British Journal of Applied Science & Technology
5(2): 110-122, 2015, Article no.BJAST.2015.011
ISSN: 2231-0843

SCIENCEDOMAIN _international_
www.sciencedomain.org

The Distribution of Silt, Clay and Exchangeable Properties of Aggregate Sizes of Four Soils

I. A. Nweke[1*] and P. C. Nnabude[2]

[1]Department of Soil Science, Anambra State University Igbariam Campus, Nigeria.
[2]Department of Soil Science and Land Resources Management Nnamdi Azikiwe University Awka, Anambra State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author IAN designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Author PCN managed the analyses of the study and literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2015/11424
Editor(s):
(1) Rui Xiao, School of Energy and Environment, Southeast University, China.
(2) Singiresu S. Rao, Department of Mechanical and Aerospace Engineering, University of Miami, Coral Gables, USA.
Reviewers:
(1) Anonymous, CSIR-Soil Research Institute, Ghana.
(2) Simone Bergonzoli, Council for Research and Experimentation in Agriculture, Research Unit for Agricultural Engineering, Rome, Italy.
(3) Anonymous, Maseno University, Kenya.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=713&id=5&aid=6456

Original Research Article

Received 15th May 2014
Accepted 10th August 2014
Published 10th October 2014

ABSTRACT

In this study the distribution of silt, clay and exchangeable properties of aggregate sizes of four soils were evaluated. The four soils studied were Entisol at Nsukka, Ultisol at Nsukka, Inceptisol at Eha-Amufu and Inceptisol at Ikem, all collected from four different sites in Nsukka area of southeastern, Nigeria. The land use types considered were fallow and cultivated. Soil samples collected from 0-25mm depth were air-dried at room temperature and were separated into five aggregate fractions 2.0-5.0mm, 1.0-2.0mm, 0.5-1.0mm, 0.25-0.5mm and < 0.25mm. Changes in the distribution of silt, clay and exchangeable properties of aggregate sizes of the four soils under wet and dried sieving of the four soils following cultivation were determined. The result of the study showed that Inceptisol had the highest silt, clay content in all the aggregate sizes among the four soils. The trend is Inceptisol > Entisol > Ultisol. Cultivation decreased the exchangeable bases, CEC and percent base saturation of those soils and their values were higher in the dry-sieved samples than wet-sieved ones. On the average acidity value of the dry-sieved samples

*Corresponding author: E-mail: nweksoniyke@gmail.com;

were found to be higher than those of the wet-sieved samples. The variation in pH values of the aggregate fractions was found to be associated with the total exchangeable bases and percentage base saturation of the aggregates. Results obtained showed relative changes in the properties of dry and wet-sieving, even though their diameters are the same, implying that their loss during erosion will have differing effects on the soils.

Keywords: Silt; clay; exchangeable properties; soils.

1. INTRODUCTION

Soils act as reservoir for the water and mineral nutrients needed by crops for healthy growth and development. Soil is a complex mixture that comprises of mineral particles of various sizes, living organisms and dead organic materials such as plant and animal residues. All these enrich the soil and constantly interact in the form of physical, chemical, and biological processes. Hence optimum plant growth and yield depend very much on the favorable physico-chemical environment of the soil. This is termed fertility status or soil fertility. According to Mulugeta, [1], physical properties determine the capacity of the soil to provide plants with anchorage, moisture and air, and soil chemical conditions determine the capacity of soil to provide needed plants nutrients and that long term fertility of soils may depend mostly on the accumulation and turnover of soil organic carbon and Nitrogen. Moreover, Fisher and Binkley, [2] re-emphasized that soil physical properties, through their effect on moisture regime greatly influenced growth and distribution of crops, aeration, soil chemistry and even the accumulation of organic matter. The chemical properties of soil is a complex reaction involving the interaction of soil solution which is the liquid phase of the soil and solid phase which are materials of organic origin and those of inorganic or mineral fractions of the soil. The abundance and diversity of soil organisms in a particular soil also influences the nature of the reaction processes. Thus the chemical and biological processes occurring in the soil solution and that at the inter phase with solid soil particles normally creates the necessary situation for soil-plant nutrient relationship. Therefore in line with the observations of Schoenholtz et al. [3], the soil chemical environment such as the soil pH influences many chemical reactions that influence nutrient availability. The influence of pH can be understood as it affects the availability of many nutrient elements.

These interactions between the physical, chemical and biological processes in the soil affect changes resulting from cultivation. Cultivation affects soil nutrient supply, distribution and biological transformation in the root zone [4]. Grant and Lafond [5] reported that cultivation generally alters soils physical, chemical and biological properties, which in turn influences plant growth, development and yield. It increases organic matter decomposition [6]. The accelerated mineralization of Soil organic matter and low nutrient contents due to continuous use of the land challenges the sustainability of crop production. When a land is continuously cropped or cultivated, productivity declines very fast [7]. Plant growth and yield are affected through the deterioration of soil structure, decline in total pore sizes and their pore size distribution [8]. Li et al. [9] affirmed that land use and management practices, through intensive cultivation and removal of plant biomass from the field, affect soil organic matter concentration and deteriorate soil physical properties. Cultivation has negative effect in soil organic matter component, decreases soil organic carbon and substantially lower nitrogen mineralization and content [1,4,10,11,12,13]. Soil content of K^+, CEC and extractable Fe decreases following intensive cultivation of an agricultural land [1,11,10,4]. The report of Yimer et al. [14] indicated that following cultivation the largest estimated net flux of carbon from land use changes are from conversion of natural ecosystem to cropland, consequently reducing the average soil carbon in the upper meter of soil to 25-30%. Hence many agricultural soils perform below their potential level. Lugo et al. [15] reported decrease in pH and exchangeable cat ion and increase in bulk density, when forested lands are converted to cultivated areas.

The development of a stable structure is highly desirable in attempt to ameliorate hard-setting behavior of soils which imposes severe restrictions on cultivation and plant growth [16]. This behavior initially involves a disintegration of aggregates of a previous aggregated layer of soil [17]. Soil aggregation influences seed emergence and root growth, soil moisture retention and aeration as well as organic carbon sequestration and dynamics [18,19,20]. The stability of the aggregates of agricultural soils to water influences physical, chemical and biological processes like organic carbon and exchangeable cat ions [21]. Massey and Jackson, [22] and Chepil and Woodruff, [23], re-affirmed the importance of the physico-chemical characterization of aggregates, since different aggregates fractions are selectively removed during erosion. The need for the characterization of the aggregates was stressed by Mbagwu and Piccolo [24] in understanding nutrient dynamics during soil erosion. The content of exchangeable cat ions and total organic carbon in dry aggregates of various sizes were found to be fairly similar by Kowalinski et al. [25]. The particle size distributions observed in different sized aggregates were however not different [26], rather they were fairly constant in aggregates of various sizes [27]. Decreasing aggregates size particle increased the content of silt and clay in larger aggregates separated by dry-sieving [28,24]. This invariable have impacts on the nutrient contents on the various aggregate fractions. Thus the reduction of these nutrients is very crucial to sustainable soil management. So continuous mining of soil nutrient without good management strategies with a view to return in equal proportion of what was taken from the soil deteriorates the quality and productivity of a soil. Therefore, practical understanding of the relationship between soil physical and chemical properties will be important to the understanding of how these properties are influenced by cultivation and practical solution to the management practices that will be adopted on the land. Hence the study was undertaken to evaluate the distribution of silt, clay and exchangeable properties of aggregate sizes of four soils.

2. MATERIALS AND METHODS

2.1 Field Method

Soil samples from the 0-25cm depth were collected from cultivated and adjacent fallow lands in four different locations in Nsukka area of south eastern Nigeria. Care was taken to minimize disturbance during sampling and transportation. The area has a rainforest savannah type of vegetation with a mean annual temperature of 24ºc. The area lies within latitude 06º 61^{1}N and longitude 07º 25^{1}E of Nigeria. The moisture regime of Eha-Amufu and Ikem are hydromorphic. It cracks when dry becomes sticky when wet, presenting problems to tillage operations. The soils samples for the study were classified according to soil taxonomy as an Ultisol (Acrisol, FAO/UNESCO) belonging to the sub-group, Typic Kandiustult (Nkpologu series), Entisol (Regosol, FAO/UNESCO) belonging to Lithic Ustorthent (Uvuru series), while the other two soils belong to Vertic Inceptisol (Cambisol FAO/UNESCO) [29]. These soils have been under continuous cultivation for over or about 8years while fallow soils varied from 3 to 4years old.

2.2 Laboratory Method

The soil samples were air-dried at room temperature and then sieved through a 5mm sieve Kemper and Chepil [30].

2.3 Determination of Physical-chemical Properties of Aggregate Sizes

2.3.1 Particle size analysis

The principle of Bouyocous [31] hydrometer method, as described by Day [32], was used to determine the particle size distribution of the soil aggregate fractions. The technique used was the dispersion of the sample with calgon (Sodium hexametaphosphate). Twenty grams (20g) of the aggregate fractions were soaked in calgon for 24 hours and later transferred to mechanical stirrer for mechanical agitation for 30 minutes before the hydrometer reading.

2.3.2 pH determination

Soil pH was determined in duplicate in both water and 0.1N potassium chloride (KCl) solution using a soil: liquid ratio of 1:2.5. After stirring for 30minutes, the pH values were read off using Beckman Zeromatic pH meter [33].

2.3.3 Exchangeable acidity

This was determined by the titrimetric method using 1N KCl extract [34].

2.3.4 Exchangeable bases

The method described by Chapman [35], as complexiometric titration, was used for determination of Ca and Mg, while Na and K were determined from 1N NH_4 OAC solution using the flame photometer.

2.3.5 Base saturation

The base saturation (BS) was calculated by dividing total exchangeable bases (TEB) by the corresponding cat ion exchange capacity value and multiplying by 100.

$$\text{Base Saturation (BS)} = \frac{TEB}{CEC} \times 100$$

2.3.6 Cat ion exchange capacity

This was determined based on the principle described by Chapman [35]. The neutral ammonium acetate method in which 0.1N KCl solution was used to counter leach and from the KCl leachate cat ion exchange capacity was determined by titration with standard 0.IN NaOH solution.

2.4 Data Analysis

Each parameter in each aggregate and soil type was replicated 4 times and the averages and means values generated for each of the parameter and soil type dry and wet sieved was later used to compare the properties that influence the physical-chemical characteristics of each soil type. The method was used because of the volume of data generated and number of replications.

3. RESULTS AND DISCUSSION

3.1 Exchangeable Properties of Aggregate Sizes

3.1.1 Exchangeable bases

The value of the exchangeable Na^+, K^+, Ca^{2+} and Mg^{2+} obtained for the dry- and wet-sieved aggregates of both fallow and cultivated soils are given in (Table 2). The result of the exchangeable bases of ENsk showed that the concentrations of Na^+ and K^+ in all the aggregate sizes of cultivated soil were lower than those of the fallow soil. However, there was no sharp difference between the Ca^{2+} and Mg^{2+} concentrations of the fallow and cultivated soils. The slightly higher values observed in the fallow soil, may be due to higher concentration of organic matter. For land use changes due to cultivation decrease soil organic matter [11,10,1]. Soil organic matter decomposed rapidly [6], to enter finer, minerals associated organic matter pools which during their subsequent mineralization contribute significantly to the soils available nutrient pool [36]. The result obtained might also be due to mineral weathering. The wet-sieved samples showed that in ENsk fallow soil, there was a decrease in the Na^+ and K^+ concentration in the 2-5mm fraction followed by an increase in the1-2 mm, 0.5-1mm fraction and progressive increase up to < 0.25mm fraction for K^+ concentration. The values of Na^+ and K^+ for the cultivated soil are quite similar. This probable may be due to organic matter depletion and the amount or concentration of Na^+ and K^+ present in the cultivated soil. Cultivation depletes soil organic matter and soil nutrients [4]. The lowest values for both Na^+ and K^+ were obtained in the < 0.25mm fraction. Cultivation decreased the Ca^{2+} concentration in the 2-5mm aggregate size by 10%, relative to the fallow Ensk (see Table 1 for explanation of symbol). There was no change on the Mg^{2+} concentration in the 2-5, 1-2 and 0.25-0.5mm aggregates fractions. The result could be due to wet-sieving process in which some Mg^{2+} present in these aggregates may have dissolved and moved out with water solution. The values of Ca^{2+} and Mg^{2+} concentration in the dry-sieved aggregates being lower than the wet-sieved aggregates could be attributed to leaching. Cat ions like Ca^{2+} and Mg^{2+} repelled by positive charged colloids and remain in the soil solution are highly susceptible to leaching [37].

The exchangeable bases of UNsk showed a higher concentration in the fallow than the cultivated soils, for the dry sieved samples (Table 2). The highest concentration of Ca^{2+} and Mg^{2+} were observed in 2-5mm aggregate size. The wet-sieved samples showed that in the fallow soil, the lowest level of Na^+ and K^+ were obtained in the 2-5mm fraction and for the cultivated soil the results of Na^+ and K^+ in the aggregates sizes were relatively similar. The highest values of Ca^{2+} and Mg^{2+} for the fallow soil were obtained in 0.25-0.5mm aggregate size fraction. The values of Ca^{2+} in the cultivated soil were relatively higher than in the fallow one. Cultivation had no effect on the Ca^{2+} and Mg^{2+} concentrations in the < 0.25mm and 1-2mm fractions. The low exchange base values observed in UNsk, may be due to the characteristics of the soil. The Ultisols are characterized by moderate soil OM and low levels of exchangeable bases, because they are stripped of most of their primary minerals and have their clay mineralogy dominated by Kaolinite and oxides of Fe and Al [38].

For the IEh, the values of Na^+ and K^+ were slightly higher in the cultivated than the fallow soils. The concentrations of Ca^{2+} and Mg^{2+} were higher in the fallow than the cultivated soil, except in the 2-5mm and 1-2mm fractions for Mg^{2+}. The wet-sieved samples of the fallow soil showed that the highest Na^+ and K^+ values were recorded in the < 0.25mm aggregate size, while the highest concentrations of Ca^{2+} and Mg^{2+} were obtained in the < 0.25mm and 1-2mm fractions respectively. The Ca^{2+} and Mg^{2+} distribution in the aggregate fractions of the fallow and cultivated soils for both dry- and wet-sieved samples of IEh were observed to be higher than the values of other soils. This could be attributed to the clay mineralogical composition of the soil and the extent of their weathering. This is because the presence of Mg^{2+}, Ca^{2+} and Fe^{2+} in an environment seems to develop montmorillonite clay mineral [39].

The distribution of exchangeable bases in Iik showed that the lower value in Na^{+} concentration was obtained in the 0.5-1mm aggregate size. The Na^{+} and K^{+} concentrations of the cultivated soil were relatively similar in the entire aggregate fraction, while the distribution of Ca^{2+} and Mg^{2+} were relatively higher in the cultivated than the fallow soils. This could be due to alluvial materials as this soil is hydromorphic in nature. For the wet-sieved samples, the distributions of Na^{+} and K^{+} were relatively similar for the fallow soil. The highest and lowest values for Ca^{2+} and Mg^{2+} respectively were obtained in the < 0.25mm aggregate size.

The result of the exchangeable bases of the four soils showed that the values of dry-sieved fractions are higher than those of the wet-sieved samples. This is most probably due to disintegration of the OM binding agents and minerals adsorbed in the clay fraction that may occur in the process of wet-sieving which can result in the dissociation of some of these minerals and their subsequent removal through water solution.

3.2 Cat ion Exchange Capacity (CEC)

The CEC of the aggregates of the fallow ENsk was slightly higher than that of the cultivated soil in all the aggregate sizes (Table 2). In the cultivated soil, the CEC of the 0.5-1, 0.25-0.5mm and < 0.25mm aggregate size were identical. For the wet-sieved samples, the result of the CEC showed that the fallow soil values in the aggregate sizes were slightly higher than those of the cultivated soil. This higher value observed in the fallow soil in both dry- and wet-sieved samples could be due to the clay or OM concentration which may invariably serve as an index of CEC in soils. That is, the CEC of a soil tend to increase with the increase in OM concentration. Khormali et al. [4] corroborated this finding that the decrease in CEC concentration of deforested land reflects on the OM content of the soil. The result is also an indication that cultivation had negative effects on the CEC of the soils. The highest CEC values of the wet-sieved samples of fallow soil was observed in 1-2mm and 0.5-1mm aggregate fractions, while the least CEC for the cultivated soil was recorded in 2-5mm and < 0.25mm fractions.

The CEC values of the fallow UNsk showed a rapid decline as the aggregate sizes decreased up to the 0.25-0.5mm fraction (Table 2), followed by an increase in the < 0.25mm fraction. The highest CEC value was recorded in the 2-5mm size, but in the 0.5-1mm size. However, there was no effect of cultivation on the CEC. The result of the wet-sieved samples showed that the CEC of the 2-5mm aggregate size were identical for fallow and cultivated soils. The higher values observed in the fallow as compared to the cultivated soils for both dry - and wet-sieved samples is an indication that cultivation had effect on the CEC of the soils. The low variation of CEC in this soil might be the expression of the low OM concentration and the presence of low activity clays such as Kaolinite [37,38].

Table 1. Location, classification and land use type location classification treatment symbol land use

Location	Classification	Treatment symbol	Land use type
Nsukka hill site	Lithic Ustorthent (Uvuru Series)	ENsk (F) ENsk (C)	Fallow cultivated
Nsukka poultry site	Typic Kandiustult (Nkpologu series)	UNsk (F) UNsk (C)	Fallow cultivated
Eha-Amufu site	Inceptisol (with vertic properties)	IEh (F) IEh (C)	Fallow cultivated
Ikem site	Inceptisol (with vertic properties)	Iik (F) Iik (C)	Fallow cultivated

Table 2. Exchangeable properties cmol (+) kg^{-1} of the dry and wet sieved fractions of soils

Na						K				Ca				Mg				CEC			
Treatments	Aggregate	Soils				Soils				Soils				Soils				Soils			
	size (mm)	ENsk	UNsk	IEh	Iik	ENsk	UNsk	IEh	Iik	ENsk	UNsk	IEh	Iik	ENsk	UNsk	IEh	Iik	ENsk	UNsk	IEh	Iik
F a	2-5																				
F b		0.24	0.17	0.13	0.11	0.23	0.16	0.14	0.09	0.4	2.6	3.2	0.9	0.4	2.0	1.9	0.7	5.5	13.0	16.0	6.5
C a		0.08	0.08	0.09	0.09	0.08	0.08	0.08	0.08	1.8	1.6	0.8	1.2	1.2	0.6	0.6	0.8	10.5	10.0	5.0	10.0
C b		0.24	0.15	0.13	0.12	0.23	0.14	0.13	0.11	0.6	0.7	2.0	0.9	0.2	0.6	2.0	0.9	5.0	6.0	16.0	6.0
		0.14	0.13	0.09	0.12	0.13	0.14	0.09	0.11	0.8	1.2	0.8	1.2	0.9	0.8	0.8	0.6	5.0	10.0	5.0	8.5
F a	1-2	2.3	0.17	0.13	0.10	0.22	0.16	0.12	0.09	0.5	2.6	2.3	0.9	0.6	1.6	0.6	0.9	6.5	12.0	14.0	6.0
F b		0.13	0.13	0.12	0.12	0.12	0.12	0.10	0.10	2.0	1.9	1.2	1.0	1.2	0.6	0.9	0.7	12.5	12.0	6.5	6.0
C a		0.20	0.08	0.13	0.09	0.19	0.07	0.13	0.08	0.6	0.8	2.0	0.8	0.3	0.6	1.9	0.8	5.5	6.0	16.0	10.0
C b		0.16	0.14	0.09	0.12	0.18	0.12	0.08	0.10	0.9	1.6	0.9	1.0	0.8	0.6	0.8	0.6	10.0	10.0	5.5	8.0
F a	0.5-1	0.24	0.16	0.14	0.07	0.23	0.14	0.14	0.08	0.6	1.0	2.7	0.8	0.8	0.8	2.6	0.7	6.5	6.0	16.0	5.0
F b		0.15	0.07	0.09	0.09	0.14	0.09	0.10	0.10	2.3	1.6	1.2	0.9	1.4	0.4	0.8	0.9	12.5	11.0	6.5	6.0
C a		0.21	0.09	0.16	0.12	0.21	0.08	0.14	0.12	0.8	0.7	2.4	2.0	0.4	0.7	2.1	1.2	6.0	6.0	17.5	10.0
C b		0.15	0.13	0.09	0.08	0.16	0.12	0.09	0.07	1.2	1.8	1.8	1.2	0.8	0.2	0.7	0.6	10.0	10.0	7.5	7.5
F a	0.25-0.5	0.24	0.18	0.13	0.09	0.24	0.16	0.14	0.08	0.8	0.9	2.5	0.7	0.3	0.7	2.7	0.7	10.0	5.5	15.0	5.0
F b		0.14	0.13	0.12	0.12	0.13	0.12	0.12	0.13	1.4	2.0	0.7	0.7	1.2	1.2	0.8	0.8	11.0	10.5	5.0	5.0
C a		0.20	0.08	0.15	0.13	0.20	0.08	0.15	0.12	0.6	0.7	2.7	1.8	0.7	0.7	2.3	1.6	6.0	5.0	18.0	10.0
C b		0.13	0.13	0.10	0.12	0.16	0.13	0.10	0.11	0.9	1.6	1.6	0.8	0.8	0.4	0.6	0.8	6.0	10.0	6.0	5.0
F a	< 0.25	0.25	0.15	0.12	0.12	0.24	0.13	0.13	0.12	1.1	0.8	2.6	0.9	0.1	0.6	2.1	0.9	10.0	6.0	12.0	5.0
F b		0.16	0.10	0.13	0.08	0.17	0.09	0.14	0.08	1.2	1.2	1.8	1.6	1.0	0.7	0.8	0.5	10.0	9.0	5.0	9.5
C a		0.23	0.19	0.14	0.12	0.20	0.09	0.13	0.13	0.7	0.8	2.1	1.6	0.5	0.8	1.6	1.2	6.0	7.0	12.0	12.0
C b		0.08	0.12	0.10	0.11	0.08	0.11	0.12	0.10	0.7	1.2	1.8	0.9	0.6	0.8	1.3	0.7	5.0	10.0	10.5	5.0

F= fallow, C= Cultivated, a = Dry Sieved, b = Wet Sieved, ENsk= Entisol at Nsukka, UNsk= Ultisol at Nsukka, IEh = Inceptisol at Eha-Amufu, Iik = Inceptisol at Ikem

The IEh showed lower CEC in the < 0.25mm aggregate size for both the fallow and cultivated soils. Cultivation increased the CEC of the 1-2mm and 0.5-1mm aggregates with values of 14.3% and 9.4%, respectively, relative to the fallow soils (Table 2). The cultivated soil showed a gradual increase in the CEC as the aggregate sizes decreased. The wet-sieved samples showed that the fallow soil value in the aggregate sizes are relatively lower than the cultivated soil. Nevertheless, cultivation decreased the CEC in the 1-2mm fraction by 15.4% relative to the fallow soil. The higher CEC value observed in this soil compared to the other three soils could be attributed to the increased amount of the hydrated cations (Table 2). This may also be the reason for the higher values obtained in the dry-sieved fractions compared to the wet-sieved fractions.

The CEC of Iik soil was higher in the cultivated than the fallow soils in all the aggregate fractions. The exception to this was the 2-5mm fraction where cultivation reduced the CEC by 7.7% relative to the fallow soil. The highest CEC was observed in the < 0.25mm aggregate size of the cultivated soil (Table 2). For the wet-sieved samples, the fallow soil showed a gradual decline in value as the aggregate sizes decreased up to 0.25-0.5mm fraction (Table 2). The highest CEC was obtained in < 0.25mm aggregate size. Cultivation reduced the CEC of 2-5mm aggregate by 15% relative to the fallow soil. The relative higher CEC observed in the cultivated soil in comparison to the fallow ones for both dry and wet-sieved samples of this soil could be due to alluviation of mineral elements or due to increased amount of the hydrated cations in the cultivated soils (Table 2).

3.3 Base Saturation

The base saturation (BS) of all the dry- and wet-sieved aggregate fractions of the four fallow and cultivated soils is given in (Table 3). The BS values in the ENsk were higher in the cultivated than the fallow soils. This could be due to loss of some cat ions from cation exchange complex of the fallow soil. This might equally be reason for the lower values obtained in the wet-sieved samples of fallow compared to cultivated soil when considered on the average basis. The highest value for the dry-sieved samples was observed in the 0.25-0.5mm aggregate size. Cultivation reduced the BS in the 1-2mm and 0.5-1mm fractions of the wet-sieved sample by 3.6% and 28.1% respectively, relative to the fallow soil. The values of BS obtained from dry-sieved aggregate sizes were lower than those from the wet-sieved samples due to their CEC, which is an index of the base saturation.

The BS values in UNsk showed that the values for fallow soil were higher than the cultivated soils among all the aggregate sizes. This is an indication that cultivation reduced the BS value of the UNsk. For the wet-sieved samples, the BS in the aggregate sizes 2-5, 0.25-0.5mm and < 0.25mm were reduced by cultivation while the BS in the aggregate sizes 1-2mm and 0.5-1mm were increased by 8.7% and 15% respectively, relative to the fallow soil. The low BS value observed in this soil in comparison to the other three soils may be due to low amount of exchangeable bases and CEC (Table 2). It might also be due to the presence of low activity clays and high proportion of exchange sites saturated by Al [38].

The BS of the aggregate fractions of the IEh showed that aggregate fractions of the cultivated soil contained relatively low values compared to the fallow soil. This was also the case for the wet-sieved samples when considered on the average, an indication that cultivation decreased the BS of the soil relative to the fallow. The highest value for the dry-sieved samples was observed in the < 0.25mm and 1-2mm aggregate sizes of the fallow soil for dry and wet-sieved samples, respectively. The highest BS value for the cultivated soil was obtained in the 0.25mm-0.5mm fraction.

In the Iik, there was an initial increase in the BS values in the 2-5mm fraction, followed by a decrease in value as the aggregate sizes decreased for the fallow soil. The highest BS value for the fallow soil was observed in the 2-5mm aggregate size (Table 2). The BS of the cultivated soil was slightly lower than that of the fallow soil, which indicates that cultivation reduced the BS value of the soil in the aggregate sizes. For the wet-sieved samples, the distribution of BS in the Iik showed a gradual increase in value as the aggregate sizes decreased up to 0.25-0.5mm fractions for the fallow soil. On the average cultivation had no effect on the BS value of the exchangeable bases and the CEC of the soil which are almost the same for the two land uses, on the average.

Table 3. Exchangeable acidity, Base saturation and pH properties of the dry and wet sieved fractions of soils

pH($H_2$0)						pH $_{KCl}$				Base saturation (%)				Al + H cmol(+)kg^{-1}			
Treatments	Agg. size (mm)	Soils				Soils				Soils				Soils			
		EN sk	UN sk	IEh	Iik	ENsk	UNsk	IEh	Iik	ENsk	UNsk	IEh	Iik	ENsk	UNsk	IEh	Iik
F a	2-5																
F b		4.0	4.6	4.6	5.2	3.3	4.3	4.1	4.2	23	35	34	43	4.4	2.4	1.6	1.6
C a		4.1	4.6	5.2	4.6	3.5	4.3	4.6	4.2	30	24	31	21	0.8	0.8	0.8	1.2
C b		4.6	5.0	4.4	4.0	3.4	4.1	3.4	3.6	25	24	27	34	1.6	2.0	3.6	1.4
		4.6	4.4	4.1	4.5	4.4	3.5	3.3	4.0	39	23	35	24	1.4	1.8	1.2	1.8
F a	1-2																
F b		4.0	4.7	4.7	4.0	3.3	4.3	4.1	3.8	24	34	25	33	2.0	1.6	0.8	1.6
C a		3.9	4.6	4.9	4.5	3.4	4.3	4.3	4.1	28	23	35	33	1.2	1.6	1.2	1.6
C b		4.2	4.9	4.4	4.3	3.4	4.1	3.4	3.5	23	26	26	22	1.2	1.2	4.4	1.2
		4.2	4.4	4.1	4.3	3.7	3.5	3.3	3.9	27	25	34	23	1.8	2.0	0.8	1.6
F a	0.5-1																
F b		3.8	4.7	4.6	4.6	3.3	4.3	4.1	4.0	23	35	35	33	5.2	1.4	1.6	0.8
C a		3.9	4.7	4.6	4.6	3.4	4.4	4.4	4.4	32	20	34	33	1.2	1.2	1.2	1.6
C b		4.2	5.0	4.4	4.2	3.4	4.2	3.4	3.5	27	26	27	34	1.6	1.2	5.0	1.6
		4.1	4.7	4.0	4.2	3.6	4.2	3.3	3.8	23	23	36	26	2.0	1.6	0.8	0.8
F a	0.25-0.5																
F b		3.9	4.8	4.8	4.2	3.3	4.5	4.3	4.0	16	35	36	31	4.2	1.2	1.6	0.8
C a		3.9	4.7	4.9	4.4	3.4	4.4	4.2	3.6	26	31	35	35	1.6	1.6	1.6	2.0
C b		4.2	4.9	4.3	4.2	3.4	4.1	3.4	4.0	28	31	29	37	2.4	1.2	4.4	1.6
		4.1	4.6	4.1	4.3	3.6	4.2	3.4	3.8	33	23	40	37	2.0	2.4	1.2	1.4
F a	< 0.25																
F b		4.0	4.7	4.7	4.3	3.2	4.3	4.1	4.0	17	28	41	41	6.4	1.2	1.6	1.4
C a		4.0	4.8	4.8	4.6	3.6	4.6	4.5	4.4	25	23	37	24	1.8	1.2	1.4	0.8
C b		4.0	4.3	4.3	4.3	3.4	4.0	3.4	3.5	27	26	33	25	2.6	1.6	4.0	1.2
		4.3	4.5	4.1	4.6	3.8	4.3	3.7	4.1	29	22	32	36	1.2	1.6	1.2	1.2

F = Fallow, C= Cultivated, a = Dry Sieved, b = Wet Sieved, ENsk = Entisol at Nsukka, UNsk = Ultisol at Nsukka, IEh = Inceptisol at Eha-Amufu, Iik = Inceptisol at Ikem

3.4 Exchangeable Acidity

The exchangeable Al^{3+} + H^+ of all the dry and wet-sieved aggregate sizes for both the fallow and cultivated soils are given in (Table 3). Cultivation increased the exchangeable acidity value in all the aggregate fractions of ENsk relative to the fallow one. The most increased exchangeable Al^{3+} +H^+ among all the aggregate fractions for both fallow and cultivated soils was observed in < 0.25mm size. For the wet sieved samples, the exchangeable Al^{3+} + H^+ increased in all the cultivated soil relative to the fallow one in all the wet aggregate sizes of the ENsk, but in the < 0.25mm aggregate sizes, the exchangeable Al^{3+} + H^+ decreased in cultivated soil relative to the fallow one by 33.3%. The increase values of exchangeable Al^{3+} + H^+ observed in this soil more than the other three soils could be attributed to the pH of the soil (Table 3). This is because if the pH of a soil is 4 or below, the clay minerals begin to disintegrate releasing more Al^{3+} and H^+ in the soil [37]. The result obtained may also be due to low variation in the exchangeable bases and base saturation as well. These increments could have resulted from the decomposition of soil OM by soil organisms. When this occurs, acid forming ions (H, Al, Fe and S) are liberated into the soil solution from exchange sites, thereby increasing soil acidity [40].

The exchangeable Al^{3+} + H^+ in 2-5mm and 0.5-1mm aggregate of the UNsk decreased due to cultivation, but increased in the < 0.25mm aggregate and had no effect on the 0.25-0.5mm aggregate size. This could be due to the OM concentration in these aggregate sizes. For the wet-sieved samples cultivation increased the exchangeable Al^{3+} + H^+ in all the aggregate sizes of the cultivated soil relative to the fallow one. The highest value was obtained in the 0.25-0.5mm fraction of the cultivated soil. The high acidity value observed in the dry sieved samples relative to the wet-sieved ones could be that the exchange sites are saturated by Al, due to disintegration of OM binding agents during wet-sieving. Nonetheless, the soil is characterized by high levels of Al due to the presence of low activity clays [38].

In the IEh, cultivation increased the exchangeable Al^{3+} + H^+ in all aggregate sizes of the cultivated soil relative to the fallow one. The wet-sieved samples showed that the acidity levels in the fallow soil were higher than in the cultivated one, for all the aggregate sizes. This indicates that cultivation increased the exchangeable acidity in the fallow relative to the cultivated soil. The exception to this is the 2-5mm aggregate fraction.

The exchangeable acidity levels in the Iik, showed that cultivation increased the total acidity value in the 0.5-1mm and 0.25-0.5mm aggregate sizes, but decreased it in the 2-5mm and < 0.25mm aggregate sizes relative to the fallow soils. The result of wet-sieved samples showed that cultivation had no effect on the exchangeable Al^{3+} + H^+ of 1-2 mm fraction, but on the average, it reduced the values of the cultivated soil by 5.5% compared to the fallow one. The relatively high exchangeable acidity observed in the two Inceptisols for both dry- and wet-sieved samples could be attributed to cation displacement from the exchangeable sites into soil solution by the Al^{3+} adsorbed on to the exchange site [37]. The result of the exchangeable acidity of the four soils showed that the dry-sieved samples have relatively similar values when compared with the wet-sieved aggregates. Nevertheless, on the average the acidity value of the dry-sieved samples were higher than those of the wet-sieved samples. The increased exchangeable Al^{3+} in some of these aggregates sizes of the soils may be as a result of decreased OM concentration in these aggregates due to cultivation. Furthermore, the higher values of exchangeable acidity observed in these soils may be due to long time cultivation as a result of high intensive rainfall, leading to excessive nutrients loss through leaching.

3.5 Soil Reaction

The pH values of the dry- and wet-sieved aggregates of four soils are presented in (Table 3). The pH showed that the values of all the aggregate fractions of the cultivated soil were slightly lower than those of the fallow soils, for UNsk, IEh and Iik. The exception was the ENsk. The pH of the aggregate of the cultivated soil of the ENsk was slightly higher than those of the fallow soil both in water and KCl. This probably may be due to the amount of exchangeable Ca^{2+} and Mg^{2+} present in these soils (Table 2). This is because an increase or decrease in pH is associated with an increase or decrease in the amount of Ca^{2+} and Mg^{2+} in the soil solution, as they are usually the dominant exchangeable bases [37]. The values of the wet-sieved soils showed that cultivated soils had slightly lower pH values than those of the fallow soils among all the aggregate fractions. The exception was the ENsk which had slightly higher value in the cultivated aggregates compared to the fallow soils in both water and KCl. The pH values of dry-sieved aggregates are similar with those of the wet-sieved aggregates.

3.6 Particle Size Distribution

The Silt and Clay values of all the dry and wet-sieved aggregate fractions of the four soils are given in (Table 4). In the ENsk, the result for the dry-sieved fallow soil show that cultivation increased the Silt and Clay contents of the 2-5mm, 1-2mm and < 0.25mm sizes but had no effect on those of the 0.5-1mm and 0.25-0.5mm fractions. The increases were 52.70, 18.75 and 10.50 percent for the 2-5, 1-2 and < 0.25mm aggregate sizes respectively relative to the fallow soil. For the wet-sieved samples, cultivation also increased the Silt and Clay contents of all the aggregate fractions. The percentage increases were 61.5, 13.3, 31.6, 23.5 and 29.4 percent for the 2-5, 1-2, 0.5-1, 0.25-0.5mm and < 0.25mm fractions, respectively relative to the fallow soil. The Silt and Clay contents in dry sieved samples were relatively higher than those of the wet-sieved ones. This is most probably due to the water sieving process that might have disintegrated the clay-organic binding agents and their subsequent removal through water solution. The average Silt and Clay contents of the cultivated soils for both dry and wet-sieved samples were observed higher than in the fallow ones. This suggests that some particles have been pulverized by the tillage or that tillage brought up clay from deeper soil layers. It can also be due to the movement of clay with the infiltrating water down the profile when tillage stopped. Mbagwu and Bazzoffi [41] made similar observation on Italian soils. The average Silt and Clay contents of both micro and macro-aggregates of untilled top soil were slightly lower than those of the conventionally tilled plots.

The Silt and Clay contents of the dry-sieved UNsk showed that cultivation had no effect on the values of the 2-5mm and 0.25-0.5mm fractions, but increased those of the 1-2, 0.5-1mm and < 0.25mm aggregate sizes. The percentage increases were 30, 33.3 and 20 percent for the 1-2, 0.5-1mm and < 0.25mm fractions, respectively, relative to the fallow soil. It was observed that in the wet-sieved samples, cultivation reduced the Silt and Clay content in the 2-5, 1-2, and 0.5-1mm aggregate fractions by 27.3, 20 and 30 percent respectively, relative to the fallow soil. The percentage increase in 0.25-0.5mm and < 0.25mm fractions relative to fallow soil due to cultivation were 16.7 and 57.1 percent respectively. The UNsk recorded the least amount of Silt and Clay content in both dry and wet-sieved samples among the four soils.

Table 4. Distribution of silt and clay (%) in aggregate fractions separated from four soils under different land uses

Treatment	Aggregate size (mm)	ENsk	UNsk	IEh	Iik	X
Fa		26	50	95	80	62.75
Fb	5-2	25	55	85	60	56.25
Ca		55	50	95	40	60.00
Cb		65	40	95	40	60.00
Fa		65	50	90	95	75.00
Fb	2-1	65	50	95	95	76.25
Ca		80	35	85	80	70.00
Cb		75	40	95	75	71.25
Fa		90	45	90	95	80.00
Fb	1-0.5	65	50	95	95	76.25
Ca		90	30	85	90	73.75
Cb		95	35	95	85	77.50
Fa		85	40	95	95	78.75
Fb	0.5-0.25	65	30	95	90	70.00
Ca		85	40	95	95	78.75
Cb		85	35	95	95	77.50
Fa		95	40	90	95	80.00
Fb		60	35	95	95	71.25
Ca	< 0.25	85	50	95	85	78.75
Cb		85	55	90	80	77.50

F= Fallow, C = Cultivated, a = Dry sieved, b = Wet sieved, ENsk = Entisol at Nsukka, UNsk = Ultisol at Nsukka IEh = Inceptisol, at Eha-Amufu, Iik = Inceptisol at Ikem

For the IEh, cultivation had no effect on the Silt and Clay values of the 2-5mm and 0.25-0.5mm sizes, but reduced those of the 1-2, 0.5-1 and < 0.25mm aggregate sizes by 5.6, 5.6 and 5.3 percent respectively, relative to the fallow soil. In the wet-sieved samples, cultivation had no effect on the Silt and Clay contents of the 1-2, 0.5-1 and 0.25-0.5mm fractions but increased that of the 2-5mm fraction by 10.5% relative to the fallow soil. The IEh had the highest Silt and Clay content in all the aggregate sizes among the four soils. The trend is IEh >Iik >ENsk >UNsk.

In the Iik the Silt and Clay content of the 2-5, 1-2, 0.5-1 and < 0.25mm aggregate fractions were reduced due to cultivation by 50.0, 15.8, 5.3 and 10.5 percent respectively relative to the fallow soil, but cultivation had no effect on that of the 0.25-0.5mm fraction. For the wet-sieved samples, there was also a reduction in the Silt and Clay content of the 2-5, 1-2, 0.5-1 and < 0.25mm sizes, with an increase in the 0.25-0.5mm fraction relative to the fallow soil. The percentage decreases were 33.3, 21.1, 10.5 and 15.8 percent for the 2-5, 1-2, 0.5-1 and < 0.25mm aggregate sizes, respectively. The percentage increase in 0.25-0.5mm fraction was 18.8%, relative to the fallow soil. The high values of Silt and Clay content observed in the two Inceptisols could be due to the nature of the soils as well as their clay mineralogical composition. The two soils are hydromorphic in nature and have swelling and contraction abilities. In view of this, there is a possibility of the presence of 2:1 or 3 layered clay minerals in these soils.

Among all the soils, it was also observed that cultivation slightly pulverized the soil particles. The proportions of the macro-aggregates were reduced and the proportion of the micro-aggregates increased as a result of cultivating the ENsk. This cultivated soil had slight increase in its Silt and Clay contents when compared to its fallow counterpart for both the dry and wet-sieved samples. The distribution of the particle size was also observed to be fairly constant in the UNsk, IEh and Iik, for both dry and wet-sieved samples. Similar results were obtained by Metzger and Hides [42], Witmus and Mazurek [27] and Tabatabai and Han way [26]. The result also showed generally that the content of Silt and Clay in macro-aggregates as separated by the sieving processes increased with decreasing aggregate size [28, 24]. This however, was more observed in the ENsk than the other three soils.

4. CONCLUSION

From the result of this study, it was observed that the distribution of Silt and Clay in the aggregates was fairly constant in the UNsk, IEh and Iik. Cultivation decreased the exchangeable bases, CEC and percentage base saturation of these soils and their values were higher in the dry-sieved samples than wet-sieved ones. There were relative changes in the properties obtained by dry and wet-sieving, even though their diameters are the same and therefore their loss during fertility erosion will have differing effects on the soils.

COMPETING INTERESTS

Authors declare that there are no competing interests.

REFERENCES

1. Mulugeta L. Effect of Land use change on soil quality and native flora degradation and restoration in the highlands of Ethiopia. Implications for sustainable land management. Ph. D. Thesis Swedish University of Agricultural Sciences, Uppsala Sweden. 2004;15-21.
2. Fisher R, Binkley D. Ecology and management of forest soil 3rd edition, Wiley, New York. 2000;489.
3. Schoenholtz S, Miegroet H, Van H, Burger JA. A review of chemical and physical properties as indicators of forest soil quality: Challenges and opportunities. Forest Ecology and Management. 2000;138:335-356.
4. Khormali F, Ghorbani R, Amoobani OR. Variation in soil properties as affected by deforestation on loess derived hill slope of Gholestan Province, Northern Iran. Sociedade and Natureza, Uberlandia. 2005;440-445.
5. Grant CA, Lafond GP. The effect of tillage and crop sequences on soil bulk density and penetration resistance on a clay soil in Southern Saskachewan. Can. J. Soil Sci. 1993;73:223-233.
6. Young A, Young R. Soils in the Australia landscape, Oxford University Press, Melbourne; 2001.
7. Brabant P, Darracq S, Eque K, Simoneaux V. Etat de degradation des terres resultants des actions humanes Collection Notice Expl. No. 112, ET Actives,

Agricoles, Unite de recherché 34 Paris; 1996.
8. Baker BJ, Fausey NR, Islam KR. Comparison of soil physical properties of two different water table management regimes, Soil Sci. Soc. Am. J. 2004;68:1973-1981.
9. Li XG, Li FM, Zed R, Zhan ZY, Singh B. Soil physical properties and their relations to organic carbon pools as affected by land use in an alpine pastureland. Geoderma. 2007;15:98-105.
10. Yoursefifard M, Khademi H, Jalalian A. Decline in soil quality as a result of land use change in Cheshmeh Ali region (IRAN), J. Agric. Sci. Nat. Resur. 2007;14(1):425-436.
11. Hajabbasi MA, Besalatpoor A, Melali AR. Effect of rangeland change to agricultural land on some soil physical and chemical properties in South of Isfahan. Sci. Technol. Agric. Nat. Resour. 2007;42:525-523.
12. Majaliwa JG, Twongyirwe,R, Nyenje R, Oluka M, Ongom B, Sirike J, Mfitumukiza D, Azanya E, Natumanya R, Mwerera R, Barasa B. The effect of land use and cover change on soil properties around Kibale National Park in South Western Uganda. Appl. Environ. Soil Sci. 2010;10:1-7.
13. Fallahzade J, Hajabbasi MA. Soil organic matter status changes with cultivation of over grazed pasture in Semi-dry West Central Iran, Int. J. Soil Sci. 2011;6:114-123.
14. Yimer F, Ledin S, Abdelkadir A. Changes in soil organic carbon and total nitrogen contents in three adjacent land use types in the Bale Mountains, South-eastern highlands of Ethiopia, Forest Ecology and Management. 2007;242:337-342.
15. Lugo AE, Sanchez MJ, Brown S. Land use and organic carbon content of some sub-tropical soils. Plant soil. 1986;96:185-196.
16. Mullins CE, McLeod DA, North Cote KH, Tisdall JM, Young IM. Hard Setting Soils; Occurrence and Management In Lal, R., Stewart, B. A. (Eds) Soil degradation. Springer New York. 1990;37-108.
17. Mead JA, Chan KY. The effect of growth and yield of Wheat on a hard setting soil Aust. Expt. Agric. 1988;28:491-498.
18. Anabi M, Houot S, Fracou C, Poitrenandi M, Bissonnais YL. Soil aggregate stability improvement with urban compost of different materials Soil Sci.Soc. Am. J. 2008;71:413-123.
19. Madari B, Pedrol L, Machado DA, Torres E. No tillage and crop rotation effects on soil aggregation and organic Carbon in a Rhodic Ferrasol from Southern Brazil. Soil Till. Res. 2005;80:1985-2000.
20. Denef K, Six J, Merks R, Pausitan K. Carbon sequestration in micro-aggregates. Soil Sci. Soc. Am. J. 2004;68:1935-1994.
21. Mbagwu JSC. A comparison of three micro-aggregation indices with other test structural stability. Int. Agro-Physics. 1992;42:27-32.
22. Massey HF, Jackson HL. Selective erosion of soil fertility constituents. Soil Sci. Soc. Am. Proc. 1952;16:353-356.
23. Chepil WS, Woodruff NP. The Physics of wind erosion and its control Adv. Agron. 1963; 15:211-302.
24. Mbagwu JSC, Piccolo A. Some physical properties of structural aggregates separated from organic waste-amended soil. Biol. Wastes. 1990;33:107-121.
25. Kowalinski S, Drozd T, Lieznar M. Characteristics of the physico-chemical properties of structural aggregates of various sizes Polish J. Soil Sci. 1982;15:119-127.
26. Tabatabai MA, Han way JJ. Some chemical and physical properties of different size natural aggregates from Iowa Soils. Soil Sci. Soc. Am. Proc. 1968;32:588-591.
27. Witmus HD, Mazurak AP. Physical and chemical properties of soil aggregates in Bronizam soil. Soil Sci. Soc. Am. Proc. 1958;22:1-5
28. Christensen BT. Straw incorporation and soil organic matter in macro-aggregates and particles size separates. J. Soil Sci. 1986;31:125-135.
29. Soil Survey Staff. Soil Taxonomy: A basic system of soil classification for making and interpreting Soil Surveys. USDA-Sci Agric. Hand book 436. US. Govt. Printing Office, Washington D. C; 1992.
30. Kemper WD, Chepil WS. Size distribution of aggregates. In: C.A Black et al (eds) part1. Method of soil analysis, No:499-510. Am. Soc. Agron. Madison, Wisconsin; 1965.
31. Bouyoucos CJ. A recalibration of Hydrometer for making mechanical analysis of soil Agron. J. 1951;43:434-438.
32. Day PR. Particle Fractionation and Particle size analysis. In: C. A. Black et al. (Eds). Methods of Soil Analysis, Part 1. Am. Soc.

Agron. No 9:545-567. Madison, Wisconsin; 1965.
33. Peach M. Hydrogen ion activity. In: C. A. Black et al. (Eds). Methods of Soil Analysis. Part 1. Am. Soc. Agron. No. 9:914-926. Madison, Wisconsin; 1965.
34. Mclean EO. Aluminum. In: C. A. Black et al. (Eds) Methods of Soil Analysis, Part 1. Am Soc. Agron. No. 9. 986-994. Madison Wisconsin; 1965.
35. Chapman HD. Total exchangeable bases In: C. A. Black et al. (Eds). Methods of Soil Analysis Part 1 Am. Soc. Agron. No. 9:702-904, Madison, Wisconsin; 1965.
36. Tiessen H, Stewart JWB. Particle size fractions and their use in studies of soil organic matter II. Cultivation effects on organic matter composition in size fractions. Soil Sci. Soc. Am. J. 1983;47:509-514.
37. Foth HD. Fundamentals of Soil Science, 6th edition, John Wiley and Sons, New York. 1951;207-265.
38. Sanchez PA. Soil Management in the Oxisol Savannas and Ultisol jungles of tropical South America. In: Characterization of Soils. (eds) D. J. Greenland. Claredon Press, Oxford. 1981;215-217.
39. Keller WD. Clay minerals as influenced by Environment of their formation, AAPG Bull. 1956;40(11):2689-2710.
40. Fairbridge RW, Finkl CW. Encyclopedia of Soil Science Part 1, 6th Editions, Dowden, Hutchinson and Rose Inc. 1962;22-26.
41. Mbagwu JSC, Bazzoffi P. Properties of soil aggregates as influenced by tillage practices. Soil use and Manag. 1989;5:180-188.
42. Metzger WH, Hides JC. Effect of certain crops and the distribution of organic carbon in relation to aggregate size, Am. Soc. Agron. J. 1938;30:833-843.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=713&id=5&aid=6456