



Assessment of physio-chemical properties and microbial population of soil under three different land uses in katsina state

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Abstract

The main objective of the study is to determine the effects of some physical, chemical properties and microbial population of soil under 3 different land uses (natural forest, forest plantation and Farmland The samples were collected from; Katsina central Hassan Usman katsina polytechnic farm land, katsina north (Daura zone) Mani Local Government Forest reserve along Katsina Mani road) and katsina south (Funtua zone) Eucalyptus camaldulensis plantation agagiwa Malumfashi LGA. The samples were collected at a depth of 0 – 15cm, 15 – 30cm and 30-45cm; while soil sample collected from different depth were mixed to obtain a composite sample that was taken for further laboratory analysis. A one-way ANOVA and turkey's honesty significant tests were used to test the mean differences of the soil chemical and physical properties and Microbial population using SAS software. The results showed that the land-use types significantly affected a number of soil physical, chemical properties and microbial populations. Results of the experiment indicated highest mean values of pH (7.2) was recorded under farm land, Cation exchange capacity (6.84 Cmolkg^{-1}) was recorded plantation land, organic matter (1.61%) under forest land and exchangeable potassium (1.12 Cmolkg^{-1}) was recorded under farm land, and fungus populations (6.33 cfu) high values were recorded farmland and lower values (0.66 mgkg^{-1}), (1.08 Cmolkg^{-1}), and (3.00 cfu), under natural forest, and plantation respectively, ($p < 0.05$). The undisturbed natural forest and plantation were superior in most of the soil quality indicators determined. Integrated land use management practices should be adopted in order to improve soil quality indicators in cropland area particularly at surface horizon.

Keywords: Soil physical properties, chemical properties, microbial population forest land farm land, plantation land

Introduction

Soil is the mixture of minerals organic matter, gases, liquids and countless organisms that together support plant life, (Chesworth. 2008). Soil is a natural body that exists as part of pedosphere and which performs four (4) important functions: it is a medium for plant growth; it is a means for water storage and supply; it is a modifier of the atmosphere of earth and it is a habitat for organisms, all of which modify the soil, (Voroney. 2006) ^[40]. Soil is the end product of the influence of the climate, relief (elevation, orientation and the slope of terrain), organisms and parent materials (original minerals) interacting over time. Soil continually undergoes development by ways of numerous physical, chemical and biological processes, which include; weathering with associated erosion. (Retallack. 2008) ^[33]. Soil consists of solid particles with liquid or gases occupying the space between particles. Soil is commonly referred to as "earth" or "dirt"; technically the term "dirt" should be restricted to displaced soil, (Needelman 2013) ^[32]. In the late 1800s soil scientist began to recognize that soils are natural bodies with size, form, and history. Just like water body has water, fish, plant and other parts; a soil body is an integrated system containing soil, rocks, root, animal and other parts, (Needelman, 2013) ^[32].

Basically, soil supplies plant with mineral nutrients held in place by clay and humus content of the soil. Beyond this the soil must provide an environment in which root can function. Typically, soils maintain a net absorption of oxygen and methane and undergo a net release of carbon dioxide and nitrous oxide. Soil provide readily available nutrient to plants and animals by converting dead organic

matter into various nutrient forms. As soil resource serve as a basis for food security, the international community advocates for its sustainable and responsible use through different types of soil governance. Soil consists of series of change or processes that affect its composition and properties and this will indirectly affect its ability to support crops. Therefore, an understanding of soil properties and their responses to artificial modification is essential for decision taking in agricultural development. The soil property encompasses the physical and chemical characteristics of soil and their relationship to plant growth. The physical and chemical properties of the soil largely determine the use to which a soil is best suited. They are regarded by Jones and Wild (1975) ^[24], as indispensable factors of management of any piece of land, whose potential is to be fully exploited. Environmental degradation caused by inappropriate land use is a worldwide problem that has attracted attention in sustainable agricultural production systems. Ethiopia is considered to be one of the least developed countries where agriculture had always played a central role in the country's economy. Although agriculture has always been the mainstay of the economy, it is characterized by very low growth rate. The rapidly increasing population has led to a declining availability of cultivable land and a very high rate of soil erosion (Abera, 2003) ^[1]. It is apparent that soil is one of the most important and determinant factors that strongly affects crop production. Soil is the foundation resource for nearly all land uses, and the most important component of sustainable agriculture (Mulugeta and Karl, 2010) ^[28]. Therefore, assessment of soil quality indicators

with respect to land use types is useful and primary indicator for sustainable agricultural land management. Understanding the effect of these factors on soil properties is useful for devising land management strategies. The information can also be used to forecast the likely effects of any potential changes in land use types and management practices on soil properties. It is apparent that the destruction of vegetative cover can promote soil erosion, which eventually increases the magnitude of soil related constraints to crop production.

Generally, a sound understanding of land use and management effects on soil properties provides an opportunity to evaluate sustainability of land use systems (Woldeamlak 2003) [45]. Singh and Sharman (2007) [36], and Augusto and Ranger (2002) stated that tree plantations influence soil physical, chemical and biological properties negatively or positively through litter fall, accretion and Decomposition of Organic Matter.

Statement of the Problems

Transformation of one land use system into another system and different management practices can affect soil physical, chemical properties and microbial populations. The information can also be used to forecast the likely effects of any potential changes in land use types and management practices on soil properties. It is apparent that the destruction of vegetative cover can promote soil erosion, which eventually increases the magnitude of soil related constraints to crop production. Generally, a sound understanding of land use and management effects on soil properties provides an opportunity to evaluate sustainability of land use systems.

Justification of the Study

The importance of physical, chemical properties and microbial population cannot be over emphasized as reveal for the numerous functions it serves in the soils. Therefore, an understanding of soil properties and their responses to artificial modification is essential for decision taking in agricultural development. The soil property encompasses the physical and chemical characteristics of soil and their relationship to plant growth.

Objectives of the Study

The main objective of the study is assessment of soil physical, chemical properties and microbial population under 3 different land uses.

Methodology

The Study Area

The Study Area: The study was conducted in three different locations;

Location I: Katsina central Hassan Usman katsina polytechnic cropland

Location II: katsina north (Daura zone) Mani Local Government Forest reserve along Katsina Mani road)

Location III: katsina south (Funtua zone) *Eucalyptus camaldulensis* plantation agagiwa Malumfashi LGA

Sample collection

The sample were collected from Mani forest reserve in Mani local government area (katsina north) (Natural forest soil), *Eucalyptus camaldulensis* plantation in Malumfashi local government area (katsina south) (plantation soil) and Farm land of Hassan Usman Katsina Polytechnic Batagarawa local government area (katsina central) (cropland soil). The samples are to be collected at a depth of 0 – 15cm, 15 – 30cm and 30-45cm respectively; while sample collected from different depth is mix to obtain a composite sample was taken for further laboratory analysis.

Determination of the Physical Properties

Bulk Density Was determined using core sampler of a known volume driven into the soil and then carefully dug out (Blake and Hartge, 1986a) [13] and the following formula was used.

$$\text{Bulk density} = \frac{\text{weight of moist sample} - \text{weight of oven dry}}{\text{volume of core samples}}$$

(Blake and Hartge, 1986a) [13]

Total porosity; The number of pores and their distribution are generally indicators of the physical condition of total porosity (Blake and Hartge, 1986b) [14] is given by

$$\text{Total porosity (volume \%)} = 1 - \frac{(\text{Bulk density})}{\text{Particle density}} \times 100$$

Particle size distribution; Particle size analysis was carried out using Bouyeous Hydrometer method as described by (Day, 1956).

Soil Texture by USDA (Textural Triangle).

Determination of the Chemical Properties

Soil Ph will be determine using Ph meter the ratio 0.01M CaCl₂ in 1:1 soil solution ratio (Bates, (1954) [5]).

Cation Exchange Capacity (CEC): Ammonium acetate method

Total Nitrogen; will be determine by The Kjeldahl method

EC: Electromagnetic Induction Method

Organic Carbon /Organic Matter: walkley black oxidation method.

Available phosphorus: Bray method

Exchangeable bases: (Ca, Mg, K, Na): leaching method

Determination of the Microbial Populations

Media Preparations

The samples will be process using serial spread method. One gram of soil sample will be serially dilute with sterilized distilled water up to 10⁻¹, 10⁻², 10⁻³, and 1 ml of each dilution will add to 20ml of nutrient agar medium in 90mm diameter sterile Petri dishes and then incubated. After incubation isolated colonies of bacteria and fungi will be selected. (Atlas and Bartha, 1998). (Widmer *et al.* 2001)

Microbial Population Count

Soil samples after serial dilution plates will be incubated to 48 hrs. to grow the microbial colonies properly. Colony forming units (cfu) will counted by the sporangium growth, sporangium of same shape and colour will counted once.

Data Analysis: Analysis of variance (ANOVA) will be used to analyze the data and mean comparison will be performed using turkey's honestly significant test (THST) using SAS Software. (Version 28).

Results and Discussion.

Physical Characteristics of Soil from different Land use

The result in table 1 showed the physical characteristics of soil from different land use. Table 1 shows that all the soil from three different land are loamy sandy textural class, there was significant difference ($p < 0.05$) under plantation

land and farm land while there was no significant difference ($p < 0.05$.) in clay and silt in forest land. The result also showed that there was no significant difference in forest land at 0-15 and 15-30cm and in farm land as well under 0-15cm and 15-30 cm with regard to Bulk density with the highest mean value of 0.96 gcm^{-3} under plantation land. Bulk density may differ in different depths of soil. (Star, 1994) There was significant difference with respect to total porosity among the land use type and between the soil profiles.

Table 1: Selected physical properties for the soil profile under different land use

Depth in cm	T.P (%)	SE	BD(g/ml^{-3})	SE	Particle Size						Textural Class
					clay (%)	SE	sand (%)	SE	silt (%)	SE	
Land Use Type: Forest Land											
0-15	30.24 ^a	0.02	0.79 ^a	0.01	11.17 ^a	0.06	89.52 ^a	0.02	3.28 ^a	0.01	Loamy sandy
15-30	29.32 ^b		0.78 ^a		11.17 ^a		87.53 ^b		1.27 ^b		Loamy sand
30-45	28.70 ^c		0.75 ^b		9.23 ^a		85.53 ^c		1.27 ^b		Loamy sand
Land Use Type: Farm Land											
0-15	32.82 ^a	0.01	0.88 ^a	0.01	23.27 ^a	0.12	77.53 ^a	0.11	5.48 ^a	0.10	Loamy sandy
15-30	31.32 ^b		0.82 ^b		21.27 ^b		73.52 ^b		5.29 ^b		Loamy sand
30-45	30.82 ^c		0.81 ^c		17.33 ^c		71.41 ^c		5.29 ^c		Loamy sand
Land Use Type: Plantation Land											
0-15	31.26 ^a	0.01	0.98 ^a	0.01	16.37 ^a	0.05	80.77 ^a	0.07	4.23 ^a	0.05	Loamy sandy
15-30	30.44 ^b		0.96 ^b		16.21 ^b		79.98 ^b		2.44 ^b		Loamy sand
30-45	29.71 ^c		0.88 ^c		15.67 ^c		78.99 ^c		2.34 ^c		Loamy sand

Notes: BD- Bulk density, TP- total porosity
Similar letters are not different in each soil profile.

Means for land use types followed by the same superscript are not significantly different from each other at $p < 0.05$.

The Chemical Properties of Soil under different Land use Types

Table 2 showed there was significant difference ($p < 0.05$.) in pH with respect to land use types and soil depth with cropland soil being more acidic (5.19) than either forestland soil (6.54) or the plantation (6.39) at 0-15cm. It showed that there is significant difference ($p < 0.05$.) with respect to all the chemical properties at the 0-15cm depth except the

organic carbon that did not show any significant different among the land use types. There was a significant difference of phosphorus contents among various land use types ($p < 0.05$) (Table 2). The phosphorus content in the crop land appeared to be significantly higher than the rest land use types. Hence, the highest (0.96 mgkg^{-1}) and the lowest (0.66 mgkg^{-1}) phosphorus contents were observed under the cropland and the forestlands.

Table 2: Selected chemical properties for the soil profile under different land use

Depth in cm	OC (%) SE=0.01	OM (%) SE=0.01	pH SE=0.06	EC SE=0.01	AVP (mg/kg) SE=0.01	TN (g/100g) SE=0.01	CEC Cmolkg^{-1} SE=0.01	EXCHANGEABLE BASES Cmolkg^{-1}			
								Mg SE=0.01	Ca SE=0.02	K SE=0.01	Na SE=0.01
Land Use Type: Forest Land											
0-15	1.45 ^a	2.53 ^a	6.9 ^a	73.2 ^a	11.4 ^a	0.51 ^a	5.81 ^a	4.93 ^a	10.20 ^a	0.75	1.43
15-30	1.30 ^b	2.27 ^b	6.8 ^a	71.8 ^b	11.1 ^b	0.49 ^b	5.43 ^b	4.62 ^b	9.75 ^b	0.71	1.12
30-45	0.98 ^c	1.72 ^c	6.6 ^c	68.4 ^c	8.6 ^c	0.30 ^c	4.93 ^c	3.85 ^c	9.34 ^c	0.68	0.64
Land Use Type: Farm Land											
	SE=0.02	SE=0.10	SE=0.08	SE=0.02	SE=0.01	SE=0.06	SE=0.01	SE=0.02	SE=0.02	SE=0.01	SE=0.01
0-15	0.94 ^a	1.62 ^a	7.2 ^a	63.22 ^a	9.12 ^a	0.32 ^a	5.66 ^a	4.86 ^a	11.99 ^a	1.12 ^a	1.75 ^a
15-30	0.69 ^b	1.20 ^b	6.8 ^b	61.78 ^b	8.55 ^b	0.26 ^b	5.61 ^b	3.72 ^b	10.60 ^b	1.09 ^b	1.62 ^b
30-45	0.20 ^c	0.34 ^c	6.5 ^c	55.84 ^c	8.33 ^c	0.18 ^c	5.24 ^c	3.54 ^c	10.32 ^b	0.92 ^c	0.84 ^c
Land Use Type: Plantation Land											
	SE=0.05	SE=0.01	SE=0.05	SE=0.01	SE=0.01	SE=0.01	SE=0.01	SE=0.07	SE=0.09	SE=0.09	SE=0.09
0-15	1.61 ^a	3.13 ^a	6.90 ^a	85.44 ^a	12.48 ^a	1.35 ^a	6.84 ^a	5.89 ^a	11.34 ^a	0.54 ^a	1.56 ^a
15-30	1.56 ^b	3.09 ^b	6.77 ^b	82.82 ^b	12.11 ^b	1.03 ^b	5.72 ^b	4.92 ^b	10.84 ^b	0.48 ^b	1.32 ^b
30-45	1.34 ^c	2.87 ^c	6.63 ^c	73.44 ^c	9.67 ^c	0.96 ^c	4.98 ^c	4.88 ^c	9.78 ^c	0.47 ^c	0.78 ^c

Notes- organic matter, OC- organic carbon, EC- electric conductivity, AVP- available phosphorus, TN- total nitrogen.

Means for land use types followed by the same letter are not significantly different from each other at $p < 0.5$

Microbial Population under different land use

Table 3 showed the result of microbial population of soil under different land use types. It showed that there was significant difference ($p < 0.05$.) in fungus with respect to

land use type and depth with forestland soil (6.33) and plantation land soil (3.00) except in Farmland which does not show any significant difference.

Table 3: Microbial populations of different land use type.

Depth in cm	Fungi	SE	Bacteria	SE
Land use Type: Forest land				
0-15	6.33 ^{ab}	0.88	184.0 ^a	0.76
15-30	5.67 ^{ab}	0.67	100.0 ^a	0.46
30-45	5.64 ^{ab}	0.63	110.0 ^a	0.48
Land use Type: Farm land				
0-15	6.67 ^a	0.33	133.5 ^a	0.63
15-30	6.67 ^a	0.88	97.3 ^a	0.65
30-45	6.67 ^a	0.88	97.3 ^a	0.65
Land use Type: Plantation land				
0-15	3.00 ^b	0.73	146.3 ^a	0.67
15-30	3.33 ^b	0.33	132.0 ^a	0.32
30-45	3.33 ^b	0.33	132.0 ^a	0.32

Physical Properties

The percent of silt in Cropland is (1.6%) lower than other land use types significantly but between forestland and plantation land (Table 1). Subsequently, sand content is increased with changing Cropland (81.9%) to plantation land (76%), most likely as a result of preferential removal of silt and adding sand in soil surface by accelerated water erosion.

Sand content is a physical parameter affected by soil erosion and, hence, can be measured and used as an indicator for evaluating soil degradation under different land use systems (Ayoubi et al; 2011). However, there was significant difference in sand and clay under forestland and cropland while there was no significant in silt in all the land use types. Under sparser vegetation covers, the clay fractions are likely to be lost to processes of erosion and migration down the soil profile (Woldeamlak 2003) [45].

The distribution of soil particle through profile were the similar in each land use types with lower variation, similarly Jaiyeoba (2003) [23] indicated that clay contents of deeper depths increase with the increase of cultivation year due to either increases in clay translocation from the surface horizon or removal of clay from the surface runoff.

The high total porosity of the forestland soil is attributed to higher organic matter content, as total porosity is affected by the levels of organic matter and bulk density (Liu *et al.*, 2007 [43]; Gebrelibanos and Mohammed, 2013) [29].

The bulk density was not significantly different between the land use types. The mean value of bulk density was lowest (1.32 gcm³) under the forest and highest (1.57 g cm³), (1.56 gcm³) in Cropland and plantation land respectively.

High bulk density values in farmland might be due to the result of excessive wet season livestock trampling and continuous shallow depth cultivation and low organic matter input. This result is in line with the works of Islam and Weil (2000) [22], Woldeamlak (2003) [45], Mulugeta (2004) and Yihnew and Getachew (2013) [49]. The reason for the lowest soil bulk density on the forest land could be due to the higher clay content and accumulation of organic matter. Similarly, less disturbance of the forestland unlike other land uses could be the other reason. Under sparser vegetation covers, the clay fractions are likely to be lost to processes of erosion and migration down the soil profile (Woldeamlak, 2003) [45].

Soil Chemical Properties

pH

The pH of the soil in 1:1 soil to water ratio had the highest value of under the forest, followed by Plantation lands and Cropland, respectively. Table 2 According to Mohammed (2003) [29], the soil in high altitude and higher slopes had low pH values, probably suggesting the washing away of solutes and basic cations from these parts.

Generally, the pH values observed in the study area were within the ranges of moderately acidic to slightly acidic reactions according the rating of Foth and Ellis (1997). Mohammed (2003) [29] also concluded that the lowest value of pH under the cultivated land could be due to the depletion of basic cations in crop harvest and leached to streams in runoff generated from accelerated erosions. A pH value of 6.5 to 7.0 is the preferred range for most crops, but lower range is too acidic for some Farms (Landon, 1991). pH decreases as depth of the soil increases.

Cation exchange capacity (CEC)

The mean of the CEC obtained are 5.81, 5.43, and 4.93 Cmolkg⁻¹ for plantation soils forest soil, 5.66, 5.61 and 5.24 Farm soil and 6.84, 5.72 and 4.98 for plantation respectively. There is significant difference within and between the land use types and soil profile (Depth). It is a general truth that both clay and colloidal OM have the ability to absorb and hold positively charged ions. Thus, soils containing high clay and OM contents have high CEC. According to Belaynesh (2009), land use highly significantly influenced the change in CEC. High organic matter and clay contents increase CEC in soils (Yihnew and Getachew 2013) [49]. Similarly, Mulugeta and Karl (2010) [28] supported the idea that high clay soils can hold more exchangeable cations than a low clay containing soils.

Exchangeable Bases

Potassium

Potassium mean of 1.12, 1.09 and 0.92 Cmolkg⁻¹ under plantation land, 0.54, 0.48 and 0.47 for Farm land, and 0.75, 0.71 and 0.68 under forest land, shows there are significant differences between plantation land soil and forest land soil but no significant different in Farm land under 15-30cm and 30-45cm. The highest exchangeable K was recorded from plantation land. Many research results supported the findings, since weathering, intensive cultivation and use of acid forming inorganic fertilizers on acid soils affect the

distribution of K in the soil systems and enhance its depletion (Baker et al., 1997^[4]; Saikh et al., 1998)^[34].

Calcium

Calcium these means were obtained 11.99, 10.60, and 10.30 Cmolkg^{-1} for Farm land, 11.34, 10.84, and 9.78 Cmolkg^{-1} plantation land and 10.20, 9.75 and 9.34 Cmolkg^{-1} forestland respectively which shows that's significant difference between the land use type and depth(profile). Exchangeable Ca concentrations increased and remained elevated following the slash-and-burn conversion of forests to pastures or crops (McGrath *et al.*, 2001).

Magnesium

The higher mean value was recorded under forestland and there is significant different. The increasing trend of Ca and Mg concentration with depth in these lands could be due to the leaching effect and organic matter degradation. This is in agreement with the findings of different researchers who indicated that continuous cultivation and use of acid forming inorganic fertilizers deplete exchangeable Ca and Mg (Saikh et al., 1998^[34]; He et al., 1999; Aitken et al., 1999).

Organic matter

Soil OM content was highest (7.03%) under the natural forest land and lowest (3.32%) on the cultivated land. The result was in agreement with that of Yihenew and Getachew (2013)^[49] who reported that lowest organic matter was registered in cultivated land and highest in the natural forestland and there is significant difference expect in cropland.

Available Phosphorus

There was a significant difference of phosphorus contents among various land use types ($p < 0.05$) (Table 2). The phosphorus content in the crop land appeared to be significantly higher than the rest land use types. Hence, the highest (0.96 mgkg^{-1}) and the lowest (0.66 mgkg^{-1}) phosphorus contents were observed under the cropland and the forestlands, respectively (Table 2). Similar findings were reported by Gebeyaw (2007) and Woldeamlak (2003)^[45]. This could be due to the application of Diammonium phosphate (DAP) fertilizer on the cultivated land in line with the explanation made by Woldeamlak (2003)^[45] and Gebeyaw (2007).

Soil Microbial Populations

Bacteria: There were no significant differences within the soil samples table 3. The type of soil was considered a determinant factor in the composition of microbial populations in cultivable soils (Damastri et al., 1999; Girvan et al., 2003)^[20]. However, no significant differences were observed. The results of Bottner (1985) indicated that soil moisture changes affect the magnitude of the soil microbial biomass because many soil microorganisms are intolerant of low water content.

Fungi: The highest number of fungi was recorded in forest soil (7.5cfu) and lower was recorded in plantation soil (2.5cfu) due to the imfact that fungus depends on the plant for energy, and in return, the fungus and its hyphae can take up nutrients for the plant, and possibly improve plant growing conditions. For instance, mycorrhizae associations have been shown to increase plant-water relations and reduce severity of some plant diseases as stated by (Smith

and Read, 1997). Although, there is significant differences observed in forest land and plantation no significant differences observed in Cropland. The type of soil was considered a determinant factor in the composition of microbial populations in cultivable soils (Damastri et al., 1999; Girvan et al., 2003)^[20].

Conclusion

From the study, it was possible to conclude that soil chemical properties and microbial populations significantly vary among land use types. Most of the important soil quality indicators were significantly influenced by different land use types, particularly at the surface horizon.

The Organic matter, soil pH, CEC, exchangeable bases and population of fungi, were affected due to intensive cultivation, soil disturbances, and use of acid forming inorganic fertilizers. The undisturbed natural forest and plantation were superior in most of the soil quality indicators determined.

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