CHARACTERISTICS OF FLUVISOLS IN SAND AND GRAVEL DEPOSIT “KRIVA BARA”, SOFIA, BULGARIA

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Abstract: The paper presents results of an investigation on Fluvisols located in “Kriva Bara” Sofia, Bulgaria. Soil samples were taken from sixteen soil profiles. The soil physical and chemical properties were studied. The changes in physical and chemical properties at varying soil depths were studied and the relationships among different soil characteristics were tested by correlation analysis. The results revealed that some soil characteristics, such as soil texture, porosity and TKN, changed strongly with soil depth, either negatively or positively, while such relationships were moderately expressed or statistically insignificant in the case of other soil characteristics, such as soil reaction (pH), CaCO_3 , silt content. There were significant correlations between the physical and chemical soil properties in 49 out of 78 cases.

Key words: Fluvisols, physical properties, chemical properties, gravel and sand deposit, quarry

INTRODUCTION

The sustainable development and productivity of suburban green areas depend to a great extent on the soil properties. Soil characteristics determine the existence and normal functioning of ecosystems. The studies on the soil composition and properties allow suitable planned activities to ensure efficient and environmentally use.

Fluvisols are intrazonal and occur in the riverside environment [1]. They are characterized by variable physicochemical properties [2; 3], but have a favourable water regime [4; 1] and good bulk density indicators [5]. They are characterized by acid, neutral or alkaline reaction in relation to river basins. Soil organic matter (SOM) is average or low, but varies strongly [3] and may reach up to 2% in the surface horizon [6]. The nitrogen content is high or average [7]. Favorable water, air indicate that these soils have been used for agriculture since ancient times. The soils are characterized by a low store of nutrient elements. Low content of organic colloids and coarse texture characterize the soils as such with low Cation Exchange Capacity (CEC) 10–15 meq/100 g and low buffer properties [8]. These soils can be used for growing of high yield cultures if fertilized properly [1; 9]. Fluvisols are found between Chernozems and Gray forest soils in Northern Bulgaria, along the rivers - Danube, Lom, Ogosta, Iskar, Osam, Yantra, Rositsa and Kamchia [10; 11]. In Southern Bulgaria they are situated between Vertisols and Cinnamonic Forest soils [12; 1]. A main soil-forming factor is the nature of the alluvial deposit [13], which differs depending on the adjacent water basin that has carried the deposits, on the location along the river, and on the distance from the water. The weather conditions are determined by the climate zone of the respective river valley, or where the hollow is located [1].

MATERIALS AND METHODS

The object. Fluvisols [14] occurring on the territory of “Kriva Bara” sand and gravel deposit (so far unexploited), located 1.5 km north-northeast of Levski-G District, Sofia, Bulgaria were the target of the study. Usually this soil type is found in the Lower forest vegetation zone (0 - 600 m a. s. l.) of the Moesian forest vegetation area [15].

Methods of study. Sixteen soil pits were done at representative plots. A systematic sampling design was used [16]. The samples were taken at a depth of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm and 80-100 cm. The following methods were used to analyze the soil samples: Bulk density (BD, $\text{g}\cdot\text{cm}^{-3}$), according to the Kachinsky method [17, 18]; Total porosity (TP, %) through calculation from bulk density and relative density [17]; Plant available water capacity (PAWC, mm), by a laboratory method, through calculation from field capacity and permanent wilting point [17]; Soil texture (Sand - 2 mm - 63 μm , %; Silt - 63 μm - 2 μm , %; Clay < 2 μm , %), using the sedimentation method [19]; Soil Organic Matter (SOM, %) by the Turin method [17]; Total Kjeldahl Nitrogen (TKN, %) content, by a modified version of the classic Kjeldahl method (Tecator 1030); P_2O_5 ($\text{mg}\cdot 100\text{g}^{-1}$) – extraction with Ammonium Acetate and Calcium Lactate-pH 4.2 (UV-VIS spectrophotometer Perkin Elmer Lambda 5) [20]; K_2O ($\text{mg}\cdot 100\text{g}^{-1}$) – extraction with Ammonium Acetate and Calcium Lactate-pH 4.2 (Flame photometer Jenway php 7) [20]; Soil acidity (pH in water extraction and CaCl_2 extraction 1:5 w/v) – measured potentiometrically (WTW 720 pH meter); CaCO_3 (%) by Shaibler’s method (Eijkelkamp 08.53 calcimeter) [21].

Data analysis. Descriptive statistics was done using Numbers and Excel on Mac and PC, respectively. Percentage data were arcsine-square root transformed

before the analysis [22]. Pearson's product-moment correlation among the soil characteristics studied was calculated using SPSS for Windows, version 16.0. Linear regression analysis was applied for additional testing for functional relationship between the soil depth and the other characteristics.

RESULTS AND DISCUSSION

Soil formation process

The soil forming factors influence the nature, direction and speed of soil forming processes [1]. The key factors are climate, biota, topography, and parent material.

The climate has a direct influence on the temperature and moisture of the soil, and an indirect one on the biota. In terms of climate, the subject of study falls within the European continental climatic region, temperate continental sub-region, climatic region of the high fields of Mid-Western Bulgaria [25]. The average temperatures in January are about 4 – 5 °C, and the average temperatures in June are 20 – 21 °C. The average annual temperature of the studied area varies around 11.5°C, the average annual rainfall varies around 837 mm, with a peak rainfall in May and a minimum in July [25]. Higher plants are the most significant biotic factors that shape the formation of soils, microclimate, supply the soil with organic matter and influence its composition and properties [26]. A number of plant species are closely related to the soil properties by influencing plant development, or by indicating changes in the soil substrate [27; 28; 29; 30]. The soils have been formed under poorly developed meadow vegetation [31; 32; 26]. Forests develop less frequently on such soils [31], but if they do, in Bulgaria they form riparian ecosystems dominated by poplars

(*Populus* spp.) and willows *Salix* spp., and less frequently – by Common oak (*Quercus robur*) and Ashes (*Fraxinus* spp.) [33]. Meadow-marsh vegetation and more rarely, salt tolerant vegetation develop in lower regions [31]. The parent material is a river deposit, mostly sandy, which becomes finer and finer as the river flows from its source to its mouth. It is layered due to its periodic precipitation when rivers burst their banks [32; 1]. These soils are young, at an early stage of development. Their periodic flushing by fast-flowing rivers during flooding and the precipitation of new sediments prevent the occurrence of permanent vegetation and soil formation [32; 1]. Over the short period of their existence no genetic horizons have formed [26; 1].

Soil characteristics. Soil physical parameters changed slightly with the soil depth. The soil texture at a depth of 0-20 cm fell into the Sandy Loam and mostly in Sandy Clay Loam groups. At a depth of 20-40 cm it fell into the Sandy Clay Loam and mostly in Sandy Loam texture group. At a depth of 40-60, 60-80 cm it fell into the sandy loam texture group. The samples at a depth of 80-100 cm fell into Sandy Loam and mainly into the Loam Sand group (Fig. 1). The soil texture variability is consistent with a study carried out by Singh et al [23].

The variation of soil texture with depth was characterized by a negative linear relationship with high statistical significance for the clay fraction ($R^2=0.817$, $p<0.001$), positive linear relationship with high statistical significance for the sand fraction ($R^2=0.7421$, $p<0.001$) and positive linear relationship with high statistical significance for the sand fraction ($R^2=0.1783$, $p<0.001$) and positive linear relationship with high statistical significance for the sand fraction ($R^2=0.1783$, $p<0.001$) (Fig. 2).

Fig. 1. Soil texture [24]

Fig. 2. Relationship between depth and soil texture characteristics

The bulk density values were between 1.22 and 1.32 g.cm⁻³ (Mean = 1.27, Coeff. of variation = 2.88%) in the upper (0-20 cm) layer, varied between 1.29 and 1.43 g.cm⁻³ (Mean = 1.33, Coeff. of variation = 2.84%) in the 20-40 cm layer, between 1.35 and 1.46 g.cm⁻³ (Mean = 1.39, Coeff. of variation = 2.12%) in the 40-60 cm layer, between 1.40 and 1.49 g.cm⁻³ (Mean = 1.45, Coeff. of variation = 2.01%) in the 60-80 cm layer and 1.42 and 1.53 g.cm⁻³ (Mean = 1.48, Coeff. of variation = 1.56%) in the lower (80-100 cm) layer. Despite the weak upward trend of the maximum bulk density values with depth, there was significant relationship between the depth and the bulk density ($R^2=0.844$, $p<0.001$) (Fig. 3).

Fig. 3. Relationship between soil depth and porosity

The study of the Fluvisols showed that there was a clear downward trend in porosity with depth ($R^2=0.8716$, $p<0.001$) (Fig. 4)

Fig. 4. Relationship between soil depth and porosity

Pearson's product-moment correlation coefficients express the relationships among the soil characteristics (Table 1). It can be seen that roughly three-quarters of the correlation coefficients (49 of 78) are significantly different from zero. In other words, there are significant relationships among different soil characteristics. There is high significant positive correlation between the clay fraction and porosity ($r = 0.967$) and a negative one between the clay fraction and Bulk density ($r = -0.961$). The clay content correlates significantly with PAWC, SOM, TKN, P₂O₅ and K₂O (positively). Sand content correlates (positively) significantly only with bulk density and pH (H₂O) and all other significant correlations are negative. (Table 1).

PAWC in the studied soils varied from 164.18 mm to 173.08 mm (Mean = 168.91, Coeff. of variation = 1.31%) and evaluation of the soils was medium.

The pH values in the H₂O extract were between 5.90 and 6.95 (Mean = 6.35, Coeff. of variation = 6.11%) in the upper (0-20 cm) layer, pH varied between 5.58 and 7.21 (Mean = 6.35, Coeff. of variation = 10.01%) in the 20-40 cm layer, between 5.66 and 6.45 (Mean = 6.01, Coeff. of variation = 3.32%) in the 40-60 cm layer, between 5.59 and 6.84 (Mean = 6.08, Coeff. of variation = 6.26%) in the 60-80 cm layer and between 5.84 and 7.56 (Mean = 6.68, Coeff. of variation = 7.34%) the lower (80-100 cm) layer. The pH values in the CaCl₂ extract were between 5.13 and 6.50 (Mean = 5.78, Coeff. of variation = 6.66%) in the upper (0-20 cm) layer, pH varied between 4.92 and 6.71 (Mean = 5.85, Coeff. of variation = 10.54%) in the 20-40 cm layer, between 4.98 and 6.06 (Mean = 5.44, Coeff. of variation = 5.17%) in the 40-60 cm layer, between 5.03 and 6.16 (Mean = 5.53, Coeff. of variation = 6.04%) in the 60-80 cm layer and between 5.11 and 7.11 (Mean = 6.04, Coeff. of variation = 8.94%) in the lower (80-100 cm) layer. There was weakly expressed linear relationship between the soil reaction in H₂O and soil depth ($R^2=0.0133$, $p=0.3086$) and no relationship between the soil reaction in CaCl₂ and soil depth ($R^2=0.0033$, $p=0.612$).

The values of the carbonate content were relatively low, which had been expected based on the pH data. There was no significant linear relationship between CaCO₃ and depth ($R^2=0.0263$, $p=0.150$).

Table 1. Matrix of the correlation coefficients among the soil characteristics studied

	<i>Sand</i>	<i>Silt</i>	<i>Clay</i>	<i>BD</i>	<i>TP</i>	<i>PAWC</i>	<i>pH (H₂O)</i>	<i>pH (CaCl₂)</i>	<i>CaCO₃</i>	<i>SOM</i>	<i>TKN</i>	<i>P₂O₅</i>
<i>Silt</i>	0.148											
<i>Clay</i>	-0.896	-0.572										
<i>BD</i>	0.866	0.542	-0.961									
<i>TP</i>	-0.873	-0.542	0.967	-0.963								
<i>PAWC</i>	-0.448	0.556	0.285	-0.331	0.309							
<i>pH (H₂O)</i>	0.221	-0.440	0.014	0.041	-0.001	-0.286						
<i>pH (CaCl)</i>	0.189	-0.423	0.033	0.002	0.031	-0.201	0.919					
<i>CaCO₃</i>	-0.079	-0.131	0.125	-0.122	0.113	-0.489	0.015	0.042				
<i>SOM</i>	-0.601	-0.184	0.581	-0.567	0.555	0.063	-0.036	-0.016	0.274			
<i>TKN</i>	-0.598	-0.269	0.617	-0.545	0.585	0.096	-0.018	0.011	0.218	0.486		
<i>P₂O₅</i>	-0.319	-0.411	0.449	-0.413	0.398	0.451	0.237	0.259	0.198	0.213	0.339	
<i>K₂O</i>	-0.649	-0.562	0.790	-0.748	0.741	0.047	-0.001	0.005	0.244	0.501	0.711	0.503

Legend: The values in Bold indicate a statistically significant correlation at $p \leq 0.05$.
For abbreviations of the names of soil characteristics, see part “Material and Methods”

The studied soils were generally characterized by low SOM and TKN values, which is consistent with Donovan [1] and Singh et al. [23]. The SOM and TKN were between 0.91 and 2.30% (Mean = 1.66, Coeff. of variation = 27.97%), 0.015 and 0.023% (Mean = 0.020, Coeff. of variation = 11.03%) in the upper (0-20 cm) layer, between 0.35 and 1.96% (Mean = 1.14, Coeff. of variation = 48.73%), 0.008 and 0.017% (Mean = 0.012, Coeff. of variation = 26.41%) at 20-40 cm, 0.69-1.71% (Mean = 1.19, Coeff. of variation = 30.66%) and 0.008-0.017% (Mean = 0.013, Coeff. of variation = 23.39%) at

40-60 cm depth, between 0.19 and 1.70% (Mean = 1.03, Coeff. of variation = 43.68%), 0.008 and 0.018% (Mean = 0.012, Coeff. of variation = 28.40%), at 60-80 cm and between 0.10 and 1.32% (Mean = 0.59, Coeff. of variation = 62.82%), 0.006 and 0.014% (Mean = 0.010, Coeff. of variation = 28.37%) respectively in the lower (80-100 cm) layer. There was a strong linear negative relationship between SOM and the depth ($R^2=0.3312$, $p<0.001$), and a strong linear negative relationship between TKN and the depth ($R^2=0.4003$, $p<0.001$) (Figures 5 and 6).

Fig. 5. Relationship between depth and SOM

The P_2O_5 and K_2O were between 0.09 and 0.40 $mg.100g^{-1}$ (Mean = 0.23, Coeff. of variation = 50.57%), 31.08 and 56.78 $mg.100g^{-1}$ (Mean = 42.28, Coeff. of variation = 17.73%) in the upper (0-20 cm) layer, between 0.05 and 0.22 $mg.100g^{-1}$ (Mean = 0.15, Coeff. of variation = 40.53%), 10.13 and 16.12 $mg.100g^{-1}$ (Mean = 12.85, Coeff. of variation = 15.54%) at 20-40 cm, 0.01-0.18 $mg.100g^{-1}$ (Mean = 0.02, Coeff. of variation = 174.34%) and 9.03-15.22 $mg.100g^{-1}$ (Mean = 11.76, Coeff. of variation = 17.81%) at 40-60 cm depth, between 0.10 and 0.14 $mg.100g^{-1}$ (Mean = 0.12,

Fig. 6. Relationship between depth and TKN

Coeff. of variation = 10.69%), 8.15 and 12.43 $mg.100g^{-1}$ (Mean = 9.99, Coeff. of variation = 14.10%), at 60-80 cm and between 0.05 and 0.12 $mg.100g^{-1}$ (Mean = 0.12, Coeff. of variation = 35.83%), 6.49 and 10.84 $mg.100g^{-1}$ (Mean = 8.01, Coeff. of variation = 16.39%) respectively in the lower (80-1000 cm) layer. There were low linear negative relationships between P_2O_5 and depth ($R^2=0.1346$, $p<0.001$, fig. 7), and medium linear negative relationships between K_2O and depth ($R^2=0.5808$, $p<0.001$, Fig. 8).

Fig. 7. Relationship between soil depth and P_2O_5 content

Fig. 8. Relationship between soil depth and K_2O content

Plant cover. Total 19 species were recorded in the scoring plots (Table 2). It should be pointed out that these plants represent late summer and partly the autumn spectrum, because the study was performed in August-September. The plants from the early vegetation period remained undetected. There was one shrub species (*Rubus caesius*), thirteen perennial plant species, three annuals and two biennials.

The phytogeographic analysis revealed that there are 8 Euro-Asiatic floristic elements, followed by 3 Euro-Siberian. Boreal and Euro-Mediterranean elements are represented by 2 species each, and there are also one SubBoreal, one Pontic-Mediterranean element, one subMediterranean and one European element.

Table 2. Plant species recorded in the scoring plots

No	Species	Phytogeographic origin	Biological type
1	<i>Achillea millefolium</i> L.	Eur-Sib	perennial
2	<i>Agrimonia eupatoria</i> L.	Eur-Med	perennial
3	<i>Alopecurus pratensis</i> L.	Eur-As	perennial
4	<i>Arrhenatherum elatius</i> (L.) P. Beauv. ex J.&C. Presl	Eur-As	perennial
5	<i>Artemisia vulgaris</i> L.	subBoreal	perennial
6	<i>Centaurea solstitialis</i> L.	eur-Med	annual
7	<i>Conium maculatum</i> L.	Eur-As	annual
8	<i>Crepis biennis</i> L.	subMed	biennial
9	<i>Dactylis glomerata</i> L.	Eur-As	perennial
10	<i>Echium vulgare</i> L.	Eur-As	biennial
11	<i>Elymus repens</i> (L.) Gould.	Boreal	perennial
12	<i>Eryngium campestre</i> L.	Pond-Med	perennial
13	<i>Galium verum</i> L.	Eur-As	perennial
14	<i>Holcus lanatus</i> L.	Eur	perennial
15	<i>Hordeum murinum</i> L.	Boreal	annual
16	<i>Tanacetum vulgare</i> L.	Eur-Sib.	perennial
17	<i>Linaria vulgaris</i> Mill.	Eur-Sib	perennial
18	<i>Lolium perenne</i> L.	Eur-As	perennial
19	<i>Rubus caesius</i> L.	Eur-As	shrub

CONCLUSIONS AND RECOMMENDATIONS

The specific soil formation factors for soils of Fluvisols group determined a variation of different soil characteristics (such as CaCO_3 , pH (H_2O), etc) and because of this there were weak relationships between different soil characteristics and soil depth. There were moderate to high relationships between some physical soil characteristic such as Soil texture, Bulk density, Porosity, and some chemical soil characteristic such as Total Kjeldahl Nitrogen, K_2O and soil depth and weak and insignificant relationships between the other characteristics and soil depth.

The studied soils were characterized by some favorable physical properties, e.g. light by texture, porosity and unfavorable physical properties like bulk density which varied from compacted to very dense. PAWC evaluation was medium. The high content of inert texture fraction (Sand) determined the low content of SOM and nutrient elements (TKN and P_2O_5) especially in lower layers, apart from K_2O . The K_2O

content was high. The CaCO_3 content was low which determined pH (H_2O) between slightly acidic to neutral.

The studied object is situated close to district Levski-G of Sofia city agglomeration. The decrease of green areas in Sofia, on the one hand, and the unfavorable effect of the mining activities on the territory of Krivina, on the other, underline the necessity of establishment of a park territory in the zone of the still nonexploited locality. Considering the soil characteristics in the object, we could recommend for cultivation some arboreal species: indigenous - *Pinus nigra* Arnold, *Quercus robur* L., *Quercus cerris* L., *Fraxinus oxycarpa* Willd., *Celtis australis* L., *Ulmus minor* Mill., *Syringa vulgaris* L., *Cotinus coggygria* Scop.; exotic – *Cedrus atlantica* Manetti, *Cupressus sempervirens* L., *Quercus rubra* L., *Ulmus pumila* L., *Morus alba* L., and many ornamental shrubs with more or less pronounced drought resistance.

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ХАРАКТЕРИСТИКА НА ПОЧВИ ОТ КЛАС FLUVISOLS В НАХОДИЩЕ НА ЧАКЪЛ И ПЯСЪЦИ "КРИВА БАРА", СОФИЯ, БЪЛГАРИЯ

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Резюме: В статията са представени резултатите от проучване на почви от клас Fluvisols, разположени в кариера "Крива Бара" София, България. Почвените проби са взети от шестнадесет почвени профила. Изследвани са физични и химични свойства на почвата. Анализирани са промените по дълбочина на почвените профили, като връзките между различните почвени характеристики са определени чрез корелационен анализ. Резултатите показват, че някои почвени характеристики, като механичен състав, порьозност и TKN, се променят значително по дълбочината на почвения профил с положителна или отрицателна зависимост. Измененията при други почвени характеристики, като рН и CaCO₃, са умерено изразени или са без статистическа достоверност. Съществуват статистически значими зависимости между физичните и химичните свойства на почвата в 49 от 78 случая.

Ключови думи: Fluvisols, физични свойства, химични свойства, находище на чакъл и пясъци, кариера

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