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# ANALYSIS ON SOME FACTORS DETERMINING SOIL PERMEABILITY

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***ABSTRACT:*** *The overall objective of the research was to study the modification of soil properties under the influence of agricultural practices, in relation to its permeability and water reserve formation. The research area was represented by the Vasluie watershed, where a pedological study was conducted to identify the soils in the area. Pedological research in the studied area was carried out using 25 main profiles, from which soil samples were taken, both in their natural state and modified, for physico-chemical analysis. The study was conducted in a three-year rotation with three types of crops: soybean, wheat, and corn. Each crop was placed in five soil management systems, and each system had five variants of mineral, organic, and crop residue fertilization. The following soil management systems were established: plowing at a depth of 20 cm, at 30 cm, plowing without turning the furrow with the chisel and the paraplow, and the one-year plowing and one-year disking variant.*
***Keywords:*** *permeability; plow; crop;*

## 1. Introduction

Soils have the property of allowing water to pass through them more or less easily. This property, as is well known, is called permeability. Water penetrates through pores, so permeability directly depends on the soil's porosity. The higher the porosity and the larger the pore diameter, the greater the permeability. Porosity, in turn, depends on texture, structure, degree of loosening or compaction, etc. During the penetration of water into soil, permeability does not remain the same. Thus, starting from dry soil, initially permeability is high and then decreases rapidly until the soil becomes saturated with water. From that moment on, the amount of water entering the soil becomes constant. Therefore, in the case of permeability, two distinct situations are distinguished: saturated soil and unsaturated soil. Under the action of gravitational force, precipitation falling on the soil is involved in two main processes, namely surface runoff and infiltration of a portion of it into the soil. The two processes influence each other and are determined by soil properties, along with numerous other factors. Forecasting infiltration and, respectively, the formation of liquid runoff in a watershed is of great interest in environmental engineering. The coefficient of the permeability function is an essential parameter in the performance analysis of infiltration in unsaturated soils. The permeability coefficient of a saturated soil is determined by the porosity figure (volume of pores/volume of solid part). The coefficient of permeability of incompressible unsaturated soils is determined by the degree of soil saturation with water. Because soils are deformable, the permeability coefficient for a deformable unsaturated soil is determined by both parameters, saturation degree, and porosity figure. The overall objective of the research was to study the modification of soil properties under the influence of agricultural works, in relation to its permeability and the formation of water reserves.

## 2. Research Methodology

### 2.1. Soil mapping and general characterization

The research perimeter was represented by the Vasluieţ watershed, where a pedological study was conducted to identify the soils in the area. Pedological investigations in the studied area were carried out using 25 main profiles, from which soil samples were taken, both in natural and modified settlements, for physico-chemical analysis. The main properties analyzed and the laboratory methods used are presented in Table 1 (Cucu Ghe. et al. 1995).

Table No. 1. Soil properties and analysis methods

| Soil Analysis | Analytical methods |
|---|---|
| Particle Size Composition | Kacinski method (treating the soil with hydrochloric acid and separating the fractions by pipetting) |
| Bulk Density | Known volume cylinders and weighing |
| Current Acidity (pH) | Potentiometric |
| Alkaline Earth Carbonates | Scheibler |
| Humus | Titrimetric after Scollenberger |
| Total Nitrogen | Kjeldahl |
| Mobile Phosphorus | Egner-Riehm-Domingo |
| Mobile Potassium | Ammonium acetate-lactate solution and measurement with a flame photometer |
| Soluble Salts | Aqueous solution, evaporation, and weighing |
| Anions: Carbonate $CO_3^{2-}$ and Bicarbonate $HCO_3$ | Titrimetric |
| Chloride Anion $Cl^-$ | Mohr |
| Sulfate Anion $SO_4^{2-}$ | Gravimetric as $BaSO_4$ |
| Cation: Calcium $Ca^{2+}$ | Complexometric |
| Cations: Sodium $Na^+$ and Potassium $K^+$ | Flame photometer |
| Cation Exchange Capacity (CEC) | Percolation with an ammonium acetate solution at pH 7 and distillation, Schollenberger-Cernescu method |
| **Exchangeable Sodium $Na^+$** | Ammonium acetate extract and flame photometry. |

### 2.2. Modification of soil properties due to its management

The analyses in the experimental field were conducted on a typical cambic chernozem soil. This soil has a clayey texture, a slightly acidic reaction, medium humus content (3,1 – 3,3%), and moderate nutrient supply.

This soil unit formed on loessoid clay and is well supplied with mobile potassium (215 - 285 ppm), moderately supplied with phosphorus (28 - 35 ppm), and nitrogen (0,150 – 0,165%). Due to the high clay content (39 - 42%), the soil is difficult to work, especially when moisture approaches the wilting coefficient (CO) of 12,2% (Jităreanu G., 2007).

In the conducted research, the influence of different soil management methods on the physical properties affecting precipitation infiltration was analyzed.

### 2.3. Methodology for calculating the volume of water infiltrated from precipitation

The volume of water (N_1) that can infiltrate a soil with a certain texture, bulk density, and hydraulic conductivity was calculated using the following relationship:

$$N_1 = K \cdot 10000\ (m^3/ha) \qquad (1)$$

Where:

*K* - soil hydraulic conductivity (m/day)

10000 - the number of m^2 corresponding to the area of 1 ha

The hydraulic conductivity (K) was calculated using the following relationship, in which the values of total porosity, determined using density and bulk density, were introduced:

$$K = 1{,}55 * 10^6 * \frac{PT}{D^2}\ (\text{m/day}) \qquad (2)$$

Where:

*PT* - total porosity (decimal number), and,

*D* - a number determined with the relationship below:

$$D = 6(1 - PT)\sum_{i=1}^{n} \frac{pi}{di} \qquad (3)$$

Where:

*n* is the number of granulometric fractions obtained in the granulometric analysis;

*pi* - the percentage content of each granulometric fraction in the soil;

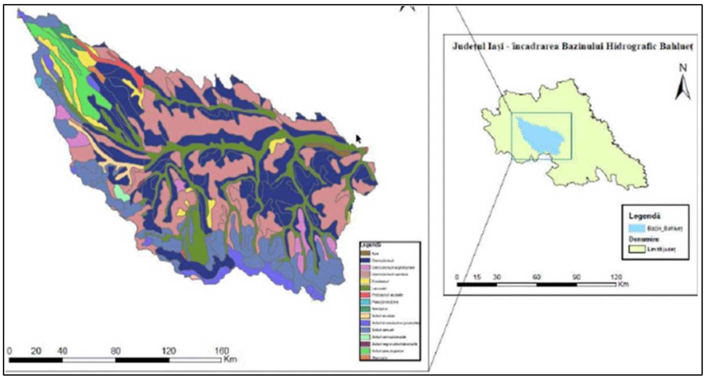
*di* - the average diameter of each granulometric fraction.

## 3. Results and Discussions

### 3.1. Soil Mapping

The conducted research highlighted the presence of a diverse soil cover. Based on their characteristics and imposed limitations, the soils in the study area were classified into 5 classes, ranging from II to VI (Fig. 1).

Fig. 1. Soil Map of the Vasluieţ Watershed




The following exemplifies only the characteristics of Class II soils. These include soils with good suitability. The limiting factor is the fine texture, with a clay content higher than optimal, which results in a reduced value of the soil's pore space and a tendency towards compaction and consolidation (Table No. 2).

Table No. 2. Characteristics of class II soils

| Soil Unit Characteristics | Clay (%) | Humus (%) | pH | N (%) | P (ppm) | K (ppm) |
|---|---|---|---|---|---|---|
| Typical Chernozem, Cumulic Cambic Chernozem | 33,1-36,9 | 3,6-4,2 | 6,5-6,9 | 0,179-0,209 | 4-10 | 204-216 |
| Mollic Colluvial Soil, Weakly Alkaline | 27,4-32,4 | 3,24-3,84 | 7,0-7,8 | 0,165-0,189 | 35-200 | 335-400 |
| Mollic Colluvial Soil, Strongly Gleyed | 24,3-31,1 | 3,07 | 6,7-7,2 | 0,143 | 13 | 175 |
| Typical Chernozem with Surface Erosion | 24,9-28,9 | 2,16-3,18 | 6,8-8,1 | 0,175 | 24 | 282 |
| Cambic Chernozem with Surface Erosion | 33,6-38,2 | 3,6 | 6,0-7,9 | 0,182 | 6 | 313-363 |

The soil texture is loamy-clayey at the surface, with clay content ranging between 33,1% and 36,9%. The soils are very deep with a very large soil volume. Physical and hydrophysical properties are favorable. The soils are slightly compacted at the top, with a moderate total porosity. The available water capacity is high. Internal drainage is good, associated with moderate external drainage. Biological activity is intense, especially in the upper horizon. The reaction is neutral to slightly acidic (pH = 6,9 – 6,5) at the surface and neutral to slightly alkaline (pH = 6,9 – 8,1) at depth, associated with the presence of calcium and magnesium carbonates in moderate quantities, from a depth of 40 – 80 cm. Organic matter is present in characteristic forms of calcareous mull humus. The humus content is moderate (3,6-4,2%) and the humus reserve is very high at a depth of 0-50 cm (204-241 t/ha). Nitrogen supply is moderate (0,179–0,209%) for field crops. Mobile phosphorus supply is very poor (4-10 ppm) and mobile potassium supply is good (204-216 ppm) for field crops. The colloidal complex is very well represented and mostly saturated with basic cations. Among the basic cations, calcium predominates, followed by magnesium.

### 3.2. Modification of some physical soil properties under agricultural management influence

The study was conducted in a three-year crop rotation with three types of crops: soybean, wheat, and corn. Each crop was placed in five soil management systems, and each system had five variants of mineral, organic, and crop residue fertilization. The following soil management systems were established: plowing at 20 cm depth, at 30 cm, plowing without turning the furrow with a chisel plow and a paraplow, and the one-year plowing and one-year disking variant. The obtained results are presented in Table No. 3.

10 – 30 cm, reaching 1,34 g/cm³, with positive influences on the hydraulic conductivity of the soil.

Figure No. 2 shows the relationship between the degree of compaction and the hydraulic conductivity of the plowed soil.

Table No. 3 The influence of soil management

| Alternative | Depth N | Apparent density g/cm³ | Degree of compaction (% v/v) | Air capacity (% v/v) | Total porosity (% v/v) |
|---|---|---|---|---|---|
| Disk | 0-10<br>10-20<br>20-30 | 1,20<br>1,37<br>1,42 | -5,60<br>6,78<br>9,57 | 22,93<br>14,45<br>12,66 | 54,72<br>48,30<br>46,42 |
| Paraplow | 0-10<br>10-20<br>20-30 | 1,14<br>1,28<br>1,42 | -9,97<br>0,22<br>9,57 | 26,17<br>18,80<br>12,66 | 56,98<br>51,70<br>46,42 |
| Chisel +FRV | 0-10<br>10-20<br>20-30 | 1,12<br>1,23<br>1,35 | -11,43<br>-3,42<br>4,42 | 27,28<br>21,35<br>15,91 | 57,74<br>53,58<br>49,06 |
| $A_{20}$ | 0-10<br>10-20<br>20-30 | 1,14<br>1,21<br>1,40 | -9,97<br>-4,88<br>8,09 | 26,17<br>22,40<br>13,57 | 56,98<br>54,34<br>47,17 |
| $A_{30}$ | 0-10<br>10-20<br>20-30 | 1,13<br>1,20<br>1,24 | -10,70<br>-5,60<br>-3,67 | 26,72<br>22,93<br>21,39 | 57,36<br>54,72<br>53,21 |

For the apparent density, values ranging between 1,13 and 1,42 g/cm³ were recorded. The highest value of 1,42 g/cm³ was recorded when the soil was worked with the disk, resulting in a sudden increase leading to a weak degree of compaction, approximately 8,3% of the volume. The increase in apparent density leads to negative effects on soil porosity and accessible water for crops. From the analyses, it can be observed that the apparent density value decreases at a depth of

When working the soil conventionally with plowing, it was observed that a low compaction degree of 0.2% resulted in a hydraulic conductivity of 45.02 mm/hour, with a favorable influence on soil permeability. A high compaction degree of 16.4% led to a low hydraulic conductivity of 4.5 mm/hour, with negative effects on soil permeability and ultimately an increase in surface runoff.

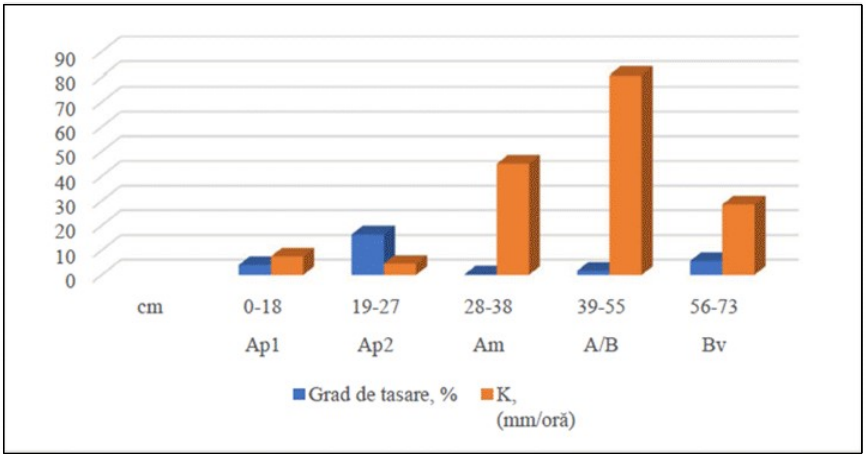



Fig. 2. The relationship between compaction degree and hydraulic conductivity in plowed cambic chernozem

### 3.3. Determining soil water reserves formed by precipitation infiltration

The results regarding the variation of soil water reserves, determined by the applied soil management, are synthetically presented in Tables 4, 5, and 6.

Soil tillage with various machinery, if not carried out under optimal moisture conditions, leads to the deterioration of soil structure, reduction in total porosity, and consequently, a reduction in water infiltration capacity.

These aspects, analyzed above, constitute important factors to be taken into account when studying runoff formation in a watershed and are also crucial in determining the stability of a slope. The physical properties of the soil, together with geomorphological properties, play a very important role in establishing the values of components in equations that underlie runoff formation on different slopes and floods in riverbeds.

Table No. 4. Calculating the volume of water that can infiltrate before soil tillage

| Depth (cm) | Total porosity (PT) (g/cm³) | D | Hydraulic conductivity of Soil (k) (m/zi) | Volume of water that can infiltrate (N1) (m³/ha) |
|---|---|---|---|---|
| 0-20 | 0,5417 | 1211,44 | 0,57 | 5778 |
| 20-30 | 0,5283 | 1180,23 | 0,58 | 5878 |
| 30-40 | 0,5056 | 1345,39 | 0,43 | 4330 |

Table No. 5. Calculating the volume of water that can infiltrate after soil tillage with the chisel and disking

| Depth (cm) | Total porosity (PT) (g/cm³) | D | Hydraulic conductivity of Soil (k) (m/zi) | Volume of water that can infiltrate (N1) (m³/ha) |
|---|---|---|---|---|
| 0-21 | 0,5057 | 1278,25 | 0,47 | 4797 |
| 22-40 | 0,5095 | 1345,06 | 0,43 | 4334 |
| 41-55 | 0,4831 | 1401,26 | 0,38 | 3813 |

Table No. 6. Calculating the volume of water that can infiltrate after soil tillage, plowing to 20 cm depth, and disking

| Depth (cm) | Total porosity (PT) (g/cm³) | D | Hydraulic conductivity of Soil (k) (m/zi) | Volume of water that can infiltrate (N1) (m³/ha) |
|---|---|---|---|---|
| 0-21 | 0,5169 | 1248,04 | 0,51 | 5143 |
| 22-40 | 0,4264 | 1472,41 | 0,30 | 43048 |
| 41-55 | 0,5132 | 1267,63 | 0,49 | 4950 |

The conducted research highlighted the following aspects:

Soil tillage with chisel followed by disking reduces water infiltration capacity in the soil as follows: by 16,97% at a depth of 0-20 cm, by 26,26% at a depth of 22-40 cm, and by 11,94% at a depth of 41-55 cm.

Soil tillage at 20 cm depth followed by disking reduces water infiltration capacity in the soil as follows: by 10,98% at a depth of 0-20 cm, by 48,14% at a depth of 22-40 cm, and by 12,54% at a depth of 41-55 cm.

The application of different soil management technologies leads to a reduction in total porosity and consequently, a reduction in water infiltration and storage capacity in the soil over time. This is why other measures are necessary to improve the permeability of agriculturally exploited soils.

## 4. Conclusions

These results are useful for understanding water movement in the soil profile and for developing hydrological models in arid and semi-arid regions after vegetation restoration. Cultivating the soil with different machinery can have various effects on soil structure, composition, and overall health. The specific impact depends on factors such as the type of machine used, working depth, and soil type. In the case presented in this study, it was observed that the long-term effect is not the desired one, as plowing to 20 cm depth followed by disking reduced water infiltration capacity in the soil.

It is important to note that while soil tillage can provide short-term benefits, such as improved seedbed preparation and weed control, excessive reliance on soil tillage can lead to long-term soil degradation, including increased erosion, loss of organic matter, and disruption of soil structure. Therefore, conservation tillage practices, such as minimizing soil tillage operations, are often recommended to minimize the negative impact on soil health. The choice of soil tillage method should be based on factors such as soil type, climate, and specific cropping systems

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