Atatürk Üniv. Ziraat Fak. Derg., 48 (1): 9-15 , 2017
Atatürk Univ., J. of the Agricultural Faculty, 48 (1): 9-15 , 2017
ISSN : 1300-9036 Araştırma Makalesi/Research Article

Changes in Structural Parameters of Soils under Different Cropping Systems

Fazil HACIMUFTUOGLU* **Taskin OZTAS**
Ataturk University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, 25240, Erzurum, Turkey
(*Corresponding author email: fazil@atauni.edu.tr)

Received Date: 24.02.2017 **Accepted Date: 19.04.2017**

ABSTRACT: Soil structure is one of the most important soil physical characteristics affecting on soil productivity. Structural development of soil is under the control of many inside and outside factors. It is expected that soil structural characteristics change with changes in plant pattern because of differentiations in agronomic properties, root system and amounts of organic matter incorporated into the soil. The objective of this study was to evaluate changes in structural behaviors of soils under different crop management systems. Soil samples collected from long-term (+10 years) experimental fields under different crop management systems; sun flower, wheat, bean, corn, potato and alfalfa, were analyzed for physical, chemical and mechanical properties and structural characteristics were evaluated. The results indicated that soil structural characteristics significantly changed depending on plant patterns. Structural conditions and aggregate stability were the highest in soils under alfalfa crops, but the worst in soils under potatoes and corn production.

Keywords: Aggregate stability, cropping pattern, soil structure

Farklı Bitki Yönetimi Altındaki Toprakların Strüktürel Ölçütlerindeki Değişimler

ÖZET: Toprak strüktürü, toprağın üretim potansiyelini belirleyen en önemli fiziksel ortam özelliklerinden biridir. Toprakta strüktürel gelişim birçok iç ve dış faktörün kontrolü altındadır. Farklı bitki yönetim uygulamaları bitkinin agronomik özellikleri, kök sistemi ve toprağa organik madde döngüsü farklılıkları dahilinde toprağın strüktürel durumunu önemli ölçüde etkilemektedir. Farklı bitki yönetimi altında bulunan toprakların yapısal özelliklerinde meydana gelen değişimlerin değerlendirmesi amacıyla yürütülen bu çalışmada; uzun yıllardan (+10 yıl) beri farklı bitki yetiştiriciliği (ayçiçeği, buğday, fasulye, mısır, patates ve yonca) altında bulunan deneme alanlarından alınan toprak örneklerinde fiziksel, kimyasal ve mekaniksel özellikler incelenerek yetiştirilen bitkilerin, toprağın strüktürel parametreleri üzerindeki etkileri değerlendirilmiştir. Elde edilen bulgular toprağın strüktürel parametrelerinde, yetiştirilen bitki çeşitliliğine bağlı olarak önemli farklılıkların meydana geldiğini göstermektedir. Strüktürel gelişim derecesi ve agregat stabilitesinin yonca ekim alanlarından alınan toprak örneklerinde en yüksek, patates ve mısır ekim alanlarından alınan toprak örneklerinde ise en düşük değerlerde olduğu saptanmıştır.

Anahtar kelimeler: Agregat stabilitesi, bitki çeşitliliği, toprak strüktürü

INTRODUCTION

The plant production potential of the soil is the function of the physical environment properties of that soil. Although the soil structure is not a plant growth factor, it is directly or indirectly related to many events, processes and factors regarding plant growth. Soil structural development affects on many subjects in soils such as the infiltration of water from surface into the soil, the percolation throughout the soil profile, the amount of water stored in the soil, the aeration capacity of the soil, the soil temperature and the soil heat transfer, plant root development, mineralization of organic material, the sufficiency of the plant nutrients for plants, the microbial activity, the suitability for the soil cultivation and the soil sensitivity to erosion (Oztas, 2015).

The development of structure in soil results in voids that form the pore structure (Chenu and Cosentino, 2011). The soils having a developed structural form and ideal physical environment properties are rich in water and nutrients and have a good aeration capacity, a high biological activity, an ideal environment for root development and a good drainage system. In the structural development of the soil, in addition to the effects of many natural physical, chemical and biological factors such as the gravitation between particles, the plant root pressure, root secretions, crop residues, the type of clay minerals and creatures living in the soil, the soil-plant management also has a significant role. The fact that plants containing high biomass and high carbon are included in the plant crop rotation is important in terms of encouraging the formation of aggregate in the soil and increasing the stability of aggregate (Bronick and Lal, 2005).

Reduced aggregate stability may decrease rate of water infiltration and crop production. Applying organic matter can improve water retention, sources of biodiversity and erosion control (Ahmad et al., 2008). Soil aggregation is important for root growth and resistance to erosion (Six et al., 2006). The effect of roots on erodibility reduces with increasing root diameter (De Baets et al., 2007).

Root growth is the factor of the main mechanism by which plants increase soil permeability, (Ghestem et al., 2011; De Baets et al., 2006). Root exudates are the main mechanism by which plant roots enhance aggregate stability (Moreno-Espíndola et al., 2007; Pohl et al., 2009). Plant roots can improve soil aggregation by releasing exudates which can stabilize soil particles (Burri et al., 2009) and roots also physically reinforce particle contacts in soil (Yoo et al., 2011).

Soil organic matter has positive effects on the conservation of soil properties (Chirinda et al., 2010, Hargreaves et al., 2008 and Papini et al., 2011). Organic matter influences soil structure and stability by binding soil mineral particles and influencing the mechanical strength of soil aggregates (Onweremadu et al., 2007). Work by Cercioglu et al. (2013) has explained that some sources of organic matter (poultry manure, bio-humus and composted tobacco waste) has an important contribution on the soil physical properties in sandy loam texture class. In agricultural systems, conserving soil organic carbon has been determined reduce soil degradation. On the other hand, residue management, organic matter, clay minerals, and sesquioxide of soil are the most important factors in the soil structural development (Bhattacharyya et al., 2009 and Wagner et al., 2007).

Soil degradation has generally been attributed to poor farming practices and deforestation (Liang et al., 2009; Stokes et al., 2010). Vegetation cover has useful effects on the stability of soil aggregates (Burri et al., 2009). The addition of plant residues, accelerate the formation of a more stable aggregates (Martinez et al., 2008) and organic matter enhance the formation of stable aggregates (Vásquez et al., 2010).

In this study, the relationships between the basic physical, chemical and mechanical properties of the soils under the cultivation of different plants (sunflower, wheat, bean, corn, potato and alfalfa) for many years (10 years or more) and their structural parameters were evaluated.

MATERIALS AND METHODS

The soils used in the study were provided from the Ataturk University Research Farm in Erzurum plain (39°56′ N, 41°14′ E). The soil was classified as Entisols according to the USA taxonomy (Soil Survey Staff, 1992) with parent materials consisting of alluvial. Disturbed and undisturbed random soil samples collected from a 20 cm soil depth in fields under sunflower, wheat, bean, corn, potato and alfalfa cropping systems and having similar pedogenesis and cultivated for at least for 10 years were properly air dried and prepared for the analysis by passing through a 2 mm sieve. In the soil samples, texture was identified by the Bouyoucos hydrometer method (Gee and Bauder, 1986), soil reaction (pH) was identified by the glass electrode pH meter (McLean, 1982), lime content was identified by Scheibler calcimeter (Nelson, 1982), organic matter content was identified by the Smith-Weldon method (Nelson and Sommers, 1982), cation exchange capacity and the amount of exchangeable cation were identified by ICP OES (Optima 2100 DV Perkin Elmer) spectrophotometer (Rhoades, 1982a; Thomas, 1982). Phosphorus content of the soil samples was determined according to the molybdoPhosphorusic blue method (Olsen and Sommers, 1982), electrical conductivity value was identified by the electrical conductivity tool (Rhoades, 1982b), bulk density was determined by the cylinder method (Blake and Hartge, 1986), aggregate stability was determined using the Yoder type wet-sieving device (Kemper and Rosenau, 1986). Moreover, dispersion rate of the soils (Bryan, 1968; Lal, 1988), air permeability (Corey, 1986), water permeability (Klute and Dirksen, 1986), liquid limit, plastic limit (Head K, 1984) and shrinkage limit (ASTM, 1974), $COLE_{rod}$ (Schafer and Singer, 1976), volumetric shrinkage (ASTM, 1974) and free swelling index (Ross, 1978) were determined by using standard methods. ANOVA and Duncan multiple comparison test methods were applied in the data analysis (SPSS 1999).

RESULTS AND DISCUSSION

Physical Properties of the Soils: The soils in the study field were identified as Ciftlik Series with clay loam texture (30% clay, 29% silt, and 41% sand) (Table 1). The bulk density varied between 0.95 g cm^{-3} (alfalfa, bean, and sunflower) and 1.06 g cm^{-3} (corn), and the difference between the averages was found to be statistically insignificant at the $P<0.05$ level of significance.

The aggregate stability values determined for different aggregate size classes were found to be significantly higher in the soil samples acquired from alfalfa cultivation areas when compared to the other plant cultivation areas (Table 1, Figure 1). On the basis of the average, the aggregate stability values of the soils, on which alfalfa is cultivated (77.42%), were found to be higher when compared to the soils, on which bean, wheat, sunflower, corn, and potato are cultivated, at the rates of 26%, 30%, 83%, 100% and 120%, respectively. On the basis of the average, the fact that the lowest aggregate stability value (35.28%) is in the soils, on which potatoes are cultivated, is related to the inadequate organic substance addition to aggregate formation and stability since potato is a tuber plant. When especially aggregates larger than 2 mm are considered, it is indicated that the aggregate stability values of the soils, on which corn is cultivated, were significantly lower when compared to others and were followed by the soils on which potatoes are cultivated.

Table 1. The physical properties of the research soils

	Textural Analysis				Aggregate Stability							
					Aggregate Size, (mm)							
Cropping System	**Clay (%)**	**Silt (%)**	**Sand (%)**	**BD ($g\ cm^{-3}$)**	**0.25-0.5***	**0.5-1***	**1-2***	**2-4***	**Avg.***	**DR* (%)**	**AP* (μ^2)**	**WP* (μ^2)**
Sunflower				0.95	39.78c	31.73d	40.13d	57.63b	42.32c	57.74bc	57.51b	0.74b
Wheat				0.99	57.64b	63.89b	56.27c	58.95b	59.19b	51.48c	31.76d	1.15b
Bean	30	29	41	0.95	53.86b	66.33b	66.43b	58.21b	61.21b	65.31b	28.88d	0.52b
Corn				1.06	22.78d	53.38c	63.24bc	14.31d	38.43cd	79.42a	33.44cd	0.54b
Potato				0.99	29.61cd	36.00d	33.40d	42.11c	35.28d	62.17bc	46.81bc	0.71b
Alfalfa				0.95	78.46a	85.54a	80.11a	65.55a	77.42a	39.79d	91.79a	2.04a

(*): Significant ($p \leq 0.05$) BD: Bulk Density, DR: Dispersion Rate, AP: Air Permeability, WP: Water Permeability

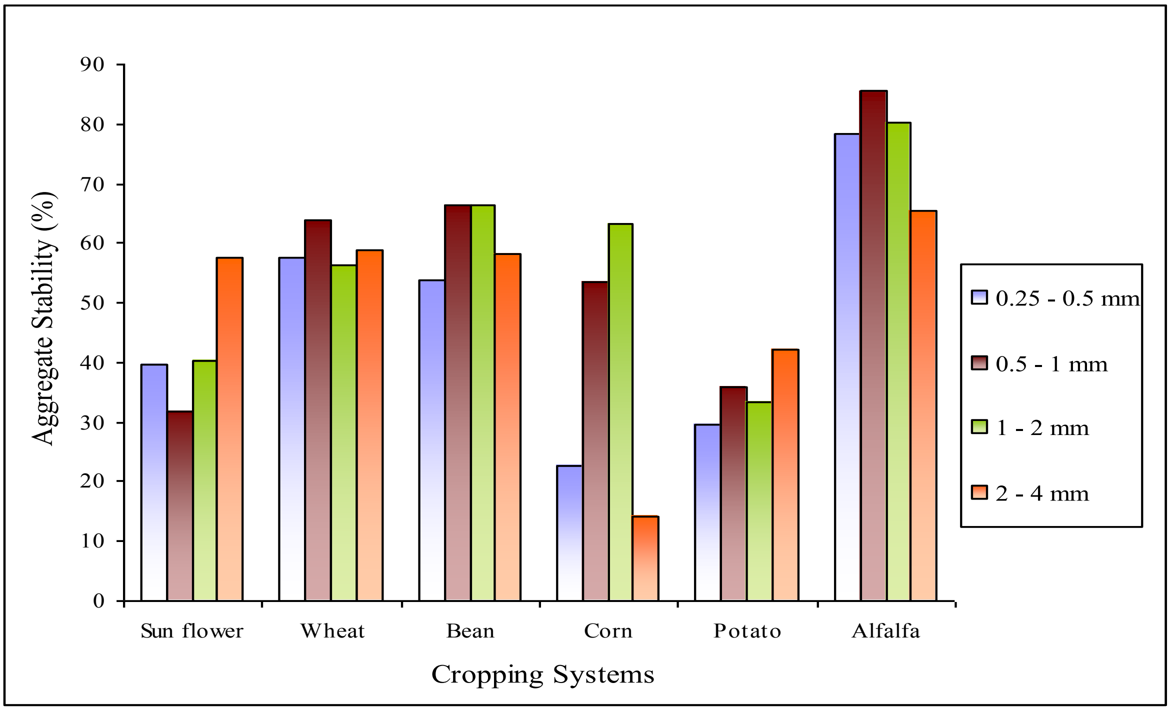

Figure 1. The aggregate stability values of the soils under different cropping systems (%)

While the highest dispersion rate value among the soil samples was measured in corn soil (79.42%), the lowest value was identified in alfalfa soil (39.79%) (Table 1). Since the aggregate stability and dispersion rate are inversely correlated, this is an expected result. As a result of the fact that the aggregating level and stability are higher depending on the high amount of organic matter returning to alfalfa soil and root intensity, the dispersion rate value turned to be quite low. The fact that the dispersion described as the disperse of aggregates by being decomposed and the fragmentation of the structural form was very low in alfalfa soil and the aggregate stability values were the highest in the same soil indicates that alfalfa plant develops structural form by increasing aggregating. Cropping system of alfalfa increased structural stability, porosity and infiltration ratio over the bare soil (Gulser, 2004).

Suitable soil physical properties and good structure provide that a high water-holding capacity, moderate saturated hydraulic conductivity, and sufficient aeration for plant growth (Riahi et al., 2009). While the highest air permeability value in the soil samples was measured in alfalfa soil (91.79 μ²), the lowest value was identified in bean soil (28.88 μ²) (Table 1). The fact that air permeability is high in alfalfa soil, in which the aggregate stability and the amount of organic matter are high, is an expected result. While the highest water permeability value was measured in alfalfa soil (2.04 μ²) among the soil samples as it was in air permeability, the lowest value was determined in bean soil (0.52 μ²) (Table 1). The fact that the aggregate stability values in Table 1 are at the highest level and the permeability rate in alfalfa soil is at the highest level are related to aggregate stability. As the structural form of the soil is enhanced, porosity increases and water infiltrates into the soil more rapidly.

Chemical Properties of the Soils: Cover crops increase soil quality by improving soil physical, chemical and biological properties (Dabney et al., 2001) as related to the content of soil organic carbon (Schmidt et al., 2011). Organic matter content of the soils in the study field was the highest in alfalfa soil (3.25%) and the lowest in bean soil (0.84%) (Table 2).

Table 2. The chemical properties of the research soils

Cropping System	OM* (%)	pH*	EC (μmhos cm^{-1})	Lime* (%)	CEC* (cmol kg^{-1})	P* (ppm)	Exchangeable Cations (cmol kg^{-1}) Ca*	Mg*	Na*	K*
Sunflower	1.1b	7.55c	341.5	0.42b	20.84c	54.5a	12.97c	2.45bc	0.8b	3.78c
Wheat	0.97b	7.80ab	370	0.6b	22.93b	35b	15.02b	2.36c	1.08a	3.35d
Bean	0.84b	7.65abc	458.5	0.53b	21.06c	35 b	12.73c	2.7ab	0.93ab	3.86c
Corn	0.94b	7.60bc	310	0.14c	18.20d	68.5a	9.61d	2.36c	0.93ab	4.65a
Potato	1.09b	7.85a	408.5	0.87a	22.20b	53a	14.04b	2.68ab	1.06a	3.33d
Alfalfa	3.25a	7.55c	328.5	0.55b	24.81a	53.5a	16.37a	2.8a	0.83b	4.07b

(*): Significant ($p \leq 0.05$) OM: Organic Matter, EC: Electrical Conductivity, CEC: Cation Exchange Capacity P: Phosphorus, Ca: Calcium, Mg: Magnesium, Na: Sodium, K: Potassium

Maintenance of the soil structure depends on organic matter (Thevenot et al., 2010) and organic matter stabilization in soil aggregates (von Lützow et al., 2008). It was found out that the highest pH value was in potato (7.85), the lowest value was in sunflower (7.55) and alfalfa (7.55) soil (Table 2), the highest electrical conductivity values was in bean (458.5 μmhos cm^{-1}), the lowest value was in corn (310 μmhos cm^{-1}) soil among the soil samples, and EC values were stated to be statistically insignificant at the $P<0.05$ level of significance. Upon examining the lime contents, it is seen that the highest lime value was in potato (0.87%), the lowest value was in corn (0.14) soil, the highest cation exchange capacity value was in alfalfa (24.81 cmol kg^{-1}), the lowest value was in corn (18,20 cmol kg^{-1}) soil. When the phosphorus contents are examined, it was found out that the highest phosphorus value was in corn (68.5 ppm), the lowest value was in wheat (35 ppm) and bean (35 ppm) soil (Table 2). It was observed that the highest Ca value among the samples was in alfalfa (16.37 cmol kg^{-1}) soil and the lowest value was in corn (9.61 cmol kg^{-1}) soil. Divalent calcium and magnesium cations improve soil structure by establishing cationic links with clay particles and organic-C (Bronick and Lal, 2005). The fact that the alfalfa soil which has the highest organic matter content also has the highest Ca values indicates that the alfalfa soil is structurally at the best level in terms of all parameters examined. It is seen that the highest Mg value among the soil samples was in alfalfa (2.8 cmol kg^{-1}) soil, the lowest value was in corn (2.36 cmol kg^{-1}) and wheat (2.36 cmol kg^{-1}) soil, the highest sodium (Na) content value was in wheat (1.08 cmol kg^{-1}), the lowest value was in sunflower (0.8 cmol kg^{-1}) and alfalfa (0.83 cmol kg^{-1}) soil. There was no Na problem for the soils. When the potassium contents of the soils are examined, the highest value was in corn (4.65 cmol kg^{-1}), the lowest value was in potato (3.33 cmol kg^{-1}) soil (Table 2). The fact that the potassium contents of the potato soils are low is considered as a consequence of the over-exploitation of this element by potato plant.

Mechanical Properties of the Soils: There were no statistical differences in $COLE_{rod}$, volumetric shrinkage and shrinkage limit values among the soils under different cropping systems at $P<0.05$ (Table 3).

Table 3. The mechanical properties of the research soils

Cropping System	COLE	VS (%)	SL (%)	FSI* (%)	LL* (%)	PL* (%)
Sunflower	0.15	61.96	13.5	0.36b	47.8ab	27.04a
Wheat	0.09	57.1	15.53	0.33b	41.65cd	22.97c
Bean	0.12	66.07	11.74	0.4b	47.1abc	24.96bc
Corn	0.11	56.41	12.69	0.28b	40.3d	23.46c
Potato	0.09	60.01	13.45	0.25b	43.07bcd	24.94bc
Alfalfa	0.13	75.44	13.96	0.79a	52.39a	28.48a

(*): Significant ($p \leq 0.05$) $COLE_{rod}$: Coefficient of Linear $Extensibility_{rod}$, VS: Volumetric Shrinkage, SL: Shrinkage Limit, FSI: Free swelling Index, LL: Liquid Limit, PL: Plastic Limit

The aggregate size can significantly affect mechanical stability (AbuHamdeh et al. 2006; Yang et al. 2012). The highest free swelling index value of the soils was in alfalfa (0.79%) and the lowest value was in potato (0.25%) soil (Table 3). The fact that the highest organic matter according to Table 2 and the highest aggregate stability values according to Table 1 are in alfalfa soil results from the relationship between the free swelling index and organic matter content and aggregate stability values. The highest liquid limit value among the soil samples was identified in alfalfa (52.39%) and the lowest value was identified in corn (40.3%) soil (Table 3). Highest liquid limit value was in alfalfa soil having the highest organic matter content was based on the fact that the high amount of organic residue from alfalfa soil mixes with the soil. The plastic limit and liquid limit of soil are indicate of soil mechanical properties and are closely related to shear strength and soil erosion intensity (Cokca and Tilgen 2010). The organic carbon (SOC) in all experimental soils significantly ($p < 0.01$) increased liquid limit (LL) plastic limit (PL), and plastic index (PI) values (Moradi, 2013). The facts that the highest plastic limit value among the samples was in alfalfa soil (28.48%), the lowest value was in wheat soil (22.97%) (Table 3) and alfalfa soil has the highest organic matter content in Table 2 indicate the relationship between the plastic limit value and the amount of organic matter. The plastic limit is an important soil property that gives information about soil mechanical behavior (Keller and Dexter, 2012).

CONCLUSION

In addition to the mineralogical composition of the soil, organic matter, sesquioxides, and components such as $CaCO_3$ have a multiple effect on the formation of the structural form. In the formation of the structure, climatic factor of that region and plant management stand out. The plant pattern affects the soil structure due to root secretions and morphological properties of the roots. While the plant roots especially the ones with long and hairy roots such as alfalfa encourage the structural development by creating a strong binding effect among soil aggregates, it is known that plants with taproots such as sunflower cannot have that binding effect.

In this study, acquired findings indicate that significant differences occurred in the structural parameters of the soil depending on the plant pattern. The most suitable parametric values of the soil samples were determined in alfalfa plant soil and the most negative values were identified in potato and corn plant soils.

The structure of the soil is one of the most important physical characteristics identifying the soil's capacity for productivity. The results of this study reveal that different plant management applications significantly affect the agronomic properties of the plant, root system and organic matter cycle in the soil and the structural behavior of the soil within its differences.

Considering the data acquired from the results of this scientific study, it is aimed to enhance the structural properties of the soil with the development of the soil structure which is the main factor in the formation of suitable air, water and food balance for plant growing, the good evaluation of the soil-plant management strategy and crop rotation of the plants such as alfalfa improving structural form.

REFERENCES

Abu-Hamdeh, N.H., Abo-Qudais, S.A., Othman, A.M. 2006. Effect of soil aggregate size on infiltration and erosion characteristics. Eur J Soil Sci 57(5) : 609–616.

Ahmad, R., Arshad, M., Khalid, A., Zahir, Z.A., 2008. Effectiveness of organic-bio-fertilizer supplemented with chemical fertilizers for improving soil water retention aggregate stability growth and nutrient uptake of maize (Zea mays L.). J. Sustain. Agric., 31 (4): 57–77.

ASTM, 1974. "Annual book of ASTM standarts." American Society For Testing And Materials, 19: 90-92 race st. pa. USA.
Bhattacharyya, R., Prakash, V., Kundu, S., Srivastva ,A.K., Gupta, H.S., 2009. Soil aggregation and organic matter in a sandy clay loam soil of the Indian Himalayas under different tillage and crop regimes. Agric. Ecosyst. Environ., 132: 126–134.
Blake, G.R. and Hartge, K.H., 1986 Methods of soil analysis. Part 1. Physical and mineralogical methods. Agronomy, 2: 366-375.
Bronick, C.J. and Lal, R., 2005. Soil structure and management: A review. Geoderma, 124 (1-2): 3-22.
Bryan, R.B., 1968. The development, use and efficiency of indices of soil erodibility. Geoderma, 2: 5-25.
Burri, K., Graf, F., Boll, A., 2009. Revegetation measures improve soil aggregate stability: a case study of landslide area in Central Switzerland. Forest Snow and Landscape Research, 82(1): 45–60.
Cercioglu M., Okur B., Delibacak S., Ongun A.R. 2013. İmpact of Some organic matter sources on physical characteristics of a sandy loam soil. Soil – Water Journal (2013). Vol.2. p. 393.
Chenu, C., Cosentino, D., 2011. Microbial regulation of soil structural dynamics. In: Ritz, K., Young, I.M. (Eds.), The Architecture and Biology of Soils. CABI, Oxfordshire, U.K, pp. 37–70.
Chirinda, N., Olesen, J.E., Porter, J.R., Schjnning, P., 2010. Soil properties, crop production and greenhouse gas emissions from organic and inorganic fertilizer based arable cropping systems. Agric. Ecosyst. Environ., 139: 584–594.
Cokca, E., Tilgen, H.P., 2010. Shear strength-suction relationship of compacted Ankara clay. Appl. Clay Sci. 28(8) : 1–5.
Corey, A.T., 1986. Air permeability. Methods of soil analysis. Part 1. Physical and mineralogical methods. 2nd edition. Agronomy, 1121-1137.
Dabney, S.M., Delgado, J.A., Reeves, D.V., 2001. Using winter cover crops to improve soil and water quality. Commun. Soil Sci. Plant Anal., 32(7-8): 1221-1250.
De Baets, S., Poesen, J., Gyssels, G., and Knapen, A., 2006. Effects of grass roots on the erodibility of topsoil during concentrated flow. Geomorphology, 76: 54–67.
De Baets, S., Poesen, J., Knapen, A., Barbera, G.G., Navarro, J.A., 2007. Root characteristics of representative Mediterranean plant species and their erosion-reducing potential during concentrated runoff. Plant and Soil, 294: 169–183.
Gee, G.W. and Bauder, J.W., 1986. Particle-size analysis. Methods of soil analysis. Part 1. Physical and mineralogical methods. 2nd edition. Agronomy, 383-411.
Ghestem, M., Sidle, R.C., Stokes, A., 2011. The influence of plant root systems on subsurface flow: implications for slope stability. Bioscience, 61(11): 869–879.
Gulser, C., 2004. A Comparison of Some Physical and Chemical Soil Quality Indicators Influenced by Different Crop Species. Pakistan. J. Bio. Sci., 7(6): 905-911.
Hargreaves, J.C., Adl, M.S., Warman, P.R., (2008). A review of the use of composted municipal solid waste in agriculture. Agric. Ecosyst. Environ., 123: 1–14.
Head, K.H., 1984. Manual of soil laboratory testing: Vol: 1.
Keller, T. and Dexter, A.R., 2012. Plastic limits of agricultural soils as functions of soil texture and organic matter content. Soil Research 50(1).
Kemper, W.D. and Rosenau, R.C., 1986. Aggregate stability and size distribution. Methods of soil analysis. Physical and mineralogical methods. 2nd edition. Agronomy, 425-442.
Klute, A. and Dirksen, C., 1986. Hydraulic conductivity and diffusivity: Laboratory methods. Methods of soil analysis. Physical and mineralogical methods. 2nd edition. Agronomy, 687-734.
Lal, R., 1988. "Soil erosion research methods." Soil And Water Conservation Society.
Liang, Y., Li, D.C., Su, C.L., Pan, X.Z., 2009. Soil erosion assessment in the red soil region of Southeast China using an integrated index. Soil Science, 174: 574–581.
Martinez, E., Fuentes, J.P., Silva, P., Valle, S., Acevedo, E., 2008. Soil physical properties and wheat root growth as affected by no-tillage and conventional tillage systems in a Mediterranean environment of Chile. Soil Till. Res., 99: 232–244.
McLean, E.O., 1982. "Soil pH and lime requirement. Methods of soil analysis." Part 2. Chemical and Microbiological Properties. 2nd edition. Agronomy, 199-224.
Moradi, S., 2013. Impacts of organic carbon on consistency limits in different soil textures. International Journal of Agriculture and Crop Sciences. 5-12, 1381-1388.
Moreno-Espíndola, I.P., Rivera-Becerril, F., De Jésus Ferrera Guerrero, M., and De Léon-González, F., 2007. Role of root-hairs and hyphae in adhesion of sand particles, Soil Biol. Biochem., 39: 2520–2526.
Nelson, D.W. and Sommers, L.E., 1982. "Total carbon, organic carbon and organic matter. Methods of soil analysis." Part 2. Chemical and microbiological properties. 2nd edition. Agronomy, 539-579.
Nelson, R.E., 1982. Carbonate and gypsum. Methods of soil analysis. Part 2. Chemical and Microbiological Properties. 2nd edition. Agronomy, 181-197.
Olsen, S.R. and Sommers, L.E., 1982. Phosphorusus. Methods of soil analysis. Part 2. Chemical and microbiological Properties. 2nd edition. Agronomy, 403-427.
Onweremadu, E.U., Onyia, V.N., Anikwe, M.A.N., 2007. Carbon and nitrogen distribution in water-stable aggregates under two tillage techniques in Fluvisols of Owerri area, southeastern Nigeria. Soil and Tillage Research, 97: 195–206.
Oztaş T., 2015. Soil Management, (Ed : S. Ersahin, T. Oztas, A. Namli, G. Karahan). Soil Structure and Management, 7: 209-225.
Papini, R., Valboa, G., Favilli, F., L'Abate, G., 2011. Influence of land use on organic carbon pool and chemical properties of Vertic Cambisols in central and southern Italy. Agric. Ecosyst. Environ., 140: 68–79.
Pohl, M., Alig, D., Körner, C., Rixen C., 2009. Higher plant diversity enhances soil stability in disturbed alpine ecosystems. Plant and Soil, 324: 91–102.
Rhoades, J.D., 1982a. Cation exchange capacity. Methods of soil analysis. Part 2. Chemical And Microbiological Properties. 2nd edition. Agronomy, 149- 157.
Rhoades, J.D., 1982b. Soluble salts. Methods of soil analysis. Part 2. Chemical and microbiological properties. 2nd edition. Agronomy,167-179.
Riahi, A., Hdider, C., Sanaa, M., Tarchoun, N., Ben Kheder, M., Guezal, I., 2009. The influence of different organic fertilizers on yield and physico-chemical properties of organically grown tomato. J. Sustain. Agric., 33 (6): 658–673.
Ross, G.J., 1978. Relationships of specific surface area and clay content to shring-swell. Potential of soils having different clay mineralojical composition. Canadian Journal of Soil, 58: 159-166.
Schafer, W.M. and Singer, M.J., 1976. A new method of measuring shrink-swell potential using soil pastes. Soil Science Society of America Journal, 40:805-806.
Schmidt, M.W.I., Torn, M.S., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I.A., Kleber, M., Kogel-Knabner, I., Lehmann, J., Manning, D.A.C., Nannipieri, P., Rasse, D.P., Weiner, S., Trumbore, S.E., 2011. Persistence of soil organic matter as an ecosystem property. Nature 478, 49–56.

Six, J., Frey, S.D., Thiet, R.K., Batten, K.M., 2006. Bacterial and fungal contributions to carbon sequestration in agroecosystems. Soil Science Society of America Journal, 70: 555–569.

Soil Survey Staff. 1992. Keys to Soil Taxonomy, 5th ed. Blacksburg, VA: Pocahontas Press.

SPSS, (1999). SPSS for Windows, Release 10.0.5., SPSS Inc., USA.

Stokes, A., Sotir, R.B., Chen, W., Ghestem, M., 2010. Soil bio- and eco-engineering in China, past experience and present priorities. Ecological Engineering, 36: 247–257.

Thevenot, M., Dignac, M.F., Rumpel, C., 2010. Fate of lignins in soils: a review. Soil Biology and Biochemistry, 42: 1200–1211.

Thomas, G.W., 1982. "Exchangeable Cations. Methods of soil analysis. Part 2. Chemical And Microbiological Properties. 2nd edition. Agronomy, 9: 159–165, 1159.

Vásquez Méndez, R., Ventura Ramos, E., Oleschko, K., Hernández Sandoval, L., Parrot, J.F., and Nearing, M.A., 2010. Soil erosion and runoff in different vegetation patches from semiarid Central Mexico, Catena, 80: 162–169.

von Lützow, M., Kogel-Knabner, I., Ludwig, B., Matzner, E., Flessa H., Ekschmitt, K., Guggenberger, G., Marschner, B., Kalbitz, K., 2008. Stabilization mechanisms of organic matter in four temperate soils: development and application of a conceptual model. Journal of Plant Nutrition and Soil Science, 171: 111–124.

Wagner, S., Cattle, S.R., Scholten, T., 2007. Soil-aggregate formation as influenced by clay content and organic-matter amendment. J. Plant Nutr. Soil Sci., 170: 173–180.

Yang, W., Li, Z.X., Cai, C.F., Wang, J.G., Hua, Z.G., 2012. Tensile strength and friability of Ultisols in sub-tropical China and effects on aggregate breakdown under simulated rainfall. Soil Sci. 177(6) : 377–384.

Yoo, G., Yang, X., Wander, M.M., 2011. Influence of soil aggregation on SOC sequestration: a preliminary model of SOC protection by aggregate dynamics. Ecological Engineering, 37: 487–495.