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Original scientific paper

SOME PHYSICO-MECHANICAL CHARACTERISTICS OF PSEUDOGLEY SOILS OF PLAINS AND SLOPES UNDER FOREST, GRASSLAND AND ARABLE LAND

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Physical and mechanical properties of pseudogley soils of southern Mačva and Pocerina, with an emphasis on differences between two (plain and slope) pseudogley subtypes and three types of land use (forest, grassland and arable fields), are given. All changes were tracked throughout all soil horizons.

The studied pseudogley soils of southern Mačva and Pocerina are moderately to highly plastic. Plasticity index in the humus (Ah, Ahp) horizon of the soils ranges from 17.52 to 20.38, being the lowest for forest varieties (17.81 to 18.49), slightly higher for grassland (17.52 -19.75) and the highest for arable fields (17.55 to 20.38). In the illuvial pseudogley Btg horizon, the plasticity index reaches its maximum values (30.47 to 39.71), always in the range of high plasticity. A narrow moisture interval (7.79 to 10.21%) in physically mature soil ready for tillage, particularly in the arable horizon, prevents soil tillage and other farming operations for a longer period of time. Pseudogley of plains compared with that of slopes shows higher statistically significant values of the lower plastic limit and linear shrinkage. However,

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lower statistically significant values of the lower plastic limit, linear shrinkage and moisture content in physically mature soil, and higher values of plasticity index were found in the arable pseudogley horizon, in contrast to forest and grassland pseudogley horizons. Grassland compared with the forest pseudogley horizon has lower statistically significant values of the lower plastic limit and linear shrinkage, and higher plasticity index values.

Keywords: pseudogley, plasticity, shrinkage, soil physical maturity for tillage, southern Mačva and Pocerina

INTRODUCTION

Physico-mechanical properties of a soil, from the standpoint of their impact on various processes taking place in the soil, then on speed, quality and soil preparation costs, as well as on the development of plant roots, and thus the crop yields, belong to the most important group of physical properties. This group of soil physico-mechanical properties comprises a number of properties, among which the soil plasticity and shrinkage, considering soil preparation, i.e. determination of an optimal moisture interval corresponding to the physically mature soil ready for tillage, have been studied as the two most important properties.

According to ATTERBERG (1911), the soil plasticity can be characterized by the following three parameters: the lower plastic limit (or the limit of rolling of soil into threads) - hereinafter referred to as Wp, the upper plastic limit (or liquid limit) – Wl, and the plasticity number (or index) - Ip. The knowledge of Wp is very important for easier and timely soil preparation because it also represents the upper limit (moisture content) of soil physical maturity, i.e. soil physical suitability for tillage. Namely, in order to obtain good quality arable land and avoid formation of a very compact sub-arable horizon, preparation of clay-rich soils should be done only when the soil is of semi-hard (friable) consistency. Otherwise, if tillage is carried out at soil moisture content much higher than that of Wp, i.e. at moisture of plastic or plastic-sticky soil consistency, then it comes to the destruction of the soil structure, soil smearing occurs, and after draining to the formation of clumps, i.e. "plow soles", and simultaneous creation of a compact, hardly permeable to water, air and plant roots, sub-arable horizon. On the other hand, if tillage is done below that limit (Wp), it comes to the breaking up and pulverizing of the arable horizon, which is also unfavorable, and in both cases much more energy is consumed.

Shrinkage reduces the volume of soil in all directions, which results in formation of vertical and horizontal cracks, increase in soil hardness and coherence, and considerable reduction in porosity. Knowledge of the shrinkage limit, which represents the moisture content at which the soil transition from semi-hard to hard consistency takes place, is very important for the determination of on optimal moisture level of soil for its preparation.

Soil tillage can be done at different moisture contents. During this operation different amounts of energy are consumed and different qualities of arable land are obtained, which reflects in the level of costs and crop yields, i.e the profitability of crop production. Therefore, effective tillage with as low as possible energy consumption should be done in the time interval when the soil is in a specific state, called soil physical maturity, i.e. at the stage when the soil is ready for tillage. The moisture range, which represents the difference between the lower plastic limit and the shrinkage limit, corresponds to the soil physical maturity.

The soil plasticity, as well as other physical and mechanical properties, in humus poor and non-carbonate containing soils to which the studied pseudogley belongs, is mainly determined by the content and mineralogical composition of the clay fraction, content of humus and the composition of the exchangeable cations adsorbed, and its values, depending on the given factors may vary in a very wide range. In the region of southern Mačva and Pocerina, two (slope and plain) pseudogley subtypes have been developed. Both subtypes are under three different plant covers: forest, grassland and arable fields. The aim of this study was to the determine differences in investigated physico-mechanical characteristics between the two pseudogley subtypes, as well as the differences resulting from different types of land use. All changes were tracked throughout the soil profiles, that is, all genetic pseudogley horizons.

MATERIAL AND METHODS

In the territory of Mačva, soil profiles were opened in locations of Petkovac, Lipolist, Bogosavac and Dobrić, and in the territory of Pocerina in locations of Culjković, Grušić, Jevremovac, Varna and Slatina. All profiles from Mačva and those from Varna location in Pocerina belong to the plain pseudogley subtype, while profiles from other locations in Pocerina to the slope pseudogley subtype. Three representative profiles, for different types of land use: forest, grassland and arable land, were opened in each location.

Physico-mechanical properties of samples taken from Ah or Ahp, Eg, Btg and BtgC pseudogley horizons were determined using the following methods (JDPZ, 1997): soil plasticity by Atterberg's method, soil shrinkage by Filatov's method and soil physical maturity by computation. The data were statistically processed applying correlation analysis and t-test using StatSoft, Inc. Statistica software package for Windows, Version 8, at the confidence level of 95%.

RESULTES AND DISCUSSION

Soil plasticity

The values of Wp Wl, as well as of Ip are given in Tables 1 and 2 for plain and slope pseudogley soils, respectively.

Table 1. Plastic limits and plasticity index of plain pseudogley soils from southern Mačva based on average values

Variety	Horizon	Humus %	< 0,002 mm %	Plastic limits and plasticity index			Plasticity class I.Lieberoth (1969)
				Wl	Wp	Ip	
Forest	**Ah**	3.51	28.51	44.71	26.45	18.26	Moderately plastic
	Eg	1.64	31.96	39.78	22.04	17.74	Moderately plastic
	Btg	0.95	38.85	54.07	21.93	32.14	Highly plastic
	BtgC	0.89	39.24	59.78	22.49	37.29	Highly plastic
Average		**1.74**	**34.64**	**49.59**	**23.23**	**26.36**	**Highly plastic**
Grass-land	**Ah**	2.00	27.54	40.81	22.18	18.63	Moderately plastic
	Eg	0.99	31.78	41.19	20.45	20.74	Highly plastic
	Btg	0.82	37.44	54.37	21.02	33.35	Highly plastic
	BtgC	0.76	37.91	57.24	22.03	35.21	Highly plastic
Average		**1.14**	**33.67**	**48.40**	**21.42**	**26.98**	**Highly plastic**
Arable land	**Ah**	2.02	28.06	39.78	20.81	18.97	Moderately plastic
	Eg	1.05	29.77	44.51	20.14	24.37	Highly plastic
	Btg	0.92	37.25	55.04	20.80	34.24	Highly plastic
	BtgC	0.76	37.33	57.88	21.12	36.76	Highly plastic
Average		**1.19**	**33.10**	**49.30**	**20.72**	**28.58**	**Highly plastic**

Table 2. Plastic limits and plasticity index of slope pseudogley soils from Pocerina based on average values

Variety	Horizon	Humus %	< 0.002 mm %	Plastic limits and plasticity index			Plasticity class I.Lieberoth (1969)
				Wl	Wp	Ip	
Forest	**Ah**	3.04	26.28	42.60	24.79	17.81	Moderately plastic
	Eg	1.45	28.45	37.12	19.86	17.26	Moderately plastic
	Btg	0.93	33.75	52.81	19.92	32.89	Highly plastic
	BtgC	0.81	38.45	56.49	21.41	35.08	Highly plastic
Average		**1.56**	**31.73**	**47.26**	**21.50**	**25.76**	**Highly plastic**
Grass-land	**Ah**	2.09	24.70	40.90	21.87	19.03	Moderately plastic
	Eg	0.83	30.95	38.31	19.70	18.61	Moderately plastic
	Btg	0.64	39.45	57.20	20.13	33.07	Highly plastic
	BtgC	0.61	40.95	58.32	20.91	34.94	Highly plastic
Average		**1.04**	**34.01**	**48.68**	**20.65**	**28.03**	**Highly plastic**
Arable land	**Ah**	1.75	29.35	39.19	20.66	19.53	Moderately plastic
	Eg	0.84	32.70	42.53	19.51	23.02	Highly plastic
	Btg	0.81	37.45	56.26	20.39	35.87	Highly plastic
	BtgC	0.74	38.08	59.53	21.22	38.31	Highly plastic
Average		**1.04**	**34.40**	**49.38**	**20.45**	**28.93**	**Highly plastic**

Pseudogley of slopes compared to that of plains have lower Wp, Wl and Ip values, only the difference in Wp ($t = -4.421007$, $p = 0.001027$) is statistically significant. The values of Wl (moisture content) vary in a considerably wider range than those of Wp.

On average, the Wp values decrease from those for forest over grass being the lowest for cultivated pseudogley. Lower statistically significant Wp values were found in grassland ($t = -2.43351$, $p = 0.045188$) and arable soil varieties ($t = -2.40552$, $p = 0.047083$) in comparison with those in forest variety, while the difference in Wp between the grassland and the arable soil was not statistically significant. Unlike Wp, the Wl values increase from those registered in forest pseudogley over grassland to arable fields, but the differences are not statistically significant. As Wl, the Ip values increase in the same direction, whereas Ip is statistically significantly higher in the arable soil variety, compared with that found in forest ($t = 3.31143$, $p = 0.012916$) and grass ($t = 3.95121$, $p = 0.005523$).

Surface Ah horizon of the slope pseudogley has slightly lower values of Wp compared to the same horizon of plain pseudogley, which are in correlation with somewhat lower contents of clay and humus. Surface horizons of grass- and arable land varieties of plain pseudogley were found to have much lower Wp values, which are about 20, i.e., 27% lower than those for the forest variety, and this can be explained by significantly lower humus content in these varieties. The highest Wl values (moisture content) in the Ah horizon were found for the forest variety with the highest humus content, and vice versa, the lowest Wl values showed arable soil variety with the lowest humus content.

In the eluvial Eg horizon, the Wp values decrease for all investigated profiles. The greatest decrease was observed in soils under forest vegetation (about 20%), then follows grassland (about 8%), and the smallest decrease (about 3%) was found in cultivated soils. A decrease in Wl in profiles under forest and grass vegetation results from a significant reduction in the amount of humus, while in profiles with cultivated fields Wl increases.

The Wp values in the illuvial-pseudogley Btg horizon, in contrast with the Eg one, are higher as a consequence of a significant increase in clay content in this horizon and in its upper layer. The Wl values increased considerably, and are always higher than 50%, which is consistent with a significant increase in clay content in this horizon.

The Ip values increase with the soil depth so that the pseudogley in the Ah horizon is mostly moderately plastic; in the Eg horizon it varies in the range from moderately to highly plastic, being finally highly plastic in the Btg and BtgC horizons (classification according to LIEBEROTH, 1969). A very high correlation coefficient ($r = 0.76$) obtained by correlation of the plasticity index with the clay content, and a high one ($r = 0.61$) correlation of the plasticity index and the content of exchangeable-adsorbed Ca^{2+}, indicate that the soil texture, i.e,, content of clay and exchangeable-adsorbed Ca^{2+}, plays a crucial role in determination of plasticity index, while with the humus content a strong but negative correlation was established (r = -0.68).

The results on pseudogley plasticity presented in this paper are very similar to those of STOJANOVIĆ (1984), for two profiles of arable pseudogley soils from Varna near Šabac. The author points to a close dependence of the plasticity on the content of clay in which mineralogical composition illite predominates. Namely, according to our results and the results of other authors (ALEKSANDROVIĆ *et al.*, 1965; PANTOVIĆ *et al.*, 1967; JANKOVIĆ, 1976; PROTIĆ *et al.*, 1995; DUGALIĆ, 1997; KOSTIĆ, 2001; DUGALIĆ *et al.*, 2004), illite is the dominant clay mineral in pseudogley soils of western Serbia. Also, the results presented in this study are in agreement with the results of other authors who examined the plasticity of pseudogley soils: STOJANOVIĆ *and* ĐORĐEVIĆ (1989, 1991), DUGONJIĆ (2001), GAJIĆ (2005), DUGONJIĆ *and* ĐORĐEVIĆ (2007), DUGONJIĆ *et al.* (2008).

Possible improvements in arable pseudogley soils were indicated by STOJANOVIĆ *and* ĐORĐEVIĆ (1988). Application of organic produced positive effects on pseudogley soil because they caused a significant decrease in Wl, especially in the Ahp horizon, and decrease in Ip value as well.

Soil shrinkage

Average shrinkage values for the pseudogley subtypes and varieties of southern Mačva and Pocerina are shown in Fig. 1.

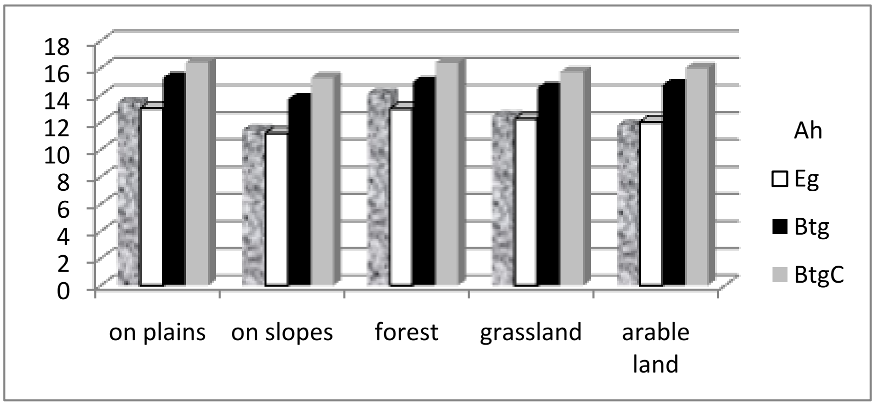

Fig. 1. Average values of soil shrinkage (%)

Pseudogley of plains, characterized by a higher clay and humus content, exhibited significantly higher levels of linear shrinkage (t = 2.839628, p = 0.016093) than the pseudogley of slopes. Also, significantly higher shrinkage values were found in pseudogley under forest compared with pseudogley under grass (t = 3.68020, p = 0.003625) and arable land (t = 2.78367, p = 0.017787).

Basically, the soil shrinkage values in the Eg compared with the Ah horizon are more or less lower as a result of rapid decrease in humus content, characterized by a very high water capacity, many times greater than the water capacity of clay. The exception is the arable pseudogley soil poorest in humus where the linear shrinkage in the Eg horizon is greater than in the Ah horizon. For both subtypes and all three varieties, the soil shrinkage values in clay-rich Etg and BtgC horizons are the highest.

Soil physical maturity

The average values of moisture content in physically mature soil of pseudogley subtypes and varieties from southern Mačva and Pocerina are shown in Fig. 2.

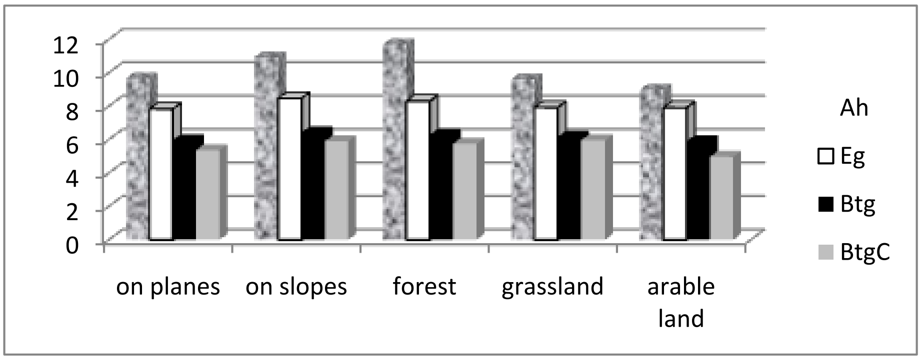

Fig. 2. Average moisture contents (%) in physically mature soil suitable for tillage

Pseudogley of slopes has a little bit higher moisture contents, at the stage of soil physical maturity, when compared with those of pseudogley of plains, but the difference is not statistically significant. Arable pseudogley soil, with the lowest humus content and lightest texture, has at the stage of its physical maturity lower statistically significantly moisture contents compared with the forest (t = -3.05367, p = 0.010975) and grassland profiles (t = -3.19551, p = 0.008523).

For both pseudogley subtypes and all three varieties of southern Mačva and Pocerina, the highest values and the widest range in moisture variation at the stage of soil physical maturity were found in the Ah horizon compared to the subsurface, Eg, Btg and BtgC horizons, which is a result of lower clay content, higher humus content and better soil structure.

Therefore, it can be concluded, on the basis of the results obtained, that the investigated pseudogley soils of southern Mačva and Pocerina at their physically mature stage are characterized by a very unfavorable moisture range (from 4.18 to 12.03%). Although the Ah horizon is characterized by the highest moisture contents and the widest range in moisture variation at soil maturity stage, that moisture range, however, especially in the case of the arable variety is very unfavorable because it prevents soil tillage and other farming operations for a long period of time. For these reasons the soils are often called "minute soils", which particularly refers to shallow pseudogley soils, according to the depth to water impermeable illuvial horizon. Similar narrow moisture content interval (from 1.33 to 14.86%) for physically mature pseudogley soils of western Serbia was found by STOJANOVIĆ (1984).

CONCLUSION

The studied pseudogley soils of southern Mačva and Pocerina are moderately to highly plastic soils. The plasticity indexes in humus (Ah, Ahp) horizons of the soils ranged from 17.52 to 20.38, being the lowest from 17.81 to 18.49 for forest varieties, slightly higher 17.52 - 19.75 for grassland, and the highest 17.55 - 20.38 for arable soil varieties. In the illuvial pseudogley Btg horizon, the plasticity index reaches its maximum values, which vary in the high plasticity range with Ip > 30 (30.47 to 39.71). A narrow interval of moisture content in physically mature soil, particularly in the arable (Ahp) horizon, from 7.79 to 10.21%, prevents soil tillage and other farming operations in a long time interval.

Pseudogley of plains, characterized by a higher content of clay and humus compared with pseudogley of slopes, showed higher statistically significant values for the lower plastic limit and linear shrinkage, while the other studied parameters were not statistically significant. Arable pseudoglay, with the lowest humus content and lightest texture, have lower statistically significant values of Wp, linear shrinkage and moisture content in physically mature soil ready for tillage, and higher Ip values, compared with forest and grass pseudogley soils. Grass pseudogley compared with that under forest has, lower statistically significantly values of Wp and linear shrinkage, and higher Ip values.

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NEKE FIZIČKO-MEHANIČKE KARAKTERISTIKE RAVNIČARSKOG I OBRONAČNOG PESUDOGLEJA POD ŠUMOM, TRAVOM I NJIVOM

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I z v o d

U radu su prikazane fizičko-mehaničke karakteristike pseudogleja južne Mačve i Pocerine sa naglaskom na razlikama između dva podtipa pseudogleja (ravničarski i obronačni) i tri načina korišćenja (šuma, trava i njiva). Sve promene su praćene po celoj dubini profila, odnosno svim genetskim horizontima pseudogleja.

Plastičnost zemljišta je određivana metodom Atterberg-a; skupljanje zemljišta metodom Filatov-a i fizička zrelost zemljišta za obradu računskim putem. Podaci su statistički obrađeni korelacionom analizom i t-testom u programskom paketu StatSoft, Inc. STATISTICA for Windows, verzija 8, na nivou sigurnosti 95%.

Ispitivana pseudoglejna zemljišta južne Mačve i Pocerine su umereno do jako plastična. Vrednost indeksa plastičnosti u humusnom (Ah, Ahp) horizontu ispitivanih zemljišta kretala se od 17,52–20,38, pri čemu su šumski varijeteti pokazali najmanje -vrednosti indeksa plastičnosti, 17,81–18,49, nešto veće livadski, 17,52–19,75, a najveće njivski varijeteti, 17,55–20,38. U iluvijalno-pseudoglejnom Btg horizontu indeks plastičnosti dostiže svoje maksimalne vrednosti, koje redovno variraju u intervalu „jake plastičnosti" sa Ip-vrednostima > 30 (30,47–39,71). Uzak interval vlažnosti pri fizičkoj zrelost zemljišta za obradu, naročito orničnog (Ahp) horizonta, 7,79–10,21%, onemogućava izvođenje obrade zemljišta i drugih agrotehničkih operacija u širem vremenskom intervalu.

Ravničarski pseudoglej, koji se karakteriše većim sadržaj gline i humusa, u poređenju sa obrončanim pseudoglejem je pokazao statistički značajno veće vrednosti donje granice plastičnosti i linijskog skupljanja, dok kod ostalih ispitivanih parametara razlike nisu bile značajne. Njivski pseudoglej, humusom najsiromašniji i najslabije ostruktureni, ima statistički značajno niže vrednosti donje granice plastičnosti, linearnog skupljanja i vlažnosti pri fizičkoj zrelosti zemljišta za obradu, i veće vrednosti indeksa plastičnosti, u poređenju sa šumskim i travnim pseudoglejem. Travni pseudoglej u poređenju sa šumskim ima statistički značajno niže vrednosti donje granice plastičnosti i linearnog skupljanja, i veće vrednosti indeksa plastičnosti.

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