Turkish Journal of Agriculture - Food Science and Technology, 10(8): 1542-1551, 2022
DOI: https://doi.org/10.24925/turjaf.v10i8.1542-1551.5084

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Multivariate Analysis of Land Use Impact on Soil Water Content and Some Physicochemical Properties of an Alfisol

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ARTICLE INFO

Research Article

Received : 31/01/2022
Accepted : 03/08/2022

Keywords:
Land use
Soil hydro-physical,
Chemical properties
Multivariate analysis
Correlation

ABSTRACT

Land use could impact soil properties and processes in varying degrees. Therefore, the impact of different land use systems on soil water status and its relationship with some physiochemical properties was studied at the Teaching and Research Farm, Ekiti State University, Ado Ekiti, Nigeria. The land use types included native forest (NF); Paddock (P); Oil palm plantation (OP); Teak (TK); new yam plot (NY) and yam plot under fallow (YF). Structure and disturbed surface soils (0 - 15 cm) samples were taken at three (3) locations in each land use type. Soil water content (SWC) significantly varied among the different land use types, with oil palm plantation storing the highest amount of water. The results also showed significant differences in soil bulk density, organic carbon, porosity, texture and hydraulic conductivity among the land use types. SWC associated positively and significantly with organic matter, silt content and silt + clay. The association between SWC and pH and silt/clay were positive but weak while particle density, bulk density and sand content showed negative and significant association. The principal component regression (PCR) showed a highly significant, positive relationship between SWC and the principal components of other physicochemical properties. Cluster analysis showed that SWC is highly related and linked to OM, Bd, Pd, Pt and silt/clay. The results implied that conversion to paddock and continuous cultivation led to depletion in soil water, physical and chemical properties, whereas cultivation of tree crops conserved these soil properties better. Therefore, establishment of tree crop and conservative soil management practices are suggested to prevent agricultural lands from degradation in areas with soils under similar conditions.

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Introduction

Land use is basically the utilization of the physical land and its resources by humans for various purpose. Land can be used for residential commercial, business, industrial, agricultural, and other relatively natural use. Land use involves the management and transformation of natural environment or bare land into built environment such as settlements and semi natural habitats such as arable fields, pastures and managed woods. Land use, which is human driven activities on land is one of the major characteristics of land (Lambin et al., 2003). Land use type could determine the total production from the land and the status of the producer, the environmental condition (soil, climate, rainfall, altitude). Agricultural activities such as continuous cultivation, deforestation, grazing cause deterioration of soil properties (Lal, 2016). The knowledge of soil properties is very useful in determining soil characteristics, quality, and productivity. These soil properties also exhibit spatial correlation among the variables that result from different management practices, for example, land use option, tillage operations, grazing, fertilizer applications, and so on (Oyedele et al., 1992; Nurudeen et al., 1994; Yimer et al., 2007; Alemayehu and Sheleme, 2013; Awe, 2017; Awe et al., 2018a, 2018b; Awe et al., 2020). The conversion of natural forest to cultivated land is a leading cause of soil degradation. It leads to reduction in soil fertility, variation in soil moisture and aeration, affects the activities of soil fauna and leads to increase in soil erosion (Bossuyt et al., 1999). Ashagrie et al. (2007) opined that cultivation of soil for agricultural production leads to the rapid decomposition of soil organic carbon (SOC). This may in turn affect many soil functions that are either directly or indirectly related to SOC. Fageria (2012) reported that reduction of SOC below critical level resulted in the destruction of soil structure, reduction in water holding capacity, decrease in soil aggregation and aeration, and increase in soil bulk density. A positive relationship was established between grain yield and SOC (Logah et al., 2011), indicating that the yield of grain can be adversely affected by the reduction in SOC. More than 75% of SOC has been depleted in soils of tropical ecosystems, and agricultural practice has been reported to be the leading cause (Lal, 2004). Agricultural activities, especially deforestation and continuous cultivation, have been reported to be the second-largest human-induced carbon emission source (Lal, 2016). This has a negative impact on climate change. Soil requires proper management to sustain agricultural production, maintain environmental health (Ashenafi et al., 2010) and for overall economic growth (Muche et al., 2015). Conversion of natural forest to agricultural use leads to land degradation which has resulted in hunger, poverty, and conflicts (FAO, 2020a, b). Understanding the changes in soil properties as a result of land use (especially for agriculture) is of great importance (Tellen and Yerima, 2018). The dominant land use type dominant in the rainforest agro ecological zone are the tree crop plantations and arable farms. This study focused on paddock, yam plot under fallow, new yam plot, teak, oil palm while natural forest was used as a reference. The Southwestern region of Nigeria accounts for about 60% of the total cocoa production in the country, and cacao plantation covers more than 650,000 ha of land (Sanusi and Oluyole, 2005). According to Olagunju (2008), oil palm plantation covers an estimated area of 1.65 million hectares in the southern part of Nigeria, out of which the southwestern region accounts for more than half. As far back as 1998, Nigeria has been identified as one of the leading countries in teak production in Tropical Africa (Pandey, 1998), and teak plantation in Nigeria was predicted to increase geometrically (Ball et al., 1999). The need to investigate changes in soil properties under long-term agricultural land-use practices informed this study. This study broadens existing knowledge on soil properties under long-term land-use practices in Southwestern Nigeria. The application of multivariate analysis in separate, of soil properties is quite reported in the literature (e.g., Juhos et al., 2015; Nawar et al., 2015; Ranjar et al., 2015; Boluwade and Madramooto, 2016; Oumenskou et al., 2018; de Souza et al., 2018). For example, the use of principal component analysis (PCA) approach in the study of the simulation of sediment yield and soil properties was reported in Boluwade and Madramooto (2016). In another study involving the use of cluster analysis, Ranjar et al. (2015) reported that wheat yield was influenced by different soil physio-chemical properties. Therefore, our study objective was to apply the descriptive and multivariate analyses (principal component and hierarchical cluster) to evaluate the impact of different land use types on soil water status and its relationship with some soil physio-chemical properties of an Alfisol in a tropical environment.

Materials and Methods

Study Area

The study was carried out on different land use types within the Ekiti State University Teaching and Research Farm, Ado Ekiti, southwest Nigeria. The sampling area lies on longitude 5° 14' E and latitude 7°42' N at an altitude of 405 m above mean sea level. The site is located in a humid, tropical climate with distinct wet and dry seasons, mean annual rainfall around 1,367 mm. The temperature is around 12 - 16°C during morning periods of dry, harmattan season and could reach about 36°C in the afternoon. During the hot, wet season, maximum temperature could reach 40°C. The soil of the study site is in the broad group Alfisol, classified as Typic Kandiudalf (Soil Survey Staff, 2014) with top sandy-loam to clay texture (Fasina et al., 2005). Six land use types were investigated in this study. They were paddock (PD), Teak (TK), Oil palm, new yam Plot (NY), Yam Plot under Fallow (YF), and Natural Forest (NF) as shown in Figure 1.

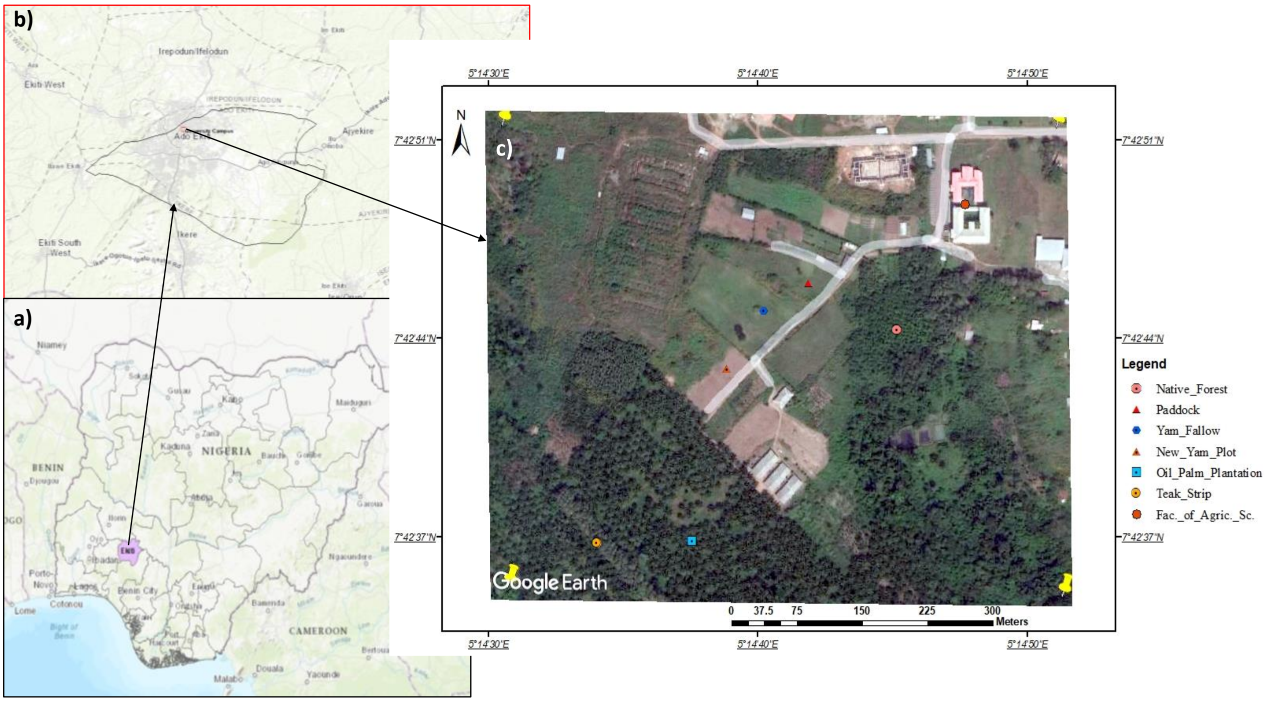

Figure 1. Maps showing the a) location of Nigeria and Ekiti State, b) location of Ekiti State University, Ado Ekiti, and c) distribution of the land use types within the Teaching and Research Farm Unit.

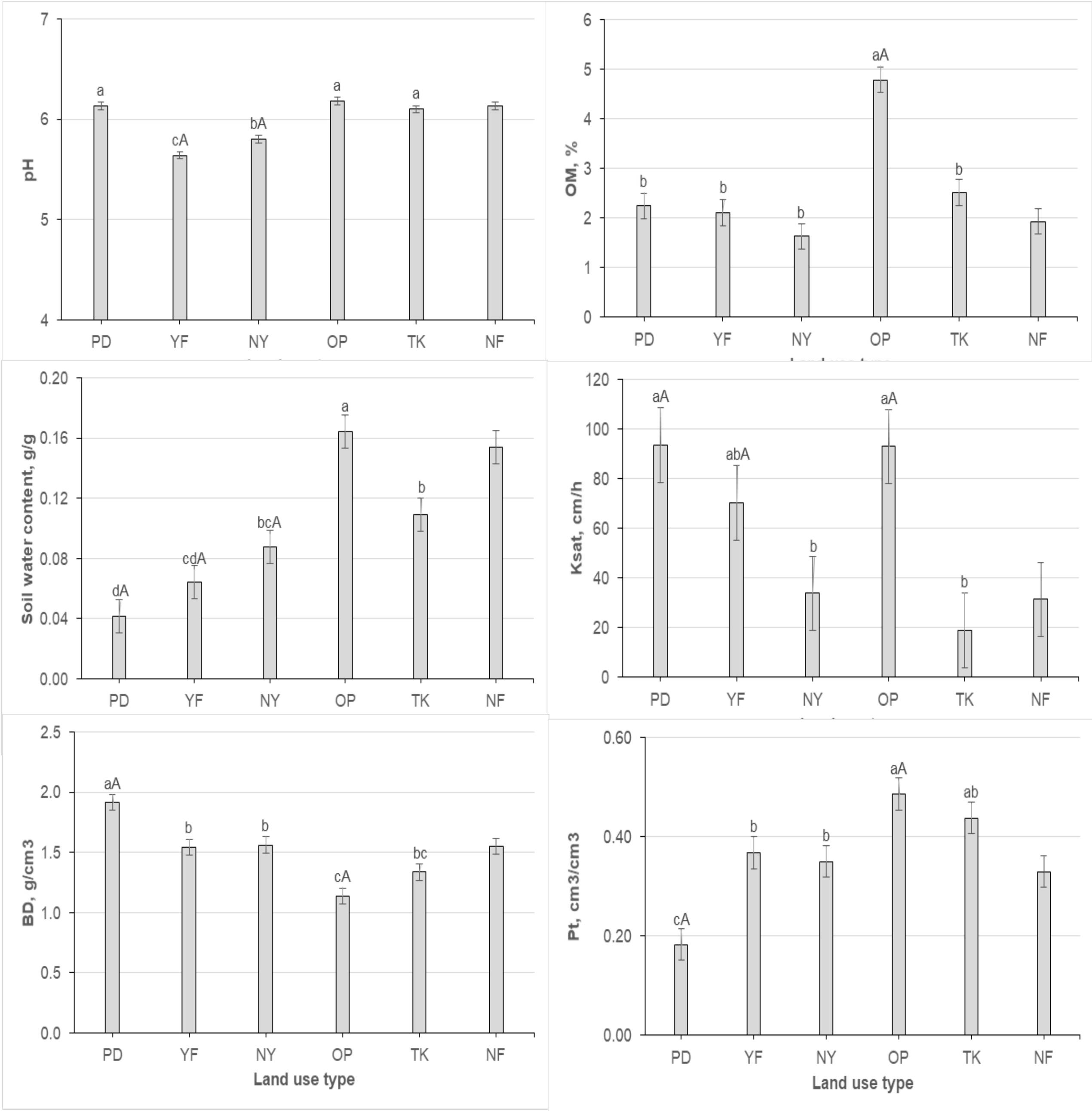

Figure 2. Soil pH, organic matter (OM), water content, saturated hydraulic conductivity (Ksat), bulk density (BD) and total porosity (Pt) of the different land use.

PD: paddock; YF: yam plot on fallow; NY: new yam plot; OP: oil palm plantation; TK: teak plantation; NF: native forest, Bars with different lowercase letters differed significantly at 5% level of probability by Duncan Multiple Range Test. Bars with uppercase letter A differed significantly from that of native forest (NF) at 5% level of probability by Dunnet's Test

The paddock is about 3 ha and was established over four years ago with more 100 cows grazing the land. The main grass in the paddock is *Panicum maximum*. The oil palm plantation is 10 ha and was established about 20 years while harvesting is done every year about 4 – 5 years after planting. Cultural management in this oil palm plantation is mainly two to three slashing in a year. Off cuts during harvesting of palm fruits were left to decay. The teak plantation is about 10 years old. Although slashing is done to control weeds, the teak plantation has been subjected to burning during the dry season. The yam fallow is the area where yam was cultivated and harvested the previous season. The place is left to fallow as it is one of the major cultural practices for yam cultivation in the region. The fallow period ranges between 3 to 5 years depending on availability of land. As at the time of sampling, the fallow period is two years. The new yam plot is just cultivated after fallowing for about three years. The land was ploughed, harrowed and ridged in October 2020 while planting of yam sets was done in November 2020. Soil sampling was done in May 2021 (about 6 months after planting). The native forest is about 1 ha and has been in existence and undisturbed for several years. The land consists of overgrown vegetation, some trees and shrubs. The native forest has been the shield to the wetland where the Teaching and Research fish ponds are located.

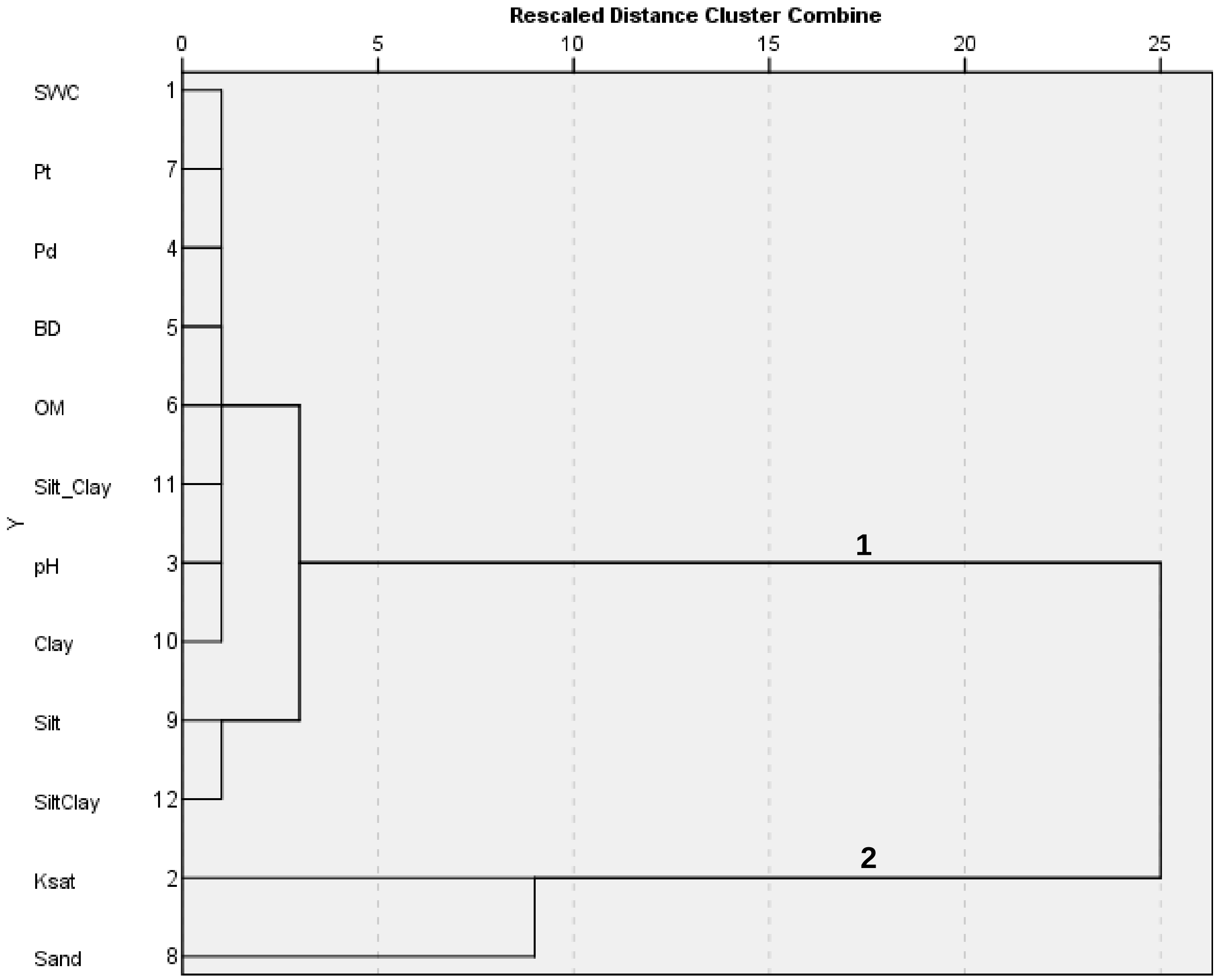

Figure 3. Dendrogram of the hierarchical cluster analysis of the soil variables evaluate

Soil Sampling and Preparation

Three (3) disturbed soil samples were taken randomly from each land use at the soil surface (0 – 15 cm). Structured soil samples were also taken at each sampling points using core samplers 57 mm diameter and 40 mm high. Each sampling point was geo-referenced with the aid of GPS (Garmin: ETREX 16055459, Taiwan). The samples were kept in well-labelled polythene bags, sealed and transported to the laboratory for further analysis.

Laboratory Analysis

Soil samples were analyzed for chemical and physical properties using standard procedures. The samples were air-dried. Soil samples of less than 2 mm fraction were used for laboratory analysis. Samples for soil organic matter was further ground to pass through 0.5 mm mesh.

Soil textural analysis was done using pipette method (Suzuki et al., 2015). Soil particle density was determined using the volumetric flask method as described by Danielson and Sutherland (1986). Soil water content (SWC) was calculated using the gravimetric method where soil samples were placed into ceramic crucibles weighed to get the fresh weight oven-dried at 105℃ to constant weight for about 24 h and the dry weight recorded. These values were then used to calculate the moisture contents of the soils using the formula;

$$SWC = \frac{100\times(fw\text{-}dw)}{dw}$$

Where SWC is soil water content (g/g); fw: fresh weight (g) of soil sample; dw: dry weight (g) of soil sample.

Soil bulk density was evaluated following the methodology described in Blake and Hartge (1986). Bulk density (BD) of soils was estimated from undisturbed soil samples collected from each land use type using a core sampler and weighed at field moisture content and then dried in an oven at 105 ℃ for 24 h. Bulk density values were later calculated using the following equation:

$$BD=\frac{DM}{V}$$

Where BD is the bulk density (g/cm^3), DM is the dry mass (g) of the soil sample, and V is the volume of core sampler (cm^3).

Soil total porosity was obtained from the relation between soil bulk density and particle density (Danielson and Sutherland, 1986). Soil hydraulic conductivity (Ksat) was determined using the constant-head permeameter following the methodology described in EMBRAPA (2011). The constant water flow that flowed through the soil sample was measured and applied into the equation for direct calculation of Ksat.

Soil pH was determined in a 1:2 soil water suspension using the digital electrode pH meter according to

Thomas1(996). Organic matter was quantified using wet oxidation method proposed by Walkley and Black (1934). The percent carbon content (OC) of the soil samples was calculated using the following formula proposed by Van Reewijk (2002):

$$\text{OC, \%} = \frac{(\text{ml Fe}^{2+}\text{ blank}) - (\text{ml Fe}^{2+}\text{ soil}) \times \text{Normality of Fe}^{2+}}{\text{Weight of soil in g}}$$

Soil organic matter was obtained by multiplying the OC values by the Van Bemmelen factor, 1.724 (Van Bemmelen, 1890), following the assumption that soil organic matter contains 58% organic carbon.

Data Analysis

Data were subjected the descriptive analysis to obtain the minimum, maximum, mean, standard deviation, coefficient of variation, kurtosis and skewness of the soil physiochemical properties. One-way analysis of variance (ANOVA) was performed to compare differences in the soil physiochemical properties among the land use types using randomized complete block design (RCBD) in three replications. Where F-value was significant, separation of the means of the soil properties was performed using the Duncan Multiple Range test at 5% level of probability. Dunnet's test was used to compare the NF and other land use types.

Multivariate analysis (principal component analysis (PCA), Pearson correlation test, multiple linear regression and hierarchical cluster analysis) was carried out. PCA was done to obtain the soil properties that will be of prime important concerning the capability of the different land use in storing water. The PCA involves the extraction of principal component factors (PC) comprising soil properties having eigenvalues greater than one (1). The extraction used was varimax rotation, whereby the redistribution of the variance of each factor maximizes the relationship between orthogonal soil properties. From the PCs, soil properties were selected based on high loading rates. Before the PCA, Pearson correlation analysis was performed to establish significant relationship between SWC and the soil properties. In order to determine soil properties highly influencing SWC, principal component regression (PCR) was conducted between SWC and PC scores generated during the PCA. The SWC was then transformed using the coefficients of the PCR, thereafter multiple linear regression was performed between the transformed SWC and other soil properties evaluated. Hierarchical cluster analysis (HCA) was carried out on SWC and other soil properties. All statistical analyses were done using the statistical package, statistical package for social science (SPSS, IBM version 20.0) (SPSS, 2011).

Results and Discussion

Descriptive Statistics of Soil Properties

The descriptive statistics of evaluated soil physio-chemical of the study area are presented in Table 1. These statistics are mean with minimum and maximum values, coefficient of variation (CV), skewness and kurtosis for the examined soil variables of different land use. The sand content varied from 57% to 82% while clay content ranged from 3% to 9% and silt content ranged from 13% to 37% which indicate sandy loam texture. The soil bulk density averaged 1.5 g/cm^3 and the maximum value of bulk density was from paddock (1.99 g/cm^3) which is above the critical value of 1.80 g/cm^3 at which hindrance to root penetration and seed emergence is likely to occur (Reinert et al., 2008) indicates that the soil in this land use is highly compacted resulting from overgrazing by animals over time. This might also lead to exposure of the land to agents of erosion. Soil particle density (Pd) determination reveals the kinds of materials the soil is composed, which could be as low as 0.9 g/cm^3 or as high as 3.0 g/cm^3. Where the Pd is high (≥3.0 g/cm^3), it means the soil's parent material is made up of densed minerals, giving insight about the geological history of the soil. Conversely, if the Pd is low (< 0.9 g/cm^3), it indicates a high organic matter, meaning the soil's tendency to release carbon to the atmosphere through decomposition over time (GLOBE, 2014). In this study, the Pd was within 0.9 g/cm^3 – 3.0 g/cm^3, indicating it was neither too low or too high. The Pd followed the trend of sand content. According to Brady and Weil (2002), in same soil type, with other things kept constant, soils with higher sand content have higher particle density and vice versa. Soil porosity informs about how much water and air are stored in the soil profile and influences the rate at which these two properties including heat move through the soil (GLOBE, 2014). Pt ranged from very low (0.16 cm^3/cm^3) to high (0.53 cm^3/cm^3), with mean= 0.36 cm^3/cm^3. Soil saturated hydraulic conductivity (Ksat) is the rate at which water flows in the soil. For humid climes, Ksat values between 20 cm/h and 180 cm/h is considered optimum for rapid infiltration, minimal surface runoff and erosion, redistribution of plant available water and drainage of excessive water (Reynolds et al., 2003). With respect to internal drainage as it affects root-zone aeration, trafficability and soil erosion (Reynolds et al., 2014), a very rapid internal drainage has been associated with Ksat above the upper critical limit of 360 cm/h while a slow internal drainage has Ksat below the lower critical limit of 3.6 cm/h (Topp et al., 1997; McQueen and Shepard, 2002). The Ksat ranged from low (16.1 cm/h), although above the lower critical limit, to high (144.2 cm/h) but less than the upper critical limit, with mean = 57.6 cm/h. Soil water content (SWC) is required for the metabolic activities of the plants and it is the medium through which plants obtain nutrients. The SWC was still low during the sampling campaign as only two rains have just been received, also sampling occurred two days after the second rainfall event. The SWC ranged between 0.016 g/g and 0.180 g/g (mean = 0.104 g/g). The pH of the soils in the different land uses ranged from moderately acidic to slightly acidic (5.54 - 6.23) with an average of 6.0, indicating a slightly acidic type of soils. Soil organic matter affects nearly all vital properties and processes of favourable soil structure, aeration, water retention, and nutrient availability for better rooting patterns and subsequently improved crop productivity (Pulleman et al., 2000; Bennett et al., 2010) as well as promoting soil aggregation and resistance to soil erosion (Liu et al., 2020). According to Tan (1996), SOM < 1.0% is considered very low, 1.0 - 2.0% low, 2.1 - 4.2% medium, 4.3 - 6.0% high and > 6.0% very high. The organic matter content of the soils ranged from low (1.59 %) to high (5.9 %).

Table 1. Descriptive statistics of the soil variables evaluated across the different land uses and undisturbed forest plantation.

Variables	Min.	Max.	Mean	Std. Error	Std. Dev.	CV, %	Skewness	Kurtosis
SWC	0.016	0.180	0.104	0.01	0.05	47.0	0.341	-0.399
Ksat	16.1	144.2	56.7	8.94	37.94	66.9	0.969	-0.009
pH	5.54	6.23	6.00	0.05	0.22	3.6	-0.932	-0.559
Pd	2.19	2.54	2.35	0.02	0.10	4.3	-0.127	-0.725
BD	1.04	1.99	1.51	0.06	0.26	17.4	0.135	-0.574
OM	1.59	5.90	2.53	0.27	1.14	44.9	2.027	3.937
Pt	0.16	0.53	0.36	0.03	0.11	30.4	-0.446	-0.694
Sand	56.6	81.5	72.4	1.51	6.40	8.8	-0.622	0.553
Silt	13.1	37.0	21.4	1.61	6.83	32.0	0.583	-0.054
Clay	2.4	8.3	6.3	0.38	1.62	25.8	-0.548	0.212
Silt/Clay	1.60	12.76	3.89	0.61	2.58	66.3	2.606	8.396
Silt+Clay	18.51	43.39	27.63	1.51	6.40	23.2	0.622	0.553

SWC: soil water content, g/g; Ksat: hydraulic conductivity, cm/h; Pd: particle density g/cm^3; BD: bulk density, g/cm^3; OM: organic matter, %; Pt: total porosity, cm^3/cm^3.

Table 2. Soil particle density (Pd), texture, and silt-clay relation of the different land use.

Land use	Pd	Sand	Silt	Clay	Silt/Clay	Silt+Clay	Texture
	g/cm^3		%		-	%	
PD	2.34	79.5	14.3	6.2	2.4	20.5	LS
YF	2.44	74.1	18.2	7.7	2.5	25.9	SL
NY	2.41	74.3	18.6	7.1	2.6	25.7	SL
OP	2.21	71.5	22.9	5.6	4.1	28.5	SL
TK	2.38	66.7	28.4	4.9	7.5	33.3	SL
NF	2.32	68.1	25.8	6.1	4.2	31.9	SL

PD: paddock; YF: yam plot on fallow; NY: new yam plot; OP: oil palm plantation; TK: teak plantation; NF: native forest; LS: loamy sand; SL: sandy loam

Table 3. Pearson Correlation between log transformed soil water content (SWC) and other soil

	SWC	Ksat	pH	Pd	BD	OM	Pt	Sand	Silt	Clay	Silt/Clay	Silt+Clay
SWC	1	-0.103	0.460	-0.562*	-0.707**	0.549*	0.597**	-0.548*	0.596**	-0.345	0.322	0.548*
Ksat		1	0.160	-0.217	0.082	0.505*	-0.122	0.329	-0.270	-0.164	-0.208	-0.329
pH			1	-0.584*	-0.170	0.453	0.039	-0.218	0.322	-0.495*	0.334	0.218
Pd				1	0.281	-0.616**	-0.056	0.207	-0.274	0.336	-0.224	-0.207
BD					1	-0.621**	-0.973**	0.499*	-0.490*	0.091	-0.278	-0.499*
OM						1	0.508*	-0.073	0.140	-0.300	0.142	0.073
Pt							1	-0.460	0.435	-0.015	0.230	0.460
Sand								1	-0.972**	0.142	-0.563*	-1.000**
Silt									1	-0.371	0.713**	0.972**
Clay										1	-0.777**	-0.142
Silt/Clay											1	0.563*
Silt+Clay												1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed)

Table 4. Results of principal component analysis.

Parameters	PC1	PC2	PC3	Comm
Ksat	-0.581	0.472	0.138	0.580
pH	0.141	0.779	0.057	0.630
Pd	-0.024	-0.730	-0.254	0.599
BD	-0.309	-0.104	-0.916	0.946
OM	-0.210	0.627	0.704	0.933
Pt	0.303	-0.061	0.897	0.900
Sand	-0.901	-0.070	-0.304	0.908
Silt	0.913	0.252	0.242	0.956
Clay	-0.287	-0.784	0.182	0.731
Silt/Clay	0.723	0.500	-0.066	0.777
Silt+Clay	0.901	0.070	0.304	0.908
Eigenvalue	4.691	2.386	1.791	
Var., %	42.648	21.693	16.278	
Cum. Var.	42.648	64.340	80.618	

Ksat: hydraulic conductivity; Pd: particle density; BD: bulk density; OM: organic matter; Pt: porosity;Var: variance; Cum. Var.: cumulative variance; Comm.: communality

Table 5. Regression of soil water content (SWC) against the principal components

Variable	Coefficients	Std. Error	t-value	P < 0.05
Constant	0.104	0.008	13.7	0.000
PC1	0.019	0.008	2.5	0.027
PC2	0.020	0.008	2.5	0.024
PC3	0.028	0.008	3.6	0.003

Table 6. Coefficients of multiple regression equation between the dependent variable, soil water content of the land uses, and independent variables after their transformation.

Variables	Coefficients	Std. Error	Pr > t
Constant	0.688	0.861	0.448
Ksat	-0.00005	0.000	0.130
pH	-0.005	0.041	0.902
Pd	-0.057	0.522	0.915
BD	-0.146	0.856	0.868
OM	0.008	0.014	0.591
Pt	-0.169	1.972	0.934
Clay	-0.029	0.010	0.017
Silt/Clay	-0.020	0.007	0.019
Silt+Clay	0.005	0.002	0.036
R^2	-	0.869	-
Overall p-value	-	0.010	-

Ksat: hydraulic conductivity; Pd: particle density; BD: bulk density; OM: organic matter; Pt: porosity; R^2: coefficient of determination

Sand, clay, pH, Pd and Pt exhibited negative skewness, indicating symmetric distribution to the left, other properties showed a positive skewness, indicating that they are symmetrically distributed to the right.

The variability of soil properties as indicated by CV values showed the soil properties differed widely for the different land use systems (Table1). For instance, the CV for pH was found to be 3.6% (the lowest), compared to that of Ksat which is about 66.9% (the highest). Sand, Pd and pH are least variable properties (CV < 12%), SWC, BD, OM, Pt, Silt, Clay are moderately variable properties (12 < CV < 60%) while Ksat and Sand/Silt are extremely highly variable properties (CV > 60%). Other studies have reported greater values for Ksat (Sanjit and Shukla, 2012). The observed differences in variability of chemical properties (Table1) could be due to variations imposed by cultivation and other management practices. Lower variation of soil pH could be result of underlying geology. Lower variation of soil pH compared to other soil chemical properties were also reported by Yost et al. (1982), Zhou et al. (1996) and Tsegaye and Hill (1998). Physical and chemical properties of the soil such as bulk density, porosity, and organic matter are usually considered as indicators of soil quality.

Differences in Soil Properties Among the Land Use Types

There were no significant differences in soil particle density, texture and silt/clay among the different land use types (Table 2). The clay content is very low, less than 10% in all cases. The predominance of sandy loam soil indicates the homogeneity of soil forming processes and similarity of parent materials of the study area which is coarse-grained granite and gneiss (Okusami and Oyediran, 1985) according to the geology of the study area. The textural composition of soil is highly influenced by parent material (Oguike and Mbagwu, 2009). It is an inherent property of the soil that is not influenced over a short period of time (Kiflu and Beyene, 2013) however, over a long period of time, pedogenesis processes such as erosion, deposition, eluviation, and weathering can change the texture of the soil.

The bulk density (BD) was significantly different (P<0.05) among the different land use types with the highest and lowest BD from PD (1.95 g/cm^3) and OP (1.14 g/cm^3), respectively (Figure 2). The opposite results were obtained from Pt with OP and PD having the significantly highest and lowest Pt. Only PD and OP land use types had BD and Pt significantly different from NF. The highest BD and lowest Pt from PD land use implies soil compaction resulting from continuous grazing. The BD of paddock is above threshold value of 1.80 g/cm^3 which indicate impaired soil function and indicator of low porosity. It may cause restrictions to root growth, poor movement of water and air through the soil (USDA-NRCS, 1996). Compaction can result in shallow plant rooting and poor plant growth influencing crop yield and reducing vegetative cover available to protect soil from erosion (Arshad et al., 1996). It also reduces water infiltration into the soil, increased runoff and erosion from sloping land and waterlogged soils in flatter areas (USDA- NRCS, 1996). Soil organic matter is an accumulation of dead plant materials and partially decayed plant and animal residues and the stability of soil aggregates largely depends on the amount of organic matter (Tisdall and Oades, 1982). The organic matter content of the soils differed significantly (P < 0.05) among the land use types, with OP land use having the highest average value (4.78 g/kg) of OM whereas the OM for other land use types is almost at par. A comparison with the NF showed that only OP had significantly higher OM than the NF. The high organic matter in OP might be as a result of residue retention on the soil surface as well as decay and decomposition of off cuts during harvesting which contribute to organic matter content. Salehi et al. (2013) reported that the effects of trees on the soil organic carbon content across the land use types was within low to medium class of organic matter content in the soil as classified by Adepetu (1990). It however appeared that the higher the amount of litter produced under a land use type, the higher the soil organic matter content. The conversion of forest ecosystem to other forms of land cover may decrease the stock of organic carbon due to changes in soil moisture, temperature regimes and succession of plant species with differences in quantity and quality of biomass returned to the soil (Offiong et al., 2009). Evrendilek et al. (2004) showed that deforestation and subsequent cultivation decreased organic matter by 48.8%. Moreover, the conversion of forest into cropland is known to deteriorate soil physical properties and making the land more susceptible to erosion since micro-aggregates are disturbed (Celik, 2005).

The soil water content showed significant differences (P<0.05) among the different land use types. The OP land use had the highest value of soil water content (0.165 g/g). The OP land use has the highest organic matter content and thus the highest SWC. Water holding capacity increases because of the affinity that organic matter has for water. Water holding capacity is controlled primarily by soil texture and organic matter (Bayer et al., 2000). Soils with smaller particles (silt and clay) have a larger surface area than those with larger sand particles and a large surface area allows a soil to hold more water (Hudson, 1994). In other words, a soil with high percentage of silt and clay particles which describes fine soil has a higher water holding capacity.

The high Ksat value in oil palm (OP) land use could be linked to the high organic matter content which would have contributed to the development of more pore space, creating more meso and macropores responsible for water flow. Macro porosity causes the hydraulic conductivity to increase and reflect the drainage level of a given soil (Heard et al., 1988). These findings confirmed the reports of Nwite (2015) and Amanze et al. (2017) who both reported high Ksat for cultivated soils. Also, the low Ksat value could be linked to high bulk density of the soil which affect the micro and macro porosity of the soil including the tensile strength of the soil.

The results showed there were significant differences (P < 0.05) in pH values among the five different land use, with YF having the lowest pH value (Figure 2). Only the NY and YF land use had pH which is significantly different compared to the native forest (NF). Based on the of classification Adepetu et al. (2014), the pH across the land use types ranged from moderately acidic to slightly acidic levels. The result of this study agrees with the findings of Muche et al. (2015) who reported the pH of cultivated land tend to be more acidic than other land use types. They mentioned factors such as poorly managed cultivation, inappropriate use of fertilizers and accelerated erosions. Soils under the NF, OP and TK were acidic owing to more uptakes of basic cations by the trees and poor return rate to the soil.

The Correlation Between Soil Water Content and Other Soil Properties

The correlations between SWC and other physical properties of the soil are presented in Table 3. The SWC correlated positively and significantly with organic matter (P<0.05), silt content (P<0.01) and silt + clay (P<0.05). The correlation with pH and silt/clay was positive but weak. Particle density (P<0.05), bulk density (P<0.01) and sand content (P<0.05) showed negative and significant correlation with SWC. Other soil physical properties did not show significant relationship.

The PCA (Principal Component Analysis) generated for the first three dimensions is shown in Table 4. The communality ranged between 0.580 (Ksat) and 0.956 (silt). Three principal components (PCs) with eigenvalues greater than 1 resulted from the varimax rotation. PC1 explained 42.65% of the total variance, PC2 explained 21.69% while PC3 explained total variance of 16.28%, resulting in cumulative variance explained as 80.6%. The PC1 group represents the soil texture with sand, silt, silt+clay and silt/clay having high loading rates. PC2 represents the soil reaction group where pH, clay and Pd had high loading rates while PC3 represents the soil aggregation and permeation with BD, OM and Pt having high loading rates. It indicates that variables pH, BD, OM and soil texture are the minimum data set (MDS) that can be used for monitoring or evaluating the quality status of the land use types. Both Pd and Pt were dropped because the BD and Pd were used to obtain Pt.

The regression of soil water content (SWC) against the principal component scores is presented in Table 5. Principal component regression (PCR) analysis at 5% significant level was conducted to establish whether there would be significant positive or negative relationship with SWC. The PCR showed a highly significant, positive relationship (P<0.05) between SWC and the principal components.

The results of the multiple linear regression between the transformed SWC and independent variables is presented in Table 6. The regression showed independent variables clay, silt/clay and silt + clay significantly (P < 0.05) influenced the estimation of transformed SWC, nevertheless regressing SWC from the measured variables was highly significant (P<0.05). The overall coefficient of determination value (R^2) was high as about 87% of the variability in SWC was explained by the independent variables.

Cluster analysis is a multivariate analysis used to find true groups of data or stations, grouping samples on the basis of their similarities (Oumenskou et al., 2018). In this study, all parameters were grouped into two (2) statistically significant clusters. It is displayed in a tree-like structure called dendrogram. The dendrogram of the hierarchical cluster analysis of soil variables is presented in Figure 3. Cluster 1 had soil water content (SWC) which is highly related and could be linked to OM, Bd, Pd, Pt and silt/clay. Cluster 2 showed SWC is linked with sand and Ksat. All the clusters are formed on the basis of existing similarities.

Conclusions

This study evaluated differences in soil water content, physiochemical properties of soils and their association from different land uses. Soil water content and physicochemical properties significantly varied among the land use systems.

There were significant negative and positive association between soil water content and the physicochemical properties evaluated.

It was apparent that shift in land use systems from natural forest to other land use systems had detrimental effect on soil physical and chemical properties.

The findings showed that conversion to paddock and continuous cultivation significantly degraded the soil physical properties and the fertility of the soil however the physical and chemical properties of soils under teak and oil palm compared favorably with long term native forest thus instead of leaving the land to native fallow, planting of the studied economic crops is recommended as it has positive impact on the soil quality. Also, soil conservation measures such as residue retention, organic amendment, cover cropping and conservation tillage should be adopted to improve the soil properties.

Conflict of Interest

The authors hereby declare no conflict of interest

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