African Journal of Agricultural Research Vol. 6(7), pp. 1750-1757, 4 April, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.502
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Bulk density of Harran plain soils in relation to other soil properties

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Accepted 28 July, 2010

Global warming is one of the most important problems of the present day. The increase of carbon dioxide (CO_2) and other greenhouse gases causes a great problem in the atmosphere. However, CO_2 gas constituted the biggest threat at present, though the other gases increase, too. One of the primary precautions to take for this is the context of soil earth atmospheric CO_2 through plants. Beside the context of soil carbon, some other factors are also affecting this context. Some of them are texture, bulk density (BD), cation exchange capacity (CEC), exchangeable cations (EC), soil reaction (pH) and electrical conductivity (Ec). In Harran plain, an organic carbon amount ranged from 0.28 to 4.95 kg C m^{-2}. The statistic analyses data in the factors are: BD, organic carbon (OC), texture (clay, silt and sand%), CEC, EC, pH and Ec. The strongest correlation was found as BD and OC (R^2 = 99.96), but when compared with the other factors, it was detected as R^2 = 99.4. The reason for its height when we consider all the parameters is the involvement of organic carbon in the calculation. When we deal with them individually, the correlation falls below 50%. In this study, a point of high correlation is made between OC and BD. The study aims to determine, in the soils, BD, which is costly, hard and time consuming, and OC which is known by means of this correlation. In the comparison analysis of the entire data and the determination of the equations, student t test was used and the data were investigated at p<0.01 significance levels. However, ANOVA techniques were used regularly in this comparison.

Key words: Organic carbon, texture, bulk density, GAP region, Harran plain.

INTRODUCTION

Soil organic carbon concentration was used to determine soil quality in the past (Peerie and Munson, 2000; Shukla et al., 2006). However, today, it is used in the carbon storage and balancing of global greenhouse gases amounts. On the other hand, how carbon dynamics are used in the soil and the effects of these on global carbon circulation are also investigated (Tremblay et al., 2006; Ouimet et al., 2007).

Soil organic carbon (SOC), soil organic matter (SOM) and the correlation between bulk densities are frequently used to estimate carbon pools (Post et al., 1982). It is indicated that bulk density values are necessary for the analyses that are done in the laboratory and as soon as SOM increases, bulk density (BD) decreases (Curtis and Post, 1964). Jeffrey (1970) also stated that the relation between SOM and BD is normal.

To predict the change, flow and concentration of nutrients in the soils, bulk density (BD) is needed to be known (Bernoux et al., 1998). Increase in the awareness of global warming threats, the effect of greenhouses and mostly the environmental conditions resulted in focusing on carbon stocks and their flows in the soil. The organic matter in the soil can evolve as the source of carbon dioxide or carbon storage in the atmosphere (Lugo and Brown, 1993). In the world's mineral, soils exist as 1,500 Pg C (Post et al., 1982; Eswaran et al., 1993; Batjes, 1996). The organic carbon stocks of the soils of the Southeastern Anatolia region were fixed as 0.63 Pg at 100 cm depth, while the inorganic carbon stocks were fixed as 1.41 Pg C. To estimate these pools correctly, we need the organic carbon contents and bulk density of the soils (Sakin, 2010). Generally, the tropical regions are lacking in BD (Bernoux, 1998).

It is indicated that in the global and large areas, in each

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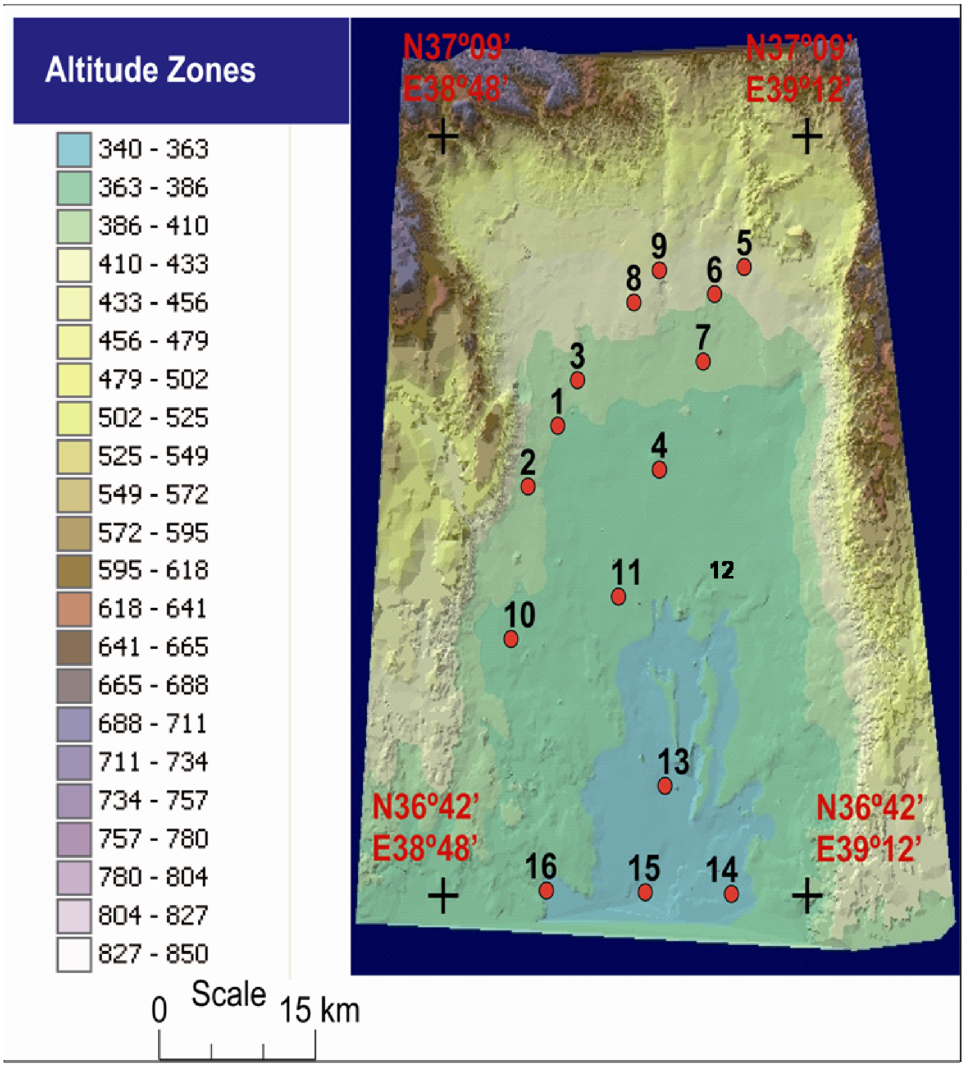

Figure 1. Study examples areas.

unit, the organic carbon content and the average bulk density are needed to estimate the organic carbon pools (Sombroek et al., 1993; Moraes et al., 1995; Batjes, 1996). The pre-existing equation is generally developed for a single private unit (Huntington et al., 1989; Arrouays and Plissier, 1994) and/or private ecosystems (Grigal et al., 1989; Honeysett and Ratkowsky, 1989; Howard et al., 1995).

In numerous studies (Curtis and Post, 1964; Saini, 1966; Adams, 1973; Alexander, 1980; Federer, 1983; Grigal et al., 1989; Honeysett and Ratkowsky, 1989; Huntington et al., 1989; Federer et al., 1993; Arrouays and Pelissier, 1994), the effect of the OC on BD was demonstrated. In these kinds of studies conducted to determine the bulk density, the OC content was used (Bernoux, 1998).

The aim of this study is to determine the BD of the Harran plain soils, through the SOC, and other effective parameters, as well.

MATERIALS AND METHODS

The Harran plain is located in the Southeastern Anatolia region (GAP), and is situated on 38º 48' to 39º 12' E longitude and 37º 09' to 36º 42' N latitude, covering an area of 225,000 ha. The soils of the plain, which are arid and semiarid, are irrigated in 1995. The plain generally descends from the north to the south. Surrounded by mountains on three sides, the plain is in the shape of a pot as can be seen in Figure 1. The distance between Harran and Akcakale districts is the lowest coded area. However, Dinc et al. (1988) determined 25 series of soil in the plain.

According to the studies carried out by Soil Survey Staff (1975), FAO/UNESCO (1974) and Dinc et al. (1988), the soils of the plain are Entisol, Vertisol and Aridisol ordos. The categories of the Harran plain soils have been given in detail in Table 1.

According to the data of the General Directorate of Rural Services (GDRS) (1995), the soils of the plain consist of large soil groups that are reddish brown and slightly red brown. The reason why the soils of the plain are categorized this way is due to the lack of rainfalls and high temperature. The soils of the working area are with clay and calcareous for the most part. The clay, silt and sand amount changed between 36.00 and 66.00, 21.00 and 41.00 and

Table 1. Soil taxonomy of Harran plain soils (FAO / UNESCO, 1974; Dinc et al., 1988).

Soil taxonomy				**Soil series**	**FAO / UNESCO**
Ordos	**Sub ordo**	**Great group**	**Sub group**		
Entisol	Fluvent	Torrifluvent	Vertic Torrifluvent	İkizce	Calcaric Fluvisol
			Typic Torrifluvent	Bellitas	
				Cekcek	
				Urfa	
	Orthent	Torriorthent	Lithic Torriorthent	Fatik	Litosol
Vertisol	Torrert	-	Typic Torrert	Begdeş	Chromic Vertisol
				Bozyazı	
				Akcakale	
				Kısas	
			Paleustollic Torrert	Ugurlu	
Aridisol	Orthid	Gypsiorthid	Typic Gypsiorthid	Cepkenli	Gypsic Xeresol
		Paleorthid	Typic Paleorthid	Gülveren	
		Calciorthid		Kap	
			Typic Calciorthid	Meydankapı	Calcic Xeresol
				Gündas	
				Hancıgaz	
				Ekinyazı	
				Akören	
				İrice	
				Gürgelen	
			Vertic Camborthid	Sultantepe	
				Harran	
				Karabayır	
				Sırrın	
					Haplic Xeresol
		Camborthid	Typic Camborthid	Konuklu	

Source: SSS (1975).

3.00 and 31.00%, respectively, whereas calcareous was between 15.44 and 45.13%, CEC was between 23.38 and 48.40 cmol kg^{-1}, electrical conductivity was between 0.31 and 902 dS m^{-1}, soil reaction (pH) was between 7.10 and 8.84, and BD was between 1.20 and 1.39 Mg m^{-3}.

In a major part of the year, rain does not fall in the Harran plain; instead it is drought that is seen. According to the 33 year data obtained between 1975 and 2008, by Turkish State Meteorological Service (TSMS) in Akcakale station, the mean precipitation was 277.80 mm, and in Sanliurfa station, it was recorded as 448.10 mm. The precipitation amount in Akcakale, which is closer to the southern point, is low, while the northward point, in the foothills of Urfa Mountains reaches 450 mm. A significant part of the soil moisture regime is Xeric; although, its temperature regime is Mesic. However, when it was brought, especially, to areas that were close to the south of the plain, Aridic soil moisture regime was partly seen (Soil Survey Staff, 1996).

The plain during a large part of the year is arid and at the same time is under the influence of high temperature for a long time. As can be seen in Table 2, generally, the plain gets very little precipitation between May and October. During the periods of little rain, it is observed that the temperature and evaporation are high, as well. It can be observed again that evaporation increases from the foothills of Urfa Mountains towards Akcakale town. The maximum annual mean precipitation falls in winters, while the minimum falls in summers.

According to the archeological studies done in the region, it is estimated that the soils of this region are approximately 4,200 years old. Additionally, in these studies, it was stated that, about 2000 to 2500 years ago, there was a drought which continued for about 200 years following excessive precipitation, flood and mud flows, lasting three hundred years (Pustovoytov et al., 2007).

In the base of genetic horizons types, spoiled and unspoiled soil samples at 16 profiles were taken from the Harran plain. These samples were analyzed after they were dried by air and sieved from 2 mm sieves. Through the textured hydrometer method (Bouyoucus, 1951), Ec and pH were made by Richard (1954), while the bulk density was made by Black (1965). The organic carbon was fixed by the titrating acid burning samples with Fe_2SO_4 (Walkely and Black, 1934). The calcareous was fixed by measuring

Table 2. Climate data of Sanlıurfa and Akcakale stations (TSMS, 2008).

	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Precipitation (mm) (Akcakale)	47.39	45.83	40.46	27.56	17.24	0.99	0.81	0.47	18.79	33.05	47.38	47.39	277.81
Precipitation (mm) (Sanlıurfa)	77.21	78.36	65.55	44.41	27.51	3.52	0.79	1.06	0.91	27.58	49.88	75.31	448.11
Evaporation (mm)	-	-	61.80	119.60	203.10	332.80	421.10	421.10	291.90	291.90	59.30	-	2022.80
Mean temperature (℃)	4.90	6.60	10.30	17.80	23.10	29.20	34.80	31.30	26.40	19.10	14.40	8.00	18.80
Lowest temperature (℃)	-2.40	-1.50	-0.60	6.10	10.60	18.50	22.70	20.40	13.80	9.40	5.70	1.00	8.650
Highest temperature (℃)	20.50	16.60	25.50	29.60	35.30	40.00	46.80	43.00	38.20	31.60	26.20	18.00	25.00
Mean humidity (%)	74.30	63.00	55.20	56.80	41.00	36.70	33.40	43.00	46.10	54.40	52.90	71.70	52.40
Mean soil temp. for 5 cm (℃)	5.60	7.60	11.70	19.70	27.40	34.70	39.80	37.20	31.30	22.40	14.50	8.10	21.70
Mean soil temperature for 10 cm (℃)	6.00	7.60	11.40	19.20	26.10	32.50	37.40	35.80	30.80	22.80	15.30	8.60	21.10

Table 3. Descriptive statistical results.

Variance	Mean	SE	Mean	SD.	CV	Minimum	Median	Maximum
BD	1.5654	0.00300	0.0344	0.00118	2.20	1.4900	1.5700	1.6200
CEC	36.925	0.384	4.398	19.345	11.91	23.380	37.080	48.400
Ec	1.441	0.173	1.979	3.917	137.38	0.310	0.750	9.210
pH	7.9660	0.0294	0.3361	0.1130	4.22	7.1000	7.9800	8.8400
$CaCO_3$	32.065	0.578	6.612	43.718	20.62	15.440	33.320	45.130
OM	0.8367	0.0342	0.3913	0.1531	46.77	0.1900	0.8300	1.7100
SOC	1.8702	0.0890	1.0190	1.0384	54.49	0.2700	1.7100	4.9500
OC	0.4652	0.0206	0.2363	0.0558	50.80	0.0600	0.4600	0.9900
Sand	15.290	0.598	6.844	46.838	44.76	2.000	15.000	32.000
Silt	33.298	0.436	4.989	24.888	14.98	22.000	33.000	45.000
Clay	51.504	0.616	7.054	49.760	13.70	29.000	52.000	66.000

SD: Standard deviation; SE: standard error.

the gas coming out via the reaction of the soil with 10% HC1 in a closed system (Allison and Moodie, 1965). To compare all data and determine the equations, the student t- test was used and the data were investigated by $p<0.01$ significance level. Consequently, the standard ANOVA techniques were generally used.

RESULTS AND DISCUSSION

Descriptive statistical results of 131 soil samples taken from 16 profiles in Harran plain were generally given in Table 3. In terms of texture, the average clay content is >50% and its maximum degree is >60%. With an exception of pH measurement, all parameters had coefficient variation (CV) >10%. The organic carbon ranged from 0.06 to 0.99% and had a CV of 50.80%. According to Wilding and Drees (1983), organic carbon is one of the most important variables of soil properties and it is indicated that it increases when factors increase, generally, in pedons (<10%), polypedons (20 to 30%) and mapping units (30 to 70%). Therefore, it is not surprising to find that the CV of carbon is generally 58.80% in this study. Manrique and Jones (1991) stated that the organic carbon content was high and its CV varied between 87 and 200%. Bernoux et al. (1988) found the CV of the organic carbon as 126.9%. In addition to this, the reason why the organic carbon CVs are high in this study is due to

Table 4. Regression equation.

Analysis of variance					
Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	3	0.0159621	0.0053207	6.22	0.001
Residual error	127	0.1085615	0.0008548		
Total	130	0.1245237			

BD(Mgm^{-3}) = 0.845 + 0.00381 % clay + 0.00614 % silt + 0.00428% sand. R^2 = 12.8%.

Table 5. Regression equation.

Analysis of variance					
Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	8	0.152724	0.019090	2509.10	0.000
Residual error	122	0.000928	0.000008		
Total	130	0.153652			

the OC contents being high in few profiles when we go up to the northern part of the plain.

The mean bulk densities ranged from 1.49 to 1.69 Mg m^{-3}, and its CVs were figured out as 2.20%. Manrique and Jones (1991), determined the bulk densities in the nine great soil groups, and found the mean values of BDs ranging from 1.2 to 1.5 Mg m^{-3} with associated CVs of 13.3 to 16.6%, respectively. The finding of Moraes et al. (1995) showed that the CV of BDs was 10.6% in Alfisols and Ultisols, and 9.7% in Oxisols. Likewise, in Amazon plain, they found that the CV of BDs was 7% in Alfisols and Ultisols, and 13% in Oxisols. According to Bernoux et al. (1998), the CVs for BD were detected in 11.9%. If we compare the results of this study with other studies done in the past, though our outcomes may be normal, we guess that the excessive clay amount in the plain leads to high bulk densities.

According to the stepwise multi-regression analysis data shown on organic carbon, it was obvious that the data were not determined to be very high in soil texture (R^2 = 12.8), pH, Ec and CEC (Table 4). It was stated that if the soil depth increased, pH played an important role in the determination of the bulk density (Bernoux, 1998). Shaffer (1988) observed that pH showed its highest correlation with BD at 0 to 15 cm, as well, but he did not indicate the reasons. In addition, Plante et al. (2006) found a correlation of about 50% between OC and texture. According to Konen et al. (2003), a high correlation was found between organic carbon (g kg^{-1}), clay (r^2 = 0.71), silt (r^2 = -0.75) and sand (r^2 = -0.74). Dupouey et al. (1997) gave a predictive equation for BD based on OC, pH in winter and gravel content for the superficial layer under temperature forest. In deeper layers, texture or other properties play an increasing significant role in controlling BD as OC, which is a minor component, as the soil depth increases. The use of pH, as a variable, is justified by the fact that pH is commonly determined at low cost. No direct physical link exists between BD and pH, but as pH is linked in these soils to the total exchangeable capacity, exchangeable Al hydroxyl, clay (content and nature) and Fe oxides, this could explain the role played by pH.

Bernoux et al. (1998) found a correlation, of about 50%, between texture and bulk density. Jones (1983) said in the soils of the tropics that the impact of the texture bulk density is much, because of the organic carbon. In this study, the ratio increased up to 12.8% (Table 4). However, when we evaluate all the parameters as a whole, a very strong correlation emerges. As can be seen in Table 5, there is a 99.4% correlation. A strong correlation was found between organic carbon and bulk density only when all the factors remained stable. According to the equation, this ratio was 99.6%, which showed that the strongest correlation was determined between these two parameters (Table 6). Particularly, in Table 6, there is a strong correlation between organic carbon and bulk density. It is guessed that this correlation, in future studies, can be determined in soils, whose bulk density is unfixed, by way of organic carbon. As long as the depth increases, the effect of the organic carbon decreases on BD (Figure 3).

As can be seen in Figure 2, a strong correlation between the organic matter and bulk density was determined. When considering the soils of Harran plain, in the event that the bulk densities or organic matter contents are undetermined, it is predicted that in the past or future studies, if one of them is analyzed, the other can easily be determined. In such circumstances, because it is generally hard to determine bulk densities, they can be determined by means of organic matter ($Y = -11.707x + 19.167$, $R^2 = 0.9996$, $p<0.01$). Here, Y axis was determined as the organic matter and X axis as the bulk

Table 6. Regression equation.

Analysis of variance					
Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	1	0.15268	0.15268	20215.94	0.000
Residual error	129	0.00097	0.00001		
Total	130	0.15365			

BD = 1.64 - 0.0876 OM; R^2 = 99.96.

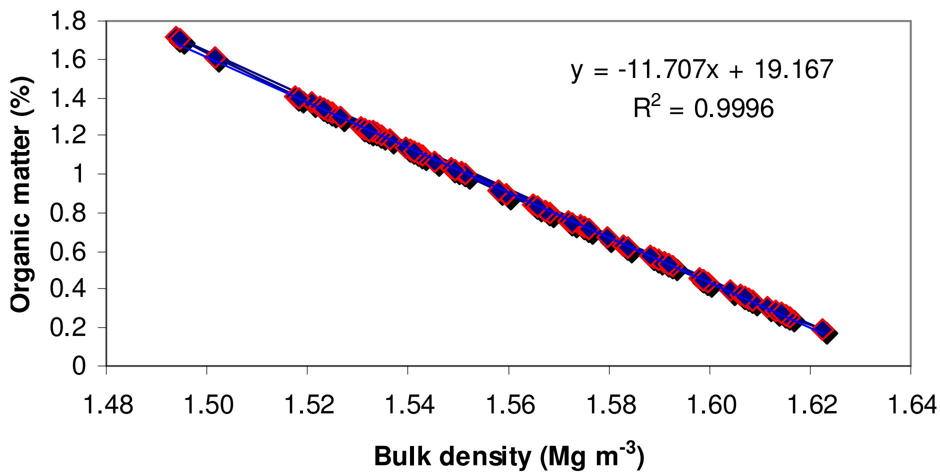

Figure 2. Regression between OM and BD equation.

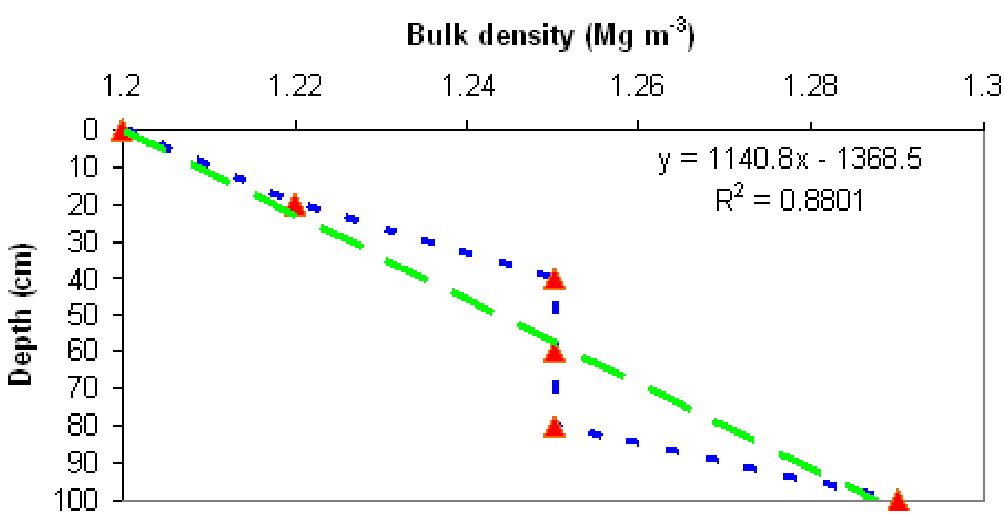

Figure 3. Changes in BD-depth.

densities. Generally, to determine bulk densities in soils is hard, expensive and time consuming. Besides, in the course of sampling, if the cylinder is less or over driven, or if it is coming across pieces like gravels, it causes the bulk densities to be high or low.

Li et al. (2007) determined a strong correlation between bulk density and organic carbon (r^2 = -0.78, p<0.01). According to Curtis and Post (1964), it was stated that there was a reverse correlation between organic matter and bulk density. According to Jeffrey (1970), it was stated that the correlation between the two was normal. Soil texture clay varied between 36.00 and 66.00%, while silt varied between 21.00 and 41.00%, and sand varied between 3.00 and 31.00%. In all soils, the amounts of clay increased along its depth. It was indicated that there was no considerable correlation between organic carbon and soil texture (McDaniel and Mann, 1985). However, Lugo and Brown (1993) and Perceive et al. (2000) observed a linear correlation between organic carbon and texture (clay + silt) at each unit. According to Quiroga et al. (2001), it is said that annual yield is related to soil texture, and at the same time, it is linked to OM. According to Quiroga et al. (2006), OM/clay + silt ratio is an indicator, limiting its products.

Conclusions

In this study, we did not determine a strong correlation between soil texture and organic carbon. However, when we looked at it from a horizon base, a correlation was observed between the two. The strongest correlation was determined between bulk densities and organic matter among the data attained from the analysis results, and this interaction was formulated for it to be used in the future. To determine bulk densities, there is need to open the soil profiles, drive the cylinder in each horizons and decompose them in the laboratory. During the progress, some difficulties may occur. Some of them are coincidence of gravel to the point where the cylinder was driven, and over insertion of the cylinder, which caused pressure in the soil and high bulk densities. Determination of bulk densities is costly, tiring and time consuming. However, it can be easily determined by using the formula developed in the correlation attained in this study. Perhaps, it may provide convenience in the future studies in determining BDs in the carbon calculation.

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