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Review paper

Variability of Water-Air Properties of Hydromorphic Soils in Relation to the Granulometric Composition

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Abstract

Background and Purpose: The study of the particle-size distribution of hydromorphic soil and its relations to water and air qualities contributes to the better understanding and use of the land. The granulometric distribution has a significant impact on physical properties of the soil, such as: water-holding capacity, available water for plants, air capacity and residual porosity. The aim of this study was to show the relationship of texture composition and water retention under the pressure of -0.33, -6.25 and -15.00 bar, the capacity for air and available water for plants in different texture classes, and the relationship between the particle-size distribution and the content of a rough, medium, fine and ultra-fine pores in the excavated soil.

Material and Methods: In order to analyze the relations of particle size distribution and air-water features of hydromorphic soil, the Middle Danube Region was researched. The following soil types were determined: fluvisol, humofluvisol, humogley and eugley. Soil samples were taken in degraded and natural state of soil profiles. Samples were analyzed in the laboratory of the Institute of Lowland Forestry and Environment, University of Novi Sad, with standard pedological methods. After the performed analysis, the mean air-water soil properties for different textural classes were calculated and presented.

Results and Conclusion: According to the presented results of moisture retention at pressures of -0.33, -6.25 and -15.00 bar, it may be concluded that pressure treatments lead to an increase of moisture retention values of the texture classes - sand to clay loam texture class, which is in close connection with the textural composition of the hydromorphic soil samples. The texture class of sand and loamy sand had the largest capacity for air, while the increased content of silt and clay decreased the air capacity and only slightly increased it in sandy clay loam and clay loam. Water available to plants was mostly present in the textural classes of sandy loam and loam.In the sand and loamy sand and sandy clay loams with clay loam the values of this parameter were lower due to the unfavorable ratio of fractions in the textural composition. According to the content of the pores in various soil textural classes, the highest content of rough pores was found in the sand and loamy sand. The content of medium-sized pores increased with the proportion of silt and clay, it was largest in the sandy loam, loam and sandy clay loam. The content of tiny and fine pores was common for textural classes of a heavier texture or clay loam.

Keywords: Central Danube Region, granulometric composition, hydromorphic soils, water-air properties

INTRODUCTION

The erosion power of a river has a major role in the formation of the land in river basins [1]. Different landform terrains are formed according to that process and different types of soil, depending on the textural composition of the formed soil particles. In the area of bottomland soils, the following hydromorphic types of soils may be found: undeveloped land, meadow land and gley soils. These soils differ primarily in the shares of certain granulometric fractions, on the basis of air-water features specific for each type of soil [2]. The granulometric distribution has a significant impact on the physical and chemical properties of the soil. As

Živanov [1] stated, it has great impact on water capacity, nutrient elements and their accessibility for plants, as well as the ability to process within the soil. The same author stated that as lands were non-structured, the influence of the particle size distribution of these features was higher. Pekeč et al. [3] also noted a close connection of the textural class and the tested parameters of physical properties of the soil in the gley soil of Middle Danube. According to Živanov [1], the average value of certain fractions of alluvial soil were presented, so that the share of the grit was 6.8%, fine sand from 19.2 to 91.0%, powder (dust) 20.6% and the clay fraction from 0.4 to 35.2%. Ivanišević [4] stated that the most important characteristic of the soil, formed in the alluvial plain of the Danube, was its textural composition or participation of certain granulometric fractions. The main indicator of this relation, was the average content of the total clay in the rhizosphere zone, and on the cross-section of the Danube River bottomland in the Middle Danube Basin. The sedimentation of the above mentioned fraction has the form of a logarithmic function. There exists a very large vertical stratification of the alluvial soil, [4], as a result of the river's fluvial sedimentation, with not many rapid changes in the properties and the high variability of the textural content.

Also, studying the Middle Danube area Živanov [5] and Živanov and Ivanišević [6] stated that fluvisol soils formed in this area were characterized by rapid changes in the particle-size distribution, while the humofluvisols feature layers were not clearly defined.

According to Galić et al. [7], the analysis of the content and layout of the silt + clay was found in the similarity of the genesis of loam forms - fluvisol and humofluvisols. Having explored different forms of fluvisol soils, Pekeč et al. [8] suggested different water-air features for each explored form, depending on the prevailing granulometric fractions. Pekeč et al. [9] analyzed the gley-marshy land in the Middle Danube region and showed a decline in the share of finer textural classes and an increase of the coarser texture class of soil with depth.

Thus, Ivanišević [10] indicated that fluvisol land had significant differences in the clay fraction between the varieties of soils. The average content of clay fraction and dust, relevant for the fertility elements [4], was 32.5%, and ranged from 4.6 up to 71.7%. The same author stated the following quantitative representation of certain fractions of the granulometric fractions: coarse sand (2.4 to 26.2%), small sand (26.9 to 71.8%), silt (0.9 to 47.6%) and colloidal clay (1.1 to 23.1%).

The granulometric features of soils may in some circumstances be essential for the productivity of the land. The occurrence of sand layers with loamy is also beneficial, since both texture components represent a favorable habitat for the growth and development of the types of trees frequent throughout the alluvial plain.

Until now, most of the soil research has indicated the importance of the particle-size distribution of the land in the inundation of our rivers. All indicators of fertility in the soil area of flooding rivers have been closely correlated with the content of the silt + clay in the soil. It should also be considered that the water-air properties, as well as the hydrological regime, depend on the granulometric composition of the soil.

MATERIALS AND METHODS

Soil samples were collected from the Middle Danube Region. Open soil profiles were present at 19 sites, also describing the internal and external morphology of the profile. The soils from the hydromorphic types were determined, namely: fluvisol, humofluvisol, humogley and eugley. Soil samples were taken in their disrupted and natural states. In their disrupted state 120 soil samples were taken, 360 undisturbed soil samples were taken by Kopecky cylinders of 100 cm^3.

The collected soil samples were analyzed in the laboratory of the Institute of Lowland Forestry and Environment, University of Novi Sad, Serbia. The following analyzes were performed:

- Determining of the soils' mechanical composition by the international B-pipette method, along with the preparation of sodium-pyrophosphate. Thus, certain mechanical earth fraction were determined [11], as well as the soil's textural class according to the ISSS (International Society of Soil Science), Baize [12];
- Determining of the soil's specific gravity by the Albert-Boggs method, with the use of xylol as an inert liquid, according to Bošnjak et al. [13];
- Determininig of the soil's bulk density in Kopecky cylinders, volume 100cm^3, according to Bošnjak et al. [13];
- The total porosity (%), calculated from the value of the specific and bulk density, according to Bošnjak et al. [13];
- Moisture retention at the pressure of -0.33 bar with the Richards-plate equipment [14];
- Moisture retention at pressures of -6.25 and -15.00 bar, with the Pressure-Membrane equipment [14];
- Available water capacity (vol.%) of soils (available water for plants), calculated from the difference between values at pressures of -0.33 bar and -15.00 [13];
- Air capacity (%) [13];
- Pore categories were determined from the difference between the total porosity and the moisture retention under different pressures;
- After laboratory analyses, all the data were processed in the computational program STATISTICA [15] so average values and the analysis of the variance for

the given parameters were determined and presented graphically.

RESULTS AND DISCUSSION

All studied samples showed large variations in the water retention effect on soil, at the pressure of -0.33 bar (Figure 1), that was primarily caused by a high textural variation in the depth profile. In order to show the importance of the soil texture and the textural class on water retention, the mean values for all samples at this pressure were presented.

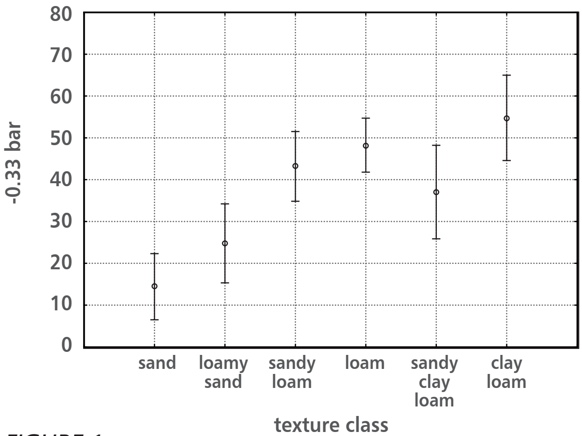

FIGURE 1
Water-retention effects at the pressure of -0.33 b (vol.%) compared to the texture class

The retention of water at the pressure of 0.33 bar was the least in the sand (13.9 vol.%) and soils of a light-mechanical composition, and gradually increased to clay loam textural classes (55.4 vol.%), except in the texture class of sandy clay loam, where the retention of water was slightly lower. The most significant differences are between the sand and loamy sand compared to clay loam (p = 0.00000). It may be noticed that the increase in the proportion of the clay fraction, also meant the increase in the value of water retention at -0.33 bar. Thus, Živanov [1,16] stated the following values of water retention at -0.33 bar for alluvial soil textural classes taken from the alluvial plains of the Danube, Drava and Tamiš: sand 7.1 vol.%, loamy sand 20.3 vol.%, sandy loam 32.2 vol.% loam 48.5 vol.%, powdered clay 51.7 vol.%. Studying the Middle Danube lands, the water retention values at -0.33 bar were in scope of the following interval: from 3.4 to 44.8 vol% [4].

In the treatment of the samples at -6.25 bar, the samples with a light-mechanical composition retained a small amount of water, in relation to patterns of heavier textures. That conclusion is presented in the following graph (Figure 2). It is evident that with the increase of silt and clay, the value of retention capacity was also increasing. There are significant differences between the texture classes sand, loamy sand and sandy loam compared to the clay, sandy clay loam and clay loam (p = 0.00000). Studying the Middle Danube lands, the water retention value, at -6.25 bar pressure, ranged from 2.0 to 21.7 vol%, according to Ivanišević [4].

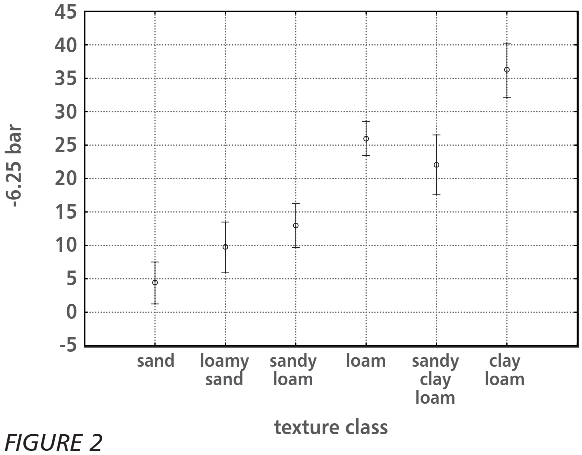

FIGURE 2
The retention of water at -6.25 bar (vol.%), in comparison with the textural class

According to Živanov [1], this water content in the soil is characterized by the lento-capillary moisture, respectively, the lower limit of available water for the plant, and according to his data, soil samples had moisture at -6.25 bar, ranging from 0.91 to 29.3 vol.%, and the average value was 11.6 vol.% for all tested samples. This value of water retention at the pressure of -6.25 bar indicated that the lower threshold humidity in plants may still be restored when it comes to wilting, and this is the lowest percentage of moisture in the soil in which it is irrigated.

As with earlier data presented here, it may also be seen (Figure 3) on the analyzed textural class, that the least value of water retention was in the soil samples

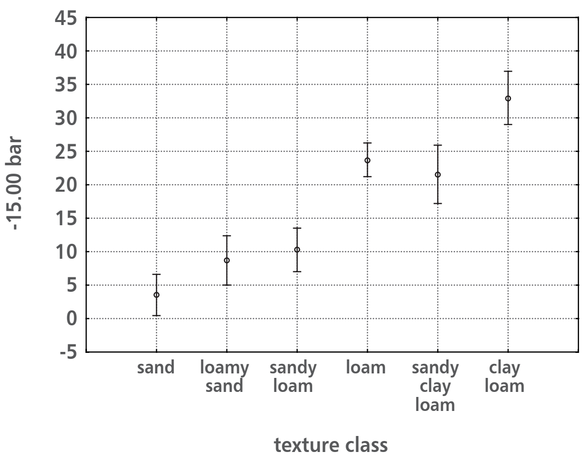

FIGURE 3
The retention of water at -15.00 b (vol.%) in comparison with the textural class

made of a light-mechanical composition, and at the increase of silt and clay, the value of water retention under the pressure of -15.00 bar also increased. Significant differences were found between textural classes identical to the previous treatment of -6.25 bar (p = 0.00000). The value of -15.00 bar was used as the lowest limit when calculating available water for plants. The humidity fading of plants raised, according to Živanov [2], the pF value of 4.2, which was conventionally taken as the value for the calculation of available water. The values of the retained water at -15.00 bar ranged from 0.8 to 22.2 vol.% according to Živanov [2]. For the soils of the Middle Danube Basin, water retention values at -15.00 bar ranged from 1.6 to 16.5 vol%, as Ivanišević stated [4]. According to the presented results of the moisture retention at different pressures, we may conclude that all treatments lead to an increase of the moisture retention values in the sand texture class to clay loam texture class, which was in close connection with the textural composition of the hydromorphic soils samples.

Air capacity is an important feature that determines the productivity of the soil. It actually represents non-capillary pores in the soil; [1], air capacity is the difference between the total porosity and the field water capacity.

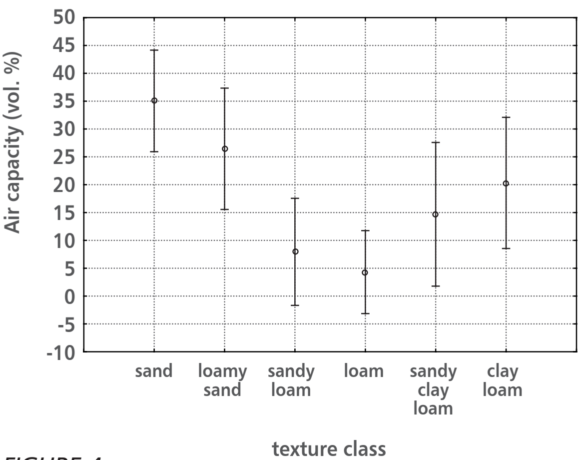

FIGURE 4
The air capacity (vol.%) of soils with different textural classes

Looking at the average values in Figure 4, we may conclude that the texture class of sand and loamy sand has the greatest capacity for air, while it decreases with the increased content of silt and clay, except in the case of sandy clay loam and clay loam where the capacity was slightly higher than the value of other samples of a heavier texture. Significant differences are between sand and sandy loam and clay (p = 0.00007). The texture class of sandy clay loam has a high variation coefficient of air capacity due to the heterogeneous texture, as Živanov interpreted it [1], and the specific the value of air capacity for the alluvial soils of Danube was up to 52.2 vol.%. According to Živanov [1], the air capacity of sandy soil was 30 to 40 vol.% and in loamy soils 10 to 25 vol.%, in soils with clay it ranges from 5 to 15 vol.%. Due to the layout and size of the soil pores at the respondents' textural classes, this actually affects the composition and distribution of various pores in the soil, the result showing that a higher proportion of textural soils with coarser particles increases the value of air capacity.

For the values of available water capacity (vol.%) of soils, it is evident that they vary according to the displayed values (Figure 5), and they depend on the texture of soil. As Živanov [1] stateed, for plants it is easiest to use water through the field-soil moisture capacity. The more soil moisture capacity is distant from the field-soil capacity, it is more difficult for plants to absorb water. This value and the amount of water accessible to plants, is the water between the threshold humidity of -0.33 bar and -15.0 bar and the fact that it is the amount of water in the soil that is more or less available for plants to absorb.

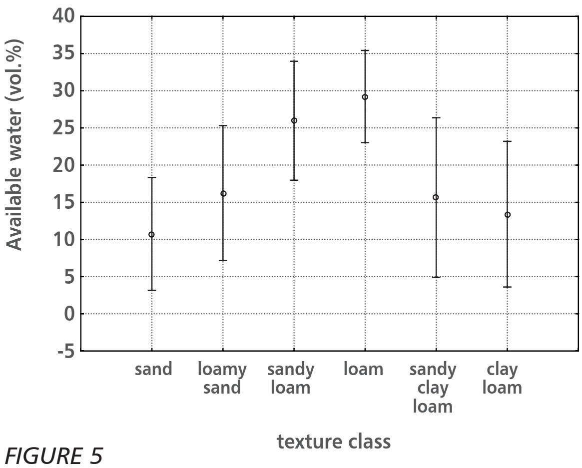

FIGURE 5
Available water capacity (vol.%) of soils compared to the textural class

Figure 5 shows that the maximum available water was in the textural classes of sandy loam and clay, which confirms that because of the share of mechanical fraction the pores of these textural classes may contain a higher proportion of physiologically active water, and these are mostly middle-sized pores to fine soil pores. In sand and loamy sand and also sand clay loam and clay values of this parameter are lower because of the negative relation of some factions within textural classes. The results were twofold: one was in the occurrence of rough pores and the swelling of large quantities of water available only for a short period (sand and loamy sand) and the second was the appearance of fine pores in heavier soils (sandy clay loam and clay loam) where water is bound with more forces, difficult to access or totally unavailable to plants. Significant differences, according to this parameter, are only between sand and clay (p = 0.00374).

The total porosity represents all the pores in the soil, while the residual porosity shows the distribution of pores according to their size. As Živanov [1] stated, it is impossible to determine the actual size of the pores, except indirectly, by assuming that water in certain pores may be displaced by a certain pressure, Vučić as explained [17].

In this paper, the pores were classified into three groups according to Miljković [18]. Rough or coarse and fine coarse pores were grouped into one category-coarse pores, the size of more than 50 and up to 10 microns (pF values in the range of 0-2.54), medium pores, which keep water accessible to plants, were of a diameter from 10-0.2 microns (pF from 2.54 to 4.2), and micro-fine pores that contain water inaccessible to plants, with a diameter below 0.2 microns (pF values over 4.2).

Since the ratio of pores in the soil is associated exclusively with the participation of the granulometric fractions in the soil, the charts show the relationship of certain categories of pores with respect to the soil texture classes.

Figure 6 presents the relation between coarse pores and textural classes. Coarse pore content was the highest in light mechanical soil compositions, such as: sand and loamy sand, and dust was reduced with the increased clay content in this category of pores.

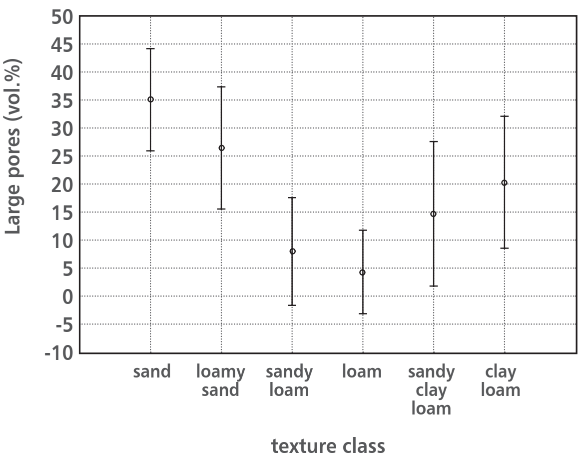

FIGURE 6
The relationship of coarse pores (vol.%) and textural classes in all samples

The textural classes of sandy clay loam and clay loam showed a somewhat higher value of coarse pores compared to other classes of clay, which may be explained by a greater variation of granulometric fractions in these texture classes. Significant differences in this the treatment are between grain size fractions of sand, loamy sand and clay (p = 0.00007).

The values of coarse pores in alluvial soils, which were in range of 10.8 to 44.3%, and the texture classes had, according to Ivanišević [4], the following air capacity: sand 42.2%, 33.8% loamy sand, sandy loam 25.5%, 14.8% loam and silt loam 10.8%.

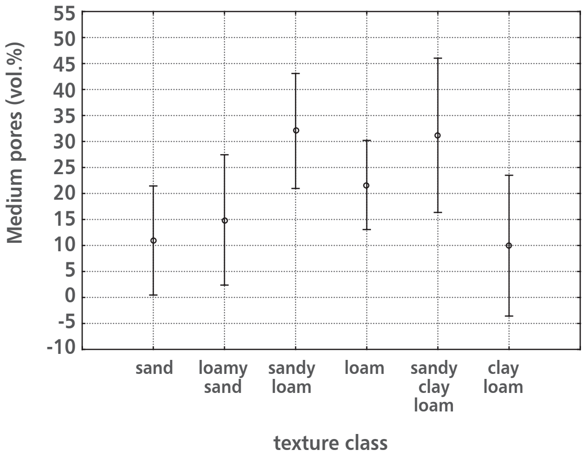

FIGURE 7
The ratio of middle-sized pores (vol.%) and textural classes of samples

Figure 7 is shown the content of middle-sized pores in relation to textural classes. Since the medium pore diameter ranged between 10-0.2 microns and water within them was retained by higher forces, the data showed that there were at least those types of pores in textural classes sand and loamy sand, consisting mostly of coarse pores, as well as clay loam, where micro-fine pores prevailed. The highest values were in the classes of sandy loam, loam and sandy clay loam. This parameter didn't show significant differences between textural classes (p = 0.3579). Middle-sized pores were directly related to the proportion of fine sand and dust in the soil and if they predominated, then the granulometric fractions were compared to medium pores present in higher percentages. The limit of this group of pores was in the range of 1.8 to 28.3%, according to Ivanišević [4].

Figure 8 presents the contents of fine pores and it may be concluded that the increased use of granulometric fractions in a heavier composition, as well as the increased content of silt and clay, lead to

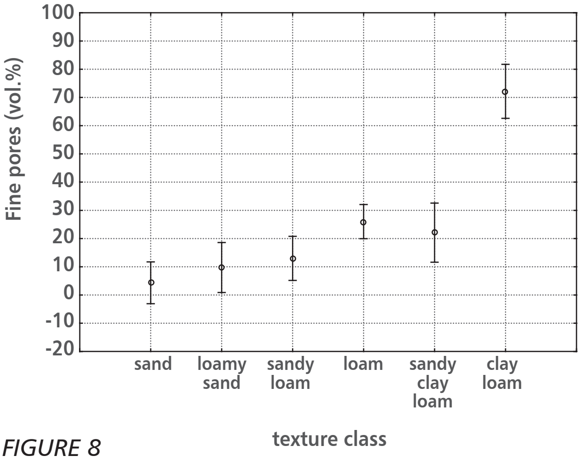

FIGURE 8
The ratio of fine pores (vol.%) and textural classes of samples

the increase of tiny pores in the soil, explained by the gap between all the fractions, so, the content of fine pores was higher in heavier-textured soils. Significant differences are showed between the texture class of sand and clay, while the clay-loam texture class is significantly different from all textural classes (p = 0.00000). According to Ivanišević [4], this group of pores in alluvial soils, determined in laboratory conditions, ranged from 1.6 to 16.5%.

CONCLUSIONS

According to the shown ratios for size distribution and moisture retention at different pressures, we may conclude that in all three treatments the moisture retention value of texture classes was increased - sand to clay loam texture class, which is in close connection with the textural composition of the hydromorphic soil samples.

The investigated capacity values for all samples showed that air capacity was higher in soil samples of a lighter mechanical composition and texture classes of sand, loamy sand, while a reduction was noticed in samples of heavier texture, or sandy loam and clay. A small increase in the sandy clay loam and clay loam was also noticed. The highest available water capacity of soils was in located in the textural classes of sandy loam and clay, due to the content of favorable medium- and small-sized pores in fine texture classes.

The contents of coarse pores was increased in the soils of a light mechanical composition, such as sand and loamy sand. The share of medium-sized pore texture classes was such that the data showed they were more present in the following textural classes: sandy loam, loam and sandy clay loam, which was directly caused by the textural composition and the granulometric size of particles. The content of tiny pores in analyzed soils increased with the domination of mechanical fractions of a heavier composition and the increased silt and clay contents.

Acknowledgments

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