Eurasian Journal of Soil Science

Journal homepage : http://fesss.org/eurasian_journal_of_soil_science.asp

Soil dehydrogenase activity of natural macro aggregates in a toposequence of forest soil

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Article Info

Received : 26.01.2013
Accepted : 04.04.2013

Abstract

The main objective of this study was to determine changes in soil dehydrogenase activity in natural macro aggregates development along a slope in forest soils. This study was carried out in Kocadag, Samsun, Turkey. Four landscape positions *i.e.*, summit, shoulder backslope and footslope, were selected. For each landseape position, soil macro aggregates were separated into six aggregate size classes using a dry sieving method and then dehydrogenase activity was analyzed.

In this research, topography influenced the macroaggregate size and dehydrogenase activity within the aggregates. At all landscape positions, the contents of macro aggregates (especially > 6.3 mm and 2.00–4.75 mm) in all soil samples were higher than other macro aggregate contents. In footslope position, the soils had generally the higher dehydrogenase activity than the other positions at all landscape positions. In all positions, except for shoulder, dehydrogenase activity was greater macro aggregates of <1 mm than in the other macro aggregate size.

Keywords: topograpy, soil, aggregate, dehydrogenase activity

Introduction

Soil aggregates are important component of soil structure and are important for soil health and quality. The size, quantity and stability of aggregates recovered from soil reflects an environmental conditioning that includes factors which enhance the aggregation of soil (Beare and Bruce, 1993). The measurement of soil aggregates depends on both the forces that bind particles together and the nature and magnitude of the disruptive forces applied. Soil aggregation influences the susceptibility of soil to erosion, organic matter storage, soil aeration, water infiltration and mineral plant supply. Many studies have shown the effects of organic constituents on the amount and stability of soil aggregates (Six et al., 2004). However, understanding the role that soil aggregation plays in fertility recapitalisation also requires a knowledge of how aggregation contributes to organic matter storage in soil (Abiven et al., 2009). Both processes are mediated by soil microbiological activity (Kiem and Kandeler, 1997).

Soil microorganisms and their activities are essential components of the biotic community in natural forests and are largely responsible for ecosystem functioning (Hackl et al., 2004; Kızılkaya et al., 2004). The microbial population and their activities of the soil surface horizon has been far better studied than that of the soil aggregates (Aşkın and Kızılkaya, 2006a, 2009; Dengiz et al., 2013). Microorganisms in soil also play not only an important role in ecosystem biogeochemical cycles of element in a soil (Madsen, 1995) but also

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ISSN: 2147-4249

assist the weathering processes or soil particles integration by providing organic ligands and acids. Several micbiological parameters have been used to define the status and sustainable development of soil productivity in natural ecosystems (Visser and Parkinson, 1992; Kızılkaya and Bayraklı, 2005). There are lots of methods currently available to study the microorganisms and their activities at the microhabitat level (Nannipieri et al., 1990). The dependence of microbiological properties of soils on site and soil factors has been studied by several authors (Vekemans et al., 1989). Some soil micbiological properties such as enzyme activities and microbial biomass are used as bio-indicators for soil quality and health for environmental soil monitoring (Rogers and Li, 1985). It has been proposed that the microbiological status of a soil can be used as an early and sensitive indicator of soil ecological stress or restoration processes in both natural ecosystems (Ruf et al., 2003; Aşkın and Kızılkaya, 2006b). Among these microbiological factors, soil enzymes have been suggested as potential indicators of soil quality due to their biological nature, simple measurement and rapid response to changes in soil management when compared to other biological properties (Ling et al., 2010). Among various soil enzymes, dehydrogenase activity has been recognized as important biochemical indicators in soil (Kızılkaya, 2008; Ryoichi and Senaratne, 2009). Lenhard (1956) introduced the concept of determining the metabolic activity of microorganisms in soil and other habitats by measuring dehydrogenase activity. The activity of the dehydrogenase activity is considered an indicator of the oxidative metabolism in soils and thus of the microbiological activity (Skujins, 1973; Alef, 1995; Garcia et al., 1997; Kızılkaya and Hepşen, 2007) because it is linked to viable cells.

This toposequence perspective has been used by most of the authors working on similar studies, especially when taking into account the microbiological and topographical aspects. Some of them estimated the link between these two factors in large or small spatial scales, comparing between microbiological properties in soils and natural ecosystems such as forest, grassland and agricultural use. In this study the authors, working over "*dehydrogenase activity in soil macro aggregates*", explain the landscape as a key concept through which we can understand the ecological processes in the forest soil, assuring that "spatial pattern of forest microbiological storages are dependent on the topography through the variability of soil macroagggate size and landscape position". The main objectives of this study were to: (i) to assess the influence of topography on soil macro aggregates size distribution (ii) to compare the relationships between macro aggregate size distribution and soil dehydrogenase activity.

Material and Methods

Description of the study area

The study area is located in the Kocadağ, Samsun (Latitude, 41º 19' N; longitude, 36º 02' W) and has an elevation between 200 – 1200 m above sea level in Northern Anatolia. The study was carried out in December 2012. The climate is semi humid, (R_f = 52.5) with temperatures ranging from 6.6ºC in February to 23ºC in August. The annual mean temperature is 14ºC and annual mean precipitation is 735 mm. Topograpy and slope show great variations and hilly and Rolling physiographic units are particularlu common in the study area. Geology of the study area is dominantly composed of sandstone and limestone. The research area is in the A6 square according to the Davis's grid system (Davis, 1965). Dominant two species of natural forest are *Quercus cerris* L. var.*cerris* and *Quercus petraea* (Mattuschka) Liebl. Subsp. *iberica* (Steven ex Bieb) Krasslin. Some part of natural forest has been fragmented and degraded bu such human disturbances. As a result of the destruction *Rhododendron lutetum* Sweet. communities replaced this forest.

Soil sampling

On the basis of hypothesis that toposequence might be the main controlling factor in Soil microbial indices of aggregates. Soils have been studied on along transect (crosswise from Southt to North direction) with representative five surface soil at summit, shoulder, backslope and footslope positions were described (Figure 1).

The samples were transported to the laboratory on the same day. To analyze some soil physicochemical analyses, crop residues, root fragments and stones >2 mm were removed from soil samples. The soil samples were crumbled gently by hand and sieved (<8mm openings) without root material. The soil aggregates were separated from different diameter sieves, thus,we obtained total 30 macroaggregate samples. These samples were used to determine microbial indices of soils at the field moisture condition. Also each sample was stored in polyethylene bags at 4 ^{0}C in the refrigerator for no longer than 72 h prior to analysis.

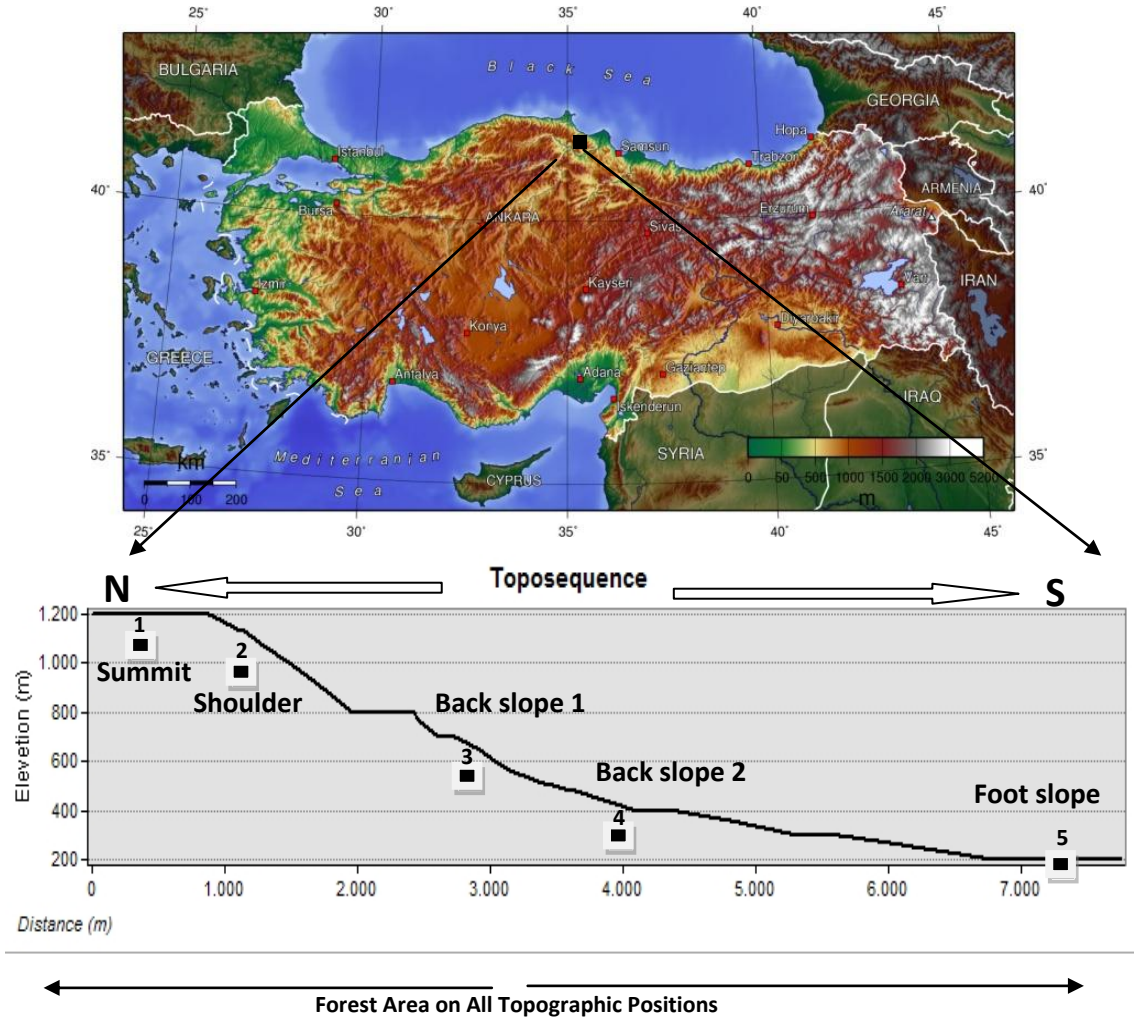

Figure 1. Transect of the five different soil sample points on the same land cover but different topographic positions

Soil physico-chemical analysis

Soil samples were then air-dried and passed through a 2 mm sieve, particle size distribution was determined by the hydrometer method (Bouyoucos 1951). Organic matter was determined in air-dried samples using the Walkley- Black wet digestion method. pH and electrical conductivity (EC) in 1:1 (w/v) in soil: water suspension by pH-meter and EC-meter. $CaCO_3$ by Scheibler calcimetric method (Rowell, 1996).

Separation of Aggregates

The initial macro aggregate size distribution was determined by sieving 2 kg soil for 2 min on a stack of sieves with openings 6.30, 4.75, 2.00, 1.40 and 1.00 mm, from the top to the bottom of stack, using an automatic sieve shaker (speed and time of shaker were same) manufactured ELE International. Each size fraction was weighed and eight size classes were obtained: [I] >6300 μm (extremely macro-aggregate), [II] 6300 – 4750 μm (very strongly macro-aggregate), [III] 4750 – 2000 μm (strongly macro-aggregate), [IV] 2000 – 1400 μm (moderately macro-aggregate), [V] 1400 – 1000 μm (slightly macro-aggregate) and [VI] < 1000 μm (very slightly macro-aggregate), indicated by Tisdall and Oades (1982) and Nearing (1995).

Dehydrogenase activity in aggregates

DHA was determined according to Pepper et al. (1995). Six grams of soil aggregates, 30 mg glucose, 1 ml of 3% 2,3,5-triphenyltetrazoliumchlorid (TTC) solution and 2.5 ml pure water were added. The samples were incubated for 24 h at 37 ^{o}C. The formation of 1, 3, 5 triphenylformazan (TPF) was determined spectrophotometrically at 485 nm and results were expressed as μg TPF g^{-1} dry sample. All dehydrogenase

activity results reported with the mean value of three replicates determinations calculated on an oven-dry basis; moisture was determined from loss in weight after drying the soil at 105^{0}C for 48 h.

Statistical Analysis

Statistical analysis was performed by variance anaylsis (ANOVA) where significant *F*-values were obtained, differences between individual means were tested using the LSD (Least Significant Difference) test, with a significance level of P <0.01. The asterisks, *, ** and *** indicate significance at P <0.05, 0.01 and 0.001, respectively.

Results and Discussion

Soil physico-chemical properties

Soil physical and chemical properties that have been taken into consideration in this research showed variability as a result of dynamic interactions among natural environmental factors such as climate, parent material and topography at short distance in study area formed on accumulated sediment depositions carried by Kocaday forest soil in Samsun, Turkey. Especially, slope has been regarded as one of the most important abiotic factors that control the pedogenic process on a local scale. The major physical and chemical properties of the soils in the current study are presented in Table 1. Soil texture varied from sandy clay loam through silty clay to clay soils. Summit soil had the highest clay content (77,99 %), while foot slope soil had the highest sand content (57.83 %). The pH values of soil samples varied from 5.70 to 7.60 and soils have low in electrical conductivity (<0.98 dS m^{-1}). Soil organic carbon content was highest at shoulder and footslope positions which may be directly related to higher surface cover rates. Effect of topography on soil thickness has been reported by many researchers (Rezai and Gilkes, 2005; McIntosh et al., 2000, Power et al., 1981). These variables are responsible for the effect of eroding forces, different slope position and parent material. Gerrard (1981) also indicated that the movement and distribution of water on slopes is one of the primary reasons for differences of soil properties on landscapes.

Table 1. Selected soil physico-chemical properties at different landscape positions

Soil properties	Landscape position				
	Summit	Shoulder	Back slope 1	Back slope 2	Foot slope
Coordinate (utm)	37T 0257721 4579115	37T 0258378 4579806	37T 0259103 4579500	37T 0260089 4578216	37T 0264006 4578763
Clay, %	77,99	58,6	67,28	38,28	20,91
Silt, %	14,76	25,76	19,55	28,18	21,26
Sand, %	7,25	15,64	13,17	33,54	57,83
Texture class	C	SiC	C	CL	SCL
Organic C, %	3,35	5,38	1,66	3,025	5,45
$CaCO_3$, %	3,4%	0,71%	1,82%	1,82%	1,74%
pH (1:1)	6,70	5,90	7,60	5,70	6,60
EC, dS. m $^{-1}$	0,24	0,20	0,47	0,29	0,93

Aggregate Size Distribution in Soils

Aggregate size distribution in soils percentage distribution of soil macro aggregates in soil samples used dry sieving method in total weight was shown in Figure 2. The contents of macro aggregates (especially > 6.3 mm and 2.00–4.75 mm) in all soil samples were higher than other macro aggregate contents. According to results, it was determined that majority of aggregates generally formed extremely macro-aggregate (> 6.3 mm) at the footslope position. But smallest macro aggregate size (< 1mm, 1.00-1.40 mm and 1.40-2.00 mm) were highest in the crest position. This case can be explained low organic matter content of this soil as compared to other soils. In other words, there was a close correlation among aggregate size and organic matter. Macroaggregate stability depends on management, because of the transient nature of binding agents (Soil Quality Test Kit Guide 1999). Tisdall and Oades (1982) formulated an aggregate hierarchy theory, which explains a gradual break down of macroaggregates, preceding complete dissociation in to primary particles. Another consequence of this principle is that younger and the more labile soil organic matter is contained in macroaggregates than microaggregates. Our result was also showed coherent with another research carried out by Qian et al. (2004), Aşkın and Kızılkaya (2006a, 2009).

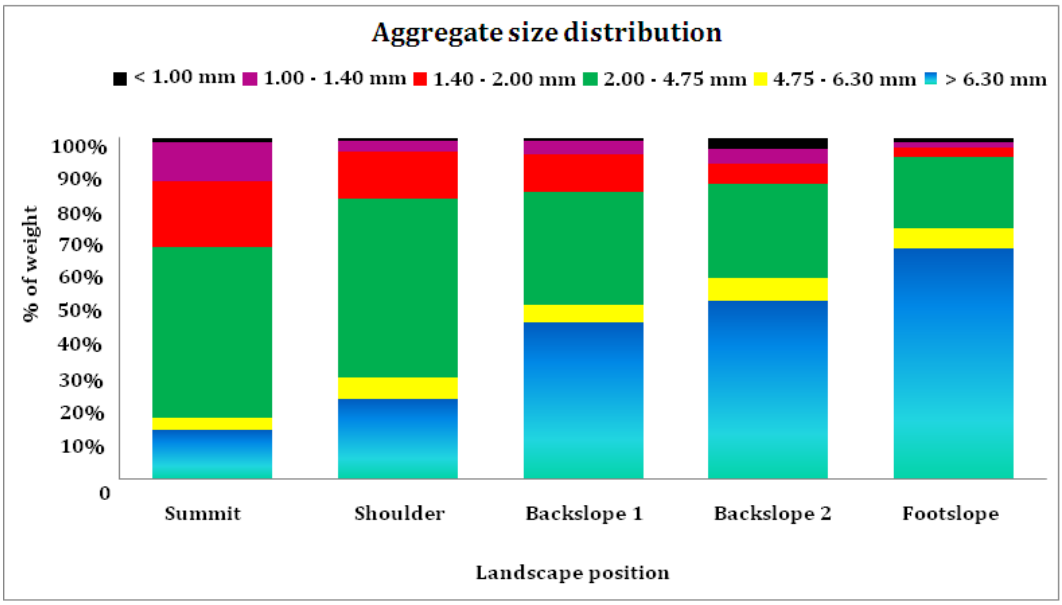

Figure 2. Distribution of natural soil macro aggregates in soil samples

Dehydrogenase activity

The dehydrogenase activity distribution in natural soil macro aggregates was given in Table 2. In Except for shoulder position, the dehydrogenase activity level increased with increasing macro aggregate size (P<0,01), reaching a maximun in the < 1.00 mm at all landscape position. Considerable variations in dehydrogenase activities were found for the different natural macro aggregate size at different landscape positions. Statistically significant variations were found in dehydrogenase activities at various aggregate size and landscape position. The analysis of variance of the results obtained in our research on the dehydrogenase activity showed that all factors (different landscape positions and aggregate size) significantly influenced dehydrogenase activity (Table 2).

Table 2. Changes of dehydrogenase activity (µg TPF g^{-1}) in natural macro aggregate sizes of soil samples

Macro aggregate size	**Landscape position**				
	Summit	**Shoulder**	**Back slope 1**	**Back slope 2**	**Foot slope**
>6,30 mm	0,88 ± 0,06	2,45 ± 0,17	1,34 ± 0,12	1,25 ± 0,09	3,48 ± 0,23
4,75-6,30 mm	1,04 ± 0,19	2,64 ± 0,16	2,11 ± 0,19	1,54 ± 0,25	4,26 ± 0,18
2,00-4,75 mm	1,90 ± 0,05	2,64 ± 0,26	2,14 ± 0,20	3,24 ± 0,18	6,36 ± 0,47
1,40-2,00 mm	2,20 ± 0,05	3,12 ± 0,18	2,19 ± 0,09	3,91 ± 0,22	8,05 ± 0,37
1,00-1,40 mm	2,57 ± 0,11	2,55 ± 0,04	2,82 ± 0,18	5,36 ± 0,07	9,52 ± 0,39
<1,00 mm	2,73 ± 0,11	1,76 ± 0,12	3,55 ± 0,14	6,43 ± 0,41	13,14 ± 2,10
Mean value*	1,87	2,65	1,82	2,32	4,47
	Statistically Analysis results				
			F-value	***LSD (1%)***	
Landscape position (L)			514,108***	0,377	
Macro aggregate size distriction (A)			157,083***	0,413	
L x A			37,451***	0,923	

*Mean value calculated from % of weight x each aggregate size

Dehydrogenase activity reflects the total range of oxdative activity of soil microflora and, consequently it may be a good indicator of microbiological activity in the soil (Skujins, 1973). In this study, dehydrogenase activity levels showed clear differences among macro-aggregate sizes. It was found that except for shoulder position, dehydrogenase activity levels were greater in macroaggregates of <1.00, 1.00-1.40, 1.40-2.00 mm than in the other macroaggregates sizes. The lowest levels in dehydrogenase activity occurred on the summit and backslope 1 position. In contrast, the highest levels in dehydrogenase activity occured on the footslope position which was agreement with previous workers such as Aşkın and Kızılkaya (2006a, 2009). The major reason for increased dehydrogenase activity in the footslope position compared to the other

landscape positions are attributed to the greater availability of organic carbon, nutrients and stimulated microbial activity in the soil. Dehydrogenase activity in soil depends on the content of soluble organic carbon (Casida, 1977; Zaman et al., 2002, Kızılkaya and Hepşen, 2007; Kızılkaya, 2008) and the increased organic matter in the surface soil enhanced the soil dehydrogenase activity. Furczak and Joniec (2007) showed that stimulation of dehydrogenase activity was accompanied by an increase in the number of the microbial groups and improvement in other living conditions such as aeration and moisture.

Conclusion

Topography and aggregate size can influence microorganisms and their activities through affecting soil microclimate, physical and chemical soil characteristics, plant growth, and below ground C inputs. This study demonstrated that changes of macro aggregate size distribution can alter the soil dehydrogenase activity within the aggregates. The results indicate that the macro aggregate size distribution and dehydrogenase activity of macro aggregates along a hillslope had great differences in the forest soil depending homogeneous plantation. The footslope position has greater organic C contents compared to the other positions, because the higher levels in the organic matter content c1early show erosional deposits at the footslope and denudation of shoulder. In conclusion, soil properties and dehydrogenase avtivity changed depending on landscape positions and aggregate sizes. Therefore, the forests must be used according to site specifie management principles. This calls for cautions in large-scale conversions of the native forests to coniferous plantations as a forest management practice on concerns of sustainable soil productivity.

Acknowledgments

We are grateful to the TUBITAK-BIDEB (The Scientific and Technological Research Council of Turkey) for their financial support.

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