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Clay activity index as an indicator of soil erodibility

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Abstract

Activity index (AI) value characterizes the relationship between the plasticity index and clay content. In this study, AI value was investigated to determine whether it might be used as an indicator of soil structural stability or not. The AI values of 75 soil samples gave the significant negative correlations with their dispersion ratio (DR), soil erodibility factors (K) and erosion ratios (ER). Also, the AI values of the soils including clay and sandy clay loam textural class showed significant positive correlation with soil structural stability index (SSI). It seems that the AI value may be used as an indicator of soil structural stability.

Keywords: AI value, erosion ratio, soil erodibility, structure stability index.

Introduction

As the world population rate increases, cultivation of agricultural lands becomes increasingly necessary to feed this high population. Therefore, soil management and cultivation practices should be improved to sustain soil fertility and to prevent high erosion vulnerability. Almost 80% of Turkish soils are affected by erosion requiring radical precautions, especially on cultivated land. Hence it is of primary importance to know the major factors, which influence erosion at various degrees (Özdemir and Aşkın, 1999; 2003). It is known that soil properties limit the land use and management or establish the severity of the limitation. An abundance of nutrients in soil does not always indicate high crop production. Soil structure one of the most important soil physical properties is known as an indicator of the productivity of a given soil and also controls the severity of soil erosion.

Soil structure can be improved or destroyed readily through our choice and timing of soil management practices (Hillel, 1982). Soil structure influences some soil erodibility indices such as, dispersion ratio (DR), erosion ratio (ER), erodibility factor (K) and soil structural stability index (SSI). These indices have been developed to determine soil erosion susceptibility and used to assess sustainable soil use and management (Bryan, 1968; Karagül, 1999; Morgan, 2005).

Atterberg limits and clay content have been combined into a single parameter called the Activity Ratio developed by Skempton (1953). Activity Raito, sometimes called the Activity Index (AI), is defined as the ratio of the plastic index to the percentage of clay sized minerals. Gülser et al. (2009) studied the relationships between soil workability and soil mechanical properties such as; activity index, Atterberg limits, soil consistency in the field of Karadeniz Agricultural Research Institute, Samsun-Turkey. It may be used for a rapid and quantitative method to assessing soil structure. The objective of this study was to determine whether clay activity index might be used as an indicator of soil structural stability or not.

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Material and Methods

In this study, 75 soil samples used were taken from 0 to 20 cm depth around Samsun province of Turkey. Some soil physical and chemical properties were determined as follows; particle size distribution by the hydrometer method (Demiralay, 1993); lime content by Scheibler calsimeter (Soil Survey Staff, 1993); soil reaction (pH) in 1:2.5 (w:v) soil-water suspension by pH meter (Black, 1965); organic matter content by Walkley-Black method (Kacar, 1994). Field capacity (FC) was measured at 33 kPa on a ceramic plate (Klute, 1986). Activity index (AI), dispersion ratio (DR), erosion ratio (ER), soil erodibility factor (K), and structural stability index (SSI) values were estimated by the following equations:

$$AI = \frac{LL - PL}{Clay, \%}$$

Where, LL is a percent moisture in liquid limits, PL is a percent moisture in plastic limits (Baumgartl, 2002).

$$DR (\%) = (a/b) * 100$$

Where, a is the percentage of silt plus clay in suspension, b is the percentage of silt plus clay dispersed with chemical agent (Bryan, 1968).

$$ER (\%) = (a/b) * (A/c) * 100$$

Where, a is the percentage of silt plus clay in suspension, b is the percentage of silt plus clay dispersed with chemical agent, A is the field capacity, c is the percentage of clay dispersed with chemical agent (Akalan, 1967).

$$K = [(2.1 * 10^{-4} (M)^{1.14} (12 - a) + 3.25 (b - 2) + 2.5 (c - 3)) 1.292] / 100$$

Where, M is the particle size parameter (% silt + % very fine sand)*(100 - % clay), a is the percentage of organic matter, b is the soil structure code and c is the profile permeability class (Wischmeier and Smith, 1978).

$$SSI (\%) = \sum b - \sum a$$

Where, b is the percentage silt plus clay dispersed with chemical agent, a is the percentage of silt plus clay in suspension (Leo, 1963).

Descriptive statistics of AI Value and soil erodibility indices was calculated by using SPSS. The correlations between AI value and the other indices, DR, ER, K and SSI were also estimated (Steel and Torrie, 1982).

Results and Discussion

Some physical and chemical properties of soil samples

Some physical and chemical properties of the soil samples used in this study are given in Table 1. According to soil particle size distribution, 75 soil samples were classified into five different textural classes with 25 in clay (C), 27 in clay loam (CL), 12 in sandy clay loam (SCL), 7 in loam (L) and 4 in sandy loam (SL). Cation exchange capacity (CEC, cmol/kg), lime ($CaCO_3$) and organic matter contents of the soil samples varied from minimum 16.00 cmol/kg, 0.31% and 1.02% to maximum 57.82 cmol/kg, 44.87% and 3.25% with the means of 34.38 cmol/kg, 5.98%, and 1.84% respectively. Soil reaction (pH) of the samples was generally alkaline and changed from strongly alkaline (8.7) to slightly acid (5.7) (Soil Survey Staff, 1993).

Table 1. Mean and standard deviation (SD) values of physical and chemical properties of soil samples (n=75)

Soil textural class	Sand, %		Silt, %		Clay %		pH (1:2.5)		$CaCO_3$, %		Org. Mat., %		CEC, cmol/kg	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C	26.13	5.9	27.34	4.7	46.52	5.1	7.38	0.5	8.02	10.1	2.31	0.4	41.47	6.4
CL	36.96	6.1	28.15	5.3	34.88	3.5	7.75	0.3	5.92	4.3	1.78	0.4	34.10	3.9
SCL	53.09	2.8	21.42	4.9	25.49	4.4	7.36	0.8	3.58	3.6	1.63	0.6	32.03	4.2
L	38.76	5.1	36.93	4.8	24.30	3.2	7.80	0.6	4.28	4.3	1.34	0.3	24.68	6.1
SL	62.02	2.5	22.00	1.1	15.98	1.6	7.63	0.5	3.93	3.9	1.35	0.1	17.60	1.1
n=75	37.34	11.8	27.39	6.3	35.27	10.3	7.57	0.5	5.98	6.7	1.84	0.5	34.38	8.2

AI value and soil erodibility indices of the soil samples

Descriptive statistical results for activity index (AI) value and soil erodibility indices; dispersion ratio (DR), erosion ratio (ER), erodibility factor (K) and structural stability index (SSI) in different textural classes are given in Table 2. The AI value describes the relationship among plasticity index and clay content in soil. Regardless of textural classes, the AI values of all soil samples varied from 0.16 to 0.78 with a mean of 0.44 and 37.36 % coefficient of variance (CV). Coefficient of variance values of AI depend on textural classes were between 4.63% found in SCL and 14.46% found in C.

Table 2. Descriptive statistics of AI value, soil erodibility indices such as, dispersion ratio (DR), erosion ratio (ER), erodibility factor (K) and structural stability index (SSI) of the soils

Factor	Soil Texture	Min.	Max.	Mean	SD	CV	Skewness
AI	C	0.49	0.78	0.62	0.09	14.46	0.39
	CL	0.33	0.48	0.41	0.04	11.87	0.11
	SCL	0.30	0.32	0.30	0.01	4.63	0.38
	L	0.21	0.27	0.24	0.02	7.63	0.35
	SL	0.16	0.21	0.18	0.02	12.21	-0.12
	n =75	0.16	0.78	0.44	0.16	37.36	0.49
DR (%)	C	11.85	31.00	20.50	5.58	27.25	0.04
	CL	20.00	47.25	27.84	6.42	23.05	0.36
	SCL	23.02	39.88	30.82	3.33	17.78	0.64
	L	27.00	54.05	35.60	8.57	24.07	1.39
	SL	31.00	41.00	37.17	4.09	10.99	-1.51
	n =75	11.85	54.05	27.90	8.26	29.69	0.46
ER (%)	C	7.12	22.00	15.72	4.34	27.59	-0.32
	CL	23.00	31.02	27.27	2.58	9.44	-0.16
	SCL	34.00	44.14	34.45	1.94	5.18	-0.04
	L	41.00	5.00	45.53	3.02	6.63	-0.15
	SL	51.00	81.00	63.66	11.25	17.68	1.41
	n=75	7.12	81.00	28.73	13.19	45.94	0.38
K	C	0.11	32	0.19	0.04	20.50	0.49
	CL	0.21	0.38	0.26	0.04	14.00	0.15
	SCL	0.33	0.42	0.37	0.02	4.74	-0.20
	L	0.42	0.44	0.43	0.01	1.60	0.31
	SL	0.46	0.50	0.48	0.02	3.25	0.01
	n=75	0.11	0.50	0.28	0.09	34.28	-0.40
SSI (%)	C	42.00	72.96	57.22	6.82	11.75	0.53
	CL	31.44	57.00	44.20	6.76	15.45	-0.19
	SCL	26.82	42.00	36.80	4.41	11.97	-1.44
	L	27.33	41.45	34.82	4.21	12.10	4.34
	SL	30.00	36.00	34.00	1.36	2.60	-2.00
	n=75	26.82	72.96	46.05	10.71	23.27	0.384

Positive values of the skewness or third central moment suggest tailing to the right, while negative values of the skewness suggest tailing to the left on the horizontal axis of a plot. A symmetrical distribution always has zero for the value of skewness (Isaaks and Sarivastava, 1989). Therefore, the AI values in CL and SL texture classes showed almost a symmetrical distribution due to their skewness values becoming close to zero. While the lowest mean AI value was 0.18 found in SL textural class, the highest mean AI was 0.62 found in C textural class. Also, the highest skewness, (0.39) and standard deviation (0.09) for AI values were obtained in the C textural class. Atterberg limits and clay content can be combined into a single parameter called activity (Skempton, 1953). Activity value is used as an index for identifying the swelling potential of clay soils. Skempton (1953) suggested three classes of clays according to activity: i) inactive, AI less than 0.75, ii) normal, AI between 0.75 and 1.25 and iii) active, AI greater than 1.25. According to this assessment, the soils sampled from around Samsun province of Turkey were mostly considered inactive. Gülser et al. (2009) reported that activity index values of soils in Karadeniz Agricultural Research Institute Field, Samsun Turkey varied between 0.44 and 0.65 with a mean of 0.53 which was less than 0.75, and they concluded that soils in the field have inactive clays with only little swelling-shrinking activity.

Dispersion ratio was used to evaluate soils erodibility by the amount of silt plus clay in a dispersed state (Bryan, 1969). Dispersion ratios for all soil samples varied between 11.85% and 54.05% with a mean of 27.90% and 29.69% CV. While the texture class changed from fine to coarse, mean dispersion ratio increased 20.50 % in C to 37.17 % in SL. Erosion ratio is the form of dispersion ratio that is combined with the ratio of "colloidal content/field capacity" (Bryan, 1968). Erosion ratio for all soil samples changed from 7.12 to

81.00% with a mean of 28.73%. While the texture class changed from fine to coarse, mean erosion ratio increased from 15.72% in C to 63.66 % in SL. Erodibility, the vulnerability or susceptibility of the soil erosion, is a function of both the physical characteristics and the management of soil (Hudson, 1995). Erodibility factors (K) for all soil samples varied from 0.11 in C to 0.50 in SL with a mean of 0.28. Structural stability index (SSI) by the sum of the difference between mechanical and aggregate analyses of silt plus clay fractions was introduced as a rapid technique for estimating structural stability of soils by Leo (1963). SSI for 75 soil samples varied from 26.82% to 72.96% % with a mean of 46.05 %. While the texture of soil samples changed from fine to coarse, the mean SSI values decreased 57.22% in C to 34.00% in SL.

Relationships between AI value and soil erodibility indices

The relationships between the AI value and the soil erodibility indices of soil samples in different textural classes are given in Table 3. It was found that AI values of soil samples in all textural classes had negative relationships with DR, ER, K and positive relationships with SSI. When 75 soil samples were evaluated together, the AI value gave the statistically significant negative correlations with dispersion ratio (-0.721**), erosion ratio (-0.910**), erodibility factor (-0.939**) and a positive correlation with structural stability index value (0.692**) in Figure 1. If the texture classes are considered individually, the AI values in C textural class gave the significant correlations with the most erodibility indices such as, DR, ER, K and SSI. Except SL textural class, AI value showed the significant negative relations with almost all ER and K values in the other texture classes too. Also, AI values only showed significant positive correlations with SSI of soil samples in C (0.524**) and in SCL (0.642**) textural classes.

Table 3. Relationships between AI Value and Erodibility Indices

Soil Textural Class	DR, %	ER, %	K	SSI, %
C	-0.545**	-0.838**	-0. 920**	0.524**
CL	-0.597**	-0.979**	-0.986**	0.217
SCL	-0.380	-0.963**	-0.931**	0.642*
L	-0.774*	-0.984**	-0.904**	0.474
SL	-0.880	-0.851	-0.778	0.540
n=75	-0.721**	-.910**	-0.939**	0.692**

*significant at the 0.05 level, ** significant at the 0.01 level.

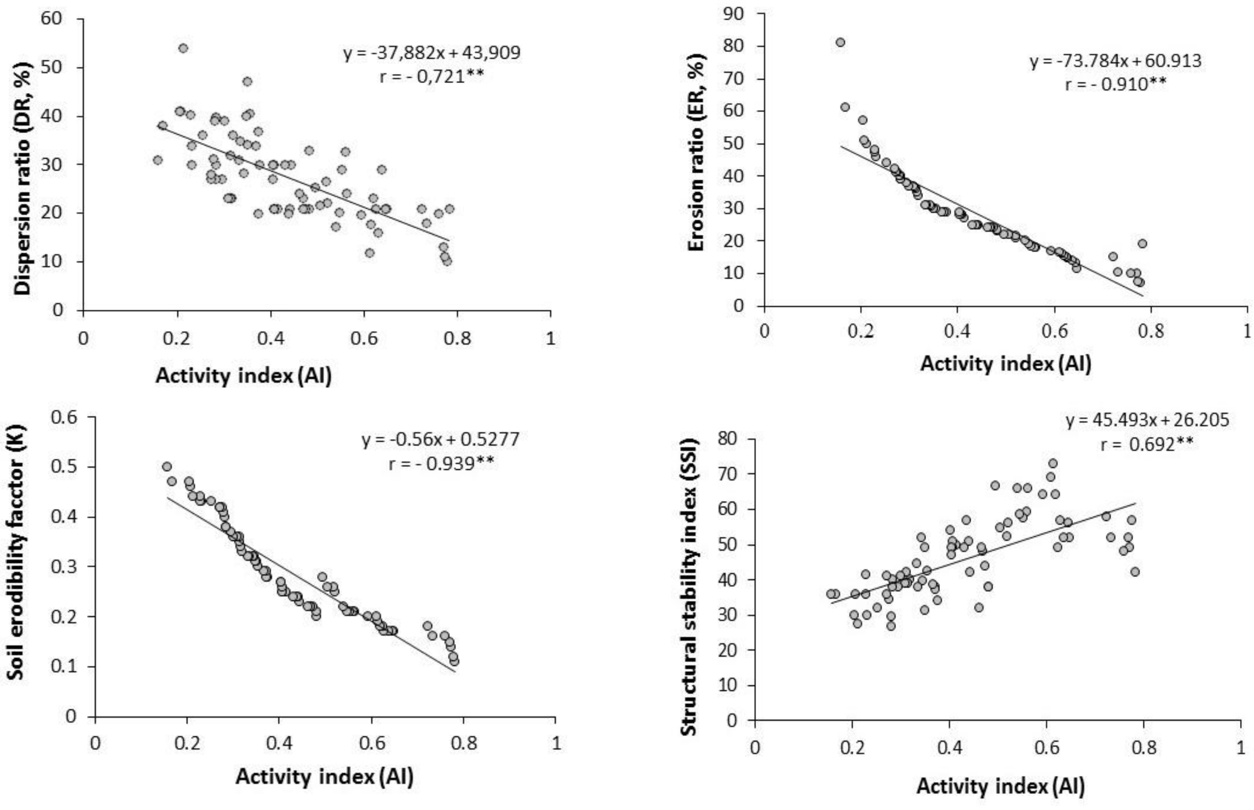

Figure 1. The relationship between AI value and soil erodibility parameters indexes within 75 soil samples

Conclusion

AI values in this study usually had higher correlation with erosion ratio and erodibility factor than the other erodibility indices. It may be explained that there are some similar parameters used in the estimations of highly correlated these indices. For example, field capacity and organic matter content used in estimation of erosion ratio and erodibility factor were only different parameters from the other parameters used in calculation of dispersion ratio and structure stability index. Because, silt plus clay content were only parameters used in estimation of DR and SSI. Plasticity index value and clay content other than particle size distribution were also used in estimation of AI value. Therefore, it seems reasonable that AI value would give high correlations with ER and K due to including similar parameters in their estimations.

As a result, due to significant relationships between AI value and the other erodibility indices, the AI value may be used as an indicator of soil structural stability especially in soils having fine textural class. Besides particle size distribution, using plasticity index value in estimation of AI value gives more details about soil structure than DR and SSI. It will be useful that further studies in field and laboratory conditions should be made along this line to increase validity of this study.

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