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Research Article

Predicting Aggregate Stability of Cultivated Soils

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Abstract In this study, aggregate stability (AS) values of cultivated soils were predicted using basic soil properties as variables in a linear regression model. A total number of 176 surface soil samples (0-20 cm) were taken from cultivated agricultural fields in Bafra Plain of Samsun, Turkey and analyzed to determine AS, texture, soil reaction (pH), electrical conductivity (EC), organic matter (OM) content and exchangeable cations (Ca, Mg, K, Na). While AS values had significant positive correlations with OM (0.44**), clay (0.51**), Ca (0.23*) and K (0.17*) contents, they gave significant negative correlations with pH (-0.22**), silt (-0.23**) and sand (-0.36**) contents. AS values were predicted using a linear regression model produced by using the variables of clay, sand, OM, pH, K and EC in stepwise analyses. The R2 value of the linear regression equation was 0.55** and statistically significant at 0.01 level. Clay, sand, pH and OM contents were the most effective variables on water stable aggregates to predict AS values of cultivated surface soils. Prediction of soil AS values of cultivated fields is important to select the best soil management system to reduce soil degradation in sustainable agriculture.

Keywords water stabile aggregates, soil properties, stepwise analysis, linear model

1. Introduction

Aggregation is an indicator of soil structure and results from the rearrangement of particles, flocculation and cementation [1]. Aggregate stability is known as a main factor improving agronomic productivity, controlling topsoil hydrology, crustability and erodibility [2]. Soil degradation involves destruction of soil structure due to loss of soil organic matter by intensive agricultural practices. Most studies showed that the amelioration of soil physical properties is largely based on increases of organic carbon in the soils [3-5].

Aggregates improve soil quality by protecting soil organic matter entrapped in the aggregates from exposure to air and microbial decomposition, decreasing soil erodibility, improving water and air movement, improving the physical environment for root growth and improving soil organism habitat [6]. Breakdown of aggregates is the first step to crust development and surface sealing, which impedes water infiltration and increases erosion. Soil aggregation can change over a period of time, such as in a season or year. Aggregates can form, disintegrate, and reform periodically [7].

Multiple regression equations which correlate the soil properties with easily available other soil properties are called as pedotransfer functions or models [8]. These models have been used successfully to determine hydrological and physicochemical properties of soils [9, 10]. The objective of this study was to determine relationships between aggregate stability and soil properties, and to predict aggregate stability of cultivated soils using basic soil physical and chemical properties.

2. Materials and Methods

In this study, 176 surface soil samples (0-20 cm) were taken from cultivated agricultural fields in Bafra Plain of Samsun, Turkey. After the soil samples were air dried and passed through 2 mm sieve, some basic soil properties were analyzed as follows. The organic carbon (OC) content was determined using the modified Walkley-Black method [11]; particle size distribution by hydrometer method [12], soil reaction (pH in 1:1 soil:water suspension) by pH meter, electrical conductivity (EC25ºC) in the same soil suspension by EC meter, exchangeable cations (Ca, Mg, K, Na) by ammonia acetate extraction [11]. Aggregate stability (AS) was determined for soil samples using a wet sieving method [13]. The equivalent of 40 g of oven dried soil aggregates was placed on a sieve with a 0.25 mm opening. The sieve was lowered to the water surface and the soil sample was allowed to be wetted via capillary action for 5 minutes. The Yoder apparatus had a vertical stroke of 45 mm and was operated for 5 minutes at a speed of 37 cycles min-1. The fractions left on the sieve at the end of sieving were oven dried at 105ºC to constant mass. Aggregate stability was expressed as a percentage of the total sieved samples. Corrections for the sand content were made in the calculations after the fractions were dispersed chemically. To predict the AS values of the soils, a multiple regression equation between AS and the soil properties was obtained with stepwise analyses using the SPSS statistic program.

3. Results and Discussion

Some physical and chemical properties of the soils used in this study are given in Table 1. Soil samples were usually fine in textural class, varied between slightly acid and slightly alkaline in pH (1:1), and non-saline according to EC values [14]. Rating of organic matter content results of soil samples showed that 11% of soil samples is very low, 41% is low, 36% is moderate and 12% is high in organic matter content. Frequency distribution of the aggregate stability values of soil samples is given in Figure 1. The results showed that AS in 17% of soil samples is very low, 29.4% is low, 20.3% is moderate and 33.3% is high [15].

Table 1: Descriptive statistics of soil physical and chemical properties (n=176)

	Minimum	**Maximum**	**Mean**	**Std. Deviation**	**Skewness**
AS, %	2.01	66.92	23.18	13.37	0.56
Clay, %	9.99	67.38	34.04	13.38	0.21
Silt, %	3.05	66.37	27.57	8.71	0.69
Sand, %	4.27	81.71	38.39	16.11	0.48
pH(1:1)	4.85	8.33	7.56	0.63	-2.03
EC, dS/m	0.11	2.95	0.65	0.45	2.77
OM, %	0.20	4.19	1.97	0.74	0.25
Ca, cmol/kg	2.36	52.53	23.37	9.60	-0.31
Mg, cmol/kg	1.01	21.12	7.77	4.33	0.55
K, cmol/kg	0.11	1.79	0.59	0.34	0.94
Na, cmol/kg	0.08	5.64	0.60	0.79	4.10

AS:Aggregate stability; OM:Organic matter.

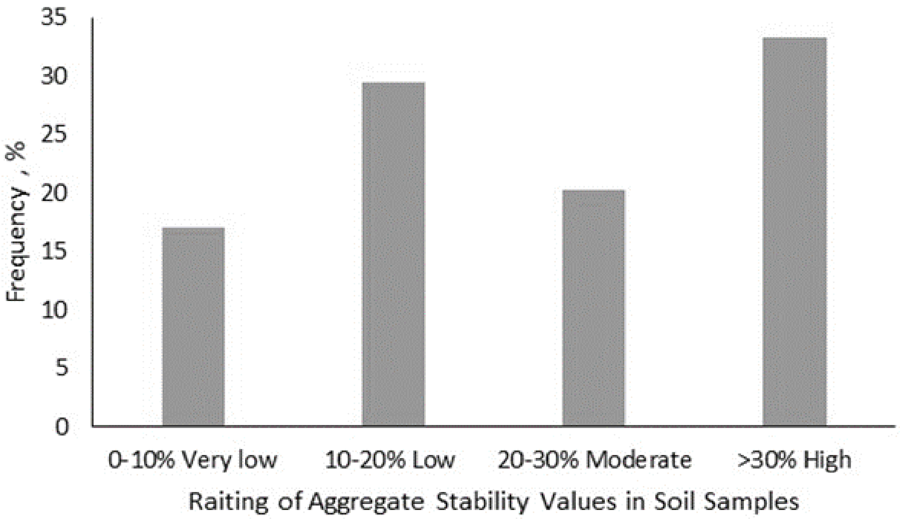

Figure 1: Frequency distribution of the aggregate stability analyses results of the soil samples

The correlation matrix between AS values and soil properties is given in Table 2. Aggregate stability values showed significant positive correlations with clay (0.51**), soil organic matter (0.44**), exchangeable K (0.17*) and Ca (.023**) contents and significant negative correlations with soil pH (-0.22**), sand (-0.23**) and silt (-0.36**) contents. It is known that there is a positive relationship between soil organic matter and aggregate stability [1, 4]. Soil organic matter is metabolized by a variety of microorganisms to produce polysaccharides that act to bind soil particles into micro aggregates [16, 17].

Table 2: Relationships among the soil properties of cultivated fields

	Clay	**Sand**	**Silt**	**OM**	**pH**	**EC**	**Na**	**K**	**Ca**	**Mg**
AS	0.51^{**}	-0.23^{**}	-0.36^{**}	0.44^{**}	-0.22^{**}	-0.01	-0.09	0.17^{*}	0.23^{**}	0.08
Clay		-0.84^{**}	0.02	0.58^{**}	0.38^{**}	0.40^{**}	0.17^{*}	0.57^{**}	0.73^{**}	0.58^{**}
Sand			-0.56^{**}	-0.57^{**}	-0.46^{**}	-0.33^{**}	-0.15	-0.48^{**}	-0.69^{**}	-0.57^{**}
Silt				0.17^{*}	0.26^{**}	-0.01	0.01	0.01	0.15^{*}	0.17^{*}
OM					0.15^{*}	0.12	-0.11	0.47^{**}	0.49^{**}	0.34^{**}
pH						0.30^{**}	0.21^{**}	0.25^{**}	0.57^{**}	0.46^{**}
EC							0.82^{**}	0.35^{**}	0.33^{**}	0.60^{**}
Na								0.17^{*}	0.07	0.47^{**}
K									0.55^{**}	0.49^{**}
Ca										0.46^{**}

*significant at 5%level, **significant at 1%level, AS: Aggregate stability; OM: Organic matter.

AS values were predicted using a linear regression model produced by stepwise analyses and given below. The variables of clay (C), sand (S), OM, pH, K and EC were used in the model.

$$AS = 17.996 + 1.157*C - 7.346*pH + 0.494*S + 4.837*OM - 7.965*K + 3.805*EC$$

The R^2 value of the linear regression between experimental and estimated AS values is 0.55 and significant at 0.01 level statistically (Figure 2). It was obtained that clay, sand, pH and OM contents are the most effective variables on water stable aggregates to predict AS values of cultivated surface soils. In another study, it was reported that the effects of organic waste treatment on aggregate stability in a sandy clay loam soil described very well using the second order pedotransfer function with a high regression coefficient (0.918**) [18].

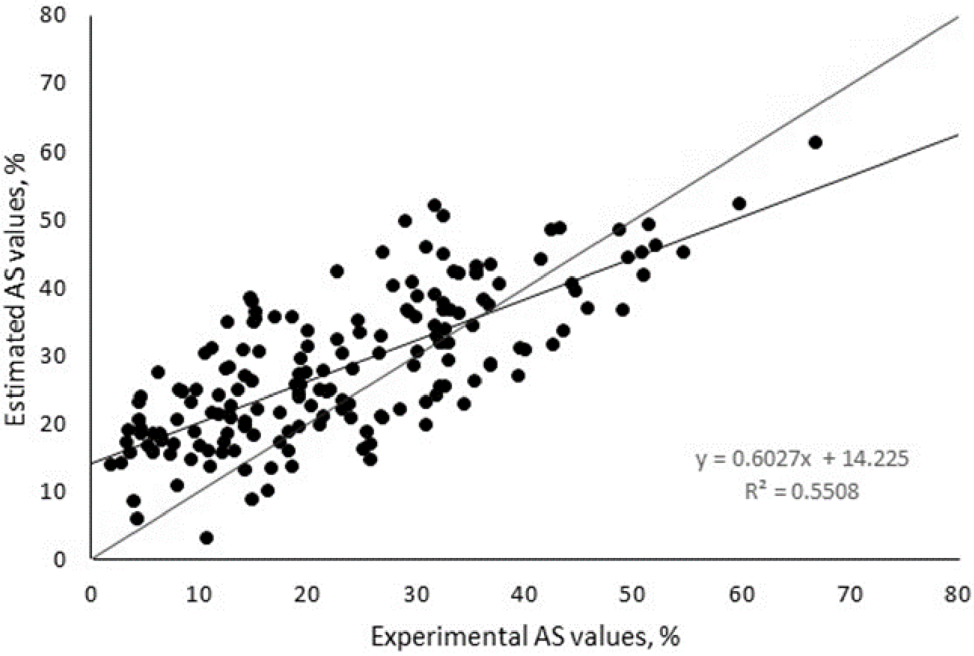

Figure 2: The relationship between experimental and estimated AS values

4. Conclusion

In this study, AS values of the soils had significant positive relationships with OM, clay, exchangeable Ca, K contents, and significant negative relationships with pH, silt and sand contents. It was determined that clay, sand, pH and OM contents of soils were the most effective variables on water stable aggregates to predict AS values of cultivated surface soils. Therefore, AS values of cultivated fields were predicted using the soil properties in the linear regression model. As a result, AS values of cultivated soils can be predicted very well with the model equation developed using soil texture together with pH, OM, exch. K and EC. Further researches are also required to increase accuracy of predicting AS under different soil textural and chemical conditions. Prediction of soil AS values of cultivated fields is important to select the best soil management practices to reduce soil degradation in sustainable agriculture.

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