

Effects of Different Land Use Systems on Selected Physico-Chemical Properties of Soils in Yamaltu, Yamaltu-Deba Local Government Area, Gombe State

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Abstract

Original Research Article

Information about influence of different land use systems on soil physico-chemical properties is crucial for best land management practices. Properties of soil vary with land use system over time and the knowledge of these changes is vital for sustainable food productivity. The study was conducted at Yamaltu located in Yamaltu-Deba Local Government Area of Gombe State, Nigeria, with the objective to evaluate the influence of different land use types and soil depths on nutrient status and potential changes in nutrient contents due to land use activities. Three major land use systems namely rain fed arable land, irrigated arable land and orchard land were identified, described and mapped on bases of their soils. Six composites soil samples from 0-15cm and 15-30cm were collected from each landuse type and then air dried, ground and passed through a 2mm sieve to determine physicochemical properties. Results of the experiment indicated that the soil were sandy clay loam in texture while Soil pH were slightly acidic to neutral under all landuse systems. In all landuse systems, organic carbon and total N, available P, exchangeable bases and CEC decreased with soil depth. The highest mean values of organic matter ($8.2(\text{gkg}^{-1})$) and total nitrogen (1.34gkg^{-1}) were recorded under the irrigated arable land while Available phosphorus (26.2mgkg^{-1}), Calcium (4.6cmolkg^{-1}), Magnesium (0.50cmolkg^{-1}), Potassium (0.26cmolkg^{-1}), Sodium (0.21cmolkg^{-1}) and cation exchange capacity (12.0cmolkg^{-1}) were recorded under orchard land at the surface soil layer. From the results of the study it was possible to conclude that rain fed arable land and irrigated arable land had detrimental effects on the soil physico-chemical properties. Therefore, reducing intensity of cultivation, adopting integrated soil fertility management and application of organic fertilizers could maintain the existing soil condition and replenish degraded soil properties.

Keywords: Land use types; Soil depths; food; fodder; fiber; fuel; degradation; socio-economic.

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INTRODUCTION

Rapid growth in population and long history of subsistence agriculture has changed the land use/land cover system and has been a major cause of environmental degradation on most parts of sub-Saharan Africa [1]. Amanze *et al.*, [2] reported that, soil properties deteriorate with changes in land use especially from forest to arable. Different land-use system greatly influence physico-chemical properties and quality of soil [3] and affect the nutrient supply and uptake [4, 5]. The increasing population and socio-economic needs impart pressure on agricultural production system which ultimately results to unplanned changes in land-use systems [6]. So, it is a big deal to meet these necessities through balanced land-uses by keeping the soil fertility intact. Oguike and Mbagwu [7] opined that, changes in land use, such as conversion of natural forest to cropland, contributed to

land degradation that manifested in losses of soil organic matter and total nitrogen. Chisci and Zanchi [8] stated that cropping results in loss of soil organic matter and reduced soil aggregate stability, increased bulk density and compaction. Agricultural activities changed the soil physical, chemical and biological properties, and play the major role for soil degradation mainly due to soil fertility decline as a result of lack of nutrient inputs. The rapid population growth demands more production of food, fodder, fiber and fuel from the land [9].

Intensive cultivation results in increase in sand fraction and bulk density, reduced soil nutrient status and water retention capacity while increasing soil acidity as against bush fallow land [10]. However, land restoration through bush fallow and conservation tillage could be effective in sequestering carbon and slowing down climate change [11]. Generally, a good

understanding of land use and management effects on soil physical, chemical and biological provides an opportunity to evaluate sustainability of land use system [12]. There is increasing awareness that reduction in soil fertility from the agro ecosystem is a very widespread phenomenon and one of the crop production constraints. A change in land use, poor soil management, erosion and socioeconomic activities of the area can negatively lead to land degradation and loss of productivity. Loss of arable land due to intensive cultivation and erosion is a widespread problem in Nigeria. Low soil fertility was reported as one of the major factors affecting crop production in the study area [13, 14]. The study area is facing with agricultural challenges such as inadequate of land for crop cultivation and livestock grazing, decline of soil fertility and rainfall variability resulting in low yield production, determining the physico-chemical property is crucial for further soil management and improvement. Therefore, the objective of the study was to evaluate the effects of different land use types on nutrient status and potential changes in nutrient contents due to land use activities.

MATERIALS AND METHODS

Study Area

The study was conducted at Yamaltu located in Yamaltu-Deba Local Government Area of Gombe State, Nigeria. The study area is situated at the eastern part of Gombe metropolis on latitudes $10^{\circ}14'17.3''$ North of the equator and longitudes $11^{\circ}26'29.5''$ East of Greenwich meridian and about 282 metres above the sea level. It is in the Sudan Savannah zone of Nigeria covering a total land area of 1,981 km². Its geomorphology comprises of greatly undulating plains and pediments [15]. The climate of the area is characterized by high temperatures and seasonal rainfall. The average annual rainfall of the area is between 800-900 mm with average temperatures ranges from 30 - 32°C and the area experience a relative humidity of 17-90 percent [15]. The area is characterized by dry sub humid zone [16]. The study area is divided into three land utilization types. The rain fed arable land which comprises of few trees like shear-butter, locust bean trees, and shrubs with scattered grasses and mainly cultivated with maize, sorghum, cowpea and vegetables. The orchard land is densely populated with mango, guava trees and few grasses. The land is relatively a flat land. The irrigated arable land is intensively cultivated all year round based on the information obtained from the farmers; it is relatively a flat land with scattered mango trees and dark coloured Vertisols soils. It is mainly cultivated with rice, maize,

tomato, onion, pepper, okra and leafy vegetables. The soil fertility was managed by the application of both organic manure and inorganic fertilizer. Weed control was managed by both the application of herbicides and manual method of hoeing.

The farmers in the study area are practicing mixed farming system that is producing a variety of crops as well as rearing animals that improved the livelihoods of local communities and their income. All crops are annual and rain feed crops, such as maize, rice, sorghum, groundnut, cowpea, soybeans, sunflower and vegetables such as tomatoes, pepper, onion, okra, lettuce, cabbage, carrot are the common one. From the fruit, sugar cane, banana, mango, cashew, guava, and orange are found in some specific study area. The livestock of study area includes cattle, sheep, goats, poultry and equine (donkeys, camels, and horses).

Site Selection for this study

Yamaltu was purposively selected from Yamaltu-Deba LGA because higher land degradation and soil erosion problems are commonly observed in this area which has a deleterious impact on soil physical, chemical and biological properties under different land use types. Prior to the collection of soil samples, discussions was made with the community leaders in order to get the prehistory and current information about the utilization of land use types and lifestyle of the local community in the study area. During the discussion, enlightenment was also made as regard to the significance of the research in their area. Reconnaissance field survey was carried out in order to have a general view of land use types and also to collect information on landforms, vegetation, cropping history, topography and slope of the area, drainage characteristics, erosion hazard and general soil conditions in the study area. Then after, for addressing the intended objective, the treatments were stratified in to four land use types viz: cultivated, grazing, forest and grasslands.

Soil sampling and preparation

Four major land use types namely rain fed arable land, irrigated arable land and orchard land were used for this study. Six composite soil samples from 0-15cm and 15-30cm were collected from each land use type and then air dried, ground and passed through a 2mm sieve to determine physicochemical properties. A total of 36 composite samples were therefore collected from the three land use types.

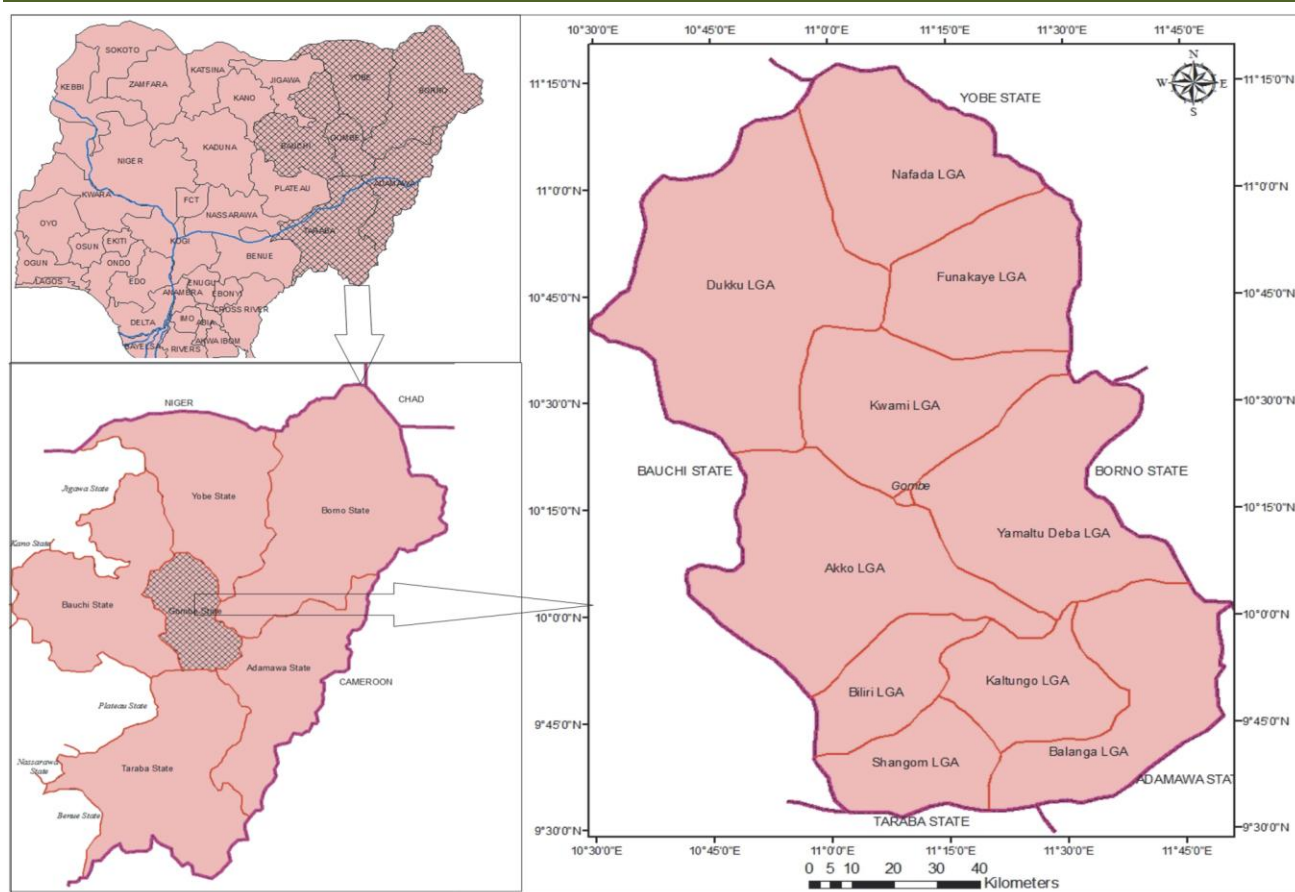


Fig-1: Map of Gombe State and Yamaltu-Deba local government area

LABORATORY ANALYSES

Soil pH of each soil sample was determined in water as described by McLean [17]. Total nitrogen was determined by the micro Kjeldahl method [18]. Organic carbon was determined by the Walkley-Black wet oxidation method of Nelson and Sommers [19]. Available phosphorus was determined by using Bray I extraction method [20]. While determining the cation exchange capacity (CEC) by ammonium acetate method (NH_4OAC). NH_4OAC extract was saved and analyzed for exchangeable cations were calcium and magnesium was read using atomic absorption spectrophotometer (AAS), whereas exchangeable sodium and potassium were read using flame photometer as described by Page *et al.*, [18].

RESULTS AND DISCUSSION

The physical properties of soils in the studied area were presented in Table-1. The particle sizes in the three land uses were dominated by sand fraction irrespective of land use system. In the surface soil layer (0–15cm depth) under different land use systems, the sand fractions ranges from 49.0-51.0% (50% average), Silt fractions ranged from 23-26% (24.3%

average) while clay fractions ranged from 25-27% (25.7% average). In the subsurface soil layer (15-30 cm depth) the sand fractions ranges from 40.0-42.0% (41% average), Silt fractions ranged from 27-28% (27.7% average) while clay fractions ranged from 31-32% (31.3% average) respectively. Oguike and Mbagwu [7], Attributed the high sand fractions in the area to parent material since the texture of the soil is highly influenced by the parent material and topography over time. Generally, the clay content was higher in the subsurface soil layer of irrigated arable land and rain fed arable land as compared to the adjacent orchard land. The reason could be due to the preferential removal of clay particles and its downward movement into the subsurface soil layer through the process of clay migration. Similarly, Chemada *et al.*, [21] attributed the increased clay content of irrigated arable land and rain fed arable land from the surface to subsurface to the long period of cultivation. The current result is in agreement with the findings of Shiferaw [22]; Mengistu *et al.*, [23] who reported an increase in clay content with depth under cultivated lands due to long period of cultivation.

Table-1: Textural class of different land use types at 0-15 and 15-20 cm depth

Land use	Sand (%)	Silt (%)	Clay (%)	Soil Texture
Surface layer (0 – 15 cm)				
Rain fed arable land	51	24	25	
Irrigated arable land	49	26	25	
Orchard land	50	23	27	
Mean	50	24.3	25.7	
Subsurface layer (15 – 30cm)				
Rain fed arable land	42	27	31	
Irrigated arable land	41	31	28	
Orchard land	40	28	32	
Mean	41	27.7	31.3	

Effect of land use on soil pH

The result on soil pH was presented in Table-2. Soils under all the three land uses were moderately acidic to neutral as rated by Black [24] (pH ranges from 5.6-6.9 irrespective of land uses and depths). Lowest values were recorded in irrigated arable land in both surface and sub-surface layers of soil in terms of soil pH. In the surface layer (0-15cm) under different land use systems, the pH value ranges from 6.4-6.9 (6.6 average) which was rated slightly acidic to neutral as rated by Black [24]. In the subsurface layer the pH value varied from 5.6-6.3 (6.0 averages) which was also rated moderately acidic to slightly acidic as rated by Black [24] (Table-2). The slightly acidic condition of the irrigated arable land is due to organic and inorganic fertilizer application by the farmers. These results are in agreement with the results of Takele *et al.*, [25] who suggested that the soil reaction was lower under cultivated land compared to forest and grazing lands at soil surface (0-20 cm depth). The slightly acidic to neutral pH of the soils agreed with the findings of [26, 14] who worked with similar soils. The values obtained in the study are within the pH requirement for most arable crops for nutrient up take.

Effect of land use on Soil organic carbon

The result on soil organic carbon content was presented in Table-2. In the surface layer under different land use systems, the soil organic carbon ranges from 7.4 - 8.2 gkg⁻¹ (7.73 gkg⁻¹ average) which was rated low as rated by Esu [27]. In the subsurface layer, the SOC varied between 6.8 - 7.9 gkg⁻¹ (7.23 gkg⁻¹ average) which was also rated low as rated by Esu [27] (appendix-1). The low SOC may be partly due to effect of land use activities and high temperature which favours rapid mineralization of organic matter [28]. This finding is in agreement with different individuals' findings Ibrahim [29], Iqbal *et al.*, [30], Takele *et al.*, [25] and Mondal *et al.*, [31] in which they reported that the soil organic carbon decrease with increasing soil depth, with more accumulation on the surface soil layer. Higher amount of organic carbon accumulation under orchard land may be due to stems, barks, flowers, leaf litter fall in the surface and through root deposition and logs microorganisms in deeper layers [32]. On the other hand, the low soil organic carbon in rain fed arable land and irrigated arable land may be due to the removal of

biomass during cultivation, a low quantity and quality carbon inputs to the soil combined with faster organic matter decomposition and mineralization rates [4, 33]. Moreover, intensive cultivation, tillage and several management practices hastens the loss of SOC through facilitating microbial activities and the process of oxidation [34].

Effect of Land Use on Total N

The result on total nitrogen was presented in Table-1. In the surface layer under different land use systems, the total nitrogen content ranges from 1.26–1.34 gkg⁻¹ (1.3 gkg⁻¹ average) which was rated low as rated by Esu [27] (appendix-1). In the subsurface layer, the total nitrogen value varied between 1.16-1.23 gkg⁻¹ (1.19 gkg⁻¹ average) which was also rated low as rated by Esu [27] (appendix-1). The highest value of 1.34gkg⁻¹ was recorded under orchard land while the lowest value of 1.22 and 1.26gkg⁻¹ was recorded under irrigated arable land and rain fed arable land. Higher amount of total N accumulation under orchard land might be due to the micro climate created by adequate vegetation cover which moderated the soil temperature, air and moisture against total N loss by volatilization. On the other hand, the relatively low value of total N observed under irrigated arable land and rain fed arable land might be due to the volatilization of nitrogen resulting from increased oxidation of nitrogenous compounds in the soil [35]. This might have been triggered by high exposure of the soil to air and increased temperature by frequent tillage operations. However, Chikamnele *et al.*, [35] stated that the increased mobility of nitrogen caused by incessant pulverization of the soil possibly resulted to losses by leaching. Similar result were reported by Oguike and Mbagwu [7] they explain that continuous cultivation of soils caused a substantial loss of nitrogen due to increased volatilization and leaching effects.

Effect of Land Use on Available P

The result on available phosphorus was presented in Table-2. In the surface layer under different land use systems, available phosphorus content value ranges from 18.9-26.2 mgkg⁻¹ (22.6 mgkg⁻¹ average) which was rated medium to high as rated by Esu [27] (appendix-1). In the subsurface layers, the available phosphorus value varied between 12.8-

19.7 mgkg⁻¹ (16.6 mgkg⁻¹ average) which was also rated medium as rated by Esu [27] (appendix-1). On the other hand, highest concentration of available P was recorded under irrigated arable land (26.2mg kg⁻¹) followed by rain fed arable land (24.7 mg kg⁻¹) and orchard land (18.9 mg kg⁻¹) whereas the subsurface soil layer of 15-30 cm depth followed a similar trend of irrigated arable land (19.7mg kg⁻¹) followed by rain fed arable land (17.2 mg kg⁻¹) and orchard land (12.8 mg kg⁻¹). Decrease in P content with depth was a common trait in all three land-uses. Better values of available P content in irrigated arable land and rain fed arable land may be due to long-term application of phosphates fertilizers and addition of organic manures that increase P availability [36]. Hishe *et al.*, [37] stated that, the presence of phosphorus content in soils depends upon a number of factors such as climate, vegetation, soil texture, land use pattern, fertilizer use, drainage, irrigation, and soil pH, whereby the availability of phosphorus is greatest in the soil pH range 6.0-6.5. This result is in agreement with the findings reported by Nega [38] who stated that soil available P was significantly affected by land use types.

Effect of Land Use on Calcium

The result of exchangeable calcium was presented in Table-2. In the surface layer of the soil under different land use system, the value of the exchangeable calcium ranges from 3.6–4.6 cmolkg⁻¹ (4.2cmolkg⁻¹ average) which was rated medium as rated by Esu [27] (appendix-1). In the subsurface soil layer, the calcium content varied between 1.6–2.2cmolkg⁻¹ (1.97 cmolkg⁻¹ average) which was rated low to medium as rated by Esu [27] (appendix-1). Based on the data recorded in the study area, the exchangeable Ca was higher at the surface soil depth than at the subsurface soil depth (Table-2). This could be the possibility of the high exchangeable Ca was available on surface soil layer with an abundance of animal and plant residues than beneath the soil layer. The present study was in contradicted the findings of Bore and Bedadi [39] who reported that exchangeable Ca increased with increasing soil depth since it is susceptible and possibility of easily leach downward by runoff and water percolation. On the other hand, the present study corroborates with the findings of Ibrahim [40]; Kiflu and Beyene [41] who reported that, the exchangeable Ca contents was higher on the surface soil layer than the subsurface soil layer due to the association of biological accumulation with biological activity and accumulation from plant residues.

Effect of Land Use on Magnesium

The result of exchangeable magnesium was presented in Table-2. In the surface soil layer exchangeable magnesium ranges from 0.34 - 0.50 cmolkg⁻¹ (0.42 cmolkg⁻¹ average) which was rated medium as rated by Esu [27] (appendix-1). In the subsurface soil layer, the magnesium varied between 0.31-0.42 cmolkg⁻¹ (0.38 cmolkg⁻¹ average) and was

also rated medium as rated by Esu [27] (appendix-1). This result agrees with Ibrahim *et al.*, [42] who reported that calcium and magnesium are the predominant basic cations in soils in the study area. The highest (0.50 cmolkg⁻¹) exchangeable Mg was recorded on the surface soil layer of irrigated arable land while the lowest (0.31 cmolkg⁻¹) exchangeable Mg was obtained under the subsurface soil layer of orchard land (Table-2).

Effect of Land Use on Potassium

The result on exchangeable potassium was presented in Table-2. In the surface soil layer exchangeable potassium ranges from 0.21-0.26 cmolkg⁻¹ (0.24 cmolkg⁻¹ average) which was rated medium as rated by Esu [27] (appendix-1). In the subsurface soil layer, exchangeable potassium values varied between 0.13-0.19 Cmolkg⁻¹ (0.16 cmolkg⁻¹ average) which was also rated low to medium as rated by Esu [27] (appendix-1). This result contradicted with the previous findings of Ibrahim *et al.*, [40] who reported higher potassium content and attributed it to the nature of irrigation water which contained high amount of potassium. The highest (0.26 cmolkg⁻¹) and the lowest (0.13 cmolkg⁻¹) exchangeable K contents were recorded at the surface layers of the irrigated arable land and the subsurface layers of the orchard land, respectively (Table-2). The low exchangeable K contents observed under irrigated arable land and rain fed land are due to continuous cultivations and continues use of inorganic fertilizers which enhances the loss of base cations through erosion, crop harvest and leaching in the study area which is supported by previous findings of Malo *et al.*, [43]; Mengistu *et al.*, [23] who indicate that intensity of weathering, cultivation and use of acid forming inorganic fertilizers affect the distribution of K in the soil system and enhance its depletion.

Effect of Land Use on Sodium

The result of exchangeable sodium was presented in Table-2. In the surface soil layers exchangeable sodium ranges from 0.15-0.21cmolkg⁻¹ (0.17cmolkg⁻¹ average) which was rated low to medium as rated by Esu [27] (appendix-2). In the subsurface horizons, the sodium content varied between 0.17-0.23cmolkg⁻¹ (0.19cmolkg⁻¹ average) which was also rated low to medium as rated by Esu [27] (appendix-1). The highest Sodium content was recorded at the subsurface soils of rain fed arable land and irrigated arable land which could be attributed to leaching of basic cation down the profile Mengistu *et al.*, [23]. This study corroborates the findings of Mengistu *et al.*, [23] who reported higher exchangeable Na under subsurface soil layer (15-30cm depth).

Effect of Land Use on CEC

The result on cation exchange capacity was presented in Table-2. In the surface soil layers of the soils cation exchange capacity ranges from 9.11-12 cmolkg⁻¹ (10.44 cmolkg⁻¹ average) which was rated

medium as rated by Esu [27] (appendix-1). In the subsurface soil layers, the cation exchange capacity content varied between 8.2 - 8.6 cmolkg⁻¹ (8.03 cmolkg⁻¹ average) which was also rated medium as rated by Esu [27] (appendix-2). CEC values decreased from the surface to the subsurface layer under different land use

types. Generally, the surface soils of irrigated arable land had the highest value of CEC (12cmolkg⁻¹) which could be attributed to difference in soil organic matter and clay content under different land use types, which is in agreement with the findings of [23, 44].

Table-2: The effect of land use types and depth on Organic C, Total N (gkg⁻¹), Available P (mgkg⁻¹) and Exchangeable bases and CEC (Cmolkg⁻¹)

Land use	Soil pH	OC	TN	AP	Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	CEC
Surface layer									
Rain fed arable land	6.6	7.4	1.26	24.7	4.3	0.34	0.25	0.17	10.2
Irrigated arable land	6.9	8.2	1.34	18.9	3.6	0.41	0.21	0.15	9.11
Orchard land	6.4	7.6	1.22	26.2	4.6	0.50	0.26	0.21	12.0
Mean	6.6	7.7	1.30	22.6	4.2	0.42	0.24	0.17	10.44
Subsurface layer									
Rain fed arable land	5.9	6.8	1.18	17.2	2.1	0.34	0.17	0.25	8.2
Irrigated arable land	6.3	7.9	1.23	12.8	1.6	0.31	0.13	0.17	7.2
Orchard land	5.6	7.0	1.16	19.7	2.2	0.42	0.19	0.23	8.6
Mean	6.0	7.2	1.19	16.6	1.97	0.38	0.16	0.19	8.03

Appendix 1: Ratings for soil fertility classes

Parameter	Low	Medium	High
Oc gkg ⁻¹	<10	10-15	>15
Total N gkg ⁻¹	<1.5	1.5-2.0	>.2.0
Available P mgkg ⁻¹	<10	10-20	>20
Ca ²⁺ cmol kg ⁻¹	<2	2-5	>5
Mg ²⁺ cmol kg ⁻¹	<0.3	0.3-1.0	>1.0
K ⁺ cmol kg ⁻¹	<0.15	0.15-0.30	>0.30
Na ⁺ cmol kg ⁻¹	<0.2	0.2-0.3	>0.3
CEC cmol kg ⁻¹	<6.0	6.0-12	>12

Source: Esu (1991) [27]

Adapted from Ibrahim *et al.*, (2010) [40]

Appendix 2: Soil Reaction (pH) Ratings

Soil reaction	(pH)
Extremely acid	4.5
Very strongly acid	4.6 - 5.0
Strongly acid	5.1 - 5.5
Moderately acid	5.6 - 6.0
Slightly acid	6.1 - 6.5
Neutral	6.6 - 7.3
Slightly alkaline	7.4 - 7.8
Moderately alkaline	7.9 - 8.4
Strongly alkaline	8.5 - 9.0
Very strongly alkaline	> 9.0

Source: Black (1965) [24]

Adapted from Mamzing *et al.*, (2014) [45]

CONCLUSION

In all landuse systems, organic carbon and total N, available P, exchangeable bases and CEC decreased with soil depth. The highest mean values of organic matter (8.2(gkg⁻¹) and total nitrogen (1.34gkg⁻¹) were recorded under the irrigated arable land while Available phosphorus (26.2mgkg⁻¹), Calcium (4.6 cmolkg⁻¹), Magnesium (0.50 cmolkg⁻¹), Potassium (0.26 cmolkg⁻¹), Sodium (0.21 cmolkg⁻¹) and cation exchange capacity (12.0 cmolkg⁻¹) were recorded under orchard

land at the surface soil layer. From the results of the study it was possible to conclude that rain fed arable land and irrigated arable land had detrimental effects on the soil physico-chemical properties. Therefore, reducing intensity of cultivation, adopting integrated soil fertility management and application of organic fertilizers could maintain the existing soil condition and replenish degraded soil properties.

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