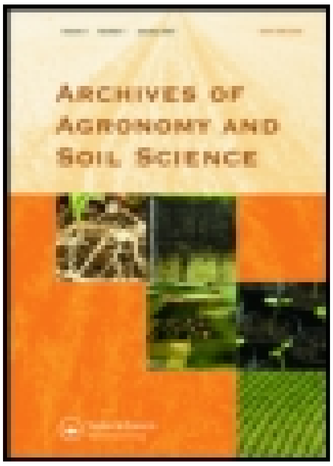

Archives of Agronomy and Soil Science
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gags20

Soil structure changes due to different land use practices in the central Zagruos region, Iran

Ali Asghar Zolfaghari[a], Ruhollah Taghizadeh-Mehjerdi[b], Farrokh Asadzadeh[c] & Mohammad-Ali Hajabbasi[d]

[a] Faculty of Desert Science, Semnan University, Semnan, Iran;

[b] Faculty of Agriculture and Natural Resources, University of Ardakan, Yazd, Iran;

[c] Department of Soil Science, Faculty of Agriculture Science, Urmia University, Urmia, Iran;

[d] Department of Soil Science, Faculty of Agriculture Science, Isfahan University of Technology, Isfahan, Iran

Accepted author version posted online: 23 Apr 2015.

To cite this article: Ali Asghar Zolfaghari, Ruhollah Taghizadeh-Mehjerdi, Farrokh Asadzadeh & Mohammad-Ali Hajabbasi (2015): Soil structure changes due to different land use practices in the central Zagruos region, Iran, Archives of Agronomy and Soil Science, DOI: 10.1080/03650340.2015.1043898

To link to this article: http://dx.doi.org/10.1080/03650340.2015.1043898

Publisher: Taylor & Francis

Journal: *Archives of Agronomy and Soil Science*

DOI: 10.1080/03650340.2015.1043898

Soil structure changes due to different land use practices in the central Zagruos region, Iran

Ali Asghar Zolfaghari[a*], Ruhollah Taghizadeh-Mehjerdi[b], Farrokh Asadzadeh[c], Mohammad - Ali Hajabbasi[d]

[a] Faculty of Desert Science, Semnan University, Semnan, Iran;

[b] Faculty of Agriculture and Natural Resources, University of Ardakan, Yazd, Iran;

[c] Department of Soil Science, Faculty of Agriculture Science , Urmia University, Urmia, Iran;

[d] Department of Soil Science, Faculty of Agriculture Science, Isfahan University of Technology, Isfahan, Iran

* Corresponding author. Email: azolfaghari@semnan.ac.ir

Abstract

In this study, effect of land use treatments and the feasibility of fractal dimension to quantify soil aggregate stability was investigated in the central Zagrous, Iran. For this purpose the non-linear fractal dimension *(Dnl)*, linear fractal dimension (D_l) and the mean weight diameter (MWD) of aggregates were compared. Soil samples from three sites with four adjacent land-use types namely: forest area (F), cultivated lands adjacent to forest (CAF), pasture (P), and cultivated lands adjacent to pasture (CAP) were collected. Results showed that soils under cultivated lands had higher bulk density (BD) (1.30-1.38 Mg m^{-3}) compared with the adjacent soils under forest (1.19 Mg m^{-3}) and pasture (1.21 Mg m^{-3}). In the 0-15 cm layer, soil organic matter content (SOM) in the cultivated plots were respectively 30 and 31% lower compared to the forest and pasture soils. The lowest CVs belonged to D_{nl} (5-8%) demonstrating that D_{nl} was more accurate than D_l (8-14%) and MWD (30-53%) methods. Cultivated pasture (CAP) had the largest value of D_{nl}, while pasture (P) had the smallest value of D_{nl}. Difference of D_{nl} between forest and pasture was not significant, whereas both of them were significantly differed from cultivated forest (CAF) and pasture (CAP). D_l did not differ significantly between forest and pasture with cultivated forest (CAF). There were significant differences between forest and pasture for the measured MWD. Both fractal dimensions had

negative correlation with MWD, SOM, hydraulic conductivity (HC) and macroaggregates (>0.25 mm) and positive correlation with BD and total porosity (TP).

Key words: Aggregate stability; Fractal dimensions; mean weight diameter; physical properties;

Introduction

The area of forests and pastures in Asia decreased by about 313 mln ha during the period from 1970 to 1980, and that was the greatest reduction in the world. In the past (1942), the area of forests in Iran was 19.5 Mha. Last estimates indicated that the forest area has decreased to 12 Mha. Some of the main causes of soil erosion and degradation in Iran are overgrazing, land use changes, and land mismanagement (Abrishamkesh et al. 2011). Rapid population growth in the residential areas of central Zagrous in Iran, has increased the demand for farmland and food production. One way to expand the cropland is clear cutting the forests and converting pastures to agricultural fields. This would result in degradation soil structure, loss of soil quality and consequently destruction of natural ecosystem (Hajabbasi et al. 1997).

Soil structure has a key role in the functioning of soil, its capacity to support plant and animal life (Braunack & Dexter 1989; Abrishamkesh et al. 2011), transport of water and contaminants through the unsaturated zone underlying agricultural fields (Bevan & German 1982), water availability, soil erodibility and response of soil to changes in the environment. Soil structure holds a vital, but often neglected role in sustainable food production and achievements toward a well-developed society (Abrishamkesh et al. 2011). Different management practices can affect the soils aggregate stability as an index of soil structure status and Soil quality (Czyz & Dexter 2009; Josa et al. 2010).

A scale is needed to quantify soil structure variation. Aggregate-size distribution (ASD), is a representative of soil structure and is potentially a useful way, even if not exhaustive, of expressing the amount of soil structure. The need to characterize soil ASD with a single parameter has long been recognized. Early workers simply used the percentage by weight of aggregates greater than some specified, but arbitrary, sieve size. However, much information is lost by this approach (Puri & Puri 1939). As a result several empirical indices have been proposed for describing the entire distribution with a single value. Van Bavel (1949) used mean-weight diameter (MWD) to integrate aggregate-size distribution obtained by mechanical sieving. Mazurak (1950) suggested that the geometric mean diameter may be more appropriate. More recently Baldock and Kay (1987) used the following power function to describe the cumulative percentage of aggregate by weight less than a characteristic linear dimension x (e.g. equivalent diameter or height);

$$W<x=A(x)^{B} \qquad (1)$$

Where W is the cumulative percentage weight of aggregates; x is the characteristic linear dimension; and A and B are regression coefficients. Since the coefficient B exhibited maximum variation, it was used as the index of aggregate size distribution. Previous indices to quantify soil structure, often, were empirical. Recent findings in fractal theory introduced scaling parameters, as fractal dimensions that may be suitable for characterizing aggregate-size distribution in soil. According to Mandelbrot (1982), fractals are characterized by a power-law relation between the number and size of objects. The value of fractal dimension D is equal to the absolute value of the exponent in the relation

$$N > x = K(x)^{-D} \qquad (2)$$

Where $N > x$ is the cumulative number of objects greater than x, and k is a parameter corresponding to the number of fragments of unit length. The value of D depends on the shape of individual objects within the distribution, and the overall extent of aggregate fragmentation. The higher value of D is associated with the greater aggregate fragmentation. This means that the shape of aggregate may be similar in various ranges of aggregate size. However, it may be assumed that the value of D is scale invariant in shape. Rasiah et al. (1992) used the fractal dimension to evaluate the influence of cropping and wetting treatments, and aggregate size on the fragmentation of soil aggregates. A significant relation between aggregate number and fragmentation fractal dimension was observed. The estimated D value varied with cropping and wetting treatments. Perfect and Kay (1991) reported that fractal theory may be used to characterize soil-aggregate size distribution from different cropping treatments. Higher D values indicated greater soil fragmentation. Gulser (2006) measured the relation between fractal dimension and organic carbon (OC) content and bulk density. He proposed that fractal dimensions decreased with increasing OC content, MWD and with decreasing BD. Zhou et al. (2007) indicated that the fractal dimension could better describe the distribution of aggregates than MWD and GMD, which reflects the changes of aggregates under three different tillage measures.

The objectives of this study were to determine the effect of different land use treatments on soil structural quality and investigate the ability of fractal dimensions to quantify soil aggregate stability. In addition, finding of relationships between fractal dimension and some soil properties such as mean-weight diameter, bulk density and soil organic matter content is other aims of this study.

Materials and methods

Study Area

The study area is located within the northern parts of Karoon watershed in the central Zagros, Iran (31° 11′ N and 51° 14′ E) with an altitude of about 2050 m above the sea level. The soil was classified as Typic Halcixerolls and Typic Haploxerepts. Land-used pattern included forest, unimproved pastures, and cultivated lands adjacent to the both forests and pastures. The prevailing climate is Mediterranean with a long-term mean annual precipitation of 502 mm. The forest area is approximately 340,000 hectare (24% of the total watershed area) with a history of at least 20 years of anthropogenic activities such as cropping and pasture grazing. Dominant tree species of these sparse forests is oak (*Quercus brontii*). This area has been subject to deforestation and tillage disturbance where barley and wheat have been cultivated continuously since 1987. Plant cover of long-term pastures ranges from 90% to 70% depending on the severity of grazing. Dominant grass species in pasture include *Astragalus spp*.

Soil analyses

A two-factor analysis of variance under randomized complete block design consisting of four replications was used. Soil samples were collected from three sites with four adjacent land-use types: forest area (F), cultivated lands adjacent to forest (CAF), pasture (P), and cultivated lands adjacent to pasture (CAP) in October 2005. Some characteristic of the soil used in this study were evaluated in soil samples taken from the 0-7 and 7-15 cm depths in the field (Table 1). After soil samples were air dried and passed through a sieve with 2 mm size opening, some soil properties were determined as follows.

Particle size distribution was determined by hydrometer method (Gee & Bauder, 1986). Soil reaction (pH) and electrical conductivity ($EC_{25°C}$) were determined in 1:1 soil water suspension. Soil organic mater (SOM) content was determined by modified Walkely-Black method (Nelson & Sommers 1982). Saturated hydraulic conductivity (SHC) in each site was measured as three replicates in undisturbed soil samples by using a steel cylinder of a 100 cm^3 volume (5 cm in diameter, and 5 cm in height) by the constant head method according to Klute and Dirksen (1986). Bulk density in each site was measured using cylindrical soil cores (5 cm diameter; 5 cm depth) by weighing undisturbed soil and oven-drying at 105 °C for 24 h

(Blake & Hartge 1986). Total porosity was calculated in undisturbed samples of 100 cm^3 assuming no air trapped in the pores and validated using dry bulk density and a particle density of 2.65 g cm^{-3} (Danielson & Sutherland 1986).

Insert table 1

Aggregate size distribution

The wet sieving method of Kemper and Rosenau (1986) with a set of 2, 1, 0.5, 0.25 and 0.1 mm diameter sieves was used to determine aggregate size distribution. After passing soil sample through an 8 mm sieve, approximately 50g of the soil was put on the first sieve of the set and was gently moistened to avoid sudden rupture of the aggregate. After moistening, the set was sieved in water at 50 vertical oscillations per minute. After 10 min of oscillation, soil remaining on each sieve was dried, and then sand and aggregate were separated (Kemper & Rosenau 1986). For determination of aggregate size distribution, the weight ratio of aggregates of each sieve (< 0.1 mm, 0.5-0.25, 1-0.5, 2-1, and>2) to the total weight of aggregates was calculated.

Mean weight diameter was calculated as follows:

$$MWD = \sum_{i=1}^{n} X_i W_i \qquad (3)$$

where X_i is the mean diameter in mm of the openings of two consecutive sieves and W_i the weight ratio of aggregates remaining on the *i*th sieve.

Estimation of fractal dimension

The number of aggregates left on *i*th sieve of a nest of sieves can be computed from aggregate mass data as follows (Tyler & Wheatcraft 1989):

$$N_i = \frac{M(x_i)}{{x_i}^3} \qquad (4)$$

where: N_i is the number of aggregates left on *i*th sieve of a nest of sieve; $M(x_i)$ is the aggregate massing on the *i*th sieve of a nest of sieves; and X_i is the size of aggregate in mm. Inserting Eqn(4) into Eqn(2) and assuming scale-invariant density and shape of aggregates, the following equation is derived for the estimation of D from mass-size distribution

$$\sum_{x=1}^{x} \frac{M(x)}{x^3} = K \ x^{-D} \qquad (5)$$

where M(x) is the total mass of aggregate with sizes less than x. Soil samples were used in a dry sieve and aggregate bulk density of different size classes was measured by Chepil (1950) as reported by Rasiah and Biederbeck (1995).

Fractal dimension in Eqn(5) was determined by linear D_l and non-linear D_{nl} method. In the linear method, according to Eqn(5), D was obtained by regression between log N ($x \geq X$) and log x. Optimization Marquradt (1963) technique was used for non-linear fitting. Statistical analysis of data was conducted using the SAS computer software package.

Results

Statistical analysis for bulk density was not possible, because this soil parameter was measured on pooled samples. However, the variation in the data was small (1290–1410 kg m^{-3}). Therefore, the aggregate bulk density was scale-invariant and the average of these values (1332 kg m^{-3}) was used as the bulk density of soil aggregates for determination of D in Eq. (5).

The size of aggregate fraction is presented in Fig. 1. Analysis of variance indicated that size distribution of aggregate fraction was influenced by land use treatments at the 1% level of probability. The greatest and the least aggregate fractions smaller than 0.1 mm were related to the CAF and P land use practices, respectively. Also the highest proportion of fractions 0.25-0.1, 0.5-0.25 and 1-0.5 mm were found in pasture, the lowest proportion of aggregate of the same fractions were found in forest treatment. The highest proportion of fraction of 2-1 mm was obtained in forest. The greatest and the least proportion of fractions 2-4 mm in size were observed in the F and CAP treatments, respectively. Distribution of soil aggregates differed significantly between cultivated and the pasture and forest soils. The cultivated soils had significantly greater mass of aggregates in smallest diameter class (<0.1 mm) than pasture and forest soils. In the 4-2 and 2-1 mm classes, however, the pasture and forest soils showed greater number of aggregates than cultivated soils. Tillage in the cultivated soils disintegrated the large aggregates into smaller aggregates, resulting in the higher proportion of small aggregates in these soils.

Insert Fig 1

Effects of the change in land use on the mean values of soil organic matter (SOM), bulk density (BD), saturated hydraulic conductivity (SHC) and total porosity (TP) are given in Table 2. Soils under cultivation had higher bulk density than the adjacent soils under forest and pasture. The forest soil had the lowest and the cultivated pastures had the highest bulk density values. Soil bulk density was not significantly different between the pasture and forest sites. The loss of SOM by the conversion of the pasture and forest into cultivated fields probably caused a higher bulk density in these treatments. Higher bulk density also can be attributed to compaction and degradation of soil structure (Igwe 2001). SOM of the cultivated soils had decrease by 30 and 31% for 0-15 cm layer compare to forest and pasture, respectively (Table 2). There was a significant difference in total porosity between cultivated soils and forests and pastures soils. As compare to total porosity of forest and pasture, that of cultivated land decreased about 8 and 13%, respectively (Table 2). The forest and pasture soils did not differ in total porosity for the layer of 0-15 cm. In this study, there was a significant difference in saturated hydraulic conductivity (SHC) between forest and the rest of treatments. No significant difference between pasture and cultivated forest was observed. While the forest had highest hydraulic conductivity, the cultivated forest had the lowest value at the depth of 0-15 cm.

Insert table 2

Fig. 2 shows linear regression between D_{nl} and D_l values. The slope and intercept of the linear regression line were 0.36 and 1.75, respectively. Statistical comparison between this line and the 1:1 line (the null hypothesis was: intercept of 0 and slope of 1) indicated that slope and intercept of this line was significantly different from line of 1:1. Consequently, the values for D_l were different from those for D_{nl}. Therefore, appropriate values for D must be selected to quantify soil structure variation, according to theoretical consideration, statistical analysis and the literature.

Insert Fig 2

Statistical analysis of data indicated that there was no significant difference in fractal dimensions (*e.g.* D_{nl} and D_l) in different depths at the 5% level of probability. Therefore, the mean values of D_{nl} and D_l were used in further statistical analysis. The values of D_{nl} and D_l for different land use treatments ranged from 2.853-3.024 and 3.04- 3.56, respectively (Table 3). Cultivated pasture (CAP) had the largest value of D_{nl}, while pasture (P) had the smallest value of D_{nl}. Difference of D_{nl} between forest and pasture was not significant, while both of them were significantly different when compared with cultivated forest (CAF) and cultivated pasture (CAP). D_l did not show a significant difference between forest and pasture with cultivated forest (CAF). There was a significant negative correlation between fractal dimensions and proportion of macroaggregates (>0.25 mm).

Insert table 3

In this study, the higher fractal dimensions were observed in soils dominated by smaller aggregates in cultivated forest and cultivated pasture. The smaller fractal dimensions have always been observed in soils with larger aggregates present in forest and pasture (Table 3).

Statistical analysis of data showed no significant difference between values of MWD at different depths, therefore the mean values of MWD were used in further statistical analysis. Mean-weight diameters (MWD in mm) for different land use treatments are shown in Table 3. The observed range of MWD was between 0.26-0.58 mm. The mean-weight diameter of soil aggregates was significantly greater in the forest and pasture soils than in the cultivated forest and cultivated pasture. Cultivation caused an approximate decrease of 48% and 32% MWD in the forest and pasture respectively compared with that of the undisturbed sites. Relationship between the values of D_{nl} and MWD is shown in Fig. 3. The best-fit equation for this relationship is as follow:

$$D_{nl} = -0.22 \ln(MWD) + 2.7 \quad (6)$$

Non-linear relationship between D_{nl} and MWD indicated that MWD was unable to quantify soil aggregate stability in the same way as D_{nl}.

Insert Fig 3

There was no systematic variation for MWD to describe the aggregate stability (Table 4). For example, the value of MWD of pasture (P) was lower than that of forest (F). D_{nl} in this study was not significantly different between forest and pasture. These results show that D_{nl} may be more useful in practice. Comparison of CVs of MWD with both fractal dimensions (e.g. D_{nl} and D_l) showed larger CVs of MWD. These findings indicated that the fractal dimensions were more accurate and more precise than MWD and better able to discriminate between land use treatments than MWD.

Linear and non-linear fractal dimensions were found by applying Equation 5 into each wet sieving soil data set. A significant linear correlation ($r = 0.83^{**}$) was found between D_l and D_{nl} parameters. The relationships among fractal dimensions (e g. D_{nl} and D_l), MWD, SOM and other parameters are given in Table 4. Both fractal dimensions had negative correlation with MWD, SOM, HC and macroaggregates (>0.25 mm) and a positive correlation with BD and TP. D_{nl} values had the highest correlations with all properties when compared with D_l values. These findings indicated that D_{nl} was more sensitive to land use changes than D_l and MWD.

Insert table 4

Discussions

Effects of the change in land use on the mean values of soil organic matter (SOM), bulk density (BD), saturated hydraulic conductivity (SHC) and total porosity (TP) are similar to findings reported by Hajabbasi et al. (1997) and Haghighi et al. (2010). Hajabbasi et al. (1997) showed that deforestation and subsequent tillage practices resulted in a 50% decrease in SOM for a soil depth of 0-30 cm in central Zagrous Mountain regions. Haghighi et al. (2010) reported that the conversion of natural pasture to dry land farming led to a significant decrease in SOM. This decrease in SOM leads to increased bulk density and decreased total porosity (TP), thus decreasing soil infiltration.

There was a significant difference in total porosity between cultivated soils and forests and pastures soils. Similar findings were reported by Celik (2005), that cultivation of forest and pasture resulted a 5% decrease in total porosity for soil in depth of 0-10cm. Mbagwu and Piccolo (2004) reported a reduction in structural stability of soil aggregates when the forested soils were converted to cultivated soils.

The values of D obtained using the non-linear procedure were always smaller than the corresponding values obtained using linear procedure. By the non-linear method, the values of D were most of the time less than 3, while for the linear method most of the values of D were greater than 3. The standard error of D_l and D_{nl} were 0.025 and 0.0024, respectively. These results are consistent with those reported by other investigators (Rasiah et al. 1995; Pirmoradian et al. 2005). Using a detailed error structure analysis, Rasiah et al. (1995) have also shown that values of D_{nl} were more accurate than D_l.

Changes in soil structure are often accompanied by changes in management practices and may affect the effectiveness of these changes. Soil aggregate composition has been found to be a good indicator of the changes in soil structure. The fragmentation fractal dimension can be inferred from the role of biological processes in soil structure formation. Inorganic and relatively persistent organic binding agents are important in the stabilization of microaggregates (<0.25mm in diameter) by implementation of different kinds of mechanisms (Zhao et al. 2006). In forest and pasture sites, soil environment is more favorable for microbial activity, so there were more water stable aggregates in forest soil and pasture in comparison with cultivation lands. It has found, that the value of fractal dimensions increases with increasing fragmentation and higher fractal dimension values indicate a distribution dominated by smaller fragment (Perfect & Kay 1991; Millan et al. 2002).

The mean-weight diameter of soil aggregates was significantly greater in the forest and pasture soils than in the cultivated forest and cultivated pasture. We can proof these results by the following descriptions. The presence of the macroaggregates is positively associated with organic matter concentration (Duiker et al. 2003). Cultivation broke up soil aggregates and exposed previously inaccessible organic matter to microbial attack and accelerated decomposition and mineralization of SOM (Shepherd et al. 2001). In this study, a significant difference in MWD between forest and pasture was observed, while Celik (2005) was not able to detect a significant difference between forest and pasture in Mediterranean highland that is practically more acceptable.

The trend of variation for MWD observed in this study cannot explain theoretically, because soil aggregate fragmentation should be practically similar in forest and pasture. Similarly, Celik (2005) could not find any significant difference in MWD between forest and pasture.

The similar positive correlation between D_l and D_{nl} was found as 0.86 by Rasiah et al. (1995) and a positive relationship was observed as R^2 =0.19 by Pirmoradian et al. (2005). Rasiah et al. (1995) and Pirmoradian et al. (2005) reported that linear fractal dimensions were not good indicators of changes in soil structure due to differences in soil management when compared to non-linear fractal dimension. In this study non-linear fractal dimension differed in narrow range (from 2.853-3.024) compared to linear fractal dimension (from 3.04-3.56).

The significant negative correlations between fractal dimensions and MWD indicated that D_{nl} and D_l values increased with decreasing aggregate size due to changes in land use. Perfect and Kay (1991) and Gulser (2006) reported that MWD was negatively correlated with fractal dimension. Fractal dimensions had a significant negative correlation with SOM content. Increases in SOM content in forest and pasture treatments increased the proportion of larger aggregates in the distribution and caused a decrease in fractal dimensions. In numerous studies, it has found that fractal dimensions are negatively correlated with SOM content and aggregate stability (Rasiah et al. 1993; Gulser 2006). Both fractal dimensions had a significant linear correlation with bulk density and total porosity. Decreasing content of macroaggregation in soil due to changes in land use caused an increase in fractal dimension, bulk density and a decrease in total porosity.

Consequently, the results showed that the changes of land use might lead to a loss in soil quality and degradation. Thus, documentation of changes is necessary to improve land management in this and in other regions. Any change in soil management and land use should be evaluated and monitored to conserve soil quality. Conservation of SOM leads to improved soil aggregate stability and soil hydraulic properties due to interactions among various soil properties. Appropriate technology for dry land farming and suitable measures are necessary to decrease soil degradation and increase soil stability where a change in land use is required. The farming of native lands should be prevented because the change in land use will not be sustainable for long periods and will increase the severity of soil and land degradation. This study shows a need for strategies regarding sustainable land management and policies that decrease the negative effects of native land cultivation. To prevent further degradation of soils in the region, a conservation reserve program (e.g. to return cropland to grassland) can be used to improve the water retention and soil structure (Haghighi et al. 2010).

Conclusion

Changes in land use led to significant changes in key soil properties including BD, mean weight diameter, soil saturated hydraulic conductivity, available water content, final infiltration rate and SOM content. The degradation of these properties can negatively affect soil productivity and erosion. Improper land management results in soil and water loss. Thus, proper land use and management play a major role in sustainable agriculture and development programmers. Identifying, quantifying and monitoring land use changes are necessary to prevent soil degradation and to improve soil and land management (Haghighi et al. 2010). In summary, the results showed that the cultivated forest and pasture significantly decreased SOM, MWD and TP and increased BD when compared to relatively virgin forest and pasture. Changing land use forest to cultivated forest had higher negative effects on SOM and MWD than changing pasture to cultivated pasture. The proportion of macroaggregates in the fractions (>0.25 mm) was decreased due to change in land use. Increases in the number of stable macroaggregates are associated with good sustainable soil structure. The values of D_l and D_{nl} decreased as the number of stable macroaggregates in the soil increased. Lower fractal dimension values indicated a distribution dominated by larger fragments rendering aggregates more resistant to fragmentation. The relationships between the fractal dimensions and the other parameters showed that fractal dimensions decreased with increasing SOM, MWD and macroaggregates (>0.25 mm) and decreased with BD and TP. The non-linear fractal dimension D_{nl} was more appropriate than mean weight diameter MWD to quantify the induced soil aggregate stability by land use treatments. When the values of coefficient of variations (CVs) between D_l and D_{nl} were compared, lower value of CV indicated the higher precision of the method. In this study the lowest CVs were detected in D_{nl}, resembling D_{nl} as more accurate and precise than D_l and MWD. Due to strong theoretical base of the fractal dimension, results of this analysis can be used to evaluate the soil aggregate stability. As a result, change in land use decreases soil structure through decreasing macroaggregates.

References

Abrishamkesh S, Gorji M, Asadi H. 2011. Long-term effects of land use on soil aggregate stability. Int Agrophys. 25:103-108.

Baldoch JA, Kay BD. 1987. Influencing of cropping history and chemical treatment on the water-stable aggregation at a silt loam soil. Can J Soil Sci. 67:501-511.

Bevan K, German P .1982. Macropores and water flow in soils. Water Resour Res. 18:1311-1325.

Blake GR, Hartge KH. 1986. Bulk density. In: Klute A, editor. Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. Madison (WI): Agronomy Society of America and Soil Science Society of America; p. 363-375.

Braunack MV, Dexter AR. 1989. Soil aggregation in the seedbed. Soil Till Res. 14:259-279.

Celik I. 2005. Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil Till Res. 83:270-277.

Chepil WS. 1950. Method of estimating apparent density of discrete soil grains and aggregates. Soil Sci. 70:351-362.

Czyz EA, Dexter AR. 2009. Soil physical properties as affected by traditional, reduced and no-tillage for winter wheat. Int Agrophys. 23:319-326.

Danielson RE, Sutherland PL. 1986. Porosity. In: Klute A, editor. Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. Madison (WI): Agronomy Society of America and Soil Science Society of America; p. 443-461.

Duiker SW, Rhoton FE, Torrent J, Smeck NE, Lal R. 2003. Iron (hydr) oxide crystallinity effects on soil aggregation. Soil Sci Soc Am J. 67:606-611.

Gee GW, Bauder JW. 1986. Particle size analysis. In: Klute A, editor. Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. Madison (WI): Agronomy Society of America and Soil Science Society of America; p. 383-411

Gulser C. 2006. Effect of forage cropping treatments on soil structure and relations with fractal dimensions. Geoderma. 131:33-44.

Haghighi F, Gorji M, Shorafa M. 2010. A Study of the effects of land use changes on soil physical properties and organic matter. Land Degrad Dev. 21:496-502.

Hajabbasi MA, Jalalian A, Karimzadeh R. 1997. Deforestation effects on soil physical and chemical properties, Lordegan, Iran. Plant Soil. 190:301-308.

Igwe CA. 2001. Effects of land use on some structural properties of an Ultisol in SE Nigeria. Int Agrophys. 15:237-241.

Josa R, Ginovart M, Solé A. 2010 Effects of two tillage Techniques on soil macroporosity in sub-humid environment. Int Agrophys. 24:139-148.

Kemper WD, Rosenau RC. 1986. Aggregate stability and size distribution. In: Klute A, editor. Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. Madison (WI): Agronomy Society of America and Soil Science Society of America; p. 425-442.

Klute A, Dirksen C. 1986. Hydraulic conductivity and diffusivity. In: Klute A, editor. Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. Madison (WI): Agronomy Society of America and Soil Science Society of America; p. 687-734.

Mandelbrot BB. 1982. The fractal geometry of nature. San Francisco: Freeman.

Marquradt WD. 1963. An algorithm for the least squares sum of nonlinear parameters. Soc Indust Appl Math. 11:431-441.

Mazurak AP. 1950. Effect of gaseous phase on water-stable synthetic aggregates. Soil Sci. 69:135-148.

Mbagwu JSC, Piccolo A. 2004. Reduction in organic matter fractions and structural stability following cultivation of tropical forests in Ethiopia and Nigeria. Int Agrophys. 18:23-29.

Millan H, Gonzalez-posada M, Benito RM. 2002. Fragmentation fractal dimensions of vertisoil simples:influence of sieving time and soil pretreatment. Geoderma. 109:75-83.

Nelson DW, Sommers LE. 1982. Total carbon, organic carbon, and organic matter. In: Klute A, editor. Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. Madison (WI) : Agronomy Society of America and Soil Science Society of America; p. 539-579.

Perfect E, Kay BD. 1991. Fractal theory applied to soil aggregation. Soil Sci Soc Am J. 55:1552-1558.

Pirmoradian N, Sepaskhah AR, Hajabbasi MA. 2005. Application of fractal theory to quantify soil aggregate stability as influence by tillage treatments. Biosyst Eng. 90:227-234.

Puri AM, Puri BR. 1939. Physical characteristics of soil. II. Expressing mechanical analysis and state of aggregation of soil by single values. Soil Sci. 33:141-163.

Rasiah V, Biederbeck VO. 1995. Fractal dimension of soil aggregation influence of bulk density, fitting procedure, and oily waste sludge incorporation. Soil Sci. 160:250-255.

Rasiah V, Kay BD, Perfect E. 1992. Evaluation of selected factors influencing aggregate fragmentation using fractal theory. Can J Soil Sci. 72:97-106.

Rasiah V, Kay BD, Perfect E. 1993. New mass-based model for estimating fractal dimension of soil aggregates. Soil Sci Soc Am J. 57:891-895.

Rasiah V, Perfect E, Kay BD. 1995. Linear and nonlinear estimates of fractal dimension for soil aggregate fragmentation. Soil Sci Soc Am J. 59:83-87.

Shepherd T, Saggar G, Newman RH, Ross CW, Dando JL. 2001. Tillage induced changes in soil structure and soil organic matter fractions. Soil Res. 39:465-489.

Tyler SW, Wheatcraft SW. 1989. Applications of fractal mathematics to soil water estimation. Soil Sci Soc Am J. 53:987-996.

Van Bavel CHM. 1949. Mean weight-diameter of soil aggregation as a statistical index of aggregation. Soil Sci Soc Am J. 14:20-23.

Zhao SW, Su J, Yang YH, Liu NN, Wu JS, Shangguan ZP. 2006. A fractal method of estimating soil structure changes under different vegetations on Ziwuling Mountains of the Loess Plateau, China. Agric Sci China. 5:530-538.

Hu Z, Lü YZ, Yang ZC, Li BG. 2007. Influence of conservation tillage on soil aggregates features in north China plain. Agric Sci China. 6:1099-1106.

Table 1. Some soil physical and chemical properties of the experiment site.

Land Use Treatments*	Sand	Silt (g kg^{-1})	Clay	EC (dS m^{-1})	pH
F	270	330	300	0.58	8.1
CAF	330	400	270	0.87	7.9
P	250	400	350	0.51	7.7
CAP	270	410	320	0.67	8

* F, forest area; CAF, cultivated lands adjacent to forest; P, pasture; and CAP, cultivated lands adjacent to pasture.

Table 2. Effect of changing land use on some parameters.

Land Use Treatments*	SOM (g kg^{-1})	BD (mg m^{-3})	HC (cm h^{-1})	TP (m^{3} m^{-3})
F	36.6^{a}±1.1	1.19^{b}±0.1	0.25^{a}±0.05	0.54^{a}±0.04
CAF	25.9^{b}±1.4	1.30^{a}±0.1	0.14^{b}±0.04	0.50^{b}±0.03
P	31.9^{a}±1.2	1.21^{b}±0.12	0.19^{b}±0.04	0.55^{a}±0.05
CAP	22.1^{b}±1.1	1.38^{b}±0.08	0.17^{b}±0.03	0.48^{b}±0.02

* F, forest area; CAF, cultivated lands adjacent to forest; P, pasture; and CAP, cultivated lands adjacent to pasture.

Means (mean ± SD) followed by same letters in each column are not significantly different at 1% level of probability.

Table 3. Linear D_l, non-linear D_{nl} and mean-weight diameter *MWD* (mean ±SD) for different land use.

Land Use Treatments*	MWD (mm)	CVs of MWD	D_{nl}	CVs of D_{nl}	R^2	D_l	CVs of D_l	R^2
F	$0.588^a \pm 0.05$	50%	$2.865^a \pm 0.1$	6.5%	0.961±0.03	$3.04^c \pm 0.11$	14%	0.970±0.02
CAF	$0.31^c \pm 0.05$	30%	$2.99^b \pm 0.12$	5%	0.965±0.03	$3.46^{ab} \pm 0.12$	12%	0.975±0.01
P	$0.42^b \pm 0.05$	35%	$2.853^a \pm 0.12$	8%	0.978±0.01	$3.25^b \pm 0.13$	8%	0.981±0.01
CAP	$0.26^c \pm 0.06$	53%	$3.024^b \pm 0.13$	6%	0.980±0.01	$3.56^a \pm 0.15$	13%	0.980±0.01

[*] F, forest area; CAF, cultivated lands adjacent to forest; P, pasture; and CAP, cultivated lands adjacent to pasture.

Means (mean ±SD) followed by same letters in each column are not significantly different at 1% level of probability.

R^2 is coefficient of determination of fitting Eq (5) on aggregate size distribution data.

Table 4. Relationships among the fractal dimensions, and mean-weight diameter MWD and some soil parameters.

Parameters	D_{nl}	D	MWD	>0.25 mm	HD	SOM	BD	TP
D_{nl}	1	0.83^{***}	-0.75^{**}	-0.67^{**}	-0.65^{**}	-0.78^{**}	0.68^{**}	-0.52*
D	0.83^{***}	1	-0.71^{**}	-0.64^{**}	-0.6^{**}	-0.7^{***}	0.64^{**}	-0.57^{**}
MWD	-0.75^{**}	-0.71^{**}	1	$+0.73^{**}$	0.56^{**}	0.64^{**}	-0.68^{**}	0.53^{*}

* Correlation is significant at 5% level.

**Correlation is significant at 1% level.

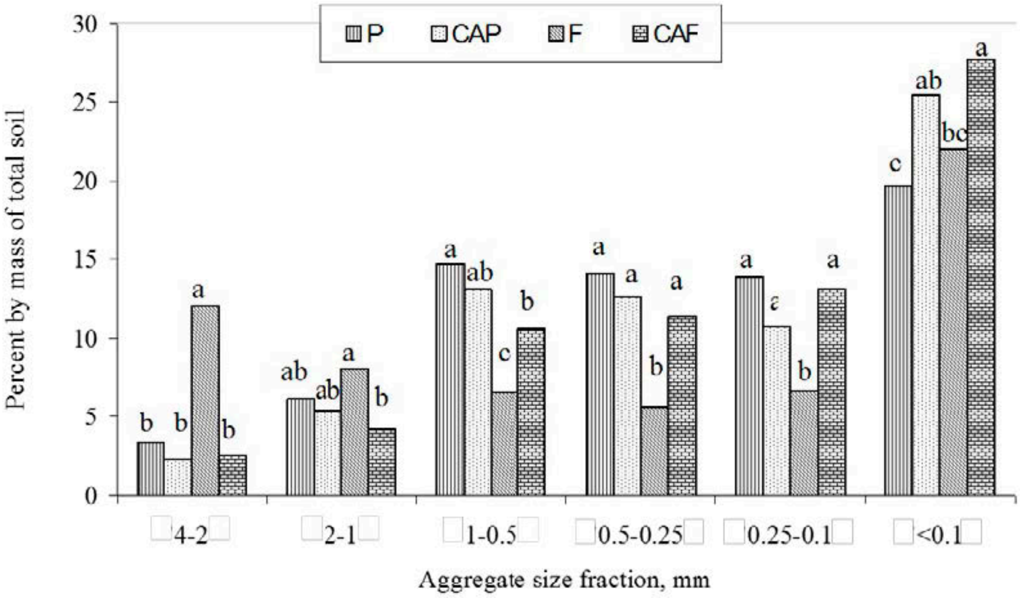

Figure 1. Effect of land use on aggregate size distribution. F, forest area; CAF, cultivated lands adjacent to forest; P, pasture; and CAP, cultivated lands adjacent to pasture.

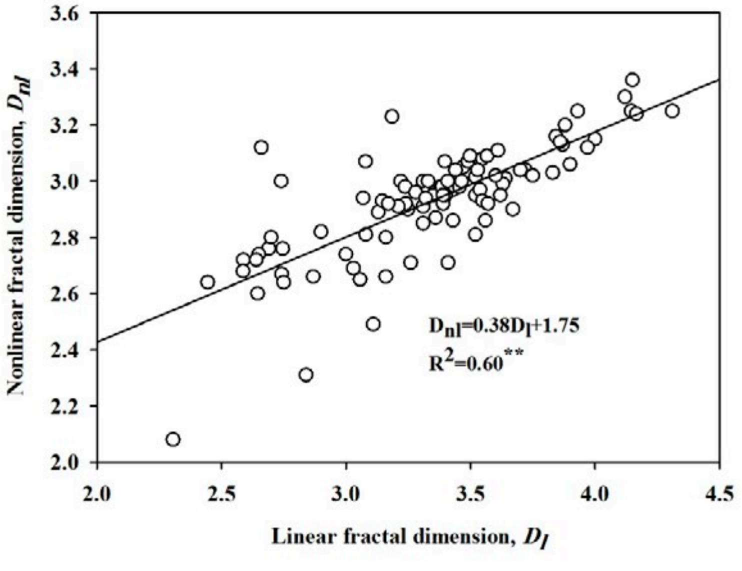

Figure 2. Relationship between the fractal dimension D_l (obtained from linear relationship) and D_{nl} (obtained from non-linear relationship); R^2, coefficient of determination.

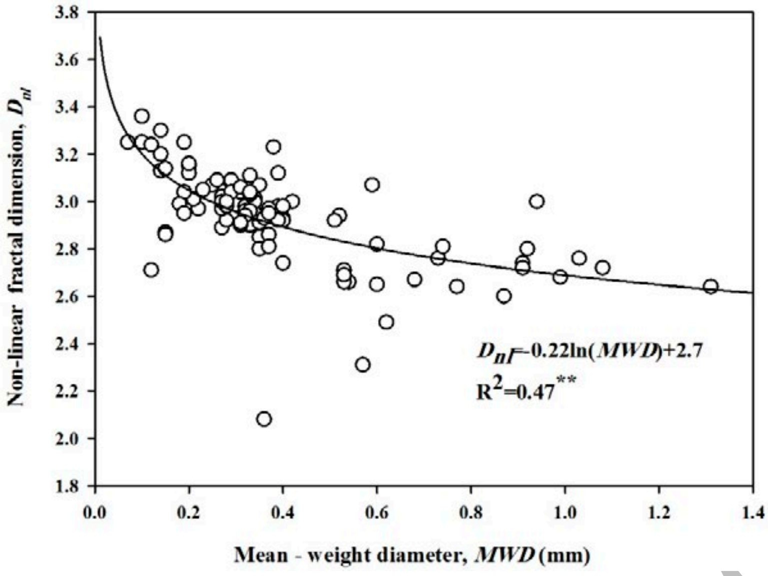

Figure 3. Relationship between the non-linear fractal dimension D_{nl} and the mean-weight diameter *MWD;* R^2, coefficient of determination.