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DRAINAGE IMPACT ON STRUCTURAL COMPOSITION PSEUDOGLEY SOILS IN REPUBLIC OF SERBIA

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Abstract

Pseudogley soils (as per WBR, 2006 clasification, Stagnosol) cover significant agricultural areas within the Republic of Serbia. This type of soils are of great importance for agricultural production due to their potential fertility, as well as the fact that occur mainly on flat areas suitable for the application of mechanized agriculture. Many years of intensive crop production lead to changes that reduce soil's productive capacity and lead to structural changes in the soil composition. The aim of this study was to examine the extent to which arable farming affect changes in the structure of pseudogley soils in drained and un-drained plots. The study was conducted in the experimental drainage field at Varna Institute of Soil Science, ten years after the installation of drainage systems. The soil waterlogging on the part of the experimental field, in which the control is derived horizontal pipe drainage led to elevated processes of structure deterioration, the formation of crumby aggregates, as well as the decrease in water stability of structural aggregates.

Key words: soil structure, soil aggregates, drainage, pseudogley

Introduction

Throughout the territory of west and northwest Serbia pseudogley soils cover an area of about 360,000 ha or 20 % of the total area, whereas 285,000 ha or 15.7 % of the area is covered only by pseudogley features (Đurovic et al., 2010). The largest pseudogley complexes are located in the pre-Pannonian part of northwestern Serbia, on flat terraces and hills formed by abrasive action of the Pannonian Sea. In the west and northwest area of Serbia, pseudogley is non-calcareous, the soil acidification is high, which is confirmed by pH values of active and exchangeable acidity. The soils, especially the surface horizons, are characterised by a high reduction of bases in the adsorption complex (the degree of base saturation of the adsorption complex is low, and declines up to 17 %). Also, the greatest amount of fine substances and organic particles, distinguished by high adsorption capacity, are leached from the surface horizons. Therefore, in west and northwest Serbia, pseudogley is a poorly humose soil. In natural conditions, pseudogley structure in the surface horizon is fine-crumby, and at the depth greater than 50cm the structure becomes polyhedral prismatic (Tanasijevic et al., 1966).

Materials and Methods

The investigation was conducted at experimental drainage field of the Institute of Soil Science, Varna, (44°41′38″ N; 19°39′10″ E) located on the tenth kilometer road which leads from Šabac, southeast to Loznica and Valjevo, at the entrance to the village Varna (44°41′38″ N; 19°39′10″ E) (Pivic, 2013). Ten years ago permanent drainage systems have been installed in the area. The aim of this study was to examine the extent to which arable farming affect changes in the structure of pseudogley on drained and un-drained plots.

The structural composition and stability of soil aggregates are most important characteristics of soil fertility. From the agronomical aspect, the most significant are structural aggregates from 1 to 10 mm (Edwards, 1991; Amezketa, 1999). The most significant properties for the evaluation of soil structure are the content of macro-aggregates, their mechanical strength and water stability, as well as porosity (Sorochkin, 1991). Soil structure is a dynamic value that depends on the soil properties, climate and tillage conditions (Angers, 1998). The factors affecting soil structure and aggregate composition are tillage, irrigation and climate (Guerif et al., 2001). Soil aggregate stability declines rapidly as the consequence of cropping, and the diameter of dry aggregates increases (Kandeler and Murer, 1993; Shepherd et al., 2001).

On the experimental drainage field of the Institute of Soil Science in Varna in 1978 a drainage sample plot was established. Drainage sample plot consists of two separate parts of rectangular form, separated by a road for mechanization. One part consists of three plots: A, B, C, and the other part consists of six plots designated I to VI. All the plots are of the same size 75.0x52.0 m, individual area 0.39 ha. The basis for dewatering of the nine sample plots is flexible perforated PVC drainage pipes, spacing 25 meters. Within the plots there are two drains ∅80 mm, at the depth of 0.95 m. Drain length is equal to plot length and amounts to 52 m, minimal design slope is 0.25 %. The experiment was amended in 2002 by adding two additional variants of drain spacing treatments: 20 m (field A) and 30 m (field C), at the same depth of 0.90 m, and perforated PVC pipes Ø80 mm.

Exploration and other field study including profile digging and description were performed in 2012 (profiles 1-4). Samples were taken in autumn after harvesting. The samples were taken from genetic horizons in the disturbed and undisturbed state. Mechanical composition was determined by pipette method, the samples were prepared with sodium pyrophosphate. Macro-aggregate analysis of the soil was performed by dry sieving method (Shein et al., 2001). The samples (about 2 kg) were sieved on a series of screen mesh sizes 10, 5, 3, 2, 1, 0.5 and 0.25 mm. The sieved samples from each sieve were weighed and their percentage in the sample was calculated.

Water stability of structural aggregates was determined using the Savinov’s wet sieving method (Shein et al., 2001), i.e. by sieving in still water through a nested column of sieves consisting proportionally of all aggregate fractions separated in the dry structural analysis. Sieving was performed on screen mesh sizes of 3, 2, 1, 0.5 and 0.25 mm. After sieving and drying the samples at 105 °C, the samples were weighed and their percentage in the sample was calculated.
Structure coefficient (K_s) was calculated by the expression:

$$K_s = \frac{\text{Content of agronomical most favourable aggregates, 0.25-10 mm}}{\text{Total content of the aggregates <0.25 mm + >10 mm separated by dry sieving}}$$

Aggregate composition of the soil was evaluated by the following scale (Shein et al., 2001):
>1.5 - good aggregate composition,
1.5-0.67 - satisfactory aggregate composition,
<0.67 - unsatisfactory aggregate composition.

The soil structure was evaluated according to Dolgov and Bakhtin’s scale (cit. Gajic, 2006).

Results and Discussion

The processed data of the soil mechanical analysis (Table 1) show that soil texture, determined using the USDA triangle (Soil Survey Manual, 1955), is loam (I) to clay loam (GI). The data on the soil mechanical composition show that the soil to the depth of 50 cm is loam, with physical clay contents in 61.6 and 69.1% respectively. The percentage of clay increases with profile depth, so in deeper horizons, the soil becomes clay loam. The increase of silt and clay contents with depth corresponds to the values characteristic of pseudogley.

Table 1. Particle size analysis of the soil

Profile	Horizon	Depth (cm)	Coarse sand >0.2 mm	Fine sand 0.2-0.02 mm	Silt 0.02-0.002 mm	Clay <0.002 mm	Total sand >0.02 mm	Silt+clay <0.02 mm	Soil textural class	Colour
PROFILE 1 CONTROL	Aoh	0-25	4.8	30.2	42.7	22.3	35.0	65.0	I	10YR7/3;6/3
	Eg	25-45	4.3	28.6	43.9	23.2	32.9	67.1	I	10YR7/3;6/3
	Btg	45-75	3.8	28.9	35.2	32.1	32.7	67.3	GI	10YR4/2;3/2
	Btg	>75	1.0	31.2	34.8	33.0	32.2	67.8	GI	10YR4/2;3/2
PROFILE 2 DRAINAGE 25 m	Aoh	0-30	2.6	35.8	38.1	23.5	38.4	61.6	I	10YR7/3;6/3
	Eg	30-47	2.7	28.0	45.8	23.5	30.7	69.3	I	10YR7/3;6/3
	Btg	47-72	1.8	27.2	37.7	33.3	29.0	71.0	GI	10YR4/2;3/2
	Btg	72-105	0.6	27.2	42.2	30.0	27.8	72.2	GI	10YR4/2;3/2
PROFILE 3 DRAINAGE 20 m	Aoh	0-30	2.0	29.2	43.8	25.0	31.2	68.8	I	10YR7/3;6/3
	Eg	30-54	3.6	28.3	42.6	25.5	31.9	68.1	I	10YR7/3;6/3
	Btg	54-80	1.9	26.6	35.9	35.6	28.5	71.5	GI	10YR4/2;3/2
	Btg	80-105	2.0	25.7	36.6	35.7	27.7	72.3	GI	10YR4/2;3/2
PROFILE 4 DRAINAGE 30 m	Aoh	0-23	3.4	27.5	44.1	25.0	30.9	69.1	I	10YR7/3;6/3
	Eg	23-40	3.6	29.4	44.8	22.2	33.0	67.0	I	10YR7/3;6/3
	Btg	40-64	2.2	24.4	40.8	32.6	26.6	73.4	GI	10YR4/2;3/2
	Btg	64-100	1.4	22.9	36.9	38.8	24.3	75.7	GI	10YR4/2;3/2

Soil structure is a dynamic characteristic which depends on numerous factors of soil genesis, physical and chemical properties, land use, and application of agro-technical measures. After ten years of intensive crop production, there were significant changes in pseudogley structure. The most represented fraction on all variants is agronomical the most favourable aggregate fraction (10-0.25 mm). The data on aggregate percentage separated by dry sieving show the decrease in the percentage of agronomical favourable aggregates from 76.9 % drained surfaces to 12.4 % the free surface drainage. The percentage of coarser aggregates (>10 mm) is higher on the land without drainage, which points to deteriorated conditions that lead to the formation of crumby structure. The percentage of granular aggregate (5-10 mm) is somewhat higher in the drained plots, whereas the percentages of all the separated aggregate fractions of smaller dimensions are higher in the non-drained variant. Based on the structure coefficient (Figure 3), all three drained variants are within well-structured soils, although the structure coefficient of the soil in control variant is higher (3.33; 2.62; 2.19).

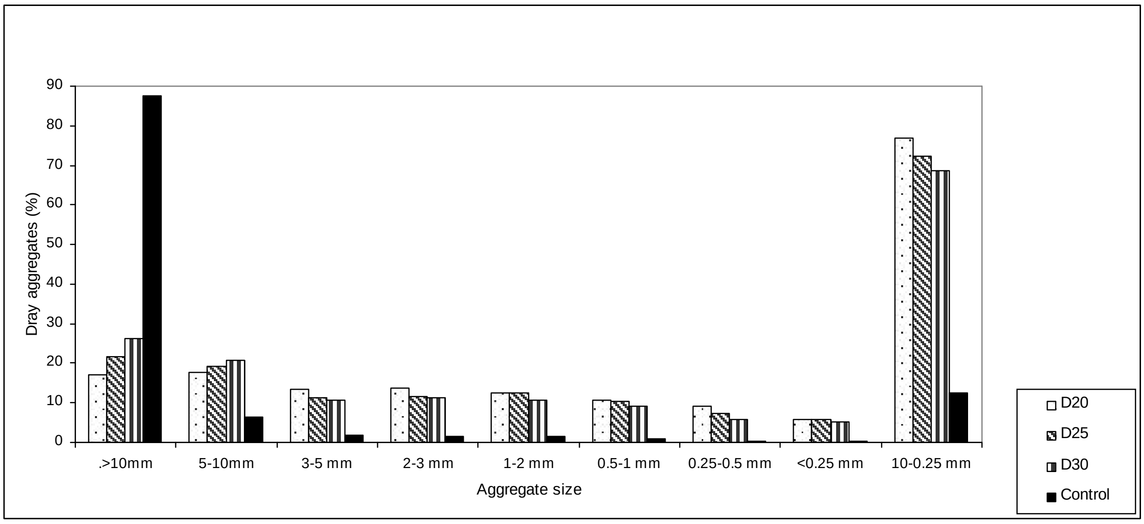

Figure 1.Dry aggregate size distribution

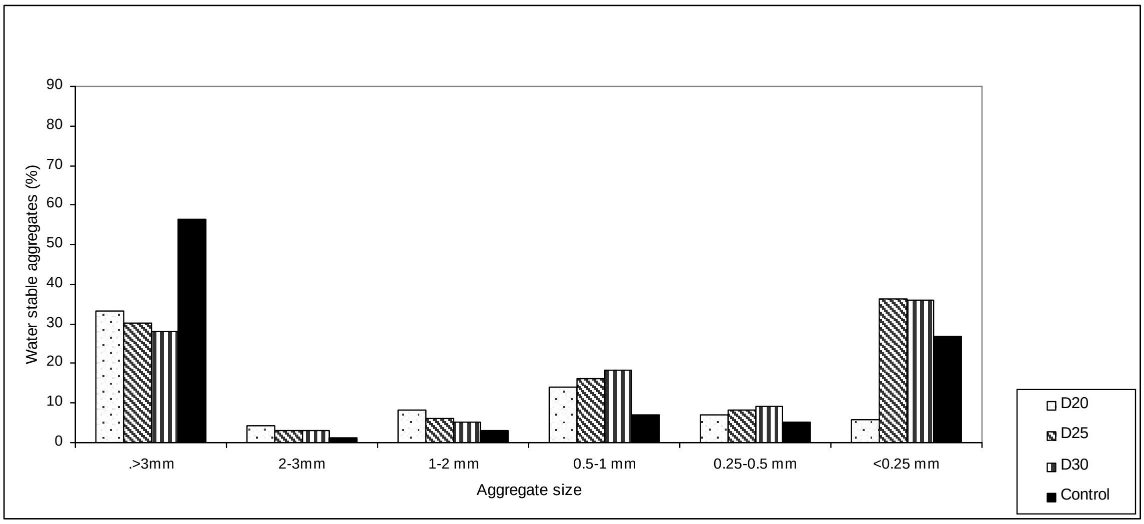

Figure 2.Water stable aggregates

The pseudogley structure in the exceedingly waterlogged areas was highly deteriorated. The percentage of agronomical favourable aggregates decreased to only 12.4 %, whereas the sizes of the dominant (87.5 %) aggregates in the soil were large, which is very unfavourable for agricultural production. The high percentage of macro-aggregates points to a significant deterioration of the conditions, which leads to the formation of crumby structure. Aggregates smaller than 0.25 mm practically was absent and the percentage of aggregates between 0.25 and 3 mm were insignificant. Based on the structure coefficient, which is only 0.14, it can be concluded that the soil structure is unsatisfactory, and that the soil waterlogging in the conditions of insufficient soil drainage, leads to rapid deterioration of soil structure which is one of the most essential indicators of the soil properties and soil fertility.

The evaluation of soil structure, based on the percentages of the agronomical most favourable aggregates, according to Dolgov and Bakhtin’s scale, shows that all four variants are characterised by a good structural state. The waterlogged soil structure, based on the content of 0.25-10 mm air-dry aggregates, is evaluated as poor.

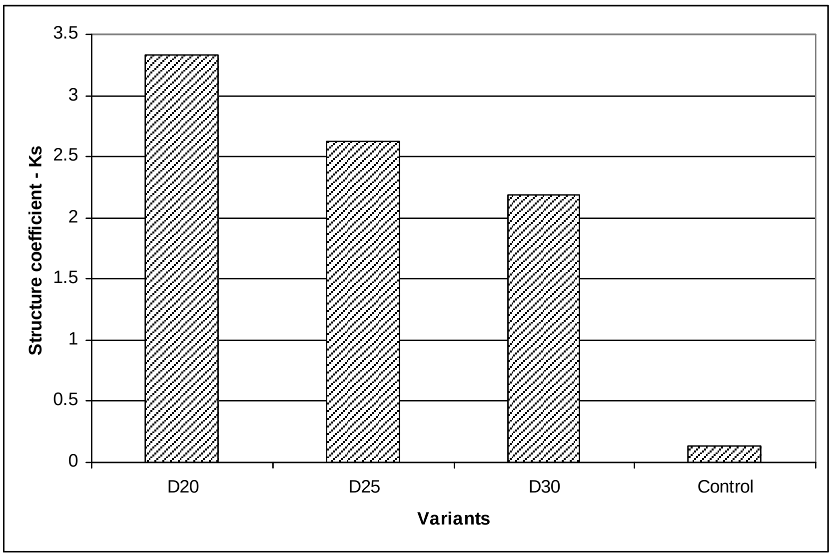

Figure 3.Structure coefficient (Ks)

The wet sieving analysis shows that the aggregate resistance to decomposition in water is higher on the variant with smaller drainage spacing. From total 48.3 % in dry sieving aggregates larger than 3 mm, on the variant of drain spacing 20 m, resistance to decomposition in water is 33.3 %, for the variant of drain spacing 25 m, from total of 52.3 %, the resistance to decomposition in water is 30.1 %, while for the variant of drain spacing of 30 m, from total of 57.6 % in dry sieving aggregates larger than 3 mm, resistance to decomposition in water is 28 %. For the control plot, without drainage on flooded surface, from total of 95.6 % in dry sieving aggregates larger than 3 mm, resistance to decomposition in water is 56.5 %.

The wet sieving analysis also shows that, in the non-drained variants, there was a decrease in the percentage of water-stable aggregates larger than 1mm, and it’s amounting up to 60.8 %. Conversely, the percentage of the fraction of water-stable aggregates smaller than 1 mm was higher in the control variant - 39.2 %, which indicates that the ratio of these fractions in the drained and non-drained variants has changed compared to the content of aggregates separated by dry sieving. The above changed ratio also refers to the fractions smaller than 0.25 mm, where on the control variant it amounts to 27 %, while on the variants with drainage it is in the range between 33.2 % to 36.4 %. The variety exposed to permanent waterlogging, control variant, shows that only the percentage of aggregates larger than 3 mm is higher than in the variants with drainage, which is not unexpected as in dry sieving the percentage of these aggregates in the waterlogged variety is almost 97.1 %, and the dominant aggregates in that fraction are crumby aggregates. The contents of all other fractions of water-stable aggregates in the waterlogged soil are lower.

Based on the above results, it can be concluded that the pipe drainage system leads to some changes in the structural composition of pseudogley, primarily in the sense of a mild increase in the percentage of larger aggregates (>5 mm) and also their greater liability to decomposition in water (decrease in the percentage of water-stable aggregates >1 mm).

Conclusions

The soil type of the study site in the experimental drainage field of the Institute of Soil Science in Varna is pseudogley. The surface horizon is loam and the deeper horizons are clay loam. The soil structure in drained plots is good, with structure coefficient greater than 2. On the structure coefficient is low and it amounts 0.14. The ten-year-long implementation of drainage system caused some changes in the soil structural composition in the sense of a mild increase in the content of larger-sized aggregates (>5 mm), but also their greater liability to decomposition, as well as a mild decrease in the percentage of water-stable aggregates larger than 1 mm. The soil waterlogging led to elevated processes of structure deterioration, the formation of crumby aggregates, as well as to the decrease in water stability of structural aggregates.

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