THE EFFECT OF TILLAGE SYSTEMS ON SOIL COMPACTION OF ARABLE SOILS COMPARED TO FOREST LAND ON THE EZĂRENI PLATEAU, IAȘI COUNTY

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Abstract

Ezăreni Farm is located in Miroslava commune, Iasi County, within a geomorphological area defined by the Iași Ridge, situated between the Central Moldavian Plateau to the west and south, and the Moldavian Plain, specifically the Jijia–Bahlui Plain, to the east.

The soil characteristics reflect the influence of land use and vegetation, with forested areas showing deeper humus and calcium carbonate accumulation horizons compared to arable lands. During winter, wind erosion and increased subsoil compaction reduce the depth of these horizons.

The soils have a predominantly fine texture, with the highest clay content in the AB transition horizon, where humus distribution gradually decreases. Cambic chernozem on the edge of the Ezăreni plateau, developed under forest vegetation, is very loose in the 0–20 cm layer, with bulk density values between 0.97 and 1.09 g/cm³. Increasing compaction and changes in soil texture between 32–160 cm depth confirm the aeolian origin of the upper soil layer. In contrast, the cambic chernozem under arable use is loose in the ploughed layer, moderately compacted in the subsoil, and strongly compacted at 80–100 cm depth. The moderate compaction in the middle part of the soil profile is due to clay illuviation and the prevailing aerohydric regime, which contribute to denser packing of soil aggregates.

Key words: bulk density, compaction, soil texture, wind erosion.

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In agricultural soils, compaction is considered a form of degradation, whereas in construction, it is a necessary operation performed through specific technological methods. Compaction may have either natural or anthropogenic causes (*Canarache et al., 1990*).

Soil compactness, also referred to as overall cohesion or compacity, is a complex property resulting from the soil's textural characteristics and degree of packing. It is expressed by the resistance the soil offers to the penetration of a tool or other foreign object and to the fragmentation of its mass during mechanical operations (Florea N., 1994).

Indicators of soil compactness include the morphological type of structure, the uniformity of root distribution, bulk density, total porosity in relation to soil texture, aeration porosity, degree of compaction, packing density, and others.

To evaluate the compaction state of soils on a slope improved with erosion control works, we analyzed the compaction status of soils developed under forest vegetation and those on arable land on the Ezăreni plateau. A comparative study of the compactness of soils on the managed slope and those representative of the Ezăreni plateau revealed the impact of slope-shaping works on soil compactness in agroterrace platforms and grassed strips (*Jităreanu et al., 2020*).

Total porosity represents the entirety of capillary pores with diameters <10 μm (10^{-6}) for clay-textured soils and <30 μm (10^{-6}) for sandy-textured soils, through which water usually circulates (capillary porosity), and non-capillary pores, with diameters >1 mm, through which air usually circulates (non-capillary or aeration porosity) in the soil mass. Total porosity values generally range between 40% and 60%. The more compacted a soil is, the lower its total porosity values, often around 42–45%. In loose, arable layers, values range between 48–50%. These values increase significantly with higher organic matter content. High total porosity values indicate a strong water retention capacity, high permeability, and good aeration, although sometimes associated with lower bearing capacity (*Jităreanu et al., 2020*).

Soil compactness affects both total porosity and the ratio between micropores, mesopores, and macropores. As a result of soil compaction processes, total porosity and aeration porosity decrease, while the proportion of micropores—where water is held in a form inaccessible to plants—increases. The lower

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threshold of aeration porosity that does not restrict plant growth is considered to be 10% v/v (*Canarache et al., 1990*).

MATERIAL AND METHOD

Location of research

To highlight the effect of soil tillage on the degree of compaction, two soil profiles were studied on the Ezăreni plateau—one located on forest land and the other on arable land (Fig. 1).

The land where the profiles were placed has a slope of less than 5%, meaning it is approximately flat, with a low risk of erosion (possibly wind erosion on arable land or water erosion in the marginal area of the plateau).

According to indicator no. 201 from the M.E.S.P., the soil surface appears normal, with no signs of salt crusting or cracking.

Soil tillage operations can be carried out without restrictions; however, it is recommended that the soil is not left exposed for extended periods to prevent wind from displacing surface particles, transporting and depositing them on adjacent areas—especially on forested land.

On the Ezăreni Plateau (La Podiș Hill), two soil profiles were made under similar relief conditions but with different land uses (Fig. 1).

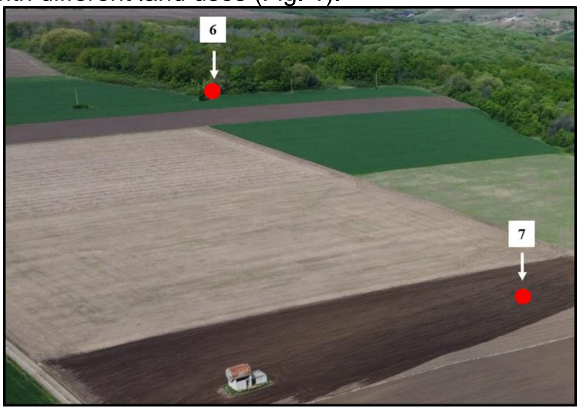

Figure 1. Location of soil profiles on the plateau of the Ezăreni farm

The soil profiles were excavated using a spade, shovel, and axe to remove the lignified roots of forest vegetation. The profiles measured approximately 65–80 cm in width, 180–200 cm in length, with a depth of 160 cm for the profile located under forest vegetation and 175 cm for the one in arable land.

In the forest profile, ten soil horizons and sub-horizons were identified and described in the field, while seven were identified in the arable land profile. From each profile, undisturbed soil samples were collected using 100 cm³ stainless steel cylinders, from depths of 0–100 (110) cm at 10 cm intervals, using the Eijkelkamp soil sampling set.

Sampling was performed immediately after the profiles were opened, to avoid data distortion caused by soil shrinkage, particularly in soils with medium to fine textures. The sampling technique involved preparing a horizontal flat surface 30–45 cm wide, which was gently trimmed to avoid pore blockage. The cylinders were then placed with the sharp edge downward and inserted into the soil by pressing with the cylinder holder and hammer.

Cylinders had to be inserted perfectly vertically, and filled with soil slightly above the upper edge (by 3–4 mm). The excess soil was removed with a knife, cut flush to the cylinder edge for bulk density determination, or trimmed more carefully with chipping motions for other measurements, ensuring the soil surface was level with the cylinder rim. Once capped, the cylinders were placed in special transport boxes.

Three replicates were taken for each depth. The 100 cm³ soil samples were transported to the laboratory, weighed, and placed in trays with water to determine capillary capacity, total water holding capacity, and bulk density. The cylinders were then oven-dried at 105°C for 48 hours or until reaching a constant weight, removed to a desiccator, and weighed again.

Based on these data, bulk density values were determined, which were later used to assess soil compaction and hydro-physical indices. The relationship between bulk density and key soil characteristics is strongly interdependent, especially regarding soil texture and organic matter content. Similar bulk density values can be favorable in sandy soils but entirely unfavorable in clay soils (Amponsah et al., .2025)

Bulk density (BD) was determined using the metal cylinder method with known volume (100 cm³) at the soil's actual moisture content, and is expressed in g/cm³. Knowing the weight of the oven-dried soil (M) in grams and its total volume (Vt) in cm³, including both the solid part (Vs) and the pore space (Vp), the bulk density can be calculated using the formula:

$$BD = M / V_t = M / (V_p + V_s),\ g/cm^3$$

Most cultivated plants prefer bulk density values between 1.0–1.4 g/cm³ (*Onwuegbunam, D.O. et al., 2025*). Soils are considered too loose when bulk density is below 1.0 g/cm³ and too compacted when above 1.4 g/cm³. Values between 1.0–1.2 g/cm³ are optimal for potato, beet, carrot, parsley, and radish, while 1.2–1.3 g/cm³ are preferred by cereals, corn, and sunflower (*Rusu T. et al., 2009*).

High bulk density values indicate reduced water retention capacity, permeability, and aeration, and increased mechanical resistance to tillage and root penetration. Conversely, low bulk densities can reduce load-bearing capacity, making traffic and agricultural operations more difficult.

It is important to note that soil compaction was influenced by both bulk density values and soil texture class. The indices and formulas used in these determinations followed the methodologies established by *Canarache A. et al. (1990) and Dumitru Elisabeta et al. (2009).*

RESULTS AND DISCUSSIONS

The bulk density of soil represents the ratio between the mass of oven-dried soil and its total volume, thus being a property of the soil as a whole, including both the solid particles and the pore spaces between them (*Canarache A., 1990*). It is one of the key indicators for assessing the compaction state of soils.

The evaluation of soil compactness based on the bulk density values recorded along the soil profile is conducted in correlation with the textural class of each pedogenetic horizon.

The cambic chernozem located on the marginal part of the Ezăreni plateau, which developed under the influence of forest vegetation, is very loose in the 0–20 cm depth interval, with bulk density values ranging from 0.97 to 1.09 g/cm³ (Fig. 2).

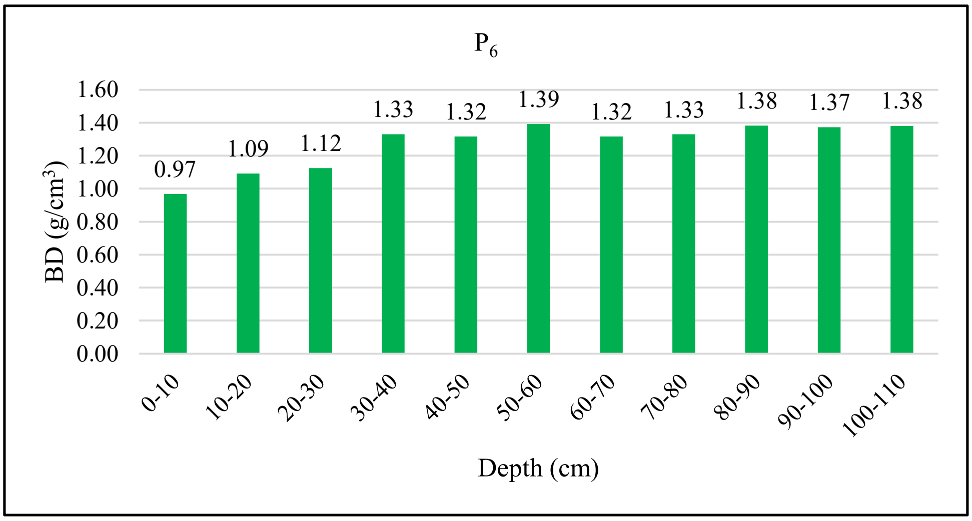

Figure 2. Bulk density values of cambic chernozem (profile 6)

These low bulk density values are due to the high frequency of herbaceous plant roots, including semi-shade species and those that develop early in spring before the leafing of trees and shrubs. In the 20–30 cm depth interval, the average bulk density value is 1.12 g/cm³, indicating a loose soil structure. It is worth noting that starting from 32 cm and down to the base of the profile at 160 cm depth, the soil texture becomes medium clay loam.

The gradual increase in bulk density values within the 0–32 cm depth and the change in textural class between 32–160 cm confirm the aeolian origin of the upper part of the soil profile, as also observed during the morphological description in the field.

In the middle and lower parts of the profile, the soil falls within the uncompacted to slightly compacted category. Notably, the variation range of bulk density values between 32 and 110 cm depth is narrow, ranging from 1.32 to 1.39 g/cm³.

Porosity was determined using undisturbed soil samples collected with metal cylinders of known volume, taken from each soil profile at one-meter depth, in 10 cm increments.

The moderately wind-deposited cambic chernozem from the marginal part of the Ezăreni plateau, developed under forest vegetation, is loose to very loose in the 0–30 cm depth interval, with total porosity values ranging from 56.77% to 62.08% (Fig. 3).

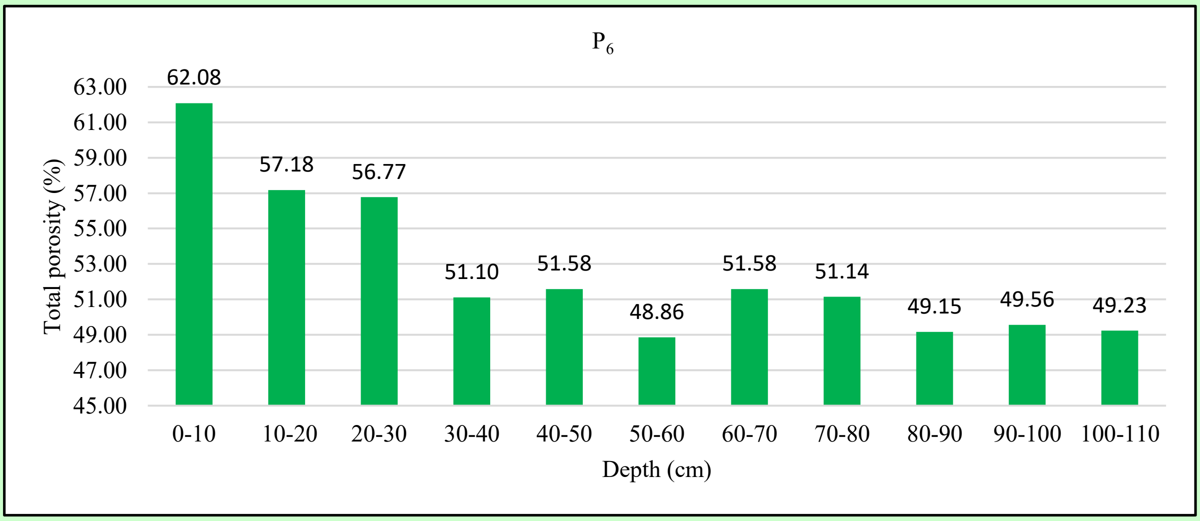

Figure 3. **Cambic chernozem total porosity values (profile 6)**

This is attributed to the higher content of decomposing organic matter and the activity of herbaceous plant roots, which promote good soil structure (*Filipov F., 2005*). The high porosity values are similar to those found in organo-mineral soils of greenhouses or meadows in wetland areas.

Below 30 cm depth, the soil shows relatively uniform total porosity values between 48.8% and 51.58%, corresponding to the slightly compacted category. This narrow range of total porosity values is due to the absence of anthropogenic influence on pedogenetic processes and the soil's physical-chemical properties. The soil has evolved strictly under natural vegetation conditions specific to the area, and under the influence of local pedoclimatic factors. The moderately wind-deposited cambic chernozem shows inactive porosity values between 9.84% and 19.11% v/v (Fig. 4).

The highest inactive porosity values, observed between 50–60 cm depth, are due to the fine texture and moderate compactness of the soil.

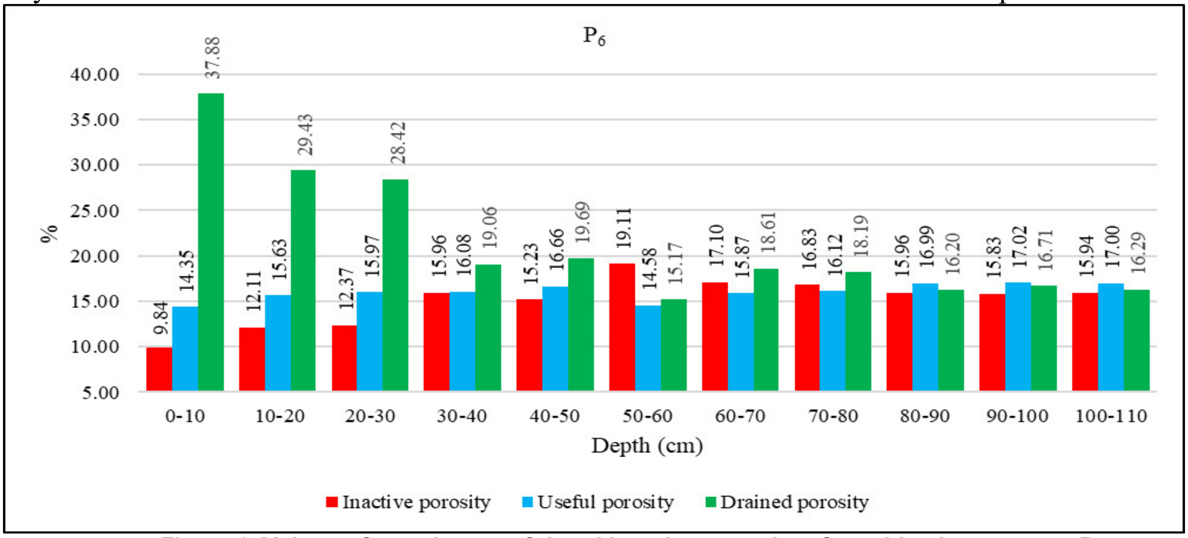

Figure 4. **Values of aeration, useful and inactive porosity of cambic chernozem – P_6**

The proportion of micropores increases within the 0–50 cm depth range and varies within narrow limits between 60–100 cm depth.

The useful porosity, represented by mesopores that retain plant-available water, ranges between 14.35% and 17.02% v/v.

High values of drainage porosity, ranging from 28.42% to 37.88% v/v in the 0–30 cm depth interval, are due to the pronounced looseness of the soil, the high organic matter content, and the presence of undecomposed organic residues.

The slight decrease in drainage porosity between 40–110 cm depth is associated with a moderate increase in soil compaction, as also indicated by bulk density values.

The cambic chernozem in the arable land of the Ezăreni plateau is loose in the topsoil, moderately compacted in the subsoil, and strongly compacted between 80–100 cm depth (Fig. 5).

The moderate soil compaction observed in the cambic B horizon is caused by natural pedogenetic processes such as clay illuviation (responsible for the formation of the cambic B horizon) and changes in the aerohydric regime resulting from frequent wetting–drying cycles, which promote denser packing of structural aggregates.

The presence of a hardpan is also indicated by moderately high bulk density values, reaching 1.58 g/cm³. Notably, there is a slight decrease in density at the 50–60 cm depth interval.

The compacted subsoil layer, identified both macroscopically and through measured bulk density values in undisturbed soil samples, highlights the necessity of deep loosening down to a depth of 50 cm.

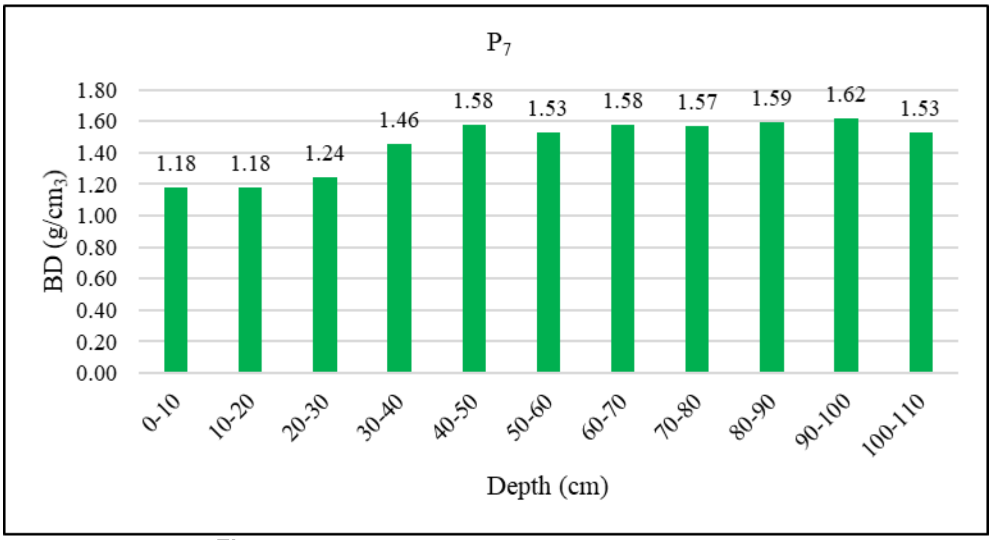

Figure 5. Bulk density values of cambic chernozem (profile 7)

The presence of the hardpan layer hinders water infiltration, root penetration, and intensifies the negative effects of prolonged droughts, which have become more frequent during the studied period.

The cambic chernozem on the arable land of the Ezăreni plateau is loose in the ploughed layer, moderately compacted in the subsoil, and strongly compacted at a depth of 80–100 cm (Fig. 6).

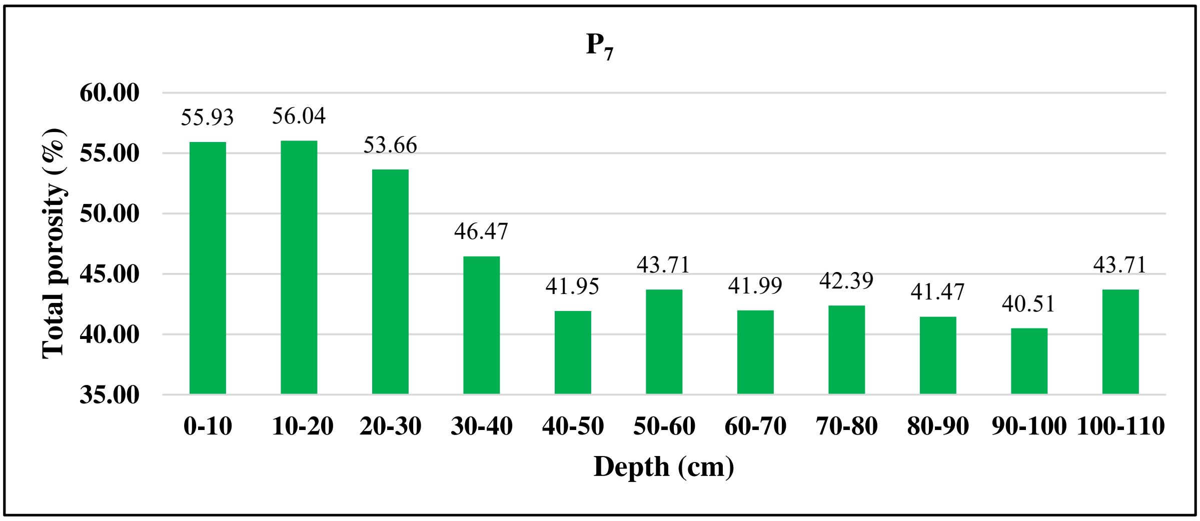

Figure 6. Cambic chernozem total porosity values (profile 7

The surface horizon (0–30 cm) is loose, with total porosity values ranging between 53.66% and 56.04%, which is due to plowing performed under normal soil moisture conditions. It is considered that the plowed layer is well-tilled and loosened when the total porosity falls within the range of 48–55%.

The underlying layer is moderately compacted, with total porosity (TP) values between 41.95% and 46.47%, and corresponds to the presence of a hardpan layer—a subhorizon strongly influenced by tillage, which is a direct result of anthropogenic activities specific to crop cultivation.

The lowest TP value is found at a depth of 80 cm, measuring 40.51%, where the soil is heavily compacted due to the lithological substrate.

In the plowed layer of the cambic chernozem from the arable land of the Ezăreni plateau, the values of drainable porosity range between 22.16% and 25.37% v/v. The share of mesopores, which retain the available water that can gradually be absorbed by plant roots, is approximately 15% v/v (Fig. 7).

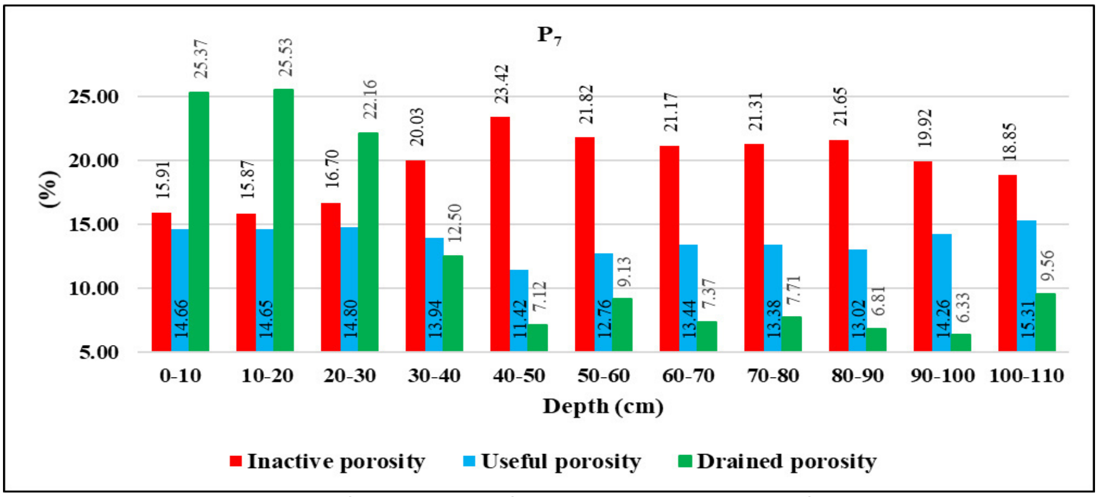

Figure 7. Values of aeration, useful and inactive porosity of cambic chernozem

The values of inactive porosity in the arable layer range between 15.87% and 16.7% v/v.

The compaction state of the subsoil layer can be expressed both through soil pedomorphological indicators, through laboratory analytical data of bulk density, and through the values of the ratio between the volume occupied by macropores, mesopores, and micropores.

In the depth interval of 30-40 cm, the value of the draining porosity was 12.5% v/v, which is 4.8% v/v higher than the lower part of the hardpan layer. This difference is due to plowing at different depths during the establishment of autumn and spring crops. It is noteworthy that in the lower part of the compacted layer, the minimum value of draining porosity is recorded at 7.12% v/v. When the soil moisture is at field capacity, an aeration deficit of 3.88% v/v is recorded.

The variation range of the draining porosity value in the 50-100 cm depth interval is between 6.33% and 9.56% v/v. With a current water content at field capacity, soil aeration in these layers is weak and moderately deficient.

It is also important to mention that in the 100–110 cm depth interval, the soil compaction decreases, as evidenced by the slight increase in aeration porosity by 3.2% v/v.

The increase in draining porosity and, implicitly, in aeration porosity is due to changes in the soil's granulometric composition and lithological discontinuity, highlighted by the dust/sand ratio value.

The values of usable porosity range from 11.42% to 15.31% v/v. The lowest values, 11.42% and 12.76% v/v, are recorded in the 40–60 cm depth interval.

The range of inactive porosity values recorded in the soil profile is broader, falling between 15.87% and 23.42% v/v.

From the distribution of draining, usable, and inactive porosity values across the profile, it is evident that as soil compaction intensifies, the proportion of macropores decreases, while the volume occupied by micropores, which define inactive porosity, increases concurrently.

CONCLUSIONS

The land use on the La Podiș hill plateau has influenced the development of soils, with the thickness of the humus accumulation horizon and the depth at which calcium carbonate appears being greater in soils developed under forest vegetation compared to those on arable land.

The manifestation of the wind erosion process on the surface of the plowed layer during the winter season, along with the stronger compaction of the sub-arable soil layer, has led to a reduction in the depth at which the calcium carbonate accumulation horizon appears.

The texture of the soils on the Ezăreni plateau is fine, and the maximum clay content is found in the AB transition horizon, where a morphologically uniform decreasing distribution of humus is observed.

The Cambic Chernozem on the marginal part of the Ezăreni plateau, developed under the influence of forest vegetation, is very loose in the 0-20 cm depth range, with bulk density values between 0.97 – 1.09 g/cm³. The gradual increase in soil compaction and the modification of the soil texture class at the depth range of 32-160 cm confirms the aeolian origin of the upper soil layer.

The cambic chernozem on the arable land of the Ezăreni plateau is loose in the plowed layer, moderately compacted in the sub-arable layer, and strongly compacted in the 80-100 cm depth range.

The moderate compaction of the middle part of the cambic chernozem on the plateau is due to the process of clay illuviation and the aerohydric regime, which has favored a denser packing of soil aggregates.

The average value of the draining porosity in the upper part of the hardpan layer, which is 4.8% higher than that recorded in the lower part, is due to the plowing carried out at different depths when establishing autumn and spring crops.

From the distribution of macropores, mesopores, and micropores along the Cambic Chernozem profile, it is observed that as soil compaction intensifies, the proportion of macropores decreases, and the volume occupied by micropores, which define inactive porosity, increases simultaneously.

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