Assessment Of Soil Chemical And Physical Properties Under Different Landuse Systems In Jos, Nigeria

Ampitan, T. A.[1*] and Ampitan, A. A.[2]
[1]Federal College of Wildlife Management, Forestry Research Institute of Nigeria, P. M. B. 268, New Bussa, Niger State, Nigeria.
[2] Federal College of Forestry, Forestry Research Institute of Nigeria, Jericho, Ibadan, Nigeria
*Corresponding author:agbeoko@yahoo.com.
Phone: +2348068554773

Abstract
A study was carried out to investigate the effect of land utilisation on selected soil physical and chemical properties in three land use types (cultivated land, pine plantation and secondary forest (riparian forest) in Jos, Nigeria. Soil samples were collected from three randomly chosen points within the land use types at three soil depths: 0-15 cm; 15-30 cm and 30-45 cm. The soil samples were analysed for pH, exchangeable bases (Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K), organic carbon (OC), available phosphorous (AP), total nitrogen (TN) and Cation Exchange Capacity (CEC). There were significant differences ($P < 0.05$) in soil properties (physical and chemical) assessed between the land use types. The findings revealed that many of the soil properties were influenced by land utilisation. The mean values of soil properties were higher in the secondary forest (riparian forest) than the other land use types an affirmation that the secondary forest was more fertile than the other land use types. Therefore, to protect the soil, agroforestry practices should be adopted in order to improve the soil productivity and quality.

Key words: Erosion, Land use, Soil properties, Utilisation, Vegetation, Soil depth

Introduction

Several studies in the past (Anifowose and Ashiru, 2019; Ogunwale, 2015) have shown that deforestation and cultivation of virgin tropical soils often lead to depletion of nutrients (N, P, and K) present as part of complex organic polymers (Tilahun, 2015; Tilahun, 2007). Forest land is rapidly converted into agriculture or pasture land by farmers and herdsmen.

According to Guimaraes *et al.,* (2013), land-use changes from forest cover to cultivated land may reduce input or organic residues that lead to a decline in soil fertility (Biro *et al*., 2013), increased rates of soil erosion, loss of soil organic matter and nutrients (Wang *et al*., 2012). Furthermore, Bernoux*et al.* (1998) indicated that long practices of deforestation and/or replacement of natural forests by agroecosystem and uncontrolled overgrazing have been the major causes for soil erosion, loss of organic matter, alteration of soil properties and climate change. Therefore, a sound understanding of land use and management effects on soil properties provides an opportunity to evaluate sustainability of land use systems (Woldeamlak, 2003).

Nigeria is a large country with a substantial part of its area extending into semi-arid belt and with a population of about 204 million people with an average population growth rate of 2.58% (CIA World Factbook, 2018;

Worldometer, 2020). Human pressure on the land particularly in the marginal areas has continued to take its toll on the environment, particularly the soils. As a result of increasing demand for fuelwood, timber, pasture, shelter, food crops, etc., natural land covers, particularly the forests are being degraded and converted to cropland at an alarming rate. Agricultural expansion on these lands often results in rapid land degradation, with a subsequent decline in production (Ogunwale, 2015).

A survey of the forest resources between 1976 – 1998 revealed that forest cover in Nigeria decreased by over 20 percent over the 18-year period, while the forest estate which covered about 10% of the country's land area in 1976 had decreased to less than 6% (Adeyoju, 2001). According to the 2000-2005 Global Forest Resources Assessment of the Food and Agricultural Organization of the United Nations (FAO, 2020) and Mfon*et al*., (2014), Nigeria has the world's highest annual deforestation rate of primary forests at 55.7%. The country is one of the two largest losers of natural forests in Africa.

Jos is located within the Guinea Savanna zone of Nigeria. Very little forest remains outside forest reserves except perhaps along river banks and the bases of the hill ranges and this has been greatly modified by human activities such as mining and farming. The vegetation naturally consists of plateau type of mosaic vegetation, grasses and short scattered trees with height ranging from about 1m to 30m and with diameter of about 2cm to 60cm in rare cases. Specifically, the vegetation of the Jos plateau reflects interactions with climate, soil and the activities of man (Odunuga and Badru, 2015). The species in the vegetation includes trees and shrubs such as *Parkia biglobosa, Vitellaria paradoxa, Acacia species, Vitex doniana* while the grasses consist of *Andropogon.* Various trees are maintained at the rural settlements for shade and for their fruit, while Eucalyptus species, *Tectona grandis* and *Gmelina arborea* are grown in plantations to supply poles, firewood and timber. The soil type is sandy loam which moderately retain water for a short period of time (Ampitan and Okoro,2012)

Land use is defined as the systematic application of human controls, to a tract of land in order to derive benefits from it (Vink, 1975; Edosomwan*et al.,* 2001). The choice of land use for any location depends on the extent to which the soil characteristics match the land use requirements. Land use changes, especially cultivation of deforested land may rapidly diminish soil quality (Islam and Weil, 2000), as sensitive components of the forest ecosystem are not able to buffer the effects of agricultural practices. As a result, severe changes in soil quality may lead to permanent degradation of land productivity. Loss of arable land due to land degradation is becoming a common phenomenon in the Jos plateau area. Therefore, information obtained from this study will provide understanding on the soil fertility indices under different land use systems and their roles in sustaining soil productivity in the area. The main objective of this study was to examine the influence of different land use on soil quality and productivity in Jos, Plateau State.

Materials and Methods

Description of the study area

The study was carried out within Jos, Plateau State, Nigeria. Jos is a mid-sized city under the pressure of urban growth (Adzandeh*etal*., 2015). The city is situated at the northern edge of a pear-shaped upland known as the Jos Plateau. It has a total area of about 8 km^2 and is situated on latitude 9^0 and 52^0 N and longitude 8^0 and 53^0 E, with an average altitude of about 1280 m above sea level. It is located within the Guinea Savanna zone of Nigeria.

The climate of Jos is tropical but cooler than the surrounding lowlands. Average temperatures range from 21^0C to 25^0C and from mid-November to late January, night time temperatures drop as low as 7^0C. Total annual rainfall ranges from 1300-1800 mm with two seasons (dry season which is between October and March and rainy season which is between April to September).

Three floristic land use types were identified within the locaion: cultivated or farmland, pine plantation and a secondary forest (riparian forest). The cultivated land (9^0 53' 45'' N and 8^0 46' 10'' E) is situated within the Federal Housing Estate, along Miango road, Jos and it is farmed yearly with potatoes, maize and groundnut but devoid of trees. The pine plantation (9^0 53' 15'' N and 8^0 50' 00'' E) is located within the Jos Wildlife Park, Jos and is used as a recreation centre. Collection of firewood, fuel wood, cutting of trees for building and picking of fruits are strictly prohibited within the park, while the vegetation of the park serves as habitat for some animals. The third location used was the secondary forest or a riparian forest (9^0 56' 51'' N and 8^0 53' 33'' E) of about two hectares located within the premises of the Federal College of Forestry, Jos. The forest is made up of indigenous tree species such as *Khaya senegalensis, Nauclea latifolia* etc. with climbers and good herbaceous cover.

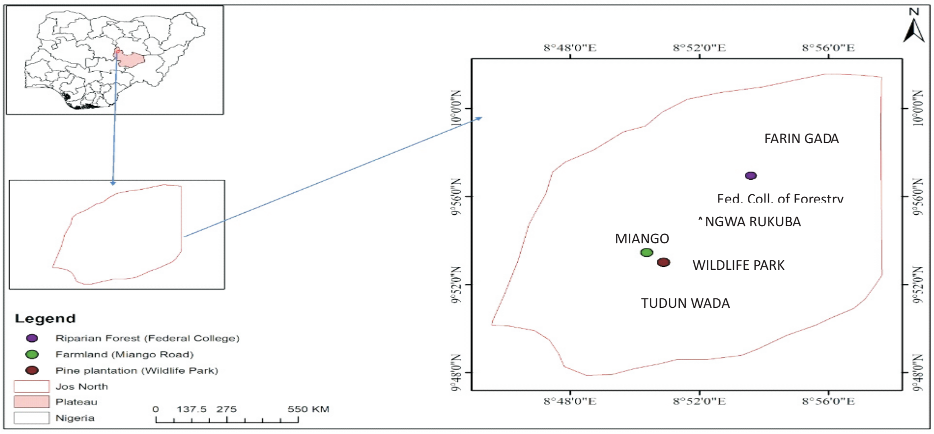

Fig. 1 Location map of the study area

Soil Sampling and Processing

Soil samples were collected using soil auger at a depth of 0-15 cm at three randomly chosen points within the land use types. The three soil samples from each land use were mixed thoroughly to obtain composite samples. The soil samples were collected in polythene bags and transported to the Soil Science laboratory of the Federal College of Forestry, Jos, Plateau State, Nigeria where they were air-dried for seven days. Samples were gently crushed with porcelain pestle and mortar and sieved through a 2 mm sieve to remove stones, roots and large coarse fragments. The fine soils separated were stored in polythene bags and taken to the Department of Soil Science, Ahmadu Bello University, Zaria, Nigeria for physico-chemical analyses.

Soil physical and chemical properties

Soil sample analyses were carried out using standard methods as described by IITA (1989) and Anderson and Ingram (1998). Soil particle distribution was determined using the Bouyoucos hydrometer method. The soil pH was determined both in water and 0.01M $CaCl_2$ solution using a soil solution ratio of 1:2.5. The organic carbon content was determined by the wet oxidation method of Walkley and Black (1934) as described by Nelson and Summer (1982). The total nitrogen content of the soil was determined using the micro-Kjeldahl digestion technique, while available phosphorus was measured colorimetrically. Exchangeable bases by extraction with neutral 1M NH_4OAC. Potassium and sodium extracts were determined using flame photometer. Calcium and magnesium contents were evaluated using EDTA titration method.

Statistical analysis

Data collected were analysed with a One-way Analysis of Variance. Differences in mean values of the parameters examined were tested at 5% significance level where significant and Duncan's new multiple range tests (DNMRTs) was used to separate the means.

Results

Results of the physical properties of the soils under the various land use are presented in Table 1. The cultivated land and the pine plantation had sandy loam as the soil texture while the secondary forest was loamy soil. The pine plantation soil was lowest in silt (100 g/kg) but higher in sand (606.7 g/kg) than the soils under the secondary forest and cultivated land The clay content of the soilin the secondary forest (370 g/kg) was significantly higher compared to pine plantation (293.3 g/kg) and cultivated land (326.7 g/kg). For the sand content, the mean value for the pine plantation (606.7 g/kg) was higher than that of cultivated land (500 g/kg) and secondary forest (450 g/kg) respectively.

Chemical properties of soils under different land use are shown in Table 2. The soils are acidic in nature. The values of pH (H_20) obtained for the pine plantation, secondary forest and cultivated land ranged from 5.1 to 5.47. For pH ($CaCl_2$), the values followed the pattern of that of pH (H_20) and ranged from 3.9 in pine plantation to 5.4 in secondary forest. The pH values however, were not significantly different.

Table 1: Mean values of particle size distribution of top soil (0-15cm) under different land use types

Land use type	**g/kg**			**Textural class**
	Sand	**Silt**	**Clay**	
Cultivated Land	500.0±12.49ab	173.3±1.15b	326.7±12.86a	Sandy loam
Pine Plantation	606.7±11.72a	100.0±2.00b	293.3±9.87a	Sandy loam
Secondary Forest (Riparian Forest)	450.0±3.06b	180.00±8.00b	370.0±5.03a	Loam

Means in a column with the same letter(s) are not significantly different at 5% leve 1

Table 2: Chemical properties of soils under different land use types in Jos, Nigeria

Chemical Properties	Cultivated Land	Pine Plantation	Secondary Forest
pH (H_2O)	5.27±0.3a	5.27±0.3a	5.47±0.2a
pH ($CaCl_2$)	4.30±0.4a	3.90±0.1a	4.40±0.4a
Organic Carbon (OC)	0.86±0.4a	1.03±0.5a	1.88±1.3a
Total Nitrogen (TN)	0.05±0.02a	0.07±0.05a	0.10±0.07a
Available Phosphorous (AP)	17.79±21.0a	7.0±3.50a	12.83±7.39a
Calcium (Ca)	5.33±21.0a	3.47±0.64a	8.13±4.01a
Magnesium (Mg)	0.72±0.3a	0.44±0.1a	1.24±1.2a
Potassium (K)	0.30±0.1a	0.28± 0.1a	0.69±0.4a
Sodium (Na)	0.13±0.04a	0.14±0.05a	0.18±0.04a
Cation Exchange Capacity (CEC)	10.47±0.7ab	8.13±0.7b	13.90±4.5a

Mean values along each row bearing the same letter(s) are not significantly different at 5% level

Compared to the pine plantation, the organic content was lowest in the cultivated land (0.86%), highest (1.88%) in the secondary. Total nitrogen (TN) content of soil was lower in the cultivated land (0.05 cmol/kg) and pine plantation (0.07 cmol/kg) than the secondary forest (0.10 cmol/kg). The mean value of available phosphorus was moderate in all the land use types, except for the pine plantation. The mean content of Available Phosphorus (AP) was highest in the cultivated land (17.79%) followed by the secondary forest (12.83%) and the pine plantation with (7.0%). However, the statistical analysis of AP shows no significant difference between the land use types. The mean values of the exchangeable cations, calcium (Ca), magnesium (Mg), and potassium (K) and sodium (Na) were significantly lower in the pine plantation and the cultivated land than the secondary forest. However, all the values of the exchangeable cations were not significantly different. The cation exchange capacity (CEC) of the land use types ranged from 8.13 to 13.9 cmol/kg, and differ significantly from each other, with the secondary forest having the highest value, while the cultivated land was the lowest.

Discussion

The cultivated land and the pine plantation had sandy loam as the soil texture while the secondary forest (riparian forest) was loam, an indication that the secondary forest was more fertile than the other land use. However, the values for the silt for both the cultivated land use and pine plantation were not statistically significant, though the values for the cultivated land was higher than that of the pine plantation. The result of lower silt in the pine plantation and the cultivated land might be due to preferential removal of silt by accelerated water erosion during the rainy season as reported by Ampitan (2013).

The pH (H_20) and pH ($CaCl_2$) obtained for the pine plantation, secondary forest and cultivated land were considered acidic. The result is in agreement with the works of Deekor*et al.* (2012) who worked on change in soil properties under different land use covers in parts of Odukpani, Cross River State, Nigeria. The acidic nature of the studied land use especially the pine plantation may be attributed to decreased organic matter and basic cations contents as a result of erosion leading to the leaching of these basic cations (Abua*et al.,* 2010, Iwara*et al.,* 2011 and Samndi*et al*., 2018). Likewise, it may be due to high microbial oxidation that produces organic acid which provides H^+ ions to the soil solution and thereby lower soil pH as observed by Tilahun (2007) in his work on soil fertility status at Maybar areas of South Wello zone, North Ethiopia.

The low organic carbon contents in the cultivated land could be attributed to the effect of continuous cultivation in the cultivated land which maybe as a result of rapid decomposition and mineralization of organic matter and poor management practices of the land (Lawal *et al*., 2012). The result obtained on organic carbon is in agreement with the findings of Negassa (2001) and Malo *et al.* (2005) as cited by Alemayehu and Sheleme (2013) who reported less organic carbon in the cultivated soils than grassed soils. This is also a confirmation of the observation by Yifru and Taye (2011) on the effect of land use on soil organic carbon and nitrogen in soils of Bale, South-eastern Ethiopia. The higher organic carbon content in the secondary forest (riparian forest) may be as a result of continuous accumulation of undecomposed and partially decomposed plant and animal residues in the surface soils which provides large amount of biomass that eventually decomposes to form nutrients in the soil.

Furthermore, the findings of higher organic carbon content is in agreement with the findings of Killham (1994) and Lechisa*et al*. (2014), while the high soil organic content in pine plantation may be as a result of partial needle decomposition. According to Schlesinger *et al* (1996) and Burke *et al.* (1998), soil organic carbon storage and distribution are controlled by the balance of carbon inputs from plant production and outputs through decomposition. This difference may also be attributed to the roots of the trees that contributed to higher amount of total organic carbon in both secondary forest (riparian forest) and pine plantation.

Similar to organic carbon (OC), there was significant variations in total nitrogen among different land use. Total nitrogen (TN) content of soil was lower in the cultivated land and pine plantation compared to the secondary forest (riparian forest). This result is in agreement with the study of Yifru and Taye (2011) and Deekor*et al*. (2012). According to Mullar-Harvey *et al.* (1985) and Girma, (1998), lower total nitrogen in cultivated land may have resulted from a combination of lower carbon inputs because of less biomass, greater carbon losses because of aggregate disruption, and probably livestock grazing, increased aeration by tillage, crop residue burning, and accelerated water erosion. While increased total nitrogen in the secondary forest (riparian forest) might be as a result of high plant population which resulted in high litterfall and decomposition with high mineralisation of nutrients.

The mean value of available phosphorus was moderate in all the land use types, except for the pine plantation which was low. According to Pantami (2017), the low available phosphorus content in the pine plantation could have been due to either aluminium or iron phosphate fixation. The mean values of the exchangeable cations, calcium (Ca), magnesium (Mg), and potassium (K) and sodium (Na) were significantly lower in the pine plantation and the cultivated land than the secondary forest (riparian forest). The low values obtained for both pine plantation and the cultivated land could be due to high runoff as a result of compaction of the soil that reduces litter and dead plant accumulation. A high K^+ in the secondary forest (riparian forest) may be due to the availability of surface biomass through litter fall or probably less soil disturbance either through rain drops or soil erosion. A similar observation was made by Tilahun (2007) and Duguma*et al*. (2010) who reported that the value of $K^+$is higher in the forest land than cultivated and grazing lands in the study carried out in the Central Highland of Ethiopia. The cation exchange capacity (CEC) of the land use ranged from 8.13 to 13.9, and differ significantly from each other, with the secondary forest (riparian forest) having the highest value, which maybe as a result of high soil clay content and soil organic matter, while the cultivated land was the lowest. The low CEC mean values obtained for the cultivated land might be attributed to lower organic matter content due to frequent use for cultivation.

Conclusion

This study showed that soil properties varied significantly among the land use types. The soils were acidic at both pH ($CaCl_2$) and pH (H_2O) and ranged in between 5.1 and 5.47. Organic carbon and total nitrogen distribution were highest in the secondary forest (riparian forest) than the other land use types. The secondary forest (riparian forest) had the highest values for calcium, magnesium, potassium, sodium and CEC among the land use types. The study revealed that the changes in mean values of some soil properties could be as a result of different land utilisation.

Using land for recreation and farming could probably result in the deterioration of soil properties of such land use as a result of erosion and compaction of soil compared to soils under secondary forest (riparian forest) that has some of its tree stock intact and is protected from soil erosion and direct sun light. It is therefore of great importance that lands that are without trees should be planted with tree crops or put into agroforestry use as to prevent soil erosion and probably improve the quality and productivity of such land.

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