	0.46	0.06	0.07
3C	0.25	0.33	0.56	0.09	0.10
	0.25	0.33	0.56	0.09	0.10
	0.30	0.67	0.78	0.02	0.12

Control	0.32	0.69	0.79	0.02	0.13

3.13 Copper

The copper content of the soil samples of the study area ranges from 0.18 mg/kg to 0.31 mg/kg, with an average value of 0.23 mg/kg. The highest copper content of 0.31 mg/kg was observed at location L8 and the control location, while the lowest value of 0.18 mg/kg was found at location L7. The statistical analysis, conducted at a significance level of $p < 0.05$, reveals that there are no significant differences in copper content between locations L1, L2, L3, and L9. Similarly, no significant differences exist between locations L4, L5, L6, L7, as well as between location L8 and the control group. The copper content in the locations is low when compared to the report by [30] that copper content value (< 0.50 mg/kg) is low, (0.50-1.00 mg/kg) is moderate, (> 1.00 mg/kg) is high. Low copper content maybe as a result of high concentration of organic matter in the soil. Figure 3.13 visually represents the average copper content at each location.

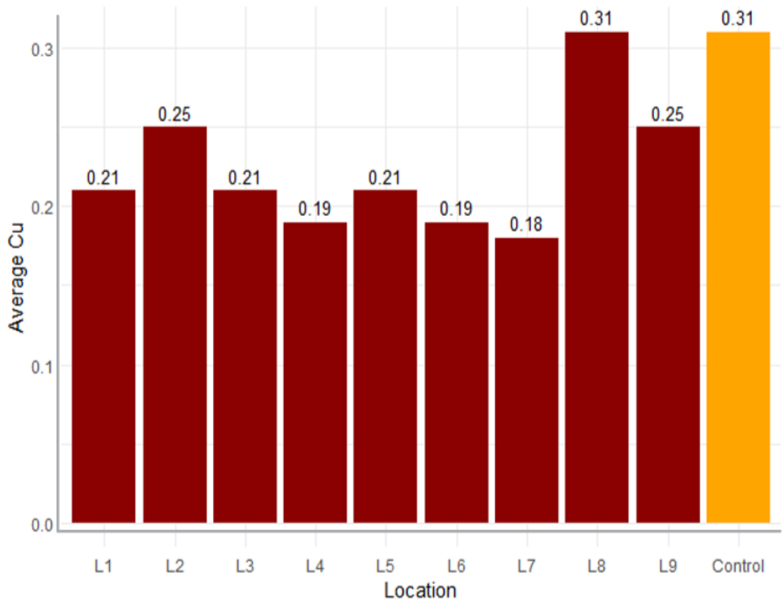


Figure 3.13: A graph showing average Copper (Cu)

3.14 Iron

The iron content data of the soil samples range from 0.33 mg/kg to 0.71 mg/kg, with an average value of 0.52 mg/kg. The highest iron content of 0.71 mg/kg was observed at location L4, while the lowest value of 0.33 mg/kg was found at location L9. The statistical analysis was performed at a significance level of $p < 0.05$, and the results indicate that there are no significant differences in zinc content between locations L1 and L3, L2 and L8, and L5 and L6. However, significant differences exist between the remaining locations. The value of iron content is found to be within low to moderate range when compared to the report by [7] that iron value content

(< 0.5 mg/kg) is low, (0.5-1.0 mg/kg) is moderate and (> 1.0 mg/kg) is high. Figure 3.14 visually represents the average iron content at each location.

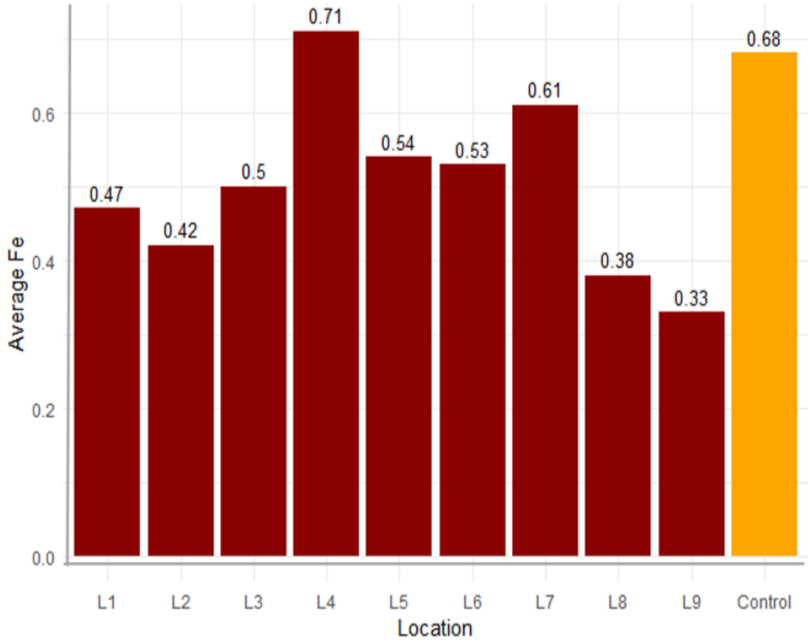


Figure 3.14: A graph showing average Iron (Fe)

3.2.4 Zinc

Zinc content data range from 0.21 mg/kg to 0.84 mg/kg, with an average value of 0.65 mg/kg. The maximum zinc content of 0.84 mg/kg was observed at location L6, while the minimum value of 0.21 mg/kg was found at location L5. Zinc level in the soil is quite low at L5 and have a moderate value at other locations on the study area when compared to the critical levels reported by [18] that Low (< 0.8 mg/kg), moderate (0.81 mg/kg-2.0 mg/kg) and High (> 2.0 mg/kg). The deficiency of the zinc content in this research could be as a result, factors affecting the availability of Zn to plants are low total Zn contents, high pH, high calcite and organic matter contents and high concentrations of Na, Ca, Mg, bicarbonate and phosphate in the soil solution or in labile forms. The statistical analysis conducted at a significance level of $p < 0.05$ reveals that there is no significant difference in zinc content among locations L2, L3, and L6. However, there is a significant difference between the remaining locations. Figure 3.15 visually represents the average zinc content at each location.

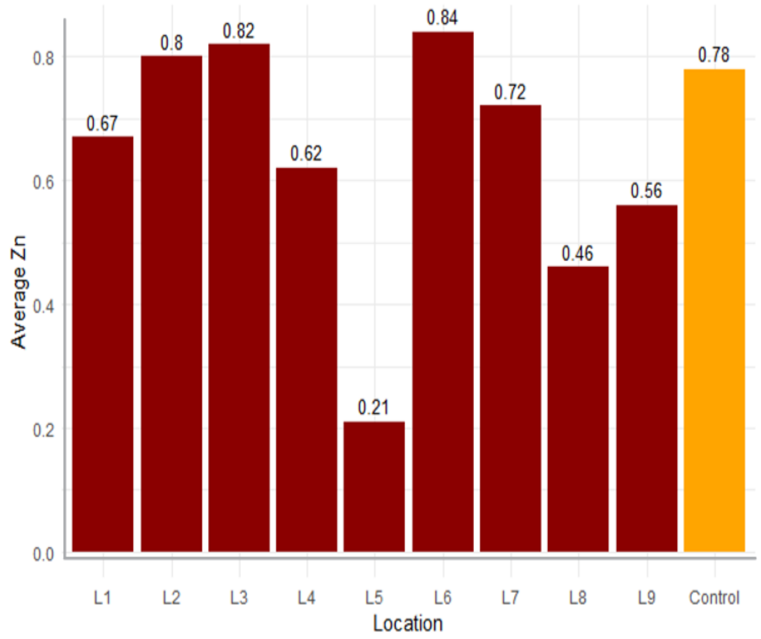


Figure 3.15: A graph showing average zinc (Zn)

3.16 Nickel

Nickel content data range from 0.01 mg/kg to 0.09 mg/kg, with an average value of 0.05 mg/kg. The maximum Nickel content of 0.09 mg/kg was observed at location L9, while the minimum value of 0.01 mg/kg was found at location L5. The statistical analysis conducted at a significance level of $p < 0.05$ reveals that there is no significant difference in nickel content at locations L1, L2, L3, L8, and L9. These is similar to ratings reported by [8] Similarly, there is no significant difference between locations L4, L5, L6, L7, and the control location. Figure 3.16 visually represents the average nickel content at each location

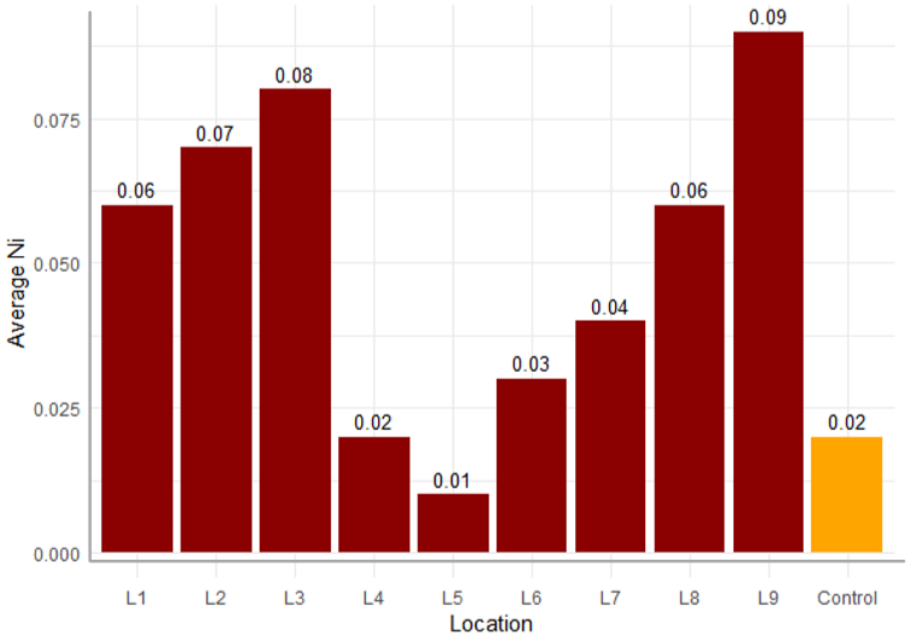


Figure 3.13: A graph showing average Nickel (Ni)

3.17 Chromium

Chromium content data range from 0.06 mg/kg to 0.12 mg/kg, with an average value of 0.09 mg/kg. The maximum chromium content of 0.12 mg/kg was observed at the control location, whereas the minimum value of 0.06 mg/kg was found at location L7. The statistical analysis conducted at a significance level of $p < 0.05$ indicates that there is no significant difference in chromium content among all the locations. Chromium content value in the locations is found to be within the moderate to high range which is similar to the report of [25] that (< 0.05 mg/kg) is low, (0.05-0.10 mg/kg) is moderate, (> 0.10 mg/kg) is high. Figure 3.17 visually represents the average chromium content at each location

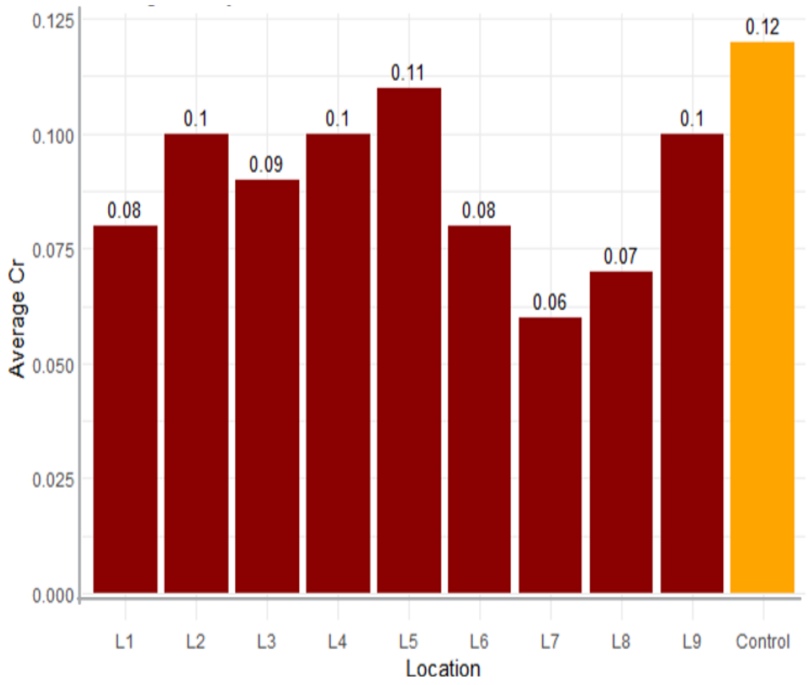


Figure 3.17: A graph showing average Chromium

4. Conclusion

The study revealed that the earth kiln method used by charcoal producers has significantly increased pH of soil (< 5.5) to be acidic. Soil organic matter (OM) and organic carbon (OC) was high at most areas of the site (74.2%), while others fall within the ranges of low to medium. Available macronutrient status for Nitrogen (0.06 % - 0.23 %) falls within moderate to high ranges while (P, K, Ca, Mg) falls within moderate to high ranges (0.22 Cmol/kg –7.15 Cmol/kg), having few points low in these contents. The availability of micronutrients was highly variable. Zinc (Zn) were moderate at almost all areas, iron (Fe) was low (41.9%), while copper (Cu) was moderate and high respectively across the site (0.18 mg/kg – 0.31 mg/kg).

Base on this result it was understood that the coarsening particles resulting from charcoal production has implication for nutrient availability resulting in less nutrients available for crops use. Therefore, the study suggest for an improved method of charcoal production should be used, regulation of indiscriminate felling of trees and woodlot should be established in areas of charcoal production.

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Appendix 1

Plate 1: View of location 2B on the study area

Plate 2: Collection of the soil samples from location 3C