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Effects of different agricultural land use types on physical properties under rainforest agroecology

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The study was conducted at the Teaching and Research Farm, Obafemi Awolowo University Ile-Ife which approximately lies on latitude 7° 28'N and longitude 4° 33' E with an altitude of about 244 m above the sea level. Different agricultural land uses examined were: Secondary forest, planted fallow with legumes, Bush fallow (*Cromolaena odoratum*), Continuous cassava/cowpea plot (*Manihot esculenta-Vigna unguiculata* (L) Walp), Continuous maize/soybean plot (*Zea mays-Glycine max*), and Tree crop (*Theobroma cacao*). Selected soil physical properties assessed were: Aggregate stability, Bulk density, Porosity, and Gravel content. Composite soil samples were taken from each of the investigated plot. The samples were sub-sampled for aggregate stability test while the other samples were air dried, crushed and passed through 2 mm sieve for other laboratory analysis. The mean bulk density of Cassava/Cowpea plot, Maize/Soybean plot, Bush fallow plot and Secondary forest were higher and significantly different from Planted legume and Tree crop. Soil compaction and low level of organic matter were the major causes of soil degradation in continuous arable crop production that practices conventional tillage system going by history. It is suggested that a rotational system involving one year of conventional tillage following every three years of no-tillage under continuous Cassava/cowpea and Maize/soybean plots might cause less soil deterioration, hence higher grain yield.

Key words: Landuse, secondary forest, compaction, porosity, farming system.

INTRODUCTION

Land and water scarcity are major constraints to food production in tropical countries, these are required for meeting the quantitative and qualitative shifts of the world's demand for food in the mid-twenty-first century. Whereas land and water availability are constrained on a global scale, there are important regional and crop-specific differences that needs to be understood, quantified and managed. With increasing population and demand for food, this consumption is projected to double by 2050, alongside increasing land use for agriculture (Pfister et al., 2011). In order to promote sustainable agriculture, there is a need for very precise estimates of water and land use and their environmental impacts. Knowledge of the spatial variability of soil water properties is of great importance for investigations associated with the management of agricultural land (Oyedele and Tijani., 2010). Water is one of the most essential resources necessary for crop production and its stewardship is becoming more critical with continued population growth and shifts in land management.

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Soils are studied to know their properties which will enable us understand their abilities for intended use and therefore ensure proper management strategies for sustainability, (Okusami, 2011). A quality soil should be able to sustain optimal crop production depending on many different processes that reflect biological, physical and chemical interactions. Among the importance physical properties of soil are those which enable the soil to receive, hold and transmit water for crop use. Olmstead and Smith. (1938) noted that the physical properties and their water relations can be considered in connections with three distinct soil zones, namely, the surface through which water may enter and leave the soil body, the root zones and the section lying blow the root zone. The in-organic portion is the residue from the decomposition of the parent rock by the mechanical and chemical process of weathering, while the organic portion consists of dead and living plants and animals and their products. Rice and Alexander (1938) noted that, the coarse and medium materials are comparatively inactive, serving mainly as a supporting frame work of the rest of the soil. A much more complicated function is served by the fine particles or clay fraction, the chief components of which is colloidal material and largely determines how much water can be held in the soil, especially in regions where rainfall is limited.

Soil properties depend on a number of factors. The factors (parent materials, organism, relief, climate, and time) though, operating independently, the combine effect after a period gives rise to distinct soil types. The knowledge of soils with respect to its properties is of utmost importance in determining the agricultural, engineering or other uses to which it may be put. For instance, soil characteristic such as texture shows the proportion of the soil separates. This (percentage of sand silt and clay) in turns shows the water holding capacity (WHC) of the soil. Furthermore, a soil with high clay content will have high cation exchange capacity (CEC) as well as high nutrient holding capacity. Thus, heavy texture soil is able to hold nutrient for plant use.

On the other hand, a sandy soil will have a low nutrient reserve for plant use. Sanchez (1940) noted that many soil physical properties deteriorate with cultivation rendering the soil less permeable and more susceptible to run-off and erosion losses. The ability of soil to retain water and supply it to plant is one of the limiting factors in the tropical agriculture. It is obvious that tropical soil cannot be uniform because of wide varieties in the climate, vegetation, parent material, geomorphology and age. The changes in soil properties that decrease its productivity for crop plant may follow from three processes, namely, cropping, erosion and leaching (Sanchez, 1940). They may adversely affect the physical condition or chemical composition of the soil or both. The overall movement of water in the soil is influenced majorly by the physical nature of the soil. Aduayi and Ekong. (1981) noted that gravely and sandy soils, which have large pores, allow free movement of water without retaining much for plant use. In contrast, soils with high level of clay and organic matter or loamy soil, containing humus or colloids have fine pores which allow increased water to rise through capillarity and high retention of water for plant use. Colloids are not soluble in water but can go into suspension and may be carried away in moving water. Because of this fineness and large surface area, colloids are able to attract and retain more water. Due to the lack of knowledge about the effects of different agricultural land uses on soil physical properties under rainforest agroecology, this necessitated the purpose of this research work.

MATERIALS AND METHODS

Study location

The experiment was conducted at the Teaching and Research Farm, Obafemi Awolowo University Ile-Ife which lies on latitude 7° 33'N and longitude 4° 33' E with an altitude of about 244 m above the sea level. The project site falls within the tropical rainforest belt with mean annual rainfall of about 1250 m and the rainfall pattern is bimodal (Figure 1). A total of six observation sites were selected. The sites were: Cacao (*Theobroma cacao*) plantation; Tree crop; a fallow planted with legume (*Centrocema pubescence*) plot; a bush fallow with predominantly herbaceous weed species (*Chromolaena odorantum*); Cassava-cowpea intercropped plot (*Manihot esculenta-Vigna unguiculata* (L) Walp), a plot of continuous Maize-soybean cropping (*Zea mays-Glycine max*) and Secondary forest. Six soil samples were collected from each experimental site. Samples were collected at different soil depth 0-15, 15-30 and 30-50 cm. Samples for aggregate stability were first taken at the three soil depth of interest in the selected experimental sites before core samples were taken. Three core samples were taken from each depth of the selected experimental sites, bulked, carefully mixed and sub-samples were taken for laboratory analysis

Laboratory analysis

Samples collected on the field were air dried, crushed and passed through a 2 mm sieve. The water aggregates were measured by wet sieving on a sieve in a manner similar to that described by Angers and Mehuys (1993). The bulk density was determined from undisturbed samples dried in an oven at 105°C to determine the water content and oven- dried weight (Burke et al., 1986). The porosity was obtained from the relationship between bulk density and particle density. Gravel content was determined by passing the air dried soil samples through a 2 mm sieve. The two separates, that is, coarse fragment (fraction that is greater than 2 mm size) and the fine earth (those less than 2 mm size fraction) were weighed separately. The percentage gravel content was calculated as: (weight of the gravel fraction) ÷ (weight of the gravel + soil particles) X 100. Soil organic carbon was determined by the chromic acid digestion method of Walkley and Black (1934) as modified by Sparks (1996).

RESULTS AND DISCUSSION

The data in Table 1 shows that the percent gravel content of planted legume plot 57.66 a % was significantly higher than other agricultural land use. It decreased in this

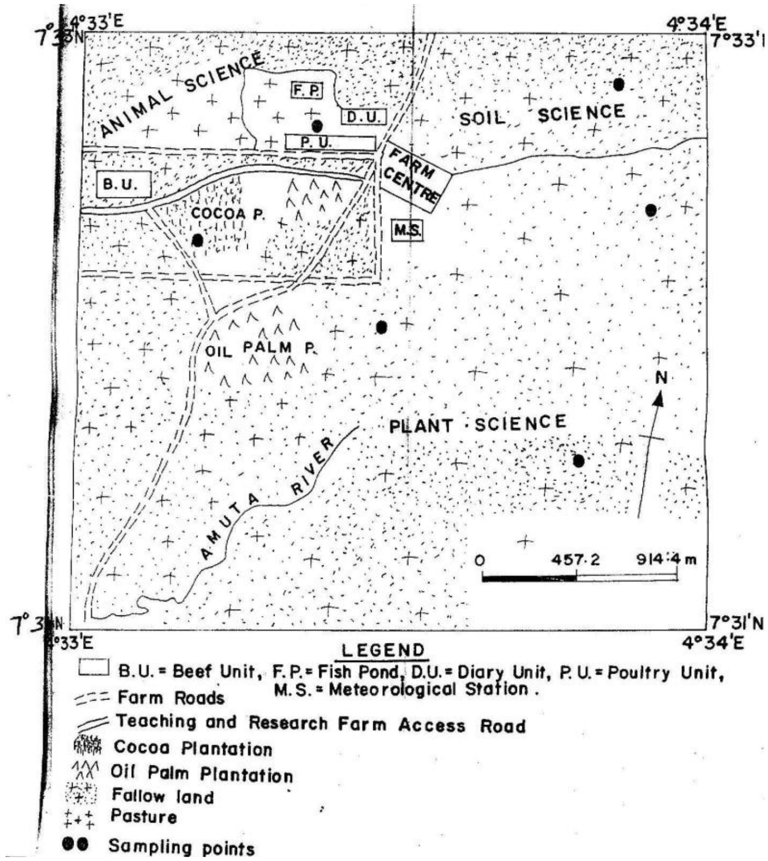

Figure 1. Map of Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, and the soil sampling points.

Table 1. Soil properties under different land use.

Land use	Gravel content (%)	Bulk density (g/cc)	Porosity (%)	Aggregate stability (%)	Organic matter (%)
Continuous cultivation					
Cassava/cowpea	32.47[d]	1.54[a]	58.67[ab]	67.61[c]	0.30[d]
Maize/soybean	28.24[e]	1.50[a]	55.50[ab]	72.63[abc]	1.28[c]
Fallow					
Planted legume	57.66[a]	1.40[b]	59.67[a]	80.29[a]	2.30[a]
Bush fallow	37.32[c]	1.52[a]	58.67[ab]	76.53[ab]	1.91[ab]
Tree crop	53.86[b]	1.32[c]	59.33[ab]	79.71[a]	1.67[bc]
Secondary forest	26.47[e]	1.49[a]	54.99[b]	70.30[bc]	1.22[c]

Mean within the same column and with the same letter are not significantly different according to DMRT at ($p<0.5$ %)

order; planted legume > tree crop > bush fallow > cassava/cowpea plot > maize/soybean plot > secondary forest. This might be probably due to erosion. The fine earth fraction might have been selectively eroded, leaving behind the coarse gravel fraction following continuous cultivation over time. The mean bulk density of Cassava/Cowpea plot 1.54a g/cm^3, Bush fallow plot 1.52a g/cm^3, Maize/Soybean plot 1.50a g/cm^3 and Secondary forest 1.49a g/cm^3 were the highest and significantly different from planted legume 1.40b g/cm^3 and tree crop 1.32c g/cm^3.

All the soils sampled had bulk density value that fell below critical values of 1.63 g/cm^3 which De-Geus (1973) reported, have no problems of high bulk density that can pose hindrance to root penetration. Ahnn (1993), observed that more favourable are the results of the

Table 2. The selected soil properties at various depths.

Soil depth (cm)	Gravel content %	Bulk density g/cm^3	Porosity %	Aggregate stability %	Organic matter %
0-15	35.59^c	1.44^a	55.83^a	76.41^a	1.94^a
15-30	38.98^b	1.48^a	58.67^a	73.90^a	1.39^b
30-50	4344^a	1.46^a	58.42^a	73.23^a	1.00^c

Mean within the same column and with the same letter are not significantly different according to DMRT at (p<0.5 %)

tropical horizon that are lower than 1.6 g/cm^3 since soil with values of 1.6 g/cm^3 to 1.8 g/cm^3 indicate poor aeration and water movement will be too low for optimum root growth. Planted legume plot had the highest percent porosity 59.67a % while the secondary forest was the least 54.99b %. The reason for this is possibly due to higher litter production of the former. Aggregate stability of planted legume plot was 80.29a % and that of the tree crop plot 79.71a % was the highest and differs significantly from other agricultural land use. The reason might be higher organic matter production most especially in the planted legume 2.30a % compared with other land use. This is in line with what Aina (1994) who observed that beneficial effect of manure were attributed to increase in the organic matter level proportion and water stability aggregates.

Table 2 shows the selected soil properties at various soil depths. Percent gravel content of 30-50 cm soil depth was the highest, 43.44 %, while that of 0-15 cm soil depth had the least value. The reason might be due to the presence of stone line as postulated by Symith and Montgomery (1961). Bulk-density, porosity and aggregate stability are statistically the same for all the soil depth considered, Table 2. Organic matter content of 0-15 cm soil depth which was 1.94a % was the highest and almost double the value obtained for 30-50 cm soil depth 1.00c %, the 15-30 cm soil depth had 1.39b % organic matter content. The reason for the highest organic matter in the top soil is partly due to the accumulation of higher litter in the top-soil that is, 0-15 cm soil depth and higher rate of decomposition and mineralization; however, organic matter content is generally low according to Obigbesan, 2000. Table 3 shows the variability in selected soil physical properties at different soil depth due to different agricultural land use. At 0-15 cm soil depth, planted legume plot had a mean gravel content of 61.89a % which is almost four times as high as that of secondary forest 16.58e %. Tree crop plot, Cassava/cowpea, Bush fallow and Maize/soybean had 42.98b %, 35.05c %, 32.61c % and 24.42d % gravel content respectively. The reason is due to susceptibility of different soil surface to soil erosion. The bulk density of Cassava/cowpea, Bush fallow, Maize/ soybean and Secondary forest plots were statically the same, with the values of 1.54a g/cc, 1.52a g/cc, 1.50a g/cc, and 1.49a respectively.

Tree crop plot 1.32c g/cc and planted legume crop with the value 1.40b g/cc were statistically lower in bulk density if compared with other agricultural land use. The reason for higher bulk density particularly in continuous cultivation plots may be due to the frequent use of heavy machinery on the plots. Aina (1994) also noted that mechanical clearing result in greater soil compaction and decline in favourable structural attributes such as the proportion of macro pores and infiltration rate than traditional or manual clearing methods. There was no significant difference in the porosity for all the land use type considered. Aggregate stability of the planted legume plot was the highest, 91.52a %, Maize/soybean, bush fallow, tree crop, and secondary forest with value of 82.73ab %, 77.09ab %, 75.76ab %, and 68.39ab % respectively, were statistically the same; Cassava/ Cowpea plot had the least aggregate value of 62.97b %. The reason for higher aggregate stability value in planted legume might be because of higher litter production and higher rate of decomposition of organic particles which holds the soil particles together. Aduayi et al. (1981) stated that the organic content of the soil promotes soil aggregation and contribute to cation exchange capacity (CEC) of the soil.

Table 3, shows the variability in selected soil physical properties at different soil depth due to different agricultural land uses. Gravel content of tree crop plot, 65.52a % was the highest while that of the secondary was the least with the value 22.25d %.The gravel content of the other land use types fell within these values and the presence of stone line at the sub-soil as postulated by Symith and Montgomery (1961) could explain this trend. Bulk density was slightly higher in continuous cultivation plot, bush fallow, and secondary forest while that of planted legume and tree crop were the least. The reason was due to the use of heavy machinery on the plots that had higher values as suggested by Aina (1994) that the blessings of mechanization are not without attendant dangers. This was also observed by Shittu (2011) that the higher value of soil strength recorded for conventional tillage system when compared with zero tillage system at sub-layer of soil might be due to soil compaction as a result of heavy machinery continuously used in the former.

Porosity was statistically the same for all the land use types. Aggregate stability is slightly higher under the tree crop when compared with the value obtained in other land use; the reason might be due to higher organic matter being produced under tree crop. The high

Table 3. Variability in selected soil physical properties due to different land use.

Land use	Gravel content %			Bulk density g/cm^3			Porosity %			Aggregate stability %			Organic matter %		
	0-15 cm	15-30 cm	30-50 cm	0-15 cm	15-30 cm	30-50 cm	0-15 cm	15-30 cm	30-50 cm	0-15 cm	15-30 cm	30-50 cm	0-15 cm	15-30 cm	30-50 cm
Cassava/cowpea	35.05^{c}	35.05^{c}	27.23^{d}	1.54^{a}	1.54^{a}	1.54^{a}	49.00^{a}	56.00^{a}	61.50^{a}	62.97^{b}	67.42^{b}	75.45^{ab}	0.17^{c}	0.30^{d}	0.5^{c}
Maize/soy^{b}ean	24.42^{d}	25.15^{d}	35.16^{c}	1.50^{a}	1.53^{a}	1.48^{a}	58.00^{a}	59.00^{a}	59.00^{a}	82.73^{ab}	66.41^{b}	68.74^{b}	1.61^{a}	1.37^{bc}	0.8^{bc}
Planted legume	61.89^{a}	52.58^{b}	58.50^{a}	1.40^{b}	1.40^{b}	1.50^{a}	55.00^{a}	62.00^{a}	62.00^{a}	91.52^{a}	74.39^{ab}	74.98^{a}	2.92^{a}	2.49^{a}	1.51^{a}
Bush fallow	32.166	33.26^{c}	46.09^{b}	1.52^{a}	1.52^{a}	1.52^{a}	59.00^{a}	60.00^{a}	57.00^{a}	77.09^{ab}	78.54^{ab}	74.35^{a}	2.25^{ab}	2.01^{ab}	1.48^{a}
Tree crop	42.98^{b}	65.52^{a}	53.07^{a}	1.32^{c}	1.37^{b}	1.26^{b}	60.00^{a}	59.00^{a}	59.00^{a}	75.7^{bab}	88.38^{a}	74.99^{a}	2.82^{a}	1.25^{bc}	0.94^{b}
Secondary forest	16.58^{c}	22.25^{d}	40.5^{abc}	1.49^{a}	1.55^{a}	1.50^{a}	54.00^{a}	56.00^{a}	52.00^{a}	68.39^{ab}	68.66^{b}	73.87^{ab}	1.92^{ab}	0.95^{cd}	0.79^{bc}

Mean within the same column and with the same letter are not significantly different according to DMRT at ($p<0.5$ %)

aggregate stability will give soil particles a good structure and higher stability as suggested by Adebayo(1997), that good soil is one in which the soil particles are bound into water-aggregate. Organic matter of planted legume plot was the highest while that of Cassava/cowpea plot was the least. Summary of the variability in the physical properties at sub soil (30-50) is shown in Table 3. Percent gravel content of planted legume plot (58.50a %) and tree crop plot (53.07a %) are statistically the same and were the highest. Gravel content of soil under bush fallow, Secondary forest, Maize/soyabean, and Cassava/cowpea plots (46.09b %), (40.59bc %), (35.16c %) and (27.23d %) respectively, were lower in value with respect to planted legume and tree crop plot. The bulk density of tree cop had the least bulk density (1.26b %) when compared with other land use probably because of the total avoidance of farm machinery, this is in line with what Blake et al., (1976) observed, that machinery induced compaction in agricultural soils and porosity was statistically the same in all the land use types.

Aggregate stability in planted legume, bush fallow and tree crop were statistically thesame and recorded the highest value, Maize/soybean plot recorded the least value. According to Obigbesan (2000), Organic matter content was generally lower in value ranging from 0.45 % to 1.51 %. The reason might be due to the presence smaller organic matter in sub-soil. Aduayi et al. (1981) reported that the accumulation of organic matter is prominent in the ploughable layer of the soil, which is rich in available plant mineral nutrients.

SUMMARY AND CONCLUSION

The gravel content of the top soil was significantly higher in continuous arable crop; however, organic matter content and aggregate stability were significantly lower when compared with other agricultural land uses. Organic matter content decreased with increase in soil depth for all the agricultural land uses considered.

In a comparative study involving the different agricultural land uses, it was observed that soil deterioration generally occur in continuous arable crop production that usually practices conventional tillage system going by history. It is recommended that a rotational system involving one year of conventional tillage following every three years of no-tillage under continuous Cassava/cowpea plot and Maize/soybean plot might cause less soil deterioration hence higher grain yield. Moreover, other sources of land degradation seem to include low level of organic matter specifically in continuous arable cropping. It is suggested that good farming systems that involve integrated arable and livestock farming can assist small-scale farmers socio-economically. Also, mixed cropping can be of great help to the farmers in order to reduce unnecessary exposure of land to raindrop, impact of erosion on the soil surfaces and for economic reasons.

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