ECOLOGIA BALKANICA
2019, Vol. 11, Issue 1 June 2019 pp. 75-84

Statistical Assessment of Alluvial-Meadow Soils Located in Busmantsi Sand and Gravel Mining Field, Sofia, Bulgaria

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Abstract. The paper presents the results of an investigation on Alluvial-meadow soils (Mollic Fluvisols), located in Busmantsi sand and gravel mining field, Sofia, Bulgaria. Soil samples were taken from twenty-five soil profiles at a depth of 0-100 cm. The changes in physicochemical properties were investigated at different soil depths and the relationships between different soil characteristics were tested using regression analysis. There are statistically significant equations that describe the changes in soil characteristics with depth for all soil characteristics except pH. There are over 30 out of 45 possible regression relationships between the soil characteristics studied. No relationships have been found to exist between pH and the other soil characteristics. There are statistically significant linear regressions between bulk density and a number of soil characteristics (total porosity, sand and silt fractions, SOM, TKN, P_2O_5, K_2O). There are regression relationships between the clay fraction and the other soil texture fractions and between the clay fraction and all chemical indicators. There are regression relationships between SOM and TKN, P_2O_5, K_2O. There are regression equations that describe the relationships between TKN and P_2O_5, K_2O, as well as between P_2O_5 and K_2O.

Key words: Alluvial-meadow soils, Fluvisols, Physicochemical properties, statistical assessment, regression analysis.

Introduction

The sustainable development of urban and suburban territories hinges on environmentally friendly landscape planning. The sustainable use of soil resources is the fundamental prerequisite of landscape planning.

The proper management of soil resources is an important issue (KACHOVA & FEREZLIEV, 2018), and the sustainable management of Alluvial-meadow soils is particularly relevant (MÜLLEROVÁ & PRACH, 1998) due to their environmentally unfriendly use in the past (BANASOVA *et al.*, 1994; PRACH *et al.*, 1996; PAVLOVIĆ *et al.*, 2017) and soil acidification caused by fertilizers (ATANASOVA & SIMEONOVA, 2013). A lot of plant species require specific soil conditions to develop or specific physicochemical soil characteristics for their optimal growth (BOGDANOV, 2014; BOGDANOV, 2018a; b). Therefore, proper soil use is crucial for the conservation of rare, endemic or engendered plant species (DIMITROVA, 2018).

Alluvial-meadow soils are intrazonal and are found along river valleys (DONOV, 1993). The physicochemical properties of

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alluvial soils reflect the properties of the soils from which the sediment originated (WEST *et al.*, 2017), their location along the river and their distance from the riverbed (PAVLOVIĆ *et al.*, 2017; HIRMAS & MANDEL, 2017). They form as a function of periodic deposition of sediment (PING *el al.*, 2017) and diverse grass and tree vegetation (ATANASOV, 1987). The soils have light texture, good bulk density values and very good aeration (KACZMAREK *et al.*, 2015), but poor water-holding capacity (PAVLOVIĆ *et al.*, 2017). The level of the soil organic matter is moderate to low, where it can reach up to 2% in the surface horizon (PAVLOVIĆ *et al.*, 2017). According to some authors, the level of soil organic matter can reach up to 5% in uncultivated lands, and up to 1% in cultivated lands (ARTINOVA, 2014). Nitrogen content is high or medium (YIGINI *et al.*, 2013). Phosphorus content varies widely, but the soils are rich in potassium (PAVLOVIĆ *et al.*, 2017). These soils are suitable for growing high yielding crops, fertilization (SHISHKOV & KOLEV, 2014; HIRMAS & MANDEL, 2017) wildlife habitat, and recreation (WILSON & SHAW 2017).

Alluvial-meadow soils are found among Chernozems and Gray forest soils in Northern Bulgaria along the rivers Danube, Lom, Ogosta, Iskar, Yantra, Rositsa and Kamchia (TEOHAROV *et al.*, 2015; HRISTOV, 2009). In Southern Bulgaria they are found among Vertisols and Cinnamon forest soils along the rivers Maritsa, Tundzha, Arda, Mesta, Struma, Iskar and Erma (ANTIPOV-KARATAEV *et al.*, 1959; DONOV, 1993).

The purpose of the study is to analyze the correlations and regression relationships between Alluvial-meadow soil properties. The analysis of these relationships will ensure the sustainable use of soil resources and will facilitate landscape planning by selecting plant species that can grow sustainably under specific soil conditions.

Materials and Methods

Alluvial-meadow soils (Mollic Fluvisols, WRB, 2014) occurring on the territory of Busmantsi sand and gravel mining field, located 1 km northeast of the village of Busmantsi, Sofia Region, Bulgaria were the object of the study. This soil type is usually found in the Lower forest vegetation zone (0 - 600 m a. s. l.) of the Moesian forest vegetation area of Bulgaria (ZAHARIEV *et al.*, 1979).

Methods of study

Eleven soil profiles at a depth of 0-100 cm were done at representative plots. A systematic sampling design was used (PETERSEN & CALVIN, 1996). The samples were taken at depths of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm. The total number of samples is 55 (11 soil samples from each soil horizon). The following soil characteristics were analyzed by using the respective methods:

- Bulk density (BD, $g.cm^{-3}$), according to the DIN ISO 11272:1998, 2001;
- Total porosity (TP, %) by calculation of bulk density and relative density (LORRAINE & FLINT, 2002);
- Soil texture (Sand - 2 mm - 63 μm, %; Silt - 63 μm - 2 μm, %; Clay < 2 μm, %), using the sedimentation method (ISO 11277);
- Soil acidity (pH in water extraction) – measured potentiometrically by WTW 720 pH meter (ISO 10390:2002);
- Soil Organic Matter (SOM, %) by the ISO 14235:1998;
- Total Kjeldahl Nitrogen (TKN, %) content, with a modified version of the classic Kjeldahl method (ISO 11261:2002);
- P_2O_5 ($mg.100g^{-1}$) – extraction with Ammonium Acetate and Calcium Lactate-pH 4.2 (UV-VIS spectrophotometer Perkin Elmer Lambda 5) (IVANOV, 1984);
- K_2O ($mg.100g^{-1}$) – extraction with Ammonium Acetate and Calcium Lactate-pH 4.2 (Flame photometer Jenway php 7) (IVANOV, 1984);

Data analysis

Descriptive statistics was done using Numbers (Apple Co., 2018) and Excel (Microsoft Co., 2016) on MacOS. SPSS for

MacOS (IBM Co., 2016) was used to determine the statistical reliability of linear regressions (ANOVA) as well as box plot graphs.

Results and Discussion

The physical and chemical characteristics are presented in Table 1. The greatest variation of bulk density has been found to occur at a depth of 40-60 cm, whereas the greatest variation of total porosity has been observed at a depth of 80-100 cm. The greatest variation of soil texture components has been observed at a depth of 0-20 cm (for the sand fraction), 80-100 cm (for the silt fraction) and 40-60 cm (for the clay fraction). The variation of physical indicators may be related to the nature of alluvial soil formation, i.e. periodic sedimentation (PING *el al.,* 2017) on the one hand, and to parent material degradation processes on the other hand. The reaction of the soil solution varies the most in the surface horizon. SOM and TKN vary most considerably at a depth of 80-100 cm. The variation of phosphorous and potassium is most significant at a depth of 60-80 cm. This great variation of SOM and TKN at the same depth may be due to the accumulation of organic matter (with uneven distribution) on the territory studied over the past years.

Bulk density increases with depth, where changes in bulk density are especially pronounced at a depth of 80-100 cm (Fig. 1), and total porosity decreases with depth (Fig. 2). Similar tendencies and correlations between bulk density and total porosity have been described in other studies on alluvial soils (ILINKIN *et al.,* 2017). The changes in bulk density and total porosity are described by linear regression equations $y=0,0028x+0,9644$; $R^2=0,7868$, $p<0,0001$ and $y=-0,0914x+60,033$, $R^2=0,8554$, $p<0,0001$. There are some patterns related to the changes in the texture of the soils studied such as: increase in the sand fraction with depth, especially at depths of 40-60, 60-80, 80-100 cm (Fig. 3), increase in the silt fraction with depth (Fig. 4) and decrease in the clay fraction (Fig. 5). The changes in the sand, silt and clay soil texture fractions are described by statistically significant linear functions: $y=0,0614x+61,259$, $R^2=0,7087$, $p<0,0001$; $y=-0,0214x+15,569$, $R^2=0,0696$, $p=0,0321$; $y=-0,04x+23,173$, $R^2=0,1812$, $p=0,0025$, respectively. The soils studied are classified as slightly acidic according to the classification by GANEV (1989). The pH variation in the soils studied (Fig. 6) is most likely the reason for the absence of any regression equations between pH and soil depth ($p=0,789$).

The soil organic matter (Fig. 7) and total Kjeldahl nitrogen (Fig. 8) decrease with depth, where the decrease in TKN is particularly marked in lower layers below 20-40 cm. SOM values are consistent with the data obtained by other authors (DONOV, 1979), and TKN values are lower than those obtained by other authors (PAVLOVIĆ *et al.,* 2017). There are statistically significant regression equations between soil depth and SOM and TKN respectively ($y=-0,0123x+1,19106$, R^2, $p<0,0001$; $y=-0,0017x+0,1542$, $R^2=0,7701$, $p<0,0001$). Available phosphorus (Fig. 9) and potassium (Fig. 10) decrease with depth and are described by statistically significant regression equations $y=-0,0661x+15,726$, R^2, $p<0,0001$; $y=-0,0981x+31,214$, $R^2=0,8088$, $p<0,0001$). Available phosphorus values are completely consistent with the data obtained by other authors for the soils in question, whereas potassium values at a depth of 80-100 are a bit lower (PAVLOVIĆ *et al.,* 2017).

There are statistically significant linear regressions between bulk density and a number of soil characteristics (total porosity, sand and silt fractions, SOM, TKN, P_2O_5, K_2O), but there are no statistically significant regressions between bulk density and the clay fraction and pH respectively (Table 1). The inverse linear regression of bulk density to total porosity is logical and other authors have also reported the existence of correlations between these two values (DONOV *et al.,* 1974).

Table 1. Descriptive statistics of soil characteristics.

Depth, cm	N		BD	TP	Sand	Silt	Clay	PAWC	pH(H_2O)	SOM	TKN	P_2O_5	K_2O
0-20	11	Mean	1.06	57.48	62.23	14.06	23.71		5.90	1.64	0.117	15.27	28.75
		Range	0.02	0.77	3.56	3.43	4.06		0.18	0.10	0.029	2.75	2.35
		SD [1]	0.01	0.24	1.25	1.09	1.12		0.06	0.03	0.009	0.76	0.63
		CV [2]	0.007	0.004	0.020	0.077	0.047		0.011	0.016	0.079	0.050	0.022
20-40	11	Mean	1.08	56.55	63.06	15.78	21.16		5.88	1.48	0.122	11.84	27.07
		Range	0.05	0.79	1.91	5.61	5.69		0.18	0.16	0.033	3.72	1.66
		SD [1]	0.02	0.27	0.59	1.58	1.52		0.05	0.06	0.010	1.35	0.51
		CV [2]	0.016	0.005	0.009	0.100	0.072		0.009	0.041	0.085	0.114	0.019
40-60	11	Mean	1.09	55.35	66.14	14.47	19.39	150.18*	5.86	1.12	0.018	11.66	27.26
		Range	0.08	0.46	1.62	7.01	7.64	7.64*	0.13	0.18	0.004	2.94	1.44
		SD [1]	0.03	0.15	0.49	2.53	2.84	2.96*	0.04	0.06	0.001	1.11	0.54
		CV [2]	0.026	0.003	0.007	0.175	0.147	0.020*	0.007	0.057	0.075	0.095	0.020
60-80	11	Mean	1.15	53.49	66.74	14.64	18.62		5.89	0.92	0.009	10.90	22.18
		Range	0.04	3.84	2.32	6.20	5.72		0.15	0.15	0.002	5.35	3.33
		SD [1]	0.01	1.23	0.85	2.37	2.07		0.05	0.06	0.001	1.80	1.27
		CV [2]	0.012	0.023	0.013	0.162	0.111		0.008	0.063	0.059	0.165	0.057
80-100	11	Mean	1.30	49.87	66.53	12.49	20.98		5.89	0.69	0.008	9.13	21.39
		Range	0.05	3.69	2.72	7.66	6.89		0.15	0.14	0.003	1.70	3.94
		SD [1]	0.02	1.20	0.80	2.64	2.46		0.06	0.05	0.001	0.51	1.21
		CV [2]	0.012	0.024	0.012	0.211	0.117		0.010	0.077	0.148	0.056	0.057

Legend: *Applies to the whole soil profile; [1] SD – standard deviation; [2] CV - coefficient of variation. For abbreviations of the names of soil characteristics, see part “Material and Methods”.

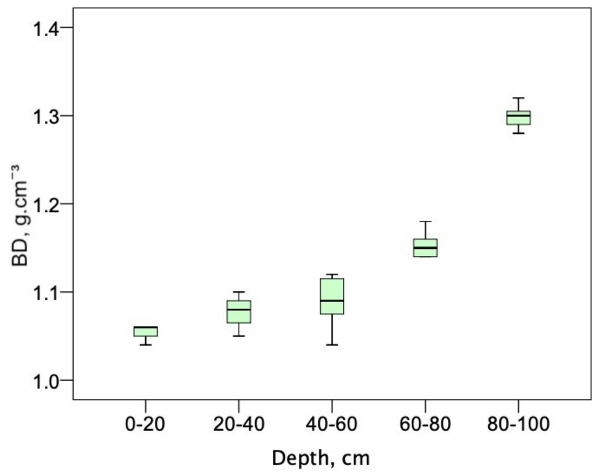

Fig. 1. A box plot graph of the changes in bulk density with depth.

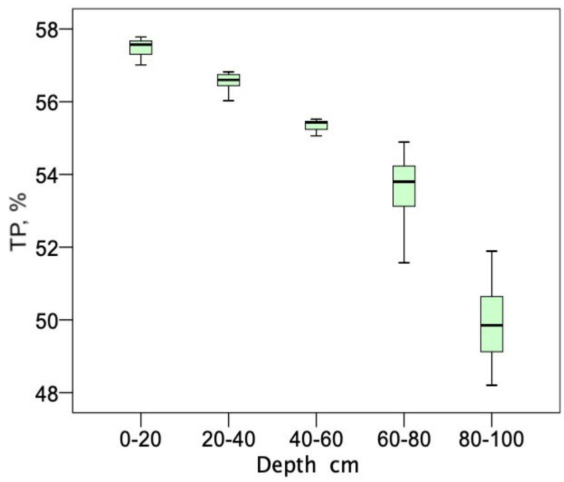

Fig. 2. A box plot graph of the changes in total porosity with depth.

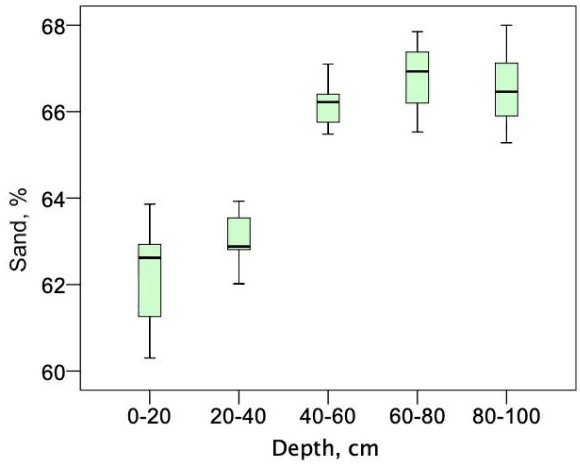

Fig. 3. A box plot graph of the changes in the sand fraction with depth.

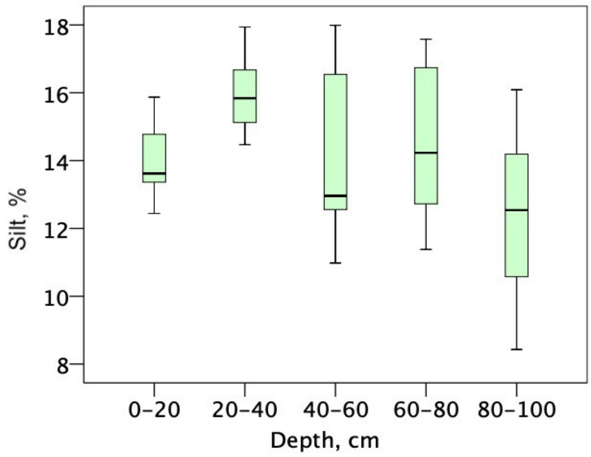

Fig. 4. A box plot graph of the changes in the silt fraction with depth.

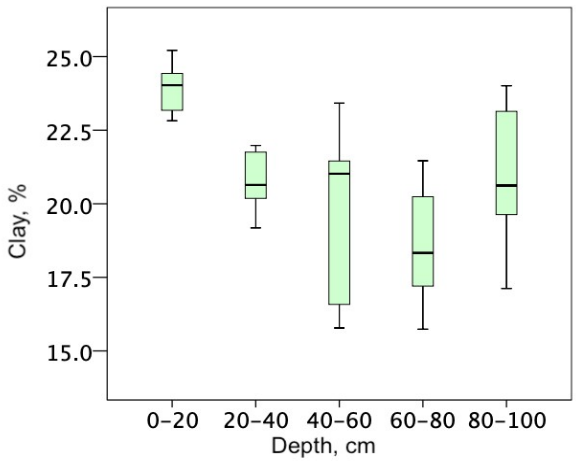

Fig. 5. A box plot graph of the changes in the clay fraction with depth.

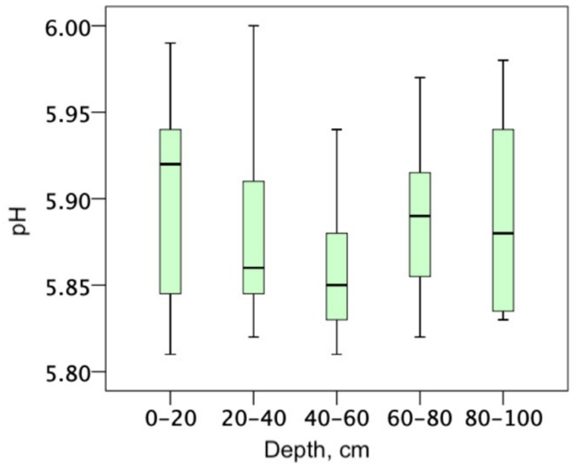

Fig. 6. A box plot graph of pH variation with depth.

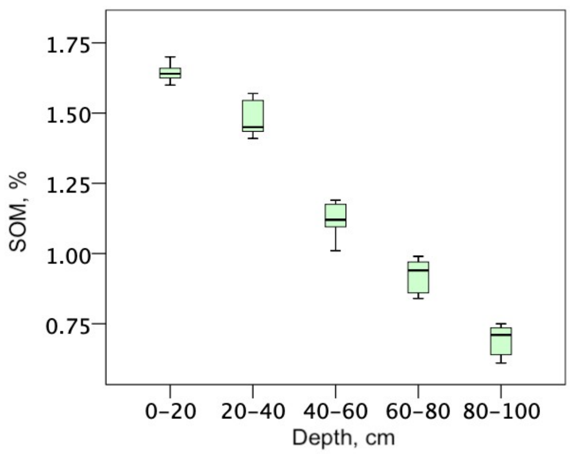

Fig. 7. A box plot graph of the changes in SOM with depth.

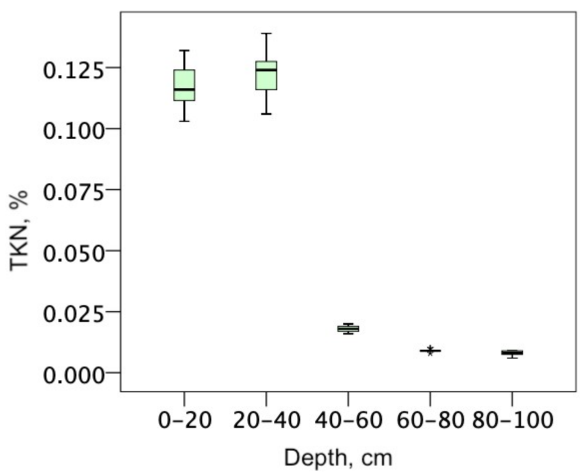

Fig. 8. A box plot graph of the changes in TKN with depth.

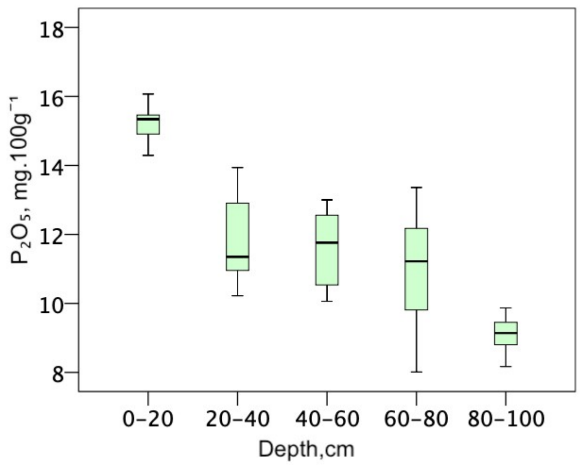

Fig. 9. A box plot graph of the changes in P_2O_5 with depth.

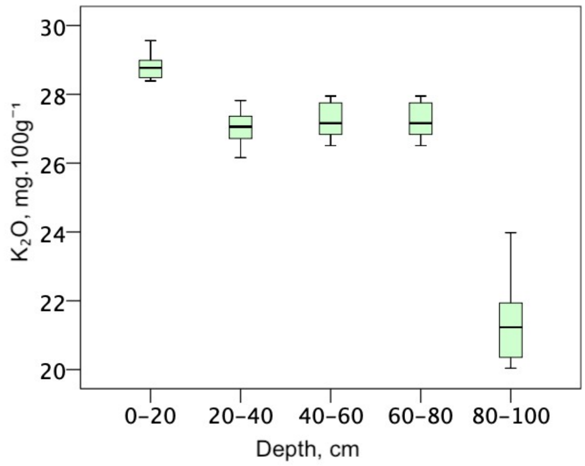

Fig. 10. A box plot graph of the changes in K_2O with depth.

The sand and clay fractions are predominant in the soils studied and have a significant effect on the bulk density (SAXTON & RAWLS, 2006). There is a regression relationship between bulk density and SOM and the nutrients studied. It is a well-known fact that the increase in organic matter results in the decrease in bulk density. The light texture of the soils studied that is typical of these types of soils (PAVLOVIĆ *et al.*, 2017) is responsible for the regression relationships between total porosity and the sand and clay fractions. The relationships between these characteristics have also been reported by other authors (SAXTON & RAWLS, 2006).

The correlations between total porosity and SOM, TKN, P_2O_5, K_2O have been reported in other publications (ILINKIN *et al.*, 2017) without using regression equations to describe these relationships.

There are a number of relationships between the soil texture fractions and the other soil characteristics (Table 2). There are negative regression relationships between the sand fraction and all other soil characteristics, but no regression relationship has been found between the sand fraction and the soil solution reaction. There are regression relationships between the silt fraction and all physical characteristics and only one chemical characteristic – SOM. There is a relationship between the clay fraction and all other soil texture fractions, as well as all chemical characteristics. The negative regressions between the sand fraction and the chemical characteristics are most likely due to the inert nature of the sand fraction. There are positive regression relationships between the clay fraction, including organic residues, micro and macro elements (FIKULOVOJ, 1957), and the chemical elements studied.

Despite the presence of correlations between soil acidity and a number of other soil characteristics (ILINKIN *et al.*, 2017), no regression relationships have been found between pH and the other characteristics of the soils studied (Table 1). This is most likely due to the great variations in this parameter, which is typical of these soils (WALKER *et al.*, 2003; HARTEMINK, 1998).

SOM is supposed to be a storehouse of plant nutrients. (DONOV *et al.*, 1974), which is most likely the reason for the presence of statistically significant regression equations between SOM and TKN, P_2O_5, K_2O.

The decomposition of plant biomass and the mineralization processes are the most likely reason for the presence of regression equations that describe the relationships between TKN и P_2O_5, K_2O, as well as between P_2O_5 and K_2O.

Table 2. Regression between soil characteristics.

y	x	TP	Sand	Silt	Clay	pH	SOM	TKN	P_2O_5	K_2O
BD	Equation, y=	-29x+87.4	14.2x+48.8	-8.5x+24	-	-	-3.4x+5	-0.39x+0.5	-17.9x+32.1	-28.9x+58.2
	R^2	0.867	0.375	0.128	-	-	0.732	0.418	0.486	0.707
	p-Value	<0.0001	<0.0001	0.008	0.2245	0.7216	<0.0001	<0.0001	<0.0001	<0.0001
TP	Equation, y=		-0.53x+93.9	0.3x-1.1	-	-	0.1x-5.1	0.01x-0.7	0.6x-22.9	0.9x-26.2
	R^2		0.508	0.134	-	-	0.808	0.545	0.597	0.728
	p-Value		<0.0001	0.0066	0.0808	0.7062	<0.0001	<0.0001	<0.0001	<0.0001
Sand	Equation, y=			-0.3x+32.8	-0.71x+67.1	-	-0.1x+10.8	-0.02x+1.6	-0.7x+60	-1.03x+92
	R^2			0.066	0.295	-	0.734	0.796	0.440	0.472
	p-Value			0.0434	<0.0001	0.2887	<0.0001	<0.0001	<0.0001	<0.0001
Silt	Equation, y=				-0.8x+31.8	-	0.05x+0.5-	-	-	-
	R^2				0.432	-	0.1007	-	-	-
	p-Value				<0.0001	0.7353	0.0107	0.0592	0.7414	0.089
Clay	Equation, y=					-	0.05x+0.08	0.01x-0.1	0.4x+2.6	0.4x+16.9
	R^2					-	0.137	0.225	0.23	0.112
	p-Value					0.2587	0.0058	0.0003	0.0002	0.0134
pH	Equation, y=						-	-	-	-
	R^2						-	-	-	-
	p-Value						0.8071	0.5453	0.2425	0.7167
SOM	Equation, y=							0.1x-0.1	4.9x+6.0	7.5x+16.5
	R^2							0.822	0.559	0.745
	p-Value							<0.0001	<0.0001	<0.0001
TKN	Equation, y=								27.8x+10.2	41.1x+23.1
	R^2								0.402	0.497
	p-Value								<0.0001	<0.0001
P_2O_5	Equation, y=									0.96x+13.9
	R^2									0.519
	p-Value									<0.0001

R^2 is one minus the ratio of the sum of squares for these two predictions (FARAWAY, 1987), but in a number of regression equations derived in this study R^2 is low (Silt/depth; Clay/depth; BD/Sand; BD/Silt; BD/TKN; TP/Silt; Sand/Silt; Sand/Clay; Clay/SOM; Clay/TKN; Clay/P_2O_5; Clay/K_2O; TKN/ P_2O_5). According to FARAWAY (1987) there is not a set R-squared value above which this measure could be accepted as a criterion for the significance of the model, and it is greatly dependent on the scientific field. In scientific fields with great variables which tend to be more weakly correlated and there is a lot of noise, a lower R^2 value would be considered normal, whereas in other scientific fields such as physics or engineering, where most data come from closely controlled experiments, we typically expect to get much higher R^2s and a value of 0.6 would be considered low (FARAWAY, 1987). In agricultural sciences CRESPELL *et al.* (2006) report statistically significant models with a low R^2 value (R^2<0,5), while other authors (KOZAR *et al*, 2002; FANTAPPIÈ *et al.*, 2011) report statistical models with an even lower R-squared value (R^2<0,3) in relation to soil characteristics.

The significance of a model in relation to a null model is determined by the p-value for this model. In case of a linear regression, the definition of a null model is one with a dependent variable which is equal to its mean. Thus, the p-value for the model indicates whether this model provides a significantly better explanation of the data than the average value of the dependent variable (MANGIAFICO, 2016). According to MANGIAFICO (2016) p-values and R-squared values are measures of different things. The p-value shows whether the model describes a significant relationship, and the R-squared value measures the degree to which the model explains the data. As a result, it is not at all unlikely to produce a high p-value and a low R-squared value. PENKOV *et al.* (1992) report that there are variations in the physical and chemical properties of Fluvisols. This variation could explain the lower R-squared values in some regression models which are, nevertheless, statistically significant.

Conclusions

The study on the Alluvial-meadow soils found that there are statistically significant regression relationships between the soil characteristics studied and depth with the exception of pH where such relationships were not determined. There are thirty-two out of 45 possible regression relationships between the soil characteristics studied. The only exception is pH which was not found to be in any correlations with the other soil characteristics. Therefore, it cannot be used as an indicator to determine whether the model is correctly specified.

There are statistically significant linear regressions between bulk density and a number of soil characteristics (total porosity, sand and silt fractions, SOM, TKN, P_2O_5, K_2O). There is a regression relationship between the clay fraction and the other soil texture fractions as well as all chemical characteristics. There are regression relationships between SOM and TKN, P_2O_5, K_2O. There are regression equations that describe the relationships between TKN and P_2O_5, K_2O, as well as between P_2O_5 and K_2O.

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Received: 11.03.2019
Accepted: 15.04.2019