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Effects of different land use types on selected soil quality indicators in Minna, Niger State

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Abstract
The effects of some land use type, namely: maize production, natural and cultivated pastures on the quality of a Typic Plinthustalf were investigated. It involved the collection of soil samples from experimental plots from the three land use types along three diagonal transects at 0 to 25 cm depth. Soil samples from each transect were bulked to form a composite. The experimental design was a randomized complete block design (RCBD) replicated three (3) times. Land use types were the treatments, while composite samples from respective transects were used as replications. A total of nine composite soil samples were collected and taken to the laboratory for routine laboratory analysis following standard procedures. Results revealed that irrespective of the land use types, soil texture was generally sandy loam. Soil reaction was neutral (pH 6.7), organic carbon and nitrogen were low. Potassium content was medium in natural pasture and maize field, but high in the cultivated pasture. Phosphorus was low in natural pasture and maize field but medium in the cultivated pasture. Land use had no significant ($P \geq 0.05$) effects on the distribution of sand, silt, clay, pH and potassium. Significant ($P \leq 0.05$) effects of land use were observed on organic carbon, total nitrogen and available phosphorus. While natural pasture showed potential for soil quality improvement, cultivated pasture and maize field would require the incorporation of organic matter and inorganic N-fertilizers to enhance the soil quality.

Keywords: Soil quality, Typic plinthustalfs, land use types, soil properties, sustainable land management

1. Introduction

All anthropogenic activities and inputs on land either for the purpose of production or for its maintenance define land use [1]. Such human-driven activities vary from place to place. Population pressure greatly influences the nature of land use and the rate of expansion of land being committed to such uses with dire consequences of deterioration on soil quality and productivity [2-5]. Thus, the most important thing is to regularly monitor the response of soil quality parameters under different land use types, especially agriculture-related land use practices. It is easy this way, to identify and rank those practices or environmental factors which are likely to cause degradation in critical soil quality parameters as a result of use [6].

Quality of soil is usually measured in terms of the soil's capacity to sustain its productivity within the purview of its natural or managed ecosystem, including enhancement of water and air quality and supporting human health and shelter to all [7, 8]. Soil quality attributes are usually considered to reflect the main aspects of the soil properties (physical, chemical and biological). These properties have varying degrees of impact on the soil quality principally in the assessment of land degradation and selection of appropriate land use practices which are sustainable [9, 10]. Differences in types and rates of fertilizer application, field cultural practices by farmers and cropping systems were identified as the main factors influencing soil fertility quality at the field level [11], even when soils were derived from similar lithology [12]. However, Willy *et al.* [6] were of the opinion that in as much as farmers adopt sustainable land management practices involving incorporation of organic matter (crop residues), soil and water conservation practices, crop rotation, among others, agricultural land use may not in its entirety a major contributor to land degradation. Therefore, periodic evaluation of soil quality status is important in order to identify potential factors that impose serious constraints on the productivity of soils under different land uses. In this way, the potential of the land can be easily established and appropriate and sustainable land management practices adopted [13].

Upland soils of Minna are products of extensive weathering of the basement complex rocks. They have weak to moderate soil structure with gravelly and concretionary layers at or beneath the topmost layers. These attributes matched the USDA's Soil Taxonomy descriptions of Typic Plinthustalf [14]. Plinthustalf or Plinthosol in FAO soil classification system are known to have many management challenges including inherent low fertility, shallow rooting depth, susceptibility to drought even under short dry spells during the rainy season and easily water-logged under high-intensity rainfall conditions [15]. Around Minna, these soils are increasingly being used for cultivation of the arable crop, pastures, fruits and vegetables as well as open grazing without baseline information on the effect of land use type(s) on soil quality indicators. Investigation of soil quality evolution process and characteristics is the basis for establishing the scientific soil quality control system and improving the land management level [10]. Therefore, this study assessed the effects of the three land use types on some quality indicators of the inherently low fertility Plinthustalf for their optimum and sustainable management.

2. Materials and Methods

2.1 Site description

The Massohi farm where this study was carried out is located at kilometer 12, Minna – Bida road located on latitude 09° 32' 10.8"N and longitude 006° 28' 54.8"E (Plate 2.1)

Plate 2.1: An Aerial View/Layout of Massohi farms and livestock development company

The ground elevation ranged from 220 and 226 m above mean sea level. Massohi farm is an integrated farm that specializes in ruminants and non-ruminants such as cattle, sheep and goats for meat and dairy, rabbits and fisheries and aquaculture. The farm is also involved in the cultivation of arable crops such as maize (*Zea mays*), cultivated pasture (mainly, *Andropogon spp*, *Brachiaria spp*, and *Panicum maxima*) and natural fallow grassland with native grass species. Minna falls within the sub-humid agroecological zone of Nigeria, characterized with distinct wet and dry seasons. Annual rainfall figures for Minna averagely are 1200 mm, with 90 % of the rain usually experienced in the months of June to August. Mean daily temperatures could be as low as 22 °C during the Harmattan season (December-January) and may reach the peak of 40 °C during February-March [16]. The dominant soil type is Typic Plinthustalf [14]. The site in which this study was carried out had been under continuous cultivation for over a period of five years.

2.2 Experimental design and soil sample collection

Experimental soils were collected with soil auger from the natural pasture, cultivated pasture and maize field at 0-25 cm depth from three diagonal transects. The samples were bulked together to give three composite samples for each land use type. Altogether, nine (9) composited soil samples were collected. The land use types were the treatments, while composited samples from each transect were used as replications. The experiment was a randomized complete block design (RCBD) with three replications. It was on this design that the samples were handled and processed for laboratory analysis.

2.3 Soil handling and laboratory analysis

The samples were air-dried, gently crushed with ceramic mortar and pestle, and then passed through a 2-mm sieve. Subsamples for the determination of total nitrogen and organic carbon were sieved using 0.5 mm mesh. The processed soil samples were analyzed according to standard laboratory procedures outlined in [17] as briefly explained below. Particle size distribution was determined by the sedimentation method using Bouyoucos Hydrometer to take the readings. The pH of the soils was measured from a 1:2.5 soil to water ratio using a standard pH meter and electrodes. Determination of organic carbon followed the Walkley-Black method of wet combustion involving oxidation of organic matter with potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4). Micro Kjeldahl method was used in the determination of total nitrogen, while the Bray P-1 method was used for available phosphorus. Exchangeable bases were extracted with the 1N neutral ammonium acetate (NH_4OAc) saturation method and the amount of potassium in the solution was measured using a flame photometer.

2.4 Data analysis and interpretation

The statistical analysis of variance (ANOVA) was performed on the laboratory-generated data using SAS software [18]. Where significant differences were observed, treatment means were further separated using the least significant difference (LSD) at 5% level of probability.

3. Results and Discussion

3.1 Land use types versus distribution of soil separates

Results of the effect of land use types on the distribution of sand, silt and clay in the soils are presented in Table 3.1.

Table 3.1: Effect of land use type on particle size distribution in the soils

Treatments	Sand	Silt	Clay	Textural Class
		(g kg^{-1})		
Land Use Types (LUT)				
Natural Pasture	762^{a}	123^{a}	115^{a}	Sandy loam
Cultivated Pasture	783^{a}	105^{a}	112^{a}	Sandy loam
Maize field	800^{a}	95^{a}	105^{a}	Sandy loam
SE±	14	15	5	
Significance*	NS	NS	NS	

*NS = not significant at 0.05 level. Means followed by different superscript letters within the column are statistically different at P≤0.05 level

The treatments had no significant (P≥0.05) effect on the distribution of sand, silt and clay particles. Numerically, the sand fraction was higher in the maize field relative to the values in natural and cultivated pastures. Similarly, natural pasture had higher amount of silt and clay content as compared to the cultivated pasture and maize field. These statistical similarities may suggest that the studied soils shared common genetic history, that is, they were probably developed from weathering of similar parent materials. However, this result differs from those reported by [19] from a similar study in Ethiopia in which they reported significant differences in the distribution of particle size fractions probably because their investigation includes protected forests among other open-field land use types. Irrespective of land use type, the texture of the soil was sandy loam. This further reaffirmed the similarity of parent materials and pedogenic processes leading to the formation of the soils [20, 21].

3.2 Land use types versus chemical properties of the soils

Results showing the effect of the treatment on selected soil chemical properties are presented in Table 3.2. The ranking of the soil chemical properties followed the fertility classification [22]. No significant (P≥0.05) difference was observed in pH and potassium status in the soil irrespective of the treatments.

Table 3.2: Effect of land use type on some chemical properties of the soils

Treatments	pH	SOC*	N(g/Kg)	P(mg/Kg)	K(cmol/Kg)
Natural Pasture	6.7^{a}	7.96^{a}	0.08^{a}	7^{ab}	0.19^{a}
Cultivated Pasture	6.7^{a}	6.28^{a}	0.06^{a}	11^{ab}	0.31^{a}
Maize Field	6.7^{a}	4.84^{a}	0.06^{a}	6^{ab}	0.23^{a}
SE±	0.08	0.55	0.01	1.17	0.06
Significance	NS	*	*	*	NS

NS= not Significant; *Significant at 0.05 level. Means followed by different superscript Letters within the column are statistically different at P≤0.05 level.
*SOC = soil organic carbon, N=nitrogen, P=phosphorus, K=potassium

The investigated soils reacted neutrally with mean pH values of 6.74, 6.69 and 6.71 for natural pasture, cultivated pasture and maize field, respectively. However, numerically, potassium content increased in the order of cultivated pasture> than maize field >natural pasture. Fertility ranking revealed that potassium content in the soil was high in cultivated pasture and medium in both natural pasture and maize field. Hence, the possibility of potassium deficiency in the soils under these land use types may not manifest in the nearest future under good soil management practices.

Organic carbon, nitrogen and phosphorus contents in the soil were significantly (P≤0.05) affected by land use types. The natural pasture was significantly (P≤0.05) higher in organic carbon compared to the maize field, but statistically similar to that of cultivated pasture. Although, in terms of fertility ranking, organic carbon was low irrespective of land use types. The highest value for soil organic carbon recorded in natural pasture may be attributed to zero tillage practice in the natural pasture as according to [23], a high proportion of organic carbon is usually removed from cultivated fields during crop harvest. On the other hand, the annual cycle of tillage activities in cultivated pasture and maize field may have contributed relatively to their lower soil organic carbon content. As reported by [24], seasonal cultivation of land aggravates the decomposition of organic matter in the soil, while conservation tillage preserves it.

Similarly, total nitrogen was significantly (P≤0.05) higher in natural pasture compared to cultivated pasture and maize field. The results partly imply that nutrient mining could be more under the cultivated pasture and maize field. [25, 26] reported that continuous cultivation of land reduces nitrogen in soil through harvest removal, leaching and humus losses. To further support the results, [27] stated that the quality attributes of agricultural land diminish through consistent cultivation without fallowing as a result of nutrient mining. Another reason for low nitrogen status in the soils irrespective of land use type could be as a result of low level of organic matter as studies have shown that total nitrogen in the soil is associated with soil organic matter [24, 25, 28 & 29].

Available phosphorus was significantly ($P \leq 0.05$) higher in the cultivated pasture compared to maize field, but statistically similar to the natural pasture. Even though [24] reported a strong correlation existing between soil organic carbon and both nitrogen and phosphorus, the highest phosphorus value recorded in the cultivated pasture could probably be a result of the application of P-fertilizers above the requirements of the cultivated species of pastures. In terms of fertility ranking, phosphorus status was medium in cultivated pasture and low in both natural pasture and maize field respectively.

4. Conclusion

The land use types investigated had no controlling effects on the distribution of sand, silt, clay, pH and potassium of the Typic Plinthustalf. Significant effects were observed on organic carbon, nitrogen and phosphorus. The natural pasture showed potential for improving organic carbon and other soil quality attributes. Continuous use of these Plinthustalfs, especially for high-intensity cultivation of pasture and maize without external input support, such as the incorporation of organic manures (or recycling of crop residues) and inorganic fertilizers could lead to their rapid degradation.

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