Research Journal of Agricultural Science, 58 (2), 2026; ISSN: 2668-926X;

http://doi.org/10.59463/RJAS.2026.2.52

ASSESSMENT OF PHYSICAL AND MECHANICAL SOIL CONSTRAINTS IN SÂNANDREI, WESTERN ROMANIA

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Abstract. *This study analyzes the physical and physico-mechanical properties of two representative soils from Sânandrei (Timiș County, Romania): molic preluvosol and eutric gleysol. The research is based on detailed pedological data, including granulometric composition, bulk density, total porosity, aeration porosity, water retention capacity, and soil compaction indicators. The results indicate that both soils belong to the fine-textured class (clayey-loam), which significantly influences their water retention capacity and aerohydric regime. The molic preluvosol is characterized by high bulk density (1.46–1.60 g/cm³), low total porosity (38–42%), and reduced aeration porosity, indicating significant compaction and limited permeability. In contrast, the eutric gleysol shows lower bulk density (1.28–1.42 g/cm³) and higher total porosity (43–49%), but negative aeration porosity values, reflecting excessive water saturation and poor oxygen availability. Water retention capacity is higher in gleysol, with field capacity values reaching up to 44%, compared to 22–24% in preluvosol. However, this advantage is offset by poor drainage and reduced biological activity. The comparative analysis highlights that preluvosol is mainly limited by mechanical constraints, while gleysol is affected by hydric excess. The study emphasizes the importance of adapting soil management practices to specific physical limitations. Recommended measures include deep loosening and organic amendments for preluvosol, and drainage and controlled tillage for gleysol. These findings contribute to a better understanding of soil functionality in the Banat Plain and provide a scientific basis for sustainable agricultural management.*

Keywords*: soils, physical properties, physico-mechanical properties, molic preluvusol, gleiosol, fertility*

INTRODUCTION

Soil is one of the most complex and valuable natural resources of the biosphere, being essential for sustaining agricultural production, maintaining biodiversity and regulating global biogeochemical cycles (BRADY AND WEIL, 2016, LAL, 2015, LAL AND STEWART, 2012). Globally, soil functionality is closely related to its physical and physico-mechanical properties, which control the processes of infiltration, water retention, aeration, and root development (HILLEL, 2004, HORN AND FLEIGE, 2009). In the current context of climate change and agricultural intensification, the degradation of the physical properties of soils, especially compaction and reduction of aeration porosity, is a major problem for global food security (LAL AND STEWART, 2012, FAO, 2015, MIRCOV ET AL., 2025, MIHUȚ ET AL., 2018).

At the European level, soil quality studies have shown that physical properties, such as apparent density, pore structure and distribution, play a decisive role in determining the productivity and resilience of agricultural ecosystems (JONES ET AL., 2012, SMITH ET AL., 2016).

Soil compaction is considered one of the main forms of physical degradation, affecting more than 30% of Europe's agricultural areas (MONTANARELLA ET AL., 2016, GREGORY ET AL., 2016, HORN ET AL., 2004). At the same time, excess moisture and

http://doi.org/10.59463/RJAS.2026.2.52
hydromorphic processes, specific to certain lowland regions, lead to the emergence of anaerobic conditions, which limit microbiological activity and nutrient availability (Gregory et al., 2016).

In Romania, soil research has highlighted the importance of physical and hydrophysical properties in assessing soil fertility and suitability for different crops (FLOREA AND MUNTEANU, 2012, MIHUȚ ET AL., 2023). The soils in our country have a high diversity, determined by variations in climatic, geomorphological and geological conditions, which leads to a wide range of physical and mechanical behaviors (IANOȘ ET AL., 1997,FLOREA ET AL., 2014). In particular, fine textures, frequently found in lowland soils, determine a high water retention capacity, but are also associated with high risks of compaction and poor aeration (STROIA ET AL., 2025, BLAGA ET AL., 2005).

In the western part of Romania, especially in the Banat Plain, soils are predominantly formed on loessoid deposits and fluvialites, which favors the development of preluvosoils and gleiosols, characterized by distinct physical properties (FLOREA ET AL., 2014). Under these conditions, the clay and glazing processes play an essential role in differentiating the soil profile and in determining the aerohydric regime (BĂLTEANU AND BADEA, 2007). Preluvosoils have a denser structure and a tendency to accumulate clay in the subsurface horizons, which leads to reduced permeability and increased mechanical strength (Ianoș et al., 1997). On the other hand, gleiosols are influenced by the high level of groundwater, which causes the appearance of hydromorphic conditions, characterized by pore saturation and oxygen deficiency (BLAGA ET AL., 2005, FLOREA AND MUNTEANU, 2012).

The physico-mechanical properties of the soil, such as bulk density, total porosity and aeration porosity, are essential indicators for assessing the structural condition and capacity of the soil to support biological and agricultural processes (DEXTER, 2004, HORN ET AL., 2004). The relationship between these indicators and hydrophysical parameters, such as field capacity and wilting coefficient, allows the characterization of water availability for plants and the identification of limiting factors of agricultural production (HILLEL, 2004, GREGORY ET AL., 2016). In this context, the comparative analysis of these properties at the level of different soil types becomes essential to substantiate agricultural practices adapted to local conditions.

The territory of Sânandrei commune, located near the municipality of Timișoara, is a relevant example for the study of the interaction between pedogenetic factors and the physical properties of soils, due to the diversity of the existing edaphic and hydrological conditions. In this area, the mole preluvosols and eutric gleiosols coexist and present contrasting physical characteristics, generated by different processes of formation and evolution.

The purpose of this paper is the comparative analysis of the physical and physico-mechanical properties of the soft preluvosol and the typical eutric gleiosol from the Sânandrei area, in order to highlight their structural and hydrophysical particularities, as well as the implications on agricultural use. The specific objectives are aimed at evaluating the particle size distribution per profile, analyzing the physical and mechanical state indicators and interpreting the relationships between these parameters in the context of dominant pedogenetic processes.

MATERIAL AND METHODS

The study was carried out in the area of Sânandrei commune, located in the north-western part of Timiș County, about 15 km from Timișoara, within the geomorphological unit of the Banat Plain, an integral part of the Tisa Plain. From a geographical and pedogenetic point of view, the analyzed area is characterized by a poorly fragmented relief, specific to the

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accumulation plains, in which the subsidence processes and the dynamics of the groundwater had a decisive role in the formation and evolution of the soil cover.

The geological conditions are dominated by loessoidal deposits and fluviates, with medium and fine textures, which constitute the parent material for the studied soils. These deposits favored the development of soils with specific physical and hydrophysical characteristics, influenced by processes such as clay and glaciation. From a climatic point of view, the region falls into the temperate-continental climate, with sub-Mediterranean influences, characterized by average annual temperatures of about 10–11°C and annual rainfall of 550–600 mm, which causes a variable water regime and, under certain conditions, the appearance of temporary excess humidity (MHUT ET AL. 2023, BRADY AND WEIL, 2016, MIRCOV ET AL., 2025).

From a pedological point of view, two representative types of soil were selected in the study, namely soft preluvosol and typical eutric gleiosol, considered relevant for the comparative analysis of physical and physico-mechanical properties. The soft preluvosol is developed on loessoid deposits, having a well-differentiated profile, characterized by clay accumulation horizons (Bt), while the typical eutric gleiosol is formed on fluvial deposits and has obvious hydromorphic features, generated by the influence of groundwater.

The data used in the analysis come from the detailed pedological study carried out in the Sânandrei area, which includes the morphological description of the soil profiles and the determination of the main physical and physico-mechanical indicators. The following categories of parameters were analyzed during the research:

– particle size indicators (coarse sand, fine sand, dust, clay and physical clay), used to establish the textural class and the degree of differentiation per profile;

– indicators of the physical condition (apparent density, total porosity, aeration porosity), which reflect the organization of the porous space and the capacity of water and air circulation;

– physical-mechanical indicators (degree of compaction, withering coefficient, field capacity, water capacity), relevant for the assessment of the hydrophysical regime and the availability of water for plants.

The data processing was carried out by descriptive and comparative statistical methods, being calculated the variation intervals and trends per profile for each analyzed parameter.

The methodological approach adopted makes it possible to highlight the relationships between physical properties and dominant pedogenetic processes, as well as to assess their implications on soil functionality and agricultural use.

RESULTS AND DISCUSSIONS

The comparative analysis of the two soils in Sânandrei, the soft preluvosol and the typical eutric gleiosol, highlights important differences in profile organization, particle size and physical-mechanical behavior, although both fall into the category of fine-textured soils. This aspect is particularly important from a pedological and agronomic point of view, since the fine texture largely controls the water retention capacity, the infiltration rate, the susceptibility to compaction, aeration, as well as the degree of accessibility of the edaphic volume for the roots. The data in the profile tables show that both soils have a high potential for water retention, but the way in which this water is stored and made available to plants differs significantly, as a result of the dominant pedogenetic processes: clay flooding in the preluvosol and gleiation in the case of gleiosol.

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In the case of the soft preluvosoil, the graphic representation of the textural fractions on the profile, shown in Figure 1, clearly shows that this soil has a more pronounced vertical particle size differentiation. It is observed that the fine sand has relatively high values in the Ap horizon, where it reaches 33.0%, after which it decreases slightly in the intermediate horizons and shows small oscillations in depth. The dust has a maximum in the ATP horizon, of 31.7%, followed by a gradual decrease towards the base of the profile. In contrast, clay grows from 36.3% in the surface horizon to 44.7% in the AB horizon, then oscillates, while remaining at high values of 39.5–48.2% in the lower horizons. This distribution confirms the existence of a textural differentiation specific to soils affected by migration and accumulation processes of fine particles, with higher concentration of clay in the subsurface and deep horizons. From a pedological point of view, this tendency supports the preluvosol character and explains, to a large extent, both the higher consistency and the lower permeability of the profile (Figure 1).

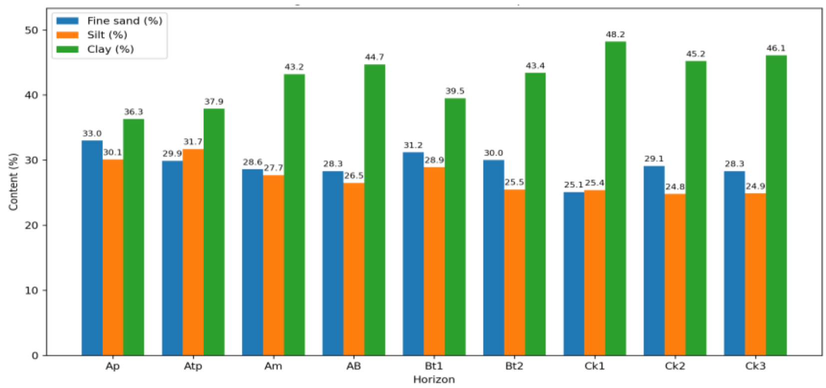

Figure 1. Texture fractions in molic preluvosol

Figure 2 shows that the distribution of particle size fractions in the typical eutric gleiosol highlights a different situation. In this case, the texture is much more uniform on the profile, with fewer variations in the content of fine sand, dust and clay. Fine sand is between 25.6 and 29.2%, dust between 26.2 and 32.6%, and clay between 37.4 and 41.4%. This textural homogeneity is characteristic of soils formed on relatively uniform fluvial deposits and suggests that the physical properties of gleiosol are less influenced by internal textural differentiation and more by excessive water regime. In other words, if in preluvosol the compaction and low permeability are strongly related to the accumulation of clay on the profile, in gleiosol the major restriction is generated by the presence of excess water and oxygen deficit, not so much by the variation in texture.

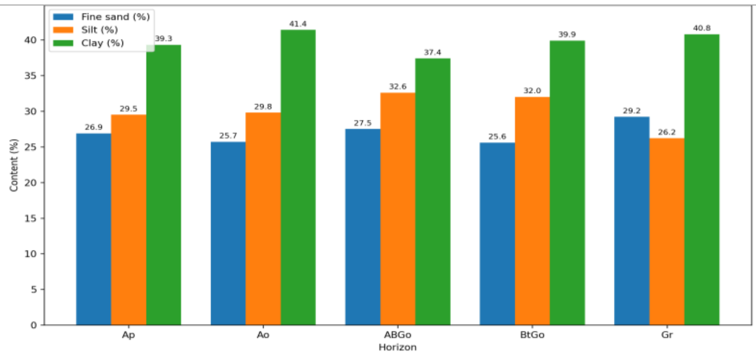

Figure 2. Texture fractions in eutric gleysol

Figure 3 shows the variation of clay content and physical clay in the soft preluvosol. The two curves remain at high levels throughout the profile, the physical clay constantly exceeding 52% and reaching up to 60.1% in the Ck horizon. This shows that, regardless of the local variations of the fraction below 0.002 mm, the soil permanently retains a fine character, with a high weight of particles capable of determining high cohesion, accentuated plasticity and greater susceptibility to compaction. In functional terms, such a profile has a high water retention capacity, but also shows an increased tendency towards the formation of a dense structure, with low aeration porosity. This explains why preluvosoil, although not a proper hydromorphic soil, can create unfavorable conditions for root development when it is improperly tilled or when soil moisture exceeds optimal limits.

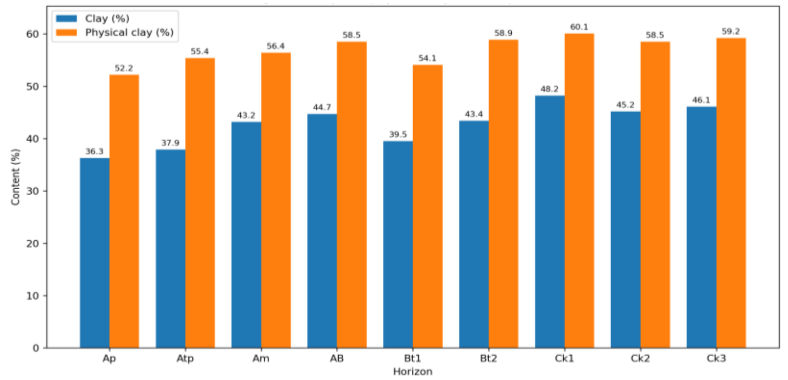

Figure 3. Clay and physical clay in molic preluvosol

Figure 4 shows that gleiosol also has high values of clay and physical clay, but with smaller variations in profile. The physical clay remains between 54.5 and 59.5%, and the clay itself between 37.4 and 41.4%. This particle size stability confirms the relatively homogeneous nature of the parental material. However, unlike preluvosol, where the accumulation of clay in certain horizons is an indicator of pedogenetic evolution, in gleiosol the textural uniformity means that its limitations do not result from marked textural alternations, but from the presence of excess water on the profile, which induces reducing conditions, purple-gray colors and diminished biological activity. From an agronomic perspective, this means that gleiosol

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breeding cannot be based only on mechanical loosening, but must primarily aim at controlling the water regime.

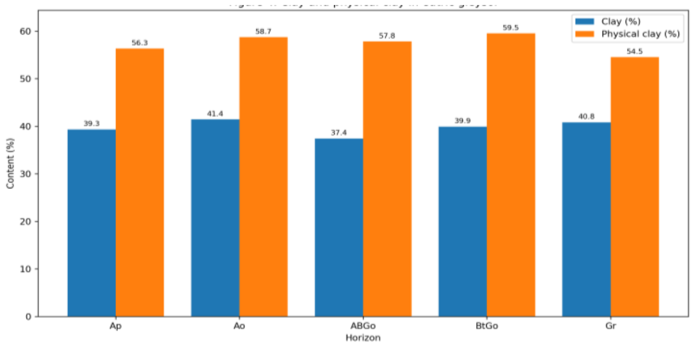

Figure 4. Clay and physical clay in eutric gleysol

One of the most relevant indicators of the physical condition of the soil is the apparent density, and the comparison between the two types of soil is shown in Figure 5. The values recorded for preluvosol are higher, at 1.50–1.60 g/cm³ in the analyzed horizons, with a minimum of 1.46 g/cm³ in Bt1. For gleiosol, the apparent density is significantly lower, between 1.28 and 1.42 g/cm³. At first glance, this would suggest that gleiosol is a looser soil that is more conducive to root development. However, the interpretation must be made with caution. In the case of preluvosol, the higher values of the bulk density are the consequence of the fine texture, natural compaction and denser structure, which determines a higher mechanical resistance to root penetration and tilling. In gleiosol, the lower apparent density does not necessarily reflect a higher physical state, but is largely the result of excessive water saturation and structural organization affected by gleization processes. Therefore, the bulk density must be correlated with the other parameters of the aerohydric regime in order to avoid simplifying interpretations.

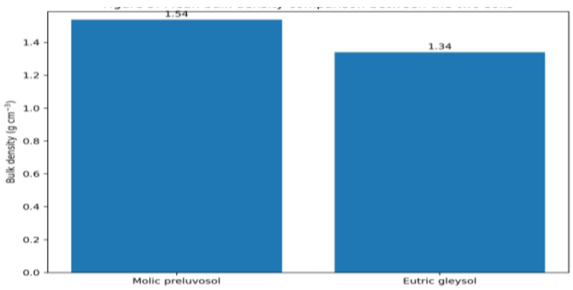

Figure 5. Bulk density comparison between the two soils

Figure 6, compares the total porosity of the two soils. The preluvosol has values of 38–42%, which indicates a relatively dense profile with limited pore space. Gleiosol has higher values of 43.42–49.60%, which shows that the total pore volume is higher. From a physical point of view, this may seem like an advantageous situation, but the type of pores and their degree of water occupation are essential. In preluvosol, lower total porosity is associated with a

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more compact structure, slow permeability and risk of settlement. In gleiosol, higher total porosity does not automatically lead to better aeration, since an important part of the pores is occupied by water.

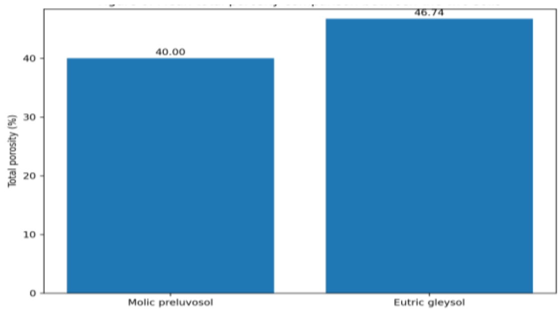

Figure 6. Total porosity comparison between the two soils

In the preluvosol, the aeration porosity has very low values of 2–9%, which confirms that the aeration of the profile is deficient, especially in horizons with a finer texture and higher density. However, the values remain positive, which means that there is still a certain volume of pores unoccupied by water, through which air can circulate. In gleiosol, the values of aeration porosity are negative, between -6.52 and -8.83%, which expresses, in fact, the state of oversaturation of the profile and the lack of an effective aeration space available for the roots. From a pedological and agricultural point of view, this is a severe restriction. A soil with negative aeration porosity cannot normally support root respiration processes, aerobic microbiological activity and efficient mineralization of organic matter. Consequently, although gleiosol can store more water than preluvosol, an important part of this water is in an unfavorable context for biological and productive use (Figure 7).

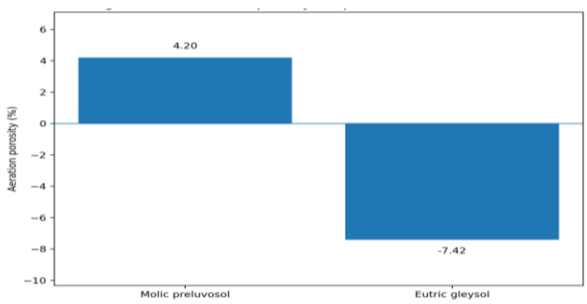

Figure 7. Aeration porosity comparison between the two soils

The degree of settlement, shown in Figure 8, complements the previous interpretation very well. In preluvosoil, the degree of compaction varies between 15 and 23%, which indicates a moderate to accentuated compaction state. This behavior is consistent with high bulk density values and low aeration porosity. Pedologically, it shows that the soil structure is prone to densification, especially under the action of mechanical works and agricultural traffic.

In gleiosol, the degree of settlement is lower, between 3.68 and 15.01%, but, again, this aspect should not be interpreted in isolation. The fact that the soil is less compacted does

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not mean that it is more favorable to crops, since excess moisture produces another, equally important category of limitation.

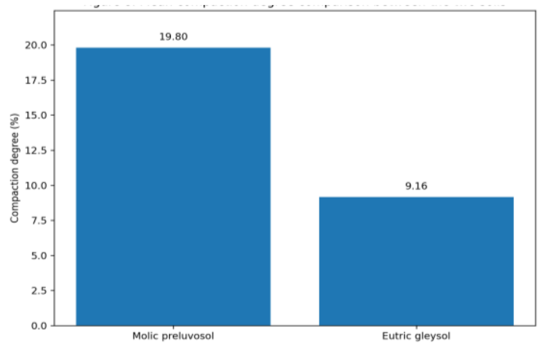

Figure 8. Compaction degree comparison between the two soils

The indicators of water retention in the preluvosol are shown in Figure 9. It is observed that the field capacity values are relatively close, between 22.4 and 24.6%, while the wilting coefficient varies between 14.9 and 17.0%. The difference between these indicators shows that the useful water available to plants is moderate, not very high, despite the fine texture. The explanation is that a significant part of the water is strongly retained by the clay fraction and cannot be easily extracted by the roots. In other words, preluvosol can store water, but not all of this water is agronomically efficient. Moreover, under compaction conditions, even existing useful water can become more difficult to access due to limited root development. Therefore, the agronomic value of the retained water is conditioned not only by the quantity, but also by the physical condition of the profile.

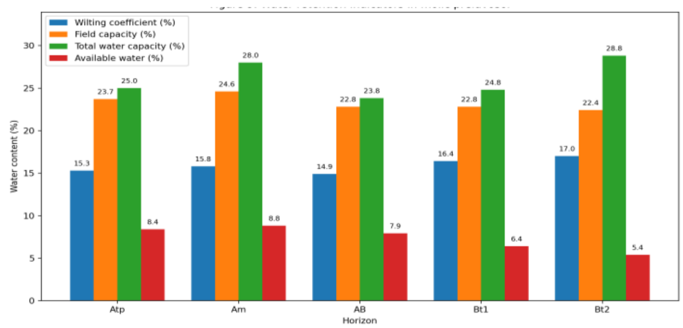

Figure 9. Water retention indicators in molic preluvosol

In gleiosol, the hydrophysical indicators shown in Figure 10 show a much higher field capacity, of 36.80–44.16%, and the useful water capacity is between 24.95 and 29.76%. These values demonstrate that gleiosol has a superior water storage capacity compared to preluvosol. However, this quantitative superiority is accompanied by a great functional disadvantage: the water is retained in an insufficiently aerated porous system, in which gas exchange is strongly affected. Thus, gleiosol cannot automatically be considered more plant-friendly just because it retains more water. On the contrary, in wet periods or in the absence of drainage measures,

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excess water becomes a major restrictive factor, causing root asphyxiation, delaying agricultural work and reducing biological activity. It is precisely this combination of high retention capacity and very poor aeration that gives gleiosol a paradoxical behavior: high water potential, but difficult agricultural use without ameliorative measures.

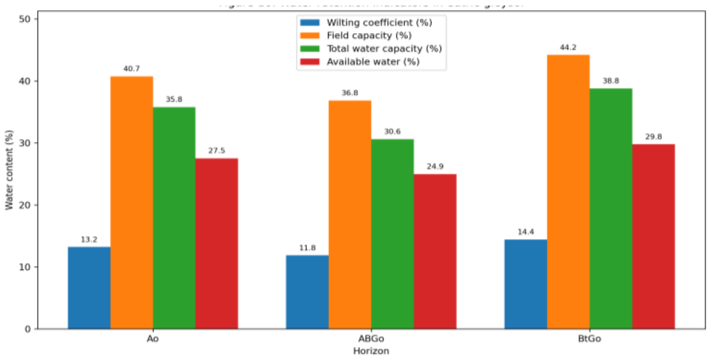

Figure 10. Water retention indicators in eutric gleysol

Taken as a whole, the two soils differ in the nature of the dominant restrictions. Soft preluvosol is a soil with a fine texture, high useful edaphic volume and relatively good agricultural potential, but affected by compaction, low aeration porosity and low permeability. For this reason, it requires careful tillage management, avoidance of interventions in conditions of excessive humidity and structural improvement measures, including the supply of organic matter and controlled loosening. In contrast, the typical eutric gleiosol is especially limited by hydromorphy. Even if the bulk density is lower and the total porosity higher, excess water and poor aeration substantially reduce effective physical fertility. Consequently, for gleiosol, dewatering and drainage works are essential, as well as the organization of an exploitation regime that avoids traffic and agricultural work when the soil is saturated.

From the point of view of comparative descriptive statistics, the average values show that the preluvosol has a higher average clay content on the complete profile and higher apparent density values, while the gleiosol has higher total porosity and field capacity. However, the fundamental difference between them is not only given by the absolute level of the indicators, but by the way in which they interact. In preluvosol, high density and compaction negatively control the operation of the profile. At gleiosol, excess water largely cancels out the advantage of higher total porosity. Therefore, the analysis does not support the idea of an absolutely "better" soil, but of soils with distinct limitations, which require different technological and ameliorative solutions.

CONCLUSIONS

The comparative analysis of the physical and physico-mechanical properties of the soft preluvosol and the typical eutric gleiosol from the Sânandrei area highlighted the fact that, although both soils belong to the fine textural class and have a relatively high water retention capacity, their functional behavior differs significantly as a result of the dominant pedogenetic processes and the specific water regime.

In the case of soft preluvosol, the distribution of the particle size fractions and the increase of the clay content in the subsurface horizons indicate an active clay-alluvial process, which determines a denser structure and reduced permeability. The high values of the apparent density, associated with low total porosity and limited aeration porosity, lead to a poor aerohydric regime, characterized by difficulties in infiltration and circulation of water, as well as insufficient aeration of the root system. Under these conditions, the preluvosol shows a marked tendency to compaction, which affects root development and the efficiency of water and nutrient use.

On the other hand, the typical eutric gleiosol stands out for a relatively uniform texture on the profile and for lower values of apparent density, but with a higher total porosity. However, the defining feature of this soil is the excess moisture, evidenced by the negative values of aeration porosity, which indicate an almost complete saturation of the porous space with water. This situation generates anaerobic conditions, unfavorable to microbiological activity and normal plant development, leading to low physical fertility, despite a high water retention capacity.

Comparatively, it can be stated that the main limitation of preluvosol is of a physico-mechanical nature, through compaction and high mechanical strength, while gleiosol is predominantly limited by excess water and poor aeration. Thus, the two soils present different constraints, which impose distinct strategies of agricultural use and management.

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