American-Eurasian J. Agric. & Environ. Sci., 17 (2): 119-127, 2017
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2017.119.127

Distribution and Stability of Soil Structural Aggregates in Relation to Organic Carbon under Changing Land Uses

[1]Birhanu Iticha and [2]Tadesse Debele

[1]Department of Soil Resource and Watershed Management,
Wollega University, Nekemte, Ethiopia
[2]Department of Plant Sciences, Ambo University, Ambo, Ethiopia

Abstract: The study examined aggregate size distribution and related structural indices in soils of natural forest, *Cupressus lusitanica* plantation and cultivated land through dry and wet sieving techniques. Variations in aggregate size distribution and structural indices were observed among land uses which might be ascribed to soil organic carbon (SOC) content and tillage practices. Alteration from natural forest to *Cupressus lusitanica* plantation and cultivated land apparently reduced the quantity of SOC and water stable aggregates (WSA) (> 1mm) but increased the quantity of WSA (1-0.25 mm) and micro-aggregates (< 0.25 mm). Long term cultivation leads to deterioration of soil structure and formation of clods. The mean percent by mass of agronomically most valuable aggregates (AVA) in soils of natural forest, *Cupressus lusitanica* plantation and cultivated land to the whole investigated depth were 86.61, 80.42 and 74.44%, respectively. Coefficient of stability (K_s) ranged from 2.48 in soils of the cultivated land to 7.94 in soils of the natural forest. Soil manipulation had increased difference in the mean weight diameter between dry and wet sieved aggregates aggravating soils vulnerability to water erosion. Our results suggested that enhancing practices that less likely disturb natural soil structure can improve aggregate stability and soil quality.

Key words: Aggregate size distribution · Water stable aggregate · Soil quality · Soil organic carbon · Land use change

INTRODUCTION

Aggregate stability is an important soil quality trait that determines root penetration, susceptibility to compaction, soil erodibility [1] and has great ecological importance. Soil aggregation, in turn, depends on the interaction of aggregating agents, soil management and environmental conditions [2]. Aggregate stability is significantly correlated with SOC (soil organic carbon) due to the binding action of humic substances and other microbial byproducts [3]. Soil aggregation protects SOC [4] and reduces SOC decomposition and CO_2 emission to the atmosphere. Soil aggregation is strongly affected by land use change and management practices. Numerous studies have been conducted on the effects of land use change on aggregate stability [5, 6]. In their natural states, forest soils have good structure, rich in organic carbon, but their conversion to arable land usually leads to deterioration of the structure and then rapid erosion [7]. Other studies also pointed that soils of the tropics are prone to degradation upon conversion of native forest to cropland systems through an increase in the intensity of soil disturbance by conventional tillage, which breaks up soil aggregates [8]. Soil aggregate stability and SOC content usually decreases with cultivation [9]. Unlike other land uses, intensive cultivation degrades soil structure and changes the distribution of soil aggregates.

Aggregate size distribution and related soil structural indices are essential parameters in understanding the structural state of the soil. Aggregate size distribution and stability could be determined at dry and/or wet conditions; most commonly for > 10, 10□5, 5□3, 3□2, 2□1, 1□0.5, 0.5□0.25 and < 0.25 mm aggregate size classes. Aggregates could be classified as micro-aggregates and macro-aggregates. Tisdall [10] proposed the boundary between micro-aggregate and

Corresponding Author: Birhanu Iticha, Department of Soil Resource and Watershed Management, Wollega University, Nekemte, Ethiopia.

macro-aggregate be 0.25 mm of aggregate diameter. The 10□0.25 mm aggregate size classes were considered agronomically most valuable aggregates [11, 12]. Agronomically valuable fractions of aggregates are particularly important because these fractions provide optimal porosity (water and air) for crop growth. Dry aggregate size distribution strongly affects soil resistance to erosion and degradation. The most common indices of dry aggregate size distribution are mean weight diameter of dry aggregates (MWDd) and coefficient of stability (K_s). High values of MWDd usually indicate high water permeability and air capacity but lower erodibility of soil. Coefficient of stability is used to judge the suitability of soil for agriculture. [11] suggested three classes of K_s>1.5, 1.5-0.67 and <0.67 for soils of good, satisfactory and unsatisfactory structure with respect to soil fertility. Wet aggregate size distribution is also commonly used as a measure of the stability of soil aggregates. Water stable aggregates and mean weight diameter of wet aggregates (MWDw) are the most common indices of wet aggregate stability. Previous studies showed that soils containing higher MWDw and WSA are likely to have a greater resistance to soil degradation and erosion [13]. Another aggregate stability index was calculated as a ratio of MWDw to MWDd [14]; an index of 1 represents perfect structural stability.

The study was conducted with the aim to give a reliable description and ranking of the behavior of soil structure under the effect of changing land use and management practices and in depth interpretation of their implication to soil quality. The results of aggregate size distribution and stability tests help to predict the relative resistance of soil to erosion and degradation, capacity of soil to transmit air and water, suitability of soils for crop production and used as relative indicator of soil quality.

MATERIALS AND METHODS

Site Description: The study was conducted in East Wollega zone of Oromia regional state, Ethiopia. About 25 years ago, the study site was entirely covered with tight native forest endowed with plenty of indigenous woody and non woody plant species. Gradual expansion of agriculture and other human interferences had encroached and degraded parts of the native forest. Therefore, an area that was completely covered with native forest before 25 years had three land use types during the present study, namely the remaining natural forest, *Cupressus lusitanica* plantation and cultivated land. The most common soil textural classes of the study site are clay and clay loam. The dominant agriculture is mixed farming system where livestock and subsistence crop production supports the livelihoods of the community. The most widely cultivated crops include cereals such as Teff (*Eragrostis tef*), millet (*Panicum miliaceum*), wheat (*Triticum aestivum*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), barley (*Hordeum vulgare*) and legumes such as horse bean (*Vicia faba*), ground nut (*Arachis hypogaea*) and oats (*Avena sativa*).

Soil Sampling and Analysis: Report by [15] indicated that cultivated land of the study area was dominated by Nitisol while forest lands were dominated by Alfisols. Due to similarity of soil types across specific land uses in the site, one representative profile was opened in each land use, namely natural forest, *Cupressus lusitanica* plantation and cultivated land. Soil samples were collected safely from genetic horizons and taken to laboratory as gently as possible to avoid breakdown of soil aggregates. Net weight of 250 g was used from samples for analysis of dry and wet aggregate size distribution. Percent by mass of dry aggregates for each size classes of> 10, 10□5, 5□3, 3□2, 2□1, 1□0.5, 0.5□0.25 and < 0.25 mm were determined by dry sieving method [11]. In this method, soil sample was added in the topmost of a nest of eight sieves of 10, 5, 3, 2, 1, 0.5, 0.25 and < 0.25 mm sizes and then, dry sieved to determine percent dry aggregates. The percentage of WSA for each aggregate size class was determined by wet sieving method [16]. Besides, sample was added in the topmost of a nest of eight sieves indicated above and manually immersed into water for 5 minutes to determine WSA. Waterstable aggregates for each size class were estimated after wet-sieving and oven-drying. Structure coefficient was calculated as the ratio between the content of AVA, with the diameter of 10-0.25 mm and the total content of the aggregates of >10 mm and <0.25 mm separated by dry sieving method [11]. Soil OC was determined by Walkley-Black oxidation method [17].

Estimation of Aggregate Stability Indices: The percentage of dry aggregates for each size class was estimated as follows:

$$\text{Dry aggregates (\%)} = \left(\frac{M_{di}}{M_t}\right) \times 100$$

where Mdi is mass of dry aggregate on the i^{th} sieve size and Mt is total mass of dry-sieved soil. Stability coefficient was calculated as the ratio of most agronomically valuable fractions (10-0.25mm) to the total content of aggregates > 10 and <0.25 mm [11]:

$$Ks = \frac{\text{Soil fractions } (10-0.25 \text{ mm})}{\text{Soil fractions } (>10 \text{ mm}) + (<0.25 \text{ mm})}$$

Percentage of WSA for each size class was estimated based on [16] equation as follows:

$$\text{WSA } (\%) = (\frac{Mr}{Mt)}) \text{ x } 100$$

where Mr is mass of resistant aggregates for each size class and Mt is the total mass of wet-sieved soil. Mean weight diameter (MWD) for dry aggregates and WSA was calculated using [18] equation as follows:

$$\text{MWD} = \sum X_i W_i$$

where Xi is the mean diameter of i^{th} aggregate size and Wi is weight proportion of aggregates in that size range as a fraction of total dry weight of the soil used.

Statistical Analysis: The values of aggregate size distribution at dry and wet conditions and stability indices were compared with critical values and limits. Generalized comparisons among values of different variables at different land use conditions were undertaken to see the relationship and disparity. Pearson correlation coefficient was used to evaluate the strength of relationship between variables and t-test was performed to assess significance of the correlation at p = 0.01 and 0.05. Descriptive statistics were employed to demonstrate means of the measured parameters.

RESULTS

Dry Aggregate Size Distribution: The results obtained from dry sieving shows that aggregate size distribution considerably varies with land use type and soil depths. Macro-aggregates (> 10mm) were relatively higher in soils of the cultivated land than other land uses (Table 1). This could be due to clodding caused by intensive cultivation. When tilled at wet condition, highly weathered clay dominated soils of the site leads to formation of clods. The mean proportion of dry aggregates of >10 mm and 10□5 mm in the investigated soils decrease in the following order: cultivated land > *Cupressus lusitanica* plantation > natural forest (Fig. 1). As compared to other aggregate size classes, the proportion of 5□3 mm aggregates was lowest in soils of all land uses and depth classes examined. The mean percentage by mass of micro-aggregates (< 0.25 mm) were lowest (4.83%) in soils of the natural forest (Fig. 1), for such soils are less likely to be disturbed by human activities than soils of the cultivated land and due to the higher binding nature of the relatively higher organic matter content of natural forest soils (Fig. 3).

Micro-aggregates (< 0.25 mm) were relatively higher for the top horizon than the underlying horizons (Table 1) and consistently decreased with depth in soils of the three land uses. The relatively higher amount of micro-aggregates recorded for topsoil of each land uses indicates vulnerability of the topsoil to disturbances than subsoil. Macro-aggregates, however, did not show consistent trend with depth. Due to nature of the parent materials, the values of > 10 mm aggregate size classes were highest at 30□75 and 60□120 cm genetic depths in soils of cultivated land and *Cupressus lusitanica* plantation, respectively. The data presented in (Fig. 1) show that the mean percentage of dry aggregates ranged from 4.67% for 5□3mm aggregate size class to 20.56% for > 10 mm aggregate size class in soils of cultivated land. Bigger aggregate size classes predominantly occur in soils of the cultivated land. In soils of *Cupressus lusitanica* plantation and natural forest, the 3□2 mm aggregates has comprised the major proportion of dry aggregates.

Table 1: Percent by mass of dry aggregate size classes in soils of different land use types at varying soil depths by dry sieving.

		% dry aggregates of size (mm)							
Land use	Genetic depth (cm)	> 10 mm	10-5 mm	5-3 mm	3-2 mm	2-1 mm	1-0.5 mm	0.5-0.25 mm	< 0.25 mm
CL	0-30	19.94	19.14	3.40	17.98	14.28	10.43	7.55	7.28
	30-75	23.29	21.54	4.39	16.60	13.46	9.51	5.77	5.43
	75-160	18.46	12.46	6.23	21.60	19.75	11.47	7.75	2.29
CLP	0-25	12.21	21.01	6.86	18.23	16.68	10.02	6.54	8.46
	25-60	14.17	14.74	3.56	16.92	15.56	19.32	11.64	4.09
	60-120	16.22	9.74	2.79	21.00	17.29	19.10	10.26	3.60
NF	0-10	9.83	19.44	6.51	20.02	17.94	12.33	8.46	5.47
	10-60	8.54	13.63	4.48	19.65	20.30	16.99	10.70	5.71
	60-115	6.06	6.78	3.77	20.90	19.93	22.50	14.94	5.13
	115-200	9.83	7.77	3.05	23.60	21.41	15.90	15.44	2.99

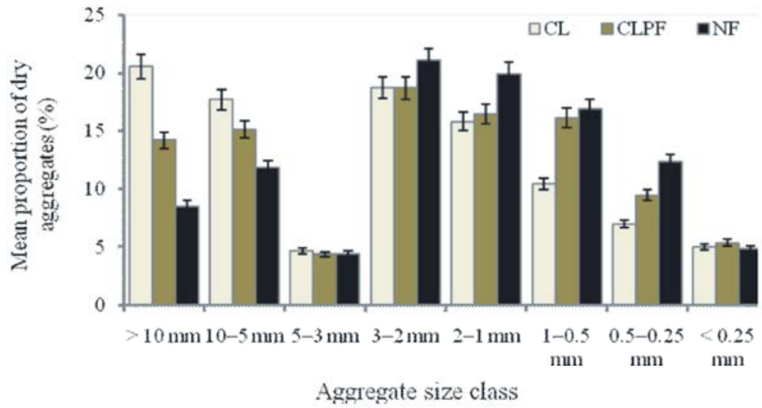

Fig. 1: Mean proportion of dry aggregates of different size classes in soils of cultivated land (CL), *Cupressus lusitanica* plantation forest (CLPF) and natural forest (NF).

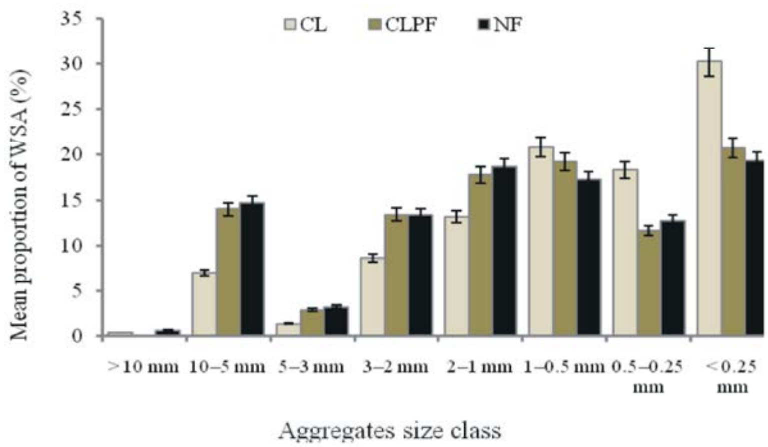

Fig. 2: Mean proportion of WSA of different size classes in soils of cultivated land (CL), *Cupressus lusitanica* plantation forest (CLPF) and natural forest (NF).

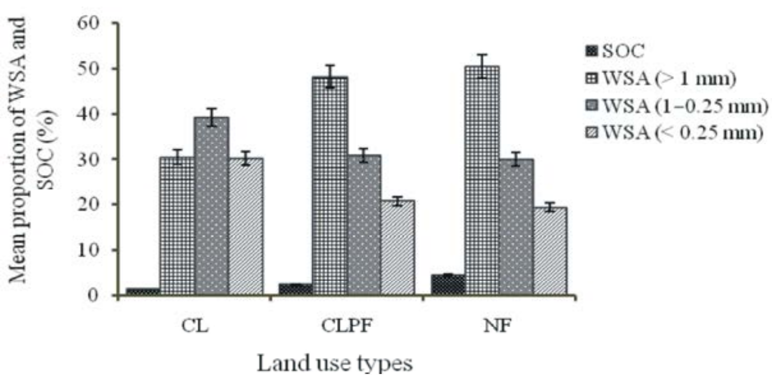

Fig. 3: Graphical representation of the relationship between mean proportion of SOC and WSA in soils of cultivated land (CL), *Cupressus lusitanica* plantation forest (CLPF) and natural forest (NF).

The mean proportion of 5□3 mm aggregate size class was lowest in soils across all land uses. The range□the difference between mean minimum and maximum percentage of dry aggregates of different size classes was highest in soils of natural forest (16.59%), followed by soils of cultivated land (15.89%) and lowest in soils of *Cupressus lusitanica* plantation (14.32%).This specifies that the size distribution range of dry aggregates have wider limits in soils of natural forest and narrow limits in soils of *Cupressus lusitanica* plantation.

Table 2: Percent by mass of water stable aggregates in soils of different land use types at varying soil depths by wet sieving.

		% Water stable aggregates of size (mm)							
Land use	Genetic depth (cm)	> 10 mm	10-5 mm	5-3 mm	3-2 mm	2-1 mm	1-0.5 mm	0.5-0.25 mm	< 0.25 mm
CL	0-30	0.00	5.46	1.15	7.63	13.25	20.24	16.69	35.59
	30-75	0.00	7.46	1.96	13.11	14.77	18.42	14.87	29.40
	75-160	1.16	8.04	1.06	5.06	11.62	23.97	23.43	25.66
CLP	0-25	0.00	16.33	3.99	16.16	17.62	15.70	7.36	22.84
	25-60	0.00	13.21	3.14	15.70	16.41	18.97	11.94	20.63
	60-120	0.43	12.50	1.73	8.47	19.32	23.03	15.68	18.82
NF	0-10	0.00	18.45	3.93	18.51	15.82	13.25	8.74	21.30
	10-60	1.07	15.96	2.64	15.86	19.07	14.46	10.96	19.98
	60-115	0.92	12.41	3.37	9.03	17.87	20.95	18.36	17.10
	115-200	0.59	11.88	2.94	10.14	21.84	20.48	13.07	19.06

Key: CL: cultivated land, CLP: *Cupressus lusitanica* plantation, NF: natural forest.

Water Stable Aggregate Size Distribution: The percentage of WSA of particular size class was different from dry aggregates of same size class for the same sample; depicting variation in soils susceptibility or resistance to the impact of water erosion. Conversion from natural forest to *Cupressus lusitanica* plantation and cultivated land had changed the distribution of WSA and considerably decreased the quantity of macro-aggregates. Soils of the cultivated land had comparatively higher average mass of aggregates in the smaller aggregate size classes (1-0.5, 0.5-0.25 and <0.25 mm). Conversely, soils of *Cupressus lusitanica* plantation and natural forest comprised higher average mass of aggregates in the larger aggregate size classes (10□5, 5□3, 3□2 and 2□1 mm) (Table 2). Those > 10 and 5□3 mm aggregates in all land uses were generally unstable although they are slightly better in soils of the natural forest (Table 2). Micro-aggregates (< 0.25 mm) showed consistent decrease with depth in soils of cultivated land and *Cupressus lusitanica* plantation but inconsistent decrease in soils of natural forest (Table 2). Comparatively, lower WSA as indicated by increased proportion of < 0.25 mm aggregates (35.59%) was observed in the plough layer of the cultivated land. This might be due to mechanical disturbance by tillage, splash erosion and decreased humus content as detected from low SOC content (Fig. 3). The mean percentages of WSA of > 1 mm size classes were dominant in soils of the natural forest whereas the mean percentages of WSA of < 1 mm size classes were dominant in soils of the cultivated land (Fig .2). The better water stability of larger aggregate size classes in soils of the natural forest could be due to cohesion of soil particles in the aggregates bound together by their relatively better OC content (Fig. 3). We found that in continuously cultivated clay loam and loamy soils, micro-aggregates (< 0.25 mm) dominate the proportion of wet sieved aggregates.

DISCUSSION

Aggregate Stability and Its Relation with Soil Organic Carbon: The correlation between SOC and aggregate stability was examined by [4, 19]. They indicated that aggregate water stability increased with increasing concentration of SOC. Comparable to report of the authors, we obtained a positive correlation between SOC and aggregate size classes of > 1 mm ($r = 0.82$). Positive relationship between SOC and aggregate stability was also reported by [20]. Aggregate size classes of 1-0.25 mm ($r = -0.81$) and < 0.25 mm ($r = -0.83$)were, however, negatively correlated with SOC. Variation in aggregate stability with land use might be ascribed to land use change induced variation in SOC content and tillage practices. The dominance of water stable larger aggregate size classes (> 1 mm) in soils of the natural forest might be due to the relatively better SOC content (Fig. 3) and less disturbance by tillage whereas the dominance of small sized aggregate classes (1-0.25 mm) and micro-aggregates (< 0.25 mm) in soils of cultivated land could be due to lower SOC content and long-term tillage practices.[21] revealed that the main cause for decrease in quantity of WSA after conversion of native vegetation to cropland was the decrease in amount of organic matter. The direct impact of cultivation in disturbing soil structure and reducing the percentage of WSA(> 0.25 mm) was reported by [22]. In this regard, the exhaustive traditional tillage practices had caused for reduction of WSA in soils of cultivated land by creating suitable condition for oxidation of SOC.

The data presented in Fig. 3 indicates that the quantity of WSA (> 1 mm) was directly related to the amount of SOC i.e. land use change from natural forest to *Cupressus lusitanica* plantation and cultivated land apparently reduced SOC content and quantity of WSA of size > 1mm. In contrast, the percentage of WSA

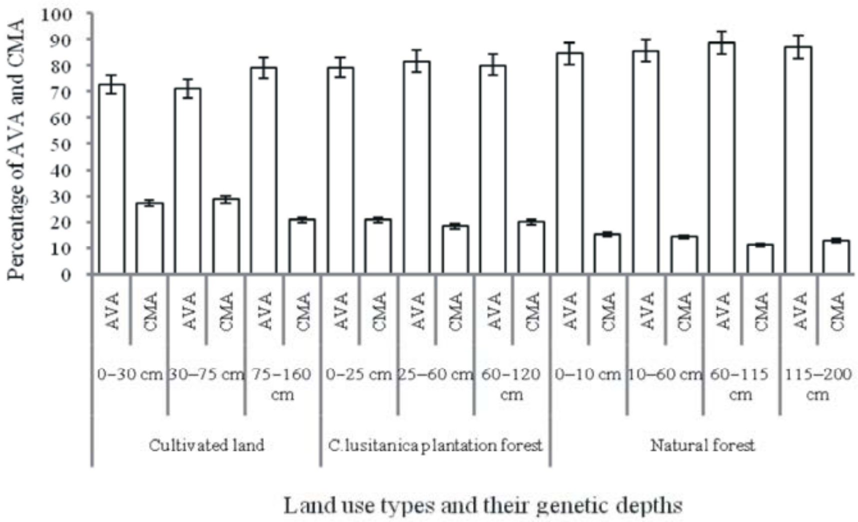

Fig. 4: Proportion of agronomically most valuable aggregates (AVA) of (10-0.25 mm) and cloddy and micro-aggregates (CMA) of (10 mm + 0.25 mm) in soils of different land use types and genetic depths.

size classes of 1-0.25 mm and < 0.25 mm were increased when SOC decreased due to land use conversions from natural forest to *Cupressus lusitanica* plantation and cultivated land. This implies that shift from natural forest to the other land uses posed negative effect on aggregate stability and SOC store. The quantity of larger aggregate classes (> 1mm) increased but that of smaller aggregate classes (1□0.25 mm) and micro-aggregates (< 0.25 mm) decreased when the amount of SOC increased; proving existence of positive relationship between SOC and water stability of aggregates. The smaller amount of micro-aggregates (< 0.25 mm) in natural forest showed that SOC acted as cementing agent, stabilizing micro-aggregates into macro-aggregates. This could be due to complex interactions that exist between SOC storage and aggregate stability [23] forming stable organo-mineral complexes. As a result, soils of natural forest were more cohesive and contained better WSA than soils of the cultivated land. On the other round, soil aggregates provides physical, chemical and biological protection to SOC against decomposition and reduces turnover rate of organic matter as indicated in the reports of [19, 24] that SOC may have encapsulated within the stable aggregates, thereby offering protection against microbial processes and enzymatic reaction.

Agronomically Most Valuable Aggregates: The quantities of agronomically most valuable aggregates (AVA) and those of cloddy and micro-aggregates (CMA) significantly differ among land uses and soil depths. Whereas the AVA (10-0.25 mm aggregate size classes) corresponds to soils with optimum total porosity, CMA (combination of cloddy aggregates of > 10mm and micro-aggregates of < 0.25 mm) lacks water and air for optimum plant growth. The term presented as cloddy aggregates of > 10mm in this paper used to mean aggregates that were formed by anthropogenic factors such as digging or plowing of land and thus differ from natural aggregates of > 10 mm. When soils dominated by clay particles are tilled at wet condition, they form bundles; their pores easily clogged and could become clods. The present study indicated that soils of cultivated land have had relatively higher quantity of cloddy aggregates (> 10 mm) than soils of the natural forest and *Cupressus lusitanica* plantation (Table 1) most probably due to traditional tillage performed during wet conditions. [25] made similar observations that the size of soil aggregates increased under intensive cultivation as a result of increased clodding. Binding of soil particles by OC in natural forest and tilling clay dominated soils at wet conditions in cultivated land might have reduced the quantity of dry sieved micro-aggregates in both land uses.

The AVA prevails in all the investigated soils, where comparatively higher amount (88.82%)recorded for soils of natural forest at a depth of 60□115 cm (Fig. 4). Due to dispersion caused by continuous tillage and compaction created by trampling, soils of the cultivated land show averagely lower AVA than other land uses [26]. Nonetheless, on the basis of the content of these aggregates and according to the classification cited by [11], all the investigated soils were well structured at dry condition. As shown in Fig. 4, the mean percent by mass

Table 3: Coefficient of stability (K_s) and mean weight diameter (MWD) of soils in different land use types.

			MWD (mm)			
Land use	Genetic depth (cm)	K_s	Dry	Wet	ΔMWD	MWD ratio (wet : dry)
CL	0-30	2.67	6.34	1.10	5.24	0.17
	30-75	2.48	7.17	1.42	5.75	0.20
	75-160	3.82	5.83	1.39	4.44	0.24
CLP	0-25	3.84	5.11	2.23	2.88	0.44
	25-60	4.48	4.93	1.97	2.96	0.40
	60-120	4.05	5.06	1.82	3.24	0.36
NF	0-10	5.54	4.59	2.40	2.19	0.52
	10-60	6.02	3.88	2.29	1.59	0.59
	60-115	7.94	2.92	1.92	1.00	0.66
	115-200	6.80	3.76	1.89	1.87	0.50

Table 4: Correlation matrix among aggregate stability indices

	Ks	MWDd	AVA	CMA	MWDw
Ks	1.00	-0.96**	0.96**	-0.96**	0.58
MWDd		1.00	-0.97**	0.97**	-0.66*
AVA			1.00	-1.00**	0.70*
CMA				1.00	-0.70*
MWDw					1.00

*Significant at $p < 0.05$, **Significant at $p < 0.01$.

of AVA to the whole investigated depth in soils of different land uses decrease in the following order: natural forest (86.61%) >*Cupressus lusitanica* plantation (80.42%) >cultivated land (74.44%). Higher proportion of AVA corresponds to soils with optimal total porosity. In contrast, the mean proportion of CMA was comparatively highest in soils of the cultivated land (25.56%) followed by *Cupressus lusitanica* plantation (19.58%) and lowest in soils of the natural forest (13.39%). This shows that land use change from natural forest to *Cupressus lusitanica* plantation and specifically to the cultivated land had considerably reduced the proportion of AVA but increased that of CMA. This was consistent with the finding of [19] that long-term tillage imposes disturbance soil aggregates. We obtained positive correlation between AVA and SOC (r = 0.98) and negative correlation between CMA and SOC (r = -0.98). As a result, soils containing better OC had optimum proportion of agronomically suitable aggregates. Practices that aggravate SOC decomposition including tillage have a negative impact on AVA. Generally, land use shift from natural forest to *Cupressus lusitanica* plantation and cultivated land over the past 25 years had averagely reduced the AVA values by 6.20 and 12.17%, respectively.

Coefficient of Stability and Mean Weight Diameter: The coefficients of stability (K_s) values of soils across all land uses at each depth classes varied between 2.48 and 7.94 and were regularly > 1.5 (Table 3). The difference between mean K_s values of natural forest and cultivated land was reported to be 1.85 by [6] as compared to 3.59 in the present study. According to the classification of [11], the Ks values of all profiles were characteristic for soils of good structure. This does not mean that land use change did not have significant impact on aggregates size distribution and stability. Conversion from natural forest to *Cupressus lusitanica* plantation and cultivated land over the past 25 years had averagely reduced the K_s values by 37.29 and 54.52%, respectively. Reduction of K_s values following land use change support the conclusion that aggregate-size distribution of arable soils during long-term tillage suffered significant qualitative changes as indicated by [27].

The mean weight diameter of dry aggregates (MWDd) ranged from (5.83-7.17) in cultivated soils, (4.93-5.11) in *Cupressus lusitanica* plantation and (2.92-4.59) in natural forest soils (Table 3). Conversion from natural forest to *Cupressus lusitanica* plantation and cultivated land averagely increased MWDd by 32.89 and 70.21% to the whole genetic depth, respectively. Higher MWDd values in the cultivated land might be due to increased quantity of larger aggregates in soils of the land use caused by long-term operations. The MWDd decreased with depth in soils of the cultivated land but did not show any regular trend with depth in other land uses. The mean weight diameter of wet aggregates (MWDw) of soils of investigated land uses decreases according to natural forest > *Cupressus lusitanica* plantation > cultivated land. The reduction of MWDw values following tillage was also reported by [28]. Higher MWDw imply greater stability of aggregates while lower values indicate lower stability and as a result forest soils were more stable than cultivated soils and less susceptible to water erosion. As indicated by [29] soils with a higher MWDw are likely to have a greater resistance to soil degradation. Except increase with depth in soils of the *Cupressus lusitanica* plantation, ΔMWD, the differences in the MWD's between the dry sieved and wet sieved aggregates did not show regular trend with depth in the other land uses. The value of ΔMWD was considerably larger in soils of the cultivated land followed by *Cupressus lusitanica* plantation and smallest in soils of the natural forest (Table 3). A smaller difference in MWD's (ΔMWD) as in forest soils indicate a higher stability of the soil aggregates and resistance to water erosion. MWDw to MWDd ratio also implies that natural forest soils (0.50-0.66) could be more stable than cultivated soils (0.17-0.24) as illustrated by [14] stability index rating. The K_s and MWD_d have strong and highly significant relationship but in opposite direction at $p < 0.01$ (Table 4). This indicates that large sized aggregates contributing to higher MWD_d reduce the K_s value. On the other round, K_s and AVA have positive and highly significant relationship, because AVA (10□0.25 mm aggregates) are relatively stable than the > 10 mm and < 0.25 mm aggregates thereby increasing the stability coefficient.

CONCLUSIONS

Forests at state of natural condition have undisturbed and healthy soil structure. Conversion from natural forest to *Cupressus lusitanica* plantation and cultivated land led to significant changes in soil structure. The size distribution and stability of soil aggregates was governed by tillage practices and SOC content. Tillage practices greatly disturbed natural soil structure leading to higher values of undesirable aggregates (clods) which imply higher MWDd, increased proportion of less water stable smaller sized aggregates and reduction of agronomically valuable fractions in comparison to soils of the natural forest and plantations. Reductions of agronomically valuable aggregates are linked to organic C depletion and tilling clay soils at wet conditions. Water stable aggregates are strongly correlated with organo-mineral complexes and as a result decreased SOC due to shift from natural forest to cultivated land had significantly reduced water stability of aggregates. Increased SOC and absence of damage from tillage operations favored the structure of natural forest soils. Tillage leads to lower stability coefficient suggesting vulnerability to erosion. Soils at natural state had smaller ΔMWD implying larger resistance to water erosion. To sustain soil productivity, preventing uncontrolled expansion of cultivated land at the expense of natural forest and practicing conservation tillage are very imperative.

REFERENCES

1. Gryze, S., L. Jassogne, H. Bossuyt, J. Six and R. Merckx, 2006. Water repellence and soil aggregate dynamics in a loamy grassland soil as affected by texture. European Journal of Soil Science, 57: 235-246.
2. Bronick, C.J. and R. Lal, 2005. Soil structure and management: a review. Geoderma, 124: 3-22.
3. Shephered, T.G., S. Saggar, R. H. Newman, C.W. Ross and J.L. Dando, 2001. Tillage-induced changes to soil structure and organic carbon fraction in New Zealand soils. Australian Journal of Soil Research, 39: 465-489.
4. Lützow, M., I. Kögel-Knabner, K. kschmitt, E. Matzner, G. Guggenberger, B. Marschner and H. Flessa, 2006. Stabilization of organic matter in temperate soils: mechanisms and their relevance under different soil conditions. European Journal of Soil Science, 57: 426-445.
5. Williams, N.D. and E.L. Petticrew, 2009. Aggregate stability in organically and conventionally farmed soils. Soil Use and Management, 25: 284-292.
6. Ciric, V., M. Manojlovic, L.J. Nesic and M. Belic, 2012. Soil dry aggregate size distribution: effects of soil type and land use. Journal of Soil Science and Plant Nutrition, 12(4): 689-703.
7. DeGryze, S., J. Six, K. Paustian, S.J. Morris, E.A. Paul and R. Merckx, 2004. Soil organic carbon pool changes following land-use conversions. Global Change Biology, 10: 1120-1132.
8. Houghton, R.A., D.L. Skole and D.S. Lefkowitz, 1991. Changes in the landscape of Latin America between 1850 and 1985. II - Net release of CO2 to the atmosphere. Forest Ecology and Management, 38: 173-199.
9. Eynard, A., T.E. Schumacher, M.J. Lindstrom, D.D. Malo and R.A. Kohl, 2004. Aggregate size and stability in cultivated South Dakota prairie ustolls and usterts. Australian Journal of Soil Research, 42: 163-170.
10. Tisdall, Oades, J.M., 1982. Organic matter and water-stable aggregates in soils. Journal of Soil Science, 33: 141-163.
11. Shein, Ye.V., T.A. Arhangel'skaya, V.M. Goncharov, A.K. Guber, T.N. Pochatkova, M.A. Sidorava, A.V. Smagin and A.B. Umarova, 2001. Field and laboratory methods of physical properties and soil status investigation. The University of Mosco, pp: 199.

12. Bosko, G., T. Angelina, T. Zorica, K. Branka, V. Dragan, P. Borivoj, 2013. Land use effects on aggregation and erodibility of Luvisols on undulating slopes. Australian Journal of Crop Science, 7(8): 1198-1204.
13. Khormali, F., M. Ajami, S. Ayoubi, Ch. Srinivasarao and S.P. Wani, 2009. Role deforestation and hillslope position on soil quality attributes of loess-derived soils in Golestan province, Iran. Agriculture, Ecosystem and Environment, 134: 178-189.
14. Silva, A.J.N., M.R. Ribeiro, F.G. Carvalho, V.N. Silva and LESF, 2007. Impact of sugarcane cultivation on soil carbon fractions, consistence limits and aggregate stability of Yellow Latosol in Northeast Brazil. Soil and Tillage Research, 94: 420-424.
15. Mesfin, A., 1998. Nature and management of Ethiopian soils. Haramaya University of Agriculture/ILRI, Addis Ababa, Ethiopia.
16. Kemper, W.D. and R.C. Rosenau, 1986. Aggregate stability and size distribution. In: Klute, A. (Ed), Methods of soil analysis, Part 1. 2nd ed. Agron.Monogr. 9. ASA, Madison, WI.
17. Walkley, A. andI. A. Black, 1934. An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Science, 63: 251-263.
18. Bavel, Van C.H.M., 1950. Mean weight diameter of soil aggregates as a statistical index of aggregation. Soil Science Society of America Proceeding, 14: 20-23.
19. Holeplass, H., B.R. Sign and R. Lal, 2004. Carbon sequestration in soil aggregates under different crop rotation and nitrogen fertilization in an Inceptisol in southeastern Norway. Nutrient Cycling and Agroecosystem, 70: 167-177.
20. Henry, O.T. and B. Mensah, 2014. Impact of aggregate size on soil carbon sequestration and aggregate stability. International Journal of Science Research in Agricultural Science, 1(5): 80-89.
21. Lal, R., 1993. Tillage effects on soil degradation, soil resilience, soil quality and sustainability. Soil and Tillage Research, 27: 1-8.
22. Martens, D.A., T.E. Reedy and D.T. Lewis, 2003. Soil organic carbon content and composition of 130-year crop, pasture and forest land-use managements. Global Change Biology, 10: 65-78.
23. Feller, C., A. Albrecht, B. Blanchart, Y.M. Cabidoche, T. Chevallier, C. Hartmann, V. Eschenbrenner, M.C. Larre-Larrouy and J.F. Ndandov, 2001. Soil Organic carbon sequestration in tropical areas. General considerations and analysis of some edaphic determinants for lesser Antilles Soils. Nutrient Cycling and Agroecosystem, 61: 19-31.
24. Lal, R., R.F. Follet and J.M. Kimble, 2003. Achieving soil carbon sequestration in the United States. A challenge to policy makers. Soil Science, 168: 827-845.
25. Hakansson, I., W.B. Voorhees and H. Riley, 1988. Vehicle and wheel factors influencing soil compaction and crop response in different traffic regimes. Soil and Tillage Research, 11: 239-282.
26. Gajic, B. and M. Zivkovic, 2006. Aggregate composition and stability of structural aggregates of non-calcareous rendzinas in Eastern Serbia. Journal of Agricultural Science, 51(2): 141-150.
27. Boško, A.G., J.K. Branka, D.D. Snežana, J.S. Zorica and M.D. Ranko, 2014. Effect of land use change on the structure of GleyicFluvisols in Western Serbia. Journal of Agricultural Science, 59(2): 151-160.
28. Emadi, M., M. Baghernejad and H.R. Memarian, 2009. Effect of land-use change on soil fertility characteristics within water-stable aggregates of two cultivated soils in northern Iran. Land Use Policy, 26: 452-457.
29. Teixeira, P.C. and R.K. Misra, 1997. Erosion and sediment characteristics of cultivated forest soils as affected by the mechanical stability of aggregates. Catena, 30: 119-134.