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Relationships between some soil properties and bulk density under different land use

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Abstract

In this study, the changes of some soil physical and chemical properties were investigated under different land use conditions in Turhal, Turkey. Soil samples were collected from 0-20 cm depth from twenty four plots under eight different land uses which are sunflower, wheat, vegetable, orchard, sugar beet, meadow, pasture and alfalfa plants. Some soil properties where these plants are grown and their effects on the bulk density were investigated. The findings show that basic soil properties and practices related to plant management are effective on the bulk density. While the lowest mean bulk density value was determined in meadow (1.00 g cm^{-3}) areas, the highest bulk density value was determined in soils cultivated with sugar beet (1.71 g cm^{-3}). Correlations between the investigated parameters were tested with the use of Pearson's correlation method. Bulk density and some soil parameters used in the evaluation of structural stability and sensitivity to erosion were found significant relationships.

Introduction

Soil is a living, breathing, natural entity composed of solids, liquids, and gases. Bulk density (BD) is defined as the dry weight of soil per unit volume of soil. It is an indicator for soil health and compaction. It affects rooting depth, infiltration, soil porosity, soil microorganism activity, plant nutrient availability and available water capacity. Total volume of surface soil is about 50% solids, soil particles, and soil organic matter (SOM); and about 50% pore space which are filled with air or water. BD is dependent on soil texture, SOM, the density of soil mineral and their packing arrangement. BD is a basic soil property that is effected by the soil properties, tillage climatic conditions and agricultural activities. In an ideal soil, solid components provide root growth medium, attachment and nutrients for plants, while pore spaces provide the air and water needed (Aşkın & Özdemir, 2003). BD which is one of the important indicators of soil quality (Abbott & Manning, 2015) is closely related to environmental quality and biomass production (Makovníková et al., 2017). BD is a dynamic soil property, as it varies in space and time. It is effected by land and crop management practices (Çerçioğlu et al., 2019; Çerçioğlu, 2020), as well as by natural processes such as the climate conditions that influence soil cover, SOM contents, porosity or soil structure (Makovníková et al., 2017). Changes in BD depending on the effectiveness of

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the degrading and forming processes in the soil are closely related to SOM content (Demir et al., 2019; Demir & Işık, 2019, 2020; Demir, 2020) and textural structure (Aşkın & Özdemir, 2003; Makovníková et al., 2017). BD increases with soil depth since subsurface layers are more compacted and have less aggregation, less SOM and less root penetration compared to surface layers, therefore contain less pore space. BD is an important parameter in soil management planning, structural deterioration, soil compaction level and suitability for plant root growth (Dexter, 2004), soil water relationships, and applications related to fertilization, determination of nutrient status and carbon stocks (Ruehlmann & Körschens, 2009; Brahim et al., 2012), and determination of soil porosity (Hillel, 1982; Blake & Hartge, 1986; Aşkın & Özdemir, 2003; Lestariningsih et al., 2013). BD depends on some factors such as consolidation, compaction and amount of soil organic carbon present but it is highly correlated to the organic carbon (Leifeld et al., 2005). Post et al. (1982) reported that SOM and the correlation between BD used frequently to estimate carbon pools. Aşkın & Özdemir (2003) reported the relation of BD with soil particle size distribution and SOM. In many studies, it has been observed that the land use type and changes in use can lead to deterioration in the soil attributes (Arshad & Martin, 2002; Doran, 2002). In this study, the relationships between the BD values and some soil physical and chemical attributes used to investigate in the evaluation of structural stability under different land use types in Turhal district of Tokat province in Turkey.

Materials and Methods

In the study, total 72 soil samples were taken from 0 - 20 cm depth from determined 24 spots (three replications) under 8 different land uses in Turhal, Turkey. Sampling points were selected according to the random sampling method from lands in different uses (90920 ha) included in the entisol soil group. The main products of agricultural production are cereals, tomatoes, sugar beets, sunflowers for oil, fodder crops (vetch, alfalfa, silage corn) and all kinds of fruits and vegetables. The study area is under the influence of a continental-temperate climate. The mean altitude above sea level is 550m. The mean annual temperature and precipitation is 12.9°C and 413.3 mm, respectively (Anonymous, 2020).

Soil particle size distribution was analyzed by hydrometer method (Demiralay, 1993). Modified Walkley-Black method was used to determine soil organic matter (SOM) content (Kacar, 1994). Cation exchange capacity (CEC) were determined as described by Shahid et al. (2018). Scheibler calcimeter was used to determine soil lime contents (Kacar, 1994). A pressure plate apparatus was used to determine soil moisture at field capacity and permanent wilting point (Black, 1965). Soil pH were measured with a pH meter (Bayraklı, 1987) and electrical conductivity were measured with an EC-meter (Kacar, 1994). Consistency limits were analyzed in accordance with the principles specified according to (Demiralay, 1993). Cylinder method was used to determine bulk density (Demiralay, 1993). A wet-sieving apparatus was used to determine aggregate stability (AS) (Demiralay, 1993). Exchangeable Na were determined with ammonia acetate extraction (Sağlam, 1997). Dispersion ratio (DR) values were estimated by the following equation (Equation 1):

Eq. (1) $DR (\%) = (a/b) * 100$

Where, a is the percentage of silt plus clay in suspension, b is the percentage of silt plus clay dispersed with chemical agent (Özdemir, 2013).

Erodibility factor (K) (Wischmeier & Smith, 1978) were estimated by the following equation (Equation 2):

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

Where, K: erodibility factor; indicates the rate of erosion per unit erosion index from a standard area (22.1 m length and 9% slope continuously in fallow). M is the particle size parameter (% silt + % very fine sand)*(100 - % clay), a is the percentage of organic matter, b is the soil structure type code and c is the permeability class code. Soil samples taken from the specified spots under the different land use conditions were analyzed so that the data basic for estimating erodibility were obtained. In estimating the K factor with this method, silt and very fine sand (0.002-0.1 mm), clay (<0.002 mm), organic matter (%), soil structure and permeability classes are used. Soil structure is determined by using soil profile definitions while the other rates are determined by laboratory analysis.

Percent shrinkage was calculated using the change in the volume of the soil paste stacked in circular molds with an inner diameter of 5mx1cm (Ferry & Olsen, 1975). Correlations between the investigated parameters were tested with the use of Pearson's correlation method by SPSS 19.0.

Results and Discussion

Soil Properties

Some physical and chemical soil properties taken from 24 plots under 8 different land uses are given in Table 1. These soils are in a range varying from coarse to fine in terms of texture, and sand contents vary between 20.2% and 65.5%, silt contents vary between

Table 1. Some physical and chemical properties of soils (n = 72)

Land use types		Sand, %	Silt, %	Clay, %	Texture class	pH, (1:2.5)	EC, dS m^{-1}	$CaCO_3$, %	SOM, %	Exc. Na, %	CEC, me 100g^{-1}	FC,%	PWC, %	PS	LL,%	PL, %	AS, %	DR, %	K
Wheat	Min.	20.2	36.4	37.5		7.90	0.313	12.3	2.0	4.58	23.5	37.4	17.4	53.4	50.7	28.1	30.2	5.2	0.018
	Max.	25.6	39.6	40.2		7.90	0.504	15.5	3.0	11.20	29.1	49.3	25.5	76.8	61.1	32.2	48.6	8.0	0.022
	Mean	23.6	37.7	38.5	CL	7.91	0.409	14.1	2.6	8.17	27.0	40.8	21.9	63.2	56.1	30.5	41.0	6.9	0.020
Pasture	Min.	28.0	19.3	7.5		7.89	0.178	11.7	0.6	4.24	15.6	17.6	10.7	13.4	32.0	18.8	17.2	5.4	0.012
	Max.	65.5	38.9	33.3		7.90	0.540	21.5	1.4	6.48	24.1	32.0	22.5	49.4	45.7	29.0	48.6	11.0	0.025
	Mean	47.1	28.8	24.0	L	7.89	0.341	17.5	1.0	5.40	19.4	27.1	16.3	36.1	40.7	24.4	36.1	8.3	0.020
Orchards	Min.	27.5	33.6	28.3		7.90	0.340	16.2	1.4	2.24	20.1	31.3	16.2	37.4	28.2	23.1	22.8	5.0	0.015
	Max.	33.7	38.2	37.1		7.91	0.677	23.4	3.2	6.57	33.4	40.4	24.2	63.7	56.0	33.4	43.5	8.1	0.025
	Mean	30.2	36.2	33.5	CL	7.91	0.507	19.1	2.5	4.85	25.8	37.7	20	52.4	43.3	28.9	34.4	6.1	0.020
Sunflower	Min.	44.2	29.8	5.5		7.99	0.282	11.2	2.3	1.68	30.1	21.4	8.11	11.8	12.5	23.2	12.9	5.4	0.016
	Max.	55.4	39.3	24.4		8.01	0.780	24.6	3.4	2.71	38.3	32.0	20.2	40.9	77.3	27.0	62.9	8.9	0.029
	Mean	48.7	31.3	17.4	L	8.00	0.468	18.6	3.0	2.07	35.2	26.5	14.2	28.4	39.4	25.1	38.7	7.8	0.022
Alfalfa	Min.	23.7	42.2	7.4		7.89	0.474	15.3	2.6	1.33	33.0	26.2	7.12	20.5	33.9	20.4	13.9	5.6	0.024
	Max.	47.9	45.1	31.1		8.04	0.596	23.0	3.1	2.31	49.3	40.3	21.3	53.3	47.3	31.2	37.2	15.0	0.036
	Mean	33.4	44.0	22.5	L	7.98	0.540	20.0	2.9	1.74	39.5	31.3	13.9	39.3	40.6	26.2	24.4	9.2	0.028
Vegetable	Min.	45.1	34.7	3.4		7.89	0.332	8.9	1.7	1.41	32.3	17.4	6.26	10.7	18.2	23.0	9.16	6.1	0.029
	Max.	61.6	42.8	13.7		8.06	0.459	12.7	2.8	1.73	42.2	31.1	116	20.4	37.7	33.3	17.6	19.0	0.040
	Mean	54.5	39.2	6.2	SL	7.95	0.388	11.1	2.2	1.59	37.1	23.2	32.2	16.0	28.3	26.8	13.2	13.0	0.034
Sugar beet	Min.	32.8	33.3	11.5		7.89	0.285	16.8	0.5	1.14	40.2	18.1	11.8	23.9	29.6	5.27	9.44	6.4	0.026
	Max.	52.7	40.7	26.6		7.91	0.363	29.9	1.7	2.62	50.7	29.5	19.8	45.3	43.4	27.4	40.3	13.0	0.037
	Mean	44.7	37.8	17.3	L	7.89	0.313	22.2	1.1	1.98	45.3	25.8	14.8	33.8	35.9	21.9	23.2	10.0	0.031
Meadow	Min.	32.8	25.4	30.4		7.89	0.432	23.2	1.8	1.13	43.4	27.3	19.2	44.7	45.4	30.6	46.2	3.0	0.013
	Max.	35.6	34.1	41.1		7.89	0.636	39.5	2.8	3.91	51.2	36.5	20.1	58.1	49.7	31.9	63.0	6.2	0.025
	Mean	33.3	30.6	35.4	CL	7.89	0.518	29.7	2.2	2.33	46.7	33.4	19.8	48.1	47.7	31.4	56.9	4.3	0.019

EC: Electrical conductivity, SOM: Soil organic matter, Exc. Na: Exchangable sodium, CEC: Cation exchange capacity, FC: Field capacity, PWP: Permanent wilting point, PS: Percent shrinkage, LL: Liquid limit, PL: Plastic limit, BD: Bulk density, AS: Aggregate stability, DR: Dispersion, K: Soil erodibility factor, CL: Clay loam, L: Loam, SL: Sandy loam.

Table 2. Correlations on some physical and chemical properties of soils (n = 72)

	S	Si	C	SOM	$CaCO_3$	CEC	Exc. Na	FC	PWC	PS	LL	PL	AS	DR	K
BD	0.424**	0.153	-0.500**	-0.627**	-0.402**	-0.253	-0,041	-0.507**	-0.470**	-0.414**	-0.333*	-0.372**	-0.652**	0.526**	0.439**
S		-0.253	-0.892**	-0.607**	-0.180	-0.055	-0.449**	-0.891**	-0.807**	-0.871**	-0.792**	-0.576**	-0.577**	0.676**	0.478**
Si			-0.200	0.036	-0.379**	0.216	-0,119	0.021	-0.140	-0.070	-0.089	-0.134	-0.426**	-0.050	0.662**
C				0.597**	0.364*	-0.045	0.509**	0.891**	0.880**	0.911**	0.842**	0.644**	0.782**	-0.659**	-0.792**
SOM					0.283	0.247	0.169	0.589**	0.538**	0.526**	0.554**	0.442**	0.593**	-0.588**	-0.487**
$CaCO_3$						0.494**	-0.284	0.182	0.199	0.193	0.185	0.387**	0.456**	-0.362*	-0.377**
CEC							-0.680**	-0.038	-0.160	-0.170	-0.144	-0.068	0.072	-0.241	0.207
Exc. Na								0.490**	0.540**	0.622**	0.621**	0.376**	0.319*	-0.102	-0.433**
FC									0.881**	0.888**	0.777**	0.625**	0.586**	-0.685**	-0.631**
PWC										0.867**	0.810**	0.689**	0.664**	-0.575**	-0.767**
PS											0.822**	0.633**	0.663**	-0.508**	-0.641**
LL												0.778**	0.640**	-0.516**	-0.638**
PL													0.431**	-0.398**	-0.492**
AS														-0.598**	-0.741**
DR															0.440**

*Significant at p<0.05. **Significant at p<0.01.

S: Sand, Si: Silt, C: Clay, SOM: Soil organic matter, Exc. Na: Exchangable sodium, CEC: Cation exchange capacity, FC: Field capacity, PWP: Permanent wilting point, PS: Percent shrinkage, LL: Liquid limit, PL: Plastic limit, BD: Bulk density, AS: Aggregate stability, DR: Dispersion rate, K: Soil erodibility factor.

19.3% and 45.1%, and clay contents vary between 3.4% and 41.1%. Rao & Wagenet (1985) stated that variation in basic soil parameters like soil texture is due to the intrinsic (weathering) and anthropogenic (cultivation) factors. The pH values of the soils are between 7.89 and 8.06, with an mean of 7.93. The electrical conductivity (EC) values of the soils vary between 0.178 dS m^{-1} and 0.780 dS m^{-1}, with an mean of 0.436 dS m^{-1}. The pH was found to be slightly alkaline in nature indicative of no salinity problem under different land use types. The EC values of the soils are below 2 dS m^{-1} and the soils are in the salt-free class (Hazelton & Murphy, 2016). The $CaCO_3$ content of the soils is between 8.9% and 39.5%, with an mean value of 19.1%. Generally, the soils have a very calcareous structure in terms of $CaCO_3$ content (Soil Survey Staff, 1993). SOM varied between 0.5% and 3.4%, with a mean value of 2.22%. Soils have organic matter content ranging from very low to high (Hazelton & Murphy, 2016). High concentration of SOM is able to affect soil pH and therefore cation exchange capacity also. SOM is able to explain maximum of the variation in cation exchange capacity, under different land uses and different techniques (Zeraatpishe & Khormali, 2012). The soil CEC varied between 15.6 and 51.2 me $100g^{-1}$. While the lowest mean CEC values (19.4 me $100g^{-1}$) was obtained from the plots under pasture, the highest mean CEC values was obtained from the meadow cover (46.7 me $100g^{-1}$). The mean CEC values are respectively pasture (19.4 me $100g^{-1}$) < orchard (25.8 me $100g^{-1}$) < wheat (27.0 me $100g^{-1}$) < sunflower (35.2 me $100g^{-1}$) < vegetable (37.1 me $100g^{-1}$) < alfalfa < (39.5 me $100g^{-1}$) < sugar beet (45.3 me $100g^{-1}$) < meadow (46.7 me $100g^{-1}$) (Table 1). In present study, the CEC had significant positive correlations with the $CaCO_3$ (0.494^{**}) and significant negative correlations with the exc. Na (-0.680^{**}) (Table 2). Changes in the CEC due to land use changes can be quite considerable. Many soil properties effect the soil exchangeable capacity especially texture, pH, and SOM up to a certain extent. CEC occur near the surface of clay and humus particles, called micelles. Cations from the soil surface can be quite easily exchangeable with the cations from the solution. Exchangeable sites on the soil colloids can be permanent or pH dependant, depending on clay, pH and SOM. Clay particles can possess both permanent and variable charge depending on clay type, while the SOM can possess only variable charge (Wang et al., 2005). In this study, the CEC across all land use types varied due to differences in the amounts of SOM contents. SOM contents in the 1.0 m soil layer varied significantly with respect to land use type and soil depth (Yimer et al., 2007). In this study, the amount of SOM varied between 1.0 - 3.0%. The mean SOM values are respectively pasture (1.0%) < sugar beet (1.1%) < vegetable = meadow (2.2%) orchard (2.5%) < wheat (2.6%) < alfalfa < (2.9%) < sunflower (3.0%) < (Table 1). In this study, soil CEC had a positive correlation with organic matter (0.247) in the entisol soils (Table 2). In addition, this causes loss of soil physical structure by clay swelling, and dispersion because of high Na^+ concentrations in the soil solution or at the exchange phase (Yu et al., 2010). Divalent cation Ca^{2+} can replace adsorbed Na^+ in soil colloids, causing flocculation of colloids and enhanging soil structure (Jalali, 2008). Ca^{2+} could improve soil structure by formed cationic bridges between clay particles and SOM (David & Dimitrios, 2002). In addition, Ca^{2+} can inhibit clay dispersion and the associated disruption of aggregates by replacing Na^+ and Mg^{2+} in clay and aggregates, thereby promoting aggregate stability (Zhang & Norton, 2002). CEC, as an important indicator for soil quality, represents soil's ability to hold positively charged ions (Li et al., 2013). It is the relative capacity of a soil to hold and exchange cations (Saidi, 2012). Parfitt et al. (1994) indicated that dissociation of carboxyl groups increased CEC of soil organic matter. CEC of organic matter was reported as between 100 to 1000 cmol kg^{-1} (Oades, 1989). On the other hand, cation exchange capacity of clay minerals was reported as between 0 (pure kaolinite) and 110 cmol kg^{-1} (smectite) (Dixon & Weed, 1989). Low CEC under different land use types was observed which may be due to presence of low activity clay (kaolinite) as the CEC of soils is immensely affected by the mineralogy of the soil (Bhattacharyya et al., 1994). The variation in cation exchange capacity values along the different land uses can be supported with the results Brevik (2009) and Mukherjee & Zimmerman (2013), as they mentioned pH, soil organic matter and particle size distribution are the main drivers of cation exchange capacity in soils. The exc. Na values of the soils varied between 1.13% and 11.20%. While the lowest mean exc. Na values (1.59%) was obtained from the plots under vegetable, the highest mean exc. Na values was obtained from the wheat (8.17%). The mean exc. Na values are respectively vegetable (1.59%) < alfalfa < (1.74%) < sugar beet (1.98%) < sunflower (2.07%) < meadow (2.33%) < orchard (4.85%) < pasture (5.40%) < wheat (8.17%) (Table 1). Exc. Na values had significant correlations with CEC (-0.680^{**}), sand (-0.449^{**}) and clay (0.509^{**}) (Table 2). The stuations of the relationships obtained may have resulted from soil characteristics (organic matter content, texture), number of soil samples studied and forms with practics of agricultural activity. High cation exchange capacity may indicate high levels of clay, internal drainage and low permeability due to high soil compaction. Low levels of cation exchange capacity may indicate a soil texture ranging from clay-sandy to sandy, with variable grain size and high permeability (Aprile & Lorandi, 2012).

Bulk Density

Relationships between the mean bulk density values and the land use type in the surface soil samples taken from 24 parcels under eight different land uses in Turhal district are given in Figure 1. While the lowest BD values (1.00 g cm^{-3}) was obtained from the plots under meadow cover, the highest bulk density values was obtained from the sugar beet producing areas (1.71 g cm^{-3}). The bulk density values are respectively meadow < orchard < sunflower < wheat < pasture < vegetable < alfalfa < sugar beet (Figure 1). It has been determined that the bulk density values are affected by the basic soil properties and land use. It has been determined that as the land use density increases, the bulk density values also increase. The variation in bulk density can be explained with the differences in organic matter content, cultivation process and biotic activities (Rao et al. 2008). Krull et al. (2003) indicated that medium and fine-textured soils (loamy and clay) had greater organic matter contents than coarse-textured (sandy) soils. Rice (2006) indicated that clay particles sheltered organic matter and prevented decomposition of organic matter. In this study, while the lowest mean soil organic matter contents (1.0%) was obtained from the plots under pasture, the highest mean soil organic matter contents was obtained from the plots under sunflower (3.0%).

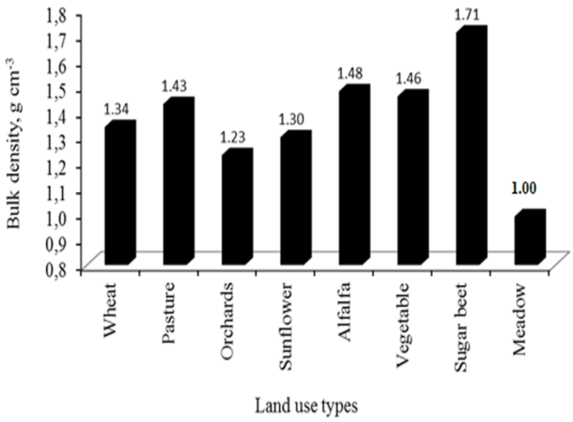

Figure 1. Changes of bulk density (BD) values depending on land use types

It was determined that the plots with weak structure and low organic matter content had higher bulk density values. Tufa et al. (2019) found that the BD were significantly effected by the land use type and basic soil characteristics, with the highest BD in cultivated land (1.37 g cm^{-3}), and the lowest in the fields used as pasture (1.10 g cm^{-3}). They stated that the low bulk density values in the pasture lands was associated with the high clay in these lands and the low density use of the grazing lands. Parlak et al. (2015) investigated the effects of different reclamation practices on soil loss and bulk density values in the grasslands of Gökçeada, Çanakkale. They found that there were significant differences between protected and unprotected plots, and there was no significant difference in aggregate stability.

The relationships between some soil properties are given in Table 2. According to Table 2, clay content (r = -0.500**), soil organic matter (r = -0.627**), $CaCO_3$ (r = -0.402**), field capacity (r = -0.507**), wilting point (r = -0.470**), percent shrinkage (r = -0.414**), plastic limit (r = -0.372**), aggreagte stability (r = -0.652**) values were found to have significant negative correlations at the level of 1% between the bulk density values of the soils. This correlation suggests that the increase in aggregation could lead to an increase in porosity, and thus, a decrease in BD. BD was negatively correlated with SOM, as SOM generally lowers the mean bulk density (Hillel, 1998). Gülser (2006) and Demir & Işık (2019) found that BD gave the negative correlation with SOM. The negative relationship of BD to aggregate stability is reflecting the extent of soil degradation that occurs over time, which in turn has effected factors such as SOM, which contribute directly to the formation of stable soil aggregates. Correlations at the level of 1% were obtained between the values of bulk density and sand content (r = 0.424**), dispersion ratio (r = 0.526**) and soil erodibility factor (r = 0.439**). There was no statistically significant relationship between the values of silt (r = 0.153), CEC (r = -0.253), exchangeable Na (r = -0.041) and bulk density values. The stuations of the relationships obtained may have resulted from soil characteristics (texture, organic matter content), number of soil samples studied and forms with practics of agricultural activity. Mamedov et al. (2002) reported that high exchangeable Na weakens cohesive forces within aggregates and enhances their slaking. However, Ca and Mg have been considered ions maintaining soil structure. Agassi & Bradford (1999) have found that erodibility varies with aggregate stability, soil textures, soil structures, shear strength, soil depth, infiltration capacity, SOM and BD. SOM has the ability to disperse or aggregate the soil, depending on the threshold level of organic matter and the ratio at which it occurs with other aggregating agents. In this study, we reported that the higher the soil organic matter of the soil the less the ability of the soil to disperse. In this study, the soil organic matter content had significant negative correlations with dispersion rate (-0.588**) (Table 2). When the soil disperses, the microaggregates that make up the structural framework of the macroaggregates are disintegrated, hence progressively detached at the weakest point of the aggregate structure (Legout et al., 2005).

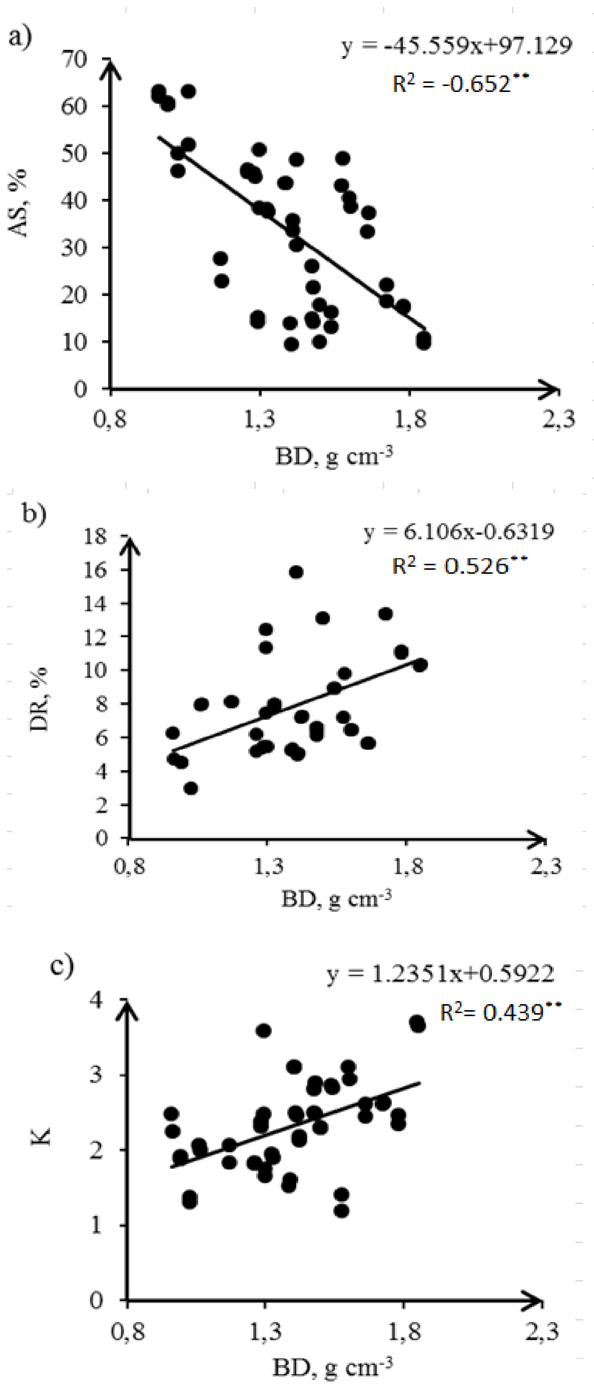

Figure 2. Relationships between bulk density and aggregate stability (a), dispersion rate (b), soil erosion factor (c), (AS: Aggregate stability, BD: Bulk density, DR: Dispersion rate, K: Soil erodibility factor)

Relationships between bulk density and aggregate stability (a), dispersion rate (b), soil erosion factor (c) were given Figure 2. According to these findings, it has been determined that the bulk density values and the parameters used in the evaluation of structural stability were in close relationship (Figure 2). It has been determined that soils with low bulk density values also have low erosion rate values and high aggregate stability values. In other words, it can be stated that low bulk density values also reflect a structure resistant to erosion.

Conclusion

In this study, the relationships between some soil properties and bulk density values under different land use types (wheat, pasture, orchard, sunflower, clover, vegetable, sugar beet and meadow) in Turhal district of Tokat province were compared. It has been determined that the bulk density values are affected by basic soil characteristics (texture and organic matter content) and land use type. The lowest BD were determined in the plots under the meadow cover (uncultivated, medium texture), while the highest BD were determined in the sugar beet production areas (frequently processed, coarse textured). Important relationships have been determined between the bulk density values of soils and the parameters used in the evaluation of structural stability and susceptibility to erosion, and it would be beneficial to expand research on these issues.

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Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Author Contribution

NÖ: Conceptualization, investigation, methodology, validation, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision, statistical analysis, project administration; **ZD:** Conceptualization, validation, data curation, resources, writing—review and editing; **EB:** Investigation, methodology, validation, software, validation, investigation, resources, data curation. All authors have read and agreed to the published version of the manuscript.

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