SELECTED PHYSICOCHEMICAL PROPERTIES AND MICROBIAL POPULATIONS OF SOIL OF BAGALE FOREST RESERVE, GIREI LOCAL GOVERNMENT AREA, ADAMAWA STATE, NIGERIA

ABSTRACT

This study evaluated the relationship between selected physicochemical properties and microbial populations of soil of Bagale Forest Reserve, Girei Local Government Area of Adamawa State, Nigeria. Five plots of 20 x 20m were laid. Soil samples were collected from five different positions at two soil depths of 0-15cm and 15-30cm. The soil samples were isolated in the laboratory for microbial populations and determination of physical and chemical properties. The results obtained revealed that fungal population (7.65 x 10^5cfu/ml) was the highest at the soil depth of 0-15cm, representing 39% of the total microbial populations in the sampled soil of the study area. The results further revealed that the population (6.84 x 10^5cfu/ml) of the bacteria had a positive effect on soils of the study area in terms of nitrogen fixation by *Rhizobacterial spp*. Chemical properties of the soil samples revealed that the available phosphorus exhibited the highest percentage (61.7%) at 0-15cm soil depth. Analyses of soil physical properties recorded the highest percentage (49.0%) of sand at 0-15cm soil depth. Similar percentage (50.0%) of sand was exhibited at the depth of 15-30cm. These percentages accounted for the high porosity (29.0%) of the soil observed at the two soil levels in the study area, and could be improved through the application of lime fertilizers. Application of appropriate fertilizers like NPK to improve the soil condition of the study area is highly recommended.

Keywords: Microbes, populations, soil properties, forest reserve.

INTRODUCTION

The physical properties of forest soils develop under natural conditions by the influence of permanent vegetation over a long period of time. They may be almost permanent properties unless modified by harvesting operations, shifting cultivation, and forest fires. Important physical properties of forest soils include texture, structure, porosity, density, aeration, temperature, water retention, and movement. The physical properties of forest soils affect every aspect of soil fertility and productivity. They determine the ease of root penetration, the availability of water and the ease of water absorption by plants, the amount of oxygen and other gases in the soil, and the degree to which water moves both laterally and vertically through the soil. Soil physical properties also influence the natural distribution of forest tree species, growth, and forest biomass production. Physical properties of forest soils affect every aspect of soil fertility and productivity. However, soil physical properties are largely controlled by the size, distribution, and arrangement of soil particles (Brady *et al.*, 2010).

Some plant nutrients and metals exist as positively charged ions, or “cations”, in the soil environment. Some of the most important plant nutrients that affect growth and development of forest plant species include nitrogen, phosphorus, and potassium. Among the more common cations found in soils are hydrogen (H^+), aluminum (Al^{+3}), calcium (Ca^{+2}), magnesium (Mg^{+2}), and potassium (K^+). Soil pH, which is a measure of the active hydrogen ion (H^+) concentration, is an indication of the acidity or alkalinity of forest soils, and also known as “soil reaction”. The most important effect of pH in the soil is on ion solubility, which in turn affects microbial and plant growth (Brady *et al.*, 2010).

Forest soil microorganisms exist in large numbers in the soil as long as there is a carbon source for energy. There are more microbes in a teaspoon of soil than there are people on the earth. Forest soils contain about 8 to 15 tons of bacteria, fungi, protozoa, nematodes, earthworms, and arthropods. The population of microbes in forest soils is determined by various factors such as soil depth, organic matter content of the soil, soil porosity, soil pH, soil moisture content, and others (Kennedy *et al*., 2007).

There is a significant change in the soil colour and depletion of soil nutrients in the study site as a result of high exploitation of the resources. The microbial populations in the soil of the study area have also been affected negatively due to high exploitation of the tree species.

The main objective of this study is to investigate the relationship between physicochemical properties and microbial populations of the soil of Bagale Forest Reserve in Girei Local Government Area of Adamawa State, Nigeria.

MATERIALS AND METHODS

Study Area

This research was carried out at Bagale Forest Reserve in Girei Local Government Area of Adamawa State. The area lies between latitudes $9^o.09$ and $9^o.33$N and longitudes $12^o.21$ and $12^o.54$E of the state and has an elevation of 339 meters above the sea level (Figure 1). The study area is located within the North-Central part of Adamawa State. Bagale Forest Reserve covers a total land area of 179.746km^2, which is equivalent to about 18 ha (Adebayo, 1999). The major vegetation formations in Adamawa State are Southern Guinea Savannah, Northern Guinea Savannah, and Sudan Savannah. In Bagale Forest Reserve in particular, the common tree species are eucalyptus, cassia, neem, and mango (Adebayo, 1999).

Data Collection and Analysis

Thirty percent (30%) of the total forest land area was randomly sampled. Five (5) plots of 20×20m were established with the aid of a measuring tape, using the field sampling method adopted by Clegy *et al*., (1996) and Barbour *et al*., (1987) for artificial forests. Soil samples were collected from five different positions, transferred into the soil-sampling plates and marked as A_1, A_2, A_3, A_4, A_5…E_5 in each of the plots with the aid of soil auger and sterile trowel. Soil samples from two (2) depths (0-15cm top-soil and 15-30cm sub-soil) were collected with the hand trowel and soil auger. A total of 50 soil samples (25 top-soil and 25 sub-soil samples) were collected, transferred into soil-sampling plates, and labelled accordingly. They were transferred to the laboratory within 24 hours for analyses for the determination of physicochemical properties and microbial populations of the study area based on the method of Clegy *et al*. (1986) and Barbour *et al*. (1987). The sieved samples of soil were used for the particle size analysis (PSA), using the hydrometer method as described by Zhou and Chen (2018).

Core samples of soils were used for bulk density determination using the formula:

Bulk density = $\frac{\text{Mass of Oven-dried soil}}{\text{Volume of core sampler}} \times 100$ (Zhou and Chen, 2018).

Total porosity was calculated using the formula:

$$F = 1 - \frac{Db}{Dp} \times 100$$

where:

F = total porosity

Db = Bulk density

Dp = particle density as used by Zhou and Chen (2018).

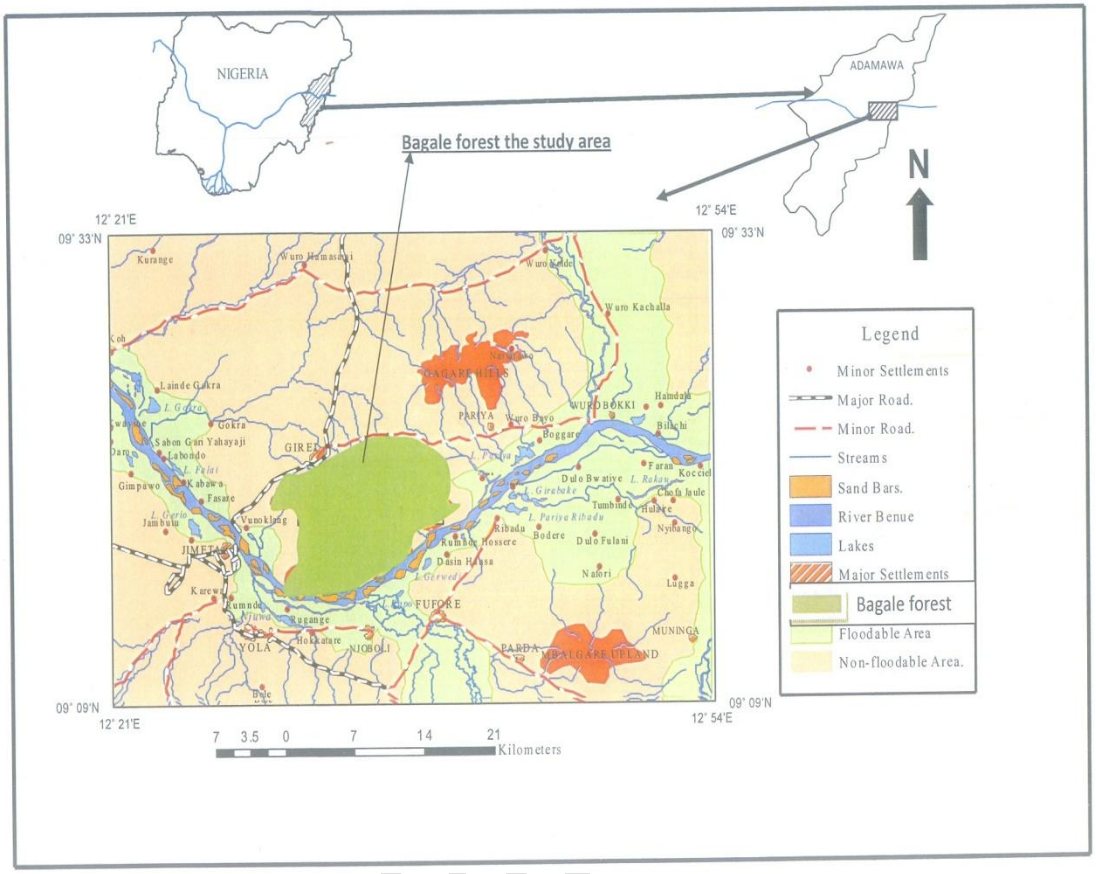

Figure 1: Map of Girei LGA of Adamawa State showing the Study Area
Source: Department of Geography, MAUTECH, Yola (2013)

RESULTS

Microbial Population Analysis of Soil in the Study Area

The result of the analysis of microbial populations in the study site is presented in Table 1. The result revealed that fungal population of 7.65 x 10^5cfu/ml was the highest at the soil depth of 0-15cm, representing 39.0% of the total microbial populations in the soils of the study site. This was followed by bacteria with an average population of 6.84 x 10^5cfm/ml, which was represented by the mean percentage of 35.0% at 0-15cm soil depth. Coliform population was recorded at 5.21 x 10^5cfu/ml with the mean percentage of 26.0% at 0-15cm soil depth. The results further revealed that fungi still constituted the highest population 4.49 x 10^5cfu/ml with 41.0% of the total microbial populations in the soil of the study area at 15-30cm soil depth. This was followed by bacteria with the average number of 3.43 x 10^5cfu/ml and the mean percentage of 32.0%, while coliform population of 2.92 x 10^5cfu/ml was found to be lowest with the mean percentage of 27.0% at 15-30cm soil depth.

Table 1: Microbial Populations of Soil in the Study Area

Soil Depth	Minimum Statistics	Maximum Statistics	Mean (cfu/ml)	(%)	Std Error
(0-15cm)					
TBC	$4.66x10^5$	$8.69x10^5$	$6.84x10^5$	35.0	23864.12
TCC	$3.22x10^5$	$9.66x10^5$	$5.21x10^5$	26.0	32920.81
TFC	$1.04x10^5$	$9.69x10^5$	$7.65x10^5$	39.0	33126.87
(15-30cm)					
TBC	$1.99x10^5$	$5.1x10^5$	$3.43x10^5$	32.0	81151.60
TCC	$1.06x10^5$	$4.72x10^5$	$2.92x10^5$	27.0	20915.35
TFC	$2.56x10^5$	$6.11x10^5$	$4.49x10^5$	41.0	14101.80

TBC=Total bacteria count; TCC=Total coliform count; TFC=Total fungi count.

Selected Physical Properties of Soil in the Study Area

The result of physical properties of soil in the study area is shown in Table 2. The result revealed that sand dominated the study site with the mean percentage of 49.0%. Porosity was high with the mean percentage of 29.0%, while the percentage of silt was recorded 10.0%. Also the percentage of clay was 10.0% compared to the percentages of texture and bulk density shown by the values of 1.0% and 1.0% respectively at 0-15cm soil depth. The result further showed that sand constituted the highest percentage at the depth of 15-30cm represented by the value 50.0%. This was followed by porosity with the mean percentage of 29.0%. The result further revealed that clay had the mean percentage of 10.0%, which was greater than the percentage of silt represented by 9.0%. Texture was found to have the mean percentage of 1.0% equal to the percentage of bulk density of 1.0% at 15-30cm soil depth.

Table 2: Descriptive Statistics of Selected Physical Properties of Soil in the Study Area

Soil Depth (cm)	Minimum Statistics	Maximum Statistics	Mean	(%)	Std Error
0-15					
Sand	50.00	94.00	70.4400	49.0	3.46751
Silt	2.00	29.00	15.0000	10.0	1.89824
Clay	4.00	28.00	14.5600	10.0	1.72345
Texture	1.00	3.00	1.9200	1.0	0.17243
B.Density	1.39	1.75	1.5460	1.0	0.02845
Porosity	34.00	48.00	41.7200	29.0	1.06383
15-30					
Sand	50.00	94.00	72.4400	50.0	3.53651
Silt	2.00	26.00	13.2000	9.0	1.75689
Clay	4.00	28.00	14.3600	10.0	1.90865
Texture	1.00	3.00	1.9200	1.0	0.19079
B. Density	1.39	1.75	1.5588	1.0	0.02995
Porosity	34.00	48.00	41.3200	29.0	1.11612

Source: Field Survey, (2018).

Selected Chemical Properties of Soil in the Study Area

The result in Table 3 showed some selected chemical properties of soil in the study area. The result revealed the highest percentage of available phosphorus (AV-P) with the mean value of 61.7% at 0-15cm soil depth. This was followed by the soil pH which was found to have the mean percentage value of 31.8%. The percentage of organic carbon (OC) was 2.9%, which was slightly higher than the mean percentage value (2.7%) of potassium (K). Furthermore, the electrical conductivity (EC) was found to have an average percentage of 0.5%, while the total nitrogen (NT) had the lowest mean percentage of 0.2% at 0-15cm soil depth. The result further revealed that available phosphorus (AV-P) was found to have the highest mean percentage of 57.8% at soil depth of 15-30cm. Also the pH (soil reaction) value of soil samples at 15-30cm was 35.4%, which was followed by potassium (K) with the mean percentage of 4.9%. Further analysis revealed that organic carbon (OC) had the mean percentage of 1.5%, which was higher than the electrical conductivity (EC) with the mean percentage of 0.3%. The least mean percentage was recorded in the total nitrogen (TN) indicated by the value of 0.1% at the soil depth of 15-30cm (Table 3).

Table 3: Descriptive Statistics of Selected Chemical Properties of Soil in the Study Area

Chemical Properties	Minimum Statistics	Maximum Statistics	Mean	(%)	Std Error
(0-15cm)					
pH	6.12	7.10	6.4868	31.8	0.05495
EC	0.06	0.16	0.1008	0.5	0.00571
OC	0.42	0.74	0.5980	2.9	0.1635
TN	0.04	0.07	0.0600	0.2	0.00163
AV-P	10.65	14.96	12.5840	61.7	0.24072
K	0.30	1.10	0.5584	2.7	0.04779
(15-30cm)					
pH	5.55	6.94	6.1456	35.4	0.07802
EC	0.03	0.10	0.0500	0.3	0.00408
OC	0.15	0.61	0.2600	1.5	0.02842
TN	0.00	0.06	0.0124	0.1	0.00428
AV-P	7.75	14.48	10.0476	57.8	0.37791
K	0.20	1.90	0.8480	4.9	0.10364

Source: Field Survey, (2018)

Pearson's Correlation of Microbial Populations with Selected Physical

Properties of Soil in the Study Area

Table 4 revealed the result of the relationship between microbial populations and the selected soil physical properties in the study area. The result indicated that all the isolated microbes (Bacteria, coliforms, and fungi) had no significant relationship with soil physical properties at 0-15cm soil depth. Although the bacteria population had a very low positive correlation with sand, silt, and bulk density with their respective correlation coefficients ranging from 0.017, 0.081 to 0.088, a low negative correlation was exhibited on clay, textural class, and porosity ranging from -0.081, -0.116 to -0.132. Similarly, coliform population had a positive correlation with silt, clay, textural class, and porosity; however, it had a low negative correlation with sand and bulk density. A low positive relationship was observed between the fungal colony, sand and bulk density, ranging from 0.189 to 0.235, while a negative correlation occurred with silt, clay, textural class, and porosity, ranging from -0.182, -0.191, -0.249 to -0.256.

Table 4: Correlation Analysis of Microbial Populations with Selected Physical Properties of Soil in the Study Area

Soil Depth	Isolated Organism	Statistics	Sand	Silt	Clay	Texture	Bulk Density	Porosity
(0 -15cm)	TBC	Pearson Correlation	0.017	0.088	-0.132	-0.116	0.081	-0.081
		Sig. (2-tailed)	0.934	0.677	0.531	0.582	0.701	0.702
	TCC	Pearson Correlation	-0.291	0.248	0.312	0.232	-0.303	0.295
		Sig. (2-tailed)	0.158	0.232	0.129	0.265	0.141	0.153
	TFC	Pearson Correlation	0.235	-0.256	-0.191	-0.249	0.189	-0.182
		Sig. (2-tailed)	0.259	0.218	0.361	0.230	0.364	0.384
(15 -30cm)	TBC	Pearson Correlation	0.433*	-0.504*	-0.339	-0.394	0.394	-0.394
		Sig. (2-tailed)	0.030	0.010	0.098	0.051	0.051	0.051
	TCC	Pearson Correlation	-0.238	0.194	0.263	0.220	-0.261	0.240
		Sig. (2-tailed)	0.251	0.352	0.205	0.290	0.208	0.248
	TFC	Pearson Correlation	0.035	-0.068	-0.001	-0.046	0.012	-0.015
		Sig. (2-tailed)	0.870	0.747	0.994	0.827	0.955	0.943

*Correlation is significant at the 0.05 level (2-tailed). TBC=Total bacterial count; TCC=Total coliform count; TFC=Total fungal count.

Pearson's Correlation of Microbial Populations with Selected Chemical

Properties of Soil in the Study Area

Table 5 shows the result of the correlation of microbial populations with selected soil chemical properties in the study area. The result revealed a significant relationship ($p < 0.05$) among the bacterial population, coliform population, and the soil chemical properties at 0-15cm soil depth, but fungal population showed no significant difference among the soil chemical properties. The result further revealed that at 15-30cm soil depth, none of the isolated microbes had significant effect on the soil chemical properties in Bagale Forest Reserve. This indicated that the sub-soil horizon was dominated by inactive microbes unlike the fungal group.

Table 5: Correlation Analysis of Microbial Populations with Selected Chemical Properties of Soil in the Study Area

Soil Depth	Isolated organisms	Statistics	pH	EC	OC	TN	AV-P	K
0– 15cm	TBC	Pearson Correlation	0.455*	0.041	-0.179	-0.183	0.184	0.328
		Sig.(2-tailed)	0.022	0.844	0.391	0.381	0.379	0.110
	TCC	Pearson Correlation	0.403*	0.091	0.149	0.094	-0.199	-0.078
		Sig.(2-tailed)	0.046	0.664	0.476	0.655	0.341	0.711
	TFC	Pearson Correlation	0.309	-0.238	0.112	0.213	0.312	0.185
		Sig.(2-tailed)	0.133	0.252	0.595	0.307	0.129	0.376
15-30cm	TBC	Pearson Correlation	-0.057	-0.019	-0.077	-0.088	-0.012	-0.050
		Sig. (2-tailed)	0.785	0.927	0.713	0.675	0.954	0.813
	TCC	Pearson Correlation	-0.261	-0.300	-0.233	-0.237	-0.053	-0.081
		Sig. (2-tailed)	0.208	0.145	0.263	0.255	0.801	0.699
	TFC	Pearson Correlation	-0.379	0.118	-0.006	-0.040	0.214	-0.005
		Sig. (2-tailed)	0.062	0.573	0.976	0.850	0.305	0.979

*Correlation is significant at the 0.05 level (2-tailed).

TBC=Total bacterial count; TCC=Total coliform count; TFC=Total fungal count.

DISCUSSION

Relationship between Microbial Populations and Selected Soil Properties

The findings of this study revealed that soil microbes play vital roles in forest soils and their effects on soils are influenced by their populations as explained by Classen *at al*. (2015). The populations of microbes in forest soils play some vital roles such as decomposition of organic matter, nitrogen fixation, and nutrient cycling. However, their activities and populations can be influenced by changes in physical and chemical properties of soils. Microbial populations in forest soils are determined by various factors such as soil depth, organic matter content, soil porosity, soil pH, and others as reported by Kennedy *et al*. (2007). The findings of this study as revealed by the ANOVA (Appendix I) indicated a significant relationship between microbial populations and soil properties of Bagale Forest Reserve. The dominant population of fungi at the top-soil level showed their significant effects on soil properties of the study site in terms of the decomposition of organic carbon. This agrees with the observation of Sylvia *et al*. (2005) that fungi are more efficient than bacteria in terms of decomposition activity with reference to organic compounds, hence they dominate the soil surface. The bacterial population on the other hand, which was relatively less than the population of fungi dominated the sub-soil level; hence, they played less active role in terms of organic matter decomposition in the study site. This variation agrees with the findings of Classen *et al*. (2015) who reported that "bacteria are hardy and can tolerate more soil disturbance than fungi; hence they normally dominate in tilled soils such as agricultural soils, whereas fungi are weak and tend to dominate in untilled soils such as forest soils". However, Brady *et al*. (2010) found that the activity and species composition of microbes were generally influenced by many environmental factors like temperature, soil reaction (pH), water potential, and salinity.

Selected Soil Physical Properties

Results further revealed that there were significant relationships between microbial populations and selected soil physical properties at both top-soil and sub-soil levels of the study site. The finding confirmed that of Zhou and Chen (2018) which revealed that the nature of forest soil physical properties also determines the populations of soil microbes. Some of these forest soil physical properties were enumerated viz: texture, structure, porosity, aeration, temperature, water retention, bulk density, and movement. These effects were exhibited by the high percentages of sand and soil porosity at 49.0% and 29.0% top-soil level, and 50.0% and 29.0% sub-soil level respectively in the study site.

Selected Soil Chemical Properties

The result of the analysis of selected soil chemical properties of the study site revealed that available phosphorus (AV-P) had the highest percentage with the mean value of 61.7% at 0-15cm soil depth. The analysis further revealed that soil pH (soil reaction) had the mean percentage of 31.8%. Soil pH is an indicator of the acidity or alkalinity of a soil as explained by Jaiwal (2003). The analysis for the determination of soil pH of the study area revealed that the soil contained a considerable amount of alkaline at 0-15cm soil depth, which could be as a result of the depletion in soil nutrients of the study site. Furthermore, the analysis revealed the percentage of the organic carbon (OC) with the value of 2.9%. As the depth of forest soils increases, the availability of organic carbon decreases, resulting in an increase of mineral layer. However, Comerford (2005) observed that the thickness of each forest soil layer varies depending on topography, vegetation, parent materials in which the forest has been established. Potassium (K) had the mean percentage of 2.7%. Potassium is an important constituent of plant tissues, it promotes the development of young plants, and it is essential for neutralization of organic acid in plants as explained by Brady *et al*. (2010). The electrical conductivity (EC) was found to have the mean percentage of 0.5%, while the total nitrogen (TN) had the lowest percentage of 0.2% at 0-15cm soil depth. Nitrogen is important in plants for growth and development or reproduction, it promotes uptake of potassium and phosphorus from soil, and it also promotes chlorophyll formation in plants leaves. The above importances are in line with the discovery of Brady *et al*. (2010).

Correlation Analysis of Microbial Populations with Soil Physical Properties

The result of correlation analysis of microbial populations with soil physical properties of Bagale Forest Reserve indicated their relationship. The result revealed that all the isolated microbes had relationship with the soil physical properties at top-soil and sub-soil levels. The dominant and structural organisation of sand at the top-soil provided a spatially heterogeneous habitat for fungal community characterised by organic carbon, oxygen concentration as well as variable soil reaction (pH) values. This agreed with the findings of Zhou and Chen (2018), that the nature of physical properties of forest soils determined the population of microbes in the soils. Although the bacterial populations had a low positive correlation with sand, silt, and bulk density, a low negative correlation was exhibited with clay, textural class, and soil porosity. Similarly, the coliforms population had a positive correlation with silt, clay, textural class, and soil porosity, whereas coliforms had a low negative correlation with sand and bulk density. Also, a low positive relationship was obtained between the fungal colony, sand, and bulk density indicated by the figures 0.235 and 0.189 respectively; whereas a negative correlation occurred with silt, clay, textural class, and porosity. The insignificant relationship of most microbes with some soil physical properties at 0-15cm soil depth indicated that the microbes were inactive at this soil level. This is in support of Brady *et al*. (2010) who highlighted that the physical properties of forest soils are influenced by the microbial populations within the soils. Similarly, at 15-30cm soil depth (Table 4) the bacteria population had a significant relationship ($p < 0.05$) with the soil physical properties, moderate positive correlation (0.433) with sand and moderate negative correlation (-0.504)with the silt particles of the soils. Fungi and coliforms showed no significant relationship ($p > 0.05$) with the soil physical properties in Bagale Forest Reserve. This indicates that forest soil microbes help in the decomposition of organic matter and nutrients cycling, hence they may serve as an indicator for land-use change and ecosystems health.

Correlation Analysis between Microbial Populations and Selected Soil Chemical Properties

The correlation between microbial populations and selected soil chemical properties at 0-15cm and 15-30cm soil depths revealed a significant effect ($p < 0.05$) on bacteria, coliform, and soil chemical properties at 0-15cm soil depth, with the exception of fungal population which showed no significant difference ($p > 0.05$) among the soil chemical properties. The results further revealed that at 15-30cm soil depth, none of the isolated microbes had a significant effect on the soil chemical properties at the depth of 15- 30cm. This indicates that the sub-soil horizon of the study site is dominated by inactive microbes and this relates to the findings of Kennedy *et al*. (2007) who pointed out that the populations of microbes and their sffects on forest soils are determined by various factors such as soil depth, organic matter content of the soil, soil pH, soil porosity, and others..

Conclusion

The high population of fungi in the soil of Bagale Forest Reserve has a significant effect in terms of organic matter decomposition. Similarly, the population of bacteria has a positive effect on soil of the study area in terms of nitrogen fixation by *Rhizobacterial spp.* The highest mean percentage values of sand in the soil samples and the porosity at the two levels of soil depths have shown that the study area is characterized by sandy soil. The analysis of selected chemical properties of soil samples revealed the highest percentage of the available phosphorus, which is good enough for effective performance of the tree species in the study site. However, the high percentage of the soil pH (soil reaction) indicated a considerable amount of alkaline in the soil depth of 0-15cm. All the isolated soil microbes had no relationship with the soil physical properties in the study area. The significant relationship between the soil microbes and soil physical properties indicated that most of the microbes were inactive at the soil depth of 0-15cm. However, since bacteria population had a significant relationship ($p < 0.05$) with soil physical properties but fungi and coliform showed no relationship ($p > 0.05$) with soil physical properties, this indicates that forest soil microbes play a vital role in the decomposition of organic matter and nutrients cycling. Since none of the isolated soil microbes had significant effect on the selected soil chemical properties of the study site at 15-30cm soil depth, it indicates that the sub-soil horizon is dominated by inactive microbes.

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